HONG CHEN

Individual Mobile Communication Services and Tariffs

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Individuele mobiele communicatiediensten en -tarieven

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To my parents

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Don't know when "the old man under the moon" tied the red cord between me and *Li*. I want to thank him for having done a great job and tying me up with the right lady, whose love, tenderness, and patience always bring me a peaceful mind.

Hong Chen
Rotterdam, December 2007

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Symbol	*Meaning*	*Dimensions*
X	service design space	*n*
Z	service perceptual space	*m*
N	assumed number of potential users of a value-added individual service (population)	*scalar*
n	number of service design attributes	*scalar*
m	number of perceived service attributes	*scalar*
P	reduced principle component coefficient matrix (mapping between the service design space and the service perceptual space)	$n \times m$
s	number of PCA learning survey respondents (sample size)	*scalar*
h	number of target point distribution estimation survey respondents (sample size)	*scalar*
E	target point distribution set in the service design space	$h \times n$
G	target point distribution set in the service perceptual space	$h \times m$
$Z=[z_1, z_2,\ldots,z_m]$, $Z \in R^m$	user's decision variable in the service perceptual space	$1 \times m$
$X = [x_1, x_2,\ldots,x_n]$, $X \in R^n$	supplier's decision variables in the service design space	$1 \times n$
x_n	supplier's decision variable that represents price for the individualized service	*scalar*
$z^0=[z_1^0, z_2^0,\ldots,z_m^0]$, $z^0 \in R^m$	user's target point in the service perceptual space	$1 \times m$
$z^a=[z_1^a, z_2^a,\ldots,z_m^a]$, $z^a \in R^m$	user's feasible point in the service perceptual space	$1 \times m$
$x^a = [x^a_1, x^a_2\ldots x^a_n]$, $x^a \in R^n$	supplier's feasible point in the service design space	$1\times n$
$t^0(X)$	user's target point in the service design space	$1 \times n$
$s^0(X)$	supplier's public offer in the service design space	$1 \times n$
$s^0(Z)$	supplier's public offer when mapped into the perceptual space	$1 \times m$
$i = 1, 2, 3, \ldots$	round of negotiation (*i*-th stage of the game)	*scalar*
$z\_user\_request^i$	user's optimization result at the *i*-th round of negotiation in the perceptual space	$1 \times m$
$x\_user\_request^i$	user's optimization result at the *i*-th round of negotiation when mapped into the design space	$1 \times n$
$x\_supplier\_offer^i$	supplier's optimization result at the *i*-th round of negotiation in the design space	$1 \times n$
$z\_supplier\_offer^i$	supplier's optimization result at the *i*-th round of negotiation when mapped into the perceptual space	$1 \times m$

n_interval, $\in N \geq 2$	number of sub-intervals that is generated when discretizing a variable.	*scalar*
$DZ = [Dz_1, \ldots, Dz_m]$, $DZ \in Q^m$	discretized user's decision variable in the service perceptual space	$1 \times m$
$DX = [Dx_1, \ldots, Dx_n]$, $DX \in Q^n$	discretized supplier's decision variables in the service design space	$1 \times n$
$Dz\_user\_request^i$	user's optimization result at the *i*-th round of negotiation in the perceptual space, which takes discretized values	$1 \times m$
$Dx\_user\_request^i$	the discretized mapping of $Dz\_user\_request^i$ in the service design space	$1 \times n$
$Dx\_supplier\_offer^i$	supplier's optimization result at the *i*-th round of negotiation, which takes discretized values	$1 \times n$
$Dz\_supplier\_offer^i$	the discretized mapping of $Dx\_supplier\_offer^i$ in the perceptual space	$1 \times m$
$Z^0 = (Z_1^0, Z_2^0, \ldots, Z_m^0)$	multivariate random variable that represents the user's preferences for the perceived service attributes $z_1, z_2, \ldots, z_m$ jointly	$1 \times m$

TABLE OF ABBREVIATIONS

Abbreviations	*Meaning*
ARPU	Average Revenue Per User per month
BER	Bit Error Eatio
B3G	"Beyond 3rd"generation wireless communication system
BPM	Business Process Modeling
BSS	Billing and Support System
CAPEX	Capital Expenditures
CDR	Call Detailed Record
CRM	Customer Relationship Management
DVB-H	Digital Video Broadcasting – Handheld
ERP	Enterprise Resource Planning
EVT	Extreme Value Theory
INTUG	International Telecommunications Users Group
IPDR	Internet Protocol Detail Record
ITU	International Telecommunication Union
Kbps	kilobits per second
LUT	Look Up Table
MGW	Media Gateway
MMS	Multimedia Message Service
OPEX	Operating Expenditures
OSS	Operational Support Systems
PAN	Personal Area Network
PCA	Principal Component Analysis
POT	Peak Over Threshold
QoS	Quality of Service
RFC	Request For Comments
SCE	Service Creation Environment
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SMS	Short Messaging Service
VaR	Value at Risk
VAS	Value-added Service
WLAN	Wireless Local Area Network,
WiMAX	Worldwide Interoperability for Microwave Access
WTP	Willingness-to-pay
WWAN	Wireless Wide Area Network,
2G/3G/4G	2nd/3rd /4th generation wireless communication system
2.5G	Second and a half generation wireless communication system
3GPP	3rd Generation Partnership Project

Executive Summary

Individual services and tariffs existed in the beginning of telecommunications history 150 years ago but soon faded away, largely under the pressure of single national operators. The industry prospered under economies of scale, and service provisioning and tariffs evolved into the current supplier-centric situation, which has many limitations for and disadvantages to the users and ultimately the suppliers. This thesis re-embraces the user-centric service provisioning and tariffing philosophy and applies it to the current mobile communication services setting, which differs significantly from the historical setting in terms of the scale and scope of services.

The research challenge lies in determining at the same time the individual user-specific services and tariffs, and in doing so in a sustainable way for users and suppliers alike, given the diversity of demands and the complexity in mobile communication service provisioning. Therefore it is essential to determine quantitatively, the benefits to the users and the suppliers, and the profit-risk-provisioning costs profile in the case of the suppliers, so that they are motivated to adopt individual services and tariffs. For a long time monopolist suppliers have been arguing that the customization costs would be too high, while in fact their marketing, CRM and churn costs are higher.

We construct a conceptual framework for individual mobile services and tariffs which serves as a theoretical foundation for a later computational design. This framework consists of behavioral models of the user and the supplier (firm) and a game theoretical negotiation mechanism to determine the individual services and tariffs. The *user* is modeled as having “bounded rationality” and “social concerns”. We address the bounded rationality by introducing a simplified *service perceptual space* as the user’s optimization and decision space when the mobile service has many attributes (e.g. $\geq$ 7) to be individualized. The service perceptual space is made up of user-perceived service attributes which are non-technical and well understood by the users. In addition, we apply satisficing decision rules to the user during the decision making process. Moreover, we employ a simple distance-based utility function which can reflect some irrational aspects of the user’s social dimension. In turn, the *supplier* is characterized as seeking a maximum profit with a minimum risk. We use an engineering and business-based *service design space* as the supplier’s decision space because he can grasp all the technical design attributes and also because he eventually needs to implement/provide the service. The supplier’s decision rules are set in such a way that he may lose in some individual contracts when compared to the initial non-negotiable offers to the public at large; but by pooling the different individualized contracts together, he can achieve the highest possible economic utility with a minimum risk at corporate level. The user and the supplier negotiate to have individual services and tariffs, and the user has a dominant influence in the negotiation. The bilateral negotiation process is modeled by a user-led recursive Stackelberg game.

We operationalize the conceptual framework with a computational design and a tool. The design allows the computation of a negotiation result when the user simply states his wishes, e.g. service specifications, budget and contract length in the beginning; it also provides business performance indicators to help the supplier to set decision parameters and criteria. We provide methods to determine the mapping relationship between the service perceptual space and the service design space because, although the user's and supplier's minds operate in different space, they still need to communicate. We construct a realistic supplier's operational model which is rather complex and has many discontinuities and non-linearities. This operator model includes switching between wireless access technologies, traffic transmission and switching/routing, network management, content access and provisioning as well as value-added expertise; it is built as an incremental model able to quantify the consequences of the individual user's requests. We develop three negotiation game algorithms. The first two algorithms are designed for the negotiation games of a complicated value-added mobile service; the first algorithm uses continuous decision variables while the second uses realistic discretized variables. The third algorithm is designed for the negotiation game for common generic mobile service bundles, as supplied currently. In this game setting, the user's mind operates in the same service design space as that of the supplier. We provide risk metrics (VaR and extreme VaR) to quantify the supplier's risks under both normal and extreme market conditions. We present a systematic method to compute the VaRs for the supplier at the individual contract level by using Monte Carlo simulation. This includes methods to characterize and simulate users' service demands that are used as inputs to the Monte Carlo simulation. The expected profit at individual contract level and the rate of deals can also be estimated. Based on these business performance indicators, the supplier can adjust parameters in his constraints and decide rules when negotiating with a group of users to achieve his goal of a maximum profit with a minimum risk. We provide a proof-of-concept software implementation of the computational design as a design tool.

As a first quantitative evaluation of the design methodology and tool, we create a "mobile singing classroom (mSinging)" case, which is a rather complicated value-added mobile service that combines wireless bandwidth needs, wireless data traffic, content and additional professional services. Thus the user's mind would operate in the service perceptual space. Using the design tool, we study the Stackelberg equilibria in the negotiation games and compare them to the initial starting points, which are the public services and tariffs offered by the supplier.

As a second quantitative evaluation of the design methodology and tool, we study a large-scale case of applying the individual service and tariffs concept to a common state-of-the-business standard mobile service bundle, involving voice, SMS, and data download. This is still individualization, because the user sets his contract length and budget, not like in the current commercial schemes offered by mobile operators. In this case, the user and the supplier would use the same service design space.

The results from the above computational cases show that the users, as the leaders of the negotiation games, always achieve gains: the average increases in user utility are 163% and 37%, in the mSinging and the generic mobile service bundle cases respectively. The supplier gains in some games and loses in others from individual users. But by taking a user portfolio approach and pooling the different users together, he can still achieve a gain on average with a reasonable risk. The supplier's average improvement in overall profit is 9% and 142% for the mSinging and the generic mobile service bundle cases respectively.

In both cases, the calculated VaRs have positive values, which mean that at the selected confidence level (i.e. 95%), the supplier can expect a profit from a randomly selected individual contract. The profit levels are indicated by the calculated VaRs respectively. Our results also demonstrate that "a maximum profit with a minimum risk" situation may not be achievable. The supplier can, however, by changing the decision parameters and decision criteria, control his risk-profit equilibrium points.

We extend our research into a community setting, where the main focus is on establishing a business model for community-based individual services. The difference lies in the fact that the community members may then take over some of the supplier duties and serve as content creators or service creators. The evaluations of the business model design are based on two case studies: one is on a wireless game community and the other is on a rural agricultural community; both bear the embryonic form of community-based individual services and tariffs. The case studies demonstrate that community-based individual service creation, provisioning and tariffing can meet precisely the demands of its members and can address both the affordability and sustainability issues.

We conduct an experimental demand analysis of individual services and tariffs in general through a global end-user survey. There are 13 questions in the survey, each of which serves a different purpose. Furthermore the questions are chosen in such a way that by nesting them, some estimates of key implicit indicators could be computed. Cooperation was established with the International Telecommunications Users Group (INTUG) to distribute the survey questionnaire. The key messages from the survey are: equal numbers of users prefer individual services and tariffs, as compared to a flat rate; cost reduction and service simplicity are the main drivers for users of individual services and tariffs; user behavior will change and drive up the network traffic. The main implications from the survey for the users are that price per bit drops by almost half to the users' advantage after the service is individualized; for the supplier, the network traffic will increase by 31% and churn rate will be significantly reduced. Furthermore, there is an extra revenue and cost reduction opportunity in service configuration and tariff negotiation.

We suggest an engineering implementation of the design tool and propose a systematic integration of it into existing communication network infrastructure using existing technologies. In addition, we recommend different user involvement styles, from offline to online in the individual service design and tariff negotiation implementation, to accommodate different user requirements and above all different operator interactions and CRM strategies.

In summary, theoretically, the research contributes to the field of service mass customization by establishing a conceptual framework based on behavioral models. Furthermore the research provides a novel methodology for the computational design of individualized mobile communication services and tariffs by integrating methods and approaches in different disciplines.

Practically, the design tool can be used and integrated into the existing infrastructure by mobile communication services providers (e.g. an operator) in both the negotiations of generic mobile service bundles and complicated value-added services. The former is at the core of the current mobile service business, and the latter represents the trend of development in the near future. In addition, the proposed business model can be readily picked up by any community which intends to provide such services and tariffs.

Further research could include: quantifying specific churn rates for users of individual services and tariffs once they are offered; constructing community behavioral and computational models; incorporating emotional aspects into the user's behavioral and computational model; characterizing and simulating user demands using multivariate extreme value theory; and identifying regulatory implications and social impacts of individual services and tariffs.

Guide to the thesis

The thesis consists of eight chapters. Fig. 0 provides a navigation map from chapter to chapter in terms of concepts, designs and evaluations, and how they are related to each other.

Chapter 1 presents the research motivation, and provides general definitions and characterizations of individual services and tariffs as well as other related concepts.

Chapter 2 surveys the existing literature in related areas, such as mobile service properties, existing tariff models, and service mass customization. The focus of this chapter is on identifying user and supplier behavior characteristics that serve as the building-blocks of a conceptual framework in the next chapter.

Chapter 3 presents the conceptual framework for the design of individual services and tariffs. The framework consists of behavioral models of users and suppliers (firms) and a game theoretical negotiation mechanism to determine the individual services and tariffs. The notions of service perceptual space and service design space are introduced, which capture the different capabilities of the user and the supplier in service design and decision making. A user-led recursive Stackelberg game is introduced to model the negotiation process in which the user has a dominant influence.

Chapter 4 operationalizes the conceptual framework with a computational design and evaluates the design with numerical cases. The computational design consists of computational models (including utility function, constraints and decision rules), negotiation algorithms, and a set of methods to capture and characterize user demands: see Fig. 0 for their relationships with the building-blocks of the conceptual framework. Three numerical cases are developed to provide quantitative evaluations of the design. The first two cases relate to the individualization of a value-added mobile service (mSinging), but with different complexities. The third case relates to the individualization of a generic mobile service bundle. Throughout this chapter, the analyses are carried out on individual negotiation games. We compare the computed Stackelberg equilibria in the negotiation games with the initial public services and tariffs, for the users and the supplier respectively. The results show that the users, as the leaders of the Stackelberg game, always achieve gains; while the supplier achieves gains in some games and losses in the others. Given the results, it is natural to ask if the supplier can benefit from individual services and tariffs, to what extent and how.

Chapter 5 addresses the aforementioned supplier's concerns with computed business performance indicators, which include expected profit, market share and risks. Although the supplier may lose on some users, by taking a user portfolio approach and pooling the different users together, the supplier can still achieve gains on average at a reasonable risk level. Risks in profit are quantified using Value at Risk (VaR) and extreme VaR, under normal and extreme market situations respectively. In addition, we identify application areas for extreme value theory in the context of individual services and tariffs. The computations of business performance indicators are based on Monte Carlo simulations.

We propose methods to characterize and simulate user demands to serve as the inputs to the Monte Carlo method. We demonstrate, using the numerical cases developed in Chapter 4, that the suppliers can adjust their risk-profit equilibrium points by changing the decision parameters.

The content in Chapters 4 and 5 contains the core computational design of firm-supplied individual services and tariffs, which is highlighted by the dashed-line box in Fig. 0.

Chapter 6 extends the concept of individual services and tariffs to a community-based setting. We provide a business model and demonstrate its feasibility by two case studies: one is a wireless game community and the other is a rural agricultural community. Both cases bear the embryonic form of the community-based individual services and tariffs.

Chapter 7 discusses management and implementation issues, and aims to bring the concepts and design in the previous chapters into realization. An experimental demand analysis for individual services and tariffs is carried out via a global user survey. Each question in the survey serves a different purpose and, by nesting them, some estimates of key implicit indicators can be computed. We also investigate the engineering implementation of the design tool and propose a systematic implementation of individual services and tariffs inside existing technologies and communications network infrastructures.

Chapter 8 provides overall conclusions and identifies the contributions of this research. Future research directions are suggested.

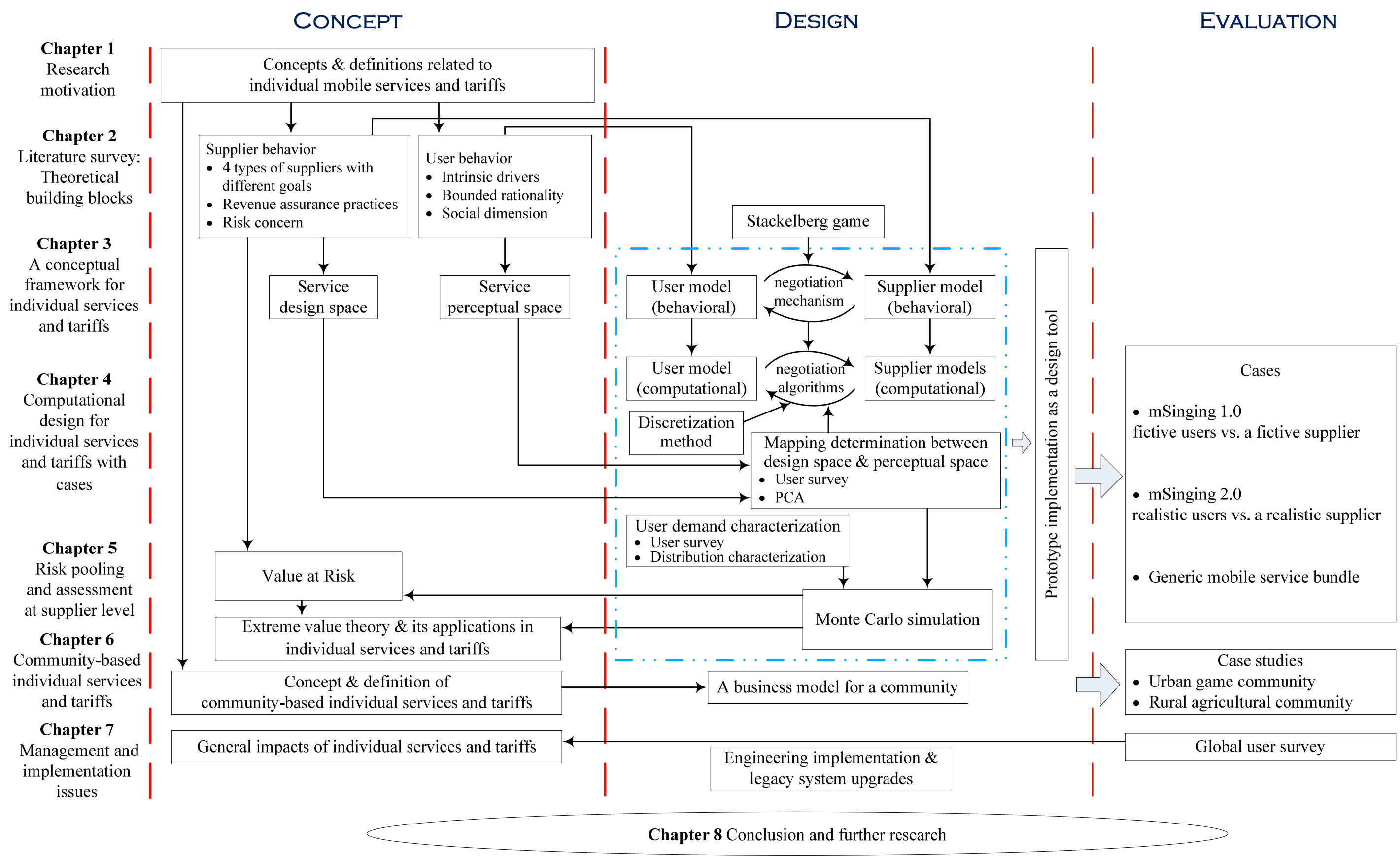

Fig. 0: Guide to the thesis

Chapter 1
Research motivation

1.1 Introduction

INDIVIDUAL services and tariffs[1] existed at the dawn of the telecommunications history. After the telephone handset was patented by Alexander Graham Bell in 1876, for quite some years, and in some markets, it served mainly high-level civil servants and privileged people (e.g. trade, news); and was the symbol of wealth and social rank:

> A wire was at once strung to Windsor Castle. Others were ordered by the Daily News, the Persian Ambassador, and five or six lords and baronets. Then came an order which raised the hopes of the telephone men to the highest heaven, from the banking house of J. S. Morgan & Co. It was the first recognition from the "seats of the mighty" in the business and financial world. (Casson, 1910, p.90)

Users were not designated by a number, but by their names; picking up the phone would get you the operator, who would then ring and connect the desired party by a polite support staff protocol. As a luxury service at that time, the demand for telephony was limited. The supply of telephone services was in general characterized by geographically limited pure monopolies, and the capacity in each country was dominated by two or three local companies able to invest in interconnections.

Due to the limited supply and demand, tariffs were negotiated between the privileged individuals and the telephone companies in a bilateral way. From the very beginning, even for a limited set of services, charging patterns diverged between flat rates and individual usage-based rates. The number of call attempts, physical destination and the duration were manually recorded – but the pricing of the calls was a matter of agreement between the telephone company sales person and the service customer (who was then not a subscriber): usage, rank, fame, location were all taken into account, and the settlement was made by bank note or cash. In some countries, an annual contract fee was charged, while others started with flat rates for a fixed number of calls (not even based on duration or distance). Fig. 1-1 shows a copy of the original tariff specifications of the Copenhagen Telephone Company KTAS in 1884 (translation is in Table 1-1). The basic tariffs were a function of the distance to the main switch (mostly because copper wire had to be installed), while the tariffs for additional connections were negotiable depending on the individuals. Note that the net domestic product at factor cost per capita in Denmark in 1884 was 653 “1884-Kroner” (Johansen, 1985, p. 408), while the cheapest option from the telephone company cost 150 Kroner/year. This means that the ratio of telephone costs to average disposable income was 25 %: only rich people could afford this, and thus always wanted to negotiate.

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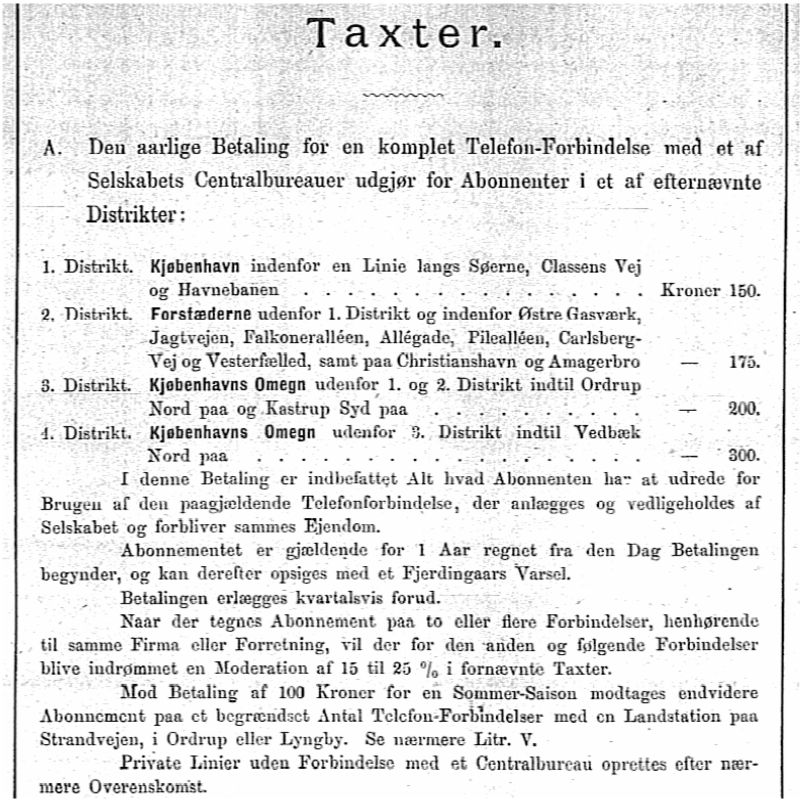
[1] A precise definition of individual services and tariffs is given in Section 1.2: a motivation discussion is presented first, based on the history of telecommunications



Taxter.

A. Den aarlige Betaling for en komplet Telefon-Forbindelse med et af Selskabets Centralbureauer udgjør for Abonnenter i et af efternævnte Distrikter:

1. Distrikt.	**Kjøbenhavn** indenfor en Linie langs Søerne, Classens Vej og Havnebanen	Kroner	150.
2. Distrikt.	**Forstæderne** udenfor 1. Distrikt og indenfor Østre Gasværk, Jagtvejen, Falkoneralléen, Allégade, Pilealléen, Carlsberg-Vej og Vesterfælled, samt paa Christianshavn og Amagerbro	—	175.
3. Distrikt.	**Kjøbenhavns Omegn** udenfor 1. og 2. Distrikt indtil Ordrup Nord paa og Kastrup Syd paa	—	200.
4. Distrikt.	**Kjøbenhavns Omegn** udenfor 3. Distrikt indtil Vedbæk Nord paa	—	300.

I denne Betaling er indbefattet Alt hvad Abonnenten har at udrede for Brugen af den paagjældende Telefonforbindelse, der anlægges og vedligeholdes af Selskabet og forbliver sammes Ejendom.

Abonnementet er gjældende for 1 Aar regnet fra den Dag Betalingen begynder, og kan derefter opsiges med et Fjerdingaars Varsel.

Betalingen erlægges kvartalsvis forud.

Naar der tegnes Abonnement paa to eller flere Forbindelser, henhørende til samme Firma eller Forretning, vil der for den anden og følgende Forbindelser blive indrømmet en Moderation af 15 til 25 % i fornævnte Taxter.

Mod Betaling af 100 Kroner for en Sommer-Saison modtages endvidere Abonnement paa et begrændset Antal Telefon-Forbindelser med en Landstation paa Strandvejen, i Ordrup eller Lyngby. Se nærmere Litr. V.

Private Linier uden Forbindelse med et Centralbureau oprettes efter nærmere Overenskomst.

Fig. 1-1: KTAS Kjobenhavns telephone - selskab 1884

Table 1-1: Copenhagen telephone company KTAS tariffs 1884

Payment covers all phone calls and the maintenance costs of the network and the phone. Tariff is a function of the distance to the main switch, users which are 30 km away pay twice. Basic tariffs are:

1. Inner city of Copenhagen … Kroner 150
2. Copenhagen suburb … Kroner 175
3. Great Copenhagen area I … Kroner 200
4. Great Copenhagen area II … Kroner 300

Payment should be made in advance on a yearly basis for a full subscription. Cancellation of service should be made ¼ year in advance. When a subscription is made, for a second or further connections for the same person or company, the additional connections will have 15-25% discount on the above tariffs, depending on the individuals. In the summer, for a payment of 100 Kroner, the subscriber can have an additional connection in one of the three designated areas.

Individual services and tariffs faded out when the telecommunications industry began to thrive in the early 20th century. Because manual recording was tedious and the goal was to provide access to services to everyone, services were standardized and service provisioning was automated by electromechanical technologies. As a result, users started to pay the same price for each pair of source-destination (Fischer, 1992).

Today, individual tariffs exist for many other types of services, in industries such as airlines, travel and hotels, where prices are associated with booking lead time, booking history, restrictions the individual users are willing to accept, etc. In some cases, individuals can bid their prices for the services that have been chosen (e.g. the "name your own price®" service offered by priceline.com, and equivalents in weekly sales on airlines).

In the telecommunications industry, customer-specific tariffs exist widely at the enterprise/group level for large companies. The tariffs depend mainly on the aggregated amount which the customer intends to buy. At the individual level, despite the fact that the number of mobile users exceeds two billion people worldwide, personalized services and tariffs are still very limited.

Most tariff models in use today in telecommunications (fixed and mobile) have been derived from those of physical goods, assuming limited capacity in either bandwidth or transmission capacity and linked to installation costs like cable length in the 19th century. This worked well when there were limited types of so-called generic standardized services, such as voice or fax.

From the technology perspective, due to the advent of fiber optical transmission and the advances in radio coding/modulation/multiple-antenna/multiple access techniques (Liu, 2006), both the backbone and the wireless access networks capacities have been greatly improved. Furthermore, services are no longer limited to voice. The gradual deployment of the third generation (3G) and Beyond 3G mobile networks (B3G) enables many value-added services (e.g. location-based services, mobile TV), while SMS revenues and profit levels were already very important in the previous 2G networks. In addition to the cellular networks, various mobile and wireless networks (e.g. PAN, WLAN, WAN, digital broadcast networks) are being developed and deployed. These networks are based on various technologies (e.g. Bluetooth, IEEE 802.11, WiMAX, DVB-H) and serve different purposes. With the movement toward all IP networks (Lin & Pang, 2005) and the development of multiradio mobile devices (Björkqvist, 2006), users can access the services offered by different networks at the same time, or access the same service or application across alternative networks seamlessly. At the same time, users' mobile devices are turned into mobile computers that have build-in audio, video capabilities, high storage capacity and processing power (Ojanperä, 2006). The result is that the users can access myriads of services and contents/applications through one single mobile device.

From the social perspective, on both the supply side and the demand side, the "power" of individuals is rising. The deregulation, privatization and liberalization movements around the globe in the past two decades have changed the industry from a rigid, monopolistic one to a more competitive one (Noam, 1983; Xu & Pitt, 2002; Geddes, 2000). The market is moving toward a "contestable market" which is characterized by having no entry barriers

(Willig, 1980). The lowered level of entry barriers is reflected in service creation and provision, which are no longer confined to large companies and operators[1]. The free software/open source movement provides the tools, the increased educational level of whole society provides distributed brainpower, and the communication networks reaching every corner serve to bring everyone and everything together. Small companies and individuals are playing increasingly important roles in creating and providing telecommunication services.

As a consequence of these developments, there is an explosion of services, which will not only put a burden on the communications infrastructure, but also overload the user. Both the wireless spectrum of the supplier, and the attention and money from the users are scarce resources that need to be used efficiently. It is high time that individual services and tariffs, which are tailor-made to satisfy idiosyncratic demands while in the meantime, cut out unnecessary services, be extended to individual users and not just limited to certain privileged corporate customers. This is a critical departure from today's thinking about telecommunication services and their tariffs.

Fig. 1-2 summarizes the current situation and our research target of mobile service provisioning and tariffing. At present, the supplier-centric design of mobile services and tariffs considers primarily the requirements of the supplier (e.g. access network capacity, billing system capacity, sales channels, etc). The result is the limited standardized services and standardized tariffs which do not satisfy many user demands. This research seeks to reach a situation where the mobile communication services and tariffs are designed in a user-centric way, i.e. a user's specific requirements are considered in the design. The result would be individual user-specific mobile services and tariffs.

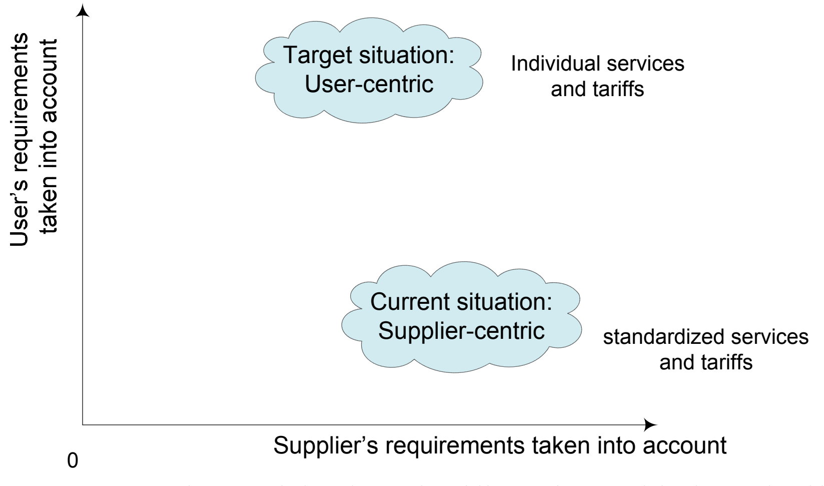


Fig. 1-2: Current and targeted situations of mobile service provisioning and tariffing

1 Due to the fact that infrastructure investment and control are very costly and "sticky", new entrants may need to share the pre-existing network infrastructure with incumbent operators, or may end up by doing so.

1.2 Concepts and definitions

In this section, we first explain the rationale behind selecting mobile services as our research focus; next we provide a definition of individual services and tariffs by identifying usage and industry trends and conducting a review of the relevant literature (see also Sections 2.4 and 2.5); and other relevant concepts and definitions that will be used throughout the research are also provided.

We focus on mobile (communication) services for two primary reasons. First, the sheer number of mobile users worldwide outnumbered fixed-line users in 2002 and surpassed two billion in mid-2005 (ITU, 2005). This number is still increasing rapidly, and in some countries the number of mobile phones per capita is larger than 1. The demands from such a user population on the quantity and diversity of mobile services are huge. Second, mobile devices are widely deemed indispensable to, integral to and intimate in a person's daily life (Fortunati, 2002; Vincent, 2005). The highly personal nature of mobile devices allows mobile services to be highly individualized.

There are numerous definitions of wireless and mobile services. The International Telecommunication Union (ITU) categorizes wireless and mobile services according to different technologies and purposes (e.g. terrestrial mobile services, amateur and amateur-satellite services, aeronautical mobile services, etc). Within a specific technology system, wireless and mobile services are defined and standardized. This is a rather limited categorization, since there have been successful research and field tests in offering the same service across heterogeneous wireless and mobile systems (Kappler, Poyhonen, Johnsson, & Schmid, 2007). In a broader sense, we define wireless and mobile (communication) services as those that are provided via wireless user equipment, through ubiquitous connections to facilitate communications anytime, anywhere, between human beings, between humans and machines, and between machines. Needless to say, the concept of "wireless service" has a broader scope than "mobile service" because the former can include, for example, fixed wireless services whose mobility is limited. In this thesis, we use the term "wireless service" to emphasize that, at access level, the service uses wireless technologies. We use "mobile service" to emphasize the mobility of the service.

In order to define individual services and tariffs, the opposite is defined first. ***Public services and tariffs*** in telecommunications refer to the regulatory-protected ability of an identified user to obtain, from a service provider, by a bilateral contract, a standard service, at a standardized price. ***Public service*** is then the communication service supplied in the manner stated above, following a request by the user. ***Public tariff*** is then the standardized tariff paid by the user for the standardized service. Public services and tariffs are common practice with current incumbent telecommunication operators: they are often offered in the form of "service bundles".

According to a recent marketing "tradition" dating from the late 1980s, the notion of ***mobile service bundle*** and ***bundle tariff*** refer to offering to customers a finite set of generic mobile services (e.g. voice, SMS) in one "package", each for a given tariff repeating itself in monthly intervals over the contract duration. Each such bundle may have certain parameters which the user can set for an additional price. Each service within a bundle has a usage ceiling: changes in these thresholds force a change in the bundle tariff or an incrementally higher price over that within the bundle; sometimes unlimited usage of a certain service is offered within a specific time period. Often, an operator provides a subsidized mobile terminal as part of the contract. There is no transparency at all as to how the whole contract has been designed. There is no interaction, other than explanations of the contract clauses, between an operator's salesperson and the user when signing the contract. A user has to choose one service bundle with its corresponding tariffs by predicting his needs and usages of the services in the future, or reject the offer and receive no service. This limited segmentation often leaves a significant number of demands from the users unsatisfied.

Individual services and tariffs in telecommunications refer to the regulatory-protected ability of an identified user to obtain from a service provider, through a bilateral specific contract, a combination of services and related content, at a specific price (called a tariff chosen by the user) corresponding to a user request specified with a service demand profile and a certain duration. ***Individual service*** is the communication service supplied in the way stated above, with a request and specification by the user. ***Individual tariff*** is the price paid by the user for such an individual service.

Per this definition, individual services do not in essence include pre-paid services and individual tariffs do not include tariffs offered by traffic or service aggregators or resellers. The notion of individual services and tariffs therefore is also different from a bundle, because in the latter, the user has no influence on the possible services or service characteristics, and he cannot specify changing usage over time. It will be explained in Section 4.9 how even a public generic service can be priced by the user according to an individual tariff different from an operator-supplied bundle.

The ***users*** of individual services are the recipients[1] of services; if there is a subscription, the user can also be called a subscriber.

The ***service provider/supplier*** is defined in a broad sense as the entity that provides access, content, applications and human resources, as well as support, or a combination of these to users.

What need to be clarified and differentiated are the concepts of **personalization** and **mass customization** and their relations to individual services. In the context of mobile communication services, personalization means configuring some service parameters by a user on the basis of configuration options specified by the supplier. Mass customization means to co-design a service, with attributes and characteristics that meet an individual's specific requests within a larger class of capabilities offered by the supplier. In both activities, solutions are found within a complete fixed solution space. The difference is that mass customization has a much higher flexibility in meeting the user's service demand. It is also stated that "the costs associated with mass customization allow for price levels that

[1] The recipients of the services can be human beings or machines. In this research, we focus on human beings as users.

do not imply a switch in upper market segment" (Piller, 2004). In this thesis, we use the notion "individualized mobile service" to represent the user-specific mobile services, which can be a result of a personalization or a mass customization activity. This thesis, however, does not cover the old-established approaches of personalization with only discrete choices driven by the supplier. In Chapter 4, we present methods to determine the service-specific fixed solution space, and any negotiated agreement within it will lead to individual services and tariffs. We also demonstrate in Chapter 4 that parts of the fixed solution space can lead to service characteristics which have continuous values, while other parts of the solution space lead to service characteristics which can only have discrete values options.

1.3 Research objectives and research questions

During a preliminary study to formulate the concepts and definitions of individual mobile services and tariffs, we identified many closely-related research dimensions, including: "the degree of freedom of mobile service pricing", "the granularity of service providers", "affordability", "risk to users and suppliers", "social effects", "migration of the system" and "policy, regulation and law" (for details, see Appendix I). These issues were too broad to tackle during a PhD study. However, there is a fundamental element in these research dimensions: they are all dependent on the existence of individualized services and tariffs. Given this, we set the objectives of this research as follows:

1. To provide a design methodology and tools to realize individual mobile services and tariffs;

2. To provide a decision basis for the users and the suppliers of mobile services to adopt individual services and tariffs.

Given the research objectives, we formulate our research questions to be:

1. How can individual-specific mobile services and their corresponding tariffs be determined and built?

2. What are the benefits of individual mobile services and tariffs to the user and the supplier respectively?

The first research question is of a design nature: it requires the design of a service and tariff determination model, which can jointly take into account the requirements and constraints from both the users and the supplier. Furthermore, the design should also provide risk assessment instruments to the supplier, as individual tariffs will inevitably introduce more uncertainty to the market share and profit than a commodity contract. In addition, the design should be technically feasible to implement as an add-on to the existing communications systems. While such mass customization was long considered impossible or unaffordable for manufactured goods, the very sophistication and flexibility of the control systems managing communication networks may turn mass customization of communication services into a reality. As much economics research has focused on the primary and secondary sectors, too little visibility has been granted to the communications and knowledge economies' own tools to show that such mass-customized communication services are in fact possible (Pau, 2003).

The second research question demands evaluations of the concept and the design of individual mobile services and tariffs. By identifying the costs and benefits, we provide a concrete decision basis for the user and the supplier to adopt individual mobile services and tariffs.

1.4 Research methodology

1.4.1 Combining behavioral and design sciences

The research perspective of design science has its roots in engineering and in "the sciences of artificial" (Simon, 1996). Ontologically, the design perspective assumes there is a single, stable physical reality, which sets the foundation of the design. Meanwhile, there are also socially and technologically created realities, which constrain and shape the design (Gregg, Kulkarni, & Vinzé, 2001). Epistemologically, knowledge is obtained through the design process: an objectively constrained construction within a context (Gregg et al., 2001). With regard to the nature of the supporting methodology, Glegg (1973) makes a simple comparison between designers and other scientists, and concludes; "A designer and a scientist travel the same road but sometimes in opposite directions. The designer goes from the abstract to the concrete, scientists from the concrete to the abstract."

Design science consists of two basic activities, build and evaluate. The "build" activity produces four artifacts (March & Smith, 1995): constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithm or guidance or process), and instantiations (implementation). The evaluation activity determines how well the artifacts perform.

Most tariffs design research in telecommunication has been done with known services. However, the concept of individual tariffs is built on the assumption of abundant individualized mobile services; and most of these are yet to be developed. Research that looks into the development and deployment of mobile services in the future poses great challenges. Trying to identify a scenario based on current technology trends tends to be unreliable. Such examples are abundant, as the predictions of the third generation (3G) mobile services have largely failed (Whalley, 2002). Besides technology development, mobile services are shaped by interactions among users, between users and providers, and during the course of usage, which serves as a means to satisfy economic and social needs (Trosby, 2004). Human behavior is guided by human values, which stay relatively constant over a long period of time when compared to the fast development of technology (Rokeach, 1973). Individuals behave under economic constraints. Furthermore, human behavior is influenced by the social environment. Human values, economic constraints and social environments, unlike technologies, change relatively slowly. For the above reasons, this research tries to incorporate the behavioral aspect into the research on individual tariffs. This is in line with the research framework proposed by Hevner, March, Park, & Ram (2004), where behavioral sciences and design science research are complementary to each other. Behavioral science has its roots in natural sciences and is concerned with how things are. It provides inputs to the design research, as the latter is concerned with how things ought to be (Simon, 1996, p. 114).

1.4.2 Research methods of individual services and tariffs

Research in individual mobile services and tariffs is in the interdisciplinary field of computer science/communications and economic decision making. We develop a research design that integrates various methods and approaches from these different fields to address different aspects of our research questions (see Fig. 1-3).

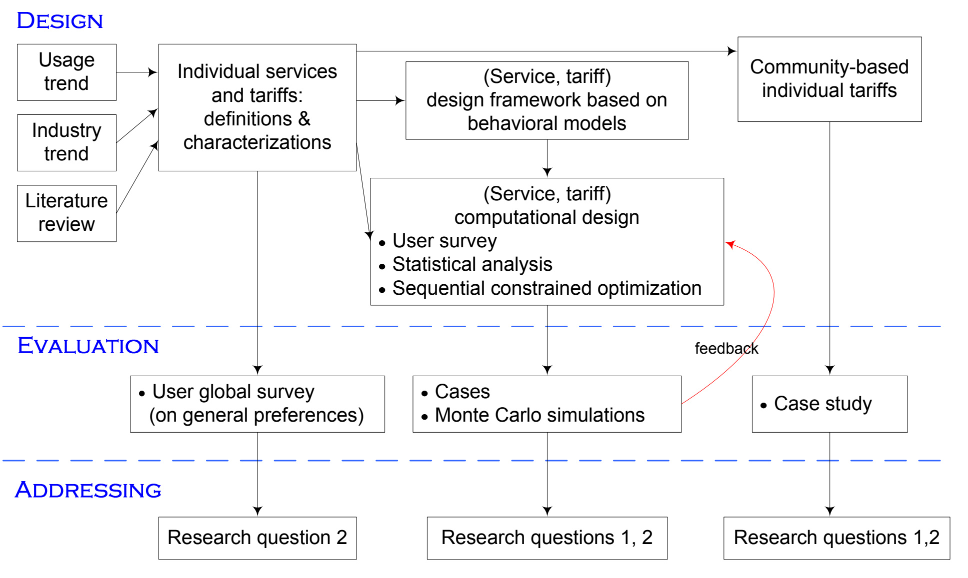


Fig. 1-3: Research design and methodology of the dissertation

Our research activities are divided into a "design phase" and an "evaluation phase", reflecting the nature of our research questions.

Before the primary design activities are carried out, we first conceptualize individual mobile services and tariffs. By identifying current mobile service usage trends, mobile industry development trends, and by conducting a literature review, we provide clear characterizations and definitions of individual services and tariffs, and other relevant concepts. The literature review focuses on user and supplier behaviors, on economic principles and on social factors which provide a solid foundation for the later design activities.

The design activities are divided into two main parts. The first design activity aims to provide a computational design for a specific class of individual mobile services and tariffs. To do this, we first construct a conceptual framework which serves as the theoretical foundation for the later computational design. The conceptual framework is built using behavioral models of the user and the supplier. We then operationalize the conceptual framework with design methods, computational models and algorithms. The methods we employ include “survey”, “statistical analysis” and “sequential constrained optimization”.

The second design activity is to extend the concept of individual service and tariffs from a corporate setting to a community environment by designing a feasible business model.

Correspondingly, there are two evaluation activities to assess the above designs, and we employ multiple methods in these evaluations. First, to evaluate the computational design, we develop cases which allow us to carry out detailed numerical analyses. Furthermore, we run Monte Carlo simulations based on the cases to provide data for the supplier’s risk analysis. Second, to assess the feasibility of the community-based individual tariffs, we conduct two qualitative case studies.

Furthermore, to determine the general impacts of individual services and tariffs to the users and the supplier, we conduct a global user survey.

Although the research design embraces a broad scope, our core research activity will focus on the computational design of individual services and tariffs, and the evaluation thereof, through which we wish to partially answer the first research question of “how to determine individual services and tariffs” (Section 1.3). The answer to the second research question regarding “the benefit of individual services and tariffs to the user and the supplier” will be jointly provided by the evaluation activities.

1.5 Scientific and managerial relevance

This research represents a “radical” departure from the current mobile communication services and tariffs design, by putting microeconomic pricing principles and full deregulation into a sector still governed by public service and monopolistic thinking. It is therefore linked to economics and sociology as well as to the evolution of technology.

1.5.1 Economic relevance

By offering individual services, suppliers can avoid the model of competing on a set of limited standardized services. The research not only opens up the way for the development of new services and tools, but could also change part of the operator’s business from a static “take it or leave it” approach to a dynamic and competitive matching of services and tariffs to individual requests, while reducing churn, securing profit and minimizing OSS/CRM costs. Pricing mobile services depending on the buyers requires a complete rethinking of the market mechanisms and channels.

Needless to say, not all service providers would wish to carry out the work involved in contracting for individuals with possibly dynamic tariffs and risks, using the fullest flexibility of their infrastructure and management platforms. But some emerging operators,

e.g. mobile virtual network operators (MVNOs) may see this business model as a market penetration mechanism, particularly if they do not have great marketing resources.
Not all consumers may want to consider flexible tariffs but instead prefer stable price bundles with little transparency and limited choices. But more consumers are participating in, and are playing more important roles in service creation and provisioning to satisfy their unique demands. From the moment such capabilities are created for individuals, small and medium size companies will follow this same trend, gaining business advantages.

1.5.2 Social relevance

By allowing the user to set a ceiling on tariffs which meets his budget and brings down the affordability barrier, individual services and tariffs will accelerate the diffusion of innovative communication services within one country and across borders. The digital divide between rich and poor users will be reduced as they each have different service needs.

On a personal scale, individual mobile services can better meet the various user demands. Mobile communication has already changed the behavior of people and their lives (Katz, 2006), and more significant changes are yet to come.

1.5.3 Technical relevance

This research also has technical relevance. The legacy circuit switching-based billing systems in the telecommunications industry do not support individual tariffs. Over the past years technical developments have provided, at the service level, limited control capability for end customers regarding end-user programmable interfaces of traffic and tariffs (SIP, IEEE 1520). Furthermore, the switching systems are now all ATM or IP-based in wireless networks, thus actually allowing for billing at packet level (Pau, 2001). This research can first provide insights into the feasibility of technical standards for individual tariffs and services. Second, the research provides guidance for the development of software and system architectures of the new billing and service/content management platforms. Third, the research provides directions for operators to design their data mining tools to better capture the demands from the users.

Chapter 2
Literature survey: Theoretical building blocks

2.1 Introduction

Individual services and tariffs constitute a new research area and the existing literature in this field is very limited, even when taking related mass customization literature into account. Given this, this literature survey would focuses primarily on the relevant topics that can shed light on our design.

The survey is divided into two parts (see Fig. 2-1). In *Part I*, we identify the properties of mobile services, review research on service customization, and look at existing telecommunication tariff models and their limitations. As has been discussed in Section 1.4.1, this research will take a behavioral science plus design science perspective. Therefore in *Part II*, we put our main efforts into identifying the various dimensions of user and supplier behavior, which would provide a solid foundation for our conceptual framework design in Chapter 3. We also look at computational game theory, which offers a structured analysis of interactions between the user and the supplier.

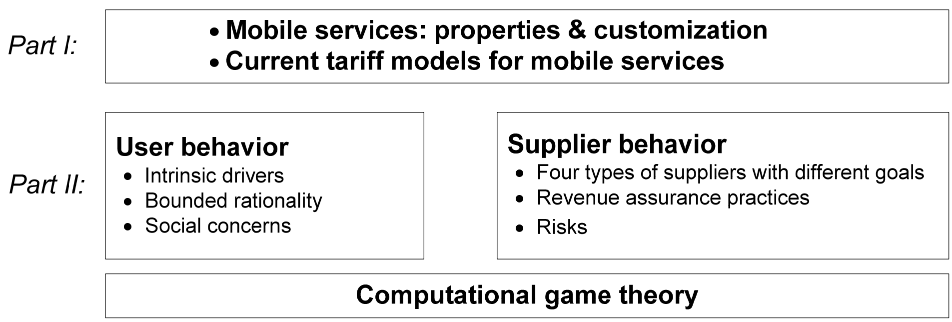


Fig. 2-1: Structure of the literature survey

2.2 Mobile services: Properties and customization

Services differ from physical goods in their intangibility, perishability, heterogeneity and in the inseparability of production (Zeithaml, Parasuraman, & Berry, 1985). Two additional traits have been identified for industrial services (Jackson, Neidell, & Lunsford, 1995): customization and technology. Mobile services are not necessarily industrial services. It is arguable whether "technology" is a characteristic of mobile services. Mobile services can however be delivered to a specific device, which is usually used by a specific person or machine. This means that, in addition to satisfying the general demands from a group of people or machines, mobile services can be tailored to satisfy the unique requirements from an individual person or a machine. In this research, the customizable or personalizable parts of mobile services consumed by a user are primarily[1] value-added services that he may need beyond basic generic services. By default, the individual tariffs apply to all such value-added services.

Mobility is one of the key advantages of wireless services over fixed-line services. Mobility has two dimensions: spatial and temporal. The former means that services can be accessed at almost any location. The latter means the user can access the service whenever there is a motivation. This brings many uncertainties as to where and when the services are being or will be consumed; and thus there are many technical (Cavalcanti, Agrawal, Cordeiro, Xie, & Kumar, 2005) and social consequences (Green, 2002), which makes the pricing of mobile services a challenging issue.

Mobile services are intangible goods. Koppius (1999) identifies 12 dimensions of intangible goods, out of which the “value determination” is the most important and difficult. First, it is because of the idiosyncratic nature of intangible goods, which make it difficult to compare them to similar goods. Second, it is because intangible goods are experience goods. The classification of the quality of a product into search, experience and credence quality has its origin in the marketing literature (Nelson, 1974; Darby & Karni, 1973; Ziethaml, 1981). Search qualities are those that can be determined before purchase; experience qualities are those aspects that can only be determined after purchase or consumption; and credence qualities are the aspect that a consumer cannot determine even after the purchase because of a gap in necessary skill. A continuum from search to experience and to credence quality provides a useful method for value-determination. Following this categorization, most mobile services fall inside the interval between search and experience goods. Mobile service has to be experienced when consumed for the first time. Communication services are however volatile, as they are not available for recurrent consumption. In this way they are in contrast to many experience goods, which are repetitive. Furthermore, heterogeneity in the production and quality of service is allowed, thus the quality of the mobile service may vary and result in new experiences.

To sum up, mobile services are perishable and have an instantaneous experience value. The production and consumption of mobile services are inseparable. Mobile services can be personalized/customized, which leads to real-time diversity and service quality heterogeneity. The intangibility of mobile services makes them more difficult to evaluate than physical goods; and also more difficult to evaluate than intangible content products because of the volatility. Furthermore, the mobility property adds uncertainty to where and when the services will be consumed. It is the combination of these properties that makes mobile communications services differ from other types of services, and makes the pricing of mobile services a challenging topic.

Recent research in mass customization primarily focuses on the customization of physical products such as clothing (e.g. footwear, garments, prêt à porter) or consumer electronics (e.g. watches, laptops), and on user design toolkits for such customizations (Abou-Jaoude & Kung, 2005; Au & Goonetilleke, 2005; Franke & Pille, 2004; Ogawa & Piller, 2006; von Hippel, 2005). Because of their properties (see above), mass customization of services

[1] we also research on the personalization of generic service bundles in Section 4.9

is rather limited, and applications are widely spread across different industries such as education, finance and health care; the corresponding research publications focus on mass customization strategy (Gabriel, Gersch, & Weber, 2006; Grenci & Watts, 2007; Lampel & Mintzberg, 1996), customization frameworks, processes and customization approaches under specific contexts (Huang & Lin, 2005; Winter, 2001), and customer value perception (Prahalad & Ramaswamy, 2004).

Current practices of mass customization in the mobile communication industry mainly focus on the industrial design of the wireless terminals, on user interfaces and sometimes on software based feature selection: see e.g. Sigala (2006) for customers' perceived value dimensions (e.g. functional, social, and emotional) of mass-customized "mobile phone + services" and the implications for suppliers in conducting a customer value-based market segmentation. Some mobile terminal suppliers make mass customization of their designs their key intellectual property rights (IPR) based business model. This is accomplished via common design platforms that help third parties produce competing customized products (e.g. Ericsson Mobile Platforms AB, Modelabs, Qualcomm). With regard to public mobile services which involve the network infrastructure for the production of mass-customized services, mass customization remains limited.

2.3 Tariff models for mobile communication services

When they first began to develop, tariff models for mobile telecommunication services were inherited from traditional fixed telephony. This was straightforward when both fixed and mobile were offering one type of service, i.e. voice; and when most of the wireless infrastructure was dependent on the fixed circuit-switched communication infrastructure (except the radio base stations). Over the years, the pricing of mobile services developed slowly and tariff bundles were introduced. Research into these areas has been carried out, to an overwhelming degree, either within the industry or by regulators.

Academic research, on the other hand, has focused on several areas, but is largely disconnected from industrial research. In pricing the usage, dynamic pricing in mobile services was first discussed by Fitkov-Norris and Khanifar (2000), who applied different tariffs dynamically according to the available network resources. Much research has followed (Viterbo & Chiasserini, 2001; Yaipairoj & Harmantzis, 2004), since mobile resources are scarce and better utilization of the network can greatly increase operator revenue. Other early articles on tariffs focused on how the tariff structure (the relationship between tariff components) affects consumer behavior and consequently the long-term profitability of operators over the mobile voice service (Danaher, 2002; Iyengar, 2004).

Existing research into "public tariffs" tends to follow two themes: focusing either on the allocation/utilization optimization of bandwidth/QoS(data packets) through tariffs, or on the optimization of the tariff structure for a set of (limited) standardized services and with a limited segmentation of consumers. The monopolistic thinking of telecommunications operators reflected in this research is still dominant where the prices are driven by suppliers. The prevalence of this thinking is due to the closed architecture of telecommunication systems, where the operators take full control over the network resources. But this is no longer the case with deregulation policies around the globe and technical standards being specified to open up telecommunication systems (e.g. the Parlay/OSA specifications, see also Moerdijk & Klostermann, 2003).

Individual mobile services and tariffs require a new mindset. First, as has been discussed, mobile services are no longer limited to a set of standard services such as voice and data. Services mixing content, either static or dynamic, and applications which enable interactions, are included. Therefore, research should no longer be limited to bandwidth or QoS, nor to only optimizing tariff structure over limited service choices. Second, services can be personalized/customized to meet the specific demands of consumers, who may then also take part in the procedure of co-creating the value of the services they demand individually. Furthermore, as the market moves from a monopolistic to a highly competitive setting, new service creation and provisioning approaches will emerge. All these trends lead to a demand-driven market, where consumers play more active roles in deciding the tariffs for the services they help to design.

2.4 User behavior

The user of individual services is the recipient of the service. In this research, we focus on human beings as users, whose behavior is guided by human values, influenced by the social environment and bounded by economic constraints. In this section, we survey the relevant research in these fields which will serve as a basis for understanding the users.

2.4.1 Intrinsic drivers

From a sociological perspective, a post-modern society (or a society in high modernity, according to Giddens, 1991, p. 4) is characterized by its lack of dominant ideology, culture or fashions (Antonides & Raaij 1998, p. 56). This is also reflected in the diversity of personal values which give meaning and direction to an individual's behavior. Not all individual users are willing to consider individual services and tariffs. Some prefer a pre-determined bundle with little transparency and limited choices. There is, however, a growing population with values that may serve to engender the adoption of individual services and tariffs (see Section 7.2 for a survey that establishes this fact). We now present a non-exhaustive list of drivers that we consider fundamental.

Individualism has been probably one of the most abused words in the last century. Different schools have contradicting interpretations. We adhere to the definition of individualism defended by Hayek (1980) as the theoretical foundation of our research. Hayek's individualism is primarily a theory of society, an attempt to understand the forces which determine the social life of man. Under this notion of individualism, there are universally accepted principles (institutions) under which man makes his own choices and takes full responsibility: he is free to follow his own will, to make full use of his knowledge and skills, and he is guided by his concerns for the particular things of which he knows and cares about. We should refute here is the belief that individualism postulates "egotism". Instead, individualism starts from men whose whole nature and character are determined by their existence in society: it affirms the value of family and all common efforts of a small community or group, and it believes in local autonomy and voluntary association. Furthermore, Hayek's individualism holds the view that man's individual reason is very limited and imperfect, that the collective efforts of mankind can achieve things which have not been designed or understood by any individuals, and are greater than individual minds. Individual mobile services and tariffs are reflections of Hayek's individualism, where a person in a free society has the freedom of choice of services and prices, at any time and anywhere. Individualism is also reflected in the freedom of service creation and provisioning, either to a family, to a small community or group, or to the whole society.

Self-identity, in a late modernity setting with rapid social changes, has to be routinely created and sustained in the reflexive activities of the individual (Giddens, 1991). "How shall I live?" has to be answered in day-to-day decisions about how to behave, what to wear and what to use. Modernity opens up the project of the self, but under the strong influence of standardization of commodities. Here, the market is assumed to be a default setting of modernity. The market promoted individualism, first out of concerns for the freedom of contract and mobility intrinsic in capitalistic employment, and second in order to extend the concept to consumption, to designate each individual's wishes. A good example is the corruption of the notion "life style", where the project of self has been associated with the possession or consumption of certain pre-determined products and services. The consequence is the suppression of the genuine development of the self. To move away from this predicament created by commodified consumption, an individual should surround himself with individual experiences. Individual services and tariffs promote the user's autonomy by encouraging the user to define what he wants, not just selecting or accepting the pre-defined services, as part of a "framed" style of life.

