

Optimized IP-CANs to Support Best Charged IMS Scenarios

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Abstract—The pricing and charging mechanisms used in Next Generation Network (NGN) deployments will influence the profitability of network operators. NGNs present an opportunity for the success of service delivery platforms designed for IP multimedia communications, like the IP Multimedia Subsystem (IMS). Moreover, they present a platform for the delivery of a multitude of applications and services to users with different expectations and budgets. Although usage-based charging schemes are more meaningful, some recent successful Internet-based applications and services have attracted widespread usage due to enforcement of flat-rate pricing. The choice of a pricing scheme often has a one-to-one relation to the access network technology and the quality of service guarantee. Flat-rate pricing may easily be associated with best effort transport. This implies that some users opt for services without QoS guarantee when favoured by the pricing methodology. This paper explores scenarios where services with different QoS requirements available to users with varying pricing preferences can be provided over a set of IP connection access networks (IP-CANs) of the IMS. We explore the use of different pricing schemes for different IP-CANs of the IMS. We perform testbed evaluations and present results depicting the income patterns of networks enforcing different pricing and charging schemes for VoIP and IPTV services. Moreover, we emphasize the use of simplified pricing schemes on communication networks.

Index Terms—Charging, IMS, IP-CAN, IPTV, Pricing, VoIP

I. INTRODUCTION

Advancements in technology have facilitated the creation of networks with much higher bandwidth and greater traffic handling capacity [1]. This capacity has fostered competition among network operators and Internet Service Providers (ISP). Competition forces network operators to lower charges levied for network transport services. The demand for network resources has increased tremendously as a result of the popularity of multimedia services delivered using IP; a good example is the advent of IPTV [1], [2]. The growth of broadband communications has benefited from the simplicity of the Internet Protocol (IP) and the Session Initiation Protocol (SIP) [3]. These protocols facilitate the deployment of cheaper network equipment, and the convergence of communication platforms. The diversity of applications and services supported by converged networks is reflected in the diversity in service quality experience and expectations end users have regarding the price paid for these services.

Voice telephony has been priced on duration basis for many years. The distance between the calling and the called parties is often considered [4]. Pricing of early circuit switched data communications adopted the pricing trends of voice

TABLE I
IP-CAN AND CHARGING MODELS FOR VoIP AND IPTV

IP-CAN	WLAN	WiMax	UMTS	xDSL	Ethernet
Charging-Model					
Flat-rate	Y	N	N	Y	Y
Duration-based	Y	Y	Y	Y	Y
Volume-based	Y	Y	Y	Y	Y
QoS-based	N	Y	Y	N	N

communications; other pricing options, e.g., cell, packet and byte based pricing for packet data communications were later adopted. Some retailers of packet data network access still charge users on duration basis. The meaningful reason for this is the simplicity of such pricing options, and the fact that users often associate pricing schemes with particular services. Thus, it would be hard for users to understand a byte-based pricing scheme for IP based voice telephony i.e., VoIP. An illustration of possible charging models for different IP connection access networks for VoIP and IPTV is given in table I.

On the Internet, packet data communications involve best effort transport, and charging is done on flat-rate basis. Despite the lack of QoS guarantee, VoIP on the Internet has become a popular and cheap option over regular circuit switched telephony.

Telco operators have been experiencing a decline in the Average Revenue per User (ARPU) for voice communications, a trend that can be attributed to the use of alternative network access options to VoIP service delivery platforms. A typical scenario is when a user connects to a free VoIP provider to make calls using their home Internet connection (e.g., ADSL). Their ISP may not guarantee any QoS for voice traffic, but the availability of adequate bandwidth in the access link and the IP core enables the achievement of satisfactory voice communication. We note that the need for mobile voice telephony still gives an advantage to mobile telco operators. However, the existence of wireless LAN (WLAN) hotspots driven by the IEEE 802.11 group of networks¹ enables users to connect to their VoIP providers almost anywhere and at anytime.

Converged billing platforms for fixed and mobile networks facilitate the management of user subscriptions. With this approach users are provided with an identity that enables them to access a subset of services via networks tied to their subscription. However, if the bundled services in the subscription do not translate to lower overall costs users may still seek for cheaper options for service delivery. It is necessary for

¹Wireless metropolitan area networks (WiMax - 802.16) are also emerging

operators to not only consider the costs associated with service delivery when formulating pricing plans, but also the value different consumers attach to requested services. In an effort to provide a fully converged platform for multimedia service delivery, the 3GPP developed the IP Multimedia Subsystem.

