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Individual Tariffs for Mobile Services: Theoretical Framework and a Computational Case in Mobile Music

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Abstract

This paper introduces individual tariffs at service and content bundle level in mobile communications. It gives a theoretical framework (economic, sociological) as well as a computational game solution method. The user can be an individual or a community. Individual tariffs are decided through interactions between the user and the supplier. A numerical example from mobile music illustrates the concepts.

1. Introduction

Telecommunication industry thrived in the 20th century under economies of scale, where users paid same prices for standard services [1]. Value-added and personalized services are quickly gaining ground. Differentiated services are calling for individual tariffs. This paper aims to develop a theoretical framework for the development of computational models of individual tariffs for mobile service bundles. The ultimate goal is to provide a tool so that the determination processes of individual tariffs are automated or semi automated and the prohibitive service provisioning overhead is avoided.

This paper is organized as follows: Section 2 introduces basic concepts; Section 3 starts with incentives for individual tariffs both from sociological and economic perspectives; it then brings out a theoretical framework for individual tariffs which is built on user and supplier behaviors and their interactions. Game theory is used as an analytical design tool and introduced in Section 4. Section 5 introduces a computational model with an example from mobile music services. The paper concludes in Section 6.

2. Basic concepts

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 some duration. In this research, we focus on individual tariffs for mobile services.

The ***users or beneficiaries*** of individual tariffs are the recipients of services. The ***service provider/supplier*** is defined in a broad sense as the entity that provides access, content and applications, or a combination of these, to users. We identify four types of service providers: firms; closed communities where membership is required; open communities which do not require a formal membership and ultimately, individuals.

3. A theoretical framework for individual tariffs

3.1 Intrinsic drivers for individual tariffs

Not all individual users are willing to consider personalized services and tariffs. Some prefer a pre-determined bundle with little transparency and limited choices. But there are values held by a growing population expecting personalized services and individual tariffs. Here is a non-exhausted list of drivers that we consider to be fundamental.

Individualism. Different schools have contradicting interpretations. We adhere to the individualism defended by Hayek [2]. Personalized mobile services and tariffs are reflections of Hayek's individualism; where a person in a free society has the freedom of movement and a choice of services, anytime and anywhere. It is also reflected in the freedom of service creation and of provision, either to a family, a community, 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 [3]. “How shall I live?” has to be answered in day-to-day decisions about how to behave, what to wear and what to use, etc. Modernity opens up the “project of the self”, but under strong influence of standardization of needed commodities. A good example is the corruption of the notion of “life style”, where the “project of self” has been associated with the possession or consumption of certain pre-determined services. The consequence is the suppression of the genuine development of the self. To move away from this predicament an individual should surround himself with personalised experiences. Personalized services and tariffs promote 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 [4] as an idea, practice or object that is perceived as new by an individual or other unit of adoption. Innovation in our context of tariffs is “user-centric”, which is in sharp contrast with the supplier-centred tradition in telecom 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 tools and shared knowledge to create new services to accommodate users’ unique demands; user-centric innovations are often freely revealed. The creation of personalized mobile services used to be inhibited by technology, knowledge and economic constraints. With the first two being greatly pushed forward nowadays, the research on individual tariffs aims to alleviate the last constraint and ultimately unleash the spirit of innovation from ordinary people.

3.2. Economic incentives for individual tariffs

Price discrimination. The concept was coined by A.C Pigou [5], who distinguished three types of price discrimination. Different types of price discrimination have different welfare effects in terms of maximizing consumer plus supplier surplus. Theoretically, first-degree price discrimination leads to a Pareto efficient outcome.

On the other hand, Eden [6] observed that price discrimination and price dispersion can occur in a competitive environment, where price dispersion equilibrium can be achieved when competitors all charge discriminatory prices but the mix of prices vary among firms. Levine [7] argued that price discrimination is not necessarily the 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 [8] demonstrated that for industries that involve technologies which exhibit increasing returns to scale, large fixed and sunk costs, and significant economies of scope, the rule of setting prices at marginal cost is no longer economically viable: the marginal cost is close to zero. The pricing principle under this context should be that marginal willingness to pay equals to marginal cost.