Innovation was defined by Rogers (2003) as an idea, practice or object that is perceived as new by an individual or other unit of adoption. Innovation in the context of individual services and tariffs is user-centric, which is in sharp contrast with the supplier-centred tradition in the telecommunications operator industry. The latter often innovates in a closed form, and uses patents, copyrights or trademarks to prevent others from imitation. The former often uses open source (software or tools), rapidly-transferred research results, shared knowledge, to create new products or services to accommodate users' unique demands; user-centric innovations are often freely revealed (von Hippel, 2005). In addition to the products or services they have developed, participants in user-centric innovations gain rewards from the innovation processes (Lakhani & Wolf, 2005). More generally, innovation is a specific expression of creativeness. Maslow (1987, p. 160) distinguishes "special talent creativeness" from "self-actualization creativeness". The former refers to the level of creativity that belongs to geniuses such as Einstein, Edison and Mozart, which is exceptional. The latter refers to the creativity that is latent universally in ordinary people, which springs much more directly from personality and shows itself widely in ordinary affairs of life, not only in great and obvious products but also in a tendency to do everything creatively. Creative people are less inhibited, less constricted, less bound. Instead, they are original, inventive, and innovative in whatever their realm of life may be. According to Maslow, self-actualization, which is the tendency of people to be actualized in what they potentially are, drives people's creativity: "What humans can be, they must be. They must be true to their own nature" (Maslow, 1987). The creation of individual mobile services used to be inhibited by technology, knowledge and economic constraints.

With the first two constraints mostly alleviated nowadays, this research aims to alleviate the last constraint and ultimately unleash the spirit of creativity in ordinary people.

Recognition from others also plays an important role in our values, as we are all social animals. In a networked society where physical boundaries are disappearing, a little effort may harvest considerable recognition from people around the world (Chan, Bhandar, Oh, & Chan, 2004; Hong, 2006; Rheingold, 2002). Recognition from community members provides positive feedback to creative activities. This feedback helps an individual establish self-esteem, which leads to the feeling of self-confidence, strength, capability and adequacy, of being useful and necessary in the world (Maslow, 1987, p. 21).

Determining the extent to which these values are spread and the degree to which these values are influencing people's behavior are beyond the scope of this research. We simply take the existence of these personal values as our working assumption: there are people keen to have individual services and tariffs. We do however validate this assumption through two extensive user surveys (see Section 4.8 and Section 7.2).

2.4.2 Bounded rationality

The concept *Homo Economicus* or "economic man" describes a model of man who seeks to attain specific and predetermined goals to the greatest extent with least costs. *Homo Economicus* can be characterized as "fully rational" and "self-interested". The model is used broadly in economic and other social sciences. However, many researchers have found limits to this model. Steele (2004) and Thaler (2000), for example, propose different directions to enhance the model.

The strict definition of rationality states that an individual's preference relation is rational if it possesses the properties of completeness and transitivity (Mas-Colell, Whinston & Green, 1995: p. 6). This means that the individual is able to compare all the alternatives and the comparisons are consistent. Furthermore, rationality implies that the individual has complete information about all alternatives and knows the consequences of his choices; he then also has unlimited time and unlimited computational power to pick his most preferred option. In reality, such a perfectly-rational person can never exist (Miller, 1956). Over the past decades, a large mass of empirical data have shown violations of the rationality assumption, and this affects also trading schemes such as auctions. Shafir and LeBoeuf (2002) provide a detailed review.

In 1957, Herbert Simon pointed out that, most of the time, an individual does not know all the alternatives relevant to his decisions (Simon, 1957). Neither does he have perfect information about the consequences of choosing a particular alternative, both because of limited computational power and because of uncertainty in the external world. The individual's preferences do not possess rational properties when comparing heterogeneous alternatives. Simon characterized this as "bounded rationality". Model construction under the bounded rationality assumption can take two approaches. The first is to retain optimization, but to ***simplify it sufficiently*** so that the optimum is computable. The second is to construct a ***satisficing*** model which provides good enough decisions, with reasonable computational cost (Simon, 1979). Neither approach dominates the other.

Following the pioneering work of Simon on bounded rationality, Kahneman and Tversky conducted a series of research projects on various types of judgment under uncertainty. Their conclusion was that people rely on a limited number of heuristic principles[1] which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations (Tversky & Kahneman, 1974). A recent revisit of these studies by Kahneman and Frederick (2002) proposed a formulation in which the reduction of complexity is achieved by an operation of "***attribute substitution***". A judgment is said to be mediated by a heuristic when an individual assesses a specified *target attribute* of a judgment object by substituting another property of that object, the *heuristic attribute*, which comes more readily to mind. Heuristics share this common process of attribute substitution; furthermore, the usage of heuristics is not limited to judgment under uncertainty.

2.4.3 Social concerns

The self-interested property implies that "economic man" is amoral and has no sense of right or wrong. He ignores all social values unless adhering to them gives him benefits: his preferences are exogenous and not affected by the societal environment at all (Camerer & Fehr, 2006). However, this is never true: in choosing to act, individuals commonly consider the consequences of actions not only on themselves but on others as well; these individuals have social preferences (Bowles, 2004). This other-regarding (in comparison with self-interested) property of social preferences is often embodied as altruism, fairness, teamwork, spite, etc. Many social preferences do not possess the properties of completeness or transitivity and thus are partially rational or irrational.

Mobile services, by bringing mobility in time and space, enable many social interactions which were hardly possible in the past (Green, 2002; Rheingold, 2002). We contend that the social preferences enabled by mobile services are determined by the benefits that an individual elicits from the interactions under different social environments and with different people. Major factors affecting social preferences are:

1. Access to the mobile services, which is an individual's right.
2. Social context, by which we mean the social environment in which an individual lives in, such as social location and social relationships. In different locations and accompanied by different people, an individual's preferences are affected by specific social norms and social relationships (Lasen, 2002; Plant, 2002). This is further complicated by a possible "absent presence effect" introduced by a mobile service, where a person is physically present but absorbed by a technologically mediated world of elsewhere (Gergen, 2002).
3. Content. The content of a communication service could be categorized as time critical and non-time critical, according to the perceived importance of a timely service. An individual's intertemporal preference is usually decided by a value function on the subject and a discount function on time. Empirical research indicates that the discount function is a generalized hyperbola (Frederick, Loewenstein, & O'Donoghue, 2002; Loewenstein & Prelec, 1992). Moreover,

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[1] The three heuristics being studied were representativeness, availability and anchoring.

content could be categorized based on whether the communication is directly or indirectly motivated. In directly motivated communication, the action satisfies a need: the content is important to the individual, which can be ideas and thoughts, feeling and emotions, comfort and support. In indirectly motivated communication, the action satisfies an intermediate goal, which can in turn lead to the satisfaction of a need. Content is less significant in indirectly motivated communication: what is important is the fact that the communication has occurred. It occurs just to confirm a relationship (Cook & Yong, 2005; Licoppe, 2003).

2.5 Supplier behavior

2.5.1 Four types of suppliers with different goals

Benkler (2002) points out that in addition to the two common forms of organizing economic production (either through a firm under the direction of a manager, or through individuals themselves in the market following price signals), there is a third model of production. Benkler calls it "common-based peer production". The distinguishing characteristic of this model is that groups of individuals *collaborate* on large-scale projects following a diverse cluster of motivational drives and social signals rather than market prices or managerial commands. A well-known example is the Linux kernel project (see www.kernel.org) where thousands of people around the world collaborate to develop the core of an operating system. Long before this, but less publicized, was the joint development of core processor architecture, UNIX, communication protocols, measurement instruments, etc, within the telecommunication supplier industry, enabling the interoperability found in communication services nowadays. The third model of production is becoming more and more common and important in today's information society. Already, mobile services exist that have been created and provided following this model. For example, a service called cellphedia (see http://www.cellphedia.com/) allows users to send and receive encyclopedia-type inquiries between specific, pre-defined groups, through text messaging. Since the group of individuals sharing a common goal can also be characterized as a community of mind (Tönnies, 1967) or a community of interest, we suggest that the "common-based peer production" can also be characterized as "community-based production". We thus identify four types of suppliers of wireless and services:

1. Operators: to distinguish them from communities as suppliers (see below), we term them operators. There are public and private operators. The former (e.g. most public mobile operators) are subject to a universal service obligation (USO) under the regulatory regime. The latter sell services to customers under the restrictions only of commercial laws (e.g. WiFi operators). What is of concern is the economic implications of the USO, as the public operators usually need to bear higher costs than private operators.
2. Closed communities where membership is required. Only the members can contribute their efforts, and consequently the usage of the services is limited to

only the members. The contributions from members of a community vary from knowledge, information, expertise, time, even empathy and sometimes money.

3. Open communities which do not require a formal membership; but a certain level of registration and authentication are still needed to meet privacy policies and regulation. At the same time, open communities are also subject to liability risks and IPR issues.
4. Individuals, who normally do not supply infrastructure, but service specifications and content.

The main differences among the four types of suppliers lie in their different goals. The nature of firms such as operators dictates that their goal is profit/market share maximization and risk minimization (Tirole, 1988). A supplier, however, may also have social preferences (e.g. preference for fairness, reciprocity) in his decisions as well as environmental preferences. There may be conflicts between a supplier's economic benefit and social preferences; he will try to achieve equilibrium/equilibria between them. The equilibrium/equilibria is seldom computation-based but mostly subjective or at best based on ranking of preferences. None of the existing models provides comprehensive measurement and calibration instruments to quantify the social preferences of a firm (Wu & Loch, 2007). In this research, we limit our firm model (see Section 3.2) to derive only economic benefits from service offerings.

The non-profit seeking nature of communities drives their goal to be achieving financial breakeven and minimizing risks. Compared to firms, they have more social aspects to deal with. This is reflected in a much more complicated utility function to accommodate social concerns from within the community. It may also be reflected in the more different setting of constraints and more complex decision rules (e.g. majority, unanimity) in a closed community environment[1].

The difference between closed and open communities lies mainly in their risk adversity (we will come back this topic shortly in Section 2.5.3) and information sharing aspects (Cornes & Sandler, 1999). When a single individual is the supplier, he can either choose to seek a profit and act as a firm, or to achieve a financial breakeven, or to maximize social benefits.

Out of the four types of suppliers identified above, the most important types are the firms and communities, who account for the majority of the suppliers and provide most of the mobile services. Weighing the complexity of the firm's and community's behaviors, the leading role that firms play in supplying mobile services, and the limited time budget of this research, we decide to focus primarily on firms as suppliers. We construct a behavioral model of a firm in the context of individual mobile communication services and tariffs in Chapter 3. Based on this, we develop a computational design in Chapters 4 and 5. We will look into community-supplied individual services and tariffs in Chapter 6, with emphasis on the business model and its feasibility.

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[1] This could be the opposite in communities with selective screening of members.

2.5.2 Revenue assurance practices

In this section, we examine two types of supplier behaviors that can affect their profit: price discrimination and user involvement.

2.5.2.1 Price discrimination

Price discrimination or price differentiation is a common practice in today's business world[1, 2]. The concept was coined by Pigou (1920), who distinguished three types of price discrimination. In first-degree (perfect) price discrimination, each unit of commodity is sold at a difference price, which is the maximum the user wants to pay. In second degree price discrimination (nonlinear pricing), commodities are divided into *n* groups and sold at *n* different prices. In third degree price discrimination consumers are divided into *n* different groups and each group is charged a unique price. Different types of price discrimination have different welfare effects in terms of maximizing consumer and supplier surplus. Theoretically, first-degree price discrimination leads to a Pareto efficient outcome, meaning that neither the consumer nor the supplier can be made better-off without another being worse-off; second and third degree price discrimination improve overall welfare in general, with some users receiving insufficient amount of product or service. Nevertheless, these users are better-off than if they were never served.

Early analyses of price discrimination were undertaken under monopolistic settings and for physical goods; the supplier's technologies involved no economies of scope, and usually possessed constant or decreasing return to scale. Varian (1987) provides a useful overview of these analyses. The general conclusion is that the firms which conduct price discrimination have some market power: they may only shuffle the prices paid by pre-existing users without serving extra user groups, neither increasing the amount of product or service. In this case, overall welfare falls.

On the other hand, Eden (1990) observes that price discrimination and price dispersion can occur in a competitive environment, where a price dispersion equilibrium can be achieved when competitors all charge discriminatory prices but the mix of prices varies among firms. Levine (2002) argues that price discrimination is not necessarily evidence of market power: in more situations, it is the optimal strategy for a firm to allocate common costs among buyers. This line of argument provides an alternative way to look at price discrimination. Furthermore, Varian (1996) demonstrates that for industries that involve technologies which exhibit increasing return to scale, large fixed and sunk costs, and significant economies of scope, the rule of setting prices at marginal cost is no longer

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1 The old legislation forbidding price discrimination in many countries around the world has all but vanished, except in the present context for minimal service bundles supplied under Universal Service provisioning rules.

2 One common practice is to segment users according to space, time, age, income difference and quality (versioning). Another approach is to bundle. Adams and Yellen (1976) demonstrated that commodity bundling can be profitable because of its ability to sort users into groups with different willingness-to-pay. Bakos and Brynjolfsson (1999) examined the bundling of information goods and found a similar result.

economically viable: the marginal cost is close to zero. The pricing principle for this context is that marginal willingness to pay should equal the marginal cost.

Current technologies already permit suppliers to track and trace user behaviors[1] and infer their preferences so as to provide services accordingly. But most users dislike the feeling of being (passively) traced and become concerned by this erosion of privacy (Odlyzko, 2003). Individual services and tariffs can invite users to be actively involved in service individualization and to pay according to their willingness. It provides a possible approach to implementing the idea of first-degree price discrimination and pushing the market to Pareto efficiency, under a fully competitive environment[2].

2.5.2.2 User involvement

Willingness to pay (WTP) is the maximum amount of money the user is prepared to pay for a service over a certain time interval, which is a measurement of the value that the user puts on the service. WTP is higher when attributes of a service meet precisely the user demands.

It is quite unlikely, if not impossible, that the supplier can identify all the demands of users simply by observations and offering every possible choice. Even if the supplier does so, the burden of having to choose from too many options may simply lead to information overload and frustrate the user. A plausible solution is to introduce interactions, and change the role of the user from being a passive audience to becoming an active player in co-creating value (Prahalad & Ramaswamy, 2004). With the technology development such as Web 2.0, this is becoming a more common phenomenon, where consumers are involved in the production and service innovation (Pascu, 2007).

By involving the consumers in service design through interactions, users' specific demands are identified and integrated into the service. The user's willingness to pay is usually higher than the comparable standard services, *ceteris paribus*. Franke and Piller (2004) studied the online design of watches with over 700 participants, and the user involvement was facilitated by a "software toolkit". They found that the user WTP for a self-designed watch even exceeds the best-selling standard watches of the same technical quality. More empirical studies which provide similar results can be found in Piller, Schubert, Koch, & Möslein (2005) and von Hipple (2005).

2.5.3 Risks

The main concern of an open or closed community when offering mobile services is not profit, but the risk of insufficient funding which leads to service disruption. The mobile

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[1] For example, HTTP cookies can be used to track user browsing behavior; the 3G systems have build-in functions that can pinpoint the location of the user by base station triangulation.

[2] Reselling the services can be prevented by personalization, where each consumer receives the service tailored exactly to his needs. Each consumer is receiving different services to a certain degree.

services offered to members of an open community can be treated as public goods. One of the most distinct characteristics of public goods is non-exclusiveness, where the free-riding problem can emerge (Hirshleifer, 1983; Diekmann, 1993; Fisher & Ackerman, 1998). A free market is unlikely to produce the optimum amount of public goods (Samuelson, 1954). Research in risk minimization of the under-provision of public goods has been mainly focused on government intervention through institutions and legislations. Reviews of this work are beyond the scope of our research.

Wireless services provisioned by an operator or a closed community can be seen as club goods. Club goods differ from public goods in several aspects (Buchanan, 1965; Sandler & Tschirhart, 1995): club goods are exclusive, which reduces the free-riding problem. Clubs divide up the population, which results in competition among clubs; and club goods involve at least two allocative choices (e.g. size of membership vs. provision level of shared goods), in contrast to the provision choice of public goods. The club goods characteristics of operator/close community-provided mobile services suggest that theories and models from the insurance industry can be applied in managing the accompanying risks (Cornes & Sandler, 1999).

Insurance alleviates financial losses by transferring risk of loss from one entity to another. The design of exclusion mechanisms of a club, the degree of heterogeneity between members, the size of the membership, the provision level of services, all lead to differences in the aggregated distribution of risks. Various models and computational techniques have been developed over years for life and non-life insurances/reinsurance (Shapiro & Jain, 2003). But there is no earlier public research applying this “pooling” thinking to telecommunication services and tariffs.

In the context of individual mobile services and tariffs, the focus will be on pooling the distribution of each individual’s willingness-to-pay for an individually designed service. The supplier receives different revenue from each individual contract: some individual contracts may even generate losses. By pooling the revenue together from all the diverse users, the supplier may generate a profit on average, with some uncertainty. The supplier needs to make decisions based on the expected profit and corresponding risks. Risk level can also be different for operator and closed community-offered individual tariffs: the only goal of a firm is profit maximization, while the goals of a community are far more diverse.

2.6 Game theory

Game theory, as a formal approach to analyzing interactions, was introduced by von Neumann and Morgenstern in 1944 (von Neumann & Morgenstern, 1944). A few years later, John Nash (1950) proposed an “optimum” solution concept for non-cooperative games which involve two or more rational players. The concept, which is now called Nash equilibrium, describes a state in which no single player can benefit by changing his strategy while other players’ strategies are kept unchanged. Repeated games were introduced by Luce and Raiffa (1957), which consist of some number of repetitions of some base game. The development in game theory flourished through the 50s to 80s, which led to its application in various fields, including evolutionary biology, political science, philosophy and telecommunication network design (Altman & Wynter, 2004).

Classic game theory assumes that the players are perfectly rational beings who can perform backward-induction and optimization over information available to them in searching for an equilibrium. However, in reality, “a typical analysis involves a collection of game theorists spending months solving for the equilibrium, and then simply assuming that this equilibrium is obvious to the players” (Samuelson, 1996). Gradually, game theory has evolved to incorporate “bounded rationality” into its analyses (Aumann, 1997; Rubinstein, 1997).

The cooperation between computer science and game theory gave birth to computational game theory, which uses computers to model interactions. While classic game theory is rich in its mathematical foundations, the emphasis of computational game theory is on computation and algorithms: it provides insight into strategic interactions which are too complicated to have an analytic solution (Nisan, Roughgarden, Tardos, & Vazirani, 2007). Computational games can be solved numerically.

In the context of individual services and tariffs, and learning from the early history of the telephone (see Section 1.1), the contracting procedure between the user and the supplier involves a series of interactions, which can be analyzed using game theory. The game model must first consider the behavior of the users and the supplier. Second, the different bargaining powers between the user and the supplier should be considered. Third, the game equilibrium solutions, if they exist, must be determined.

There are many classes of games, such as symmetric games, zero-sum games, and prefect information games: see Fudenberg & Tirole, (1991). We are interested in a specific type of game called a Stackelberg game, which is a model of duopoly (von Stackelberg, 1934). In a standard Stackelberg setting, there is a leader and a follower and they compete on quantity. The leader moves first, choosing a quantity, the follower observes the leader’s move and picks a quantity. The leader usually has a first-mover advantage which depends on his commitment power.

Stackelberg games were investigated in the design of communication networks. Korilis, Lazar, & Orda (1997) considered a network manager acting as the Stackelberg game leader, who could control part of the network flow. The users, as the game followers, were allowed to choose routes after the leader had chosen routes. Korilis et al. demonstrated that by controlling a small portion of the network flow, the system performance can often be driven into optimum. Başar and Srikant (2002) studied a usage-based pricing scheme of the Internet, where the network (leader) sets the price and the non-cooperative users (followers) react to price and congestion caused by overall traffic. They derived an optimal price which can maximize network revenue with a large number of users. Ninan and Devetsikiotis (2005) applied a similar game setting to connection-oriented networks and provided algorithms for attaining the optimum network prices.

In Section 3.4 we will use the Stackelberg concept to construct our conceptual framework for individual services and tariffs.

2.7 Summary

This chapter has provided a non-exhaustive survey of the literature that is relevant to the design of individual mobile services and tariffs.

In Section 2.2, we identified five properties of mobile services. It is the combination of these properties, not any one alone, that makes the design and pricing of individual mobile services a challenging issue. We also reviewed current research in service customization, which showed that the research area is still in its early stage, especially in mobile services customization.

In Section 2.3, we surveyed the existing telecommunication tariff models, which focus mostly on a set of limited standardized services defined by the suppliers. These supplier-centric tariff models cannot be used for individualized services. Therefore a more user-centric service and tariff design method needs to be established.

Sections 2.4 and 2.5 provided insights, from a behavioral science perspective, into the design of individual mobile services and tariffs. In Section 2.4, we first reviewed the existing literature on the intrinsic drivers, and decided to use the identified personal values as the bases for our working assumption that there are people willing to have individualized services and tariffs (we attempt to determine their proportion in the population in Section 7.2, through a survey). Second, we reviewed the literature on user behavior when making a decision in a relatively complex setting. In this setting, user behavior is characterized by having "bounded rationality" and "social concerns." The literature related to the supplier's behavior was presented in Section 2.5. We identified four types of suppliers who have different goals when offering a mobile service. These different goals lead to different behavior. We decided to focus primarily on firms as suppliers in this research. We then looked at the revenue assurance and risk management practices of the suppliers, which could shed light on the modeling of supplier behavior as part of the design.

The last piece of the literature review in Section 2.6 focused on how to provide a structured analysis of the interactions between the user and the supplier, when they jointly design the individual service and tariff for the user. Computational game theory is identified as a useful tool that provides insight into strategic interactions which are too complicated to have an analytic solution. A specific type of game called the Stackelberg game was also identified, which would be used in our later design.

The theoretical building-blocks presented in this literature review lead us to Chapter 3, where we develop a conceptual framework for the design of individual services and tariffs.

Chapter 3
A conceptual framework for individual services and tariffs

3.1 Introduction

In this chapter[1], we construct a conceptual framework for individual services and tariffs by using the theoretical building blocks from Chapter 2. The framework consists of behavioral models of the user and the supplier (firm), and a game theoretical negotiation mechanism to determine the individual services and tariffs. The framework provides a theoretical foundation upon which the computational design of individual services and tariffs in Chapters 4 and 5 can be based.

This chapter is structured as follows: Section 3.2 suggests a supplier behavioral model and introduces the concept of the service design space; Section 3.3 proposes a user behavioral model and introduces the concept of the service perceptual space; Section 3.4 describes a negotiation process between a user and a supplier in which the user has a dominant influence. The negotiation process is investigated by a user-led recursive Stackelberg game; Section 3.5 summarizes the chapter. The linkage between the content at section level is shown in the Table below.

3.2	***Supplier behavioral decision model, service design space***	
	Based on	Section 2.5 on supplier behavior
	Results used in	Section 4.2 in mapping relationship, Section 4.4 in supplier computational models, Sections 4.5, 4.9 in negotiation algorithms, Sections 5.2 in supplier's decision under risks
3.3	***User behavioral decision model, service perceptual space***	
	Based on	Section 2.4 on user behavior
	Results used in	Section 4.2 in mapping relationship, Section 4.3 in user computational model, Sections 4.5, 4.9 in algorithms
3.4	***Negotiation and the Stackelberg game***	
	Based on	Section 2.6 on game theory
	Results used in	Sections 4.5, 4.9 in algorithms

3.2 Supplier behavioral decision model, service design space

In this section, we provide a behavioral decision model of the supplier in the context of individual services and tariffs. We introduce and articulate the concept of a service design space as the decision space for the supplier.

In modern decision theory, decisions are made based on preferences. The art of decision making is to obtain a complete ranking of the alternatives that reflect the preferences (Roberts, 1972). Often, this is done by assigning a numerical value to each alternative. The

[1] This chapter is partially based on Chen & Pau (2006a).

value is usually called utility. In many situations, the alternative outcomes are associated with different probabilities; thus many choices have to be made under uncertainty. Furthermore in reality, there are conditions that the decision must meet, and these conditions are usually modeled as constraints. These concepts provide the basic elements in constructing a behavioral decision model.

Recall that in Section 2.5.1 we decided to focus primarily on firms as the suppliers of individual services and tariffs. The firms' behavior is characterized by seeking maximum economic utility (i.e. profit or market share) with minimum risks.

The supplier's utility function should be built on the specific mobile service features it is offering to the customers. As wireless, communications and computing technologies evolve, and interoperability is mandated with a growing set of services, the specification of a mobile service becomes much more complex. From a supplier's perspective, it is common to define tens or even hundreds of service attributes for a single service, most of which are technical: signaling and control, synchronization data, network parameters, specific protocol tunings, security settings for different traffic flows, application interfaces, etc.; and others are business-based: price, contract length, content diversity, etc. For the sake of simplicity, we characterize such supplier-defined service attributes as (service) ***design attributes***. We call the Euclidean space constructed by these design attributes a (service) ***design space,*** which is the space within which the supplier makes decisions. The supplier's utility function is a function of the service design attributes.

The firms' behavior is constrained by the specific individual services they are offering. For example, a supplier must balance the relationship between the values of the design attributes and other engineering attributes (link capacities, etc.) to guarantee a minimum Quality of Service (QoS) (see the mSinging case in Section 4.8). The number and types of constraints are service dependent.

Regarding the decision rules, although the supplier seeks to maximize economic benefit in each individual contract, his decision rules are however set in such a way that he may lose in some contracts when compared to the initial non-negotiable offers to the public at large; but by pooling the different individualized contracts together, he can achieve the highest economic utility with minimum risks at corporate level.

3.3 User behavioral decision model, service perceptual space

In this section, we provide a behavioral decision model of the user in the context of individual services and tariffs, and introduce the concept of service perceptual space.

Recall that in Section 2.4, the user's behavior was characterized as having bounded rationality and social concerns. Having the social dimension means first that the user elicits not only economic but also social benefits from a mobile service[1] and second that there is irrationality in the user's preferences.

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[1] Economic benefit in a given situation is derived from the various service attributes, or from the transactions that the mobile service enables, either with an economic agent, or

A preference relation can be represented by a utility function only if it is rational (Mas-Colell et al. 1995), where the preference must satisfy completeness and transitivity. Many preferences, especially social preferences, are partially rational or irrational. Therefore many situations cannot be described by utilities but only by preferences. Here we assume that there are partial preferences, which can be mapped out by types and contexts. If a selection of a subset of preferences leads to a locally continuous function, then there exists a utility function that can be used for computational purposes over that range of preferences.

The implication of bounded rationality (see Section 2.4.2) is that, although the user tries to optimize his overall utility from a mobile service, he optimizes in a much simpler way using simplified utility functions and constraints, and satisficing decision rules: i.e. the user tries to achieve an acceptable level of utility before he stops

Unlike the supplier, who knows and deals with the technical details of a mobile service, the user usually has a much simpler understanding of a mobile service. We propose that, from a user's perspective, there are ***perceived attributes*** of a given mobile service. For example, the perceived attribute 'wireless connection' can be mapped into design attributes such as uplink, downlink, Bit Error Rate of each link, and retransmission rate of each link. Thus a user's requirement for a "good wireless connection" may be designed as 'an uplink speed at 128kbps, downlink speed at 384kbps, Bit Error Rate below 5%...etc'. The perceived attributes are actually the results of a reductionist mapping or an ***attribute substitution plus simplification*** (Section 2.4.2), which not only simplifies the understanding of the service attributes but also significantly reduces the number of them. The reductionist mapping can be based on certain heuristics or be the result of learning of selected technical attributes into features that the user in general can relate to. For a specific service, we define a (service) ***perceptual space*** as a Euclidean space constructed by the reduced perceived attributes of a service. This is the space in which the user makes his decisions.

The user's utility function is constructed based on the perceived service attributes (e.g. connection, content richness). There can be multiple perceived attributes for a given mobile service. A user's utility function in such a case can be constructed by following the method of multiple attribute utility (MAU) theory (Clemen & Reilly, 2001; Keeney & Raiffa, 1993). First, a utility function for each service attribute is assessed. Then a multiple attribute utility function determines how the level of one attribute affects overall utility vis-à-vis a set of assessed weights of their relative importance.

A distance-based utility function was used by Wold (1943), Arrow and Hahn (1971) among many others. The process involves selecting a reference point and measuring the distance to it from the elements in the choice set; the distance can be any Minkowski distance of order p. Very often it is the L^2-norm distance, which is also known as Euclidean distance. For an individual user, a reference point in the perceptual space can be the vector that consists of the ideal values for the perceived service attributes. The distance

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with a machine (e.g. an application server). A user elicits social benefits from the social interactions and benefits that the mobile service enables.

to the reference point can provide a simple measurement of the satisfaction that the user expects to obtain from the supplier's offer.

The user's constraints are also functions of the perceived attributes.

3.4 Negotiation and the Stackelberg game

Learning from the history of telecommunications (Section 1.1), where the users and the suppliers negotiated to have individual services and tariffs, we apply this "negotiation" mechanism in our research as the method to design the services and tariffs. The difference with monopolistic setting of the 1880s is that we assume the market of mobile services to be fully competitive: there are plenty of suppliers, and the users have a dominant influence in negotiation with any of them.

The user and the supplier negotiate on service attributes and their values, and the contract sum for a given period. The process consists of a sequence of offers and counter-offers, leading eventually either to an agreement or to an abandonment of the process of negotiation. The negotiation could have three settings:

1. One user vs. one supplier
   In this setting, a user negotiates with one supplier once at a time. A user who fails to reach an agreement acceptable to him with this supplier may switch to another supplier, or change his initial requirements.

   The Stackelberg game model (Section 2.6) can be applied here to model the dominant influence of the user in the negotiation. The bilateral negotiation procedure between the user and the supplier can be modeled by a repeated game. Thus this negotiation is modeled as a user-led recursive Stackelberg game, where the payoffs are the utilities that both parties receive from the individual service which they design together through the process.

   The recursive Stackelberg game is non-cooperative in essence because the user and the supplier have different goals in the negotiation; therefore, it is not a bargaining game. This is a game with imperfect information. As the negotiation proceeds, there is a process of learning. The adjustments will be in the player's constraints and are based on the offers from the other player. The game is assumed to be deterministic. The complexity of the game depends on the utility functions and constraints of the players. The existence of equilibria depends on the parameters in the constraints and decision rules, which will be the studied in the following Chapters 4 and 5.

2. Many users vs. one supplier
   This setting represents the situation in which a user community negotiates with a supplier. The difference between this setting and the one user vs. one supplier setting is that in this setting, the user side has a higher bargaining power but at the same time has the difficulty in reaching a consensus amongst the users. The

research focus could be on the design of mechanism to reach consensuses during the negotiation, which is outside the scope of this research.

3. One user vs. many suppliers
   This setting represents the situation where a user uses a reverse auction by sending out his service requirements to many suppliers at the same time; the suppliers then compete to attain the business with different offers and prices. The bidding process can be in one or several steps, and the different suppliers have different utilities. Although such a reverse auction is a possibility, it is highly unlikely to be used for value-added services[1]. One of the reasons lies in the varying number of interactions for different suppliers to estimate/learn about a user's preference sensitivity. Another has to do with possibly different content assets and different third-parties-assisted value-added services, the characteristics of which cannot be exchanged during the reverse auction process. Finally, yet another reason is that suppliers will use different user interfaces and never delegate the auction process to a broker (regulatory impossibility). Instead, the one user can still run Q different Stackelberg negotiations in parallel with Q suppliers, and decide at the end amongst those for which a valid offer has been received as a result of the negotiation; this offer is not just one price but also based on qualitative and quantitative service attributes. Thus the basic element is still the one user vs. one supplier Stackelberg negotiation setting.

Given the above discussion, we decide to focus on the "one user vs. one supplier" Stackelberg negotiation setting in this research.

3.5 Summary

This chapter has provided a conceptual framework for the design of individual services and tariffs in an interactive way.

In Section 3.2, after weighing their relative importance and complexity, we decided to focus on firms as suppliers rather than focusing on other types of suppliers in this research. We provided a behavioral model of the firm, which is characterized by seeking maximum economic benefits and minimum risks. We introduced an engineering and business-based "service design space" as the supplier's decision space. The service design space allows the detailed technical attributes to be used in the service design and consequently to be implemented by the supplier.

In Section 3.3, we provided a model of the user that is characterized by having bounded rationality and social concerns. To address the bounded rationality, we introduced a simplified "service perceptual space" as the user's optimization and decision space when the mobile service to be individualized is complicated (e.g. attribute number ≥ 7). In addition, we applied satisficing decision rules to the user during the decision making process. Moreover, we employed a simple distance-based utility function which can reflect some irrational aspects of the user's social dimension in his model.

[1] The mechanism is more likely to be used for commodity services.

In Section 3.4, we discussed three negotiation settings as the mechanisms to design individual mobile services and tariffs. In all these settings, the user has a dominant influence in the negotiation. We decided to focus on the “one user vs. one supplier” setting where the negotiation process is modeled by a recursive user-led Stackelberg game.

Now that we have laid out all the theoretical groundwork for individual services and tariffs, we continue in the next chapters with the concrete computational design.

Chapter 4
Computational design of individual services and tariffs with cases

4.1 Introduction

In this chapter[1], we operationalize the conceptual framework presented in Chapter 3 by introducing methods, computational models and negotiation algorithms for the design of both a complicated value-added mobile service and a common generic mobile service bundle. The purpose of the computational design is that, when implemented as a tool, it can determine a negotiation result when the user simply states his wishes in the beginning.

We evaluate the design through numerical cases using a prototype implementation. We then compare the computational results of the negotiations with the initial public services and tariffs. The analyses in this chapter are carried out on individual negotiation games. It is in the next chapter that we address the supplier's business concerns in term of profits, market share and risks.

This chapter is structured as follows: in Section 4.2, we articulate how to determine the service-specific mapping between the service design space and the service perceptual space; this is followed by Sections 4.3 and 4.4 introducing the computational models of the user and the supplier respectively. After these preliminary steps, we present the negotiation game algorithms for value-added mobile services in Section 4.5. In Section 4.6, we describe a proof-of-concept software implementation of the computational design. In Sections 4.7 and 4.8, we provide evaluations of the design and tool through a value-added mobile music service under two different settings: a fictive user vs. a fictive supplier and a realistic user vs. a realistic supplier. In Section 4.9, we extend our design to the individualization of a common generic mobile service bundle. We provide a negotiation algorithm and evaluate the design with a large-scale case. Section 4.10 summarizes the chapter. The linkage between content at section level is shown in the Table below.

4.2	***Mapping between the design and the perceptual space***	
	Based on	Sections 3.2/3.3 on the concept of service design/perceptual space
	Results used in	Section 4.5 in algorithms, Sections 4.7, 4.8 in numerical case computations, Section 5.2 in user preferences distribution characterization
4.3	***User / supplier computational model***	
4.4	Based on	Sections 3.3 /3.2 on user/supplier behavioral model
	Results used in	Sections 4.5, 4.9 in negotiation algorithms
4.5	***Computational Stackelberg negotiation game***	
	Based on	Sections 2.6, 3.4 on computational game theory & Stackelberg game model
	Results used in	Section 4.6 in prototype implementation, Sections 4.7, 4.8 in numerical cases; Section 4.9 as a design basis for generic service bundle negotiation algorithm; Sections 5.2, 5.3 as the basis for Monte Carlo simulation.

[1] This chapter is partially based on Chen & Pau (2006b, 2007a)

4.6	***Prototype implementation (I)***	
	Based on	Sections 4.2-4.5 on mappings, computational models and algorithms
	Results used in	Sections 4.7-4.9 in numerical cases (as a computing tool), Sections 5.2, 7.3 as the basis for complete prototype and real systematic implementations
4.7	***Case mSinging v1.0: fictive users vs. a fictive supplier***	
4.8	***v2.0: realistic users vs. a realistic supplier***	
	Based on	Section 4.2 on mapping, Sections 4.3, 4.4 on user and supplier behavioral models, Section 4.5 on algorithms, Section 4.6 on implementation
	Results used in	Sections 5.2, 5.3 to provide case-based evaluations of the risk metrics
4.9	***Generic mobile services***	
	Based on	Sections 4.3-4.5 on user, supplier behavioral models and the Stackelberg negotiation algorithms, Section 4.6 on implementation
	Results used in	Section 5.2 to provide case-based evaluations of the risk metric.

4.2 Mapping between the design and the perceptual spaces

In Chapter 3, we introduced the concepts of the service design space and the service perceptual space, where the latter is a reductionist mapping of the former. In this section, we proceed to introduce methods to determine the mapping relationship, which will be used later in the computational model and the negotiation algorithms. The methods we use are “survey” and “principle component analysis”. The latter is a statistical method that analyzes data obtained from a survey.

Generally, users can be divided into broad groups that share similar preferences for a class of services (e.g. people interested in mobile banking, or mobile health care, or mobile music). When designing a new class of individual mobile services, we conduct a user survey on a specific group of users having broadly similar interests (a.k.a. the targeted user group of the services). The survey asks the users to state their preferences for the service attributes in the service design space. Training may be necessary for the randomly selected respondents to understand the technical specifications. Furthermore, training is necessary when the supplier introduces a novel service of which the users have no past experience. We then perform a principle component analysis (PCA), which is a statistical method, on the obtained data to determine the mapping relationship. The user survey is named *PCA learning survey* after this purpose.[1] The obtained data is called the *PCA learning data set*. Because of the manner in which the survey is conducted, the mapping relationship is service dependent and user (population) dependent. We assume the mapping is valid for a new user, who can be placed in the same user target group for the same class of mobile services.

Let N be the number of the “potential users” (population) in the target group. Let s be the number of respondents (sample size) in the survey. Let n be the number of attributes in the service design space. The PCA learning data set is an *s-by-n* data matrix. Each row corresponds to a user’s preferences for the design attributes (an observation), which can be

[1] In the telecommunications industry, such target group data (anonymized) are widely available from specialist suppliers, who may access categorized subscriber usage data collected by the operators via the networks. This is an alternative way to obtain the user preferences data other than by the survey method.

seen as the coordinates of a point in the design space: call it a *user target point* in the service design space, denoted as t^0. Each column in the matrix corresponds to a service design attribute.

The principle component analysis generates an *n*-by-*n* coefficient matrix: each column corresponds to a principal component, and the principle components are sorted by order of decreasing variance. The PCA method has two advantages:

- The first principal components often explain more variance than the rest of the components, which can be left out without losing much differentiating information.
- The generated principal components are orthogonal to each other (Lattin, Carroll, & Green, 2003).

In practice, we usually take the first *m* principle components that cover most of the total data set variance (e.g. 80%, as a rule of thumb[1]) as the mapping dimensions; usually $m \ll n$. Thus the dimensionality of the data will be significantly reduced after the principle component transformation and selection.

Let *P* be the reduced principle component coefficient matrix constructed by the first *m* principle components ranked by decreasing variances, *P* is an *n*-by-*m* matrix. We treat the selected generated principle components as the revealed perceived service attributes of the users. The coordinate system constructed by these selected principle components is what has been called service perceptual space in Section 3.3.

Given the orthogonality property of the PCA method, we can presume that the perceived attributes are mutually exclusive. The interpretation of the principle components is dependent on a specific user group and service attribute set; it may need help from experts who specialize in the areas related to that class of value-added services. The interpretation process has several steps (Pau, 1981):

1. Sort the selected principle components by decreasing variances. Create new coordinate systems (also called maps) by taking pair-wisely the principle components, ranked by decreasing total variance weight: i.e. the 1st and 2nd components define the first coordinate system, the 1st and 3rd components define the second, the 2nd and 3rd components define the third map, etc. Each axis corresponds to a component.
2. Visualize on each map the magnitude and sign of each design attribute's contribution to the chosen pair of principal components. Each design attribute is visualized in the map by a vector, and the direction and length of the vector indicates the degree to which each design attribute contributes to the chosen pair of principal components.
3. In the map created by the 1st and 2nd components, locate the design attributes/vectors which are far away from the origin in one direction (e.g.

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1 Other criteria to determine the number of principle components to be retained are discussed in Lattin et. al (2003, p. 112-117)

horizontal or vertical); find out the common characteristics among these design attributes from their verbal descriptions, which is the meaning of the PCA component linked to that direction.
4. Validate the interpretation by looking at the original (raw) data and the related textual descriptions.
5. Repeat step 3-4 with maps of less total variance.

An example is provided in Section 4.8 through a numerical case, where we show how the new coordinate systems are constructed and what are the interpretations of the perceived service attributes. It is also reported in Section 4.8 that the joint analysis of the perceived attributes based on a learning data set with users sometimes allows us to obtain better interpretations in words of the nature of these perceived attributes. This practice is also important for the acceptability of the method amongst users.

The determination of principle components depends on the user preference data obtained from the survey. Given the assumption that the mapping is valid for a new user who has similar preferences to the target group or the surveyed users, it is natural to ask what the appropriate sample size is in order to have stable principle components. A variety of rules were recommended by researchers and textbook authors about how the sample size *s* should be determined as a function of the number of service design attributes *n*. Guadagnoli and Velicer (1988) performed a literature survey and found that few of these rules were based on empirical evidence. They used Monte Carlo method and systematically varied sample size (from 50 to1000), and the number of design variables (from 36 to 144), and found that *s*/*n* ratio was not an important factor in determining stability. The absolute sample size *s* was the most important factor. Osborne and Costello (2004), based on Guadagnoli's work, checked when interaction happened between *s* and *s*/*n*. Their results showed that as *s* increases, *s*/*n* becomes less important and the converse is also true: as *s*/*n* increases, *s* becomes less important. The best outcome occurs when large *s* and *s*/*n* are both present. But their results also indicate there is no "critical mass" or "critical ratio". Thus the recommendation is that the more data, the better, with respect to the objective of having stable principle components. However in practice, we should keep in mind that the survey sample size is often constrained by available time and budget.

From another perspective, Pau (1979) gives algorithms to determine *s* and *s*/*n* from Mahalanobis distance between the pair-wise variances and a given number of maps needed for an interpretation. This provides a minimum requirement for the sample size.

4.3 User computational model

Decision variables and the user target point

The user makes decisions in service perceptual space because this is a space that he is familiar with and in which he can make decisions without much effort. Let **Z** represent the service perceptual space. Let $Z = [z_1, z_2,\ldots,z_m]$, $Z \in R^m$ be a vector of *m* variables in the perceptual space. $z_1, z_2,\ldots,z_m$ are the user's decision variables, and each corresponds to a user perceived service attribute. Let $z^0 = [z_1^0, z_2^0,\ldots,z_m^0]$, $z^0 \in R^m$ be the vector that contains the set of ideal values that the user wishes to reach for the perceived attributes jointly. z^0 is called a user target point in perceptual space.

During the design phase, the user's target point is first obtained in the service design space together with the PCA learning survey. The corresponding target point in the perceptual space is obtained by multiplying the vector by the reductionist mapping *P* (Section 4.2). Thus $z^0 = t^0P$.

Constraints

The user has constraints on the individual service. In our design, these constraints are first expressed in the service design space and then mapped into the perceptual space. This is because during the service design phase, the constraints expressed in design space can be concretely related to the design attributes, while the constraints in perceptual space are hard to quantify. For example, it is rather straightforward to define the minimum tolerant level of downlink speed to be 10kbps. It is however difficult to quantify a perceived attribute, e.g. "a fast connection". There is no reference based on which the user can set the lower limit for this attribute. The concept "fast connection" itself is a relative concept.

User constraints can be divided into generic constraints (e.g. budget constraints, time constraints) and service-specific constraints. Some of the user's constraints are static; others are dynamic and depend on the input from the previous round of negotiation from the supplier. The constraints can also be categorized into linear and non-linear constraints and into unilateral and bilateral constraints.

We define a "feasible region" of a user's decision variable as the feasible range of a perceived service attribute. This feasible region is the boundary constraint of a user's decision variable.

Given the service design attributes $x_1, x_2 \ldots x_n$[1], let a unilateral user constraint in the service design space be $f_{xu}(x_1, x_2 \ldots x_n) \leq 0$. The mapping of a unilateral constraint from the design space to the perceptual space generates a new function $f_{zu}(z_1, z_2, \ldots, z_m) \leq 0$ such that anytime a vector x^a satisfies $f_{xu}(x_1, x_2 \ldots x_n) \leq 0$, its corresponding mapping z^a ($z^a = x^aP$) satisfies $f_{zu}(z_1, z_2, \ldots, z_m) \leq 0$.

Let the supplier's offer from the previous round of the negotiation in the service design space be x_supplier_offer, which is a vector. Let a bilateral user constraint in the service design space be $f_{xb}(x_1, x_2 \ldots x_n, x\_supplier\_offer) \leq 0$. Let the mapping of x_supplier_offer in the perceptual space be z_supplier_offer, z_supplier_offer = x_supplier_offer *P*. The mapping of a bilateral constraint from the design space to the perceptual space generates a new function $f_{zb}(z_1, z_2, \ldots, z_m, z\_supplier\_offer) \leq 0$ such that a vector x^a satisfies $f_{xb}(x_1, x_2 \ldots x_n, x\_supplier\_offer) \leq 0$, its corresponding mapping z^a ($z^a = x^aP$) satisfies $f_{zb}(z_1, z_2, \ldots, z_m, z\_supplier\_offer) \leq 0$.

[1] N.B. $x_1, \ldots x_n$ are the decision variables of the supplier. Here, for simplicity, we use them in the expression of the user's constraints in the design space, and $x_1, \ldots x_n$ represents the mapping of the user's decision variables $z_1, z_2, \ldots, z_m$ from the perceptual space into the design space.

Feasible solution

Let $z^a = [z^a_1, z^a_2 \ldots, z^a_m]$, $z^a \in R^m$ be a set of values in perceptual space which satisfies all the user's constraints. z^a can also been seen as a point in perceptual space. Call it a feasible point for the user.

Utility function

The user's utility function is defined in relation to the Euclidean distance between a feasible point and the target point. Let U_user(z) be the user's utility function in the perceptual space, U_user(z) = $\exp(-\|z^a - z^0\|)$. The user elicits higher utility when the offer from the supplier is closer to his wishes. This utility function has limitations, but to a certain degree, it also reflects certain "irrational" aspects: a user may not prefer lower prices than his target value *ceteris paribus*, or his social preferences may overshadow a more favorable price. Another concern is that the range of the utility function is (0,1]. 1 represents the situation in which the offer from the supplier matches exactly the user's wishes. The small range of the utility function may cause problems in later computation when the user and supplier jointly optimize their utility, and when the supplier's utility range is much larger than that of the user (see Sections 4.7.3, 4.7.5).

The user's decision rules are described in Section 4.5.2 as part of the negotiation algorithms.

4.4 Supplier computational model

4.4.1 Simplified supplier

Decision variables and the public offer

The supplier makes decisions in the service design space because he can grasp all the technical design attributes and also because he eventually needs to provide/implement the service. Let **X** represent the service design space. Let $X = [x_1, x_2, \ldots, x_n]$, $X \in R^n$ be a vector of *n* variables in the service design space: $x_1, x_2, \ldots, x_n$ are the supplier's decision variables, and each corresponds to a service design attribute. For convenience purpose, let the last variable x_n represent the price for the individualized service.

Some high-level service design attributes can be broken down into many more detailed engineering attributes which can be readily implemented. Each of the engineering attributes corresponds to an internal decision variable (a parameter), the value of which depends largely on the specific service requests (see Section 4.8.1.3 for examples).

The supplier of individual services and tariffs also publishes the service design attributes and corresponding value settings of a non-negotiable service to the public. Let this non-negotiable offer be the public offer $s^0(X) = [x_1^0, x_2^0, \ldots, x_n^0]$.

Constraints

The supplier's constraints are expressed in the design space because the supplier needs to set technical attributes with explicit bounds understandable in an engineering sense. The supplier must balance the relationship between the values of the service attributes to guarantee capacity and minimum QoS requirements. Some of the supplier's constraints are dynamic and depend on the user's input in the previous round of negotiation. There are also linear and non-linear constraints, as well as unilateral and bilateral constraints.

We define a "feasible region" of a supplier's decision variable as the meaningful range of a service design attribute. This feasible region is in fact the boundary constraint of a supplier's decision variable.

Let a unilateral supplier constraint in the service design space be $g_{xu}(x_1, x_2 \ldots x_n) \leq 0$. Let the user's request at the current round of negotiation be x_user_request, which is a vector. Let a bilateral supplier constraint in the design space be $g_{xb}(x_1, x_2 \ldots x_n, \text{x\_user\_request}) \leq 0$.

Feasible solution

Let $x^a = [x^a_1, x^a_2 \ldots x^a_n]$, $x^a \in R^n$ be a set of values in service design space which satisfies all the supplier's constraints; call it a feasible solution for the supplier.

Utility function

The supplier's utility, when offering individual services, is defined as the incremental profit ($\Delta\pi$) from serving the specific individual demands of an additional user to his existing customer base. The incremental revenue is mainly decided by the price the user of that individual service intends to pay, and by the contract duration, for the service satisfying the user-requested characteristics. By assuming a unit cost for each service attribute (u_n), a simplified linearized supplier's utility function can be written as[1]

$$\text{U\_supplier(X)} = \Delta\text{profit(X)} = \Delta\pi(\text{X}) = x_n - \sum_{a=1}^{n-1} x_a u_a$$

The supplier's decision rules are described in Section 4.5.2 as part of the negotiation algorithms. In Chapter 5, we will discuss market share and the risk aspects of the suppliers

4.4.2 Approximated supplier

We designed and built a detailed and complex realistic computational model of a wireless and mobile service supplier (Chen & Pau, 2007a). In this model, the supplier's decision variables and constraints setting are the same as in Section 4.4.1. The supplier's utility is also defined as the incremental profit from serving an additional user. The improvement, when compared to the simplified model introduced above, lies in the incremental cost and revenue model of the supplier.

The realistic model is, however, not a full business model: it does not include the marketing, finance, facilities, stock, administration, etc. overheads. Furthermore, the realistic model is only an approximated incremental model for the supplier when he adds a customer to the system for a stated duration, while investments and installation for the pre-

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[1] This formula is only given for explanation purposes and will not be used elsewhere in this thesis.

existing subscriber base have already been undertaken. It is an approximation to the derivative but not the profit function itself.

First, the improved realistic model addresses the investment and operational cost non-linearities linked to the necessary wireless access links, transmission links and switching/routing nodes. Second, the model allows a possible alternative provisioning of the individualized service by 2G/2.5G/3G and broadband generic access, each having different provisioning costs; the corresponding infrastructure capacity needs are decided based on the total traffic requirements derived from the needed service attribute values, from the management traffic and from the user's willingness-to-pay. Third, the model handles the individualized service-specific usage of the customer relationship management (CRM) system, the operation support system (OSS), and the content acquisition / storage / billing systems, besides handling the necessary incremental manpower costs involved in providing the individualized service to the single incremental user.

To provide individual mobile services, the supplier generally needs to spend on:

1. communication (network) infrastructure;
2. and/or value-added content;
3. and/or value-added applications;
4. and on the setup, maintenance and management thereof.

The expenses of a supplier can be categorized into capital expenditures (CAPEX), which are investments, and operating expenditures (OPEX), which are ongoing running and maintenance costs. The total cost is the sum of CAPEX and OPEX.

The incremental CAPEX

The CAPEX for communications (network) infrastructure can be roughly broken down into investments in core network, site buildout and radio access networks. The core network consists of authentication, backbone transmission, switches, routers, charging and billing, roaming gateways, and the CRM system. Radio access networks consist of base stations, radio network controllers and the transmission to core network. Site buildout cost is embedded in the base station CAPEX in our model.

The supplier usually also needs to make investments in content and/or in applications. The investment in contents could be a shared investment (e.g. 5%) together with other firms or organizations (e.g. a music label or a publisher), so the supplier can have access to the latest content at a relatively low price; or a full investment (100%) by the supplier himself in order to have full control over the content. Investment in needed applications (e.g. software and storage) is usually borne 100% by the operator as they are deemed usable for other services or customers. Some investments, which will generate extra incomes to the supplier (e.g. royalty fees paid by other firms), are also considered in the model; either in the CAPEX part (if the income is one-time based) or in the OPEX part (if the income is repetitive).

One additional characteristic of the CAPEX is that most of the investment objects usually last much longer than the service request duration of users of individual service (see

Section 7.2.2.); e.g. communications infrastructure usually lasts 10-15 years. In our model of the incremental profit from an individualized contract, we therefore only consider the depreciated/amortized [1] value of the investment objects (infrastructure, content, applications) over the individual contract period.

We use the simplest depreciation method: straight-line depreciation, where the monthly depreciated amount is calculated by taking investment acquisition price subtracted by salvage value divided by the productive months of the asset. Here the salvage value is assumed to be zero and productive months are assumed to be the life spans of the investment objects (see Section 4.8.1.3 for examples of the life spans of different investment objects). The depreciated amount of an investment object over the contract length is simply the product of the monthly depreciation amount by the individualized contract length.

Let $X = [x_1, x_2, \ldots, x_n]$, $X \in R^n$ be the supplier's decision variables which correspond to the service design attributes (see Section 4.4.1). For convenience purpose, let the first variable in the vector x_1 be the variable that represents the individualized contract length; let the last variable x_n represent price for the individualized service; let $X' = [x_2, x_3 \ldots x_{n-1}, x_n]$, $X' \in R^{n-1}$.

Let the CAPEX of different investment objects be a function of the decision variables X', denoted as $C_h(X')$, where h = 1, 2, 3… represents the different investment objects determined by X', and certain internal decision variables which are only known to the supplier and used in the service design (e.g. content diversity, user diversity, etc: see Section 4.8 for more examples). Let the incomes from different investment objects be a function of the decision variables, denoted as $D_h(X')$. Let dep() be the function that computes the monthly depreciated amount of an investment object. If the investment object generates income, the dep() function computes the monthly income that is attributable to that investment object.

Given the assumed number of customers of a specific class of individual service (N), for which the base value CAPEX investments are made, the incremental CAPEX from serving an additional individual user, denoted as ΔCAPEX (X), is estimated as:

$$\Delta CAPEX\ (X) = \left(\sum_{h=1,2,3\ldots} \mathrm{dep}(C_h(X')) - \sum \mathrm{dep}(D_h(X')) \right) \times x_1 / N \quad (4\text{-}1)$$

The incremental OPEX

OPEX are ongoing running costs that include individual service specific payments to employees, power, rents, costs in software system maintenance/upgrade, infrastructure running and maintenance, network management, billing and payment operations, and CRM. While it is viable to calculate the incremental CAPEX, it is challenging to estimate the incremental OPEX. First, the OPEX of some cost items decrease as the capacity grows

[1] In finance and accounting, the concept of depreciation is usually applied to tangible assets while amortization is usually applied to intangible assets. In this thesis, we do not distinguish between them.

(e.g. storage); second, some items can substitute for other items to a certain degree (transmission bandwidth vs. switch buffer size); third and most importantly, OPEX accrues in relation to the traffic, and to the size and number of nodes of the whole service-provisioning infrastructure, especially with regard to complexity (including service complexity). Fourth, as demonstrated by the teletraffic theory, the traffic and therefore OPEX costs are congestion and time dependent.

To estimate OPEX, full traffic data, enterprise resource planning (ERP) data, business process management models, and real time accounting system data are needed. This research had no access to such an overwhelming amount of data.

Instead, inspired by the production functions used in microeconomics, we construct a simplified but nevertheless realistic incremental service provisioning production and cost function. The parameters are to be fitted to real data under stable conditions. This approach is also justified by the fact that only incremental costs from one individual contract need estimation, not the aggregate amounts. The specific incremental OPEX cost function has two parts:

1. The *infrastructure and content-based service provisioning* part models the incremental operational costs associated with setting up the complex service provisioning infrastructure. It has a product form which is similar to a Cobb-Douglas production function, with explicit marginal elasticities and production factor substitution between the investment objects. The production factors can be transmission infrastructure, storage, or content (see Section 4.8.1.3 for examples). Each item in this part is indispensable and may affect (e.g. substitute) other items.

2. The *service operations provisioning* part models the incremental operational costs associated with service operation objects. It has an additive form because some of the service operational objects are optional and they have separate linear relationships regarding the incremental service costs. The service operation objects can be the salaries paid to the employees, or to the music teachers such as in the mSinging case (Section 4.8), or the content distribution fee paid to the content owner, etc.

Let $\alpha_h > 0$, $h = 1, 2, 3 \ldots$ be the marginal production elasticity associated with each investment object. Given the assumed aggregated number of customers of a specific class of individual services (N), $X' = [x_2, x_3 \ldots x_n]$, and the cost of the investment object $C_h(X')$ (see above and Section 4.4.1), the incremental infrastructure and content-based part of the service provisioning incremental OPEX function can be written as:

Δ infrastructure and content-linked operational costs (X) = $\prod (\beta c_h (X')^{\alpha_h}) / N$ (4-2)

h=1, 2, 3…

Here β is a scaling factor that is used to obtain operational costs from the investment objects. The condition $\sum_h \alpha_h > 1$, reflects the fact that capital items have increasing returns to scale of the service production factors. For example, if the number of base stations doubles, the infrastructure and content-based operational provisioning costs associated with them will be more than double.

Let $O_w(X')$ be the monthly cost associated with each operational object for an additional user, $w = 1, 2, 3\ldots$represents the different operational objects; the number of operational object is service dependent. Given contract length x_1 (see above), the incremental operations based service provisioning cost for an additional individualized contract is then:

$$\Delta \text{ service operations provisioning costs } (X) = (\Sigma\, O_w(X')) \times x_1 \qquad \text{(4-3)}$$
$w = 1, 2, 3\ldots$

The supplier's incremental profit
Based on formulae 4-1, 4-2, and 4-3, the supplier's incremental profit from an individualized contract, denoted as *Δ π (X)*, can be written as

$$\Delta \pi (X) = x_n - \Delta CAPEX\ (X) - \Delta \text{ infrastructure and content-linked operational costs } (X) - \Delta \text{ service operations provisioning costs } (X) \qquad \text{(4-4)}$$

In summary, the inputs to the supplier's incremental cost and revenue model are the user's requests on the service design attributes (including price and contract duration), given a pre-existing subscriber base in the same service class, and given certain communications technology options. However, the engineering, content and value-added service-related attributes are the ones embedded in the contract and resulting from a mutually agreed negotiation. They are not necessarily in the initial user requests. The output is the supplier's incremental operational profit from the provisioning of that individual service design before overheads (financial, administration, marketing etc). The parameters of the supply model were estimated from real systems supplier data, and further parameters were fitted to real wireless operator operations for a typical geographical coverage[1].