Pricing for IP transport services is often related to the level of network performance guarantee achieved by a flow. Considering the various QoS capabilities of IMS IP-CANs, existing business scenarios, and requirements and behaviors of a diverse range of users, we explore trends for the creation of logical optimized IMS IP-CANs to facilitate the best-charged option for network access for a set of user needs of IMS services. Best charged IP-CAN essentially means that, based on service customization by a user, the network will setup a logical IP-CAN on the physical IP-CAN the user is currently connected to, to provide a certain level of quality guarantee at an accompanying charge that suits the user's needs and budget. In essence a network that supports best-charged IP-CANs for its users will provide interfaces for the users to specify their primary IP-CAN.

Facilitating a best-charged service delivery environment will not only enable telco operators to compete against network access options that offer their previously lucrative services freely, but it will also ease the burden users experience in seeking a cheaper option for network services, e.g., IPTV and VoIP. This paper explores mechanisms for assigning networks and allocating resources to users according to pricing options that will influence the charges incurred. This work is explored in the domain of the IMS; hence, we present discussions based on IMS procedures. The rest of the paper is structured as follows: section II reviews literature related to access network dependent QoS-based charging, and also reviews QoS provisioning in the IMS, a brief introduction to IPTV in the IMS is presented; section III presents the approach proposed in this paper for the achievement of best-charged service delivery for IMS services; section IV presents a testbed implementation of charging in the IMS, this takes into account the access network used by the user and pricing preferences indicated by the user; section V presents testbed results of charging IPTV and VoIP services and analysis of the expected user distribution on different IP-CANs when best charged IP-CANs are employed; section VI concludes the paper.

II. CHARGING AND QoS IN COMMUNICATION NETWORKS AND THE IMS

Pricing for network transport services relates to the amount of resources allocated to or reserved for a given flow. The widespread deployment of newer services e.g., video telephony and IPTV utilizes packet switched networks. The simplicity of IP contributed to the widespread deployment of IP networks. However, it has the disadvantage of less control on which connections get allocated network resources².

With the convergence of communication platforms, the same IP core networks are used for the transport of data, voice and video. Different network access technologies support

different data rates and QoS. Thus, the bottleneck on an end-to-end connection between communicating nodes may lie in the access networks. This is evident, for example, when considering 3G access.

If WiMax and the 3GPP Long Term Evolution (LTE) Radio Access Networks (RAN) were deployed in the access domain, more bandwidth would be available on the common channels.

The business model governing Internet access via mobile networks consists of subscribers paying a network usage fee for all services. The deployment of WLANs created an Internet access scenario with a business model involving mid-term to long-term payments for Internet access. In private deployments of WLANs subscribers pay only for the back-haul connection to the Internet. The back-haul connection may be priced based on the maximum achievable data rate, and a data cap over a specified period, e.g., one month. To remain competitive in the provisioning of data services, 3G operators also adopted the data cap dependent bundle pricing scheme for Internet access.

Main stream telcos may achieve QoS on their IP networks. It should however, be noted that VoIP on the Internet is currently provided with slightly degraded quality, but the level of service satisfaction users get increases when network congestion levels decline. Low service cost is the main justification for user satisfaction.

In order to attract more subscribers to utilize their networks, mainstream telco operators may support classes of service that approximate to a better than best effort performance. In the 3GPP family of networks, the provisioning of VoIP and IPTV services [6] has been standardized as part of the the IP Multimedia Subsystem (IMS). The 3GPP rel. 7 [7] harmonizes policy control and charging in the Policy Control and Charging (PCC) architecture.

A. QoS Provisioning in the IMS

Initially policy control in the IMS was standardized for the UMTS access network; later other access technologies were incorporated. The QoS management architecture defines an Application Function (AF), e.g., a Proxy Call Session Control Function (P-CSCF), a Policy and Charging Rules Function (PCRF), and the Policy and Charging Enforcement Function (PCEF). The AF would request resources from the transport plane; the PCRF performs resource management, while the PCEF resides on the transport plane where network policies are enforced [7].

B. Charging in the IMS

The 3GPP defined charging model caters for volume, time and event based charging [8]. High level charging requirements include the ability to change the tariff based on location, access network connection and time of day. Essentially charging in the IMS involves Charging Trigger Functions (CTF), and offline and online charging systems.