Individual tariffs invite users to be actively involved in service personalization and pay according to their need and willingness. It provides a possible approach to implement the idea of first-degree price discrimination and push the market to Pareto efficiency under a fully competitive environment.

Willingness-to-pay *(or* WTP) is the maximum amount of money the user is prepared to pay for a service, which is a measurement of the value that the user puts to the service. WTP is higher when attributes of a service meet precisely the user demands, which is also one of the economic reasons that call for personalized services and tariffs.

It is quite unlikely, if not impossible, that the supplier can identify all the demands of users simply by observations and offer every possible choice. Even if the supplier does, the burden of having to choose from too many options may lead simply to information overload and frustrate the user. A plausible solution is to introduce interactions and change the role of the user from being hidden inside a passive audience to become an active player in co-creating value.

3.3 User behaviours

The concept of the “economic person” describes a model of a person who seeks to attain specific and predetermined goals to the greatest extent with least possible costs. He/she 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.

Bounded rationality. The strict definition of rationality states that, an individual’s preference relation is rational if it possesses the properties of completeness and transitivity. It means the individual is able to compare all the alternatives and the comparisons are consistent. Furthermore, rationality implies that the individual has complete information of all alternatives and knows about the consequences of his choices; he also has unlimited time and unlimited computational power to pick his most preferred option. In reality, such perfectly-rational person never exists.

Herbert Simon has pointed out that most of the time an individual does not know all the alternatives. Simon characterized this as “bounded rationality”. Model construction under the bounded rationality assumption can take two approaches. First is to retain optimization, but to ***simplify it sufficiently*** so the optimum is computable. Second is to construct a ***satisficing*** model which provides decisions good enough, with reasonable computational cost [9]. Neither approach dominates the other.

Following the work of Simon on bounded rationality, Kahneman and Tversky [10] conducted research on various types of judgement about uncertain events. Their conclusion was that people rely on a limited number of heuristic principles which reduce the complex tasks of assessing probabilities and predicting values to simpler judgemental operations.

A social dimension. The "self-interested" property of the "economic person" implies that he/she is amoral and has no sense of right or wrong. He/she ignores all social values, unless adhering to them gives benefits; preferences are exogenous and not affected by societal rules at all. However, it is never true. In choosing to act, individuals commonly consider the consequences of actions not only for themselves but others as well; they have social preferences [11]. We contend that the social preferences for mobile services are decided by the benefits that an individual elicits from the communications based interactions under different social environments and with different people. Major factors affecting social preferences are: a.) Social context, by which we mean the social environment that an individual lives in, such as location and social relationships. At different locations and accompanied by different people, an individual's preferences are affected by specific social norms and social relationships [12]. b.) Content. The content of a communication service can be categorized as time critical or non time critical according to the perceived importance of a timely service. Moreover, content can be categorized based on whether the communication is motivated directly or indirectly. In directly motivated communication, the action satisfies a need; in indirectly motivated communication, the action satisfies an intermediate goal, which can in turn lead to the satisfaction of a need; what is important is the fact that the communication has occurred[13].

Modified behaviour model. The differences in behaviour among users can be studied by analyzing the decision rules, which lead to different choices. Specifically, we consider two types of utilities of mobile communication services, namely economic utility and social utility. Economic utility 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 with a machine. An individual elicits social utility from the social interactions which the mobile service enabled. A preference relation can be represented by a utility function only if it is rational, where the preference must satisfy completeness and transitivity. Many preferences, especially social preferences, are partially rational or irrational. Therefore many situations can not 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 monotonic function, then there exists a utility function that can be used for computational purposes.

A mobile service normally has multiple attributes; the utility function is then constructed by following the methods from multiple attribute utility theory. 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 relative importance.