4.5 Computational Stackelberg negotiation game

In the conceptual framework developed in Section 3.4, we proposed that the user and the supplier jointly design the individual services and tariffs through a negotiation. The negotiation, however, has a non-cooperative and recursive nature and is modeled as an *n*-stage user-led two-player Stackelberg game.

The negotiation process is designed as follows: in the beginning of the individual service creation, the user sets forth his wishes on a set of service attributes and their values, including a tariff and a duration based on a non-negotiable public offer s^0 (Section 4.4.1) that he has been informed about. The negotiation starts with the user proposing his requests after optimizing his own utility under his constraints. The supplier replies with an offer after his optimization. This offer and counter-offer can go on recursively and the players update their constraints based on what the other proposed as values leading to changes in the variable tolerance bounds as a learning process. The negotiation either ends

[1] The model cannot be released without supplier permission.

with a contract or a service level agreement (SLA) written in the service design space (we will return to this issue in Section 7.3), or with the user or the supplier quitting.

4.5.1 Information structure

The information structure in this negotiation plays an important role due to the user and supplier constraints, and due also to the negotiation recursions with single-player optimization by each player separately based on inputs from the other player in the previous step.

Essentially, each player has a private information set including utility, constraints (see Sections 4.3 and 4.4), and decision rules, and furthermore the supplier has an operational model; but there is an information communication between the players as set forth in Fig. 4-1. The players share the same design space **X**, but only the supplier makes use of it, deriving from the design attributes in **X** engineering attributes (see Section 4.8.1.3 for an example), while the user only observes a very limited subset of **X** and operates in the perceptual space **Z**. Two cases exist:

1. either the supplier computes the PCA mapping and communicates the complete mapping relationship to the user. The user makes a selection of the principle components (perceived attributes), and owns alone the reduced mapping result P (and its pseudo-inverse, P^{-1}). The players then communicate in the design space **X**.
2. or the user computes the PCA mapping, selects the principle components to be retained, which form the reduced mapping P (and P^{-1}), and communicates to the supplier with P and P^{-1}. In this case, the two players communicate in the perceptual space **Z**.

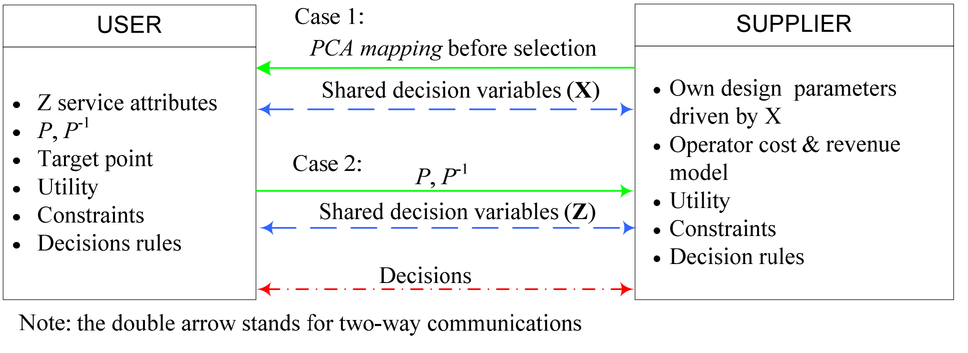

Fig. 4-1: Information structure of the Stackelberg negotiation game

In both cases, the transformation between the service design space and the service perceptual space is necessary. We call the transformation from the service design space to the service perceptual space *the direct mapping*; while the transformation in the opposite direction *the reverse mapping*. Given the reductionist PCA mapping coefficients P (see

Section 4.2) and its pseudo inverse P^{-1}, the direct mapping of a design space vector x^a in the perceptual space (denoted as z^a) can be obtained by multiplying by P, $z^a = x^aP$; while the reverse mapping of a perceptual space vector z^b in the design space (denoted as x^b) can be obtained by multiplying by P^{-1}, $x^b = z^b P^{-1}$.

In this research, we consider the first case where the user owns alone the selection of the service category, and the PCA mapping P. One more complication is that for the user, the utility function is expressed in the service perceptual space and the optimization is carried out in the perceptual space. The target point and constraints are, however, expressed in the service design space in the beginning due to the reasons mentioned in Section 4.3; thus, a "direct transformation" on them is carried out when necessary.

The transformation from the service design space to the service perceptual space will cause some loss of information. The degree of loss depends on the total variances accounted for by the retained m principle components. On the other hand, the transformation from the service perceptual space back to the service design space, e.g. mapping a user feasible point (see Section 4.3) in the service perceptual space to the service design space, will not cause loss of information.

4.5.2 Negotiation algorithm

Let i = 1, 2,…, k represent the round of negotiation (*i-th* stage of the game).

Let $Z = [z_1, z_2,\ldots,z_m]$ be the user's decision variables in the service perceptual space. Let $z\_user\_request^i$ be the user's optimization result at the *i-th* round of negotiation in the perceptual space, $z\_user\_request^i$ is an m-dimensional vector; let $x\_user\_request^i$ be the corresponding mapping of this result in the design space, $x\_user\_request^i$ is an n-dimensional vector. Let $t^0(X)$ be the user's target point in the service design space, which is an n-dimensional vector. Let $z^0 = [z_1^0, z_2^0,\ldots,z_m^0]$ be the user's target point in the service perceptual space. $z^0 = t^0P$.

Let $X = [x_1, x_2,\ldots,x_n]$ be the supplier's decision variables in the service design space. Let $x\_supplier\_offer^i$ be the supplier's optimization result at the *i-th* round of negotiation, $x\_supplier\_offer^i$ is an n-dimensional vector; let $z\_supplier\_offer^i$ be the corresponding mapping of this result in the perceptual space, $z\_supplier\_offer^i$ is an m-dimensional vector. Let $s^0(X)$ be the supplier's public offer in the service design space, which is an n-dimensional vector. Let the mapped supplier's public offer in the service perceptual space be $s^0(Z)$, which is an m-dimensional vector $s^0(Z) = s^0(X)\,P$. Let $x\_supplier\_offer^0 = s^0(X)$; Let $z\_supplier\_offer^0 = s^0(Z)$.

The full negotiation algorithm consists of one preparation step and two recursive steps, which is illustrated in Fig. 4-2. The detailed algorithm is as follows:

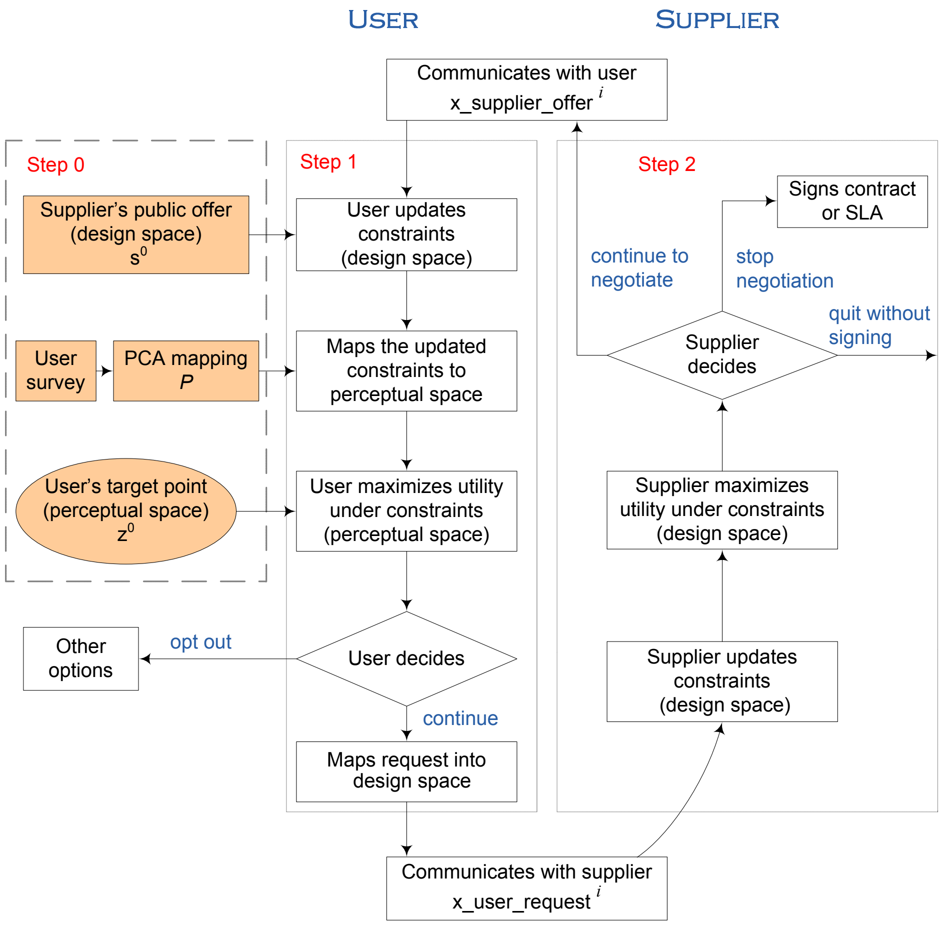

Fig. 4-2: The Stackelberg negotiation game algorithm between a user and a supplier

Step 0: preparation

1. In the beginning, the supplier announces the offering of a class of individual mobile services. He publishes the non-negotiable public offer s^0(X), which is a set of service attributes (including price and duration) and their values expressed in the service design space.
2. A PCA learning survey is carried out. A principle component analysis is performed on the obtained data and the reductionist mapping coefficient *P* is determined, as described in Section 4.2. The design attributes are translated into the perceptual attributes through the procedure described in Section 4.2. Here we assume that the user owns alone the PCA mapping *P* and its pseudo inverse P^{-1}, and thus must communicate with the supplier in the service design space **X** (see Section 4.5.1)

3. A new user, who is assumed to be in the same user target group as the surveyed user, sets his target point $t^0(X)$ in the design space based on the public offer $s^0(X)$ published by the supplier. The corresponding user target point in the perceptual space, denoted as z^0, can be obtained by multiplying by *P*: $z^0 = t^0(X)\ P$.
4. The supplier's public offer $s^0(X)$ is mapped into the perceptual space, denoted $s^0(Z)$, $s^0(Z) = s^0(X)\ P$.
5. The user's utility from the supplier's public offer $s^0(z)$ is determined by $\exp(-\|s^0(Z)-z^0\|)$.

The game starts with $i=1$.

Stage i

Step 1: user designs and proposes

The goal of the user at stage *i* is to maximize his utility subject to his constraints. He then makes a decision and communicates with the supplier. There are several sub-steps:

1. Constraints update
The user has unilateral constraints and bilateral constraints (Section 4.3). At stage *i* (a.k.a. iteration *i*), the user updates his bilateral constraints according to the supplier's offer $x\_supplier\_offer^{i-1}$ in the previous iteration *i*-1. Because the user's constraints are expressed in design space, a transformation is necessary to map the user's constraints to the perceptual space (see Section 4.3). Let the bilateral user constraints in the perceptual space be $f_{zba}(z_1, z_2,\ldots,z_m, z\_supplier\_offer^{(i-1)}) \le 0$; a =1, 2, 3… represents the bilateral user constraints, the number of which is service dependent. Let the unilateral user constraints in the service perceptual space be $f_{zud}(z_1, z_2,\ldots,z_m) \le 0$; d =1, 2, 3… represents the unilateral user constraints, the number of which is service dependent.

2. Utility maximization
The user maximizes his utility $U\_user(z) = \exp(-\|z^{ai}-z^0\|)$ (Section 4.3) by minimizing the distance between a feasible point and the target point, subject to the updated bilateral constraints and the unilateral constraints; the initial starting point of the maximization is the supplier's offer from the previous iteration $z\_supplier\_offer^{(i-1)}$.

$$\begin{array}{ll} \textit{Max} & U\_user\ (z) \\ \textit{Subject to} & f_{zba}(z_1, z_2,\ldots,z_m, z\_supplier\_offer^{(i-1)}) \le 0\ \& \\ & f_{zud}(z_1, z_2,\ldots,z_m) \le 0\ ,\quad a = 1, 2, 3\ldots;\ d = 1, 2, 3\ldots \end{array}$$

Let the user maximization result at iteration *i* be $z\_user\_request^i$.

3. Decision
Based on the maximization result $z\_user\_request^i$ and his own decision rules, the user decides to stop or not. The user's decision rules are:

1) If at iteration i, the maximization result leads to a utility that is worse than which he elicits from the public offer $s^0(Z)$, quit.
   i.e. $U\_user(z\_user\_request^i) - U\_user(s^0(Z)) \leq 0$
2) If at the 1^{st} iteration (i=1), the feasible set is empty, quit. An empty feasible set indicates that the user's constraints exclude all the inputs and thus $z\_user\_request^i$ is a null vector.
3) If at iteration i ($\geq$2), the feasible set becomes empty, backtrack by one iteration and continue.
4) If the feasible set is empty for two consecutive iterations i-1and i, ($i\geq$2), quit.
5) Otherwise, continue.

4. Communication

1.) If the user decides to continue with the current negotiation, he needs to send his service requests to the supplier. Given that P and P^{-1} are not shared with the supplier, the user needs to map his maximization result $z\_user\_request^i$ into the service design space. Let the mapped result be $x\_user\_request^i$, the user sends this service design space vector to the supplier
2.) If the user decides to stop and quit, he informs the supplier about his decision.

Step 2: supplier designs and proposes

The goal of the supplier at stage i is to maximize his utility (incremental profit) subject to his constraints. He then makes the decision and communicates with the user. There are several sub-steps:

1. Constraints update
   The supplier has unilateral constraints and bilateral constraints (Section 4.4.1). At iteration i, the supplier updates his bilateral constraints according to the user's offer $x\_user\_request^i$ in the current iteration i. Let the bilateral supplier constraints in the design space be $g_{xbe}(x_1, x_2, \ldots, x_n, x\_user\_request^i) \leq 0$, e = 1, 2, 3 … represents the bilateral supplier constraints, the number of which is service dependent. Let the unilateral supplier constraints in the service design space be $g_{xul}(x_1, x_2, \ldots, x_n) \leq 0$. l =1, 2, 3… represents the unilateral supplier constraints, the number of which is service dependent.

2. Utility maximization
   The supplier maximizes his utility U_supplier(X), which is the incremental profit from serving an additional user (Section 4.4), subject to the updated bilateral constraints and the unilateral constraints; the initial starting point of the maximization is the user's request $x\_user\_request^i$ at current iteration i.

$$\begin{array}{ll} \textit{Max} & U\_supplier(X) \\ \textit{Subject to} & g_{xbe}(x_1, x_2, \ldots, x_n, x\_user\_request^i) \leq 0 \ \& \\ & g_{xul}(x_1, x_2, \ldots, x_n) \leq 0,\ e = 1, 2, 3\ldots;\ l = 1, 2, 3\ldots \end{array}$$

Let the maximization result at iteration i be $x\_supplier\_offer^i$

3. Decision
   Based on the optimization result x_supplier_offer^{i} and his own decision rules, the supplier decides whether to accept the proposal, or to propose back his last optimized values; or stop the game.

   We introduce a parameter which will be used in the supplier's decision rules. The parameter is called *minimum profit threshold*, denoted as θ. The supplier will not agree to sign a contract with an individual user when the expected profit from that user is below θ (θ and the related calculation will be discussed in details in Chapter 5).

   Supplier decision rules are:

   1) If at the 1st iteration (i=1), the feasible set is empty, quit. An empty feasible set indicates that the supplier's constraints exclude all the inputs and thus x_supplier_offer^{i} is a null vector.
   2) If at iteration i ($\geq$2), the feasible set becomes empty, backtrack by one iteration and continue.
   3) If the feasible set is empty for two consecutive iterations i-1and i, ($i\geq2$), quit.
   4) If there is no difference between the maximization results of two consecutive iterations i-1and i, ($i\geq2$) of the supplier, and the supplier's utility from the user's request at iteration i is larger than or equal to θ, sign the contract and quit.
      i.e. U_supplier(x_supplier_offer^{i}) - U_supplier(x_supplier_offer^{i-1}) = 0 &
      U_supplier(x_user_request^{i}) $\geq \theta$, ($i\geq2$)
   5) If there is no difference between the maximization results of two consecutive iterations i-1and i, ($i\geq2$) of the supplier, and the supplier's utility from the user's request at iteration i is less than θ, quit without signing.
      i.e. U_supplier(x_supplier_offer^{i}) - U_supplier(x_supplier_offer^{i-1}) = 0 &
      U_supplier(x_user_request^{i}) < θ, ($i\geq2$)
   6) If oscillation happens among iterations i, i-1 and i-2 ($i\geq3$) as defined below, and the supplier's utility from the user's request at iteration i is larger than or equal to θ, sign the contract and quit.
      i.e. U_supplier(x_supplier_offer^{i}) - U_supplier(x_supplier_offer^{i-2}) = 0 &
      U_supplier(x_supplier_offer^{i-1}) - U_supplier(x_supplier_offer^{i-3}) = 0 &
      U_supplier(x_user_request^{i}) $\geq \theta$, ($i\geq3$)
   7) If oscillation happens among iterations i, i-1 and i-2 ($i\geq3$) as defined below, and the supplier's utility from the user's request at iteration i is less than θ, quit without signing.
      i.e. U_supplier(x_supplier_offer^{i}) - U_supplier(x_supplier_offer^{i-2}) = 0 &
      U_supplier(x_supplier_offer^{i-1}) - U_supplier(x_supplier_offer^{i-3}) = 0 &
      U_supplier(x_user_request^{i}) < θ, ($i\geq3$)
   8) Otherwise, if conditions 1) – 7) are not met, continue to negotiate.

   Note: oscillation may happen between 3 or more iterations, and the decision rules for such situations are similar to rules 6) and 7) of the supplier. This indeed happened in the mSinging case presented in Sections 4.7 and 4.8.

4. Communication

   1) If the supplier decides to continue with the current negotiation, he needs to inform the user about his latest offer $x\_supplier\_offer^i$. The game enters the next stage: ($i = i+1$).
   2) If the supplier decides to stop and quit, he communicates to the user his decision and the game terminates.

Recursion: the procedure repeats from Step1-Step2 until either player decides to stop, with or without reaching an equilibrium and signing a contract.

Negotiation outcomes

1. If the negotiation game produces an accepted outcome for both players, with acceptance established by the decision rules of both players, then a service level agreement (SLA) can be agreed upon and the system will be notified by a normal handshaking protocol such as session initiation protocol (SIP) (Section 7.3).
2. If either player after iteration 2 refuses to continue, then the game stops and the user can either propose his service requests to another supplier, or accept the closest public generic service offer of the supplier (who cannot discriminate against him under public service provisions).
3. If the initial service requested by the user is outside the feasible sets of either player, the game stops and the previous outcome applies.

4.5.3 Negotiation algorithm with discretization

The non-linearities and possible discontinuities of the investment and operational costs make it difficult to build an approximated supplier's incremental cost and revenue model using one single or a few explicit mathematical formulae. Our model (Section 4.4.2) was built using spreadsheets and an instantiation of the operational model is in Section 4.8.

Next, some of the decision variables in the model can take only integer or discrete values to be meaningful (e.g. contract duration of 1 month but not 0.9123 month). For constrained nonlinear optimization, most of the commercial optimization software (e.g. MATLAB[1] routine FMINCON and NAG Foundation Toolbox[2] routine E04UCF) requires an explicit target function and that all variables have continuous real values. There are almost no commercial non-linear integer optimization packages with continuous utility functions; therefore such commercial tools cannot be used in the computation which involved the approximated model.

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[1] MATLAB is a numerical computing environment and programming language created by Mathworks, Inc.

[2] NAG Foundation Toolbox: a software for numerical computing from the Numerical Algorithms Group.

4.5.3.1 Discretization and exhaustive search

To compute a function that has both discrete variables and continuous variables, we discretize all variables and conduct an exhaustive search (Romeijn & Pardalos, 1995); the continuous variable samplings are made to converge by fractional decompositions with increasing resolutions. The exhaustive search is on alternative values of all variables within intervals which are either fixed (due to the usage of the variable) or made to have increasing resolutions (for continuous variables).

Discretization takes several steps:
Step 1: intervals Generate sub-intervals for each variable based on its feasible region defined in Sections 4.3 and 4.4, and a chosen number of intervals (n_interval). This is done by equally dividing the feasible region into n_intervals. n_interval is an integer ranging from 2 to *N*. The number of interval is the same for all variables in one computation. For variables which are only meaningful when discrete, the number of intervals is adapted to usage.

Step 2: discretized values Generate representative values of the variables inside the sub-intervals. There are three conventions to generate the discretized values: left edge/center/right edge, which take the smallest/median/highest value of each sub-interval correspondingly. During one negotiation computation, only one convention should be followed.

Step 3: map (real) values to discretized values. When the value of a continuous variable falls within a sub-interval, it will be mapped onto the representative value of this sub-interval. Discrete variables will always have true exact values

Fig. 4-3 illustrates the discretization process of a design space variable x_7 (tariff) in the mSinging case v2.0 of a user (Section 4.8). The feasible region is decided by the lower bound and the upper bound of the variable, which are 5 and 185 respectively. n_interval = 3. A "center convention" is followed in generating the representative discretized values; the results are x_7_low=35, x_7_medium=95 and x_7_high=155. The close proximity to x_7_low decides that x_7^a, which can be an offered price from the supplier, will be represented by the value of x_7_low, which is 35. The representing value will be used in the computation (i.e. in the exhaustive search) instead of the actual value (x_7^a), thus significantly reducing the possible combination of inputs in the exhaustive search.

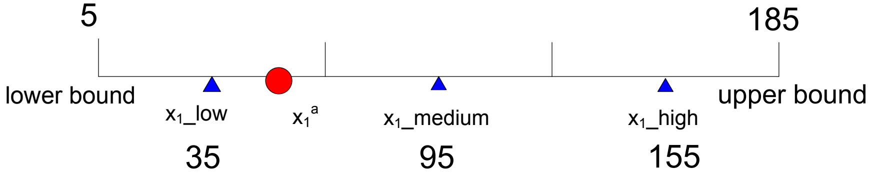

Fig. 4-3: Discretization of a variable in service design space

The discretization rate of the variable can be indicated by the number of intervals. When the discretization rate is low, the discretization significantly reduces the number of possible values of each variable. This greatly reduces the computational complexity. But it is at the expense of less accurate results. The results are more of a qualitative indication of the service attributes rather than a quantitative one. When the discretization rate becomes higher, the result becomes more accurate and thus gives a quantitative indication of the values of the service attributes.

In our computation, the user's target point is not discretized. Given that the user can choose discretized values of his variables, it is possible that the user cannot reach the target point (distance to target point $\neq 0$) even all the constraints are slack. The boundary values of the constraints of both the user and the supplier are not discretized.

This method only provides exact results subject to certain convergence conditions. However its exhaustivity guarantees that no local optimum is chosen, but always a global optimum, which is an advantage. It is recommended to verify the results found against the real-valued algorithm.

4.5.3.2 Algorithm

In this section, we present the negotiation algorithm with discretization of the decision variables and the constraints.

Let i= 1, 2,…, k represents the round of negotiation (*i-th* stage of the game).

Let DZ = $[Dz_1,\ldots,Dz_m]$, $DZ \in Q^m$ be the discretized user decision variables in the service perceptual space. Let $Dz\_user\_request^i$ be the user's optimization result at the *i-th* round of negotiation in the perceptual space, $Dz\_user\_request^i$ is an m-dimensional vector and takes discretized values; let $Dx\_user\_request^i$ be the discretized mapping of $Dz\_user\_request^i$ in the service design space, $Dx\_user\_request^i$ is an n-dimensional vector. Let $t^0(X)$ be the user's target point in the service design space, which is an n-dimensional vector; let the mapped target user point in the perceptual space be $z^0 = [z_1^0, z_2^0 \ldots z_m^0]$.

Let DX = $[Dx_1,\ldots,Dx_n]$, $DX \in Q^n$ be the discretized supplier's decision variables in the service design space. Let $Dx\_supplier\_offer^i$ be the supplier's optimization result at the *i-th* round of negotiation, $Dx\_supplier\_offer^i$ is an n-dimensional vector and takes discretized values; let $Dz\_supplier\_offer^i$ be the discretized mapping of $Dx\_supplier\_offer^i$ in the perceptual space, $Dz\_supplier\_offer^i$ is an m-dimensional vector. Let the supplier's public offer in the service design space be $s^0(X)$, which is an n-dimensional vector. Let the mapped supplier's public offer in the service perceptual space be $s^0(Z)$, which is an m-dimensional vector. Let $x\_supplier\_offer^0 = s^0(X)$; Let $z\_supplier\_offer^0 = s^0(Z)$.

The full negotiation game algorithm with discretization is similar to the normal algorithm presented in Section 4.5.2. It consists of one preparation step and two recursive steps, which is illustrated in Fig. 4-4. The explanations below only show the differences in sub-steps or iterations from the normal algorithm.

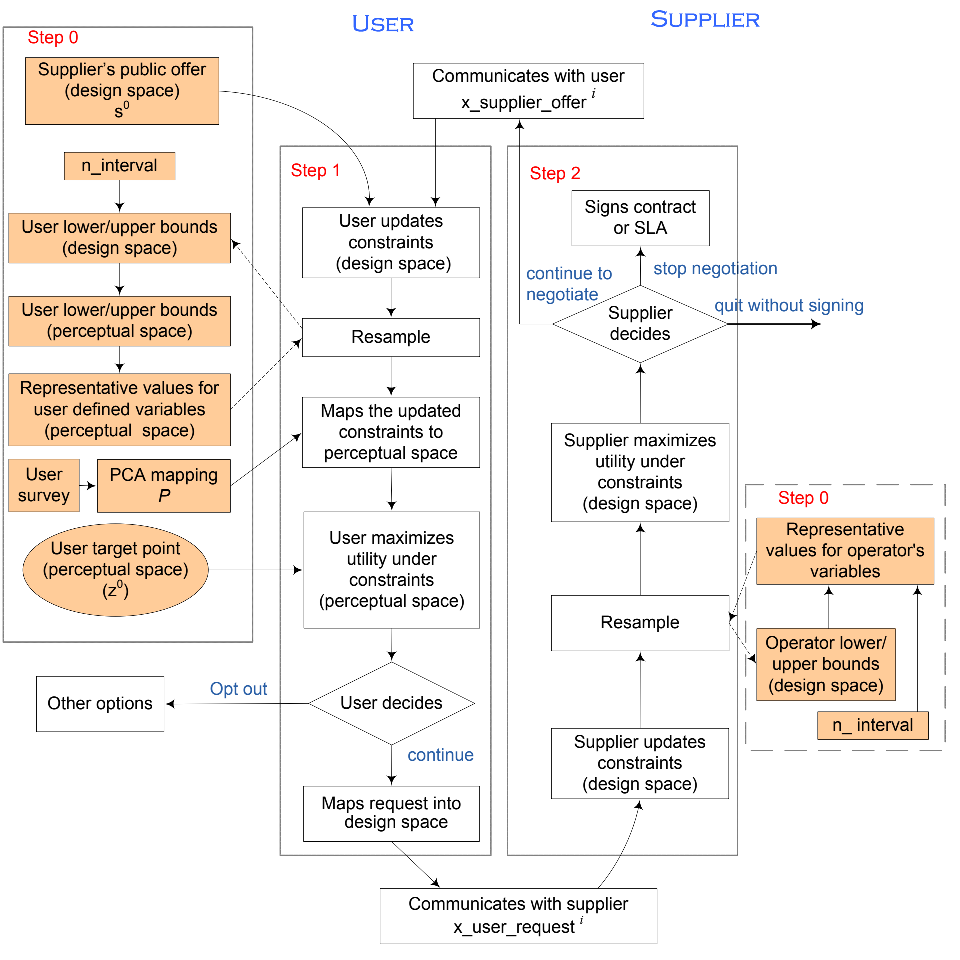

Fig. 4-4: Discretized Stackelberg negotiation game algorithm between a user and a supplier

Step 0: preparation

Part of the preparation procedure is similar to the sub-steps 1-5 of Step 0 of the normal algorithm in Section 4.5.2. The extra sub-steps here are:

6. Choose the number of sub-intervals (n_interval) which determines the quantitization level.
7. Choose a value generation convention which will be used throughout the computation.

The game starts with i =1.

Stage i

Step 1: user designs and proposes

The goal of the user at stage *i* is to maximize his utility subject to his constraints. He then makes a decision and communicates with the supplier.

There are several sub-steps, which are similar to the sub-steps 1-4 in the normal algorithm in Section 4.5.2. The difference is that the current algorithm uses discrete decision variables DZ, and discrete constraints, which can either be unilateral: f_{zud} (DZ) ≤ 0, d = 1, 2, 3…, or bilateral: f_{zba} (DZ, Dz_supplier_offer$^{(i-1)}$) ≤ 0 , a = 1, 2, 3… Exhaustive search is carried out to find the maximum utility. We apply a resampling technique as a refinement process on discretization to improve the computation efficiency. The details will be explained shortly.

Step 2: supplier designs and proposes

The goal of the supplier at stage *i* is to maximize his utility (incremental profit) subject to his constraints. He then makes the decision and communicates with the user.

The sub-steps are similar to the sub-step 1-4 in the normal algorithm in Section 4.5.2. The current algorithm uses, however, discretized decision variables DX and discrete constraints, either unilateral g_{xul} (DX) ≤ 0, *l*= 1, 2 , 3… or bilateral g_{xbe} (DX, Dx_user_request^{i}) ≤ 0, e=1, 2, 3… Exhaustive search is carried out and resampling is also applied.

Recursion: the recursion rules are identical to the normal algorithm in Section 4.5.2

Resample: we update the feasible boundary of the decision variables according to the negotiation results of the previous round; thus the representative value of each discretized variable will be re-generated at each iteration. See the dashed-arrows in Fig. 4-4. The resample serves as a refinement process on the discretization resolution to improve computational efficiency. When a variable's usage range and sampling for meaning interpretation are reached, we do not resample that variable. If variable can have real values, then fractional convergence is stopped by the decision rule on the stability of the optimization results.

4.6 Prototype implementation (I)

In this section, we introduce a proof-of-concept implementation of the computational design described in Sections 4.2-4.5. The implementation serves as a design tool; it automates the numerical calculation of the negotiation equilibrium between the user and the supplier when the user sets his service and price requirements to the supplier. We will present an extension of this prototype implementation in Section 5.2.3. A real implementation of the computational design in the existing communications systems will be discussed in Section 7.3.

The prototype implementation has two separate parts (see Fig. 4-5). One statistical analysis part computes the mapping relationship between the service design space and the service perceptual space. The other negotiation part determines if an equilibrium/equilibria exists based on the algorithms, utility functions, constraints and decision rules set by both players (Sections 4.3, 4.4, and 4.5). The design tool is implemented in a MATLAB environment[1].

The statistical analysis part consists of two functional blocks: the “principle component analysis” block and the “display” block. The principle component analysis block conducts principle component analyses by the MATLAB function princomp(). The input data are the PCA learning survey results (Section 4.2) from users regarding their ideal values of the service design attributes (a.k.a. user target points in design space, see Section 4.3). The output is the principle component coefficients ranked in order of decreasing component variance. The number of principle components to be retained can either be decided based on the percentage of variance they account for (e.g. 80% as a rule of thumb); or can be based on the methods mentioned in Lattin et al. (2003, p. 113). The reductionist principal component coefficient P and its pseudo inverse P^{-1} are saved for later use in the “direct mapping” and “reverse mapping” (Section 4.5.1) during the negotiation and for the purpose of display. Regarding the implementation details, the PCA is performed based on correlations; thus the data are normalized by mean shifting and rescaling. The means and standard deviations are saved for a later usage in mapping the data from the service perceptual space back to the service design space.

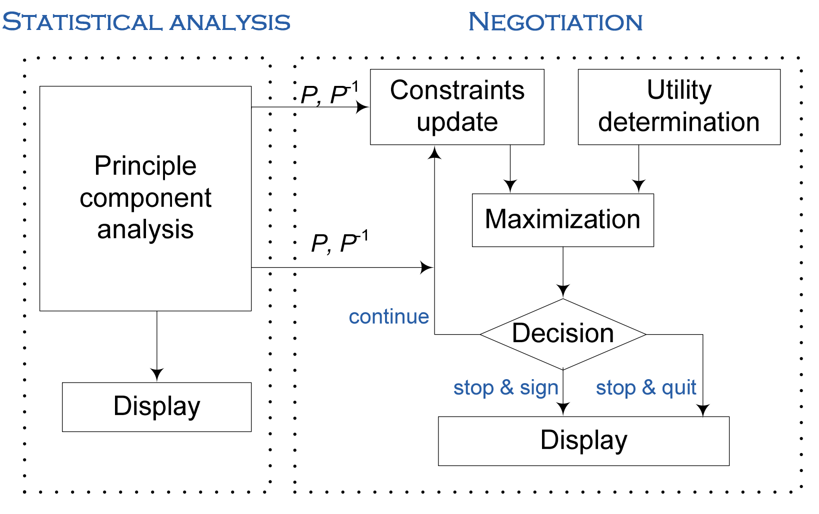

Fig. 4-5: Prototype implementation of the computational design (I)

The “display block” visualizes the result of the PCA by showing each design attribute's contribution to a chosen pair of principal components, as described in Section 4.2. The

[1] The MATLAB environment was chosen for the prototype building because it allows easy matrix manipulation, implementation of algorithms, visualization of functions and data, and interfacing with other applications (e.g. MS Excel).

visualization by MATLAB function biplot() facilitates the interpretation of the principle components as user-perceived service attributes.

The negotiation part plays an n-stage Stackelberg game between one user and one supplier: it consists of several blocks (see Fig. 4-5). As has been discussed in Section 4.5.1, there are two cases regarding information structure. We implemented the first case where the user alone owns the PCA mapping P and its pseudo inverse P^{-1}, and thus both the players communicate in the design space $\mathbf{X}$ about the values of the service attributes during the negotiation.

Before each optimization iteration, constraints are updated based on the adversary's service request. The "utility determination" block calculates the utility of each player during the negotiation process from the user model (Section 4.3) and the supplier's operational models (Section 4.4). The "maximization" block searches for the maximum utility under the specific constraints for each player using the MATLAB, or the NAG[1] optimization functions, or the exhaustive search of Section 4.5.3.1. After each maximization, the player makes a decision. The "decision block" contains decision rules upon which the players decide whether to continue, or to stop with or without an agreement (equilibrium). The player then sends the decision to the counterpart. The reverse mapping or direct mapping (see Section 4.5) is done when necessary using the results of the statistical analysis block. The "display" block visualizes the negotiation process by showing the computed utility of the players during each round of the negotiation, including the starting point and the equilibrium point, if it exists (e.g. see Fig. 4-6). The user's choices over a three-dimensional perceptual space can also be plotted.

Regarding the implementation details, the optimization block has two instances of implementation. The first one is based on the algorithm of Section 4.5.2, which assumes the variables in the computation to be continuous and take real values; NAG optimization routine e04ucf() is used, which minimizes an arbitrary smooth function subject to linear and nonlinear constraints (a similar MATLAB function fmincon() can also be used). The second implementation is based on the discretized negotiation algorithm of Section 4.5.3. We use exhaustive research instead of a non-linear optimization routine. The exhaustive search does calculations from all possible feasible combinations of the discretized values of each variable, and ranks the outputs according to the computed values. If the maximum value corresponds to multiple identical outputs, we randomly choose one input that leads to the maximum value; priority can also be given to certain variables or to certain constraints.

Regarding the computational time, the negotiation computation of the prototype implementation of the algorithm in Section 4.5.2, using non-linear optimization routines, takes seconds to complete. The computational time of the algorithm with exhaustive search (Section 4.5.3) is much longer and depends on the complexity of the supplier's operational model and the discretization rate of the variables. Furthermore, our main program is written in MATLAB and the supplier's operational model is built using MS Excel with

[1] Numerical Algorithms Group, a company specializing in the provision of software for the solution of mathematical, statistical and data mining problems.

lookup tables, IF-THEN rules, plus additional modules such as Erlang traffic calculator, the communications between the two software applications consume most of the computation time. Thus for the mSinging v2.0 case in Section 4.8, it takes 2-3 minutes on average to complete a negotiation computation on a normal desktop pc (2GHz processor, 1GB RAM). Note that this means a long computation time when Monte Carlo simulation is carried out where thousands or tens of thousands of negotiations need to be run (see Section 5.2): it may take days to complete. However in real practice, the whole computational design can be implemented solely using C or Fortran, which can improve computation efficiency and eliminate the communications between different application interfaces. Furthermore, the suppliers (e.g. telecom operators) often have or share high performance computing facilities, thus the computational time will be significantly reduced.

4.7 Case mSinging v1.0: fictive users vs. a fictive supplier

We have created a mobile service with limited service attributes to illustrate the computational design and to test the prototype implementation. Our service is called "mobile singing classroom" or "mSinging": it is an extension to the many mobile music services and belongs to that category[1].

The service allows the users to improve their singing performance by following the courses, getting instructions and receiving content chosen by themselves. Users are supposed to be just individuals with interests in singing and/or music; the supplier is a mobile operator assisted by teachers from music colleges. This is an interesting case for this research as it combines wireless bandwidth needs, wireless data traffic, content and additional professional services. For experiment and testing purposes, we take the approach of having a "simple" working service first and then extend it to much more complex situations. We tag the service developed in this section as mSinging v1.0, A much more complex version 2.0 will be introduced in Section 4.8.

4.7.1 Individual service description: mSinging v1.0

The mSinging service provides music and vocal training to users via mobile technologies. The prerequisite of the service is a mobile device which supports high-end audio functions both for recording and listening, and has multiple wireless interfaces (e.g. 2G/3G/WiFi).

To initiate the service, a user first needs to carry out a search (via e.g. Enhanced SMS) in a music content database located at the operator's network, and find out which music lessons he would like to follow. After the selection, he can download the music as well as other instructional materials via the mobile device to learn and to practice his singing.

Each song has background information such as a brief introduction to the composer, introduction to the specific types of music, stories and anecdotes about a particular song,

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[1] Many operators have already begun to offer mobile music services (Manes, 2005); some can even be personalized (e.g. the "Radio DJ" service by Vodafone: www.vodafone.de/music), but none of them offer yet individual tariffs.

scores and lyrics (supported by music fonts displayed on the mobile device); and an interpretation of the song (an example of performance).

Text and audio-based instructions are associated with each song. The content of an instruction includes: description of general techniques when interpreting certain music “genres”; techniques for building one’s own style; homework or assignment for users to practice.

A user can ask questions to a real teacher regarding how to perform a specific part, or he can ask a more general question regarding the styles of songs (via e.g. voice call or Enhanced SMS). He will receive prompt professional answers from the teachers.

A user can sing to the background music and record it with his high-end mobile device. He can send in a recording of his performance for the teacher to evaluate and provide feedback.

The service is individual in many ways: type of music, extent of the tutoring, number of practices, number of submissions, and contract length.

4.7.2 Fictive supplier and service design attributes

The supplier is a fictive converged fixed and mobile operator who offers both basic (generic) and value-added services, where both services can be made individual (see Section 4.9 for generic service individualization). In this case, we focus on the individualization of the value-added mSinging service.

4.7.2.1 Service design attributes

The mSinging service has nine service design attributes exchanged between the user and the supplier: each of the service design attributes corresponds to a decision variable of the supplier. Let the decision variables be $X = [x_1, x_2, \ldots, x_9]$. The service design attributes are:

- x_1, the size of the song database, which is measured in thousands of songs.
- x_2, the number of text instructions for each song. Additional instructions provide more details on the subject.
- x_3, number of songs to receive and learn per month.
- x_4, length of contract, in months.
- x_5, number of questions user intends to ask teachers during the whole contract period.
- x_6, number of evaluations user intends to receive from teachers during the whole contract period.
- x_7, download/upload method (pure fixed broadband/mixed/pure wireless, 1-10). A user can choose to download the content via fixed or mobile network or a mix of them. This option is in line with the current converged service offerings. The user can choose from a scale between 1 and 10. The value 1 corresponds to the case where all the content is downloaded through the operator’s fixed network and 10 all through the operator’s wireless networks.

- x_8, sound quality of the music (coding rate: 144 - 400kbps). Sound quality of music can be indicated by the coding rate of songs; measured in kilobits per second (kbps) and ranges from 144 to 400 kbps. Higher coding rates have better sound quality but also larger file sizes: they will generate more traffic and will cost more.
- x_9, a user's bid for the individual service in €. The bid is for all the service attributes with user-individualized values; the amount is for the whole contract period.

4.7.2.2 Supplier constraints and a feasible solution

The supplier's constraints are all expressed in design space **X**. In turn, these design constraints serve to determine the many detailed engineering constraints which are only seen and used by the supplier. We provide more details in mSinging v2.0 in Section 4.8.

The supplier has boundary constraints, which represent the supplier's region of tolerance regarding extreme requests from the users. The supplier also has linear and nonlinear constraints, which are mainly concerned with the quality of service (QoS). The operator must balance the relationship between the values of the design attributes and other engineering attributes (link capacities, etc.) to guarantee a minimum QoS. For example, for the mSinging service, the supplier has constraints regarding raw content diversity, teaching content diversity, wireless share in the "converged" (wireless, fixed broadband) service offering and costs. The supplier must also update some of these constraints based on the requests from the user during each round of the negotiation. A feasible solution for the supplier is defined as any decision vector in **X** which satisfies all the supplier's constraints.

4.7.2.3 Supplier utility function

The supplier's utility is defined as the incremental profit from serving an additional user who has an individual service and tariff request, on top of a pre-existing base of customers buying generic services. The incremental profit is decided by the user bid price minus the incremental costs from provisioning the infrastructure, the traffic, the content, the incremental human resources, and the management and billing according to user-requested service characteristics. The incremental human resources include the teachers for providing instructions, answering questions and providing feedback to the students.

Since the mSinging service is based on the generic services such as SMS and mobile data, the user also has to have a basic subscription with an operator to ensure connectivity. Although technically it is feasible to have basic services from another operator, few operator are willing to do so: usually the generic service subscription and the optional value-added service subscription are sold by the same operator. For the basic subscription, the user pays a monthly subscription fee for a bundle of basic services such as voice minutes, SMS, MMS and some data traffic. There are several generic service bundles for the user to choose from, all with different usage ceilings (e.g. see Table 4-3). To represent this effect here in a simplistic way, we assign a coefficient k to the user's generic service bundle: this coefficient represents the fraction of the generic service bundle capacity that the user will use for the mSinging service. When calculating the operator's cost, we first subtract $k\times$(user bundle amount) of usage from the calculation because they have already been paid in the generic service bundle (k is set to be 0.3).

Let X' = [x_1, x_2,…x_8]. As a simplified estimation, let the incremental costs of individualized SMS search, data transmission, database maintenance (cost related to the size of song base), instructions and individual coaching via questions and evaluations be a function of X', denoted as Δc_SMS(X'), Δc_data(X'), Δc_DB(X'), Δc_instr(X'), Δc_question(X'), and Δc_evaluation(X')[1]. The supplier's utility function U_supplier(X), to be maximized, is defined as the incremental profit $\Delta\pi$:

$$\text{U\_supplier}(X) = \Delta\pi(X) = x_9 - \Delta\text{c\_SMS}(X') - \Delta\text{c\_data}(X') - \Delta\text{c\_DB}(X') - \Delta\text{c\_instr}(X') - \Delta\text{c\_question}(X') - \Delta\text{c\_evaluation}(X') \quad (4\text{-}5)$$

4.7.3 Fictive users

For testing purposes, three different user groups (*A*, *B*, *C*) were created based on the different preferences for the mSinging service design attributes. The main characteristics of the preferences of these three types of users are shown in Table 4-1.

User type A: Just wants to listen to the music and wants to know how to perform or improve his background knowledge of certain types of music. He asks few questions to the teacher. The number of songs available is important to him. Due to the fact that it takes much less time just to listen to the music than actively learn how to perform, the user can download many songs each day.

User type B: Studies actively and spends a lot of time on practicing according to the instructions. He is eager to ask questions to improve his performance skill. He would like to focus on a certain type of songs. The number of songs the user will download each month is small, but at the same time, the user tends to ask a lot of questions.

User type C: Represents the type of user who wants an average level of service attributes when compared to the other two types of users. He downloads a moderate number of songs, subscribes to a moderate number of instructions and asks a moderate number of questions.

Table 4-1: Preference characteristics of the three fictive user groups

User group type	*Number of songs*	*Number of instructions*	*Number of questions*
A	high	low	low
B	low	high	high
C	medium	medium	medium

[1] There are also internal decision variables in these functions. To keep the explanation concise, we omit them here. Similar examples will be provided in Section 4.8.1.3

Each fictive user has a target point, which consists of the jointly chosen values for the 9 service design attributes, denoted as $x^0=[\ x_1^0,\ x_2^0,\ \ldots,x_9^0]$. For pilot testing purposes, we created 50 fictive users for the mSinging v1.0 case. We will report a large-scale user survey that elicits real user preferences in the mSinging v2.0 case (Section 4.8); the survey has more than 360 respondents.

4.7.3.1 User perceived service attributes

The user target points were used to compute the principle component analysis mapping coefficients. The first three principle components cover 81.07% of the total variances of the data, and were chosen as the reductionist mapping coefficient *P*. For that data set, the first component can be interpreted as the price performance of customized content, which is the teaching intensity in terms of personal instructions and evaluations. The second component can be interpreted as the price performance of raw content (i.e. the content is same to everyone) in terms of quantity (i.e. number of songs) and quality (i.e. sound quality). The third component can be interpreted as the degree of the service comfort in terms of sound quality and mobility. Each of the components corresponds to a perceived service attribute of the user for the mSinging service v1.0.

4.7.3.2 User constraints and a feasible solution

The user's constraints are expressed in the service design space **X** and later transformed into the service perceptual space **Z** for a given mapping *P* (see Section 4.3). Some of the user's constraints are unilateral; others will be updated based on the supplier's offers. We describe the constraints using the categorization of the optimization software we use[1], which classifies the constraints into boundary constraints, linear and non-linear constraints.

1. Boundary constraints in the service design space

The lower bound and upper bound represent the user's region of tolerance regarding values of the design attributes. These values do not change during the negotiation process for a specific user[2]. When transformed into perceptual space, these boundary constraints become linear constraints.

2. Linear and nonlinear constraints in the service design space

Each user has his own budget constraint and time constraint. At the same time, each user has his unique preferences about the service design attributes which may be represented by linear or non-linear constraints.

The user's budget constraint is that the total cost must be less than his available budget. The total cost of usage includes:

1.) basic bundle subscription fee;
2.) cost of the individualized mSinging v1.0 service;

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[1] NAG foundation toolbox, non-linear optimization routine e04ucf().

[2] This condition applies in the normal algorithm introduced in Section 4.5.2. In the algorithm with discretization (Section 4.5.3) when resampling is used, the boundary values are updated in each iteration.

3.) investment in access units (e.g. a mobile device that supports high-end music functions).

We consider the first two factors in our case and the third to be amortized inside the generic service bundle, as is the case with most mobile subscriptions (see Section 4.9.1).

Time constraint: the time the user spends on the mSinging service must be less than his available free time. Different attributes of the service take the user different amounts of time. For example, it takes on average 5 minutes to listen and comprehend one instruction; the length of each song is 10 minutes, etc. If the user's free available time to spend on each song is less than 15 minutes, he cannot pick both attributes but may still pick one of them. We have estimations of time consumption of all relevant design attributes.

Regarding the individual specific constraints, they can be related to the preferences for songs, instruction, questions, etc. Due to space limitations, the constraints are not listed here, but they are similar to the constraints listed in Section 4.7.5.

A feasible solution for the user (z^a) is defined as any decision vector in Z which satisfies all the user's constraints.

4.7.3.3 User utility function

The user's utility function is defined in the service perceptual space. Let the user's decision variables be $Z = [z_1, z_2, z_3]$, each corresponds to a perceived attribute identified in Section 4.7.3.1. The user's target point t^0 in the design space, is mapped into the perceptual space by the reductionist mapping coefficient *P*. Let the mapped target point be $z^0 = [z_1^0, z_2^0, z_3^0]$, $z^0 = t^0 P$.

The assumed behavior, as discussed in Section 3.3, makes the user use implicitly the distance-based function as his utility function. The user's utility function, to be maximized, is defined as a function of the Euclidean distance between a feasible solution (z^a) and the target point z^0:

$$U\_user(Z) = \exp(-\| z^a - z^0\|) = \exp(-\text{sqrt}\,[(z_1^a - z_1^0)^2 + (z_2^a - z_2^0)^2 + (z_3^a - z_3^0)^2]) \qquad (4\text{-}6)$$

This utility function is simple and straightforward and can, to a certain degree, reflect the irrationality in the user's behavior. But this function also has its drawbacks. In an operational environment, it is advised to use logarithm form utility functions, which have higher sensitivity and can lead to a rapid convergence in numerical computations. Furthermore, the scale of the utility function is bounded and independent of the user. A user-specific constant may be introduced as a multiplier to bring the user's utility to the same level as the supplier's. Although this does not affect the Stackelberg game outcome, where the user and the supplier optimize in their own decision space, it may affect the results of the Pareto computation, which we discuss later in Section 4.7.5.

4.7.4 Numerical results of Stackelberg negotiation game

The supplier's public offer of the mSinging v1.0 service is listed in Table 4-2. The generic service bundles upon which the mSinging v1.0 is based are listed in Table 4-3. The coefficient k (Section 4.7.2.3) is set to 0.3. We use the normal negotiation algorithm presented in Section 4.5.2 in the computation.

Table 4-2: Supplier's public offer, mSinging v1.0

Service attributes	*Pubic offer*
Database size (thousand songs)	1.5
Number of instructions/song	3
Number of songs/month	4
Length of contract (in months)	4
Number of questions (contract period)	8
Number of evaluations (contract period)	4
Download/upload method (fixed/mixed/mobile, 1-10)	6
Sound quality of the music (coding rate: 144 - 400kbps)	210
User's bid for the service in € (contract period)	200

Table 4-3: Generic service bundles upon which the mSinging v1.0 service is based

Basic bundles	*Max. voice minutes*	*Max. data traffic (MB)*	*Max. sms*	*€/month*
1	100	20	100	20
2	150	40	150	30
3	200	70	200	40
4	300	100	300	50

Fig. 4-6 shows a negotiation process between a user and the supplier. The user starts the negotiation and his requests are represented by the points with odd numbering; the supplier's counter-offers are represented by crosses with even numbering. The coordinates of each point/cross are the values of the utilities that the user and the supplier have reached from the request and counter-offer. A point (e.g. point 1) and a cross (e.g. cross 2) make up of one stage of the game. The equilibrium of this Stackelberg negotiation game is reached at point 11 (stage 6 of the game). It is a win-win outcome for both players when compared to the pay-offs derived from the initial public tariff. Fig. 4-7 shows how the user's requests evolve in the perceptual space **Z**.

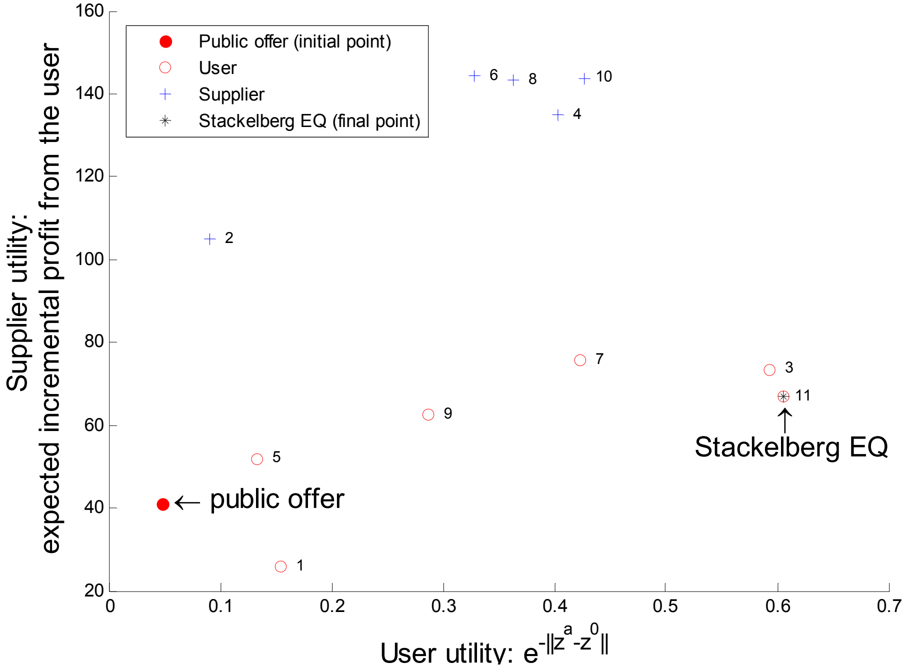

Fig. 4-6: The Stackelberg negotiation game between a fictive user and a fictive supplier, mSinging v1.0

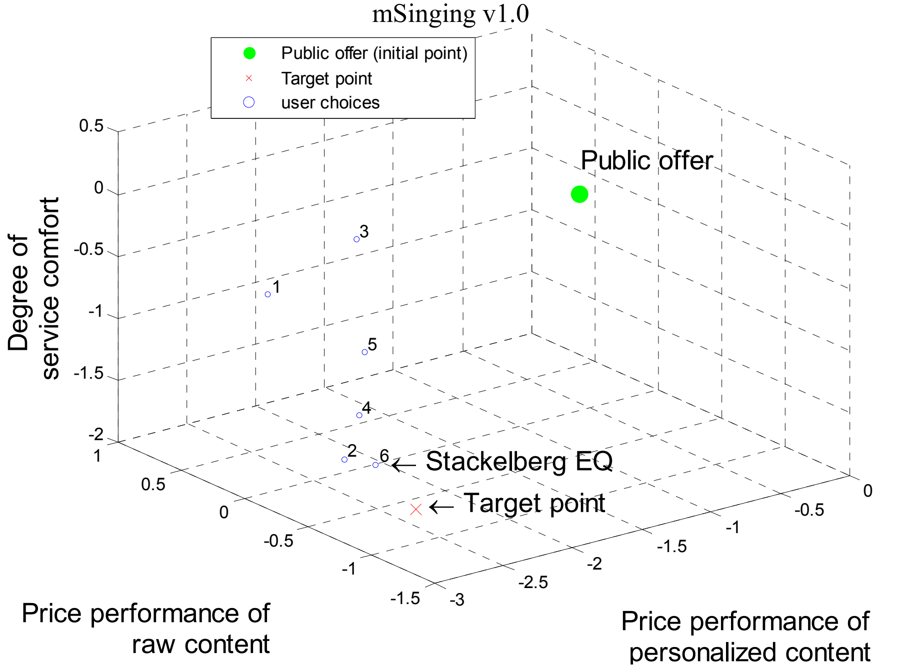

Fig. 4-7: User's requests at different stages of the Stackelberg negotiation game in perceptual space, mSinging v1.0

We have created three representative users (*a*, *b*, *c*) whose preferences are close to the three types of users identified in Section 4.7.3.2. These users are, however, not the 50 fictive users created for the PCA learning survey (Section 4.7.3). The users' (*a*, *b*, *c*) respective target points and final Stackelberg negotiation equilibrium points are shown in Table 4-4. N.B. this table gives equilibrium results which are not always integers when they should be: see Section 4.8 and Table 4-10.

Table 4-4: User target points, Stackelberg negotiation game equilibrium points, mSinging v1.0

Service attributes	***Initial points***			***Final equilibrium points***		
	user			user		
	a	*b*	*c*	*a*	*b*	*c*
Database size (thousand songs)	5	1	6	5.3	0.8	5.1
Number of instructions/song	1	6	2	0	5.7	1.7
Number of songs/month	20	3	15	24.6	2.2	13.9
Length of contract (in months)	3	6	5	2.2	5.7	5.1
Number of questions (contract period)	5	18	10	2.4	22.1	14.8
Number of evaluations (contract period)	0	6	5	0	7.8	5.1
Download/upload method (fixed/mixed/mobile, 1-10)	8	3	5	6.2	3.9	7.1
Sound quality of the music (coding rate: 144 - 400kbps)	224	330	196	189.8	291.9	227.7
User's bid for the service in € (contract period)	150	360	350	112.4	377.7	320.8

Table 4-5: Stackelberg negotiation game results when compared to the public offer from different users, mSinging v1.0

User	***Services and tariffs***	***Utilities***		***Results***	
		user	supplier	user	supplier
a	public offer (initial)	0.33	46	win	win
	individual service & tariff (final)	0.78	76.88		
b	public offer (initial)	0.05	40.87	win	win
	individual service & tariff (final)	0.61	66.85		
c	public offer (initial)	0.34	46	win	lose
	individual service & tariff (final)	0.77	1.01		

The negotiation, when comparing the final utilities to those derived from the initial public offer, can lead to win-win or win-lose situations for the user and the supplier respectively. Table 4-5 shows the comparisons for the three representative users *a*, *b* and *c*. The user, as the leader of the game, always achieves gain. The differences in gains between different users stem from their different preferences and constraints. The supplier achieves better results in two cases but a worse result in one case. In these negotiations, the operator uses the same constraint update mechanism and therefore treats all the users similarly.

4.7.5 Pareto equilibrium calculation

The user-supplier Stackelberg negotiation game is an incomplete information game that has a non-cooperative nature (Section 3.4), which usually prevents full Pareto-efficiency. For comparison purposes, we calculate the Pareto equilibrium set (also called Pareto frontier) by assuming the user and the supplier have full information about each other.

It is well known that the Pareto equilibria, if they exist, belong necessarily to the compact set of solutions of an optimization problem which has, as a goal function, a convex weighing of the two players' utilities (assumed to be continuous) (Mas-Colell, Whinston & Green, 1995). We introduce a convex allocation coefficient λ, ranging from 0 to 1. The λ dependent combined goal can be written as:

$$\text{total\_utility}(X) = \lambda \times \text{U\_user}(Z) + (1-\lambda) \times \text{U\_supplier}(X) \qquad (4\text{-}7)$$

In our conceptual framework and computational model, the supplier optimizes in the design space **X** with the decision variables $x_1, x_2, \ldots, x_9$ (see definitions in Section 4.7.2.1). The user optimizes in perceptual space **Z** with the decision variables z_1, z_2, z_3 (see interpretations in Section 4.7.3.1). In order to calculate the Pareto optimal set, the two players' utilities must be optimized in the same space. Given the mapping relationship P between the two spaces (Section 4.7.3.1), we use linear combinations of $x_1, x_2, \ldots, x_9$ to represent the user's decision variables z_1, z_2, z_3. Let the mapping of the user's feasible point z^a in the service design space be x^f. We assume that the players have full information about each other (see Section 4.5.1 for discussion on the information structure).