C. QoS aware charging

QoS charging utilizes pricing models that reflect the achieved level of network performance. Flat-rate pricing is the simplest and most attractive scheme for charging network transport services. Flat-rate pricing may be used on all of the IP-CANs standardized for the IMS; different tariff values and

²IP does not have QoS support capabilities; schemes like the DiffServ architecture [5] were designed to achieve wholesale-style QoS guarantees for IP flows

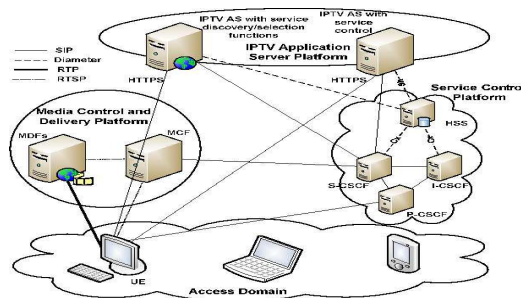


Fig. 1. IMS-based IPTV architecture [6]

data caps can be used for various access technologies. Higher QoS classes may be defined for the IP-CANs, and corresponding tariff rates would apply. Duration-based charging for VoIP, IPTV and other multimedia services is an attractive candidate for the higher QoS classes.

D. IPTV in the IMS

IMS-based IPTV benefits from the enhanced service control capability of the IMS, e.g., QoS control, charging and billing services [6]. Figure 1 illustrates a high level view of an IMS-based IPTV architecture. The IMS Session Control Functions (SCFs) execute and control user sessions. For the purpose of billing, some of the elements are responsible for usage accounting. The IPTV application server provides service information to the User Equipment (UE), the Media Control Function (MCF) selects and controls content distribution to the Media Delivery Function (MDF); the MDFs are responsible for the delivery of media to the UE.

There are three types of IPTV services, i.e., broadcast services, unicast services e.g., Video on Demand (VoD) and Personal Video Recorder (PVR) [6]. The IPTV scenario explored in this paper implements broadcast and unicast (VoD) services.

III. OPTIMIZED CHARGING FOR IMS IP-CANs

The IMS core facilitates the establishment of multimedia sessions whose requests originate and terminate at user agents that connect via different IP-CANs. Telco operators may attract greater usage of their networks by enabling users to indicate their primary IP-CAN for services like VoIP and IPTV, and the desired level of service quality. We define a virtual (logical) IP-CAN as a channel of specific characteristics that is created within a given physical IP-CAN and has characteristics similar to an emulated IP-CAN. For example a logical WLAN IP-CAN may be created within a UTRAN IP-CAN; the logical IP-CAN will exhibit WLAN performance. A media session delivered on logical IP-CAN will be charged according to the pre-defined charging mechanisms for the emulated (primary) IP-CAN. We explore the use of user oriented pricing models to support VoIP and IPTV services within the IMS using various IP-CANs. We consider 3G, WiMax and WLAN IP-CANs. 3G and WiMax exhibit QoS control, while WLAN offers best effort service.

Whenever a user registers to the IMS and establishes a media session, the network will attempt to offer service delivery according to the characteristics of the user's primary IP-CAN. Thus, services will be offered to the user on any

TABLE II
PAYMENT MODELS FOR WLAN IMS ACCESS

Originating Network	Terminating Network	Access and service Fees
WLAN	PSTN	Caller only
WLAN	PLMN (e.g., UMTS)	Caller only
WLAN	WLAN or Ethernet	Caller and Callee

network and at any time with applicable IP-CAN charging. The network will provide interfaces for users to specify their primary IP-CAN.

A. Charging for WLAN IMS Access

The majority of WLAN deployments are based on IEEE 802.11a,b,g standards; they support high data rates but do not offer QoS support to users. In commercial deployments users of VoIP and IPTV will pay for services provided by a WLAN provider. Assuming the user initiates a VoIP call to a callee who is using a PLMN or PSTN phone, the caller would also pay a fee for the interconnection service provided by a VoIP provider to the terminating network. In an IMS scenario, the network operator would be the WLAN and VoIP or IPTV provider. Network transport and service fees will be merged, hence transparent to the caller. Table II illustrates the possible service payment options for WLAN VoIP and IPTV access.

B. Charging for WiMax and 3G IMS Access

The WiMax standard defines four QoS classes with distinct characteristics [9]. Specific to optimized IP-CANs for the IMS, the Unsolicited Grant Service (UGS) class can be used with user profiles that support guaranteed delay and bandwidth. The real-time polling service (rt-PS) can map to profiles that translate to guarantees on bandwidth bounds and minimal delay guarantees. The non real-time polling class (nrt-PS) class would fit a profile that supports loose guarantees on bandwidth and no guarantee on delay. This class is comparable to WLAN in lightly loaded conditions. Finally the best effort (BE) class doesn't offer any QoS guarantee.