The individual tries to optimize his utility. Due to his bounded rationality, his optimizations are carried out in a much simpler way. We propose that the user builds his utility function based on a set of "perceived attributes" of a mobile service. The "perceived attributes" are different from the service attributes defined by the service provider using full technical specifications. For an individual user, an operation of "***attribute substitution + simplification***" takes place in such a way that it not only simplifies the understanding of service attributes but also significantly reduces the number of them. As a consequence, the individual optimizes on a much simpler utility function in lower dimensionality space.

The individual does not have complete information of all the alternatives; neither does he have full information of the supplier. Indeed, the individual learns from the service personalization and tariff negotiation process. He acquires more information through the interactions with the service provider, either explicitly or through inference.

When making a decision to accept or not an individual tariff, the individual uses satisficing rules and tries to achieve an acceptable level of utility before he stops.

3.4. Supplier behaviours

We also take a utilitarian approach when modelling a supplier's behaviour. When the supplier is a single firm, economic utility is elicited from economic benefits such as profit or market share, which are generated by the service offering.

The goals of a community, when offering mobile services, are to achieve financial breakeven and minimize service provisioning risks. On one hand, a community can buy or exchange services with a firm or a community. In a way, it plays the role of an aggregator who accumulates demands from its members and acts as an entity with more bargaining power than a single individual while negotiating with other suppliers. On the other hand, the services can be created, maintained and used by the members of the community. In this setting, users themselves act as a supplier.

When a single individual is the supplier, he can either choose to seek profit and acts as a firm, or to achieve financial breakeven.

4. Analytical design calculation using computational game theory

Game theory, as a formal analytical approach, has applications in a variety of fields. The main advantage of game theory is that it provides a structured analysis of decisions, which are made as reactions to another player's decisions. Over years, game theory has evolved to incorporate "bounded rationality" in its analyses [14]. Further, the cooperation between disciplines such as computer sciences, artificial intelligence and economics gave birth to computational game theory which enables richer ways of modelling complex problems of interactions in an efficient way by computers.

Individual tariffs are decided in the interactions between the user and the supplier. The bilateral contracting procedure between them can be modelled by an imperfect information game, where the payoffs are the utilities that both parties receive from the service. In general, the negotiation process is modelled by a recursive Stackelberg game, where the first player has a dominant influence over the followers. We empower the user by letting him move first. Different decision rules and constraints can be applied to investigate the equilibrium, if it exits, when the individual sets his service and price requirement to the supplier.

5. A computational model and an example

5.1 Service design space & perceptual space

As mobile and computing technologies evolve, technical specifications of a mobile service become much more complex. From a supplier's perspective, it is common to define tens or even hundreds of service attributes in a single service. We define a space that is constructed by these technical attributes as a service design space (or an explicit space). Each dimension in this space corresponds to a technical attribute of the service, including tariff, duration, etc.

We define a perceptual space as a space constructed by the perceived attributes of a service (e.g. 'a fast connection'). The perceived attributes are actually the results of a reduced mapping or an "attribute substitution plus simplification". The reduced mapping is based on certain heuristics or as a result of the matching of technical attributes into features that the user in general can relate to; in our proposed approach the perceived attributes are determined by surveying inside user communities.

When reaching an agreement with a supplier, the user wants the details to be specified in text or on a specification form. Service level agreements (SLAs), which use to be a way to ensure quality of service (QoS), are becoming increasingly common to set commercial and business terms for service provisioning [15]. SLAs generally take the form of a structured template, with specific QoS metrics that are evaluated over a specific time interval or to a set of defined objectives. Thus SLAs are often written in technical language. To reach a concrete SLA, a translation or a mapping between the explicit space and the perceptual space is necessary.

5.2 The user

Suppose users can be divided into groups which share similar preferences for a specific class of services. We employ a statistical method called principle component analysis (PCA) to find out the mapping between an explicit space and a perceptual space for a specific group. We assume the mapping to be valid for a new user, who can be placed in the same group.