The user's utility function has the numerical range of (0,1], while the supplier's utility level is unbounded. This will cause problems during the optimization, where the supplier's utility will dominate the solutions. One solution is to equalize the players' utility functions by multiplying the user's utility with a coefficient (here 160). Given formulae 4-5, 4-6 and 4-7, the target function can be written as:

$$\text{total\_utility}(X) = \lambda \times 160 \times \exp(-\| x^a - x^0 \|) + (1-\lambda) \times \Delta\,\text{profit}(X) \qquad (4\text{-}8)$$

We randomly select a negotiation in the mSinging v1.0 case that reaches a Stackelberg equilibrium, and use the constraints and decision rules of that user to calculate the Pareto equilibrium set. N.B the constraints need to have slight modifications when used in the Pareto calculation. The result is shown in Fig. 4-8. The frontier is not continuous, which means there is no feasible solution for certain allocation coefficients meeting the conditions of the theorem cited above. The Stackelberg game equilibrium is an improvement over the public service and tariff, but it is not on the Pareto frontier and therefore not Pareto efficient.

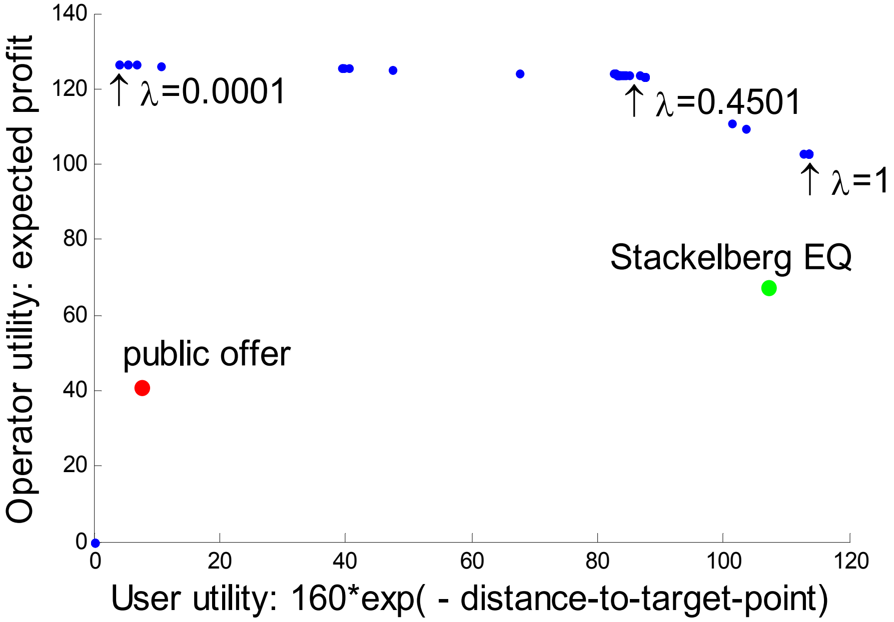

Fig. 4-8: Assumed Pareto set derived by convex optimization, for the negotiation game between a fictive user and a fictive supplier, mSinging v1.0

Lagrange multipliers

The Lagrange multiplier values (shadow values) can, among other uses, help to show which constraints are binding, which in turn can be used to adjust the parameters in the constraints. Table 4-6 gives a list of Lagrange multipliers at the Pareto equilibria solutions when λ takes values of 0.0001, 0.4501 and 1 respectively. See Table 4-7 for the explanations of the constraints.

Table 4-6: Lagrange multipliers of different constraints at Pareto equilibria solutions of the parametric optimization of equation (4-8)

λ	*binding constraints*	*Lagrange multiplier value at optimum*
λ=0.0001		
	n2	-2.336
	n5	-0.6841
	l1	-0.3598
	l2	-0.283
	b2	0.2443
	n1	3.01E-02
	b8	-1.63E-03
λ =0.4501		

	n2	31.49
	l2	4,735
	n7	-2,230
	l1	-0.6793
	n1	-0.40
	n5	5.09E-02
	n6	1.91E-02
λ =1		
	n2	70.06
	l2	10.84
	n7	-4,903
	l1	-1,131
	n5	0.95
	n1	0.0247

n: nonlinear constraints; l: linear constraints; b: boundary constraints

Table 4-7: List of constraints in the Pareto equilibrium computation of equation (4-8)

Constraints		*lower bound*	*upper bound*
Boundary constraints			
b1	Size of the database (measured in Ksongs)	0.1	15
b2	Number of instructions student requests for each song	0	15
b3	Number of songs per month	1	10
b4	Length of contract (month)	1	20
b5	Number of questions the student asks during the whole contract period	0	100
b6	Number of performance evaluations the student intends to have during the whole contract period	0	100
b7	Download/upload method (mobile/fixed/mixed, 1-10)	1	10
b8	Sound quality of the music downloaded (coding rate: 144-400 kbps/s)	144	400
b9	User's bid for the individual service in € (contract period)	5	500
Linear constraints			
l1	User's budget constraint	0	400
l2	Minimum number of evaluations from the teacher per month	0	4
Nonlinear constraints			
n1	More content is distributed via the mobile terminal when student wants to have more instructions from the teacher	-4	0

n2	Size of database is proportional to how many songs the user wants in total for his contract period	0.08	0.21
n3	The level of personal tutoring (questions, evaluations) should be set according to the requirements from the student	1.15	2
n4	Number of songs to download should be set according to user's requirement	16	25
n5	Price should less than 1.5 × cost	-30	0
n6	User's time constraint (minutes): the time consumption of the service should not exceed the user's available time but can be less than it.	-138	0
n7	Price per song should be set according to user's requirement	16	23

4.8 Case mSinging v2.0: realistic users vs. realistic supplier

In this section, we present the negotiations between a group of realistic users and a realistic supplier. Based on the mobile singing classroom service described in Section 4.7, we create an updated version. The updated mSinging (v2.0) modifies the design attributes according to some of the comments we received from the previous version. We carried out a large-scale survey to elicit the real users' preferences during the service design. The most important change is that we developed a close-to-real supplier's incremental cost and revenue model, which quantifies the consequences of an individual user's service requests.

4.8.1 Realistic supplier and the service design attributes

The supplier of mSinging v2.0 is an operator, as it is in the mSinging v1.0. The close-to-real supplier's model is based on estimates from a real telecommunication system supplier's data, and additional parameters were fitted to a real mobile operator's operations (more details will be discussed later this section).

4.8.1.1 Service design attributes

The mSinging v2.0 has seven design attributes X=[x_1, x_2, …, x_7], and each of them corresponds to a decision variable of the supplier. The seven design attributes in turn drive the values of about 70 engineering design parameters for the supplier. The seven individual service design attributes are:

- x_1, contract period (1-). The user can specify his ideal contract length for the mSinging service; the unit is months.
- x_2, degree of use of a mobile terminal from a converged operator (1-10). A converged operator offers fixed, broadband and mobile services in one service contract. The user can choose a number from 1-10, where 1 indicates that he wants all the content of the mSinging service to be downloaded via fixed internet (which means no mobility and cheapness). The value 10 indicates that

all the content is downloaded using a mobile terminal (which means higher mobility and expensiveness). A number from 2-9 means a mixture of fixed and mobile usage, with a larger number indicating a higher degree of wireless usage.
- x_3, sound quality of music (1-10). The user can choose a number between 1-10. The value 1 indicates the lowest sound quality of music (e.g. normal mp3) and the smallest music file size. The value 10 indicates the best sound quality of music (e.g. CD quality) and the biggest music file size.
- x_4, number of evaluations to have during the contract period (0-). The user can choose not to have any evaluation by setting the parameter to 0.
- x_5, number of questions to ask during the contract period (0-). The user can choose not to ask any question by setting the parameter to 0.
- x_6, number of songs to download in total during the contract duration (1-). The user can specify how many songs he wants to learn or download in total for the whole contract period.
- x_7, user's bid tariff for the individual service in € for the whole contract period.

4.8.1.2 Constraints and decision rules

The constraints of mSinging v2.0 are similar to those described in the mSinging v1.0 service, which are listed in Table 4-7. There are linear, nonlinear, static and dynamic constraints for the supplier. We use the decision rules described in Section 4.5.2 and set the supplier's minimum profit threshold θ to 0.

4.8.1.3 Supplier model and utility function

The supplier model is an instantiation of the realistic supplier's model developed in Section 4.4.2. The model is tailored to the mSinging service v2.0. The inputs of the model are the decision variables that represent the service design attributes. The output is the supplier's incremental operational profit from the provisioning of that individual service design before overheads. As explained earlier in Section 4.4.2, we distinguish between decision variables, parameters and constants in the supplier's model:

- **Decision variables**: each variable represents a service design attribute, the value of which is exchanged between the supplier and users. In the mSinging service v2.0, these are: $X=[x_1, x_2, \ldots, x_7]$. Let $X' = [x_2, x_3, x_4, x_5, x_6, x_7]$, and x_1 represents contract length, x_7 represent the user's bid price (Section 4.8.1.1).
- **Parameters**: other than the explicitly stated input X, there are also implicit engineering parameters that need to be set during the service design phase[1]. Such engineering parameters are often computed on the basis of the service design attributes, and their number is about 70 in the mSinging v2.0 case. Such parameters include the assumed subscriber base (N) for the mSinging service; the content diversity factor, which is the number of different content catalogs of minimum song database size; the user diversity factor, which is the expected ratio of diverse users of diverse songs; the coefficient k, which is the generic bundle capacity proportion used (see Section 4.7.2.3); and the service

[1] They are also called the "internal decision variables".

provisioning speed, which is the effective access bandwidth available to the user. Some parameters are static, which means they must be decided in advance; other parameters can be decided based on user-specific demands.

- **Constants**: Constants can generally be divided into three categories: infrastructure, content and service. In the infrastructure category, the data include access technology-specific capacity constants; the capacity of core network components; charging and billing data formats; and content storage costs. In the content category, the data include the estimated file size of the content: this can be used, for example, in estimating the download time over the air interface, or can be used in estimating the storage cost; the content distribution fee; and the royalty fee. The service category includes the minimum/maximum wage of the teachers. In total, we have about 60 constants. The data is either obtained from industry specifications, or from vendors' proprietary products, or from common practices (e.g. music coding format/coding rate).

To provide the mSinging service, the supplier needs to make various investments and pay for the operational costs (Section 4.4.2). Table 4-8 summarizes the investment objects and service operations objects that are modeled in the mSinging v2.0 service.

Table 4-8: Investment and service operations objects, mSinging v2.0

Investment objects	*Service operations objects*
1. communication infrastructure	1. tutoring
2. storage (content)	2. CRM and billing
3. content (initial music + new music)	3. content (management)
4. content (instruction)	4. infrastructure
5. application software	

Investment objects

- **Infrastructure, $C_1(X')$:** The estimation of the infrastructure-related investments is based on the assumed subscriber base (N); the investment is technology dependent. We assume access to four different wireless technologies: 2G/2.5G/3G/B3G. Each has an effective bandwidth, and each access technology needs an incremental investment for serving the assumed user base, which includes the BTS, BSC, MGW, routing and the transmission investments. The specific wireless technology provided by the supplier is decided as a function of the user's desired music quality (x_3) and user's bid price (x_7). The principle is that a user who has a higher willingness to pay can access networks with higher bandwidth, which have also shorter download times. Certain combinations are eliminated: for example, when the user requires the best quality of music while bidding very low price. This implies that large files must be transferred over low bandwidth networks (according to the principle mentioned above); for the supplier, this may cause network congestion in the low bandwidth networks; for the user, the long download time may be an unpleasant experience; therefore this combination is not offered to the user. Congestion and blocking are explicitly computed via Erlang formulae inside the model. Communication equipment usually lasts for quite a long period when compared to the contract length of a value-added service. In our model, the life spans of the investment objects that belong to the infrastructure category are set to be 15 years. Because there are many objects inside this class of investment in infrastructure, to facilitate a clear presentation, we use a simple notation to represent this whole class of investment objects, denoted as $C_1(X')$.

- **Content storage cost, $C_2(X')$:** The content storage-related investment is decided by the needed storage capacity and the basic storage infrastructure. Storage capacity cannot be increased in continuous increments, but only by adding servers with a fixed minimal capacity. We model this and the declining necessary incremental storage unit investment by assigning a basic storage capacity to the mSinging service, which has a higher tariff per storage unit: the tariff for the capacity exceeding the limit is set to be lower. The needed storage capacity is decided by size of the music content catalog, the size of each song before compression for mobile distribution and the size of the audio instructions. The music content catalog size is decided by the content diversity factor and the user diversity factor, and can also be affected by the expected number of songs the user wants to download. We set the life span of storage equipment to be 5 years and represent this class of investment by $C_2(X')$.
- **Content music, $C_3(X')$:** The music content related investments includes the initial content setup investment and new content acquisition investments. The initial content setup includes a certain number of songs accessible to the initial assumed subscriber base. The needed new content is decided by the content catalog size. Because the total investment in a new song can be very expensive and also because music production is not the core business of an operator, we assume that the supplier will only invest a share in the song creation (e.g. 5%). In this way, he can have full access to the latest content. Furthermore, the supplier needs also to pay the royalties for the songs. Some types of music content (e.g. pop) depreciate quite fast. Here we assume the life span of the content to be 2 years, and let this class of investment be $C_3(X')$.
- **Content instruction, $C_4(X')$:** This category consists of two investment objects: the investment in producing instructions for each song in the catalog and the investment in developing special software for instruction purposes. (e.g. to read music scores on a mobile phone); the former is decided by the catalog size and the cost of producing one instruction. We assume the life span of this investment class to be 5 years. The investment class is represented by $C_4(X')$.
- **Income from the share of investment, $D_1(X')$:** The supplier's investment in music content will generate income in the format of royalty fees. Typically, the royalty fee is settled on a yearly basis. This is a rather long period when compared to the expected length of contract from the users (see Section 7.2.2) and is thus categorized as a CAPEX. Because this is an income for the supplier, it should be subtracted from the cost, denoted the yearly income as $D_1(X')$.

Service operations objects

- **Tutoring, $O_1(X')$:** The supplier needs to hire music teachers to answer specific questions from students and to evaluate their singing performance. The time spent on one user can be estimated by the number of questions (x_5), the number of evaluations (x_4) the user requests, the average time to answer a question and the average time to perform an evaluation. We also consider that there are differences in the teachers' wages due to their experience; we assign a higher probability to the condition that low-wage teachers will be hired. The total cost of the tutoring is decided by the time a user demands and the expected wage of a music teacher. Let the cost of this class of service operations objects be $O_1(X')$.
- **CRM and billing data storage, $O_2(X')$:** This operational cost is technology dependent because the different access technologies use different call record formats (i.e. Call Data Records - CDR, Internet Protocol Detailed Records - IPDR), which have different sizes and require different storage space. Inside each technology, the cost is proportional to contract length (x_1). Due to EU regulations[1], the data must be kept for a period between 6 and 24 months, which adds to the storage cost. Let the monthly cost of this class of service operations objects be $O_2(X')$.
- **Content management fee, $O_3(X')$:** There are increasing costs associated with the number of songs that the user requires (x_6) regarding the management cost of the content (the cost per song increases as the number of songs the user requires increase). Denote the monthly cost of this class as $O_3(X')$.
- **Infrastructure $O_4(X')$** The supplier needs to pay for the maintenance of the incremental transmission capacity cost in the core network; there are also possible incremental maintenance costs in the media gateway, switches, routers, and civil engineering. Most of the costs are wireless communication standards dependent; they are also proportion to contract length (x_1). Let the monthly cost of this class of service operations objects be $O_4(X')$.

The detailed relationship of the parameters, the constants, the service design attributes and the cost objects mentioned above is illustrated in Fig. 4-9. Note that the decision variable "contract length" is related to costs of most of the investment and service operations objects because the supplier's incremental cost needs to be attributed to contract length. But due to space limits, we do not draw this variable as frequently as it should be but only show it when it is related to certain internal decision variables.

The supplier's incremental profit

We assume that the user base of the mSinging v2.0 service (N) to be 10^4. According to formula (4-1) and the different depreciation rates given above, the incremental investment from serving an additional individual user of mSinging v2.0, denoted as ΔCAPEX (X), is estimated as:

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[1] Directive 2006/24/EC of the European Parliament and of the Council, 15 March, 2006.

$$\Delta CAPEX\ (X) = (dep(C_1(X')) + depC_2(X')) + dep(C_3(X')) + dep(C_4(X')) - dep(D_1(X'))) \times x_1 / 10^4 \quad (4\text{-}9)$$

Let the marginal production elasticity associated with each investment object class be $\alpha_1 = 0.65$, $\alpha_2=0.4$, $\alpha_3=0.41$, $\alpha_4=0.5$. The scaling factor β is set to be 0.01. Based on formula (4-2), the incremental infrastructure and content-linked operational costs of mSinging v2.0 can be written as:

$$\Delta\ \textit{infrastructure and content-linked operational costs}\ (X) = (\beta C_1(X')^{\alpha 1} \times \beta\ C_2\ (X')^{\alpha 2} \times \beta\ C_3\ (X')^{\alpha 3} \times\ \beta\ C_4\ (X')^{\alpha 4})\ /\ 10^4 \quad (4\text{-}10)$$

According to formula (4-3), the incremental service operations provisioning costs are estimated to be:

$$\Delta\ \textit{service operations provisioning costs}\ (X) = O_1(X') + (O_2(X') + O_3(X') + O_4(X')) \times x_1 \quad (4\text{-}11)$$

The supplier's utility is the incremental profit ($\Delta\pi$) from serving an additional user of mSinging v2.0, which can be estimated based on formulae 4-9, 4-10, 4-11 as:

$$\Delta\ \pi\ (X) = x_7 - \Delta CAPEX\ (X) - \Delta\ \textit{infrastructure and content-linked operational costs}\ (X) - \Delta\ \textit{service operations provisioning costs}\ (X) \quad (4\text{-}12)$$

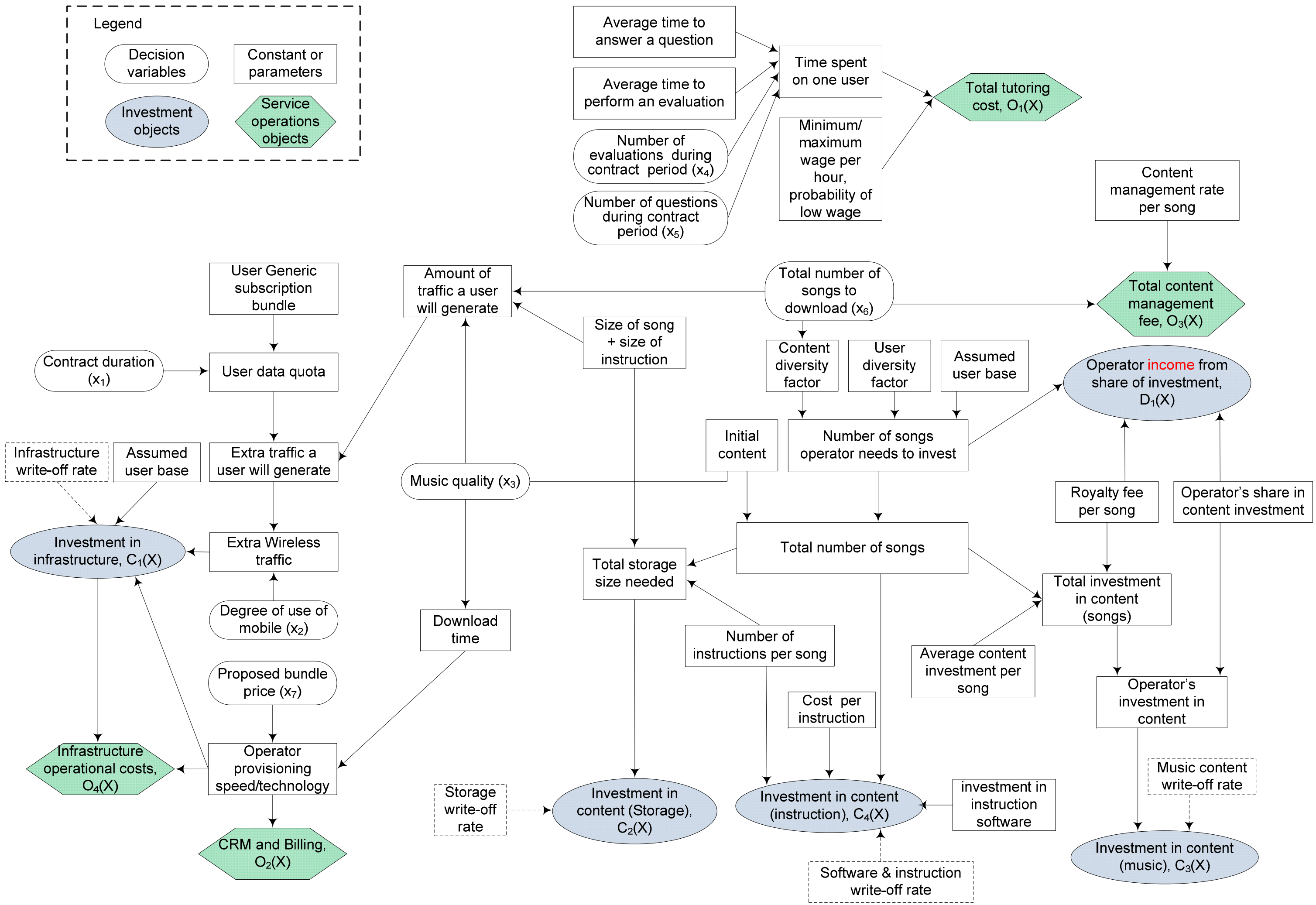

Fig. 4-9: The relationship among the investment and service operations objects, mSinging v2.0

4.8.2 Realistic users

In contrast to the case of mSinging v1.0 with fictive users (Section 4.7.3), a large-scale survey was carried out in the mSinging 2.0 case among the students at RSM. The survey provided a realistic characterization of user preferences. The obtained data have been divided into two sets. We use one set of the data to generate the PCA mapping coefficients *P* (the data set is called "PCA learning data set", see Section 4.2); we use the other set of data later in Section 5.2.4 to randomize the data points as a preliminary step to carrying out the Monte Carlo simulation to calculate the supplier's value at risk (the data set is called "target point distribution data set").

The survey procedure is as follows: we first familiarized the participants with the concept of individual services and tariffs by giving them examples of existing personalizable mobile services provided by operators. We also pointed out the limitations of these offers. Next, we presented an experimental setting similar to the popular "Idol" show in which students were signed up by their friends. The students needed to train themselves but they had very limited time and budget, and their singing techniques were at different levels. In the third step, we introduced the mSinging service (v2.0) to the students as a solution to the above problem they were facing. A public offer by a supplier was supplied. Students who were not satisfied with the offer were given the opportunity to have individualized services and tariffs; they were asked to state their desired values of the service attributes in service design space (a.k.a. user target point x^0 in design space). A detailed survey setting and service description is in Appendix II.

We collected 599 valid results, of which 88 participants indicated no interest in individual services and tariffs and therefore were eliminated from the data set. We randomly divided the remaining 511 valid results into two data sets: the PCA learning set (with 150 valid student results) and the target point randomization set (with 361 valid student results).

4.8.2.1 Perceived attributes of surveyed users

We perform a principle component analysis on the 150 students' target points of the service design attributes. The result is shown in Table 4-9. The first three principle components explain 67.3% of the variance of the student's preferences; the first four components explain almost 80% of variance. We need to decide whether to retain the first three or four components. Besides the total accounted variance, another rule of thumb method to determine the number of principle components is the "scree plot" method (see Lattin et al, 2003, p. 113). This method involves plotting the variance accounted for by each component in a decreasing order. We then look for an "elbow" in the curve: a point after which the remaining eigenvalues decline approximately linearly, and retain the components prior to the elbow. On this basis, (see also Fig. 4-10), we decide to take only the first three components.

Table 4-9: Variance explained by each principle component, mSinging v2.0

Principle components	***Eigenvalues***		
	Total	*% of Variance*	*Cumulative variance %*
1	2.284	32.631	32.631
2	1.399	19.982	52.613
3	1.026	14.652	67.265
4	.885	12.645	79.910
5	.652	9.308	89.218
6	.513	7.324	96.542
7	.242	3.458	100.000

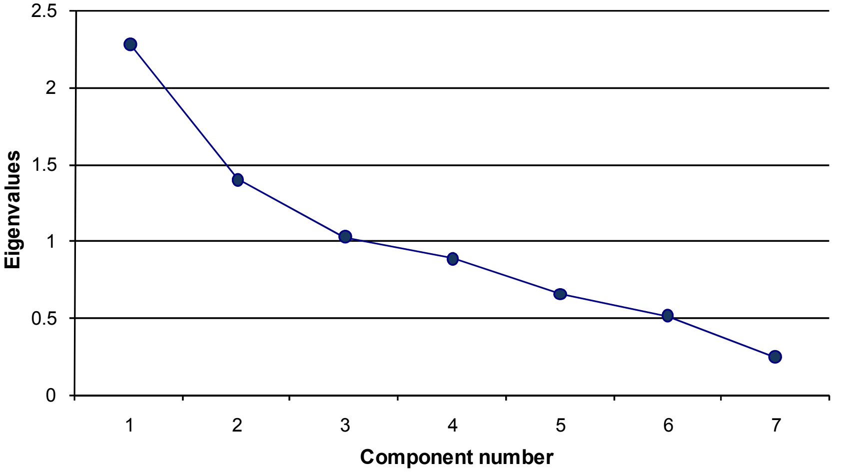

Fig. 4-10: Scree plot of the Eigenvalue of each principle component, mSinging v2.0

The interpretation of the principle components was carried out following the procedure described in Section 4.2. We also held some joint discussions with the survey respondents regarding their perceived service attributes. Fig. 4-11 shows the projection of the service design attributes onto the coordinate system formed by the 1st and the 2nd principle components. Each design attribute is represented by a vector; each user target point (here: target points from the 150 students) is also projected onto this new coordinate system and is represented by a dot.

Figures 4-12, 4-13 and 4-14 provide a detailed zoomed view of the projection of the design attributes onto the coordinate systems formed by the 1st and 2nd, 1st and 3rd, 2nd and 3rd principle components respectively.

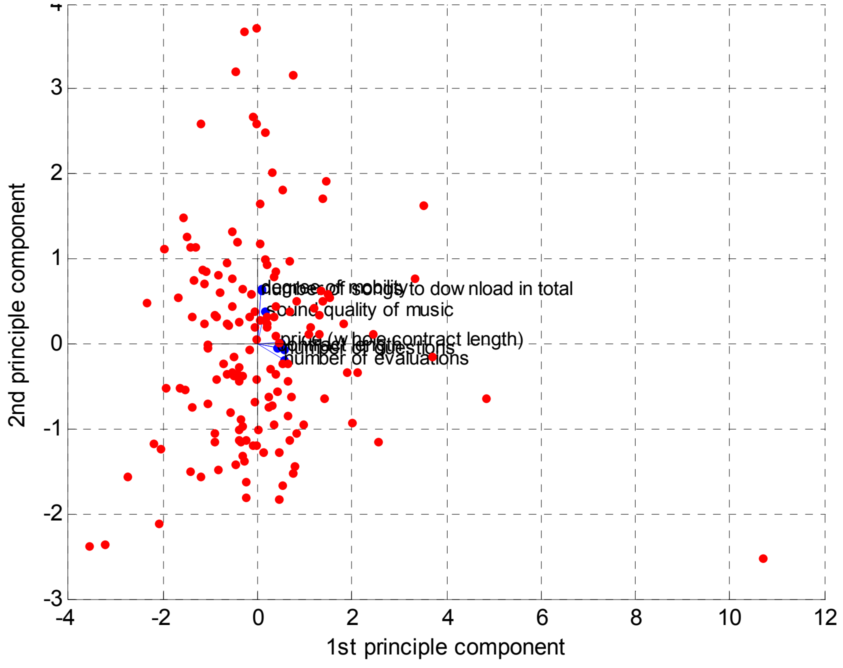

Fig. 4-11: Projection of the service design attributes onto the coordinate system defined by the 1st and 2nd principle components, with all 150 data points

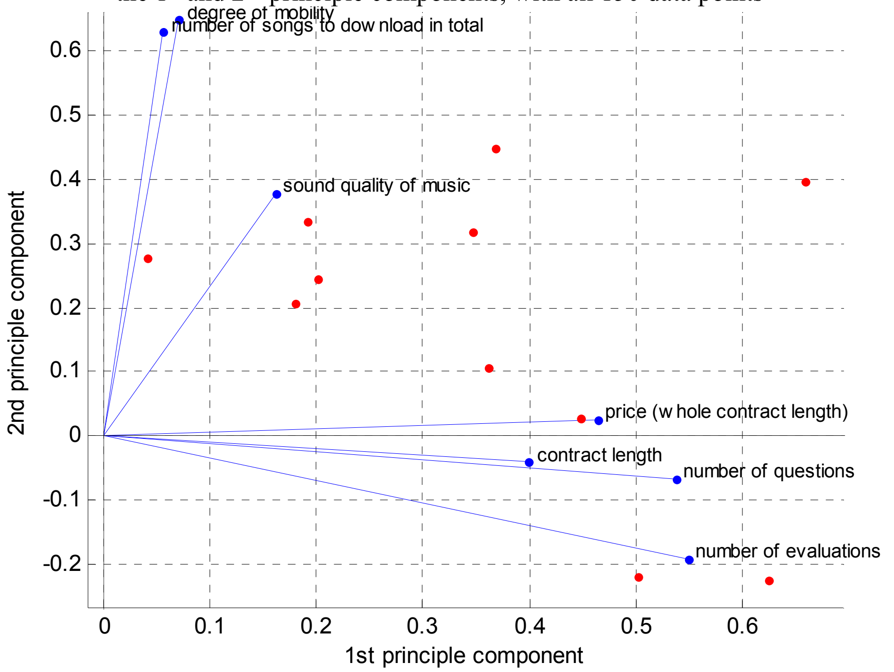

Fig. 4-12: Projection of the service design attributes onto the coordinate system defined by the 1st and 2nd principle components

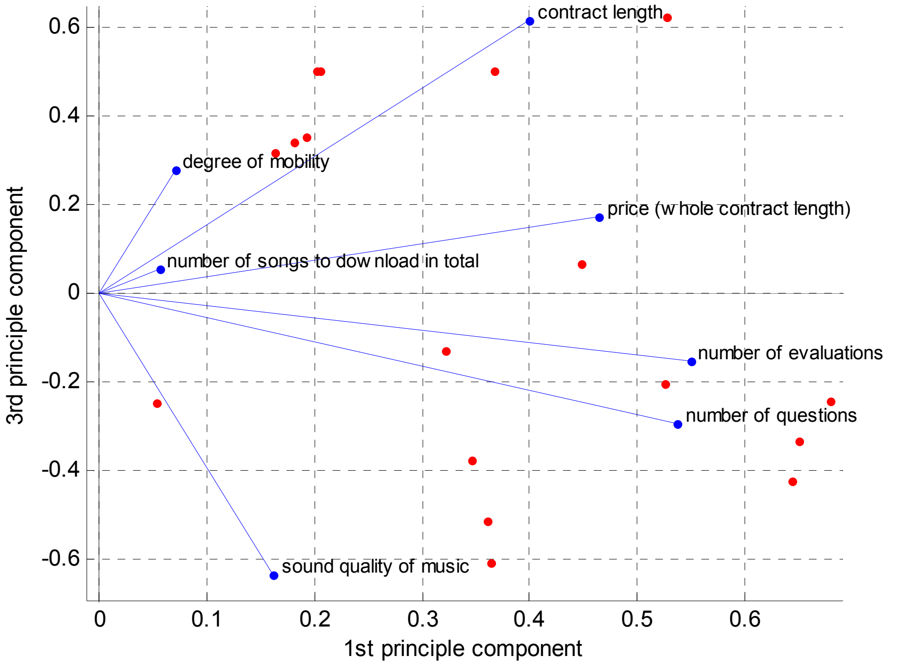

Fig. 4-13: Projection of the service design attributes onto the coordinate system defined by the 1st and 3rd principle components

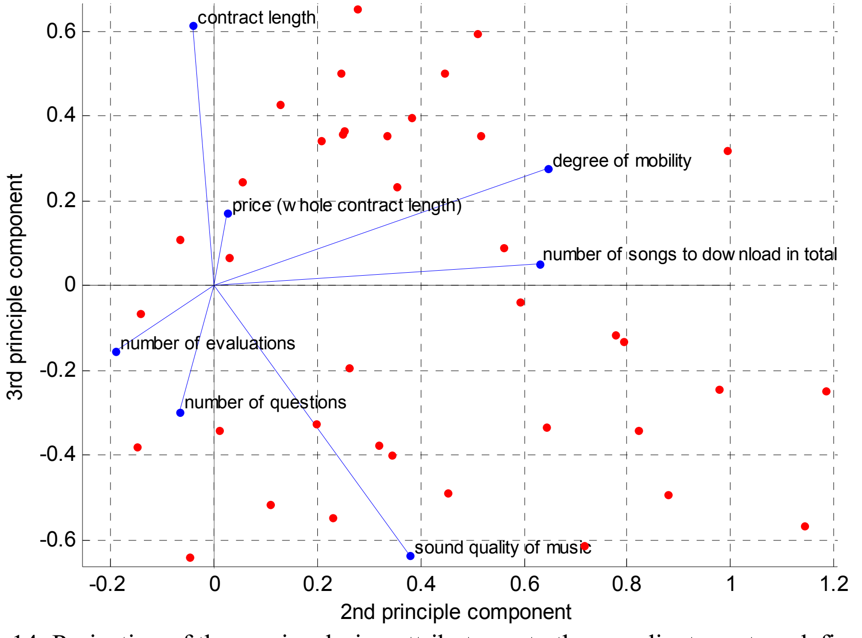

Fig. 4-14: Projection of the service design attributes onto the coordinate system defined by the 2nd and 3rd principle components

Based on Figures 4-12, 4-13, 4-14, we have the following interpretation of the first three principle components as the perceived service attributes:

1. price performance of the teaching content in terms of personal instruction and evaluations;
2. service comfort in terms of ubiquity and sound quality together;
3. service flexibility in terms of contract length and quality of raw music.

Compared to the preference data and the interpretation of the perceived service attributes of mSinging v1.0, the data of v2.0 exhibit higher heterogeneity. And the interpretation for v2.0 is slightly different and much more difficult. This is expected because the former data are fictive while the latter data are from the real world.

4.8.2.2 Constraints, decision rules and utility function

The user's constraints are similar to those in the mSinging v1.0 described in Section 4.7.3.2 and listed in Table 4-7. There are linear, nonlinear, static and dynamic constraints for the user. The user sticks to the decision rules given in Section 4.5.2.

Let the user's decision variables be $Z = [z_1, z_2, z_3]$, and each corresponds to a perceived attribute identified above. The user's target point t^0, which was specified in the design space, was mapped into the perceptual space by the reductionist mapping coefficient *P* determined in Section 4.8.2.1. Let the mapped target point be $z^0 = [z_1^0, z_2^0, z_3^0]$. Note that the decision variables will be discretized in the computation.

The assumed behavior as discussed in Section 3.3 makes the user select implicitly the distance as the basis of his utility function. Thus the utility function, to be maximized, is defined as the function of the Euclidean distance between a feasible point (z^a) and the target point z^0 in the perceptual space. The maximum/minimum value of the function is 1/0. The same remarks on this function as in Section 4.7.3.3 apply here.

$$U\_user(Z) = \exp(-\| z^a - z^0\|) = \exp(-\mathrm{sqrt}\,[(z_1^a - z_1^0)^2 + (z_2^a - z_2^0)^{2+} (z_3^a - z_3^0)^2]) \qquad (4\text{-}13)$$

4.8.3 Numerical results of Stackelberg negotiation game

For a user whose preferences for the mSinging v2.0 service are close to those leading to the mapping *P* in Section 4.8.2.1, we compute the equilibrium of the Stackelberg negotiation game using the prototype implementation (Section 4.6) with the algorithm presented in Section 4.5.3.2, and the supplier's incremental cost and revenue model developed in Section 4.8.1.3.

Fig. 4-15 shows the negotiation process between such a user and the realistic supplier. The starting point is the public offer. The notations are similar to those in Section 4.7.4. The equilibrium of the Stackelberg game is reached at point 19 after 9 rounds of negotiation. It is a win-lose outcome when compared to the pay-offs from public offer: the user achieves a gain while the supplier is slightly worse off.

Recall that in the mSinging v1.0 case, we distinguish three types of users (Section 4.7.3.1): type *A* users are mainly interested in the music content and they pay little attention to the teaching materials; type *B* users learn in an active mode and are eager to ask questions and have evaluations to improve their performance skill; type *C* users are interested in both the music and teaching content. Such different types of users can also be found amongst the surveyed users in the mSinging v2.0 service. We randomly generated three users whose preferences represent the three types of users respectively (see Section 5.2.1 for the approach by which we generate the user preference). We compute the Stackelberg game negotiation equilibria of the users. The users' revealed preferences, the supplier's public offer and the final negotiation equilibria are shown in Table 4-10.

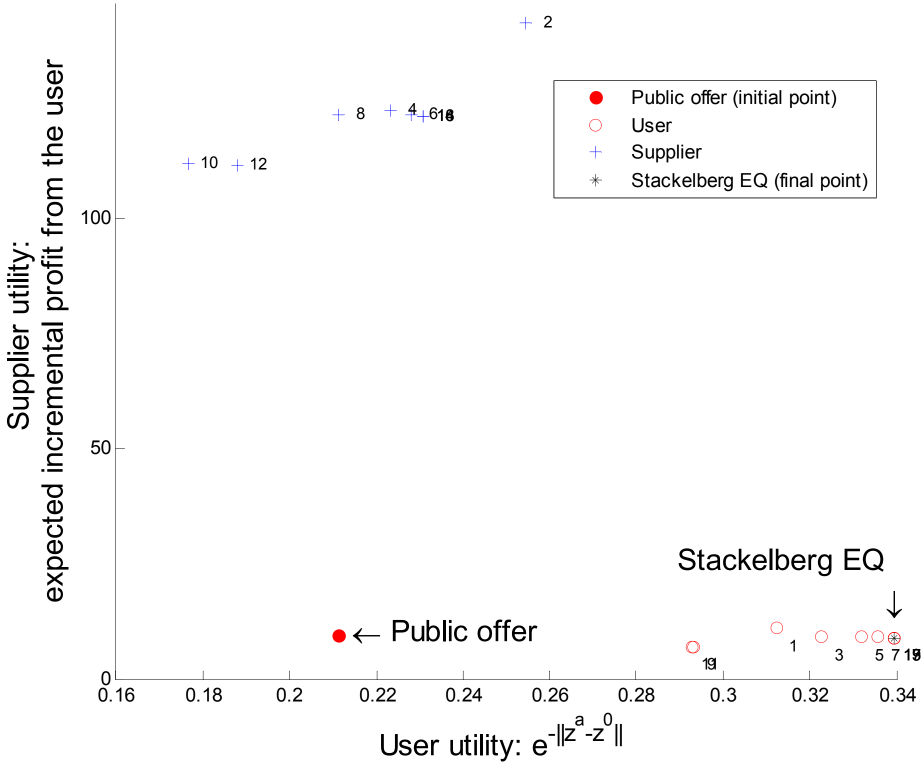

Fig. 4-15: The Stackelberg negotiation game between a realistic user and a realistic supplier, mSinging v2.0

Table 4-10: User revealed preferences, public offer and final game equilibrium points, mSinging v2.0

Service attributes	***Initial user requests***			***Initial public offer***	***Final negotiation EQ points***		
	User				User		
	a	*b*	*c*		*a*	*b*	*c*
Contract duration in month(s)	3	6	4	4	5	8	5
Degree of use of mobile terminal (1-10)	7	7	7	6	9	7	6
Sound quality of the music (1-10)	10	9	5	5	7	7	6
Number of evaluations to have during contract period	3	15	5	4	2	14	5
Number of questions to ask during contract period	6	25	8	8	5	23	7
Number of songs to download in total	60	30	16	16	81	54	34
User proposed bundle price (€)	200	280	210	150	176	284	184

The negotiation results can be a win-win or win-lose situation when compared to the public offer (Table 4-11). The users, as leaders of the games, achieve gains. The relative improvements over the initial public offer utilities differ significantly, as the users' requests are heterogeneous. The supplier is better-off in one negotiation but worse off in two. The supplier's worst payoff is actually limited by the minimum profit threshold θ, which is set to 0.

Table 4-11: Stackelberg negotiation game results when compared to the public offer from different users, mSinging v2.0

User	***Services and tariffs***	***Utilities***		***Results***	
		user	supplier	user	supplier
a	public offer (initial)	0.07	10.23	win	win
	individual service & tariff (final)	0.21	16.35		
b	public offer (initial)	0.02	9.65	win	lose
	individual service & tariff (final)	0.27	3.49		
c	public offer (initial)	0.55	9.55	win	lose
	individual service & tariff (final)	0.80	8.03		

4.9 Generic mobile services

4.9.1 Introduction

A typical mobile operator offers 5-30 service bundles: each bundle has a set of bounded standardized service usages and a tariff for some duration, plus excess usage conditions. The bundle may cover usage within ceilings for voice minutes, SMS, MMS and/or a certain amount of data traffic, plus limited customer support. A user chooses a service bundle, signs a contract (minimum duration is often fixed by supplier lasting 1 or 2 years), receives possibly an upgrade to an existing mobile terminal, and pays a fixed monthly fee corresponding to the chosen bundle. Additional tariffs for usage exceeding the "bounded" ceilings of the chosen bundle vary slightly among bundles, but usually an overprice applies to the excess usage, unless sometimes unlimited usage of a certain service is offered within specified hour/date/destination combinations. As discussed in Section 1.2, the limited segmentation often leaves a significant number of demands from the users unsatisfied

This section deals with the individualization of a common generic mobile service bundle. Generic mobile services differ from value-added mobile services by usually having a much larger number of customers, so that the pre-existing installed base is much larger than the ones used in Section 4.4. The result of this research setting can be used by users who want only individualized generic services, or it can be used in connection to the negotiation of a value-added service which uses some of the generic service attributes, as in the case in Section 4.8.

4.9.2 Behavioral models

In the same way as with the user behavioral model in Section 3.3, the user is characterized by having both economic and social concerns when designing an individual generic service bundle. He has bounded rationality and uses a simplified decision model with satisficing decision rules.

To reduce the complexity for the user in service design, we introduced earlier the concept of a service perceptual space (Section 3.3), which is a reductionist mapping of a service design space. The reductionist mapping is, however, not necessary when the user and supplier jointly design a generic mobile service bundle for the user. Most of the time, the service bundle consists of straightforward and well understood services such as voice, SMS and data. Other attributes of the service bundle include contract length and price per month. The number of service attributes to be individualized is only between three and five; therefore the service perceptual space is not used here[1]. The supplier and user share the same generic service bundle design space for the negotiation, which is also their decision space. However, like in Section 4.4.2, the supplier will still have for his internal use a large number of engineering attributes for this generic service bundle.

The supplier is a mobile operator characterized by seeking a maximum profit with a minimum risk.

4.9.3 Computational models

The computational models of the user and the supplier are similar to those presented in Sections 4.3 and 4.4.2. The approximated supplier's model in Section 4.4.2 and prototype implementation from Section 4.6 can be used directly with minor modifications, which are mainly to the traffic estimation and congestion aspects. It is used however with a far

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[1] Evidence from empirical research has shown that although information processing capability varies among individuals, the limit lies between five and nine distinctive information cues. See Miller (1956), "The magic number of seven, plus or minus two".

greater number of users in the installed base than in Section 4.4.2: typically, the additional user will be an increment to an existing base of many millions.

The supplier usually publishes a list of generic service bundle offers (see an example in Table 4-12). Each bundle has consumption ceilings of the generic services, contract duration and a unique bundle price. Let the bundle that is closest to the user's wish (targeted situation) be the initial public offer for the negotiation, denoted as s^0. The closeness is determined by the Euclidean distance from the offer to the user's target point t^0. If the user's target point has equal distance to two offers, he randomly picks one offer.

4.9.4 Negotiation algorithm

The negotiation algorithm is similar to the algorithms introduced in Section 4.5, and the user and the supplier use the same decision rules as in Section 4.5. The main difference is that in the generic service bundle negotiation, the user's constraints, maximization and decisions are all in the same service design space as the supplier; thus mapping between the different spaces in the algorithms in Section 4.5 is not necessary.

Let $i = 1,2 , \ldots, k$ represent the round of negotiation (i-th stage of the game). The negotiation algorithm with discretization but without service attribute mapping is illustrated in Fig. 4-16.

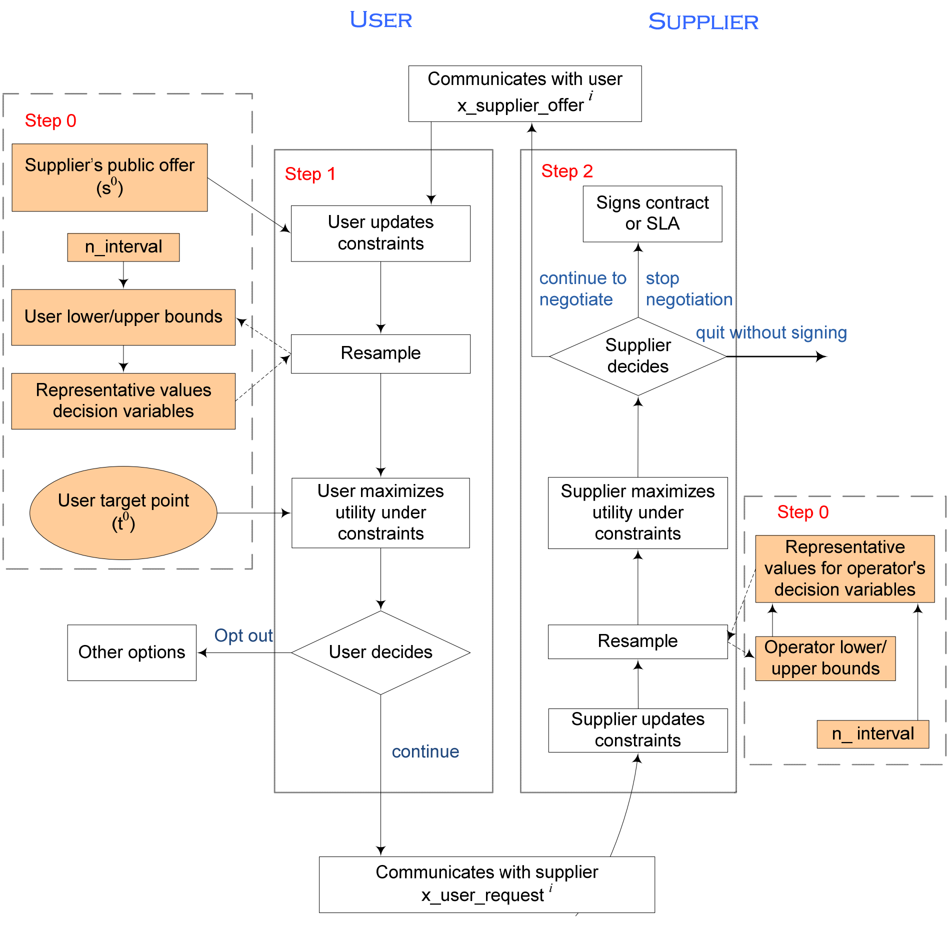

Fig. 4-16: The Stackelberg negotiation game algorithm for individualization of a generic mobile service bundle

4.9.5 Case

We develop a case to evaluate the computational design for the negotiation of individual generic mobile service bundles. The key difference with current practices as described in Section 4.9.1 is that now there is no need to choose between discrete bundles of the same basic services (e.g. voice, SMS, MMS, data), but the user negotiates instead with a supplier a tailored bundle meeting his individualized usage, price and duration demands. This means that unused service quotas because of discrete bundle design and choices can be vastly reduced and that the user does not pay for things he does not use. Also a dynamic adaptation can take place, as the user can adapt his service demand ceilings each time a new contract is renegotiated (e.g. a contract for the holiday months and another one for the usual working months). Furthermore, the user also can avoid tying himself up to long fixed durations like one or two years; however, he may still choose to do so if the supplier has an built-in incentive in the offer.

In the analysis below we eliminate the effect of a possible upgrade or supply of a new mobile terminal to the user. This does not change the approach, as the possible amortization of terminal costs borne by the supplier, or other costs for the same terminal borne by the user, are traffic and usage independent.

The supplier's offer consists of three generic services: voice, SMS and data (typically Web access). Let the decision variables for an individual bundle of such generic services be $X = [x_1, x_2,\ldots,x_5]$, and each corresponds to an individualized bundle design attribute:

- x_1, max voice minutes for contract duration
- x_2, max number of SMS for contract duration
- x_3, max amount of data download in MB for contract duration
- x_4, contract length in months.
- x_5, price in € paid to the bundle for contract duration.

Based on the information retrieved from one of the major operator's websites[1] (with no terminal included) on 3rd December 2006, we compile a public offer list. What needs to be emphasized is that these discrete bundles give the possibility of only an acceptance or rejection decision by the users, and the contract duration is also a supplier condition with no choice.

Table 4-12: An operator's public offer list of generic mobile service bundles (terminal not included)

Price plan	*Max. voice minutes*	*Max. number of SMS*	*Max. data download (MB)*	*Contract length (month)*	*Price per month in €*	*Total contract cost excluding excess usage in €*
1	75	100	0.5	12	20	240
2	200	150	0.5	12	30	360
3	500	200	2	12	40	480
4	800	250	4	12	50	600
5	1200	250	10	12	75	900

User's constraints

The user' constraints for an individualized generic service bundle are mainly of two types: the budget constraints, and the time constraints (e.g. he cannot spend all his time talking on the phone). There are also boundary constraints which are the user's region of tolerance regarding the value of a design attribute (e.g. a user wants between *a* and *b* voice minutes as max ceilings).

1 Vodafone UK http://shop.vodafone.co.uk/index.cfm?go=paymonthly.selectaplan

Supplier's constraints

The supplier has constraints on the price he charges for the contract duration, i.e. the contract revenue. He may also want to differentiate incentives between the different service categories, by giving better treatment e.g. to data traffic vs. voice traffic. He may also want to put in contract duration-based incentives by offering cheaper voice, SMS and data download when the user is willing to sign a longer contract. Furthermore, his offer in each round of negotiation should not be radically different from the user's request.

All in all, the supplier will have to better adapt the service mix and usage request to his own technical and operational efficiencies, as well as making better use of his competitive advantages in these subjects.

Numerical results

The generic services are offered to a large population of users: their preferences for the service design attributes follows a distribution, which could be found out by a user survey. What needs to be pointed out is that in reality, in a competitive environment, user survey may be of limited use, as survey results are only valid until a competitor undertakes a new campaign, which happens frequently.

Due to lack of user survey results of generic service usage and conditions, we assume the user preferences for "voice minutes", "data download" and "price per month" to follow a multivariate normal distribution. Although real user preference distributions can only be conjectured to differ from it, the means/variances of the user preference multivariate normal distribution are approximated by the means/variances between the discrete bundles offered by a supplier (see Table 4-12). It should be stressed that in practice the assumption of a multivariate normal distribution is far from correct, but it is used here for lack of a better and simpler option. We assume the user's preference for contract length/ and SMS usage to be independent of other design attributes and that each of them follows a normal distribution. The mean and variance of the preference distribution for SMS are approximated from the public discrete bundle in Table 4-12. For the mean and variance of the preference distribution for contract duration, we use the data obtained from the global user survey in Section 7.2 (mean =7, standard deviation =5): see also Appendix III. We randomly generated some user preferences obeying the distributions described above. The generated values are mostly monthly based due to the nature of data in Table 4-12. We approximate a user's total demands of each generic service by multiplying the generated user preference values by the generated individual contract length.

We feed the randomized user preferences into the prototype implementation of the negotiation algorithm described in Section 4.6. We assume the subscriber base $N = 10^6$. We set the number of sub-intervals, which is a discretization related parameter (Section 4.5.3), to 5. We set the supplier's "minimum profit threshold" θ to 0. The supplier will not sign a contract if the incremental profit from the individual user is below θ (Section 4.5.2). Some randomly selected individualized users' requests (*a, b, c, d*), public offers and negotiation results are shown in Table 4-13. Note that the public offer is selected from Table 4-12 as the one that is closest to the user's request. The value of each service attribute is shown for contract length.

In the negotiation game, the user maximizes his utility by minimizing the distance to his target point. The supplier maximizes his utility, which is the incremental profit from that user. When there is a game equilibrium, which means an agreement is reached, we compare the utilities of the user and the supplier at the final equilibrium with their initial utilities from the corresponding initial offers. The user always achieve gains; the supplier in some negotiations makes less profit than in the public initial fixed bundle situation, but nevertheless, he still makes a positive incremental profit in all three negotiations. If we decrease the threshold θ, the supplier may have losses from some users. This will be discussed in the next chapter.

Table 4-13: Individualized user requests, initial fixed bundle offers, and negotiation results of individualized generic service bundles

User		Service design attributes					Utilities		Results	
		x_1	x_2	x_3	x_4	x_5	user	supplier	user	supplier
a	Request	3486	1140	18	6	264				
	Public	6000	2400	24	12	480	0.92	103.86	win	lose
	EQ	4235	1400	20.7	7	329	0.59	41.82		
b	Request	10656	1488	108	12	708				
	Public	14400	3000	120	12	900	0.54	19.21	win	win
	EQ	11700	2990	117	13	754	0.65	37.42		
c	Request	2295	1160	25	5	195				
	Public	6000	2400	24	12	480	0.51	103.86	win	lose
	EQ	1900	960	14.6	4	164	0.86	19.06		
d	Request	5873	1393	56	7	399				
	Public	9600	3000	48	12	600	0.54	2.15	win	lose
	EQ	5600	1295	51.1	7	434	0.89	60.23		

The negotiation process of user-b is shown in Fig. 4-17. The result is a win-win situation for both the user and the supplier.

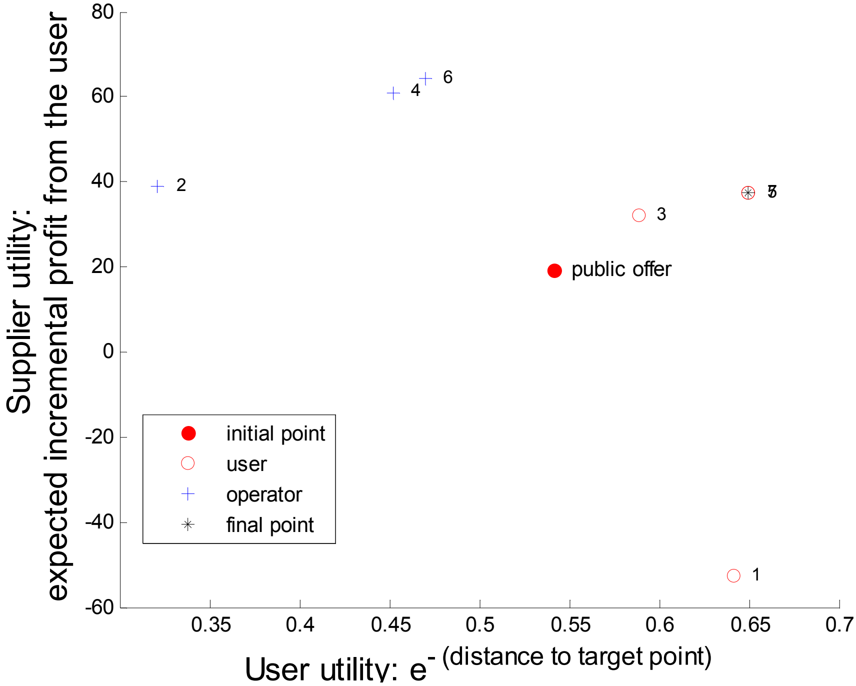

Fig. 4-17: The Stackelberg negotiation game between a user and a supplier on a generic mobile service bundle

4.10 Summary

This chapter has presented a computational design of individual mobile services and tariffs. By doing this, we have partially answered the "how" question raised in the beginning of the thesis. The benefits to the users and the supplier were evaluated through three computational cases using a prototype implementation of the design.

Section 4.2 proposed to use a user survey and the principle component analysis method to determine the mapping relationship between the user's service perceptual space and the supplier's service design space. This mapping relationship is service and user group dependent. A method to interpret the obtained principle components as perceived service attributes was also provided.

Section 4.3 described a computational model of the user with decision variables, constraints, and a distance-based utility function. It also introduced the concept of user target point z^0, which is represented by a vector that contains the set of ideal values that the user wishes to reach for the perceived service attributes.

Section 4.4 first introduced a fictive simplified supplier's computational model with decision variables, constraints and a utility function. This section then described a detailed and complex close-to-real model of a wireless and mobile service supplier which addresses the mobile communications services' specific features. It is built as an incremental model that is able to quantify the consequences of the individual user's service requests.

Based on the models of the users and the suppliers, Section 4.5 provided two negotiation algorithms for the Stackelberg game between the two players when designing a complicated value-added mobile service. The first algorithm is designed for the negotiation between fictive users and a fictive simplified supplier, where the decision variables can take real values and the optimization can be resolved algorithmically using existing software routines. In view of the non-linearities and possible discontinuities in the close-to-real supplier model and constraints, there is no way non-emptiness or convergence of the feasible sets for the two players can be established mathematically. Furthermore, in reality, some of the decision variables must take only integer or discrete values in order to be meaningful (e.g. contract length, data rate). Thus the second algorithm is established based on the first one, but allows the discretization of the variables and uses exhaustive search as the maximization method.

Section 4.6 described a prototype implementation of the computational design as a tool. The design tool can automate the numerical calculation of the negotiation equilibrium between the user and the supplier when the user sets his wishes for the service attributes in the beginning.

We presented two cases relating to one service (i.e. mSinging) but with different complexity, in Sections 4.7 and 4.8, respectively to demonstrate the feasibility and evaluate the benefits of the computational design. The mSinging service combines wireless bandwidth needs, wireless data traffic, content and additional professional services, and thus serves as a good representative case. The individual service and tariff negotiation, when comparing the final utilities to those derived from the initial public offer s^0, can lead to win-win or win-lose situations for the user and the supplier respectively. The user, as the leader of the game, always achieves gains for his utility over the public offer s^0. The supplier achieves better results in some cases but worse results in the others.

In Section 4.9, we provided a negotiation algorithm for the design of a common generic mobile service bundle, involving, for example, voice, SMS and data download. Because of the limited number of straightforward design attributes, the user would use the same service design space as the supplier. This is the main difference between this algorithm and the aforementioned two algorithms. We studied the Stackelberg game equilibria of a large-scale case and obtained similar results to those of the mSinging cases: the user always gains while the supplier sometimes loses.