For VoIP and IPTV services the level of charges would depend on the applicable scheme as discussed for WLAN charging; duration based charging may be used. Logical WLAN IP-CANs can be created on the WiMax IP-CAN using the nrt-PS class.

For 3G, charging mechanisms similar to the WiMax IP-CAN may be used. It is acceptable to assume that the 3G operator would also be the IMS provider, thus the convergence of service and network transport charges would suffice.

In this paper we investigate the relation between the use of different VoIP and IPTV codecs and the volume of exchanged media traffic in a typical media session. We also investigate hypothetical income trends of IMS operators when optimally charged IP-CANs are enabled. We conduct tests to investigate the feasibility of optimized IP-CAN charging for the IMS on a real IMS prototype. The IMS testbed was setup using open source software from Fraunhofer Fokus [10]; the tests also utilized the UCT IMS client [11] and the UCT advanced IPTV server [12]. An IMS IPTV charging system designed and developed as part of this work is presented.

C. Online and Offline Charging

Online charging requires credit control to enforce, in real-time, restrictions to the usage of network resources. We design

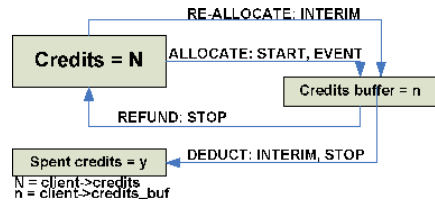


Fig. 2. Online Charging System

an online charging system (OCS) according to 3GPP standards [7]. Figure 2 illustrates the operation of the credit control algorithm in the OCS.

A CTF located where service usage control is enforced performs service usage accounting and sends charging data records to the charging data function (CDF) for offline charging and the OCS for online charging. In the design of an IPTV charging system, when a user makes a service request, e.g., a TV channel, a 'client container' is created at the CTF³. An accounting authorization request is sent to the respective charging systems.

In online charging a Credit Control Request (CCR) is sent to the OCS; the OCS responds with an allocation of credits to authorize service usage for a given time frame. On receiving credit allocation, the CTF responds to the IPTV server, which then completes the session request by sending media content address to the UE. The CTF continuously monitors resource usage and sends periodic *INTERIM* reports of the consumed resources, e.g., duration of the session to the OCS. If needed the OCS allocates more credits for continued service delivery. In offline charging, the CTF accounts for resource usage and sends *INTERIM* reports on resource usage to the CDF.

D. User Profiles

Through user profiles, the network obtains information for selecting an applicable charging model and allocation of a logical IP-CAN; this translates to the selection of media codecs and allocation of network resources.

IV. IMPLEMENTATION AND TESTING

The Open Source IMS (OSIMS) software from Fokus was extended to support VoIP and IPTV charging for event-based, flat-rate and duration based charging. It supports offline and online charging. We account for the volume of data transferred for different VoIP sessions and analyze its relation to different audio codecs. This gives an insight into relative tariff levels to be used for different pricing profiles, and also motivates the use of simpler duration based charging for VoIP and IPTV.

Figure 3 illustrates the signaling flows for IPTV charging - the dotted lines correspond to online charging, while solid lines are for offline charging. The UCT advanced IPTV server [12] was used in the tests.

To implement VoIP charging, an Initial Filter Criteria (iFC) is defined at the Home Subscriber Server (HSS) to redirect all calls to the VoIP CTF responsible for each realm. Due to space limitations the message flows for VoIP charging are not shown in this paper.

³In IPTV provisioning the CTF embeded in the IPTV application server

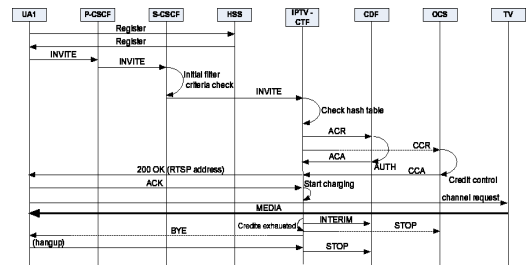


Fig. 3. IPTV Charging in the 3GPP IMS

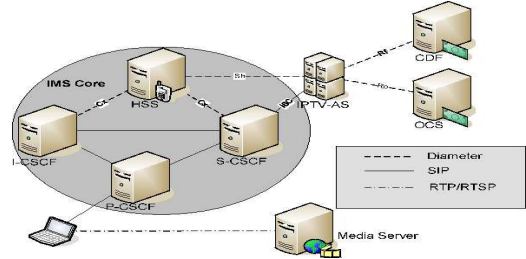


Fig. 4. Implementation Layout

Charging Trigger Function (CTF)

For IPTV charging the CTF is co-located with the IPTV server. For VoIP the CTF is embedded in a generic charging server.