Denote the explicit space as the x space; the technical attributes as vector $x = [x_1, x_2 \dots x_n]$. The samples are the members in the group's revealed target values for service attributes in the x space. PCA generates new vectors which are linear combinations of $x_1, x_2 \dots x_n$ [16]. Denote the PCA space as z space, the PCA components as $z = [z_1, z_2 \dots z_n]$, and the principle component coefficient matrix as p (each column containing the coefficients for one principal component), we have $z=x\,p$.

The interpretation of the PCA components is service specific. In reality z space has much smaller dimensionality than x space due to user's perceptual capabilities. For a given service, we analyze the first components which cover +/-80 % of variance. Experiment has shown that these first few components often are just three or four, which is very convenient for users.

The next step is the elicitation of a utility function. User's utility function, if it exists, is derived based on the reduced set of (PCA) components, following the multiple attribute utility theory approach. In simple terms, the user sets his target /desired point in the service specific perceptual space, and will seek out a deal close enough to this point. Mobile services involve lots of social aspects. User's revealed preferences may not possess the properties which are the necessary conditions to find a utility function. On the other hand, by working only in a perceptual space, it is easy for the user to set where he would like to be, and that is called a target point (actually a vector of values), which mixes economic and social aspects of the service. In this model, we assume the user's utility function is the inverse of the Euclidean distance from a user's best reachable points (because of constraints) to his target point. A user optimizes his utility by approaching as close as possible to his target point. This is also a simplified decision process. The 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 interaction preferences may overshadow a more favourable price.

5.3 The supplier

The supplier, as a profit-oriented company, is assumed to make decisions based only on his economic utility. We define this utility as the expected marginal profit that the supplier receives from serving a specific individual user. The utility function is defined in terms of attributes in the explicit space including price and service provisioning costs. The supplier maximizes his utility, under certain provisioning constraints.

5.4 The negotiation process

During service personalization, a user and a supplier negotiate on a set of service attributes and their values, including tariffs/price/duration in view of an SLA. The negotiation process has a non-cooperative and recursive nature. It is modelled as an n-stage user-lead Stackelberg game. The individual user is the leader as he sets forth first his wishes in the context of individual tariffs, and not the supplier as it in supplier driven public tariffs. During each stage, each player tries sequentially to optimize his own utility taking into account what the other has proposed under his own constraints. Players update their constraints based on what others proposed as mutually dependent decision bounds.

Payoffs & constraints*:* the players' payoffs are expressed by their utility functions. User's utility function is expressed in a perceptual (z) space while the supplier's is expressed in the technical (x) space. Optimization of the user utility is carried out in the z space and optimization of the supplier utility in the x space. Players set their constraints separately and explicitly in x space, such as maximum price or minimum QoS features. The final SLA is expressed in technical x space in view of provisioning by the supplier. Since the user's utility function, constraints, optimization and SLA are expressed in two different spaces, transformations from one space to another is carried out when necessary.

Equilibrium: A one-stage Stackelberg game can be solved to find a Nash equilibrium, which is a profile of actions with the property that no player can deviate to achieve a better payoff, given the actions of the other player. In the recursive Stackelberg game used in our model, we define an equilibrium point as a point where no player can elicit a higher utility by deviation or entering a new stage of the game; furthermore, the point should also provide the supplier a non-negative payoff.

Negotiation process: It has several steps.

Step 0: In the beginning, the supplier advertises the offering of a class of mobile services. The service attributes (including "list price") and their values are expressed in x space (denoted as x_offer^0). The service attributes are translated into perceptual attributes, thanks to a pre-existing survey amongst potential users of the service. The individual user sets his target values for the perceptual attributes based on his individual preferences. The values of the attributes of the public offer from the supplier are also mapped into the user's perceptual space: it serves as an initial reference point for the user (denoted as z_offer^0).