This chapter has provided the details of a computational design of individual services and tariffs. The implemented design tool allows us to compute the equilibrium of individual negotiation games. Given the results of the above numerical cases of the supplier, it is natural to ask if the supplier can make an overall profit from offering individual services and tariffs, to what extent and how. More importantly, how to quantify the risks and minimize them? These questions will be answered in the next chapter where we carry out analyses at a user group level.

Chapter 5
Risk pooling and assessment at supplier level

5.1 Introduction

In Chapter 4, our main focus was on the computational design and the tool that facilitate the automated computation of the negotiation game equilibria. The design and analysis was carried out at individual game level. In this chapter[1], our goal is to help the supplier (typically a mobile operator) of individual services and tariffs to design his individual contract acceptance decision criteria when facing the uncertainties brought by the various needs of a group of users, so that he could achieve his goal of obtaining a maximum profit with a minimum risk (Section 3.2). This chapter, together with Chapter 4, constitutes the complete computational design for individual services and tariffs.

Recall that in Chapter 4, the numerical case analyses showed that the supplier makes different profits and sometimes losses from different individual users when compared to the public tariff situation. This higher volatility in profit means higher risk to the supplier at individual contract level. However, a supplier often has a large user-base even for a specific value-added service. The risk from individual users can be mitigated by pooling the profits and losses from individual users across a user-base for that (class of) service offer[2]. Furthermore, the supplier can set certain parameters in his decision rules, which decline extreme requests from users, but at the expense of possibly losing customers from the potential user base. It is important to notice that the changes in the parameters of the decision rules will not only affect the expected profit and risk from the individual contracts, but also the rate of deals, which is defined as the proportion of negotiations ending in a mutually accepted contract. Together, the changes in these three aspects affect the supplier's total expected profit (corporate profit) and total risk from the potential user base of the individual service, and ultimately affect the supplier's final decision.

Based on the above discussion, it is necessary to have a set of methods and a tool that computes the expected profit, risk, and rate of deals, so that analysis can be carried out at the individual user level and, most importantly, at the corporate level. This helps the supplier to intelligently adjust the parameters in his decision criteria according to the corporate policy. This chapter serves this purpose and is organized as follows. In Section 5.2, we focus on Value at Risk (VaR), and related computations and analyses. We first present the Monte Carlo method to calculate the supplier's VaR. Second, we analyze the supplier's profit and risk at corporate level when he offers individual services and tariffs. Third, we describe an extension to the prototype implementation presented in Section 4.6 which can carry out statistical computations and analyses. We finally illustrate the concepts with two numerical cases, which are based on the mSinging v2.0 service and the

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[1] This chapter is partially based on Chen & Pau (2007a)

[2] The assumption here is that the uncertainties in profits from individual users are uncorrelated or have a low degree of correlation.

individual generic mobile service bundle. In Section 5.3, we focus on extreme value theory and analyze the possible application areas of this theory in the context of individual services. We describe a systematic statistical method in dealing with the extreme data. This is followed by a numerical case on the estimation of the extreme risk in supplier's profit and loss distribution at the individual contract level. Section 5.3 concludes the chapter. The linkage between the content at section level is shown in the Table below.

	Value at Risk and related computations	
5.2	Based on	Section 3.2 on supplier behavioral model, Section 4.2 on mapping, Sections 4.8, 4.9 on numerical cases.
	Results used in	Section 5.3 in extreme value computations
5.3	***Extreme value theory & its applications to individual services and tariffs***	
	Based on	Section 5.2 on VaR computation results, Section 4.8 on the surveyed user preferences distribution and the numerical case.
	Results used in	Section 8.3 as the further research issues

5.2 Value at Risk and related computations

There are many definitions of risk in different contexts and for different application areas (e.g. credit/market risk). In general, risk is proportional to the perceived degree of uncertainty of an event: it does not always imply merely negative outcomes. In economics and finance, risk is often defined as the volatility of the return on an investment/asset over a certain period.

A standard benchmark of risk is Value at Risk (VaR), which offers a statistical summary of risk. In essence, it answers one simple question: "how bad can things get?" (Hull, 2003). VaR was first used in the late 1980s by major financial firms to measure the risks of their trading portfolios. During the 1990s, it became widely spread in the risk analysis community. The concept is quite simple: for a given time horizon t, and the confidence level α, the VaR at confidence level α is given by the smallest number l such that the probability that the loss L exceeds l is no larger than (1- α) (McNeil, Frey, & Embrechts, 2005, p. 38): see also Fig. 5-1.

$$\mathrm{VaR}_\alpha = \inf \{ l \in \mathrm{R}: \mathrm{P}(L>l) \leq 1- \alpha \} \qquad (5\text{-}1)$$

In the context of individual services, we define the supplier's VaR of a specific class of value-added service as an estimate of the supplier's loss across the assumed base of subscribers, at a given confidence level for a given contract period[1]

The calculated VaR can have a positive or a negative value, with the negative value corresponding to a loss to the supplier. When the value is positive, it should be interpreted as the minimum profit at a certain confidence level from an individual service contract of stated duration. For example, given a contract period and a confidence level of 95%:

[1] N.B. as individual service contracts have different durations, strictly speaking sensitivity should be carried out vs. contract duration.

1. if the VaR = - 4, the supplier can expect with 95% confidence level that the loss from one randomly selected individual contract from the subscriber base will not exceed 4 (€);
2. if the VaR = 4, the supplier can expect with 95% confidence level that the profit from one randomly selected individual contract from the subscriber base will exceed 4 (€).

In general, there are three methods to calculate VaR. The main difference lies in the generation of the statistical distributions of the risk factors. A risk factor is a random variable whose value will be realized during the time $(0,t]$ and will affect the value being measured (return, profit, etc) at time t.

1. Historical simulation

This method assumes that risk factors in the future will have the same statistical distribution as they had in the past; and therefore the distributions of risk factors are generated based on historical data. The advantage of this approach is that it is straightforward and requires few assumptions about the distribution of the risk factors. See Linsmeier and Pearson (2000) for more details.

2. Variance-covariance

This method assumes that the risk factors can be approximated by a multivariate normal distribution and that the change in the return is *linearly* dependent on all risk factors. The means, variances and covariance can be obtained from historical data, or can be generated based on certain assumptions (Linsmeier & Pearson, 2000). The advantage of the method is that it is easy to implement and easy to examine alternative assumptions about the standard deviations and covariance. However, the actual distribution of risk factors often has a "fat" tail when compared to the normal distribution (e.g. a *t*-distribution); therefore the high risk is often underestimated.

3. Monte Carlo simulation

The Monte Carlo method requires the specification of the probability distribution function (PDF) of each risk factor. These distributions may be, or can be, approximated by relatively well-known distributions (e.g. Pareto distribution, Poisson distribution), as well as by distributions derived from empirical data only. The Monte Carlo method generates scenarios based on the *joint* distribution of the risk factors, and feeds them as inputs to calculate the returns. VaR can be calculated based on the empirical distribution of the returns. Detailed steps can be found in Linsmeier and Pearson (2000). Compared to the other two approaches, the freedom to pick the distributions of risk factors from non-tradition distributions allows a better approximation of the reality. But this is at the expense of computational intensity and it usually takes a long time.

In the context of an individual service, there are several concerns in choosing the method to calculate the supplier's VaR. In the service design phase, especially when designing a new service, there are limited records about users' preferences over the service attributes, therefore the historical simulation method can be of limited use in our case. The variance-covariance method assumes that the risk factors are distributed following a multivariate normal distribution. This may not be the case for users' preferences in reality. More importantly, the variance-covariance method assumes that the change in the final result is linearly dependent on the risk factors, so that the supplier's profit distribution can be resolved by mathematic formulas. Because of the non-linearities and discontinuities inside the supplier's cost-revenue model (see Sections 4.4 and 4.8), the negotiation result, i.e. the supplier's profit from an individual contract, does not have a linear relationship with the risk factors. Therefore the variance-covariance method is not suitable here.

Compared to the first two methods mentioned above, the Monte Carlo method satisfies all the requirements of the VaR calculation of individual services. The probability distribution functions of risk factors can follow any distribution. The supplier's profit distribution is obtained through intensive computation by feeding all the risk factors into the individual negotiation game model developed in Section 4.5. VaR and other risk metrics can be computed based on the empirical distribution of the negotiation outcomes: see Fig. 5-1.

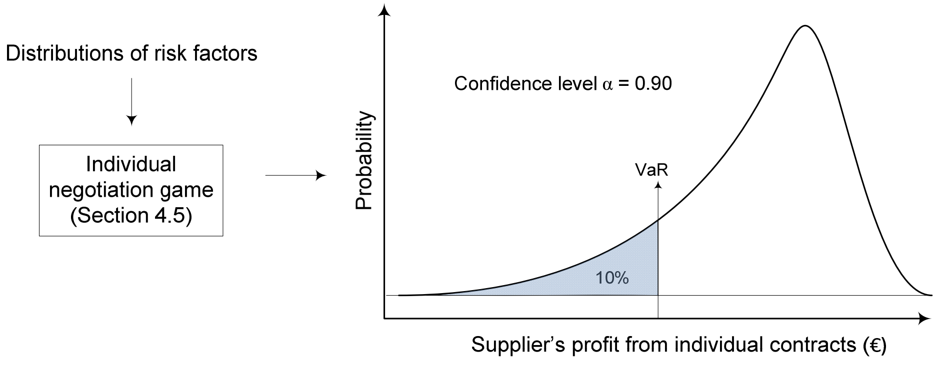

Fig. 5-1: Using Monte Carlo method to calculate supplier's VaR

5.2.1 Monte Carlo method to calculate supplier's VaR from individual service contracts

In the context of individual services, there are several factors that contribute to the uncertainty of the supplier's profit:

1. the nature of the distribution of users' preferences;
2. the variability in the operator's cost and revenue structure;
3. the selection of negotiation constraints and decision rules.

We first assess the risk which stems from the first factor. To calculate the supplier's VaR when offering a specific class of individual services and tariffs, we employ two methods: "user survey" and "Monte Carlo simulation". We use the former to obtain users' preference distributions on one specific class of service; the results will be used by the latter to compute VaR.

The user survey polls the users from the same potential user group from whom the reductionist mapping *P* was obtained (see Section 4.2). This is to ensure that the mapping relation *P* holds for the "newly" surveyed users. The content of the survey is the same as the "*PCA learning survey*" (see Section 4.2), which asks the users to state their individual preferences of the service design attributes (a.k.a. target point t^0) of a specific service, and thus obtains the preferences distributions in the design space. We then use the reductionist mapping coefficient *P* to obtain the user target point distribution in the perceptual space. The detailed process will be explained in the first step of the Monte Carlo simulation.

To distinguish the two surveys, we shall call the second one *target point distribution estimation survey* to emphasize its purpose. We call the survey result *target point distribution set.* In practice, the two surveys can be combined into one, while the obtained data will be randomly divided into two sets that serve different purposes. Fig. 5-2 illustrates the different usages of the surveys.

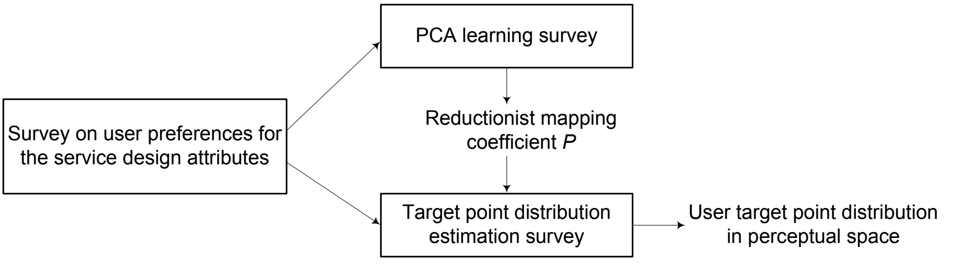

Fig. 5-2: The summary of the usages of the user surveys

The Monte Carlo method to calculate the supplier's VaR has four steps, as explained below:

Step 1: obtain the empirical distribution of z^0 (sample target points) from the distribution estimation survey when mapped into the user's perceptual space.

Let the number of service design attributes be *n*, and the number of perceived service attributes be *m.* Let the reductionist mapping between the design space and perceptual space, which is obtained through the PCA learning survey, be *P* (see Section 4.2). Let *h* be the sample size of the "target point distribution estimation survey"; let *E* be the survey result, which is a *h-by-n* matrix in the service design space. Let *G* be the mapped survey result in the service perceptual space, which is an *h-by-m* matrix. Let $Z^0 = (Z_1^0, Z_2^0, \ldots, Z_m^0)$ be the multivariate random variable that represents the user's preferences for the perceived service attributes $z_1, z_2, \ldots, z_m$ jointly. Each row in *G* represents a user's target point z^0; each column of *G* is the sample distribution of preference for the perceived attributes.

First, map the sample target points from the service design space to the service perceptual space. This is done by multiplying the target point distribution set *E* with the reductionist PCA loadings *P*, $G = EP$ (see Fig. 5-3).

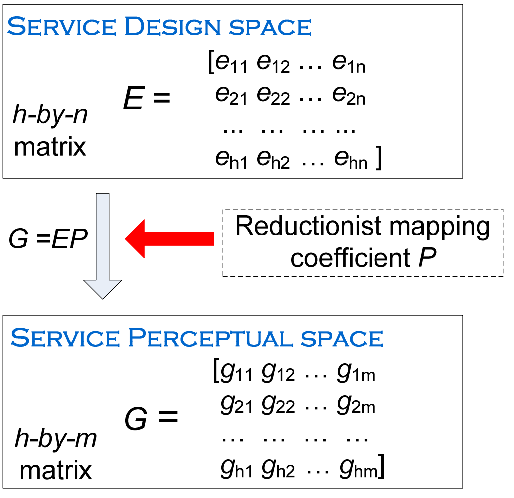

Fig. 5-3: The reductionist mapping of target points from design to perceptual space

Next, we need to check the correlation between the random variables Z_1^0, Z_2^0,…,Z_m^0 in the reduced data set *G*. This can be done by examining the off-diagonal elements of the covariance matrix of *G*. There can be three results:

1. If the random variables Z_1^0, Z_2^0,…,Z_m^0 are independent of each other, the multi-dimensional empirical distribution of the target points can be represented by several statistically independent one-dimensional empirical distributions: each perceived attribute corresponds to a distribution.
2. A less favorable situation occurs when some of the random variables are independent, while some others are correlated. In this case, the multi-dimensional distribution can be decomposed into lower-dimensional distributions.
3. The worst case occurs when correlation exists between all the random variables (perceived attributes). Thus the multi-dimensional distribution cannot be reduced to simple forms.

Finally, a characterization of the distribution is necessary. For one-dimensional distributions, both parametric and non-parametric methods can be used. For higher dimensional joint distributions, distribution fitting using software tools is suggested.

Step 2: randomize target points (z^0) based on their estimated distributions in perceptual space

The implementation of this Step 2 depends on the characteristics of the distributions obtained in the previous step. The purpose of the randomization is to create more target points, by generating them to comply with the distributions obtained in the first step.

If the random variables Z_1^0, Z_2^0,…,Z_m^0 are independent (result 1 in Step 1), we can use the 1-dimensional empirical distributions estimated from data set *G* to generate more multi-dimensional target points. Each dimension of the target point takes a value generated from the empirical distribution of the user's preference over a perceived attribute. The method to generate these values is as follows: first create a random number generator that provides floating point numbers that are uniformly distributed between [0, 1]. Then treat each randomly generated number as a probability and map the probability to the empirical cumulative distribution. The quantile in the cumulative distribution is the random value generated for that perceived attribution by randomization.

If the random variables Z_1^0, Z_2^0,…,Z_m^0 are dependent (result 2, or 3 in Step 1), the randomization of the target points become more complicated. Depending on the specific distribution (e.g. multivariate normal), software tools (e.g. MATLAB or SPSS) can be used.

Step 3: calculate supplier profits from individual contracts

The generated target points from Step 2 are fed into the negotiation game computational model developed in Section 4.5 (see Fig 5-1). For a given supplier's computational model including constraints and a cost-revenue model, and an assumed equilibrium type with decision rules by both players, we can obtain an empirical distribution of the supplier's profit from individual contracts. Note that it is also important to analyze negotiation games that do not reach an equilibrium (e.g. by analyzing the Lagrange multiplier, see Section 4.7.5).

Step 4: calculate supplier's VaR from individual service contracts

Sort the supplier's profits from individual contracts, and we can obtain their cumulative distribution (CDF). VaR at a particular confidence level α can be calculated using the (1-α) percentile (quantile) of the CDF (Linsmeier & Pearson, 2000). For example, if 10^5 target points are generated to represent the potential users, the estimate of the 95% percentile would correspond to the 5000^{th} largest loss, i.e. $(1- 0.95) \times 10^5$.

In practice, more target point distribution estimation surveys as needed in Step 1 can be carried out during the life-cycle of the service so as to capture the (slowly) changing preferences of the subscribers.

5.2.2 Supplier's profit and risks at corporate level

Of the three factors that affect the randomness of the supplier's profit when offering individual services and tariffs, the first two (see Section 5.2.1) cannot be controlled by the supplier. What the supplier can do is to choose the equilibrium type and change the parameters in the constraints/decision criteria. The effect of the supplier's adjustments will be shown in the percentage of equilibria (called rate of deals), the expected profit and the VaR from the individual contracts. Here the percentage of equilibrium gives an indication of potential subscribers from the targeted user population. The expected profit can be interpreted as the profit amount from a randomly selected individual contract from the potential subscriber base. Given a set of decision criteria, and a confidence level, if the value of VaR is positive, the supplier bears no risk of losing money from the potential subscribers obeying the chosen target point distribution. The value can be interpreted as the minimum level of profit that the supplier can expect from an individual contract. However, a positive VaR does not imply that the supplier always makes a positive profit from an individual contract. When VaR is negative, the supplier has a risk of losing money from the potential subscribers obeying the chosen target point distribution; the risk increases as the value of VaR decreases.

If the supplier's decision rules and parameters are set to represent a greedy manner in the negotiations, there will be fewer successful negotiation outcomes (which means a lesser number of contracts), higher expected profit, and lower risk across the subscriber base. An opposite strategy will result in more deals, lower expected profit from individual contracts and higher risk. How should the supplier decide?

The supplier of individual services and tariffs makes decision based on the expected profit and risk at corporate level. Let N be the assumed number of potential subscribers (for a given service, it is assumed to be a constant). $E(R)$ the expected percentage of equilibrium (rate of deals); $E(\Delta\pi)$[1] the expected incremental profit from an individual contract; and VaR_α the Value at Risk at confidence level α of an individual contract. The supplier's total expected profit $E(\pi)$ can be defined as:

$$E(\pi) = N \times E(R \times \Delta\pi) \qquad (5\text{-}2)$$

Under a primary assumption that the percentage of equilibrium is independent of the expected profit from the individual users, we have

$$E(\pi) = N \times E(R) \times E(\Delta\pi) \qquad (5\text{-}3)$$

Similarly, under a similar assumption, the supplier's total expected risk can be estimated as

$$E(\text{total risk}) = N \times E(R) \times VaR_\alpha \qquad (5\text{-}4)$$

Of all the parameters in the supplier's constraints and decision criteria, the most important is "minimum profit threshold" θ (see Section 4.5.2): the supplier will not sign the individual service contract when the negotiation result leads to an incremental profit less than the threshold value. Fig. 5-4 gives a simple illustration of how the parameter can affect the expected profit and the VaR from individual contracts. Fig. 5-5 (a) illustrates how θ will affect the percentage of equilibrium. Based on the assumption that the "percentage of equilibrium" and the "expected profit" from an individual user are independent, we can calculate the total expected profit and total risk of the supplier: see Fig. 5-5 (b). In practice, the shape of the curves may be much more complex (see Figures 5-15, 5-16 and 5-17). The supplier then must decide the setting of the parameters based on the computed curves and his profit-risk policies.

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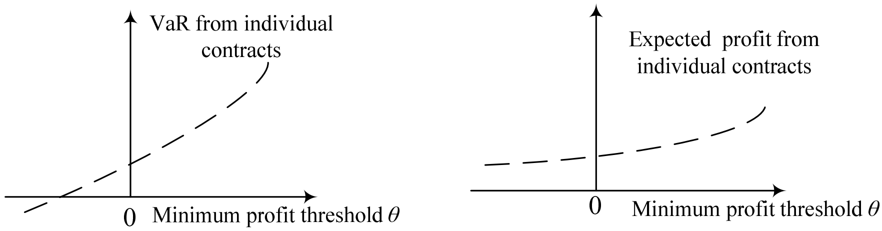
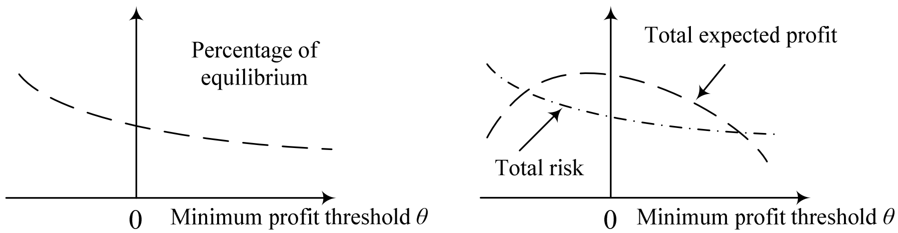
[1] For convenience purpose, let $\Delta\pi$ be the random variable that represent the supplier's incremental profit from a user.



(a) Adjusting "minimum profit threshold" θ affects "VaR" from individual contracts

(b) Adjusting "minimum profit threshold" θ affects "expected profit" from individual contracts

Fig. 5-4: Effect of minimum profit threshold θ on VaR and expected profit at individual contract level for the supplier



(a) Adjusting "minimum profit threshold" θ affects "percentage of equilibrium"

(b) Adjusting "minimum profit threshold" θ affects "total expected profit" and "total risk"

Fig. 5-5: Effect of minimum profit threshold θ on percentage of equilibrium; and expected profit and risk at corporate level for the supplier

Small sample effect: In the VaR computation, the nature of the distribution of users' preferences is assumed to be obtained from the "target point distribution estimation survey" (Section 5.2.1). It would be ideal if the survey were carried out among all the potential users of the value-added individual service. In reality, such practice is not feasible because of all kinds of constraints. A smaller group of people needs to be selected and the survey will be carried out among these people. Such a small sample introduces errors. The magnitude of the error is a function of the sample size and the homogeneity of the population. Thus, in different contexts, the sample-size needs to be carefully decided so that the error is within certain limits. There are several approaches. For example, one can specify the desired confidence level and determine the sample size that achieves that goal; or a Bayesian approach can be used where one can balance the sampling precision and the actual cost (Lenth, 2001). The determination of the sample size is outside the scope of this research.

Error estimation from the Monte Carlo method: It has been proved that under the normality assumption, the Monte Carlo method has an absolute error of estimate that decreases as $T^{-1/2}$; here, T is the number of runs (Holton, 2003). If we quadruple the number of runs by feeding a quadruple number of generated target points into the game computational model, we will halve the error. In reality, the number of runs is also constrained by the available computational resource.

5.2.3 Prototype implementation (II)

Based on the risk measurement methods provided in Sections 5.2.1 and 5.2.2, we extend the prototype implementation (Sections 4.6.) by adding the Monte Carlo simulation and the risk analysis functions to the statistical analysis part: see Fig. 5-6. The “distribution analysis” block analyzes the data from the “target point distribution estimation survey” and provides distribution characterization to the “user preferences randomization” block. The latter generates randomized user target points that are used in the Monte Carlo simulation. The “risk analysis” block computes the supplier’s expected profit, percentage of equilibrium, VaR and extreme VaR (see Section 5.3.1) from the data generated by the Monte Carlo simulation.

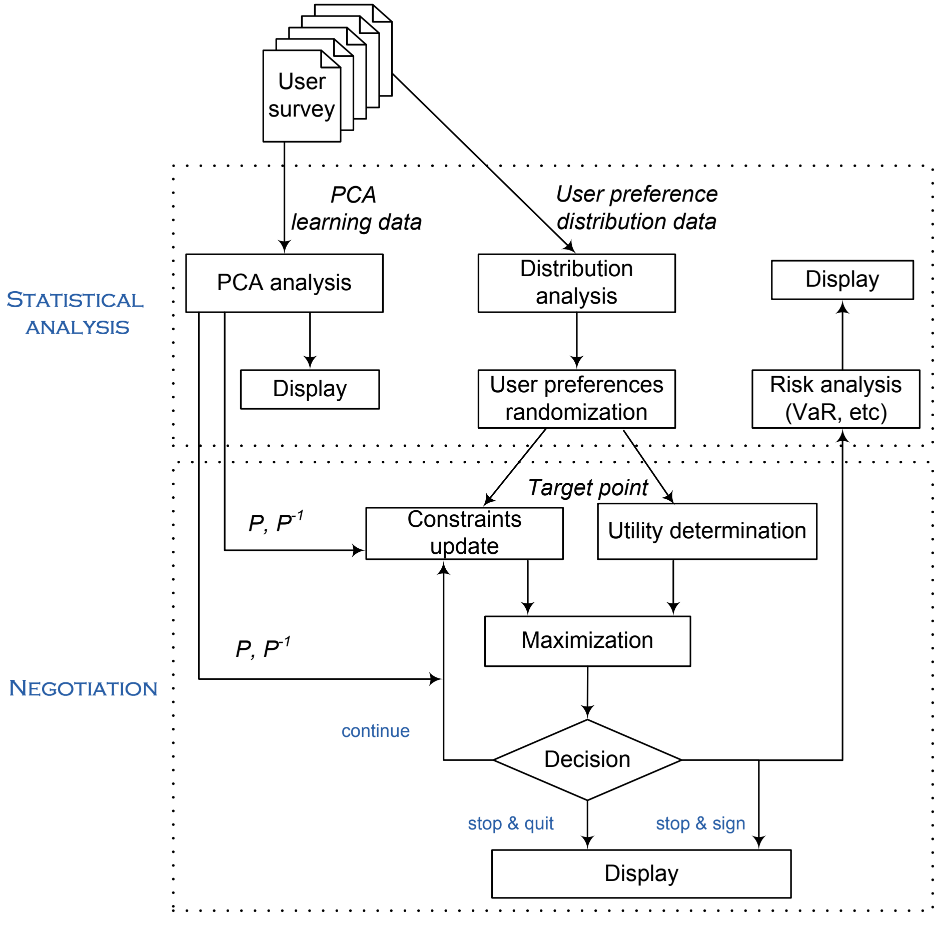


Fig. 5-6: Prototype implementation of the computational design (II)

Regarding the implementation details, the distribution analysis block uses the distribution fitting tools provided by Matlab. It is suggested to use other tools (e.g. SAS[1]) to perform a similar analysis, due to the limited number of available distributions of Matlab. We implemented the methods described in Step 2 of the Monte Carlo simulation in the user preference randomization block. In the risk analysis block, we used the block maximum method to calculate the extreme VaR.

5.2.4 Case: Operator's profit and risk from mSinging v2.0

Based on the mSinging v2.0 case developed in Section 4.8, we apply the Monte Carlo method described in Section 5.2.1 to estimate the supplier's profit and risk (VaR) at both individual contract level and corporate level, when he offers individual services to a population of potential subscribers assumed to exhibit homogeneity at survey level.

5.2.4.1 User preference characterization

The data used to obtain the user's target point (t^0) distribution come from the survey that we conducted amongst RSM students (see Section 4.8.2). Recall that out of the 511 valid answers, we randomly selected 150 results to perform the principle component analysis and picked the first 3 principle components as the reduced mapping coefficients *P*. The remaining 361 results were mapped from the 7-dimensional design space into the 3-dimensional perceptual space by multiplying by *P* (see also Fig. 5-2).

Fig. 5-7 shows the actual distribution of the 361 target points in the service perceptual space **Z**: most of the points cluster together but there are also outliers.

Let $Z^0 = (Z_1^0, Z_2^0, Z_3^0)$ be the multi-dimensional random variable of the students' target points in the service perceptual space. Z_1^0, Z_2^0, Z_3^0 are one-dimensional random variables that correspond to the students' goals expressed in terms of the 1st, 2nd and 3rd perceived attributes. We try to reduce the complexity of analysis by first analyzing Z_1^0, Z_2^0, Z_3^0 separately instead of Z^0.

The (marginal) distribution of Z_1^0, Z_2^0, Z_3^0 can be obtained by projecting the target points on each of the perceived attribute axes. Figures 5-8, 5-9, and 5-10 show the histograms of the 361 sample target points when projected on each of the perceived attributes. Clearly there are outliers in each histogram. The problem with the outliers is that they will affect the estimation of the distributions of Z_1^0, Z_2^0, Z_3^0 significantly. At this stage of the study, we will eliminate the outliers only to simplify the VaR calculation. The outliers will be treated in Section 5.3.

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[1] Statistical Analysis System is an integrated system of software packages of the SAS Institute that provides, among other functions, statistical and mathematical analyses.

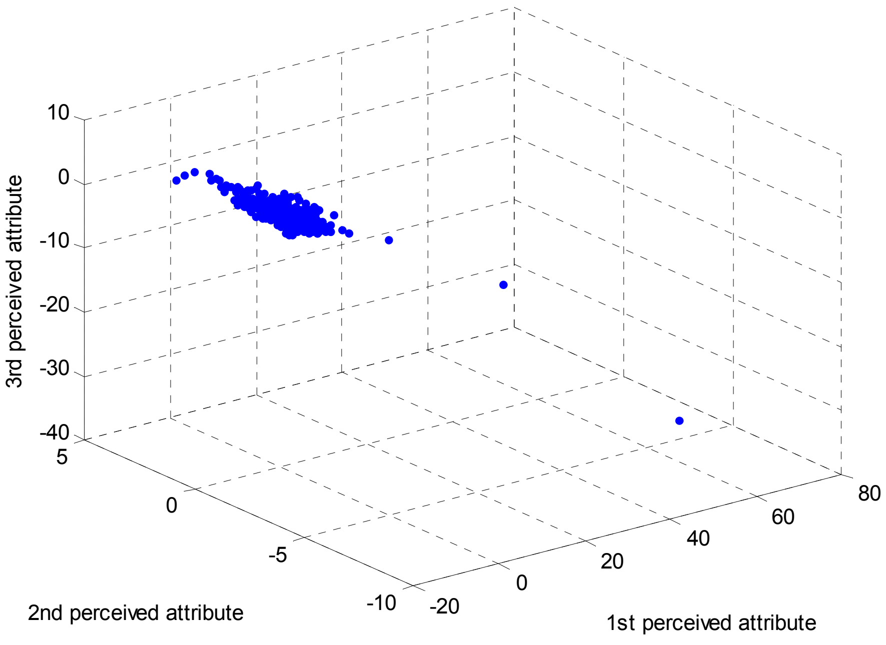


Fig. 5-7: Scatter plot of user target points in perceptual space from the survey described in Section 4.8.2, mSinging v2.0

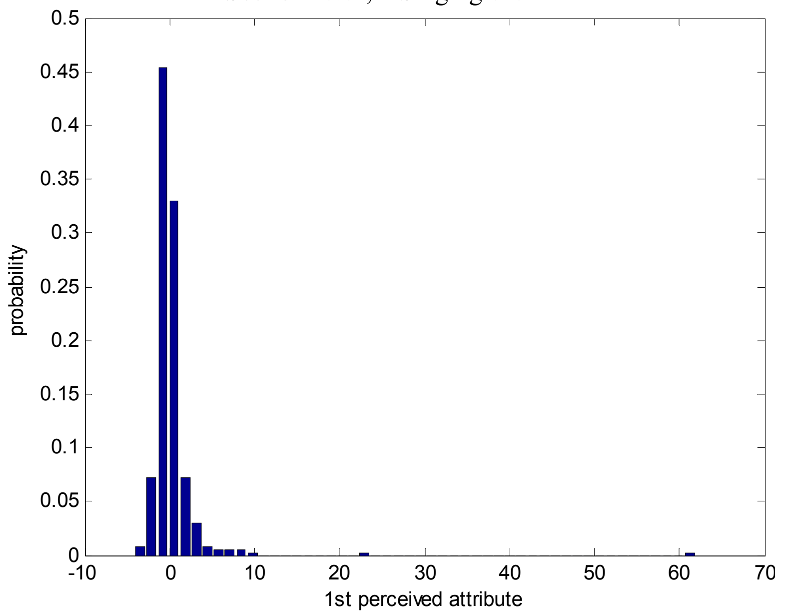


Fig. 5-8: Histogram of users' target points from the survey in Section 4.8.2 when projected on the 1st principle component

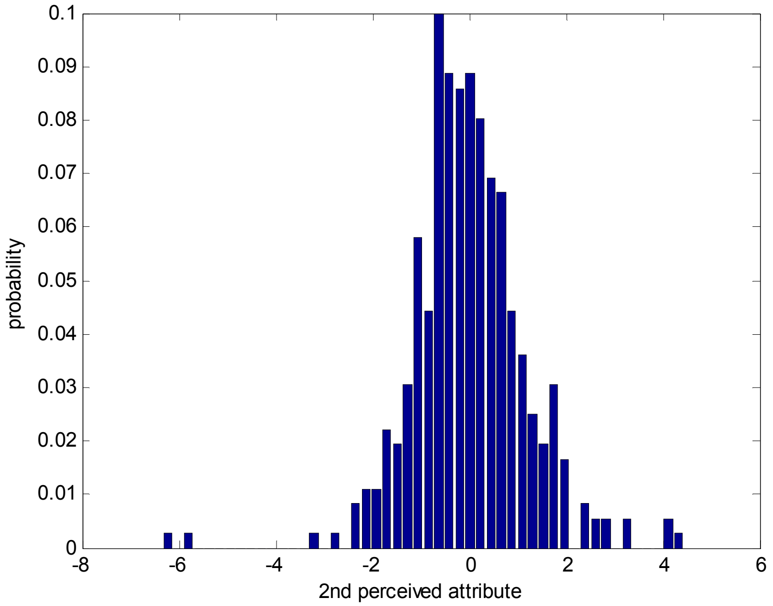


Fig. 5-9: Histogram of users' target points from the survey in Section 4.8.2 when projected on the 2nd principle component

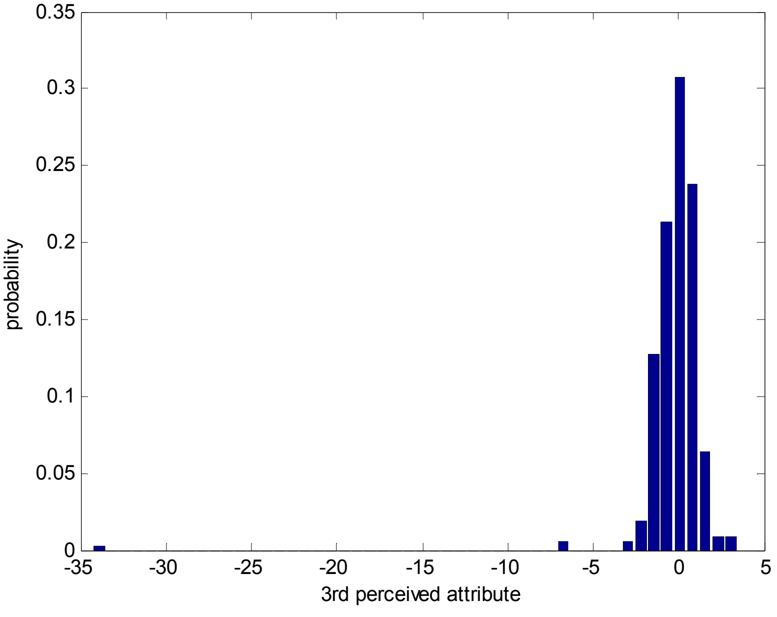


Fig. 5-10: Histogram of users' target points from the survey in Section 4.8.2 when projected on the 3rd principle component

Judging from the histograms, we conjecture that Z_1^0, Z_2^0, Z_3^0 may follow normal distributions when the extreme points are cut off. In order to validate this suggestion, we shall first discuss a procedure to identify outliers of each sample univariate distribution and then perform univariate normality tests respectively.

Cut-off values need to be determined for each univariate distribution. The minimum and maximum cutoff values can be used to separate outliers from the main data. The histograms and the descriptive statistics (see Table 5-1) show that Z_1^0 and Z_3^0 are highly skewed. In this case, using the mean and the standard deviation of the sample distribution to identify the outliers is not recommended because these two measures are sensitive to the outlying values. Instead, we use the median and inter-quartile range (IQR) to identify the outliers of the univariate distributions (Hoaglin, 1983). IQR was originally defined from Tukey's hinges (Hoaglin, 1983, p. 35), which can be approximated by quartiles. Let the 25% lower quartile be FL and the 75% upper quartile be FU, the inter-quartile range dF is defined as dF = FU - FL. The chosen cutoff values for outliers are FL – 1.5dF and FU + 1.5dF (see Fig. 5-11).

Table 5-1: Descriptive statistics of the user target point distributions, from the survey described in Section 4.8.2, mSinging v2.0

Distributions	Z_1^0	Z_2^0	Z_3^0
Skewness	10.7	(-0.1)	13.2
Number of outliers (out of 361 points)	29	12	8

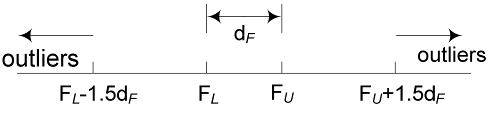


Fig. 5-11: The Inter-quartile range method to identify outliers of a univariate distribution

The numbers of outliers among the 361 user target points in each univariate distribution are listed in Table 5-1. There are overlaps among the identified outliers in the three distributions; the joint outliers in two or three distributions are identified and excluded. In total, 41 unique users from the 361 respondents are identified as outliers and are excluded from the data sample. We then run the Jarque-Bera test for the univariate normality of Z_1^0, Z_2^0, Z_3^0; the null hypothesis is that the sample data come from a normal distribution. At a significant level of 0.05, the null hypothesis cannot be rejected (the *p*-value for each distribution is p_1= 0.0660; p_2= 0.4097; p_3= 0.4315).

Given Z_1^0, Z_2^0, Z_3^0 are univariate normal distributions, it is natural to ask if their joint distribution Z^0 is a multivariate normal distribution. To verify this, we shall conduct a multivariate normality test. But before doing this, we need to identify the multivariate outliers. Unlike univariate outliers, which are data that are very far from the mean, multivariate outliers are data that have strange patterns. It is possible for a multivariate outlier not to be an outlier with regard to any one of the underlying univariate distributions (Jobson, 1992, p.150). A common method to identify multivariate outliers is to use the chi-square quantile-quantile (Q-Q) plot of the squared Mahalanobis distances of the sample data from the mean vector. As a rule of thumb, the multivariate outliers are those whose Mahalanobis distance exceed the chi square value with i (here i=3) degrees of freedom. Using this method, we cut out another 26 points.

We then conduct a multivariate normality test based on the (361-41-26 = 294) samples, measuring the multivariate skewness and kurtosis (Mardia, 1974). The null hypothesis is that the sample data follows a multi-normal distribution. At a significance level of 0.05, the null hypothesis cannot be rejected.

Thus the 294 sub-sample of the user target points can be characterized by a multivariate normal distribution, and its mean vector and covariance matrix can be estimated:

$\text{Mean}(Z^0) = [-0.2568 \quad -0.0149 \quad -0.0597]$	$\text{Cov}(Z^0) = \begin{bmatrix} 0.6630 & 0.0207 & 0.1139 \\ 0.0207 & 0.7153 & -0.0833 \\ 0.1139 & -0.0833 & 0.6562 \end{bmatrix}$

5.2.4.2 Effects of minimum profit threshold θ on supplier

Recall that in Section 5.2.2, we discussed how the setting of the "minimum profit threshold" θ may affect the percentage of equilibrium, the supplier's expected profit and VaR, both at individual contract level and at corporate level. We now carry out numerical computations based on the mSinging v2.0 developed in Section 4.8 using Monte Carlo simulation.

We compute six scenarios: the minimum profit threshold θ is set to be +2, 0, -2, -4, -6 and -8 respectively. In each scenario, we carry out 5000 runs of computation: each run is a negotiation between a user and the supplier. In addition to the supplier-related indices, we also obtain user-related data at group level from the Monte Carlo simulation.

Fig. 5-12 shows the distribution of the user's utility of successful negotiations (i.e. a contract is mutually agreed) when $\theta = 0$. The thin line in Fig. 5-12 represents the average utility of the users. When compared to the initial non-negotiable public service and tariff, the users achieve an average improvement of 163% in utility (closer to their wishes), while the supplier is 9% better-off in expected profit at individual contract level.

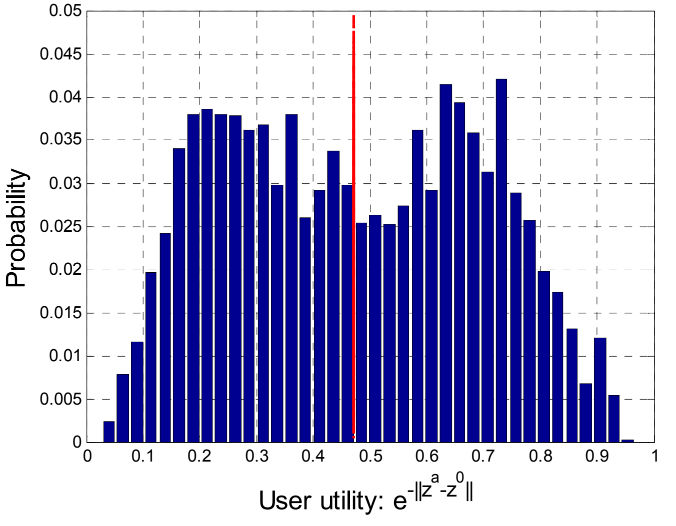


Fig. 5-12: User's utility distribution of successful negotiations when $\theta = 0$, mSinging v2.0

Fig. 5-13 shows the distribution of the supplier's profit from successful negotiations when $\theta = 0$, and the thin line represents the supplier's expected profit, 11.07: see also Table 5-2. Because θ is set to be 0, there is no negative profit in the figure.

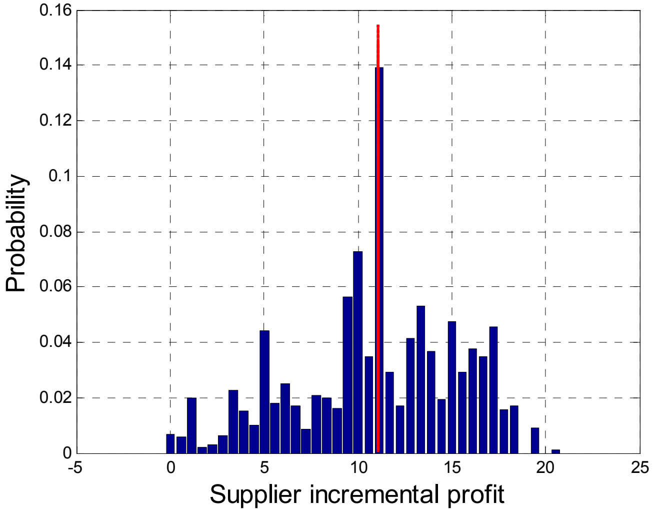


Fig. 5-13: Supplier's profit and loss distribution of successful negotiations when $\theta = 0$, mSinging v2.0

Fig. 5-14 shows the supplier's profit distribution when $\theta = -6$, and the thin line represents the supplier's expected profit, 10.17: see also Table 5-2. Compared to the scenario of

θ = 0, the supplier accepts small losses in the current scenario, which is shown in Fig. 5-14, and that also leads to a minor difference in the expected profit (10.17-11.07 = -0.9).

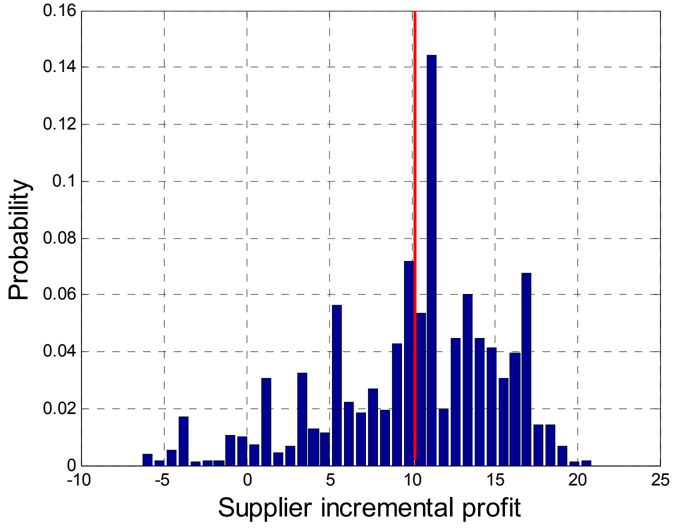


Fig. 5-14: Supplier's profit and loss distribution of successful negotiations when θ = -6, mSinging v2.0

The results of the different computational scenarios are summarized in Table 5-2. The total expected profit and the total risk is calculated by assuming the potential users of the mSinging service v2.0 (N) to be 10^4.

Table 5-2: Summary of Monte Carlo simulation results of mSinging v2.0

Equilibria statistics	***Supplier's minimum profit threshold θ***					
	-8	-6	-4	-2	0	+2
Percentage of equilibrium (%)	57.29	56.50	55.72	55.00	53.40	49.87
User expected utility	0.4794	0.4770	0.4742	0.4730	0.4719	0.4716
User avg. utility improvement (%)	167.37	166.03	164.47	163.80	163.18	163.02
Supplier expected incremental profit*	10.14	10.17	10.61	10.71	11.07	11.44
Supplier avg. profit improvement* (%)	0.21	0.51	4.85	5.84	9.40	13.06
VaR @ 95% confidence level*	0.03	0.03	0.94	1.35	3.61	4.33
Total expected profit for supplier (10^5)	5.81	5.74	5.91	5.89	5.91	5.70
Total risk supplier (10^5)	0.02	0.02	0.53	0.74	1.93	2.16

* at individual contract level

By decreasing the minimum profit threshold θ from +2 to -8, the percentage of equilibrium (rate of deals) increases by 7.42%; the users' expected utility increases by 1.66%. The disadvantage is that the supplier's expected utility (profit) at individual contract level decreases by 11.36%. The VaRs at 95% confidence level are all positive, which indicates that the supplier bears little risk of making a loss from an individual contract (n.b. it is possible to make a loss from an individual user when θ<0). The VaR is decreasing much faster than other parameters with θ. (see Table 5-2). The supplier's total expected profit increases by 2%; however, the total risk increases also by 99%.

Fig. 5-15 shows how the percentage of equilibrium (rate of deals) changes with the supplier's minimum profit threshold θ (= +2, 0, -2, -4, -6, -8) in the mSinging v2.0 case. Fig. 5-16 shows how the supplier's expected profit and VaR at individual contract level change with θ in the mSinging v2.0 case. Any suggestion of convergence is invalid as they are using different vertical axes. The percentage of equilibrium, the supplier's expected profit and VaR at individual contract level changes at different speeds; these lead to a non-linear total expected profit (assuming 10^4 potential users) curve and a non-linear total risk curve: see Fig. 5-17. Judging from Fig. 5-17, a θ that can lead to maximum total expected profit and at the same time has minimum risk does not exist. The supplier then must make a decision based on the computed curves and his own risk policy.

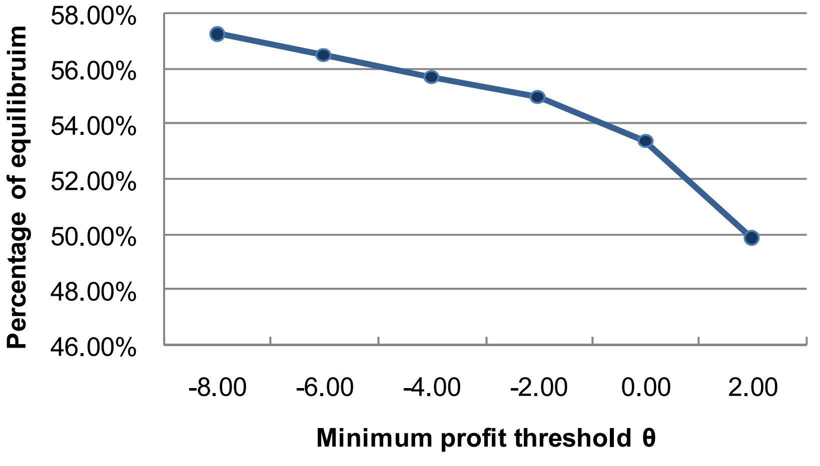


Fig. 5-15: Effect of minimum profit threshold θ on percentage of equilibrium, mSinging v2.0

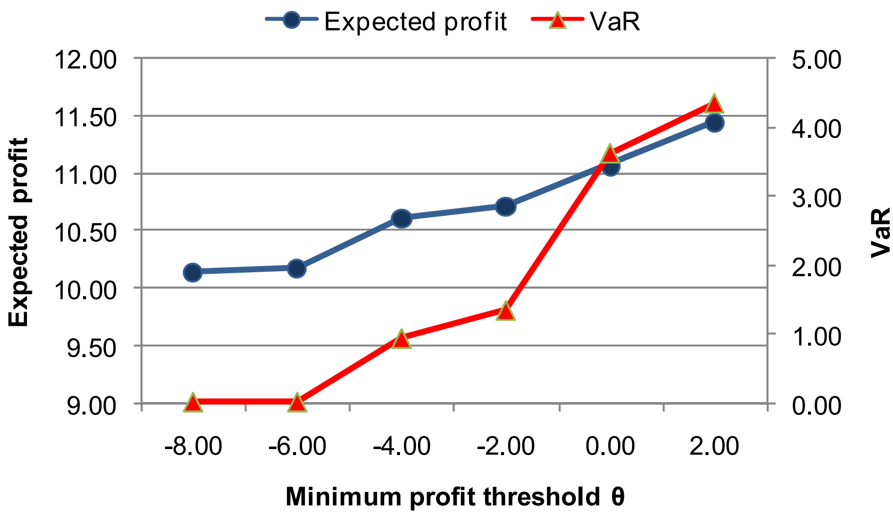


Fig. 5-16: Effect of minimum profit threshold θ on expected profit and VaR at individual contract level for the supplier, mSinging v2.0

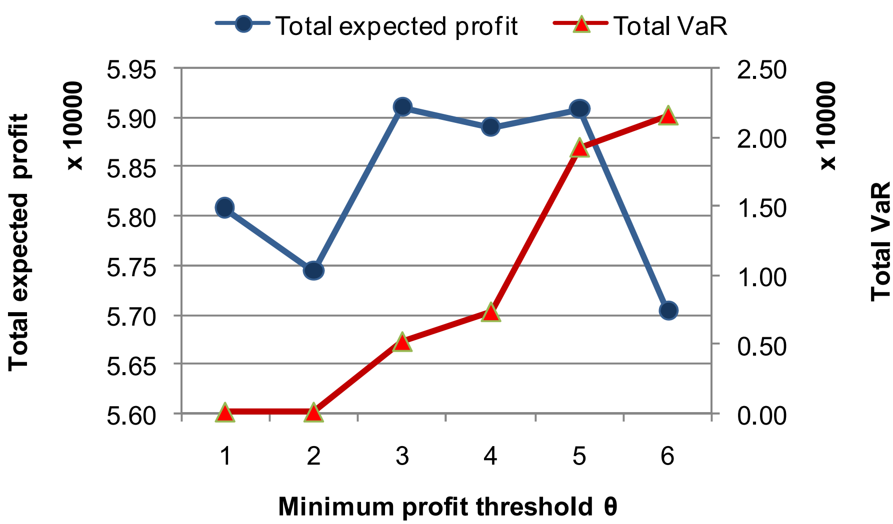


Fig. 5-17: Effect of minimum profit threshold θ on expected profit and VaR at corporate level for the supplier (assuming 10^4 potential users), mSinging v2.0

5.2.5 Case: Operator's profit and risk from individualized generic service bundles

Recall that in Section 4.9.5, we developed a case to evaluate the game negotiation algorithm designed for the individualization of a generic mobile service bundle. User demands were approximated based on the published service and tariff list from a real mobile operator. In this sub-section, we carry out a Monte Carlo simulation to compute the equilibria statistics of this case following the procedure described in Section 5.2.1.

Similar to Section 4.9.5, we set the subscriber base N to 10^6, which corresponds to a normal generic service user base, the number of sub-intervals to 5, and the number of runs to 10^4. For illustration purposes, we compute two scenarios, with the supplier's minimum profit threshold θ set to 0 and -5000 respectively. θ is a parameter that safeguards the supplier from making too much loss from an individual contract. The case $\theta = 0$ corresponds to a decision that no incremental loss is allowed in a negotiation. Besides, because of the supplier's expected profit level (see Table 5-3), the case of setting θ to -5000 represents actually allowing any incremental profit or loss; it also means that the supplier (implicitly) allows a user to propose a price to the service, although he would pay nothing for it. This scenario allows the supplier to achieve a maximum rate of deals (market share) at the expense of other business performance indicators, the values of which are shown in Table 5-3.

Table 5-3: Summary of Monte Carlo simulation results of generic mobile service bundle individualization (assuming a large user base N=10^6)

Equilibria statistics	***Supplier's minimum profit threshold θ***	
	-5000	0
Percentage of equilibrium/rate of deals (%)	93.19	57.50
User expected utility	0.82	0.84
User average utility improvement (%)	51	37
Supplier expected incremental profit*	38.66	90.60
Supplier average improvement in expected profit*(%)	49	142
VaR @ 95% confidence level*	-79.51	3.96
Total expected profit for supplier (10^7)	3.6	5.21
Total risk for supplier (10^7)	-7.41	0.228

* at individual contract level

For the users, setting θ to 0 allows them to achieve an average gain in utility of 37%; the average gain increases to 51% when θ is set to -5000. This difference between the improvements in average user utility can be explained by the fact that in the θ = -5000, more user-specific requests which were not addressed in the θ = 0 setting are now allowed. This is also reflected in the significantly increased rate of deals.

For the supplier, changing θ from 0 to -5000 significantly increases the rate of deals (market share), but this is at the expense of a much higher risk: VaR at 95% confidence level changes from 3.96 to -79.51 at individual contract level. The supplier's average improvement in expected profit at individual contract level decreases with θ. This is because lowering the value of θ allows the acceptance of requests that bring large losses.

5.3 Extreme value theory and its applications to individual services and tariffs

In the previous Section 5.2, there are extreme deviations from the median of a probability distribution (Fig. 5-8). We labeled them as outliers and ignored them in the computation. In this section, we introduce extreme value theory, which enables us to deal with these outliers. We first provide some examples in the context of individual services and tariffs where extreme value theory can be applied. We then introduce the block maximum method that enables us to carry out extreme value computation, and illustrate with a case based on the mSinging v2.0.

As defined in Section 5.2, the supplier's VaR is the lower quantile (usually the 1% or 5% quantiles) of the profit and loss distribution. Good estimates of VaR depend on an accurate model of the distribution. In Section 5.2.1, we based our estimation of VaR on the simulated profit and loss distribution of the supplier using the Monte Carlo method. The main advantage of the method is that we do not need to make distribution assumptions of the profit and loss data. The main drawback is that it is impossible to extrapolate beyond the sample. For example, in the generic service bundle case in Section 5.2.5, the scenario of setting θ to $-\infty$ could lead to the acceptance of extreme requests that have small probabilities (outliers) which may not be simulated by the Monte Carlo method. This leads to an underestimation of the risk.

In the Monte Carlo method used to calculate the supplier's VaR, an important step has been the characterization of the multi-dimensional user target point (z^0) distribution, which is derived from, for example, a survey of user goals in a specific individual service (Section5.2.1). There are often unusual and rare user demands, which show up as outliers in the survey data set (e.g. see Fig. 5-7). The existence of outliers reflects the non-homogeneous nature of service and quality of service preferences amongst users. In the previous calculation in Section 5.2.4, these extreme requests were, however, eliminated to ease the characterization by fitting the data to well-known distributions. This approach was to some extent justified, as the percentage of outliers in the survey was around 15% and also θ was set in such a way as to eliminate the extreme requests. These extreme requests may cause large losses (but maybe also revenues) to the supplier when the minimum profit threshold θ is set to $-\infty$. How can we model the extreme user requests?

Other problems leading to extreme statistics that we could possibly encounter in the context of individual services and tariffs are:

- How the supplier decides what amount of content to acquire when designing individual services to be offered to a potential user group (e.g. in terms of number of songs, as in the case in Section 4.8). Each user has his own needs; but because of some homogeneity of the users, their demands will have a significant overlap. Thus the amount of content needed can be significantly reduced. There are, however, users who ask for “rare content” which is not normally acquired by the supplier. The supplier then needs to make sure that the probability that a user’s uncommon content request cannot be satisfied lies below a certain level.

- How to handle the uncertainties derived from the supplier’s service provisioning cost model. The model (see Section 4.4) was built upon an aggregate view of the infrastructure in stable conditions without failures or congestions: in this way it is an approximation. Missing data, extreme traffic peaks or valleys, failures or congestions represent real extremes which are not captured, but still affect the provisioning model as well as its use in individual service tariffing.

All the problems above are caused by rare events which may have considerable impacts on the subjects being studied. Extreme value theory (EVT) can be a useful tool if we assume these rare events do follow a certain distribution. Just as the central limit theorem deals with the sum of many independent and identically distributed (i.i.d.) variables, EVT concerns itself with the extreme deviations from the medians of probability distributions.

The first problem with regard to estimating the extreme VaR when θ is set to $-\infty$, and the third problem with regard to estimating needed content, are univariate extreme problems. The second problem with regard to characterizing extreme user target point (z^0) distribution, and the fourth problem with regard to estimating the extremes in the cost and revenue model, may involve multivariate extreme value theory. It would be ideal that we could analyze the first two problems together because they are closely related. However, for practical matters, we decided to focus on the univariate extremes in this research and leave the multivariate extremes to further research. Specifically, we focus on the first problem, as the answers to it have a direct impact on the supplier’s decision making processes relating to offering individual services.

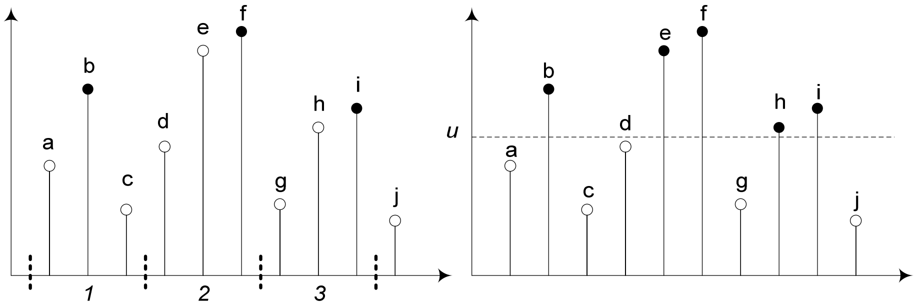
5.3.1 Block maxima method to analyze extreme values

Extreme value theory was first used in hydrology. It became widely used in finance, insurance, engineering, and other areas in the 1960s. Currently, there are two systematic statistical methods in dealing with the extremes of real data: the block maxima (BM) method and the peak over threshold (POT) method (McNeil et al., 2005).

The BM method divides the data into blocks. Each block contains the same or a similar number of observations. In certain applications, there are natural ways of dividing the data. For example, in hydrology, the daily measurements of water level are divided into yearly blocks. In financial applications, the stock market returns are divided into yearly or quarterly blocks. The BM method only retains the maxima/minima in each of the sub-blocks.

The POT method focuses on the observations that exceed a given threshold, which are also called “exceedances”.

Fig. 5-18 gives a simple illustration of the extreme data selection processes by the two methods; the selected observations are also marked with black dots. Given the same set of data, the extreme observations selected by the BM method are {b, f, i}, while the observations selected by the POT method are {b, e, f, h, i}.



(a) block maxima (BM) method (b) peak over threshold (POT) method

Fig. 5-18: Extreme data selection by the block maxima and the peak over threshold methods

In choosing the appropriate method to be applied in the individual tariffs context, our main concern is the assumptions that each method requires. The POT method requires that (Embrechts et. al 1997, p. 366):

1. The exceedances follow a homogeneous Poisson process over time;
2. The excess amounts over threshold have a generalized Pareto distribution;
3. The excess amounts over the threshold are i.i.d and independent of exceedance times.

The BM method only assumes that the maxima/minima are i.i.d (and this assumption can also be dropped: see Gencay (2003)). This weaker assumption led us to select the BM method in this specific research because the first and third assumptions in the POT method do not hold, as dynamics are not studied in this research.

5.3.1.1 Generalized extreme value distribution and block maximum method

The BM method is based on the theorem of Fisher and Tippett (1928), and on the theorem of Gnedenko (1943): "Divide the data into j blocks of size k, let the block maximum of the ith block be M_{ki}; the block maxima $M_k = [M_{k1}, \dots M_{kj}]$. Let X_k be a sequence of i.i.d random variables. If there exist real constants c_k, d_k, where $c_k > 0$, and some non-degenerating limiting distribution functions H such that the normalized $(M_k - d_k) / c_k$ converge to H; then H must be a generalized extreme value (GEV) distribution, denoted as H_ξ .

$$H_{\xi}(x) = \begin{cases} \exp(-(1+\xi x)^{-1/\xi}) & 1+\xi x > 0, \quad \xi \neq 0 \\ \exp(-e^{-x}) & x \in R, \quad \xi = 0 \end{cases} \tag{5-5}$$

The parameter ξ is called the shape parameter of the GEV distribution." When $\xi > 0$, the distribution is a Fréchet distribution; when $\xi = 0$, it is a Gumbel distribution; when $\xi < 0$, it is a Weibull distribution. Fig. 5-19 shows the shapes of three probability density functions of H_ξ when $\xi = -1$ / 0/ 1.

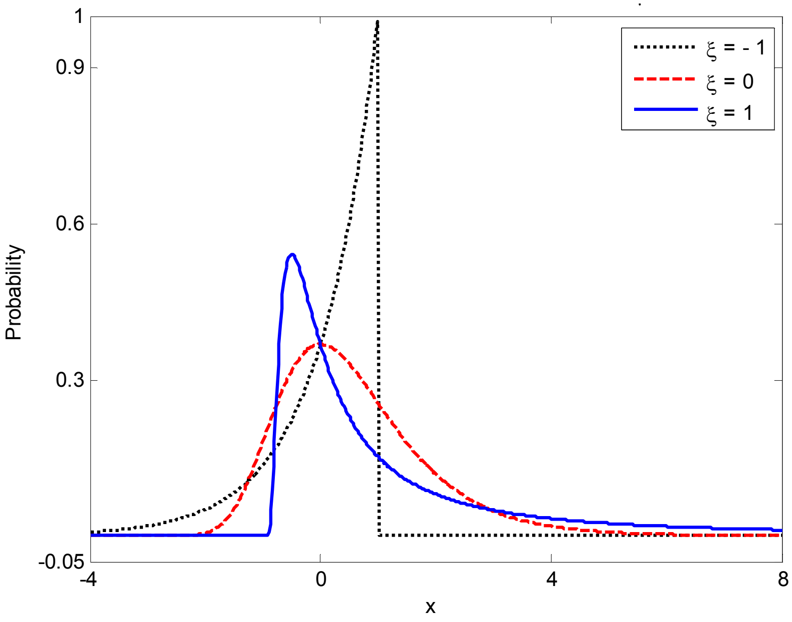


Fig. 5-19: The shapes of the probability density functions of generalized extreme value distributions (GEV) for different values of the shape parameter ξ

For well-known underlying distributions, their GEV limit can be obtained by choosing appropriate normalizing sequences c_k and d_k. For example, if the underlying data distribution is an exponential distribution with distribution function $F(x) = 1- ce^{(-\gamma x)}$ for c, $\gamma > 0$ and $x \geq 0$, then by choosing $c_k = 1/\gamma$ and $d_k = \ln(ck)/\gamma$, we can obtain the limiting distribution of maxima as $\exp(-e^{-x})$, $x \in R$. This distribution of maxima is called the Gumbel distribution (see Embrechts et. al (1997) for more details). This method can be useful when the extreme observations are few, while at the same time we can identify the underlying distribution from the data.

For unknown underlying distributions, we do not know the normalization constants c_k and d_k, and we need to use the three-parameter specification of GEV $H_{\xi,\mu,\sigma}(x)$:

$$H_{\xi,\mu,\sigma}(x) = H_{\xi}(\frac{x-\mu}{\sigma}) \text{ , where } \begin{cases} x > \mu - \frac{\sigma}{\xi} & \xi > 0 \\ x \in R & \xi = 0 \\ x < \mu - \frac{\sigma}{\xi} & \xi < 0 \end{cases} \qquad (5\text{-}6)$$

μ and σ are the location parameter and the scaling parameter respectively (Embrechts et. al 1997, p. 294).

The use of BM method involves several steps:

Step 1: Generate the block maxima (M_k), verify if M_k are i.i.d

Let the underlying data be Y_i, divide the data into j blocks of size k. The block maxima vector is $M_k = [M_{k1}, \ldots M_{kj}]$. Verify if M_k is independent and identically distributed. As mentioned before, in certain applications there are natural ways to divide the data. In other cases, the block size k must be carefully selected. On one hand, a large k will give a more accurate approximation of the extreme distribution and low bias; it will also lead to a lesser number of block maxima and therefore high variance in the estimation. On the other hand, a small k may take in data that are not large enough to be considered as true extremes, which will lead to skewed analyses; at the same time the higher number of block maxima will lead to a low variance in the parameter estimation. In practice, the block size k is set to be quite large, so even if there are dependences between the data within a block, the block maxima can still be taken as independent (McNeil et al., 2005).

Step 2: Parameter estimation ($\hat{\xi}, \hat{\mu}, \hat{\sigma}$)

The parameters can be estimated by fitting the GEV distribution to the data vector M_k. We use the maximum likelihood estimation[1] (MLE). Let L be the log-likelihood estimator of the GEV distribution $H_{\xi,\mu,\sigma}(x)$ in Equation (5-6), which can be written as (McNeil et al., 2005, p. 272):

$$L(\xi,\mu,\sigma \mid M_k) = \begin{cases} -j\ln\sigma - (1+\frac{1}{\xi})\sum_{i=1}^{j}\ln(1+\xi\frac{M_{ki}-\mu}{\sigma}) - \sum_{i=1}^{j}(1+\xi\frac{M_{ki}-\mu}{\sigma})^{-1/\xi} & \xi \neq 0 \\ -j\ln\sigma - \sum_{i=1}^{j}\exp(-\frac{M_{ki}-\mu}{\sigma}) - \sum_{i=1}^{j}\frac{M_{ki}-\mu}{\sigma} & \xi = 0 \end{cases} \qquad (5\text{-}7)$$

We maximize L subject to the constraints $\sigma > 0$ and $1+ \xi (M_{ki} - \mu) / \sigma > 0$ (i.e. the constraints from the logarithm). Differentiating L with respect to ξ, μ, σ yields the

[1] For the alternative methods see Embrechts et. al (1997, p 321-323)

likelihood equations with the estimates $\hat{\xi}, \hat{\mu}, \hat{\sigma}$ as solutions. But often there is no explicit solution to the likelihood equations (see Embrechts et. al, 1997, p. 318). Thus the solution is found out by numerical procedures. Furthermore, Smith (1985) showed that the consistence and asymptotic efficiency properties of the MLE hold when $\xi > -1/2$. Let the MLE estimated shape/location/scaling parameters be $\hat{\xi}, \hat{\mu}, \hat{\sigma}$.

Step 3: Return level ($R_{k,t}$) and return period ($t_{k,u}$) estimation

Given H, the true distribution of the *k*-block maximum, the *t* *k*-block return level $R_{k,t}$ is defined as the (1-1/*t*)-th quantile of H (see Equation 5-8). The *t* *k*-block return level can be interpreted as the level that is exceeded in one out of every *t* *k*-blocks on average.

$$\hat{R}_{k,t} = H^{-1}{}_{\hat{\xi},\hat{\mu},\hat{\sigma}}(1-\frac{1}{t}) = \begin{cases} \hat{\mu} + \frac{\hat{\sigma}}{\hat{\xi}}((-\ln(1-\frac{1}{t}))^{-\hat{\xi}} - 1) & \hat{\xi} \neq 0 \\ \hat{\mu} - \hat{\sigma}\ln(-\ln(1-\frac{1}{t})) & \hat{\xi} = 0 \end{cases} \quad (5\text{-}8)$$

For example, if the distribution under study is the right tail of a profit and loss distribution; let $k=50$, $t = 30$, if the return level $R_{50,30} = a$, this means that the expected profit from a randomly selected individual user will exceed *a* once every 1500 users.

Given the true distribution of *k*-block maxima H, the return period of the event $\{M_k > u\}$ is defined as $t_{k,u} = 1 / (1 - H(u))$. This means that in every $t_{k,u}$ *k*-blocks we can expect an observation in a single block that exceeds level *u*.

For example, if H is the right tail distribution of supplier's profit and loss; let $k=50$, $u=100$, if the return period $t_{50,100} = b$, this means that we can expect to observe the profit from an individual user to exceed the level of 100 every $50\times b$ users.

Step 4: Quantile estimation of the underlying distribution

With the estimated parameters $\hat{\xi}, \hat{\mu}, \hat{\sigma}$ from Step 2, the quantile for the *k*-block size maxima can be calculated. But the calculated quantile is not the quantile of the underlying data. The quantile of the underlying data can be approximated by the following method (Longin, 2000). Given the underlying data Y_i and the block maxima M_k, and let q_α^M be the *α-th* quantile of the block maxima M_k, if the Y_i are independent, then we have:

$$p(M_k \leq q_\alpha^M) = p^k(Y_i \leq q_\alpha^M) \quad (5\text{-}9)$$

$$p(M_k \le q_\alpha^M) = H_\xi(\frac{q_\alpha^M - \mu}{\sigma}) = \begin{cases} \exp(-(1+\xi\frac{q_\alpha^M - \mu}{\sigma})^{-1/\xi}) & \xi \ne 0 \\ \exp(-\exp(-\frac{q_\alpha^M - \mu}{\sigma})) & \xi = 0 \end{cases} \quad (5\text{-}10)$$

Given Equations (5-9) and (5-10), we have:

$$q_\alpha^M = \begin{cases} \sigma\frac{[-\ln(p^k)]^{-\xi} - 1}{\xi} + \mu & \xi \ne 0 \\ (-\ln(-\ln(p^k))\sigma + \mu & \xi = 0 \end{cases} \quad (5\text{-}11)$$

Thus the *p-th* quantile of the underlying distribution can be estimated by Equation (5-11), which is actually the *α-th* quantile of the block maxima M_k. Equation (5-11) can also be used to estimate the extreme profit from outlying users.

For example, if we have 5000 data samples of the underlying distribution of the supplier's profit and loss; given the estimated parameters $\hat{\xi}, \hat{\mu}, \hat{\sigma}$ of the distribution of the maxima, we can calculate the 0.9999^{-th} and the 0.99999^{th} quantile of the underlying distribution and we will obtain different results; while the method based on the fractional part of the empirical data will produce the same result for the 0.9999^{th} and the 0.99999^{th} quantile.

5.3.1.2 Extreme VaR

The above analysis concerns the limiting distribution of block maxima. However, in some application areas, such as finance and insurance, losses are the main concern and the analysis needs to focus on the minima. The above analysis can be applied to the block minima by assuming that the limiting behavior of the minima has the following property:

$$\min(X_1,\ldots X_k) = -\max(-X_1,\ldots,-X_k)$$

If $H_\xi(x)$ is the limiting type of distribution for maxima, then $(1 - H_\xi(-x))$ is the limiting type of distribution of minima (McNeil et al., 2005).

Extreme VaR

VaR is defined as the lower quantile of the profit and loss distribution (Section 5.2). In finance and insurance applications where extreme VaR is used, the concern is over losses and therefore the computation focuses on the minima. In the context of individual tariffs, it is possible that the 95% confidence level VaR has a positive value (see Sections 5.2.1 and 5.2.4). But when considering the extreme situations (e.g. remove "minimum profit threshold" θ from the supplier's decision rule in the mSinging case), we must consider losses. Therefore the computation of the extreme VaR from individual services focuses on fitting the GEV distribution to the negative values (losses) from the individual contracts.

Given the underlying data $B_i < 0$ to be analyzed, we analyze the negated values of these underlying data $-B_i$ (which are then positive). Divide the data into j blocks of size k; the block maxima vector is $M_k = [M_{k1}, \ldots, M_{kj}]$ and verify if M_k is i.i.d. We then fit the GEV distribution from Equation (5-6) to M_k and obtain the parameters $\hat{\xi}, \hat{\mu}, \hat{\sigma}$ by the procedure in the above Section 5.3.1.1. Let q_α^M be the *α-th* quantile of the block minima.

$$p(-M_k \le q_\alpha^M) = p(M_k \ge -q_\alpha^M) = 1 - p(M_k \le -q_\alpha^M)$$

Given B_i are independent, then we have

$$p(M_k \le -q_\alpha^M) = p^k(-B_i \le -q_\alpha^M)$$

Therefore,

$$p(-M_k \le q_\alpha^M) = 1 - p^k(-B_i \le -q_\alpha^M) = 1 - p^k(B_i \ge q_\alpha^M) = 1 - (1 - p(B_i \le q_\alpha^M))^k$$

Thus

$$p(M_k \le -q_\alpha^M) = (1-p)^k$$

$$p(M_k \le -q_\alpha^M) = H_\xi\left(\frac{-q_\alpha^M - \mu}{\sigma}\right)$$

Given the Equation (5-6), we have

$$q_\alpha^M = \begin{cases} -\left[\dfrac{\sigma((-\ln(1-p)^k)^{-\xi} - 1)}{\xi} + \mu\right] & \xi \ne 0 \\ \sigma(\ln(-\ln(1-p)^k) - \mu & \xi = 0 \end{cases} \qquad (5\text{-}11)$$

Thus the *p-th* quantile of the underlying loss data can be estimated by (5-11), which is the VaR of the underlying data B_i by the definition in Section 5.2. An example of extreme VaR calculation will be given in the next Section.

5.3.2 Case analysis: Operator's extreme VaR at individual contract level of mSinging v2.0

In the mSinging case in Section 5.2.4, we calculated the supplier's expected profit and VaR at individual contract level under different scenarios when the minimum profit threshold θ changes from +2 to -8. In this section, we set the θ to be -500 (<<-8) to approximate the scenario when θ is set to - ∞ in the supplier's decision criteria. Note that the inputs (i.e. the randomized user target points) follow the same multivariate normal distribution that we characterized in Section 5.2.4.1.

The supplier's equilibria statistics (θ = -500) are shown in Table 5-4. Compared to the other scenarios where θ= 2, 0, -2, -4, -6, -8 (Section 5.2.4), the percentage of equilibrium shows a considerable increase, but not as significant as that in the generic service bundle case when θ was set to be very low (Section 5.2.5). This could be explained by the loss control function of θ in the negotiation. In the generic service bundle case, cost-related constraints are the main constraints in the negotiation (see Section 4.9), thus changing θ would have a considerable impact on the negotiation outcome. In the value-added mSinging case, cost constraints are among many other service-specific constraints in the negotiation. Thus in the mSinging case, changing merely the value of θ would not lead to a significant change in the rate of deals.

The VaR at 95% confidence level is negative, which means that the supplier may bear loss from a randomly selected individual contract. The total expected profit is even higher than the scenario where θ =-8, but this is at the expense of higher total risks.

Table 5-4: Supplier's equilibria statistics when minimum profit threshold θ = -500, mSinging v2.0

Equilibria statistics	***θ = -500***
Percentage of equilibrium/rate of deals (%)	62.85
User expected utility	0.4812
User average utility improvement (%)	168.43
Supplier expected incremental profit*	9.40
Supplier average profit improvement* (%)	-7.1
VaR @ 95% confidence level*	-4.08
Total expected profit for supplier (10^5)	5.91
Total risk for supplier (10^5)	-2.56

*at individual contract level

Fig. 5-20 shows the supplier's profit and loss distribution of successful negotiations. There is a long tail on the left side of the zero loss line. The tail represents losses from individual contracts and is formed by users who have low willingness to pay.

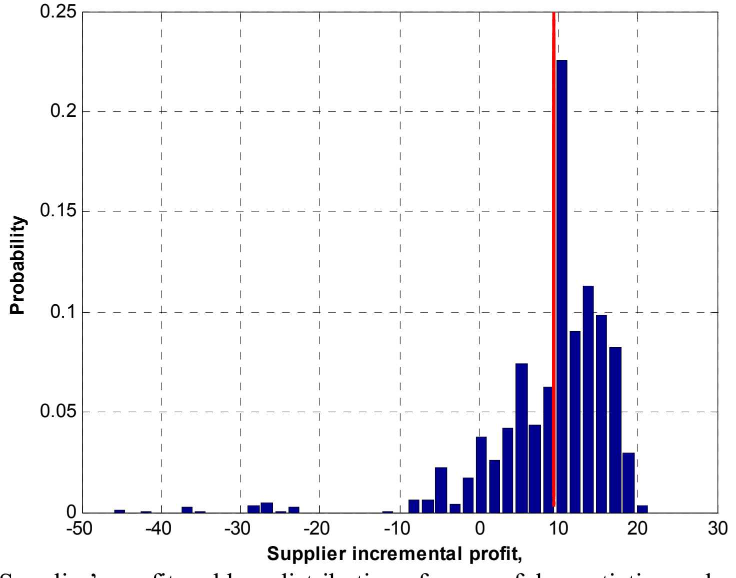


Fig. 5-20: Supplier's profit and loss distribution of successful negotiations when θ = -500, mSinging v2.0

Dividing the data into blocks

The number of successful negotiations is 2852. We divide the users into blocks: each block has the same or similar total revenue from the users. This revenue is the sum of all individual tariffs paid by users belonging to that block. Thus the number of users differs in each block: the block with higher user revenues has fewer users; the block with low user revenues has more users.

The profit and loss distribution is generated based on the Monte Carlo method. The inputs to the Monet Carlo simulation are the randomized user goals following the multivariate normal distribution characterized in Section 5.2.4.1; they are assumed to be independent. Therefore the outputs (i.e. profits from individual contracts), after a deterministic non-linear transformation, are also independent. Furthermore, because the block minima are drawn from the same underlying profit and loss distribution, we can assume that these minima have the same probability distribution. Thus the basic assumption of the BM method that the block minima must be i.i.d is assumed to be met.

Analysis of the extreme loss situation

We analyze the extreme loss situation which corresponds to the left tail (minima) of the supplier's profit and loss distribution:

1.) Given a total revenue volume per block of 20,000, the data is divided into 28 sub-blocks, with block size ranging from 103 to 109.
2.) Fitting the GEV distribution to the negated minima, we obtain $\hat{\xi}$=-0.324 $\hat{\mu}$= 15.01, $\hat{\sigma}$=36.44. The fitted distribution is a Weibull distribution.
3.) Return level $R_{100,\,5}$ = 54.27. This means that the supplier can expect that the loss from an individual contract will be more than (-54.27) once every 500 subscribers.
4.) Return period $t_{100,20}$= 1.08. This means that the supplier can expect the loss from an individual contract to exceed (-20) once every 108 subscribers.
5.) The extreme VaR corresponding to different values of the *p-th* quantile are:

p	*0.05*	*0.01*	*0.005*	*0.001*	*0.0001*
VaR	-4.08	-36.36	-45.73	-60.79	-72.34

The negative values of VaR represent losses.

The above extreme VaR calculations provide estimations of the risks at individual contract level when the minimum profit threshold is actually removed (θ = -500). Although the probabilities of these extreme losses are low, because of their magnitude, the damage may still be significant. The supplier must then make a decision on whether he wants to achieve a higher market share (high percentage of equilibrium, see above calculation) with higher risks, or the opposite when setting the value of θ.

5.4 Summary

In order to have a robust business, the supplier first needs to have positive expected profits from the individual service contracts. Second, the probability of not reaching the expected profit should be small and less than a given threshold. Third, there are a sufficient number of subscribers from the potential user population. This chapter helps the supplier of individual services and tariffs with the estimations of these essential business performance indicators with emphasis on risks, so that the supplier can adjust the parameters in his constraints and decision rules to achieve a favorable situation when negotiating with a group of users.

Section 5.2 introduced the concept of Value at Risk as a risk measurement tool under usual market conditions. We presented a systematic method to compute the VaR for the supplier at the individual contract level by using Monte Carlo simulation. This includes methods to characterize and simulate users' service demands that are used as inputs to the Monte Carlo simulation. The expected profit at individual contract level and the rate of deals can also be estimated using the Monte Carlo method. Based on the above computation results, an assumed number of potential subscribers, and under a primitive assumption of independence, the total expected profit from potential individual service subscribers, and the corresponding total risk, can be estimated.

Section 5.3 introduced extreme value theory (EVT) as a risk measurement tool under extreme market conditions. Out of the many potential applications of EVT, we described a method to calculate extreme VaR, which has a direct impact on the supplier's decision making processes when offering individual services and tariffs.

The cases in Sections 5.2 and 5.3 were based on the mSinging case and the generic mobile service bundle case developed in Chapter 4. In the mSinging case, when the value of one of the supplier's key parameters, "minimum profit threshold" θ, is set to 0, the users achieve an average improvement of 163% in utility through individual services and tariffs when compared to the initial non-negotiable public service and tariff; while the supplier is 9% better-off in profit at individual contract level. Adjusting the value of θ can lead to different total expected profits and total risks at corporate level for the supplier. For the extreme situation where θ is set to -500 (as an approximation to $-\infty$), the supplier can achieve maximum market share and a relatively high expected corporate profit, but this is at the expense of a high risk. In the mSinging case, a setting that has a maximum total expected profit and a minimum risk does not exist. The supplier then must make a decision based on the computed curves and his own profit-risk policy.

In the generic service bundle case, when θ is set to 0, the user achieves on average a gain of 37% in utility while the supplier achieves a gain of 142% in profit at individual contract level. When θ is set to -5000 (as an approximation to $-\infty$), the users achieve an average gain of 51%, while the supplier achieves a gain of 49% in profit at individual contract level. Changing θ from 0 to -5000 significantly increased the market share: from 57% to 93%. But it is at the expense of a higher risk at individual level: the calculated VaR at individual contract level are 3.9 and -79 for the two scenarios respectively.

Now that we have developed a complete computational design for individual services and tariffs, under a firm-supplied setting, in the next chapter we will broaden our research into community-based individual services and tariffs.

Chapter 6
Community-based individual services and tariffs

6.1 Introduction

In Chapters 4 and 5, we focused on firm-supplied individual services and tariffs. We introduced a computational design that automates the service individualization and tariff negotiation, provided performance measurements that assist the supplier to make decisions, and assessed the design with numerical cases.

In this chapter, we turn our attention to the setting of communities as suppliers. Communities are already playing a role today in wireless and mobile service provisioning (e.g. the FON WiFi community[1]). And, as we will argue in this chapter that community will play a more important role in the near future, it is necessary to investigate the community-supplied individual mobile services. Compared to firms, communities have more diverse goals and more social concerns to deal with. To address these aspects, much more complicated behavioral models (including utility functions, constraints and decision rules) need to be constructed, which are outside the scope of this research. As a first attempt to study community-supplied individual services and tariffs, in this chapter we put our emphasis on establishing a business model, and on analyzing the feasibility and benefits to the users and the suppliers.

The chapter[2] is structured as follows: Section 6.2 defines and characterizes community-based individual services and tariffs and proposes a business model, followed by a supply and demand analysis; Section 6.3 demonstrates, through two case studies of communities at different development levels, that community-based individual services and tariffs can address both the affordability and the sustainability issues: they are beneficial to both the users and suppliers. Section 6.4 concludes the chapter. The linkage between the content at section level is shown in the Table below.

6.2	***Community-based individual services and tariffs***	
	Based on	Section 1.2 on concept and definition of individual services and tariffs
	Results used in	Section 6.3 on case evaluation of the business model
6.3	***Case analysis in Chinese context***	
	Based on	Section 6.2 on the business model design
	Results used in	Chapter 8, conclusion and further research issues

6.2 Community-based individual services and tariffs

Although mobile communication services are nowadays predominantly provided by firms, communities are increasingly emerging as an alternative provider. In the following

1 "FON" is a company that runs a system of shared wireless networks (see www.fon.com)
2 This chapter is primarily based on Chen & Pau (2008)

paragraphs we provide a vision of the mobile services in the near future which are enabled by existing and developing technologies. This provides the basis for the definition and characterization of community-based individual services and tariffs.

About ten or twenty years from now on, advanced personal communication technologies will enable people to stay connected any time, anywhere, with access network alternatives. Users' devices will seamlessly roam between PAN, WLAN, WAN, fuelled by new services yet unknown (Frattasi, Fathi, Fitzek, Prasad, & Katz, 2006). With a high penetration rate of wireless devices in most part of a country, mobile services will be provided quite differently from now.

While connectivity is the most cherished property, as in the year 2000 (Odlyzko, 2001), the key differentiating values of mobile services in the 2030s will be totally different. Through a combination of a large number of users, technology improvements, and operator productivity gains, the pure transport and access tariffs for wireless and mobile will plummet to very low values. Content-based service will generate certain revenue. Content exists in two variants:

1. "static", from data warehouses with only periodic modifications (e.g. Wikipedia, YouTube, Flickr etc.);
2. "dynamic", from real-time information sensors and other sources, including user-originated content (e.g. weather radar map, tidal heights, etc).

By profiling and data mining, besides individual selections, service providers will know in real time much more about users than they do now. However, in an age with information "overload", static content has only low commercial value; higher commercial value content demands copyright licenses negotiated with the creators, or information access provisions. Advertisements will generate some commission revenue for service providers, but it will probably not be sufficient to support a whole mobile communication industry living from the "law of large numbers" and from very low tariffs.

Mirroring the early trend in video/broadcasting industries for dynamic content (Huuskonen, 2006), the relative share of the intellectual property right owners in tariffs will be larger; and the multiplication of dynamic content channels will also add price pressure to tariffs. Consequently, by 2030 the true value of wireless and mobile services will lie in the interactions, where the services are formed as a result of multiparty interactions. These interactions can be divided into three categories:

1. Community-based human-to-human interactions;
2. Cluster-based machine-to-machine interactions;
3. Human-to-machine interactions.

Here we focus on the first category as the starting point of the research. Sociologist Barry Wellman (2001, p. 228) has defined communities as: "Networks of interpersonal ties that provide sociability, support, information, a sense of belonging, and social identity." Because of their business, sociological or process-linked nature, the communities mentioned above rely on membership fees (in kind or in money, eventually free) and on managed access privileges, which are essentially similar to current operators' customer care administration, but in diverse forms and with more freedom in the organization thereof. More precisely, belonging to a community requires an identity and membership for a user in order to receive services; it also requires a degree of self-care and support to the rest of the community. The community collectively provides information, know-how, and services to members through interactions and access to static or dynamic content. It is based on this vision of a community that we define and characterize the community-based individual services and tariffs.

6.2.1 Definition and characterization

Community-based individual services and tariffs means that each individual obtains from a community, by a bilateral specific contract, a combination of services and related content, at a specific price for some duration, whether the services are user-defined or community-defined. ***Community-based individual service*** is the communication service supplied in the way stated above. ***Community-based individual tariff*** is the price paid by the user for such an individual service provided by a community.

Even if the individual belongs, say, to an enterprise, the members of the enterprise may have different individual tariffs, simply because their service demands and content flows (contributions and receipts) are different. Even different users of an identical service (if any such service exists) may value it differently as they decide to belong to different communities of their choice. As a consequence, the users of an identical service may pay different tariffs.

The access to services inside a community is based on prices and competition, or possibly quasi real-time spot service prices (Meij & Pau, 2006). There are also prices for community peering arrangements, or community-to-community interactions, but these may be on a periodic flat rate basis once a service-level agreement has been enacted between them.

In the above definition, each community ends up supplying a number of services of which only some are initiated by consensus at the community level or by the service manager. A community does not need to own part of or the entire fixed and wireless transmission infrastructure. Such infrastructure can be sourced competitively from an infrastructure owner under a simplified MVNO scheme (Varoutas, Katsianis, Sphicopoulos, Stordahl, & Welling, 2006). Also these community-supplied services are not necessarily entered into service level agreements (SLA) with other communities or the public at large.

The above definition says nothing about the transparency of prices and pricing provisions. More precisely, the information disclosure rules are of at least three types, with one between the member and his community (especially if this is managed formally), one within a community, and the last one between communities. The information disclosure rules may lead to price equalization, but this effect is limited in that it can only happen for the same service, while each community member will have a different and possibly dynamic service usage profile.

The above definition says nothing about the service provisioning duration the community commits to its members, or which communities commit to themselves. Duration of the service will be one attribute in the multi-attribute service demand from a user in the community: e.g. sporadic uses are possible, just as long-term ones, but the difference with current service offering is that they can be priced differently and made user-specific.

Very importantly, per this definition of community-based individual services and tariffs, when the end user requests a service from a community, he/she is also responsible for the existence and survival of the community through contributions (money, but also information, knowledge). The individual will take and share the risk if the service is underfunded and ceases to exist. So, if the user appreciates the service, he may end up paying slightly more than other members, or even more than users of the same service from other communities, to ensure the existence of the service. The person can also consider paying an insurance premium to the community to cover against the risk of service loss. By paying an individually-negotiated premium, which may be only a small amount of money, the user maintains his access to key services and he also contributes to the survival of the community (Harrington & Niehaus, 2003).

6.2.2 Community business model

Based on the above definition and characterization of community-based individual services and tariffs, we propose the following business model of a community.

The income base to a community could be made up of a combination of:

1. membership fees;
2. competitive specific service usage revenues within the community;
3. service usage revenues generated from non-members;
4. possible premium income from members who select to cover themselves against specific service disruption;
5. flat fees from other communities;
6. and, last but not least, contributions in kind (work, information, know-how, knowledge, innovation) by members.

On the cost side, they include:

1. costs of managing community memberships; but this cost does not bear significant marketing and publicity costs, so it will be far less than with today's public operators who, often devote 1/3 of their income to such marketing and CRM functions;
2. investments in infrastructures and possibly service access devices;
3. partial service creation expenses, possibly shared with community users or other communities;
4. service provisioning and operations expenses, with in some cases community members being member-employees;
5. flat fees to other communities;

6. and, last but not least, intellectual property right expenses for service creation and innovation, and from access to information or knowledge shared in the community.

We estimate that the community management overhead share will be 25%, the community service creation or usage share will be 60%, and the transport plus access share (to the infrastructure owner) will be 15% of the total costs.

6.2.3 Supply and demand analysis

The supply of services will be abundant, and the price will be low, driven not only by the deregulation and technology advances, but above all by the freedom to define, request and bear a share of the risk around service and content creation. Still, backbone transmission will be essential, as will be different authentication/roaming/settlement/digital right management functions, but it remains to be seen if traditional operators can offer competitive services, in terms of flexibility, price, quality and scalability, compared to what some larger communities may do themselves. What should be kept in mind is that, due to exploding traffic demand and competition driven by many community-clients, the revenue from pure transport or access will become minimal compared to the added value of individualized services.

The total demand will be large, as people can customize their services according to their means and needs, and furthermore because community proliferation may multiply this effect. Compared to the situation with generic public services offered in limited numbers, used by very many, communities offer viable alternatives in terms of revenue and demand. The reason is that within a community, the above two multiplicity factors are replaced by four:

1. number of community members;
2. overlapping sub-communities that share some common interests but have some interests and service demands different from others;
3. number of specific services for and made by a sub-community;
4. number of common services to all members in the community.

These four distributions allow replacement of flat rates for all by individual tariffs, subject to the condition that each community has simple but efficient digital rights management tools, network management and monitoring tools to be able in real-time to quantify equilibrium break-even tariffs (Pau, 2002). People will pay the amount of money, and put in their individual contributions, exactly according to how they value the individualized service bundles offered or requested by them.

6.3 Case analysis in the Chinese context

In this section, we evaluate the design of a community business model in the Chinese context, where the community culture is deeply rooted. We study two representative cases which bear the embryonic form of community-based individual services and tariffs: one relates to urban game communities and the other relates to rural communication communities. Before going into the details of the specific cases, we first present the relevant issues of the community culture of China and apply our analysis in general.

Two important characteristics of traditional Chinese culture are the emphasis on the long-term perspective and on collectivism (Hofstede, 2001). Since Confucius, the culture has stressed the enduring relationship with one's "in-group" at different levels from family to nation (Fei, 1992). This serves as a guarantee of reciprocal exchange to maintain the relationships, or "Guanxi", among members of a Chinese community. As a consequence, it discourages free riding of the community resources and makes collaboration and cooperation more appealing to Chinese people; furthermore, the cultural environment leads to much more diverse communities than western societies (Kluver & Powers, 1999). For example, the traditional "families and group" notions such as regionalism (xiangtu) and clan loyalties (zongzu) exist widely in both rural and urban areas (Wang, 2006). In addition to communities formed based on business, occupation, hobbies and interests, it is common to find communities which are formed under a common origin, or under a common dialect. There are abundant communities. The community-based service creation and provisioning mechanism can assist each community in having its own services based on the demands of its members, provided their skills level is sufficient. But here the fantastic strengthening of the skills base in China and in some groups drives this into reality. Furthermore, services creation, which has the largest proportion in the total service cost, can be linked to the affordability at community level. All these factors contribute to a flourishing of mobile services. At the tariff level, the pricing settlement arrangement of individual tariffs makes services affordable to each individual member of various types of communities. Take the example of a family-based community: the membership fee will be very low (close to zero); similarly within a rural village. But the differences lie in the fact that in a formally organized community, such as in a village, affordability will be higher, as set largely by users themselves in view of their social, economic and information needs, which may result in non-zero membership fees. Similar analysis can be applied to other aspects of the pricing mechanism of the business model.

6.3.1 Case 1: Urban game communities

History, Background and Stakeholders

Lianzhong (www.ourgame.com) is a company founded in 1998. It offers online and mobile gaming, which mainly includes board games, card games, and arcade games. Many games are deeply rooted in Chinese culture in their traditional forms (e.g. Go, Chinese chess, Tractor) and therefore quickly gain acceptance in their electronic forms. Registered online members have reached 150 million, including more than 1 million paid (premium) members (2004). Registered mobile game members have reached 1 million, with active users of 130,000 per month (March 2006). By providing games and related services, Lianzhong has created one of the largest Chinese game communities.

Besides the large community, many sub-communities have been created in Lianzhong. Lianzhong uses the concept "Jianghu" to provide a fictional environment for the sub-communities. Jianghu is a unique term originating from classical Chinese "wuxia" stories. Metaphorically, Jianghu means a wild, romantic, or unsettled region where legends take place. People inside Jianghu are usually associated with different "Menpai" to learn martial arts as well as other knowledge to fight for their own interests. The concepts of Jianghu and Menpai provide a perfect setting for sub-communities. There are over 7,300 sub-communities (in November 2006) that are formed on various bases, which can be based on location, interests in games, or interests in other aspects such as poems, philosophy, Chinese literature, and so forth. Or some sub-communities are formed under catchy titles. An average sub-community has 600 members, and over 15% are paid premium members.

Deployment, Usage and Prices

Software needs to be downloaded and installed for each specific game. Online (fixed) versions are free while mobile versions charge about CNY 5-8 per month (c.a € 0.5-0.8).

A player needs to register and become a Lianzhong member to play the games. There are two types of membership: non-paying free membership and paid premium membership. Basic game services are the same for both types of memberships. Lianzhong offers virtual game halls and virtual tables where members can meet and play games. "Scores" can be earned with regard to different game results. Lianzhong keeps records of the scores as well as other game statistics for the members. While most of the basic game services are free of charge, Lianzhong also introduces some paid services/functions to let the members have enhanced experiences when playing games or staying in the Lianzhong game community. For example, a member can purchase equipment to be used in games (e.g. a tool that keeps track of all the cards that have been played). Or a member can pay for services offered outside the games (e.g. a service that sends virtual flowers to a player). Paid services are charged in the form of (Lianzhong) credits. Free members and premium members pay slightly different tariffs for the same service/function. The credits need to be bought using real money, which can be done via bank transfer or via mobile phones.

Premium members need to pay CNY 15/35/120, for 30/90/365 days of a premium membership. Premium members, when compared with (nonpaying) free members, have certain privileges. For example, they have the privilege of entering a crowded game hall (the virtual game space); they can become a referee in a game. Also premium members are entitled to more services. For example, their names can be listed in the "Hall of Fame" based on the scores that they have earned in the games, while free members do not have this service. Furthermore, premium members can create sub-communities while free members can only choose to join an existing one. Some premium services are free, while the others require payment.

A sub-community can be created by a premium member, who pays a certain amount of credits to Lianzhong and becomes the leader of a sub-community. Membership fees of sub-communities are decided by sub-communities themselves, which can also be free. Lianzhong offers a Web page to each sub-community to advertise itself to potential new members. Each sub-community can have not only fixed game halls for its members to gather, but also a forum to discuss internal affairs. Besides the common game services offered by Lianzhong, each sub-community offers to members its own specific services. These services, most of which are free, can be game-specific training at different levels. Or they can be tournaments within and between sub-communities. The winners of the tournaments are often awarded with credits, which are either collected from members as registration fees for the tournament or donations from sub-community members. Organizers of a tournament have to submit detailed planning to Lianzhong. The tournament has to be checked and approved manually by a Lianzhong administrator (to prevent possible gambling and other illegal conduct). Actual matches are arranged by the organizers in their own game halls. Lianzhong collects the registration fee (credits) and donations for the tournament and later distributes the rewards to the winners automatically according to the results reported by the organizers. Lianzhong charges a transaction fee for every transfer of credits.

Direct Relevance of Individual Tariffs

The income base of Lianzhong is made up of:

1. (premium) membership fees;
2. money paid by premium members and free members to buy Lianzhong credits which are used to play games and to access services on the Lianzhong game platform;
3. banner advertisement payments from advertising companies;
4. payments from title sponsors of various game tournaments;
5. revenue sharing payments from operators for generated network traffic;
6. revenue sharing payments from operators for value-added services (e.g. SMS-based VAS).

Lianzhong's costs include:

1. investment in creating the game platform and developing new games;
2. investment in game servers;
3. service provisioning and operations expenses, which includes payment to staff, hardware running and maintenance costs, software (game) upgrade costs, access bandwidth leasing cost to owners of the last-mile access infrastructure, etc.
4. CRM cost on paid premium members.

The introduction of paid (premium) membership/ services since June 2000 has brought Lianzhong stable revenue streams. Membership fees once contributed to more than 50% of Lianzhong's income. The introduction of Jianghu and Menpai in 2001 brought Lianzhong faithful members: the virtual settings for the sub-communities suit especially well the Chinese culture and traditions from a game-playing perspective as well as from daily social-life perspective. Members are willing to spend money, and contribute their time and efforts to create their own sub-community specific services, which serve as supplements to Lianzhong's common services. These community-created services benefit both the users and Lianzhong.

As a result, Lianzhong became one of the earliest Internet companies in China who made a positive profit: i.e. CNY 30 million in 2001. After that, it grew steadily until 2004. Due to managerial changes, Lianzhong introduced few new games and services in 2003. Similarly, not much effort was put into community building. As a result, Lianzhong's growth slowed down a great deal in terms of new members and revenues. At the same time, other companies like Shanda (www.snda.com) and Tencent (www.tencent.com) caught up. Lianzhong's profit became negative in several quarters between 2004 and 2005. In 2005, the company underwent a series of restructurings. It outsourced some of its services; introduced a series of new games, and put more effort into community building by introducing more community services for the sub-communities. Lianzhong recovered its growth at the end of 2005.

6.3.2 Case 2: Rural communication communities

History, Background and Stakeholders

Sichuan is one of the poorest provinces in southwestern China, with a farming population of over 76%. Mountainous areas cover 90% of the province's territory. Due to the poor conditions of telecommunications and transportation, much of the farm produce cannot be traded in time and therefore loses its value. The economic development in Sichuan rural communities was lagging behind other provinces. Thus the "Tianfu agriculture community" was created in the spring of 2003 to help people in these rural communities to acquire and exchange information and to shake off poverty.

The Tianfu community was created as an initiative from Sichuan Unicom (a subsidiary of China Unicom). Thus the communication infrastructure was initially based on Sichuan Unicom's existing network resources, which includes mobile and wireless networks that cover about 70% of the areas in Sichuan province, and fixed networks with less coverage. A call center and a Web portal which integrate information from several government-supported agricultural-related Web sites were added as part of the core infrastructure. The Tianfu community also set up over 1,000 information collection sites all over the rural areas (December 2004). Each site is equipped with a computer and appointed with trained support staff.

Deployment, Usage and Prices

To join the Tianfu agriculture community, a user must be a Sichuan Unicom subscriber who owns a user terminal. User terminals can have diverse formats, including be mobile phones, pagers, or other special designed terminals attached to fixed telephone lines. There is no need to install additional software: services are tailored to each specific device. Users here can be an individual user, or a "collective user" when many individuals share one user terminal.

The membership fee of the agriculture community is CNY 2-5 per month, depending on the different user terminals. Because of the immense size of the province (485,000 km^2), 21 local (sub)-communities were created based on prefecture-level cities. The purpose is to improve communication efficiency by having more location-dependent information. Members of the Tianfu community can choose to associate with one of the sub-communities during registration.

The Tianfu community provides dynamic content services to its members. There are 10 major categories of content such as local weather forecasts, farming techniques, trading information, plant disease diagnostics and treatment, and so forth. Members can choose more specific subcategories according to their needs. The related information will be sent to the user terminals each day or in real-time (e.g. weather updates). A user pays CNY 2-8 Yuan per month for each category he/she has selected. Some content is created by experts; some content is selected from the agricultural Websites by the community service managers. Content is also created by the support staff associated with the information sites; very often, these support staff are members of the community themselves but are more experienced. They are willing to share their knowledge with other members so that the community as a whole will be better-off. The content generated by support staff can be very relevant and helpful to local people.

Each member can post their supply/demand information on the community Website or can have their messages sent to user terminals in a specific geographical region. This can be done by dialing the call center and asking support staff to carry out the operations (the member pays only the communication fee). Or the members can go to an information collection site and use the computer to log on to the community Web portal and go through several simplified steps, with or without the help of support staff (free of charge now). The information will be checked by one of the Tianfu community administrators before being sent out. Furthermore, as a service to community members, they can also call a service hotline and receive professional assistance on their specific issues from agricultural experts (the service is free of charge now and members need only pay the communication fee).

Besides the 21 sub-communities at the prefecture level, other types of sub-communities can be formed among members. A sub-community can be formed based on a smaller geographical region, which can be as small as 3-5 closely located villages. Or it can be formed based on interests, for example a community of peach growers. Sub-communities are created with the help of a system administrator from the Tianfu community, who groups user terminals together in the system and assigns a group account (free of charge now, and to be charged in a later phase). Each sub-community needs to appoint its own administrators for daily operations such as adding/deleting a sub-community member, sending information to community members, and so forth. The daily sub-community administration can be done either via a Web portal, or it can be done by calling the service center and asking support staff to perform the operations. Each sub-community is charged by Sichuan Unicom based on the communication services it has used (i.e., calls made and messages sent). Each sub-community has its own selection criterion of members; most sub-communities require zero membership fees. Each sub-community can have its own specific services, and costs are shared among members. For example, in a peach grower sub-community, members can give their produce the same brand name when the produce meets a community quality standard, and sell them together at a better price. A rice-growing community can arrange to share rice reapers among members during harvest seasons.

Furthermore, the content service from the Tianfu community can be offered to users outside the community. A Sichuan Unicom user can subscribe to the content service of the Tianfu community as a value-added service to his/her normal subscription. He/she does not need to register himself/herself with the Tianfu community. The subscription procedure is similar to that of a standard value-added service. Tariffs for content so far are the same as Tianfu community members.

Direct Relevance of Individual Tariffs

The incomes of the Tianfu community include:

1. membership fees;
2. subscription fees for content paid by members;
3. subscription fees for content paid by non-members;
4. administration fee for setting up sub-communities.

The costs of the Tianfu community are:

1. investment in information release sites;
2. investment in a call center and a web portal;
3. running costs of the call center, the web portal and the information sites, including payment to the support staff;
4. payment for content generation to the experts (free of charge in the beginning);
5. payment for "hotline" services to the experts (free of charge in the beginning).

The community does not need to invest in communication infrastructure, as it is owned and run by an operator. Regarding the communication tariffs, the Tianfu community also has a special agreement with Sichuan Unicom. Community members pay only for the communications that they have initiated; receiving calls or SMS is free of charge. The agreement was granted permission from the Sichuan government and Ministry of Information Industry (MII) as a special policy to help rural people.

The services from Tianfu community and sub-communities are partially provided and managed by the members themselves, thus the costs can be linked to the local economic development level and tariffs can be relatively low. This is especially true for collective users who share the cost of "one membership." Secondly, because the goal of the community is to help rural people to shake off poverty, it has received special policies from the local government (e.g. the tariffs arrangement mentioned previously). The community has also received many contributions of this kind from society, especially the help and advice from the experts. Thirdly, user terminals can take various formats from high end (mobile phones) to low end (pagers), which means the user can choose a suitable one based on his income. Due to the aforementioned reasons, the services are affordable to most of the rural people.

Created as a not-for-profit organization in the spring of 2003, the Tianfu community now has 1.2 million members (August 2006). The number is still expected to increase in the next few years. More than 3 million farmers have benefited directly from the services. As a result, the collective income of the agricultural community has increased and their living standard notably improved. The initiative also won the best e-business award in the World Summit on Information Society 2005. Sichuan Unicom also benefited from the agriculture community: the ARPU from the members are CNY 40. With 900,000 subscribers, the revenue was about CNY 360 million in 2005. Before the introduction of the agriculture community, this revenue was hardly possible. Furthermore, the churn rate of the community member is less than 3%, which is lower than the Unicom average. This implies a stable revenue stream in the coming years.

6.4 Conclusion

Through the two cases that bear the embryonic form of the community-based individual services and tariffs, we have demonstrated its potential from both the service aspect and the tariff aspect.

The Lianzhong case represents the communities in a relatively developed area who are demanding more value-added services. Although the number of services in each sub-community is limited, the community-based service creation, provisioning, and tariffing can already meet the demands for value-added services. The space for new creative services is huge. The Tianfu case represents the communities in a less developed area, where many people still lack basic mobile services. The Tianfu case has shown that by linking service creation and management to the local economic development level, the pricing settlement arrangement of individual tariffs makes services affordable to each individual member. In both cases, while various demands are met individually by user-set affordability, sustainable development in the economics aspect is achieved.

From Chapter 3 until now, we have been focused on various models: conceptual models, computational models and a business model of individual mobile services and tariffs. In order to bring the models into realization, we discuss the management and implementation issues in the next chapter.

Chapter 7
Management and implementation issues

7.1 Introduction

In this chapter[1], we focus on the management and implementation issues of individual services and tariffs, which aim to bring the concepts and designs developed in the previous chapters into realization[2].

This chapter is structured as follows. Section 7.2 describes the design and reports the findings from a worldwide survey regarding general user preferences for individual services and tariffs; an experimental demand analysis is performed based on the obtained survey results, supplementing the conceptual demand drivers discussed in Section 2.4.1. Section 7.3 investigates the engineering implementation of the design tool (the architecture was described in Section 5.2.3) and proposes a systematic integration of the design tool into existing communication network infrastructure using existing technologies. The linkage between the content at section level is shown in the Table below.

7.2	***Experimental demand analysis for individual services and tariffs***	
	Based on	Section 1.2 on concept and definition of individual services and tariffs
	Results used to	Validate the assumption of user's demand for individual services and tariffs in Section 2.4.
7.3	***Existing technologies for implementation***	
	Based on	Section 4.6 and 5.2 on prototype implementation of the design as a tool
	Results used in	Section 8.2 when identifying research contributions.

7.2 Experimental demand analysis for individual services and tariffs

In Chapters 4 and 5, we conducted quantitative evaluations of the benefits of individual services and tariffs to the users and the suppliers. The evaluations were carried out either through a specific class of value-added mobile service (mSinging), or through a generic mobile service bundle. In order to assess general impacts of individual services and tariffs, we need to conduct an analysis at a higher level. There is, however, neither prior research on the subject, nor any marketing studies or models which we can refer to. Therefore, we decided to use a user survey (Fowler, 2002), which is a rather straightforward method, to elicit users' general preferences for individualized services and tariffs. And based on that, we conducted an experimental demand analysis. What needs to be emphasized here is that the survey and the subsequent analysis are only a pilot study which aims to provide a rough estimation, instead of a comprehensive treatment of the subject. The number of

[1] This chapter is partially based on Chen & Pau (2007b).
[2] It is important to point out that implementation is an important issue but not the core issue of this research.

questions in the survey is limited and they only relate to the most important aspects of individual services and tariffs.

7.2.1 User survey design and data collection

We designed a draft survey questionnaire and sent it out to the members of a worldwide discussion group on “personalized pricing of mobile service bundles” established by RSM. The discussion group consists of academics, industry researchers and experts from 14 countries. We finalized the survey questionnaire based on the comments and a few additions by the discussion group members. There are 13 questions in the survey, each of which serves a different purpose. Furthermore the questions were chosen in such a way that by nesting them, some estimates of key implicit indicators could be computed. The full questionnaire is in Appendix III. Here we provide a summary of the question types and elaborate the rationale behind each question.

1. User type
   We distinguish different types of respondents by identifying them as end users, suppliers and researchers. Different types of respondents may stand in different positions and have contrasting views on the same topics. As there may be overlap between the roles (e.g. a researcher can also be an end-user), we ask the respondent to consider his/her primary role.

2. Flat fee vs. individual services and tariffs
   This question is designed to see how the respondents will choose between the two options: one is simple and straightforward (flat fee) but may not serve/reflect the user’s actual demand very well; every user has the same service bundle and tariff. The individual services and tariffs may require the active involvement in service personalization and tariff negotiation which meet very well user demands.

3. User-specific individual service demands
   This question aims to elicit the specific service demands for individual mobile services from the survey respondents, which may provide a useful insight for researchers and suppliers. Another purpose of the question is to familiarize the respondents with different individual mobile services and prepare them for later questions.

4. User’s perception of the main function of individual services and tariffs
   This question asks the respondents whether they perceive individual services and tariffs as a cost reduction feature, a productivity feature, or a lifestyle feature. The rationale behind this question is that the composition of a service, methods of service creation and the pricing strategy can be different when the users perceive the main function of individual tariffs differently.

5. User perceived pattern changes in communications
   This question tries to measure the perceived changes in communications patterns brought by individual services and tariffs. These changes should be mapped into

traffic characteristics and should be taken into consideration in network planning. The changes can also affect the pricing of the services.

6. User perceived usefulness of mobility
   This question asks the respondents' concern about the mobility of a service. Mobility is one of the key aspects of wireless services. The answers to this question can provide guidance to the pricing strategy of a converged operator who offers individual services with different degrees of mobility.

7. Simplicity
   This question tries to find out the degree of simplicity respondents want from an individualized service. The complexity can be measured by the number of service attributes. The answer to this question could help the design of individual services. This question can be linked to question No.4

8. Ideal contract length
   Assuming flexibility in contract length, the question tries to determine if the ideal contract length from individual services is different from current offers from operators. The question is important to the suppliers.

9. Individual price elasticity
   We define the "individual price elasticity" as the "% change in the demand of service attributes / % change in the individual price which a user is willing to pay. The question can be linked to questions No.4 and No.7.

10. Wireless & operator-configured service vs. fixed & self-configured service
    This question measures the survey respondents' willingness-to-pay (WTP) for the wireless services that are configured by the operator, when compared to the fixed broadband versions of the same services which can be self-configured by the user on the Web, as conventional personalized Internet services are. The small screen and restricted input methods of most mobile devices make service personalization difficult at the user side. Thus it is reasonable to ask the respondent's WTP when a self-configured fixed service goes wireless.

11. Self-configured vs. operator-configured wireless service & individual tariffs
    Despite the small screen and the limited input methods, self-configuration via a wireless mobile terminal allows the user to have more control over the service. This question measures the respondents' willingness-to-pay (WTP) for the mobile services that are configured by themselves vs. configured by the operator. The question can be linked to questions No.4 and No.11.

12. Time spent on individualizing a mobile service
    This question measures the amount of time the respondents are willing to spend on individualizing a mobile service of their liking, as a reward for cost savings, or the capability for the respondents to choose unique service aspects to differentiate themselves with others. The result can provide insight into the individual service

creation and tariff negotiation processes and about the proportion of users willing to do this.

13. Community related question
    This question measures how "private" the respondents consider the configuration of a mobile service to be. The results can provide indications of how the supplier can make use of social networks to facilitate the diffusion of individual services and of the corresponding tariff negotiations.

The survey was put online 1st Nov 2006 and was closed on 31st Feb 2007. Cooperation was established with the International Telecommunications Users Group (INTUG), which is an association of national telecommunications user groups and of representatives of large international users of telecommunications services. Through INTUG, we obtained responses from end-users or their representatives all over the world. Furthermore, a similar request was sent to the International Telecommunication Union (ITU), whose Telecom World 2006 event attracted many experts in the area. Unfortunately the request was turned down by ITU due to policy reasons. Moreover, the survey request was sent to several mailing lists (e.g. AISworld list[1], RSM mailing list) and also to the contacts in the discussion group member's personal social networks. The mailing list consists mostly of academics.

7.2.2 Findings

There were 102 respondents worldwide. The full results and detailed analyses are presented in Appendix III. The major survey findings are summarized below:

- Equal numbers of people prefer flat rates and individual tariffs. (Q2)
- Regarding user-specific demands for individual wireless services, there is a wide variety of needs but also a significant overlap (in terms of proposed applications and services) amongst individual users. (Q3)
- Cost reduction and service simplicity are the main drivers of users. Individual services and tariffs are considered by the respondents mainly to be a cost reduction feature (51%), a lifestyle feature (28%) and a productivity feature (10%). The majority of the respondents want a simple version of the individual services. Regarding the pricing, when the number of service features in the individual service is reduced by 50%, 47% of the respondents would pay less than 50% of the original price, 39% of the respondents will pay exactly half, and 14% of the respondents are willing to pay more than half. (Q4, Q7, Q9)
- In terms of number of contacts, communication frequency and session duration, about 1/3 of the respondents think that individual services will not change their current behavior. About 60% of the respondents consider a slight increase of up to 50%. On average, the increase will be 17% (in number of contacts), 20% (in communication frequency) and 35% (in communication duration). (Q5)
- The majority of the respondents (99%) prefer a contract length of less than (including) 1 year. The average is 6.9 months. (Q8)

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[1] Association for Information Systems.

- Self-configured, and possibly self-negotiated, wireless individual service features and individual tariffs are preferred. (Q6, Q10, Q11)
- About 3/4 of the respondents are willing to spend from 5 minutes to 1 hour individualizing a service. The majority choose 30 minutes (21.6%) and 1 hour (41.2%). (Q12).
- An individual service bundle configuration is mostly perceived as being private information which may be shared within a small circle of less than 5 persons. (Q13)

7.2.3 Implications on demand structure

In this section, we provide an analysis of the general implications of individual mobile services and tariffs to the users and the suppliers. The analysis is based on the estimations of some key indicators derived from the survey results.

Changes in "price/bit"

Changes in price per bit can be approximated by the following formula around given service design attributes:

$$\partial(price/bit) = [\partial(\text{price})\times\text{bit} - \text{price}\times \partial(\text{bit})] / \text{bit}^2 = \partial(\text{price})/\text{bit} - \text{price} \times \partial(\text{bit}) / \text{bit}^2$$

Consider a scenario which, as a result of the individualization of the service configuration, reduces the number of service features to 50% when compared to the number of features of the complete version of the service (as a result of users' wishes for simplicity). According to the processed answers from Q9, the expected price the user is willing to pay will change to 0.4450 of the original price (of the complete version). The user-initiated traffic under this (feature poor) scenario will change to 93% of the original service and content bundle traffic (see Table 7-3). A rough estimation of the changes in the (price/bit) ratio by compounded derivatives is thus:

$$[(-0.5550\times\text{price/bit} - \text{price}\times (-0.0643)\text{bit/bit}^2 = - 0.4907\times (\text{price/bit})].$$

The result can be interpreted as that the price/bit drops almost by half to the users' advantage after the service is individualized according to the users' wishes.

User's perception of the main purpose of individual services and tariffs

The users' perceptions relating to individual mobile services and tariffs as a "cost reduction feature", "lifestyle feature" or "productivity feature" have different implications for service design (service attributes), service individualization strategy and pricing strategy. The supplier should be able to apply different strategies to different user groups with different perceptions. Table 7-1 provides some suggestions on this issue.

Table 7-1: Different strategies for individual services and tariffs provisioning

	Service design	***Service Individualization strategy***	***Pricing strategy***
Cost reduction	Offer abundant features (service attributes) to the users so that they can choose and combine.	Reduce redundant unnecessary features	Cost-saving measure for users
Lifestyle	Offer features (service attributes) that can express the user's uniqueness.	Help or allow users to differentiate	Prestige pricing
Productivity	Offer abundant features (service attributes) to the users so that they can choose and combine.	Help or allow users to improve work efficiency	Business-oriented value-addition

Total traffic change

The increases in the number of contacts, communication frequency and session duration (Q5) by the users will lead to increased individual service usage and network traffic demands. *Ceteris paribus*, if we assume that network traffic will change linearly with each of the changes in communication patterns, then the increases in the number of contacts (16.31%), communication frequency (19.78%) and session duration (34.33%) will lead to an increase in the network traffic demand, due to individual services, of: (1+ 16.31%) × (1+19.78%) × (1+34.33%). i.e. 187 %.