Step 1: User optimizes his utility in z space, under his own constraints and taking into consideration the supplier's offer. Denote the user's choice in z space as z_user. User's objective at stage *i* is to maximize his utility $z\_user\_utility(z\_user^i)$, subject to $z\_constraint\_user(z\_user^i, z\_offer^{(i-1)}) \leqslant 0$. The constraints can be linear and nonlinear. *i=1, 2 ... k*, represents the round of negotiation (*i-th* stage of the game). $z\_offer^{(i-1)}$ represents the supplier's offer in the (*i-1)-th* round. The result of user's optimization at stage *i* is denoted as $z\_user\_result^i$; it is then transformed into x space as $x\_user\_result^i$.

Step 2: User decides whether to stop or not, based on his own decision rules. In case of the former, he may opt out to take the public "list price" or to negotiate with another supplier. If the user decides to continue the present negotiation, he communicates with the operator about his request, which is $x\_user\_result^i$. The user may at the same time signal to the supplier a possible tolerance region in x space.

Step 3: The supplier updates his constraints regarding the proposed value $x\_user\_result^i$ and the possible tolerance region signalled by the user. He then calculates his own optimum under the updated constraints. Denote the supplier's choice in x space as x_operator. The supplier maximizes at stage i his utility x_operator_utility(x_operator^i), subject to x_constraint_operator(x_operator^i, x_user_result^i)$\leq$ 0. The constraints can be linear and nonlinear. $i=1, 2\ldots k$ represents the round of negotiation. The result is denoted as x_operator_result^i. The supplier then decides whether to accept the proposal, or to propose back his last optimized values. He may stop the game based on his own decision rules.

Recursion and Stopping rules: the procedure repeats from (1)--(3) until it satisfies one of the following conditions: z_user_result$^{(m+1)}$ = z_user_result^m or x_operator_result$^{(m+1)}$ = x_operator_result^m. Either player can stop the game when the results show a non-convergence trend, which either appears as an oscillation (e.g. $\|$z_user_result$^{(m+1)}$ - z_user_result$^m\|$ = d, d $\neq$ 0) or an amplification (e.g. $\|$z_user_result^m - z_user_result$^{(m-1)}\|$ < $\|$z_user_result$^{(m+1)}$ - z_user_result$^m\|$). Furthermore, the supplier will stop the game when the result of his optimization leads him to negative profit.

5.5 Implementation and preliminary results in mobile music

We developed a tool to automate the numerical calculation of utilities and the negotiation process of tariff and service personalization. One off-line part calculates the PCA mapping between the explicit space and the perceptual space from a group-survey of potential users with latent interest in the service. The other on-line part decides if an equilibrium exists based on the utility functions, constraints and decision rules set by both players, and computes the equilibrium.

We applied our technique in the context of the fast growing personalized mobile music services. Many operators have already begun to offer mobile music services [17]; some can even be personalized (e.g. the "Radio DJ" service by Vodafone: www.vodafone.de/music), but none of them offer yet personalized tariffs. Our service is called "mobile singing classroom" where the users can improve their singing performance by following the courses and getting instructions and content. Users are supposed to be just individuals with interest in singing and/or music; the supplier is a mobile operator assisted by teachers. Table I shows for illustration purposes the revealed preferences from three users (A, B, C) and the negotiation results. Gains and losses (when compared to the public "list price") are analysed for each player; the results can be a win-win or win-loss situation. Users, as leaders of the games, achieve gains. The differences in gains across users stem from their different preferences and constraints. The operator achieves better results in two cases but a worse result in one case. Detailed descriptions of the software implementation and full results of the mobile singing classroom case are available in [18].

Table I: User revealed preferences, operator's public "list price" offer and negotiation results

	Initial service requests			Public offer by opera-tor	Final negotiation result		
Name of users	A	B	C		A	B	C
Database size Thousand song)	6	1	3	2	5.6	1.9	2.6
Instructions per lesson	2	8	4	4	2.1	6.2	3.2
Coding rate of songs (kbps)	128	144	144	114	130	119	122
SMS searches per lesson	7	1	3	2	6.2	1.9	3.0
Distribution method (1-10 from fixed to mobile)	3	9	7	5	5.8	7.3	5.6
Number of question student asks (full contract period)	2	60	30	10	1	58.3	1.3
Contract length (month)	2	4	3	2	1.6	5.2	2.5
Number of lesson per month	20	8	10	5	19	6.1	8.4
User's bid for the service (full contract period €)	100	100	70	30	63	98	53