On the other hand, individualization of service design put eventually in the hands of the users will drive simplification of the services. If we assume that the amount of network traffic is proportional to the number of features of the individual service configuration, simplification due to demands for simplicity could lead to a decrease in network traffic. From the answers to Q7, there are 70% of respondents who considered that an individual service should be simpler when compared to a complete version of the service as found e.g. in broadband; 20% of respondents would keep it unchanged and 10% wanted more features. The expected change in the number of service features is estimated in three different scenarios. The number of service features of individual services in the scenarios is set to be low, medium and high respectively: see Table 7-2. (Here, 25% means that the individual service configuration will keep 25% of the features of the original service, 100% means unchanged, 175% means the individual service configuration will add 75% more features to the original service). As shown in Table 7-2, in the feature-poor scenario, the result of individual service configuration is a reduction of 50% of the original service features.

Table 7-2: Different scenarios regarding the number of service features and traffic changes

Scenarios	***Relative changes in the number of service design features***		
	Feature-poor	*Medium*	*Feature-rich*
Respondents want simplification (70%)	25%	50%	75%
Respondents want to keep the service design unchanged (20%)	100%	100%	100%
Respondents want more features (10%)	125%	150%	175%
Expected change in the number of individual service features	50%	70%	90%

Total traffic change can be estimated as the joint effect of the changes in communication patterns (revealed by Q5) and changes in the number of service features due to individual configurations. In the feature-poor scenario, the total amount of network traffic will decrease by about 7% when compared to the situation of the non-negotiable public services and tariffs. In the other two scenarios, there will be a growth in network traffic. See Table 7-3.

Table 7-3: Total network traffic due to individual services and tariffs under different scenarios

Scenarios	***Feature-poor***	***Medium***	***Feature-rich***
Traffic changes due to changes in communication patterns	187 %	187 %	187 %
Traffic changes due to changes in the number of features after individual service design	50%	70%	90%
Total network traffic due to individual services and tariffs when compared to public service and tariff	93%	131%	168%

If we assign a probability to each of the scenarios from Table 7-3, i.e. feature-poor (0.3), medium (0.4) and feature-rich (0.3), the expected network traffic will be 131%, which is a 31% increase from the previous situation with no service design configuration and no individual tariffs.

Number of subscribers

By allowing flexibility in the length of individual service contracts, the supplier may have a shortened average contract length with the users compared to the current dominant 12 or 24 month terms (with or without a new mobile terminal). From the questionnaire, the average length of an individual service contract is 6.9 months (Q8), which is in sharp contrast with today's practices. On one hand, it becomes easier for the users to switch network operators. But on the other hand, individualization can greatly improve user satisfaction, which in turn will reduce churn. This could mean that more users would like to prolong or renew the contracts with the same supplier for an individual service when the old one expires.

The churn rate can be defined as the percentage of subscribers who leave their contractual relationship with one supplier during a given period (e.g. 1 month) (ITU, 1999). There are several different measures of churn. "Net churn" is the overall loss of subscribers, while "Gross churn" is the absolute loss. Net churn (%) = [Gross churn (%) - New contracts (%)]. Here we only consider "Gross churn".

According to Wireless Intelligence (Wieland, 2006), and spot data from wireless operators worldwide, the churn rate for mobile subscribers or prepaid users usually falls in the interval 1.5% - 3%/month, with operator, bundle and country specifics. We estimate the gross churn rates under two scenarios: see Table 7-4, with 1.5 % (low) and 3 % (high) monthly gross churn rates for all users. The corresponding yearly gross churns are calculated for reference purposes. Using the results of the survey, which indicated an average individual service contract length of 6.9 months, the 7 months gross churn (rounded up from 6.9) can be calculated.

These data can be assumed to be the upper boundary of churn rate for individual services: the users of individual services and tariffs would NOT fall in the category of users churning for 7 months. The reason is that they have contracted for 7 months by their own wishes. This means that for that sub-category of mobile subscribers using individual services, when compared to others, gross churn rate over 7 months is certainly less than 10.4 % under a low churn rate scenario, and less than 19.2 % under a high churn rate scenario.

Table 7-4: Churn rate estimations for all users

	Scenario low churn	***Scenario high churn***
Monthly gross churn rate	1.5%	3%
Yearly gross churn rate	16.59%	30.62%
7 months gross churn	10.04%	19.20%

What still needs to be investigated is the specific churn rate for users of individual tariffs alone, once compounded back to a monthly churn rate for such specific users, over a number of cycles of individual service contracts. This analysis should clarify how much smaller the specific churn rates would be for these specific users than the common ones under the two scenarios. Some early reports from the industry (Wieland 2006) showed that by allowing very preliminary levels of personalization, much simpler than the individual services studied here, operators can already greatly reduce churn.

Service configuration & tariff negotiation

From the survey (Q11), 23% of the respondents will pay less when they are offered to undertake the service design individualization themselves, when compared to the same service design managed by the operator. Suppliers can earn extra revenue by offering service configuration for this group of subscribers. About half of the respondents would like to be actively involved in service design and tariff negotiation (Q11). The high willingness to spend about 1 hour on self-configuration (Q12) shows eagerness to differentiate and save if cost savings can be generated and/or unique service features can be chosen. Suppliers can also save costs from those who configure themselves. In both cases, it is necessary for the supplier to have an individual service design and tariff negotiation tool to automate the process. The tool should function either in a simplified mode without much involvement by the users (e.g. users only provide simple service feature, acceptable price and contract duration wishes), or in an interactive mode where users actively participate in the service design and tariff negotiation. We will have further discussion on this topic in the next section.

7.3 Existing technologies for implementation

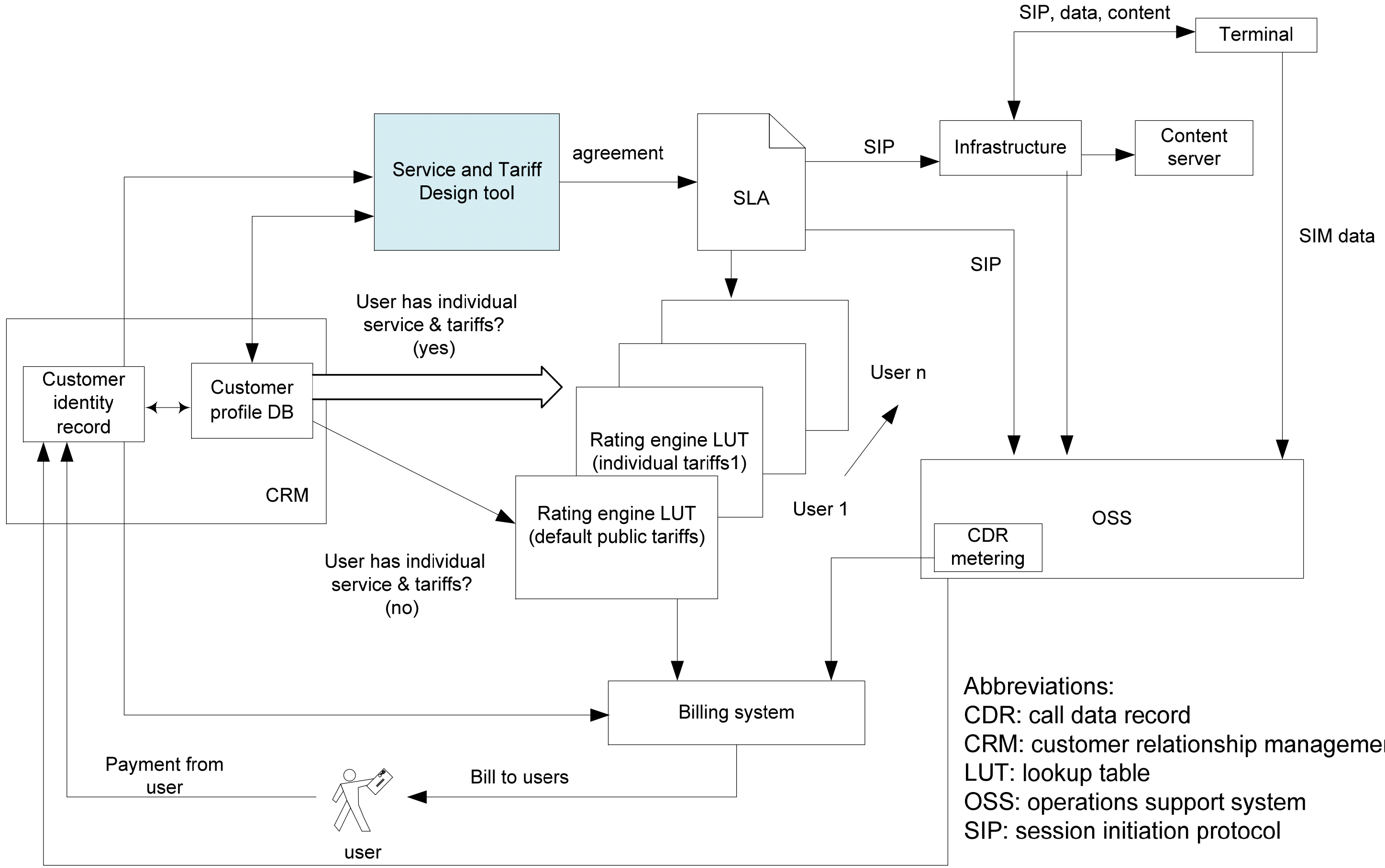
Recall that in Sections 4.6 and 5.2.3 we presented a prototype implementation of the service design and tariff negotiation tools based on the Matlab platform and suggested that, in real practice, the design tools can be implemented (coded) in high performance computing languages such as C or Fortran. However, to bring individual services and tariffs into realization, the design tools alone are not enough. First, the design tools need to be integrated into the communication systems and second, corresponding changes need to be made to the systems. Already today technical means exist for the full realization of individual services and tariffs, and the wireless infrastructure industry together with the billing platform industries, have shown that the complexity and costs involved in individual user multi-service and multiple-access monitoring and control are surmountable (Karunamurthy, Khendek, & Glitho, 2007). In this section, we propose a systematic implementation of individual services and tariffs by leveraging these existing technologies.

The full implementation should consider the following aspects:

- Information collection by the users and the suppliers in view of possible individual services;
- Preemptive service design and related changes in communications and content management infrastructure; the term "preemptive" refers to a normal service capability design and process management prior to sales to customers.
- Interactive tariff agreement through negotiation and related changes in the business support systems and the rating system;
- Settlement of SLA for individual service and tariff;
- Post processing at operational level, including billing, CRM, etc;
- Notification of end of service and renegotiation via the CRM system.

Information collection

Prior to a new service and/or tariff design, information on users' preferences are collected. For example, when designing a generic mobile service bundle that can be individualized, users' preferences over the bundle attributes need to be acquired (Section 4.9). For a complicated value-added service, in addition to the preferences distribution, the mapping relationship (P) between users' service perceptual space and the supplier's service design



Abbreviations:
CDR: call data record
CRM: customer relationship management
LUT: lookup table
OSS: operations support system
SIP: session initiation protocol

Fig. 7-1: An implementation of individual services and tariffs in an existing system space needs to be determined (Section 4.2). Mapping exists by broad user groups based on supplier-specific segmentation thereof. The collection of information can be done by either user surveys within certain interest groups, previous customer information from CRM data records, and/or from actual service usage and traffic measurements, as communications networks offer unique monitoring capabilities (usually embedded in the infrastructure and in the network management platform integrating capabilities) not found in other application areas[1].

Preemptive service design and related changes in communications and content management infrastructure

The supplier then identifies broad service classes, each characterized by sets of service attributes and content/resource needs (e.g. Mobile TV, Mobile music, tracking, etc). The supplier thereafter runs pre-emptively the individual services and tariffs design tool using the collected data to design different individual services and corresponding tariffs for different average users of each service class; the average user data and preferences are determined by the sources mentioned above; the service classes are those chosen by the supplier. The resulting default individual service results, subject to supplier's decision rules, could be public offers that are used to set individual service classes. The results are stored in look-up tables until required by potential subscribers: see Fig. 7-1.

The supplier must make sure that the individual specific service attributes and tariff information is carried along in the communication and content infrastructure. Means for such purposes are derived from engineering platforms, research and standards in the following fields, and include (among others):

- **Active Networks,** which allow network services to be programmed to some extent when the packet processing is distributed and performed by the routers along the path (or tree) to a destination (IST, 2000). Senders at active nodes expecting special processing of their packets by the network simply address the packets to their destination, and routers recognize them as special packets and process them according to a given code. In this code may reside the label or tag representing the individual services and tariffs attributes; and the code can be distributed to the active nodes at which individual service features are provisioned. The propagation of the tariff labels can be either via the node hierarchy control or via additional fields in the routing tables. While active networks as defined above are quite complex and costly, simplified versions of the same concepts are found in some service creation environment (SCE) functionalities tied to the core infrastructure, but subject to the willingness of the suppliers to let users re-program the SCE (directly or indirectly).

- **Flow Label** In the IPv6 protocol, and not in IPv4, a field is reserved in all packets for a label on each packet. Whereas some have proposed using this field for QoS features, others (Pau, 2001) have proposed its use in part to encode the individual

[1] The up-to-date research in this area is being discussed in the IFIP/IEEE International Symposium on Integrated Network Management.

tariffs information for this packet. This approach offers the added advantage over the previous approaches in that the packet to which the individual tariff code applies does not have to originate in some service node, but only in those which have the decoding key to this field. The key itself would be distributed via IPv6 protocol's IPSEC feature with PKE. A standard would have to be designed for the coding of this flow label, when used for this purpose. Some skeptics criticize the data overhead, failing to note that the flow label must be carried anyway in IPv6 unless compression is used.

- **SIP**. Session Initiation Protocol is a text-based IP-based control protocol intended for creating, modifying and terminating sessions with one or more participants; it is designed to be independent of the lower-layer transport protocol (Johnston, 2004). In SIP, a P-Charging-Vector header (Garcia-Martin, Henrikson, & Mills, 2003)[1] is defined to convey charging-related information. The information inside the vector can be filled in and retrieved by multiple network entities during the establishment of a dialog or standalone transaction outside a dialog. In this way, charging-related data processing is reduced to session-based. Regarding the individual service attributes and tariff information, they can be carried by the extension protocols to SIP. For example, Marshall & Andreasen (2003)[2] proposed an SIP extension to exchange in a secure way customer-specific information amongst service provisioning parties (within or across administrative domains). This extension can be used to convey individual service attributes and tariff information.

Interactive service design and tariff negotiation and related changes in the CRM and rating systems

When a potential user decides to engage the supplier, he has several interaction possibilities:

1. either he can select from the operator's default individual service and tariff designs, and then choose/personalize some discrete service attribute values inside the service of interest;
2. or a negotiation takes place between the user and the computer agent (based on the individual service design and tariffing tool) representing the supplier. The agent uses the parameters and decision criteria decided in advance by the supplier, weighing expected profit, risk, market share information provided by the design tools. This negotiation is implemented in tight connection with the rating engine of the supplier, and with the service creation environment of the supplier (located e.g. in the SGSN or in an SCE tied to it).
3. Or a real "live" negotiation is carried out between a user and a salesperson from the supplier: the salesperson uses the results provided to him by the individual service and tariff design tool during the negotiation. The user then does not need

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[1] The document is also known as RFC 3455: the Request For Comments (RFC) document from the Internet Engineering Task Force (IETF), the series number is 3455.
[2] The document is also known as RFC 3603.

to have a user interface (UI) to the tool nor spend much time. But in this case the profit of the supplier is reduced by the negotiation cost, which is proportional roughly to the number of negotiation iterations multiplied by the number of potential subscribers choosing this approach.

Most of the existing contracting function in the supplier's billing and support system (BSS) can already support the third option. The first two options can be implemented in a web-based self-service system, which can be easily integrated into the existing BSS and CRM. As the telecommunication industry is evolving to embrace the structural style of a service delivery platform, the service and tariff negotiation function can be added as a default capability to the CRM support.

The rating systems need to be extended to accommodate the individual services and tariffs information (i.e. individual tariffs lookup tables). The information is linked to the customer profile database and is ultimately connected to the customer identity record, see Fig. 7-1.

Settlement of an SLA for individual service and tariff

When reaching an agreement with a supplier, the user wants the details to be specified in text or a specification form. Service Level Agreements (SLAs), which used to be a way to ensure QoS, are becoming increasingly common to set the commercial and business terms of service provisioning (Pau 2005). An SLA generally takes the form of a structured template: it specifies the service components offered (e.g. via a UML or Parlay specification, or a pointer to such specifications), the QoS metrics, the QoS range values, the individual tariff, and penalties on the provider if he fails to provide the individual service as stated. Thus an SLA can be used in the contract between the user and the supplier to specify the detailed service design attributes and the individual tariff.

Post processing at operational level

After signing each individual contract based on the SLA, the supplier needs to provide the agreed individual service, record the actual usage of those service attributes subject to ceilings, and bill the user. What should be kept in mind is that the individual service may be provided as the result of the cooperation/collaboration between several suppliers/content owner/human expertise pools/operators, and utilizes the heterogeneous network resources belonging to different suppliers. Thus the individual service SLA needs to be carried along, and this very requirement adds to the need for a formal SLA.

The individual service and tariff information needs to be sent via the means mentioned above (e.g. using SIP) to several places in the service provisioning system, as shown in Fig. 7-1. The information will be sent to the rating system, where the individual-specific lookup tables are generated. The information will be sent to the communication and content infrastructure to provide the corresponding service with specified QoS. This information will also be sent to the OSS to record the actual usage of the specified service attributes. The billing system will generate one integrated bill to the user.

Notification of end of service and renegotiation via CRM

The subscriber will be notified when the contract for an individual service is ending and will be prompt to renegotiate via the CRM system. This is important, as it is indicated by the user survey that the average contract length of individual services is about 7 months. The user needs to decide more frequently what individual services he needs. On the other hand, if the user is satisfied with the current individual service and wants only minor changes or no changes at all, the supplier should be able to simplify the contacting process in the renegotiation in the CRM system.

7.4 Summary

This chapter has focused on the management and implementation issues of individual services and tariffs.

In Section 7.2, we reported the findings of a global user survey that was designed to elicit the general user preferences for individual services and tariffs. The survey results indicated that the mobile service market is ripe for the introduction of individual services and tariffs – as many as 50% of the respondents wanted to have these. Other messages from the survey were: cost reduction and service simplicity are the main drivers for users; user behavior will change and drive up the network traffic. By nesting the questions, we were able to estimate some key implicit indicators: for the users, price/bit drops by almost half to the users' advantage after the service is individualized; for the supplier, the network traffic will increase by 31% and churn rate will be significantly reduced. Furthermore, there is an extra revenue and cost reduction opportunity in service configuration and tariff negotiation.

Section 7.3 described an implementation of individual services and tariffs by leveraging existing technologies in the existing system, and demonstrated that the concepts and designs can be readily brought into realization.

It has been argued by some over the years that the administration and management overheads of individualization would kill suppliers' positions. This argument does not first recognize that suppliers today have marketing and CRM as their first budget item in operational costs; by allowing to individualize in a user-centric way, a significant fraction of these expenses would just vanish as marketing-push is replaced by service pull. Next, the proposed approach finds different implementation styles: offline and online. It is to be expected that people with less computer proficiency or trust to IT systems will find the offline option attractive. While more users with higher computer proficiency will normally want the online interactions, for which suppliers will not have major incremental management costs compared to their current situation (assuming that they are willing to open up their CRM systems to user inputs in line with established e-business practices). In the future situation where Mobile Internet will be offered in a user-friendly way, the weight to online negotiation will increase and add a layer of loyalty to the relationship at a negligible cost.

Chapter 8
Conclusion and further research

In this chapter, we summarize the research results (Section 8.1), identify the research contributions (Section 8.2) and discuss future research directions (Section 8.3). Before presenting the results, it may be helpful to re-state the initial research questions that we were trying to answer in the beginning:

1. How can individual-specific mobile services and their corresponding tariffs be determined and built?

2. What are the benefits of individual mobile services and tariffs to the user and the supplier respectively?

8.1 Results

8.1.1 Design methodology and tool for individual services and tariffs

The first research question has been jointly answered by our research conducted in two different settings:

A Firm as a supplier
In this setting, we have established a design methodology and a tool for the numerical computation of individual mobile services and tariffs through negotiations.

We have constructed a conceptual framework which serves as the theoretical foundation for the later computational design of individual mobile services and tariffs. The framework consists of the behavioral models of the user and the supplier (firm) and a game theoretical negotiation mechanism to determine the individual services and tariffs. The user is modeled as having "bounded rationality" and "social concerns". We have addressed the bounded rationality by introducing a simplified *service perceptual space* as the user's decision space when the mobile service has many attributes (e.g. ≥ 7) to be individualized. In addition, we have applied satisficing decision rules to the user during the decision making process. Moreover, we have employed a simple distance-based utility function which can reflect some irrational aspects of the user's social dimension. The supplier is characterized as seeking a maximum profit with a minimum risk. We have used the engineering and business-based *service design space* as the supplier's decision space because he understands all the technical design attributes and also because he needs to eventually implement/provide the service. The supplier's decision rules are set in such a way that he may lose in some individual contracts when compared to the initial non-negotiable offers to the public at large; but by pooling the different individualized contracts together, he can achieve the highest economic utility with a minimum risk at corporate level. The user and the supplier negotiate to have individual services and tariffs and the user has a dominant influence in the negotiation. The bilateral negotiation process is modeled by a user-led recursive Stackelberg game.

The computational design is one of the possible operationalizations of the conceptual framework. The computational design consists of user and supplier computational models, negotiation algorithms, risk metrics and a set of methods that capture/identify, characterize and simulate user demands. The design allows the computation of a negotiation result when the user simply states his wishes in the beginning; it also provides business performance indicators to help the supplier to set decision parameters and criteria. First, we have developed computational models of the user and the supplier based on their behavioral models. The models consist of service-specific utility functions and constraints, as well as decision rules which are rather general. Specifically, we have constructed a realistic supplier's operational model which is rather complex and has considerable discontinuities and non-linearities. The model has been used to determine the supplier's incremental profit from a user's service request during a negotiation. Second, we have developed negotiation game algorithms for both complicated valued added mobile services and simple straightforward generic mobile service bundles. Third, we have proposed to use a user survey to capture user demands; and to use principle component analysis methods to determine the mapping relationships between the service perceptual space and the service design space. The mapping relationship is important because, although the user's and supplier's minds operate in different space, they still need to communicate. Fourth, we have provided business performance indicators such as expected profit, market share, VaR and extreme VaR. The last two risk metrics quantify the supplier's risks under both normal and extreme market conditions. By using the indicators, the supplier could adjust parameters in the constraints, and decide rules when negotiating with a group of users on a specific class of individual services, to achieve his goal of a maximum profit and a minimum risk. The computations of business performance indicators are based on the Monte Carlo simulation method. We have proposed methods to characterize and simulate user demands to serve as the inputs to the Monte Carlo method.

Community as supplier

In the second setting, the supplier of individualized services and tariffs is a community. We have focused on establishing a feasible business model for the community. The difference lies in the fact that the community members may then take over some of the supplier duties and serve as a content creator or a service creator. The costs and revenues are summarized as below:

The income base to a community could be made up of a combination of:

1. membership fees;
2. competitive specific service usage revenues within the community;
3. service usage revenues generated from non-members;
4. possible premium income from members who select to cover themselves against specific service disruption;
5. flat fees from other communities;
6. and, last but not least, contributions in kind (work, information, know-how, knowledge, innovation) by members.

On the cost side, they include:

1. costs of managing community memberships; but this cost does not bear significant marketing and publicity costs, so it will be far less than with today's public operators who, often devote 1/3 of their income to such marketing and CRM functions;
2. investments in infrastructures and possibly service access devices;
3. partial service creation expenses, possibly shared with community users or other communities;
4. service provisioning and operations expenses, with in some cases community members being member-employees;
5. flat fees to other communities;
6. and, last but not least, intellectual property right expenses for service creation and innovation, and from access to information or knowledge shared in the community.

8.1.2 Benefits to users and suppliers

Regarding the second research questions, we have demonstrated, through both quantitative and qualitative analyses, that individual mobile services and tariffs are beneficial to the users and the suppliers. It is however, essential to understand that for user and supplier alike, their benefits and risks are not just those linked to their utility functions, and also that the very concept of individualized services and tariffs opens up other side-benefits for both when compared to current practices.

Quantitative evaluations and analyses
As a first quantitative evaluation of the design methodology, we have created a "mobile singing classroom (mSinging)" case, which is a somewhat complicated value-added mobile service that combines wireless bandwidth needs, wireless data traffic, content and additional professional services. Thus a user's mind would operate in the service perceptual space. Using a prototype software implementation of the computational design, we study the Stackelberg equilibria in the negotiation games and compare them to the initial starting points, which are the public services and tariffs offered by the supplier.

As a second quantitative evaluation of the design methodology, we have studied a large-scale case of applying the individual service and tariffs concept to a simple standard mobile service bundle, involving voice, SMS, and data download. This is still individualization because the user sets his contract length and budget, not like in current commercial schemes by mobile operations. In this case, the user and the supplier would use the same service design space.

The results from the above computational cases have shown that the users, as the leaders of the negotiation games, always achieve gains: the average increases in utilities have been 163% and 37% in the mSinging and the generic mobile service bundle cases respectively.

The supplier achieves gains in some games and losses in others from individual users. But by taking a user portfolio approach and pooling the different users together, he can still achieve a gain on average, with a reasonable risk. Our results also demonstrate that a "maximum profit with minimum risk" situation may not be achievable due to the non-linearities and discontinuities in the computational game model. The supplier can, however, by changing the decision parameters and decision criteria, control and improve his risk-profit equilibrium points significantly.

As a third quantitative evaluation, we have conducted an experimental demand analysis of individual services and tariffs in general through an end-user survey. There are 13 questions in the survey, each of which serves a different purpose. Furthermore the questions were chosen in such a way that by nesting them, some estimates of important implicit indicators could be computed. The key messages from the survey are: equal numbers of users prefer individual services and tariffs, as compared to a flat rate; cost reduction and service simplicity are the main drivers for users of individual services and tariffs; user behavior will change and drives up the network traffic. The main conclusions from this analysis have been: for the users, price/bit drops by almost half to the users' advantage after the service is individualized; for the supplier, the network traffic will increase by 31% and churn rate will be significantly reduced. Furthermore, there is an extra revenue and cost reduction opportunity in service configuration and tariff negotiation in addition to the benefits from the risk-profit equilibrium shift.

Qualitative evaluations and analyses
As qualitative evaluations of the business model design for community-based individual services and tariffs, we have conducted two case studies: one is on a wireless game community and the other is on a rural agricultural community; both bear the embryonic form of community-based individual services and tariffs. The case studies have demonstrated that community-based individual service creation, provisioning and tariffing can meet precisely the demands of their members and can address the affordability issue. Thus sustainable development can be achieved.

8.2 Contributions to theory and practice

Theoretically, the contribution of this research is twofold. First, it contributes to the field of service mass customization by establishing a conceptual framework for computational design of mass customized services. The conceptual framework has the following characteristics:

1. It is based on behavioral models and is thus independent of the underlying technology or service. Therefore, it can be applied to a broad range of mobile services.
2. It introduces interactions, thereby releasing the user from choosing among a large number of service options. This improves customization efficiency.
3. It is user-centric, i.e. instead of requiring users to adopt predefined services and set usages thereof, it assists in tailoring services as per the user's specific demands.

Second, the research provides a novel methodology to determine individualized mobile communication services and tariffs by combining methods and approaches from different disciplines:

1. The concept of "service perceptual space" and "service design space" is presented and methods to determine mapping relationships between these spaces are provided. The former captures a user's bounded rationality in dealing with complex issues, while the latter allows the development of sophisticated mobile services.
2. Computational models of the user and the supplier that address their specific behavioral concerns are developed.
3. Three different algorithms for the negotiation game between the user and the supplier are developed. The first two algorithms are used for the negotiation games of a complex value-added mobile service that has many attributes to be individualized. The first algorithm uses continuous decision variables while the second one uses discretized variables. The third algorithm is designed for the negotiation game of simple generic mobile service bundles.
4. Risk metrics and computational methods to assist the supplier in making decisions are provided. This includes VaR calculation as well as extreme theory.

Practically, the contribution of the research is also twofold. First, it provides a concrete tool that can automate the service individualization and tariff negotiation process. The tool can be used by mobile communication services providers (e.g. an operator) in both the negotiation of generic mobile service bundles as well as the negotiation of complicated value-added services. The former is at the core of the current mobile service business and the latter represents the trend of development in the near future. In addition, the research results can be readily implemented and integrated into the existing infrastructure of the communication service suppliers. Second, the research provides a concrete business model for community-based individual services and tariffs, and demonstrates its feasibility. The business model can be readily picked up by any community that intends to provide such services and tariffs.

8.3 Suggestions for further research

Besides the questions from the seven research dimensions that we identified in the beginning of the research (see Appendix I), a number of open issues emerged during the research that we would recommend for further research.

User behavior

The result of the global user survey (Section 7.2.2) indicates that half of the respondents still prefer a flat rate for all the services; it would be valuable to find out the reasons behind that preference.

We have undertaken some basic research regarding the "simplification" concerns (Sections 3.3 and 7.2.2) of the users who choose to have individual services and tariffs. We have introduced the concept of "service perceptual space" for the users when they need to design a rather complicated value-added mobile service (e.g. attribute number ≥7). In turn, there is a "service design space" for the supplier. The perceptual space is a reductionist mapping of the design space. So far, the analysis works one way: we conduct a PCA analysis on the obtained user preference data in design space to determine what are the perceived attributes. There is, however, no immediate solution for what should be included in the design attributes so that the perceived attributes of a service meet the user's demands. Furthermore, it would be valuable to investigate if similar concepts in the perceptual spaces of different value-added services are mapped to a similar set of service design attributes. If so, these service design attribute sets can serve as building blocks when designing a new individual service for the user: the user simply spells out his wishes for a unique new service that he needs in plain languages, i.e. stated in service perceptual space. The supplier will be able to map this unique combination of perceived service attributes into service design attributes and offer him a truly individual service.

The perception of individual services and tariffs as a cost reduction/lifestyle/productivity improvement feature implies different user behavior during the service configuration and tariff negotiation process (Section 7.2.3). Our previous study used a coarse method by assuming all the users have a similar form of utility function (Section 4.3). Further research can be done by identifying different utility functions for different categories of users.

Our user behavioral model (Section 3.3) considers a user who has bounded rationality and social concerns under a normal condition. In many situations and especially for teenagers, there are often feelings and emotions attached to their mobile devices and services (e.g. mobile dating, mobile gaming). Thus the challenge lies in how to incorporate the emotional aspects in the services and tariffs design. A good start would be the hyperbolic discount function on time for the utility functions (Loewenstein & Prelec, 1992).

Multivariate extremes

In Section 5.2.4, we cut off the outliers of the multivariate user target point distribution obtained from the user survey in Section 4.8.2. By doing so, we can use a multivariate normal distribution, which is rather simple, to approximate the distribution of the remaining target points to use in our calculation. The cut-off of the extreme values would lead to an under-estimation of events that have a small probability but considerable impacts. Therefore, the challenging research issue will be characterizing and simulating the multivariate extremes. A direct use of the result would be feeding the generated extreme data into a Monte Carlo simulation when the "minimum profit threshold" θ is set to be very low to simulate to a no limit ($-\infty$) scenario (e.g. Sections 5.2.5 and 5.3.2). This could significantly improve the accuracy of the estimation of extreme VaR.

Churn

A major benefit of individual services and tariffs is probably to reduce churn as users who obtain individualized services from one supplier will tend to be repeat customers (on their own terms) rather than those shopping around much for better deals. The global user survey (Section 7.2.2) has indicated that the average ideal contract length for individualized services and tariffs is about 7 months. What still needs to be investigated is the specific churn rate for users of a specific class of individual services and tariffs alone, once compounded back to a monthly churn rate for such users, over a number of cycles of individualized service contracts. This analysis should clarify how much smaller the specific churn rates would be for these specific users than the observed ones under the two scenarios in Section 7.2.3.

Community behavioral model

In this research, we focused primarily on the firm-supplied individual services and tariffs by providing a behavioral and a computational model of the firm. A further research avenue would be constructing the behavioral models and computational models of different types of communities as the suppliers of individual services and tariffs. Inevitability, this will involve the modeling of social concerns of the communities, which poses a great challenge.

User-centric research

The research on individual mobile services and tariffs is part of a broader research theme under the user-centric service provisioning philosophy. Embracing such philosophy may bring profound changes to the research landscape of different fields such as technologies, regulation, and economics. Traditionally, researchers specialize in their own world and seldom look at other fields, thus economic analysis often ignore important technical aspects or unaware of new development, and engineering models of lack of economic factors. To deliver a best service experience to the user, the user-centric philosophy calls for interactions and collaborations among the researchers from different disciplines; more challenges are yet to come.

References

Abou-Jaoude, G., & Kung, S. (2005). The science of fit in garment MC. In: *Proceedings of the Third Interdisciplinary World Congress on Mass Customization and Personalization*, Hong Kong.

Adams, W. J., & Yellen, J. L. (1976). Commodity bundling and the burden of monopoly. *The Quarterly Journal of Economics, 90*(3), 475-498.

Altman, E., & Wynter, L. (2004). Equilibrium, games, and pricing in transportation and telecommunication networks. *Networks and Spatial Economics, 4*(1), 7-21.

Antonides, G., & van Raaij, W. F. (1998). *Consumer behaviour: A European perspective*. Chichester [etc.]: Wiley.

Arrow, K. J., & Hahn, F. H. (1971). *General competitive analysis* (1st ed.). San Francisco, CA: Holden-Day.

Au, Y. L. E., & Goonetilleke, R. S. (2005). Comfort characteristics of ladies' dress shoes. In: *Proceedings of the Third Interdisciplinary World Congress on Mass Customization and Personalization*, Hong Kong.

Aumann, R. J. (1997). Rationality and bounded rationality. *Games and Economic Behavior, 21*(1-2), 2-14.

Bakos, Y., & Brynjolfsson, E. (1999). Bundling information goods: Pricing, profits, and efficiency. *Management Science, 45*(12), 1613-1630.

Basar, T., & Srikant, R. (2002). A Stackelberg network game with a large number of followers. *Journal of Optimization Theory and Applications, 115*(3), 479-490.

Benkler, Y. (2002). Coase's penguin, or Linux and the nature of the firm. *Yale Law Journal, 112*(3), 367-445.

Best, M. (2003). *The wireless revolution and universal access*. Geneva: International Telecommunication Union.

Bjarhov, M., & Friberg, C. (2004). GSM network solutions for new-growth markets. *Ericsson Review, 1*.

Björkqvist, J., & Virtanen, S. (2006). Convergence of hardware and software in platforms for radio technologies. *IEEE Communications Magazine, 44*(11), 52-57.

Bowles, S. (2004). *Microeconomics: Behavior, institutions, and evolution*. New York: Russell Sage Foundation.

Buchanan, J. M. (1965). An economic theory of clubs. *Economica, 32*(125), 1-14.

Camerer, C. F., & Fehr, E. (2006). When does "Economic Man" dominate social behavior? *Science, 311*(5757), 47-52.

Casson, H. N. (1910). *The history of the telephone*. Chicago: A. C. McClurg & Co.

Cavalcanti, D., Agrawal, D., Cordeiro, C., Xie, B., & Kumar, A. (2005). Issues in integrating cellular networks WLANs, and MANETs: A futuristic heterogeneous wireless network. *IEEE Wireless Communications Magazine, 12*(3), 30-41.

Chan, C. M. L., Bhandar, M., Oh, L. B., & Chan, H. C. (2004). Recognition and participation in a virtual community. In: *Proceedings of the 37th Hawaii International Conference on System Sciences (HICSS-37 2004)*, Big Island, HI.

Chen, H., & Pau, L.-F. (2006a). Individual tariffs for mobile communication services. In Lu, T., Liang, X. & Xu, Y. (Eds.), *Proceedings of the 16th Biennial Conference of the International Telecommunications Society*, Beijing. (www.itsworld.org). ERIM Report Series Reference No. ERS-2007-054-LIS.

Chen, H., & Pau, L.-F. (2006b). Individual tariffs for mobile services: Bargaining model and calculation. In: *Proceedings of the IEEE International Conference on Services Computing 2006 (SCC '06)*, (p 293-296). Chicago, Illinois, USA. IEEE Computer Society Press: Los Alamitos, CA

Chen, H., & Pau, L.-F. (2007a). Individual tariffs for mobile services: Analysis of operator business and risk consequences. In: Archer, H., Hassanein, K. & Yuan, Y. (Eds) *Proceedings of the International Conference on the Management of Mobile Business (ICMB'07)*, Toronto, Canada: IEEE Computer Society Press: Los Alamitos, CA. ERIM Report Series Reference No. ERS-2007-052-LIS.

Chen, H., & Pau, L.-F. (2007b). Mass customization in wireless communication services. *In Proceedings of the World Conference on Mass Customization and Personalization*, Cambridge USA and Montreal Canada. (www.mcpc2007.com) ERIM Report Series Reference No. ERS-2007-051-LIS.

Chen, H., & Pau, L.-F. (2008). Individual telecommunications tariffs in Chinese communities. In W. Huang, Y. L. Wang & J. Day (Eds.), *Global Mobile Commerce: Strategic Perspectives and Implementation Cases* (pp. 301-316). Hershey, USA: Idea group.

Clemen, R. T., & Reilly, T. (2001). *Making hard decisions with decision tools* (2nd rev.ed ed.). Pacific Grove, CA [etc.]: Duxbury.

Cook, A., & Yong, C. (2005). *Social network and telecommunications networks.* Paper presented at the Social Network Forum, Oxford University.

Cornes, R., & Sandler, T. (1999). *The theory of externalities, public goods, and club goods* Cambridge [etc.]: Cambridge University Press.

Danaher, P. (2002). Optimal pricing of new subscription services: Analysis of a market experiment. *Marketing Science, 21*(2), 119-138.

Darby, M. R., & Karni, E. (1973). Free competition and the optimal amount of fraud. *Journal of Law & Economics., 16*(1), 67-88.

Diekmann, A. (1993). Cooperation in an asymmetric Volunteer's dilemma game: Theory and experimental evidence. *International Journal of Game Theory, 22*(1), 75-85.

Eden, B. (1990). Marginal cost pricing when spot markets are complete. *Journal of Political Economy, 98*(6), 1293-1306.

Embrechts, P., Mikosch, T., & Klüppelberg, C. (1997). *Modelling extremal events for insurance and finance*. Berlin [etc.]: Springer.

Fei, X. (1992). *From the soil: The foundations of Chinese society (a translation of Fei Xiatong's Xiangtu Zhongguo)* (G. Hamilton & W. Zheng, Trans.). Berkeley: University of California Press.

Fischer, C. S. (1992). *America calling: a social history of the telephone to 1940*. Berkeley [etc.]: University of California Press.

Fisher, R. A., & Tippett, L. H. C. (1928). Limiting forms of the frequency distribution of the largest or smallest member of a sample. In: *Proceedings of the Cambridge Philosophical Society, 24*(2), 180-190.

Fisher, R. J., & Ackerman, D. (1998). The effects of recognition and group need on volunteering: A social norm perspective. *Journal of Consumer Research, Vol.25*(3), 262-275.

Fitkov-Norris, E., & Khanifar, A. (2000). Dynamic pricing in mobile communication systems. In: *Proceedings of the First International Conference on 3G Mobile Communication Technologies*, London, UK.

Fortunati, L. (2002). The mobile phone: Towards new categories and social relations. *Information, Communication & Society, 5*(4), 513-528.

Fowler, F. J. (2002). *Survey research methods* (3rd ed. Vol. 1). Thousand Oaks: Sage publications.

Franke, N., & Pille, F. (2004). Value creation by toolkits for user innovation and design: The case of the watch market. *Journal of Product Innovation Management, 21*(6), 401-415.

Frattasi, S., Fathi, H., Fitzek, F. H. P., Prasad, R., & Katz, M. D. (2006). Defining 4G technology from the user's perspective. *IEEE Network 20*(1), 35-41.

Frederick, S., Loewenstein, G., & O'Donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of Economic Literature, 40*(2), 351-401.

Fudenberg, D., & Tirole, J. (1991). *Game theory* Cambridge, Mass., [etc.]: The MIT Press.

Gabriel, R., Gersch, M., & Weber, P. (2006). Mass customization as an adequate strategy for education-services. In: *Proceedings of the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*.

Garcia-Martin, M., Henrikson, E., & Mills, D. (2003). *Private header (P-header) extensions to the Session Initiation Protocol (SIP) for the 3rd-Generation Partnership Project (3GPP)* (No. RFC 3455): Internet Engineering Task Force

Geddes, R. (2000). Public utilities. In G. D. Geest & B. Bouckaert (Eds.), *Encyclopedia of Law and Economics* (Vol. III The Regulation of Contracts, pp. 116-205). Cheltenham: Edward Elgar.

Gencay, R., Selcuk, F., & Ulugulyagci, A. (2003). High volatility, thick tails and extreme value theory in value-at-risk estimation. *Insurance: Mathematics and Economics, 33*(2), 337-356.

Gergen, K. J. (2002). The challenge of absent presence. In J. E. Katz & M. A. Aakhus (Eds.), *Perpetual contact : Mobile communication, private talk, public performance* (pp. 227-241). Cambridge [etc.]: Cambridge University Press.

Giddens, A. (1991). *Modernity and self-identity: Self and society in the late modern age*. Cambridge: Polity Press.

Glegg, G. L. (1973). *The science of design*. Cambridge, UK: Cambridge University Press.

Gnedenko, B. V. (1943). Sur la distribution limite du terme maximum d'une serie aleatoire. *Annals of Mathematics, 44*, 423-453.

Green, N. (2002). On the move: Technology, mobility, and the mediation of social time and space. *The Information Society, 18*(4), 281–292.

Gregg, D. G., Kulkarni, U. R., & Vinzé, A. S. (2001). Understanding the philosophical underpinnings of software engineering research in information systems. *Information Systems Frontiers, 3*(2), 169-183.

Grenci, R. T., & Watts, C. A. (2007). Maximizing customer value via mass customized e-consumer services *Business Horizons, 50*(2), 123-132.

Guadagnoli, E., & Velicer, W. F. (1988). Relation of sample size to the stability of component patterns. *Psychological Bulletin, 103*(2), 265-275.

Harrington, S. E., & Niehaus, G. R. (2003). *Risk management and insurance* (2nd ed.). Boston [etc.]: McGraw-Hill/Irwin.

Hayek, F. A. (1980). Individualism: True and false. In *Individualism and economic order* (1980 ed., pp. 1-32). Chicago: University of Chicago Press.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly, 28*(1), 75-105.

Hirshleifer, J. (1983). From weakest-link to best-shot: The voluntary provision of public goods. *Public Choice, 41*(3), 371-386.

Hoaglin, D. C., Mosteller, F., & Tukey, J. W. (Eds.). (1983). *Understanding robust and exploratory data analysis*. New York: Wiley.

Hofstede, G. H. (2001). *Culture's consequences: Comparing values, behaviors, institutions and organizations across nations* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Holton, G. A. (2003). *Value at Risk: Theory and practice*. Amsterdam [etc.]: Academic Press.

Hong, S. J., Tam, K. Y., & Kim, J. (2006). Mobile data service fuels the desire for uniqueness. *Communications of the ACM, 49*(9), 89-94.

Huang, E. Y., & Lin, C. Y. (2005). Customer-oriented financial service personalization. *Industrial Management & Data Systems, 105*(1), 26-44.

Hull, J. (2003). *Options, futures, and other derivatives* (5th ed.). Upper Saddle River, NJ Prentice Hall.

Huuskonen, M. (2006). *Copyright, mass use and exclusivity: On the industry initiated limitations to copyright exclusivity, especially regarding sound recording and broadcasting*. Helsinki: Helsingin Yliopisto.

IST. (2000). *Global communication architecture and protocols for new QoS services over IPv6 networks (GCAP)*: EU Framework 4 program.

ITU. (1999). *World telecommunication development report*. Geneva: ITU.

ITU. (2005). *ITU Internet reports 2005: The Internet of things*. Geneva: International Telecommunication Union.

Iyengar, R. (2004). A structural demand analysis for wireless services under nonlinear pricing schemes. *Submitted to Marketing Science*.

Jackson, R. W., Neidell, L. A., & Lunsford, D. A. (1995). An empirical investigation of the differences in goods and services as percerived by organizational buyers. *Industrial Marketing Management*(24), 99-108.

Jain, S., & Agrawal, D. P. (2003). Wireless community networks. *Computer, 36*(8), 91-93.

Jobson, J. D. (1992). *Applied multivariate data analysis: Categorical and multivariate methods* (Vol. 2). New York [etc.]: Springer.

Johansen, H. C. (1985). *Danish historical statistics 1814-1980*. Copenhagen: Gyldendal.

Johnston, A. B. (2004). *SIP: Understanding the Session Initiation Protocol* (2nd ed.). Norwood, MA: Artech House.

Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin & D. Kahneman (Eds.), *Heuristics & Biases: The Psychology of Intuitive Judgment* (pp. 49-81). New York: Cambridge University Press.

Kappler, C., Poyhonen, P., Johnsson, M., & Schmid, S. (2007). Dynamic network composition for beyond 3G networks: a 3GPP viewpoint. *Network, IEEE, 21*(1), 47-52.

Karunamurthy, R., Khendek, F., & Glitho, R. H. (2007). A business model for dynamic composition of telecommunication web services. *IEEE Communications Magazine, 45*(7), 36-43.

Katz, J. E. (2006). *Magic in the air: Mobile communication and the transformation of social life*. New Brunswick, NJ: Transaction Publishers.

Keeney, R. L., & Raiffa, H. (1993). *Decisions with multiple objectives : preferences and value tradeoffs*. Cambridge [etc.]: Cambridge University Press.

Kluver, R., & Powers, J. H. (Eds.). (1999). *Civic discourse, civil society, and Chinese communities*. Stamford, CT: Ablex Publishing.

Koppius, O. (1999). Dimensions of intangible goods. In: *Proceedings of the 32nd Hawaii International conferences on System Science (HICSS-32)*, Maui, Hawaii.

Korilis, Y. A., Lazar, A. A., & Orda, A. (1997). Achieving network optima using Stackelberg routing strategies. *IEEE/ACM Transactions on Networking (TON), 5*(1), 161-173.

Lakhani, K. R., & Wolf., B. (2005). Why hackers do what they do: Understanding motivation and effort in free/open source software projects. In J. Feller, B. Fitzgerald, S. Hissam & K. R. Lakhani (Eds.), *Perspectives on free and open source software*. Cambridge & London: MIT Press.

Lampel, J., & Mintzberg, H. (1996). Customizing customization. *Sloan Management Review, 38*(1), 21-30.

Lasen, A. (2002). A comparative study of mobile phone use in public places in London, Madrid and Paris. Retrieved Feb 5, 2005, from http://www.surrey.ac.uk/dwrc/Publications/CompStudy.pdf

Lattin, J. M., Carroll, J. D., & Green, P. E. (2003). *Analyzing multivariate data*. Pacific Grove, CA: Thomson/Brooks/Cole.

Lenth, R. V. (2001). Some practical guidelines for effective sample size determination. *The American Statistician, 55*(3), 187-193.

Levine, M. E. (2002). Price discrimination without market power. *Yale Journal on Regulation, 19*, 1-36.

Licoppe, C. (2003). The social context of the mobile phone use of norwegian teens. In J. E. Katz (Ed.), *Machines that become us : The social context of personal communication technology*. New Brunswick, N.J: Transaction Publishing.

Lin, Y.-B., & Pang, A.-C. (2005). *Wireless and mobile all-IP networks*. New York [etc.]: Wiley.

Linsmeier, T. J., & Pearson, N. D. (2000). Value at Risk. *Financial Analysts Journal, 56*(2), 47-67.

Liu, G., Zhang, J., Zhang, P., Wang, Y., Liu, X., & Li, S. (2006). Evolution map from TD-SCDMA to FuTURE B3G TDD. *IEEE Communications Magazine, 4*(3), 54-61.

Liu, X. (945). Biography of Wei Zheng. In: X. Liu (Ed.), *Book of Tang*. Chang'an. 刘昫主编 旧唐书• 魏徵传.

Loewenstein, G., & Prelec, D. (1992). Anomalies in intertemporal choice: Evidence and interpretation. *Quarterly Journal of Economics, 107*(2), 573-597.

Longin, F. M. (2000). From value at risk to stress testing: The extreme value approach. *Journal of Banking and Finance, 24*(7), 1097-1130.

Luce, R. D., & Raiffa, H. (1957). *Games and decision*. New York: Wiley.

Manes, S. (2005). Music in the air. *Forbes, 176*(11), 74.

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems, 15*(4), 251-266.

Mardia, K. V. (1974). Applications of some measures of multivariate skewness and kurtosis in testing normality and robustness studies. *Sankhya: The Indian Journal of Statistics, 36*(B), 115-128.

Marshall, W., & Andreasen, F. (2003). Private Session Initiation Protocol (SIP) Proxy-to-Proxy extensions for supporting the PacketCable distributed call signaling architecture (RFC3603), 2007, Retrieved Aug 1, 2007, from http://www.ietf.org/rfc/rfc3603.txt.

Mas-Colell, A., Whinston, M. D., & Green, J. R. (1995). *Microeconomic theory*. New York [etc.]: Oxford University Press.

Maslow, A. H. (1987). *Motivation and personality* (3rd ed.). New York [etc.]: Longman.

McNeil, A. J., Frey, R., & Embrechts, P. (2005). *Quantitative risk management: concepts, techniques and tools*: Princeton University Press.

Mead, C. A. (2002). *Collective electrodynamics: Quantum foundations of electromagnetism*. Cambridge Mass.: MIT press.

Meij, S., & Pau, L. F. (2006). Auctioning bulk mobile messages. *Computational Economics, 27*(2), 395-430.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for information processing. *Psychological Review, 63*(2), 81-97.

Moerdijk, A. J., & Klostermann, L. (2003). Opening the networks with Parlay/OSA: Standards and aspects behind the APIs. *IEEE Network, 17*(3), 58-64.

Nash Jr, J. E. (1950). Equilibrium points in N-person games. *Proc. Nat. Acad. Sci. US, 36*, 48-49.

Nelson, P. (1974). Advertising as information. *Journal of Political Economy, 82*(4), 729-754.

Ninan, B. M., & Devetsikiotis, M. (2005). Game-theoretic resource pricing for the next generation Internet. In A. Girard, B. Sanso & F. Vazquez-Abad (Eds.), *Performance evaluation and planning methods for the next generation Internet (Gerad 25th Anniversary)* Berlin [etc.]: Kluwer Academic Publishers, Springer.

Nisan, N., Roughgarden, T., Tardos, E., & Vazirani, V. (Eds.). (2007). *Algorithmic game theory*. Cambridge, UK: Cambridge University Press.

Noam, E. M. (1983). *Telecommunications regulation today and tomorrow*. New York: Law & Business.

Odlyzko, A. (2003). Privacy, economics, and price discrimination on the Internet. In: *Proceedings of the 5th International Conference on Electronic Commerce*, Pittsburgh.

Odlyzko, A. M. (2001). Content is not king. *First Monday*, *6*. Retrieved Oct 12, 2004, from http://firstmonday.org/issues/issue6_2/odlyzko/index.html.

Ogawa, S., & Piller, F. T. (2006). Reducing the risks of new product development. *MIT Sloan Management Review, 47*(2), 65-71.

Ojanperä, T. (2006). Convergence transforms Internet. *Wireless Personal Communications, 37*(3), 167-185.

Osborne, J. W., & Costello, A. B. (2004). Sample size and subject to item ratio in principal components analysis. *Practical Assessment, Research & Evaluation, 9*(11).

Pascu, C., Osimo, D., Ulbrich, M., Turlea, G., & Burgelman, J. C. (2007). The potential disruptive impact of Internet 2 based technologies *First Monday, 12*(3).

Pau, L.-F. (1979). Finite learning sample size problems in pattern recognition. In C. H. Chen (Ed.), *Pattern recognition and signal processing* (Vol. E-29, pp. 83-116). Alphen aan den Rijn: Sijthoff & Noordhoff.

Pau, L.-F. (1981). The multivariate statistical analysis method (correspondence analysis). In C. Carlsson, A. Törn & M. Zeleny (Eds.), *Multiple criteria decision-making: Selected case studies* New York: Mc Graw-Hill.

Pau, L.-F. (2001). *Note on proposal to IETF as to use of IPv6 flow label for tariffing and encoding thereof*: Ericsson Utvecklings AB.

Pau, L.-F. (2002). The communications and information economy: Issues, tariffs and economics research areas. *Journal of Economic Dynamics and Control, 26*(9-10), 1651-1675.

Pau, L.-F. (2005). *Privacy management contracts and economics, using Service Level Agreements (SLA)*, ERIM report series research in management; No. ERS-2005-014-LIS, Rotterdam: Erasmus Research Institute of Management. Available in EU PRIME project www.prime-project.eu.org

Pau, L.-F., & Dits, J. (2002). Business modeling framework for personalization in mobile business services: A case and sociological analysis. In B. Stiller, M. Karsten, P. Reichl (Eds.), *From QoS provisioning to QoS charging*. Berlin: Springer-Verlag Berlin and Heidelberg GmbH & Co. KG.

Pau, L. (2003). *How and why communications industry suppliers get "squeezed out" now, and the next phase*, ERIM report series research in management; No. ERS-2003-033-LIS, Rotterdam: Erasmus Research Institute of Management (ERIM).

Pigou, A. C. (1920). Discrimination monopoly (Part II, Chapter XVII). In *The Economics of welfare*. London: Macmillan and Co.

Piller, F., Schubert, P., Koch, M., & Möslein, K. (2005). Overcoming mass confusion: Collaborative customer co-design in online communities. *Journal of Computer-Mediated Communication, 10*(4, article No. 8).

Piller, F. T. (2004). Mass customization: Reflections on the state of the concept. *International Journal of Flexible Manufacturing Systems, 16*(4), 313-334.

Plant, S. (2002). On the mobile: The effects of mobile telephones on social and individual life. Retrieved Aug 20, 2007, from http://www.motorola.com/mot/doc/0/234_MotDoc.pdf.

Prahalad, C. K., & Ramaswamy, V. (2004). *The future of competition: Co-creating unique value with customers*. Boston, MA: Harvard Business School Press.

Qian, Z. (2001). On happiness. In *Marginalias of Life.* Shenyang, Liaoning: Liaoning People's Publishing House. 《写在人生边上》钱钟书著, 辽宁人民出版社 2001 年 6 月重版 (1941 年上海开明书店初版).

Rheingold, H. (2002). *Smart mobs: The next social revolution*. Cambridge, MA: Basic books.

Roberts, F. S. (1972). What if utility functions do not exist? *Theory and Decision, 3*(2), 126-139.

Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). New York, London, Toronto, Sydney: Free Press.

Rokeach, M. (1973). *The nature of human values*. New York: Free Press.

Romeijn, H., & Pardalos, P. M. (Eds.). (1995). *Handbook of global optimization*. Dordrecht [etc.]: Kluwer Academic Pub.

Rubinstein, A. (1997). *Modeling bounded rationality*. Cambridge, Massachusetts: The MIT Press.

Samuelson, L. (1996). Bounded rationality and game theory. *Quarterly Rev. Econom. Finance, 36*, 17–35.

Samuelson, P. A. (1954). The pure theory of public expenditure. *The Review of Economics and Statistics, 36*(4), 387-389.

Sandler, T., & Tschirhart, J. (1997). Club theory: Thirty years later. *Public Choice, 93*(3), 335-355.

Shafir, E., & LeBoeuf, R. A. (2002). Rationality. *Annual Review of Psychology, 53*(1), 491-517.

Shapiro, A. F., & Jain, L. C. (2003). *Intelligent and other computational techniques in insurance:Theory and applications*. London [etc]: World Scientific Publishing Company.

Sigala, M. (2006). Mass customisation implementation models and customer value in mobile phones services: Preliminary findings from Greece. *Managing Service Quality, 16*(4), 395-420.

Simon, H. A. (1957). A behavioral model of rational choice. In *Models of man*. New York: Wiley.

Simon, H. A. (1979). Rational decision making in business organizations. *American Economic Review, 69*(4), 493-513.

Simon, H. A. (1996). *The sciences of the artificial* (3rd ed.). Cambridge, MA [etc.]: The MIT press.

Smith, R. L. (1985). Maximum likelihood estimation in a class of nonregular cases. *Biometrika, 72*(1), 67.

Spann, M., Skiera, B., & Schaefers, B. (2004). Measuring individual frictional costs and willingness-to-pay via name-your-own-price mechanisms. *Journal of Interactive Marketing, 18*(4), 22-36.

Steele, G. R. (2004). Understanding economic man: Psychology, rationality, and values. *The American Journal of Economics and Sociology, 63*(5), 1021-1055.

Thaler, R. (2000). From homo economicus to homo sapiens. *Journal of Economics Perspectives, 14*(1), 133-141.

Tirole, J. (1988). *The theory of industrial organization*. Cambridge, Mass., [etc.]: MIT Press.

Tönnies, F. (1967). Gemeinschaft and gesellschaft. In C. Bell & H. Newby (Eds.), *The sociology of community* (pp. 7-12). London: Frank Cass and Co. Ltd.

Trosby, F. (2004). SMS, the strange duckling of GSM. *Telektronikk*(100), 187-194.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: heuristics and biases. In D. Kahneman, P. Slovic & A. Tversky (Eds.), (pp. 1124-1131). New York: Cambridge University Press.

Varian, H. R. (1987). Price discrimination. In R. Schmalensee & R. D. Willig (Eds.), *Handbook of industrial organization* (Vol. 1, pp. 597-654). Amsterdam [etc.]: Elsevier science pub. Co.

Varian, H. R. (1996). Differential pricing and efficiency. *First Monday*, *1*. Retrieved Aug 20, 2007, from http://www.firstmonday.dk/issues/issue2/different/

Varoutas, D., Katsianis, D., Sphicopoulos, T., Stordahl, K., & Welling, I. (2006). On the economics of 3G mobile virtual network operators (MVNOs). *Wireless Personal Communications, 36*(2), 129 - 142.

Vincent, J. (2005). Are people affected by their attachment to their mobile phone? In K. Nyíri (Ed.), *A Sense of Place: The Global and the Local in Mobile Communication, Vienna: Passagen Verlag* (pp. 221-229). Vienna: Passagen.

Viterbo, E., & Chiasserini, C. F. (2001). Dynamic pricing for connection-oriented services in wireless networks. In: *Proceedings of the 12th IEEE International Symposium on Personal, Indoor and Mobile Radio Communication (PIMRC),* San Diego, USA.

von Hippel, E. (2005). *Democratizing innovation*. Cambridge & London: The MIT Press.

von Neumann, J., & Morgenstern, O. (1944). *Theories of games and economic behavior*. Princeton NJ: Princeton University Press.

von Stackelberg, H. (1934). *Marktform und gleichgewicht*. Vienna: J. Springer.

Wang, T.-Y. (2006). Clan's function and Its historical changes. *Journal of Shangrao Normal College, 25*(2), 50-53.

Wellman, B. (2001). Physical place and cyberplace: The rise of personalized networking. *International Journal of Urban and Regional Research, 25*(2), 227-252.

Whalley, J. (2002). Change within the mobile communications market. *Communication and Strategies, 45*(1), 177-194.

Wieland, K. (2006). The customer retention challenge. *Telecommunications International, 40,* 8.

Willig, R. D. (1980). What can markets control. In R. Sherman (Ed.), *Perspectives on postal service issues*. Washington: American Enterprise Institute Press.

Winter, R. (2001). Mass customization and beyond–evolution of customer centricity in financial services. In: *Proceedings of the International NAISO Congress on Information Science Innovations (ISI'2001)*, Dubai, United Arab Emirates.

Wold, H. (1943). A synthesis of pure demand analysis I, II and III. *Skandinavisk Actuarietidskrift, 26*, 85-118.

Wu, Y., & Loch, C. (2007). *Social preferences and supply chain performance: An experimental study*. Unpublished manuscript, submitted to Management Science.

Xu, Y., & Pitt, D. C. (2002). *Chinese telecommunications policy*. Norwood: Artech House.

Yaipairoj, S., & Harmantzis, F. C. (2004). Dynamic pricing with "alternatives" for mobile networks. In: *Proceedings of the IEEE Wireless Communications Networking Conference '04*, Atlanta, Georgia.

Zeithaml, V. A., Parasuraman, A., & Berry, L. L. (1985). Problems and strategies in services marketing. *Journal of Marketing, 49*(2), 33-46.

Ziethaml, V. (1981). How consumer evaluation processes differ between goods and services. In J. H. Donnelly & W. R. George (Eds.), *Marketing of services.* Chicago: American Marketing Association.

Appendix I:
The seven behavior and business dimensions of individual services and tariffs

During the preliminary study which aims to provide a clear definition and characterization of individual mobile services and tariffs, we identified current mobile service usage trends and mobile industry development trends and conducted a literature survey. In the same process, we also identified seven research dimensions of individual services and tariffs. These research dimensions are closely related and, by answering the research questions raised within each dimension, we could have a better understanding of individual services and tariffs. The following text examines these dimensions.

1. Freedom of Mobile Service Pricing

   This dimension reflects how much freedom consumers have to decide the price they pay for the mobile services.
   The freedom axis of mobile service pricing starts from zero (no freedom), where all the consumers pay the exact tariffs requested by the service provider for frozen sets of services and usage. At the other end of the axis is the "complete freedom", where people pay what they want to pay (based on how they value the services) for services, benefitting from the full freedom of design and creativity empowered by software based systems. In between these two extreme, as the degree of freedom increases, we can find the limited negotiable tariffs (as offered nowadays); community-based individual tariffs (Chen & Pau, 2008), and auctions (Meij & Pau, 2006; Spann, Skiera & Schäfers, 2004). In all these, additional service options may be priced separately and add to the total price. There are also other intermediate possibilities between the current situation and complete freedom. Abundant questions rise from this dimension. Will pricing still serve as a method of congestion control when more pricing and service creation freedom is granted to consumers? What degree of freedom can achieve a Pareto Equilibrium among all actors under a specific social and economic environment? When the consumers have complete freedom, prices are set by them according to their valuation of the service. Then, price will no longer serve as a signal of supply. Will the consumers have references to get inspired by pre-existing novel services and set the prices? Pau and Dits (2002) identified five factors (excluding prices) deciding the individual value of a specific personalized service, are they sufficient?

2. Granularity of Service Provider

   The research questions in this dimension concern the size of the service provisioning companies/organizations. The telecommunication industry thrived in the 20th century under economic of scale while being protected by monopolistic or oligopolistic regulations. But, first with the advent of advanced technology, next with the higher education level of the population, and third with the deregulation movement in the industry, the entry barriers have been brought down to some extent. The barriers still exist because the fact remains that infrastructure investment and control are very costly and "sticky", in the sense that new entrants must share, or end up sharing, pre-existing networks. Nevertheless, the services can now be provided not only by telecommunication giants, but also by SMEs, content owners, broadcasting companies, private communities and even individuals. Each party has its advantages and disadvantages in offering different kinds of services. The research in this dimension is to uncover the optimal granularity of service providers to meet maximally the individual demands from the users.

3. Affordability

The concept of affordability applies not only for a single service, but also for a bundle of different services; the quality and usage of services will also have to be considered. There are digital divides within a country and among counties. The United Nations created a task force in 2001 whose goal was to harness technology and make it accessible to all. Researchers are developing low-cost infrastructure ranging from cellular networks (Bjarhov & Friberg, 2004) to wireless LANs (Jain & Agrawal, 2003), and have conducted pilot projects (Best, 2003). While these efforts may eventually eliminate technical differences in the access to infrastructure, little research has been done on providing affordable services. Too much research has however been undertaken on law and management relate to the "Universal Service Obligation" without satisfactory solutions, just because such research has never redefined the exact services according to the user's choice. As has already been observed in developed countries, the usage patterns of services vary greatly between people from different income groups.

Individual services and tariffs enhance affordability of services by allowing people to pay exactly what they can/want and not more than that. But on the other hand, the service providers may encounter the problem that, when payments cannot cover the cost of services provision. It leads to service downgrade and ultimately, both bankruptcy and no protection of the communications rights of the users. In the meantime, what developing countries are facing is the lower education level of the population, which may reduce needed diversity of the available services. If there are few services which cover all user needs, the significance of individual services and tariffs will be greatly reduced. Therefore, the main task according to this dimension is to study whether individual services can achieve sustainable service provision, also for developing countries and low income groups.

4. Risk

There are two sides of the coin of risk: the service provisioning side (including all possible actors) and the risk of the consumers when they commit to individual services and tariffs.

There are four possible approaches to providing mobile services: commercially offered, offered in a closed community, offered in an open community and ultimately, self-offered by an individual, maybe shared with selected others. This leads to risks to both providers and customers. Risk dynamics also change within each approach: for example, commercially offered mobile services can, to some extent, be re-insured while members in a closed community cannot re-insure against their loss.

The research in this dimension will first be to characterize the risk dynamics of the above-mentioned four service-offering approaches. The main efforts will be put into the hedging of the user diversity and risk dynamics and into providing the corresponding tools. The design of mechanisms to hedge communication rates once fully deregulated (like some spot bandwidth products or bulk services like SMS) is not within the scope of the research.

5. Policy, Regulation and law

Policy, (de)regulation and law will have effects on all other dimensions, either negative or positive.

The deregulation movement in telecommunications started in the US in the 1970s and spread around the world. The degree of deregulation varies among countries, but it did change the rigid, monopolistic industry to a better competing one (Noam, 1983; Xu & Pitt, 2002; Geddes, 2000). Together with privatization and liberalization, the market is moving toward a "contestable market" where it is characterized by having no entry barriers (Willig, 1980), although technical barriers and sometimes government levies (like licensing fees) remain as barriers.

Research in this dimension will focus on how policy, regulation, and law allowing for and protecting individual services and tariffs, can accelerate the realization of them. The key emerging issues are: regulatory feasibility worldwide for individual tariffs; the legal treatment of price discrimination: can the service providers charge different prices for individual services to consumers, as they already do with companies; the contracts among service providers, between service providers and customers for individual tariffs; the legal commitments of the providers in case of a service failure; and the Intellectual Property Right issues which provide incentives to service creation.

On the other hand, the user cannot sue the service provider if he thinks he has paid too much (individual tariffs) for an individual service, as it was agreed upon by a signed contract and SLA: the current competition law (e.g. EU Competition Act) does not cover such a situation.

6. Social effects

This dimension analyzes the social and intangible costs and benefits of individual services and tariffs to the whole society, communities, families and individuals.

People nowadays have already changed their behavior under the influence of basically just two types of mobile services: voice and simple text service (e.g. SMS), and possibly toys like ringtones, or images. Individual services and tariffs will create great incentives for service creation amongst all people. The abundance and diversity of mobile services will bring profound changes to the way people work, live and entertain themselves.

Most of the academic research nowadays focuses on the impact of mobile voice and SMS, although suppliers and operators are ahead with more diverse services. Little has been done on the impacts of various mobile services enabled by individual services and tariffs. Key issues are: how will individual services and tariffs improve the efficiency of a society? Will individual services and tariffs reduce/enforce the hierarchical structure of the society? How will the structures and processes of formal organizations change when their services go mobile and are tailored for each customer? How will individual services affect the formation and functioning of a community? And, the most important, what will be the impact on each individual.

7. The migration of the legacy system/ evolution of the telecommunication systems

The old Public Switch Telephone Network (PSTN), which had two separate layers (control and transport) plus management, is technically possible for individual services and tariffs for voice (see the Danish history reported in Section 1.1), but id rejected by monopolies. This is similar for the current second generation mobile networks (e.g. GSM).

On one hand, there are organizations such as OSA/Parlay and OMG[4] which are making standards to open up the telecommunication networks for service creation by third parties and make such creation interoperable. On the other hand, the migration toward an all-IP network is progressing slowly, which is flattening the network structure and reducing the barriers for third party service developers. Furthermore, developments in hardware, content management, storage and software technologies also make service creation by a third party easier.

The challenges in this dimension are not to build a new communication system from scratch, but to evolve from existing systems, with certain goals set in advance, towards systems which enable individual services and tariffs. Key elements are service provisioning information technology, information architecture, software architecture and standards, and above all the willingness of suppliers to allow for individualization. The recent history of the reluctance of suppliers to enable open signaling is evidence of the difficulty perceived by operators.

The above identified research dimensions are not isolated pillars of individual tariffs. In fact, they are closely interrelated and together form the foundation of individual services and tariffs. The research questions which lie across two or more dimensions are, very often, the most important and urgent questions which need to be answered.

Appendix II:
Case description of mSinging v2.0

Your friends have registered you on a program which is similar to the currently very popular "Idol" show. But unlike the "Idol", which competes only in singing expertise, the program asks you to show your other talents, such as dancing, acting or playing musical instruments.

You'll have 9 months to prepare yourself for the competition. (At the same time you need to finish your study at EUR). Although you are talented, you still want to attend some classes to improve your expertise. Because of your tight schedule, you cannot attend all the training classes.

Your friends have seen an offer (called mSinging) from an operator who provides music and vocal training to users via mobile technologies. Below is the description of the services:

𝄞 mSinging: a Mobile Singing Classroom service

♪ Prerequisite:
A mobile terminal which supports high-end music functions. Specifically, the mobile can play high-fidelity music and record the singing voice with high quality.

♪ Service provider
A mobile operator assisted by coaches and teachers from a music college. The mobile operator hosts the service portal and content database. The portal can be accessed both from mobile and fixed internet.

♪ Users
The users are supposed to be students who seek vocal training or want to listen to music via mobiles.

♪ Service
The service provides music and vocal training to users via mobile technologies.

Each song has background information such as a brief introduction of the composer, introduction to the specific type of music, the stories and anecdotes of a particular song, etc; scores and lyrics (supported by special software to display it on the mobile device); and an interpretation of the song (an example of performance).

An instruction is associated with each song. The content of an instruction includes: general techniques when interpreting a certain genre of music, techniques for building one's own styles, homework or assignments for users to practice.

A user can ask questions regarding how to perform a specific part, or can ask a more general question regarding the styles of songs. He will receive prompt professional answers from the teacher.

A user can sing to the background music and record it with his high-end mobile phone. (The software that comes with the service can separate the vocal performance from the background music of the example.) He can send in a recording of his performance for the teacher to evaluate and provide feedback.

𝄢 Service attributes

The mSinging service has several attributes. The values of the attributes can be set by a user according to his preferences. Below is the description of the attributes.

♪Attribute description

1. Contract period /in month(s) (1-)
A user can specify his ideal length of contract for the mSinging service. The unit is months.

2. Degree of use of mobile terminal from a converged operator (1-10).
A converged operator offers fixed and mobile service in one service contract. A user can choose a number from 1-10. With 1, indicates that he wants all the content of the mSinging service to be downloaded via fixed internet (which means no mobility and cheapness). 10 indicates that all the content is downloaded using mobile (which means more mobility and expensiveness). A number from 2-9 means a mixed fixed and mobile usage, with a larger number indicating a higher degree of mobile usage.

3. Sound quality of music (1-10)
A user can choose a number between 1-10. 1 indicates the lowest sound quality of music (normal mp3) and smaller music file size. 10 indicate the best sound quality of music (CD quality) and largest music file size.

4. Number of evaluations to have during contract period (0-)
A user can choose not to have any evaluation by setting the parameter to 0.

5. Number of questions to be asked during contract period (0-)
A user can choose not to ask any question by setting the parameter to 0.

6. Number of songs to be downloaded in total (1-)
A user can specify how many songs he wants to learn or download in total for the whole contract period.

7. A user's bid for the service in € (whole contract period)
The user specifies his bid (price) for the values he sets for the other service attributes

♪ Public offer

The operator offers a standard package (public offer), which is a set of standard service specification with a fixed price. A user who wants to accept the public offer can sign a contract with the operator directly. The public offer of mSinging is:

Attributes	***Values***
1. Contract period /in Month(s) (1-)	4
2. Degree of use of mobile terminal from a converged operator (1-10)	6
3. Sound quality of music (1-10)	5
4. Number of evaluations to have during contract period (0-)	4
5. Number of questions to ask during contract period (0-)	8
6. Number of songs to download in total (1-)	16
7. User's bid for the service in € (whole contract period)	200

♪ Service individualization and individual tariff

A user can also have an individualized service and tariff. Based on the public offer, he can propose the values of all the 7 attributes (including price) to the operator.

However, the user can only propose ONCE. If the proposed values are too low, the operator may reject the request.

****

Your considerate friends think the mSinging service can help you to prepare the singing part and also save you a lot of time. Knowing that you already have a high end mobile phone, they have decided to buy you the service as a gift. Not sure about your exact preference, they bought you a coupon of € 200, which entitles you to use the public offer of the mSinging service.

When you used the coupon, you learned from the operator that you can also individualize the service yourself. If your individual service and tariff request is accepted by the operator, and your bid price is less than €200, you will receive the remaining money from the operator; if you require more services and bid for a higher price, you need to pay extra. If your bid is not accepted by the operator, you have to take the public offer.

Based on your singing expertise, you can decide how to make use of the mSinging service. You can only download songs without asking questions, or having evaluations (as a brush-up). Or you can have extensive interactions with the teachers. You may also save some money from the individualized service and tariff and use the money somewhere else (e.g. for a dancing class).

1. Please specify your preferences:
a. I want to take the public tariff
b. I want to have the individual service and tariff.

2. If your answer to the above question is b, please also specify your preference. Remember, you can only bid ONCE.

Attributes	***Public offer***	***Your personal bid***
1. Contract period /in Month(s) (1-)	4	
2. Degree of use of mobile terminal from a converged operator (1-10)	6	
3. Sound quality of music (1-10)	5	
4. Number of evaluations to have during contract period (0-)	4	
5. Number of questions to ask during contract period (0-)	8	
6. Number of songs to download in total (1-)	16	
7. User’s bid for the service in € (whole contract period)	160	

Appendix III: User survey questionnaire and results

Introduction:
The research survey on "individual pricing of mobile service bundles" was conducted by an international group consisting of academics, industry researchers and experts from 14 countries.

Survey dates: 1st Nov, 2006 – 31st Jan, 2007.
The survey results were made available to participants on 15th Feb, 2007.

Definitions:

Individual tariffs in telecommunications refer to the regulatory protected ability for an identified user to obtain from a service provider, by a bilateral specific contract, a set of service-specific prices corresponding to a request or a proposal from the user, specified with a service demand profile and certain duration. In short, you have a tariff unique to you depending on the services you require.

Questions:

1. Please pick one of the following roles that describes you best:
○ End user (private)
○ End user (company/public institution)
○ Content owner
○ Network operator
○ Communications systems supplier
○ CRM or billing vendor
○ Researcher
○ Other

2. Which of the following do you prefer?
○ A single flat rate for all services
○ Personalized service features and an individual tariff for each service

3. Mention the application contexts in which PERSONALIZED SERVICES would be especially useful to you:
-- Access to unique third party content (e.g. music)
-- Processing data about yourself (e.g. health related services)
-- Your specific service needs (e.g. trip planning)
-- OTHERS (please give examples)

4. Do you consider individual TARIFFS for mobile services as a:
○ Lifestyle feature
○ Productivity feature
○ Cost reduction feature

○ OR

5. How many more people (number, frequency, intensity) would you interact with if a mobile service of relevance to you and them was personalized?
Number of contacts (±%)
Frequency (±%)
Intensity (i.e. duration of interaction) (±%)

6. How much more useful would you find personalized SERVICES to be, if delivered ubiquitously to you ANYWHERE, as opposed to being delivered from a FIXED access point?
○ Much less useful
○ Less useful
○ Same
○ More useful
○ Much more useful

7. How much simpler should a USER-FRIENDLY personalized service be vs. the complete version of the service for general usage?
○ Much simpler
○ Simpler
○ Same
○ More features
○ Many more features

8. What is the ideal length of contract for a unique personalized mobile service with an INDIVIDUAL tariff?
(e.g. 9 months)

9. For a given bundle of mobile services, how much would you be willing to pay with an INDIVIDUAL tariff, if you can select a personalized subset represented by HALF of the original bundled services?
○ 30 % of the original bundle price
○ 40 % of the original bundle price
○ 50 % of the original bundle price
○ 60 % of the original bundle price
○ 70 % of the original bundle price

10. It is assumed in this question that a service has two versions: a fixed broadband version and a mobile version. Suppose the fixed version can be configured by yourself on fixed broadband network. Suppose also that the mobile version is configured for you by a service provider (e.g. an operator). How much MORE/LESS would you be willing to PAY for the usage of the OPERATOR-CONFIGURED PERSONALIZED MOBILE service, instead of a SELF-CONFIGURED PERSONALIZED FIXED service? (e.g. -30% for less, +50% for more).

11. Suppose a personalized MOBILE service can also be configured by yourself, or alternatively for you by a mobile operator. How much less/more would you be willing to PAY via an INDIVIDUAL tariff for the usage of this personalized mobile service, when configured by yourself, instead of having this service configured by the operator?
(e.g. -30% for less, +50% for more)

12. How many hours would you spend on personalizing or configuring yourself a (personalized) mobile service?
(e.g. 3 hours)

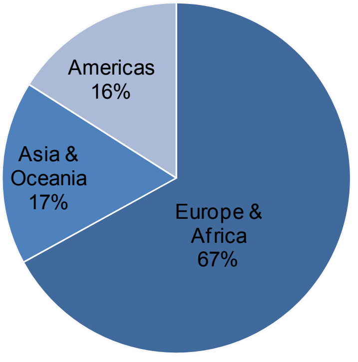
13. With how many people would you like to share the configuration of your personalized mobile service?
○ 0 -1
○ 1 -5
○ 5 -20
○ 20 – 100
○ more than 100

Optional question

14. Please provide your email address if you want to receive the research results.

Results and analysis

There were 102 respondents worldwide. Their geographic locations could be obtained from their IP addresses. See Fig. AIII-1.



Europe	66
US	16
Asia	14
Oceania	3
Africa	2

Fig. AIII-1: Geographic distribution of the respondents

Q1: User type

1. Please pick one of the following roles that describes you best		Response Percent	Response Total
End user (private)		**64.7%**	**66**
End user (company/public institution)		8.8%	9
Content owner		0%	0
Network operator		5.9%	6
Communications systems supplier		1%	1
CRM or billing vendor		0%	0
Researcher		18.6%	19
View Other (please specify)		1%	1
		Total Respondents	**102**
		(skipped this question)	0

The majority of the respondents are from Europe, Asia and America (US). Regarding their roles, the majority are end-users (private) and researchers, who account for over 83% of the respondents.

Q 2: Flat rate vs. personalized service and individual tariffs

2. Which of the following do you prefer?

		Response Percent	Response Total
A single flat rate for all services		46.1%	47
Personalized service features and an individual tariff for each service		**53.9%**	**55**

Slightly more than half of the respondents (53.9%) prefer personalized services and individual tariffs; the rest prefer a single flat rate for all services. The margin of error at 90% confidence level is 0.0812, i.e. 8.1%. The result can be interpreted as that there will be an equal number of people who prefer flat rate and individual tariff.

Q3: User-specific personalized service demands

3. Mention the application contexts in which PERSONALIZED SERVICES would be especially useful to you:

			Response Percent	Response Total
View	Access to unique third party content (e.g. music)		68.1%	49
View	Processing data about yourself (e.g. health related services)		55.6%	40
View	**Individual's specific service needs (e.g. trip planning)**		**72.2%**	**52**
View	OTHERS (please also give examples)		30.6%	22

The respondents are not obliged to fill in all the four application areas. They can just fill in what they consider to be useful. Judging from the answers and response rate in each application area, there is a wide variety of needs but also with significant overlap between individual users.

Table AIII-1: Number of proposed applications vs. number of responses

	Number of applications under different context	***Number of responses***
Access to 3rd party content	19	49
Process data about yourself	10	40
Individual's specific needs	8	52
Other applications	5	22

Table AIII-2: User-suggested applications related to the access to third party content

1. access file stored on another server
2. access to company applications
3. education
4. game
5. mobile blogging
6. movie/movie trailers/cinema listings
7. music
8. news
9. newsletter /email
10. picture
11. information about stores and theatres
12. story
13. text
14. training
15. travel schedules
16. video
17. weather reports
18. web surfing
19. book

Table AIII-3: User-suggested applications related to processing data about oneself

1. bank-related services
2. health-related services/health care
3. insurance/benefit selection
4. mobile payment
5. personal briefcase containing important personal data stored in one place
6. personal finance
7. real time agenda/calendar
8. stock

9. weight, sizes, diet
10. personal knowledge management

Table AIII-4: User-suggested applications related to individual's specific needs

1. air ticket/hotel/car reservations
2. facility booking
3. follow-me data and calendar
4. menu planning
5. navigator / route planner
6. personal location information
7. real time traffic reports (road, railway, flight, ferry, etc)
8. trip planning/ maps/ travel guides and timetables for tube, trains and ferries

Table AIII-5: Other user-suggested applications

1. discount information
2. mobile chat, Skype
3. international services in own native language
4. call to specific subscribers at reduced rates/ personalized international calls/roaming tariffs
5. jokes

Q4: User's perception of the main function of individual tariff

4. Do you consider INDIVIDUAL tariffs for mobile services as a:

		Response Percent	Response Total
Lifestyle feature		29.4%	30
Productivity feature		11.8%	12
Cost reduction feature		**48%**	**49**
View OR (please specify)		10.8%	11

Individual tariffs are considered by nearly half (58%) of the respondents as a cost reduction feature, while about 1/3 respondents consider them as a lifestyle feature, and about 10% respondents consider them as a productivity feature.

Other than these three views, some respondents consider individual tariffs as both lifestyle and cost reduction features, or both productivity and cost reduction features, or all of them. Other answers include: marketing hype and leisure activity (NOT lifestyle). One respondent considers individual tariffs are another way to make money from customers by the operators.

Q5: Effects of personalized services on communication patterns.

5. How many more people (number, frequency, intensity) would you interact with if a mobile service of relevance to you and them was personalized?

			Response Percent	Response Total
View	Number of contacts (±%)		100%	102
View	Frequency (±%)		100%	102
View	Intensity (i.e. duration of interaction) (±%)		99%	101

Table AIII-6: The perceived increase in the number of contacts brought by individualized mobile services

		Frequency	*Valid Percent*	*Cumulative Percent*
Valid	-.30	1	1.0	1.0
	.00	28	28.3	29.3
	.01	3	3.0	32.3
	.02	3	3.0	35.4
	.03	3	3.0	38.4
	.04	2	2.0	40.4
	.05	12	12.1	52.5
	.07	1	1.0	53.5
	.10	12	12.1	65.7
	.12	1	1.0	66.7
	.15	2	2.0	68.7
	.20	12	12.1	80.8
	.25	3	3.0	83.8
	.30	4	4.0	87.9
	.40	2	2.0	89.9
	.50	4	4.0	93.9
	.75	1	1.0	94.9
	1.00	4	4.0	99.0
	2.00	1	1.0	100.0
	Total	99	100.0	
Missing	System	3		
Total		102		

About 30% of the respondents consider personalization will not bring a difference with regard to the number of contacts. 64.6% of the respondents consider a slight increase up to 50% in the number of contacts. The mean is a 16.31% increase in the number of contacts.

Table AIII-7: The perceived increase in the frequency of communication brought by individualized mobile services

		Frequency	*Valid Percent*	*Cumulative Percent*
Valid	.00	25	32.5	32.5
	.01	3	3.9	36.4
	.02	1	1.3	37.7
	.03	1	1.3	39.0
	.05	4	5.2	44.2
	.10	12	15.6	59.7
	.15	1	1.3	61.0
	.20	11	14.3	75.3
	.25	2	2.6	77.9
	.30	7	9.1	87.0
	.50	6	7.8	94.8
	.80	1	1.3	96.1
	1.00	1	1.3	97.4
	2.00	2	2.6	100.0
	Total	77	100.0	
Missing	System	25		
Total		102		

About 1/3 of the respondents consider personalized services will not increase the frequency of their communication. The majority of the respondents (62.3%) consider a slight increase of up to 50% in the frequency of communications. The mean is a 19.78% increase in the frequency of communications.

Table AIII-8: The perceived increase in the duration of communication brought by individualized mobile services

		Frequency	*Valid Percent*	*Cumulative Percent*
Valid	-.50	2	2.7	2.7
	-.10	1	1.4	4.1
	.00	24	32.9	37.0
	.01	2	2.7	39.7
	.02	1	1.4	41.1
	.05	5	6.8	47.9
	.10	12	16.4	64.4
	.12	1	1.4	65.8
	.15	1	1.4	67.1
	.20	10	13.7	80.8
	.30	6	8.2	89.0
	.50	4	5.5	94.5
	.60	1	1.4	95.9
	1.00	1	1.4	97.3
	2.00	1	1.4	98.6
	15.00	1	1.4	100.0
	Total	73	100.0	
Missing	System	29		
Total		102		

About 1/3 of the respondents consider personalized services will not change the duration of their communication. The majority of the respondents (57.5%) consider a slight increase up to 50% in the duration of communications. The mean is a 34.33% increase in the duration of communications.

Overall, about 1/3 of the respondents think personalized services will not change their current behavior. About 60% of the respondents consider a slight increase up to 50% in terms of number of contacts, communication frequency and duration. The average increases in the number of contacts, communication frequency and duration are 16.31%, 19.78% and 34.33%.

Note: some of the answers are not valid and therefore are discarded.

Q6: Mobility

6. How much more useful would you find PERSONALIZED SERVICES be, if delivered ubiquitously to you ANYWHERE, as opposed to being delivered from a FIXED access point?

		Response Percent	Response Total
Much less useful		3.9%	4
Less useful		2.9%	3
Same		15.7%	16
More useful		**46.1%**	**47**
Much more useful		31.4%	32

Nearly 80% of the respondents consider a ubiquitous service offer more useful than if the services are available at a fixed access point. The difference between “more useful (46.1%) and “much more useful (31.4%)” indicates that about 1/3 of the respondents are willing to pay higher prices.

Q7: Simplification

7. How much simpler should a USER-FRIENDLY personalized service be. vs. the COMPLETE version of the service for general usage?

		Response Percent	Response Total
Much simpler		32.4%	33
Simpler		**34.3%**	**35**
Same		19.6%	20
More features		11.8%	12
Many more features		2%	2

Over 68% of the respondents think a user-friendly personalized service should be simpler than the complete version of the service. This can be related to question No.4 in such a way that simpler service may reduce the cost (48% of the respondents concerned), or may improve productivity (11.8% of the respondent concerned).

Q8: Contract length

8. What is the ideal LENGTH OF CONTRACT for a unique personalized mobile service with an INDIVIDUAL tariff? (e.g. 9 months)

Table AIII-9: Distribution of the users' preference for contract length

		Frequency	*Valid Percent*	*Cumulative Percent*
Valid	.00	5	5.1	5.1
	1.00	13	13.3	18.4
	3.00	12	12.2	30.6
	5.00	1	1.0	31.6
	6.00	31	31.6	63.3
	9.00	1	1.0	64.3
	10.00	1	1.0	65.3
	12.00	33	33.7	99.0
	24.00	1	1.0	100.0
	Total	98	100.0	
Missing	System	4		
Total		102		

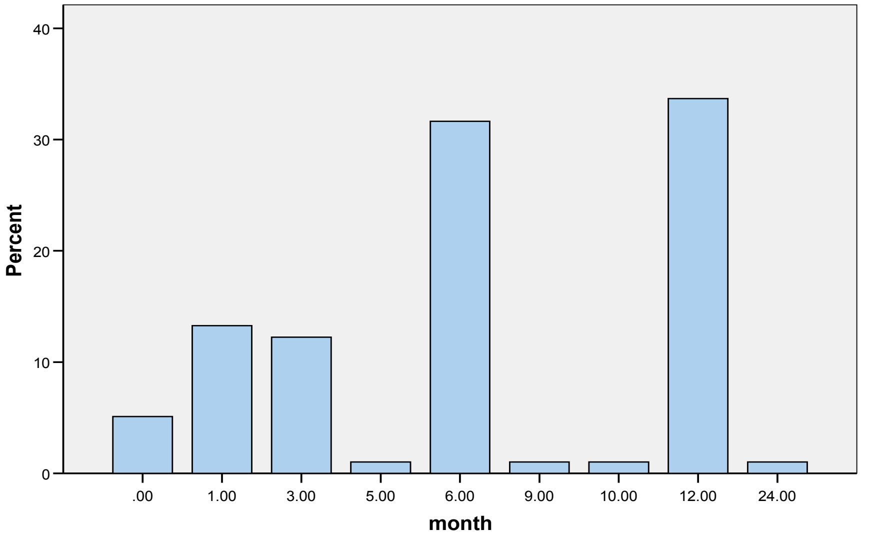


Fig. AIII-2: Distribution of the users' preference for contract length

The majority of the respondents (99%) prefer a contract length less than (including) 1 year. The most preferred contract periods are 1 year (33.7%) and 6 months (31.6%), and some of the respondents (about 26%) want even a shorter period (equal to or less than 3 months). The distribution is also shown in the graph. The mean is 6.9 months, standard deviation 4.6 months. This is in sharp contrast with today's operator's offers: 1 year or 1.5 years or 2 years.

Some comments from the respondents indicate that they want to have the ability to change/terminate the contract at any given time: thus a fixed contract length is not preferred.

Q9: Personalized bundle price elasticity

9. For a given bundle of mobile services, how much would you be willing to pay with an INDIVIDUAL tariff, if you can select a PERSONALIZED SUBSET represented by HALF of the original bundled services?

		Response Percent	Response Total
30 % of the original bundle price		26.5%	27
40 % of the original bundle price		19.6%	20
50 % of the original bundle price		**39.2%**	**40**
60 % of the original bundle price		11.8%	12
70 % of the original bundle price		2.9%	3

46.1% of the respondents would pay less than 50% of the original price if the services attributes/features are reduced by 50%; 39.2% respondents will pay exactly half; and 14.7% of the respondents are willing to pay more for the personalized service with reduced features. (A possible explanation is that personalization reduces redundancy/improves efficiency).

If we define "price elasticity of service attributes" as "% change in the demand of service attributes / % change in the service bundle", then 46.1% of the respondents have elastic demand (>1); these respondents are sensitive to the change in the number of features in the bundle. 39.2% of the respondents have a demand of unit elasticity (=1): these are the "so-called" rational consumers. 14.7% of the respondents' demands are inelastic (<1): these respondents are insensitive to a change in the number of features in the service bundle.

Q 10: Mobile and operator-configured service vs. fixed and self-configured service

10. It is assumed in this question that a service has two versions: a fixed broadband version and a mobile version. Suppose the fixed version can be configured by yourself on fixed broadband network. Suppose also that the mobile version is configured for you by a service provider (e.g. an operator). How much MORE/LESS would you be willing to PAY for the usage of the OPERATOR-CONFIGURED PERSONALIZED MOBILE service, instead of a SELF-CONFIGURED PERSONALIZED FIXED service? (e.g. -30% for less, +50% for more).

Table AIII-10: Distribution of the users' preferences relating to mobile and operator-configured service over fixed and self-configured service

		Frequency	*Valid Percent*	*Cumulative Percent*
Valid	-.60	1	1.0	1.0
	-.50	3	3.1	4.2
	-.40	2	2.1	6.3
	-.30	10	10.4	16.7
	-.25	2	2.1	18.8
	-.20	8	8.3	27.1
	-.10	6	6.3	33.3
	.00	22	22.9	56.3
	.05	1	1.0	57.3
	.10	18	18.8	76.0
	.15	1	1.0	77.1
	.20	10	10.4	87.5
	.30	4	4.2	91.7
	.40	1	1.0	92.7
	.50	7	7.3	100.0
	Total	96	100.0	
Missing	System	6		
Total		102		

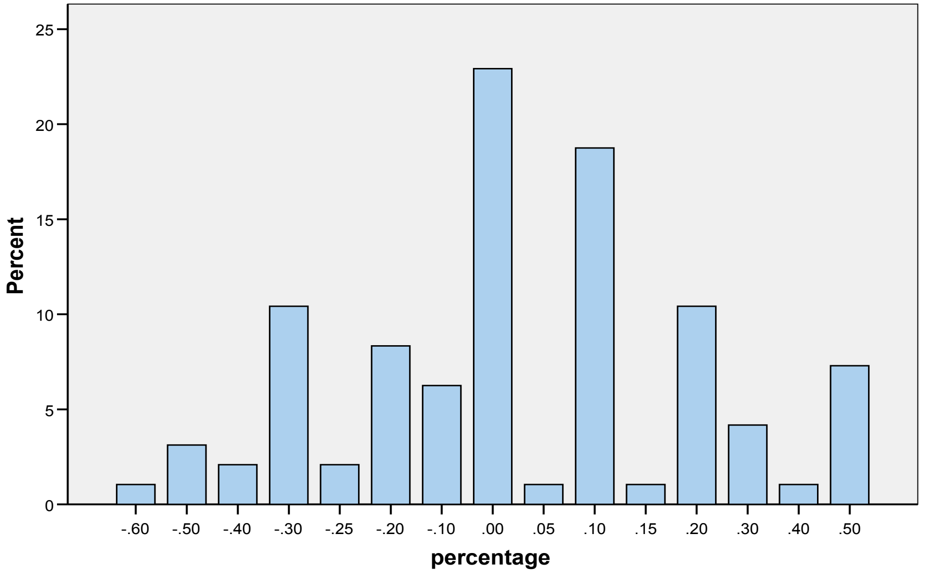


Fig. AIII-3: Distribution of the users' preferences relating to mobile and operator-configured service over fixed and self-configured service

1/3 of the respondents prefer to have a self-configured fixed service. About 23% of respondents would pay the same if their personalized fixed service had a mobile version.

Still, there are about 45% of respondents who are willing to pay more if their personalized fixed service goes mobile. On average, these 45% of respondents are willing to spend 22% more if their fixed personalized service goes mobile.

Q11: Self-configured vs. operator configured service and individual tariffs

11. Suppose a personalized MOBILE service can also be configured by yourself, or alternatively for you by a mobile operator. How much LESS/MORE would you be willing to PAY via an INDIVIDUAL tariff for the usage of this personalized mobile service, when configured by yourself, instead of configured by the operator? (e.g. -30% for less, +50% for more)

Table AIII-11: Distribution of the users' preferences relating to self-configured mobile service over operator-configured service

		Frequency	*Valid Percent*	*Cumulative Percent*
Valid	-.60	1	1.0	1.0
	-.50	1	1.0	2.1
	-.30	11	11.3	13.4
	-.20	6	6.2	19.6
	-.15	2	2.1	21.6
	-.10	2	2.1	23.7
	.00	31	32.0	55.7
	.05	3	3.1	58.8
	.10	17	17.5	76.3
	.20	10	10.3	86.6
	.25	2	2.1	88.7
	.30	4	4.1	92.8
	.40	2	2.1	94.8
	.50	3	3.1	97.9
	.54	1	1.0	99.0
	.80	1	1.0	100.0
	Total	97	100.0	
Missing	System	5		
Total		102		

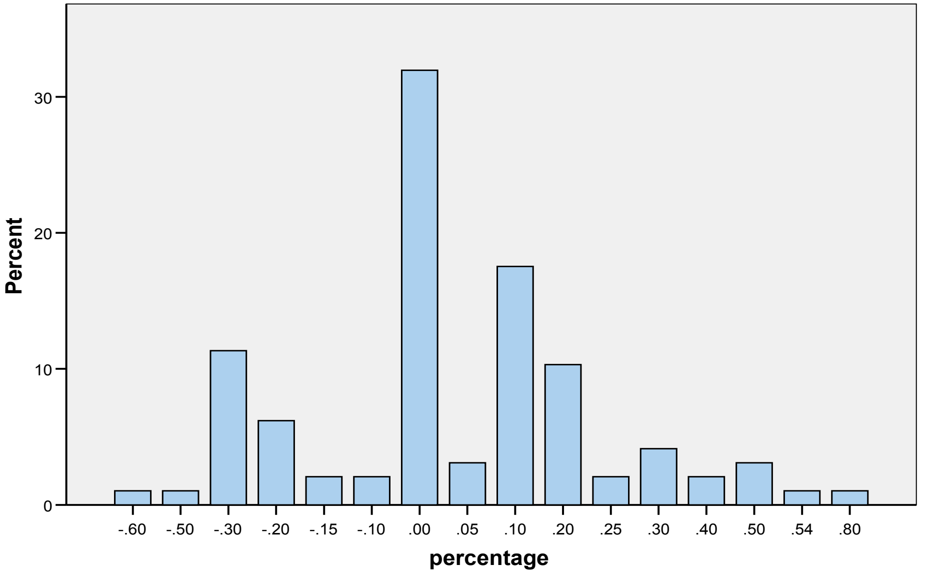


Fig. AIII-4: Distribution of the users' preferences relating to self-configured mobile service over operator-configured service

23.7% of the respondents would pay less if they needed to do the service personalization themselves, when compared to the same service that is configured by the operator. 32% of respondents are indifferent to the two situations. 44.3% percent of the respondents are willing to pay more if they can do the service personalization themselves. On average, these 44.3% respondents are willing to spend 21.4% more if they can take control of the service personalization.

If we correlate the answers from questions 10 and 11, the conclusion with low error is that self-configuration, and possibly self-negotiation of individual tariffs, is preferred.

Q12: Time spent on personalizing a mobile service

12. How many hours would you spend on personalizing or configuring yourself a (personalized) mobile service? (e.g. 3 hours)

Table AIII-12: Distribution of the amount of time (hours) the users are willing to spend on individualizing a mobile service

		Frequency	*Valid Percent*	*Cumulative Percent*
Valid	.00	4	4.1	4.1
	.08	3	3.1	7.2
	.10	1	1.0	8.2
	.17	2	2.1	10.3
	.25	3	3.1	13.4
	.33	2	2.1	15.5
	.50	21	21.6	37.1
	1.00	40	41.2	78.4
	2.00	13	13.4	91.8
	3.00	4	4.1	95.9
	4.00	3	3.1	99.0
	5.00	1	1.0	100.0
	Total	97	100.0	
Missing	System	5		
Total		102		

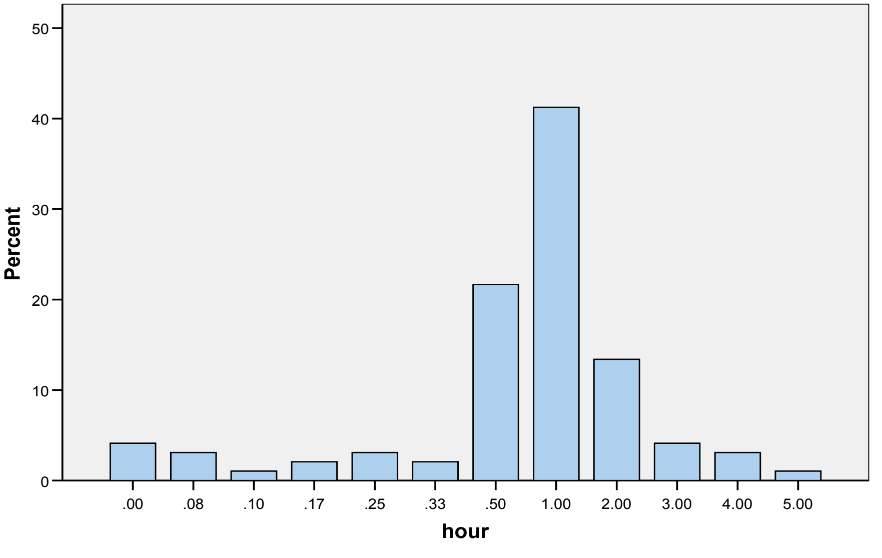


Fig. AIII-5: Distribution of the amount of time (hours) the users are willing to spend on individualizing a mobile service

More than 3/4 of the respondents are willing to spend ≤ 1 hour personalizing a service. The three most observable thresholds are 1 hour (41.6%), 0.5 hour (21.3%), and 2 hours (13.5%). The average is 1.1 hour.

Q13: Community related question

13. With how many people would you like to share the configuration of your personalized mobile service?			
		Response Percent	**Response Total**
0 -1		32.4%	33
1 -5		**38.2%**	**39**
5 -20		19.6%	20
20 – 100		2.9%	3
more than 100		6.9%	7

About 1/3 of the respondents do not intend to share their configuration; about 40% of the respondents would share the configuration within a small circle of 1-5 people, probably family members and close friends. Together, the two categories account for more than 70% of the respondents: thus, an individual configuration is mostly perceived as a private data structure.

About 20% of the respondents would like to share the configuration information with 5-20 people, probably a small and closed community. Note that there are about 7 percent of the respondents who would like to share with more than 100 people, which could indicate a large and open community.

Q14: Optional

14. Optional question Please provide your email address if you want to receive the research results.

More than half (53 vs. 49) of the respondents want to know the research results.

Samenvatting (Abstract in Dutch)

Individuele diensten en tarieven hebben voor korte tijd bestaan in het begin van het telecommunicatietijdperk 150 jaar geleden, maar zijn geleidelijk verdwenen. Het diensten aanbod heeft zich ontwikkeld tot de huidige aanbieder-centrale situatie, die vele beperkingen en nadelen heeft voor gebruikers en uiteindelijk ook voor aanbieders. Dit proefschrift neemt opnieuw de filosofie van een gebruiker-centraal aanbod van diensten en tariefstelling op. Ze past deze toe op de hedendaagse situatie van mobiele communicatiediensten, die belangrijk verschilt van de grootte en het bereik van het dienstenaanbod in het verleden. Er wordt ontwerpmethodologie gepresenteerd en een instrument voor het vaststellen van geïndividualiseerde mobiele diensten en tarieven, en de voordelen voor zowel gebruikers als aanbieders worden geëvalueerd.

Het ontwerp heeft drie specifieke onderdelen. Het eerste betreft het bouwen van een conceptueel raamwerk dat bestaat uit gedragsmodellen voor gebruikers en aanbieders (ondernemingen) en een speltheoretisch onderhandelingsmechanisme voor het bepalen van individuele diensten en tarieven. Het tweede is het verwerken van het conceptuele raamwerk tot een rekenkundig ontwerp, bestaande uit methoden, rekenmodellen, onderhandelingsalgoritmen, risicomaatstaven en een prototype toepassing. Het derde is het uitbreiden van het concept van individuele diensten en tarieven naar de situatie van een gemeenschap en het ontwerpen van een bedrijfsmodel voor deze gemeenschap.

Er worden twee soorten evaluaties uitgevoerd. In de eerste plaats is een gebruikersenquête uitgevoerd en zijn rekenkundige toepassingen van toegevoegde waarde mobiele diensten en generieke mobiele dienstenbundels ontwikkeld ten behoeve van het onderneming-gebaseerde ontwerp. De numerieke analyses laten zien dat gebruikers altijd nutsvoordeel kunnen bereiken. De voordelen voor de aanbieder omvatten regelbare risico-winst evenwichtspunten, verhoogd netwerkverkeer en verminderde uitval. In de tweede plaats zijn gevalstudies uitgevoerd voor twee gemeenschappen met verschillende ontwikkelingsniveaus. De resultaten tonen dat de voorgestelde bedrijfsmodellen van gemeenschap-gebaseerde individuele diensten en tarieven precies kunnen voldoen aan de vraag van de leden van de gemeenschap en rekening kunnen houden met kwesties van betaalbaarheid en duurzaamheid.

Ten slotte, wordt een specifieke technische toepassing en integratie van ontwerpinstrumenten van geïndividualiseerde diensten en tarieven in de bestaande infrastructuur van aanbieders van communicatiediensten voorgesteld. Ook wordt ingegaan op overige onderzoeksonderwerpen

Аннотация (Abstract in Russian)

Индивидуальные услуги связи и индивидуальная тарификация были популярны на заре эпохи телекоммуникаций около 150 лет назад. С тех пор услуги утратили ориентацию на потребности отдельного абонента; сейчас их содержание определяется исключительно провайдерами, что приводит к существованию ограничений и недостатков как для абонентов, так и для самих провайдеров. В рамках данной диссертации предпринята попытка возродить индивидуальную ориентированность телекоммуникационных услуг и тарифов; диссертация рассматривает реализацию данной концепции в современном контексте услуг мобильной связи, который отличается от ранее существоваших условий как по спектру, так и по содержанию услуг. Мы разработали методологию и инструментарий для предоставления индивидуальных услуг мобильной связи и тарификации таких услуг, а также провели эмпирическую оценку их преимуществ для клиентов и провайдеров.

Структура исследования включает три блока. Первый блок включает концептуальную модель, состоящую из моделей поведения клиента и провайдера услуг, а также основанного на теории игр механизма переговоров для определения содержания индивидуальных услуг и тарифов на них. Второй блок реализует концептуальную модель посредством математических моделей, разработки алгоритмов переговоров, показателей оценки рисков, а также посредством разработки прототипа. Третий блок охватывает реализацию концепции индивидуальных услуг и тарифов в контексте сообществ, включая разработку бизнес-модели для данного контекста.

Эмпирическая верификация результатов включает два этапа. Во-первых, для случая, когда услуги предоставляются компанией, проведен опрос пользователей и разработаны математические примеры конкретных услуг, включающие как пакеты базовых услуг, так и дополнительные сервисы. Согласно результатом анализа, пользователи всегда получают прирост в полезности. Для фирмы-провайдера выгода состоит в снижении риска и/или повышении прибыли в условиях равновесия, росте сетевого трафика и снижении «текучести» абонентской базы. Во-вторых, проведено исследование двух конкретных сообществ на различных стадиях развития. Результаты показали, что наша бизнес-модель индивидуальных услуг и тарификации мобильной связи для сообществ удовлетворяет потребностям членов сообществ и учитывает такие аспекты как доступность и устойчивость услуг.

В заключение, мы предлагаем инженерное решение для внедрения и интеграции индивидуальных услуг и тарифов в существующую инфраструктуру провайдеров телекоммуникационных услуг. Сформулированы темы дальнейших исследований.

内容摘要 (Summary in Chinese)

早在 150 年前电信业发展之初，个性化业务及资费即已存在。但不久就由于电信业务的国家垄断而淡出。电信产业在规模经营下蓬勃发展，业务和资费逐渐演变成以运营商为中心的局面。对用户而言，由运营商决定业务和资费存在许多缺点和局限性。这些缺点和局限最终也会影响运营商。本文重新倡导以用户为中心的个性化业务及资费理念，并将其应用于当前移动通信业务环境中。与 150 年前相比，移动通信业务的规模和范围都已截然不同。

本文在用户需求多样化和移动通信业务复杂性的背景下，以保持运营商可持续发展为前提，研究了个性化业务的定制和资费问题。为了让用户和运营商接受这种理念，必须定量分析个性化业务和资费给他们带来的益处。同时，对于运营商而言，必须分析盈利-风险成本。在相当长时间内，垄断运营商一直以实施定制的成本过高为由拒绝提供个性化业务；而事实上，他们的市场营销，客户关系管理和用户转网成本却更高。

本文首先为个性化业务和资费构建了一概念框架，并将其作为进一步量化设计的理论依据。该框架包括了用户和业务提供商（运营商）的行为模型以及他们之间为定制个性化业务和资费的博弈协商机制。用户的行为具有“有限理性”和“社会性”两个特征。对于用户的有限理性特征，我们引入了简化的“业务感知空间”。这个空间由用户所感知的业务属性所构建，其均为易于用户理解的非技术性属性。当一个复杂的，具有多种属性（如属性数≥7）的业务需要定制时，此空间将作为用户的优化和决策空间。在决策过程中，用户采用的是“追求满意”（satisficing）的决策规则。对于用户的“社会性”特征，我们则采用了一个简单的基于距离的效用函数来反映其由于考虑社会层面而导致的一些非理性行为。相应的，运营商具有追求利润最大化风险和最小化的特征。由于运营商掌握所有的技术设计属性，并且最终负责实施/提供业务，因此我们引入了基于技术和商业属性的“业务设计空间”作为供应商的决策空间。运营商采用如下决策规则：从个别用户的个性化合同中获取的利润与公众业务合同相比，可能有所减少；但运营商可在整个用户群上获得最好的经济收益和最低的风险。用户和运营商之间通过协商来定制个性化业务和资费；协商的过程是一个以用户占主导地位的递归 Stackelberg 博弈。

基于上述的概念框架，本文提出了一种量化设计以及相应的计算工具。这种设计可以根据用户表达的简单愿望（如业务属性，预算，以及合同长短等等）来计算用户和运营商协商的结果。同时，这种设计也提供了企业绩效指标以帮助运营商设置协商时的决策规则和参数。具体来说，我们首先提供了决定“业务感知空间”和“业务设计空间”映射关系的方法。这是因为尽管用户和运营商使用不同的优化与决策空间，他们之间仍需要沟通与交流。其次，我们构建了一个逼真的运营商的运营模型。该模型是个增量模型，用于量化单个用户的个性化业务需求所带来的影响。由于该模型考虑了无线接入技术之间的切换，流量传输，交换路由，网络管理，内容

获取以及增值业务等方面，因此具有大量的不连续性和非线性方程。再次，我们提出了三个博弈算法。前两个算法用于复杂的增值业务定制时的博弈：第一个算法使用连续决策变量，第二个算法使用离散变量，应用于具有大量的不连续性和非线性方程的运营商模型中。第三个算法则应用于定制当前运营商提供的基本移动业务套餐的博弈。在这种设置中，用户和运营商使用同一个业务设计空间。此外，我们还提出了在正常和极端的市场条件下如何运用风险价值和极端风险价值来量化运营商的风险。这包括在单个合同层面上利用蒙地卡罗方法计算运营商的风险价值，预期的利润以及协商成功率；基于这些绩效指标，运营商在同整个用户群进行协商时，可以调整约束条件和决策规则中的参数以实现其对于该用户群利润最大化与风险最小化的目标。基于以上设计理念，本文同时提供了一个软件模型做为计算工具。

为了初步定量评估以上的设计方法和设计工具，本文开发了“移动音乐课堂”（mSinging）业务作为一个算例。这个业务是一个相对复杂的增值服务，它结合了无线带宽需求、无线数据流量、内容和音乐专业服务等。此例中，用户使用“业务感知空间”作为优化和决策空间。我们按照以上的量化设计，通过使用计算工具找到了 Stackelberg 协商博弈的均衡点，并将它与初始点进行对照。这个初始点指的是由运营商提供的公众业务和资费。

为进一步定量评估以上的设计方法和设计工具，本文同时研究了把个性化业务和资费理念大规模地应用于当前基本移动业务套餐中的案例。在该案例中，移动业务套餐包括语音、短信和数据下载等业务，用户可以自由地设置所需业务的数量，合同期限和预算。这有别于当前仅由运营商设置固定参数的情况，所以我们仍称其为个性化定制。在此例中，用户和运营商采用同一个“业务设计空间”作为其优化和决策空间。

上述两个算例均表明，用户作为协商博弈的的主导者，始终可以获益：用户的效用在两个算例中平均增长了 163 %和 37 %。在单个合同层面上，运营商在有些博弈中获益，而在另一些博弈中则可能受损。但从整体来看，在合理的风险条件下，运营商的整体利润在这两个算例中分别提高了 9 %和 142 %。两案例中，计算出的风险价值均为正，这意味着在选定的置信区间中（如 95 %），运营商可以从随机挑选的单个合同中盈利。计算结果还表明运营商可能无法同时实现利润最大化与风险最小化的目标，但其可以通过调整约束条件和决策规则中的参数来控制风险-盈利均衡点。

本文同时将研究由企业拓展至由社区提供的个性化业务和资费。研究重点在于为社区提供一个可行的商业模式。在本研究中，社区与企业的区别在于社区成员可能会取代企业（如运营商）成为内容和业务的提供者。我们通过两个实际案例对所设计的商业模式进行评估：一是无线游戏社区，二是农业合作化社区。这两个案例都具有社区个性化业务和资费的雏型。案例研究表明，基于社区的个性化业务的开发、提供和资费能很好地满足社区成员的需求，同时也能很好的解决可持续发展问题。

本文还通过调查问卷，从整体上对用户的个性化业务和资费需求进行了分析。问卷包括 13 个问题，每一个问题的设计都针对不同的目的，并且从问题的相互嵌套中可以估算出一些隐含的关键指标。我们通过与国际电信用户协会（INTUG）合作来分发调查问卷，调研的对象来自全球的终端用户。调研的结果表明：选择个性化业务及资费的用户数与选择单一业务费率的用户数基本相同；追求低成本和简洁的业务是用户选择个性化业务的出发点；用户的行为会由于使用个性化业务及资费而改变并带动网络流量。对调研数据的分析表明：个性化业务对用户的主要影响是每比特的价格下降了近一半；对运营商的主要影响包括网络流量增加（+31％）和用户离网率降低。另外，运营商可以从提供业务配置和费率协商的服务中获得增加收入和减少成本的机会。

最后，本文建议了如何在工程上实现上述量化设计工具，并提出了如何利用现有的技术，将这种工具系统地集成到通信网络基础设施中去。此外，我们推荐了不同的用户与运营商之间的协商方式，包括离线或者在线协商，从而满足不同用户的需求，适应不同运营商的客户关系管理策略；同时运营商之间也能进行业务互动。

综上，本研究的理论贡献在于建立了基于行为模型的个性化业务和资费概念框架。此外，本研究通过整合不同学科领域的研究方法，提供了一套新颖的方式来量化设计个性化的移动通讯业务和资费。

从实践上说，本文提供的设计工具有广泛的应用空间：移动通信运营商可以在现有基础设施上集成该设计工具，以用于基本移动业务套餐和复杂的增值业务的协商。前者是当前移动通信的核心业务，而后者则代表了未来的发展趋势。此外，有意提供个性化业务和资费的社区也可以很容易地实施本文提出的商业模式。

下一步的研究包括：定量分析在个性化业务和资费情况下的用户离网率；建立社区行为模式和计算模型；在用户行为模式和计算模型中考虑情感因素的影响；采用多元极值理论描述和模拟用户需求；以及分析个性化业务和资费对监管和社会的影响。

Curriculum Vitae

Hong Chen (陈宏) was born on January 7th 1977 in Daqing, Heilongjiang, China. He studied Telecommunications Engineering in Beijing University of Posts and Telecommunications from 1995 to 1999. His bachelor dissertation was on "Multi-user detection in an over-saturated CDMA system". He received an MSc degree (cum laude) in Computer Science in 2003 from the University of Twente, the Netherlands. His Master dissertation was on "Accounting facilities in mobile and wireless Internet".

Since January 2004 he has been working as a research assistant and a Ph.D. candidate at the RSM Erasmus University. His research is about individual mobile communications services and tariffs. His research framework, research design and interim research results have been presented at the Fourth International Conference on Electronic Business (2004), the International Conference on Mobile Business (2006, 2007), the IEEE International Conference on Services Computing (2006), the IEE/ACM International Conference on e-Business (2006), the Biennial Conference of the International Telecommunications Society (2006), and the World Conference on Mass Customization and Personalization (2007). He has participated in several research projects in the mobile communications areas. He has also supervised graduate students with their Master's dissertations.

From 1999-2001, he worked in Huawei Technologies (Shenzhen) as an engineer on the GSM and UMTS product lines. In 2002 and 2003, he worked as an intern in Lucent Bell Labs.

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INDIVIDUAL MOBILE COMMUNICATION SERVICES AND TARIFFS

Individual services and tariffs existed briefly in the beginning of telecommunications history 150 years ago but have faded away over time. Service provisioning evolved into the current supplier-centric situation which has many limitations and disadvantages. This thesis re-embraces the user-centric service provisioning and tariffing philosophy and applies it to the current mobile communication services setting, which differs significantly in scale and scope from the historical practices. A design methodology and tool for the determination of individualized mobile services and tariffs is provided, and its benefits to both the user and the supplier are evaluated.

The design has three aspects. The first involves the construction of a conceptual framework consisting of the behavioral models of the user and the supplier (firm) and a game theoretical negotiation mechanism to determine individual services and tariffs. Second is the operationalization of the conceptual framework in a computational design with methods, computational models, negotiation algorithms, risk metrics and a prototype implementation. Third is the extension of the individual services and tariffs concept to a community setting via a proposed community business model.

Two evaluations are performed. In the first evaluation, for the firm-based design, a user survey is conducted and computational cases which address value-added mobile services and generic mobile service bundles are developed. The numerical analyses show that the users always achieve gains in utility. The benefits to the supplier include adjustable risk-profit equilibrium points, increased network traffic and reduced churn. In the second evaluation, for the community-based design, two case studies on communities are conducted. The results demonstrate that the proposed business model of community-based individual service provisioning and tariffing can meet the demands of their members precisely and address both affordability and sustainability issues.

Last, a specific engineering implementation and integration of the individualized service and tariff design tools into the existing infrastructure of the communication services suppliers is proposed. Further research issues are pointed out.

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