6. Conclusions

This paper tries to carve out a small piece of land in the uncharted field of individual tariffs in mobile communication services at bundle level (traffic, content, support). The work aims to provide guidance to build computational models. In terms of practical implementation, our negotiation approach allows for users essentially just to compare their wish with the list price in the perceptual space, or to enter the wishes into a customer relation management system toolbox, or to engage in a full interactive negotiation with no high costs on operator side. Thus the old argument that "personalization costs" were a show-stopper, does not apply anymore.

The preliminary results from the computational model in a mobile music case show that individual tariffs can be beneficial to both users the supplier. Our next steps of work involve limited operational deployment, possibly with a supplier. The other part will be on the risk pooling at operator level for the explicit determination of lowest profit.

References

[1] H. Chen and L. Pau, "Individual Telecommunications Tariffs in Chinese Communities: History as a Mirror of the Future, and Relevance for Mobile Service Development in China," presented at The Fourth International Conference on Electronic Business, Beijing, 2004.

[2] F. A. Hayek, *Individualism and economic order*: University of Chicago Press, 1980.

[3] A. Giddens, *Modernity and self-identity: self and society in the late modern age*. Cambridge: Polity Press, 1991.

[4] E. M. Rogers, *Diffusion of Innovations*, 5th ed. New York, London, Toronto, Sydney: Free Press, 2003.

[5] A. C. Pigou, "Discrimination Monopoly (Part II, Chapter XVII)," in *The Economics of welfare*. London: Macmillan and Co, 1920.

[6] B. Eden, "Marginal Cost Pricing When Spot Markets are Complete," *Journal of Political Economy*, vol. 98, pp. 1293-1306, 1990.

[7] M. E. Levine, "Price Discrimination Without Market Power," in *Law-Econ Discussion Paper No. 276*: Harvard Law School, 2001.

[8] H. R. Varian, "Differential Pricing and Efficiency," *First Monday*, 1996.

[9] H. A. Simon, "Rational Decision Making in Business Organizations," *American Economic Review*, vol. 69, pp. 493-513, 1979.

[10] A. Tversky and D. Kahneman, "Judgment under Uncertainty: Heuristics and Biases," D. Kahneman, P. Slovic, and A. Tversky, Eds. New York: Cambridge University Press, 1974, pp. 1124-31.

[11] S. Bowles, *Microeconomics: behavior, institutions, and evolution*. New York: Russell Sage Foundation, 2004.

[12] A. Lasen, "A Comparative Study of Mobile Phone Use in Public Places in London, Madrid and Paris," Digital World Research Centre, University of Surrey, 2002.

[13] C. Licoppe, "The Social Context of the Mobile Phone Use of Norwegian Teens," in *Machines That Become Us: The Social Context of Personal Communication Technology*, J. E. Katz, Ed. New Brunswick, N.J: Transaction Publishing, 2003.

[14] R. J. Aumann, "Rationality and Bounded Rationality," *Games and Economic Behavior*, vol. 21, pp. 2-14, 1997.

[15] L.-F. Pau, "Privacy management contracts and economics, using Service Level Agreements (SLA)," Erasmus Research Institute of Management, Rotterdam, ERIM report series research in management; ERS-2005-014-LIS, 2005.

[16] J. M. Lattin, J. D. Carroll, and P. E. Green, *Analyzing multivariate data*. Pacific Grove, CA: Thomson/Brooks/Cole, 2003.

[17] S. Manes, "Music in the Air," *Forbes*, vol. 176, pp. 74, 2005.

[18] H. Chen and L.-F. Pau, "Individual Tariffs for Mobile Communication Services: a Computational Model," Accepted by 16th Biennial Conference of the International Telecommunications Society, Beijing, 2006.

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