Charging Data Function and Online Charging System

The CDF and OCS were developed using the C programming language and utilize the C Diameter Peer from Fraunhofer Fokus. The complete implementation layout is shown in Fig. 4.

The User Equipment

The UCT IMS client [11] is utilized for the user equipment. It was extended to provide an interface for users to view and update their primary IP-CAN pricing profiles.

V. RESULTS, ANALYSIS AND DISCUSSIONS

Two sets of tests were performed; the first series of tests were proof of concept of the implementation of charging for the IMS. The second series of tests were performed to determine the amount of bandwidth consumed by the PCMU (64kbps), PCMA (64kbps) and the GSM (13.6kbps) codecs. We motivate the use of duration based charging for IMS services, since data volume relates to the media codecs.

Proof of Concept Tests

For IPTV offline charging, once the CDF returned a Diameter Accounting Answer (ACA) to the IPTV CTF service delivery continued until the user ended the session. For online charging; this also implemented pre-paid billing, after receiving a Diameter Credit Control (CCA) from the OCS with the appropriate credit allocation (a once-off charge of 10 credits and a time-based charge of 1 credit per second) the IPTV server started service delivery to the user. *INTERIM* reports were sent to the OCS at different periods ranging from 5 seconds and 30 seconds. The OCS only replenished the exact amount of consumed credits. With a starting balance of 200 credits and interim report period set to 30 seconds, service

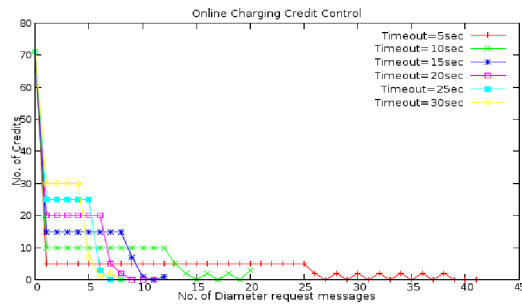


Fig. 5. Normalized Credit Control Trends

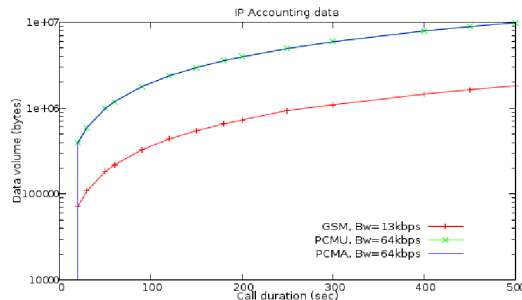


Fig. 6. IP Accounting with different audio codecs

termination due to credit exhaustion occurred 8 seconds after the 5th *interim* report was sent to the OCS. This is shown in the graph in Fig. 5, which also shows the number of CCR messages sent to the OCS for different *INTERIM* report periods. It also illustrates credit management as enforced by the OCS.

Bandwidth Usage Tests - volume accounting

Media traffic of audio that was encoded using different codecs was transmitted between two clients. The traffic volume was measured at a Policy and Charging Enforcement Function (PCEF) router. The IP accounting results obtained are depicted by the graphs in Fig. 6 and Fig. 7.

Figure 6 shows that the volume of traffic depends on the codec and the call duration. The lines for PCMU and PCMA codecs overlap fully. A network that only supports high QoS levels on its IP-CAN may be designed to only use high bandwidth (quality) codecs. If lower quality codecs, as defined in logical IP-CANs, were supported budget users may be accommodated in the same network. A large number of users translates to a bigger pool for customized advertisements and other rich services leading to a boost in revenues.

The steady average volume of exchanged media traffic,

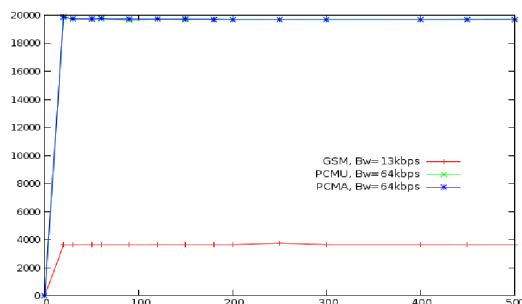


Fig. 7. Average no. of bytes per second

shown in Fig. 7 indicates that duration based charging can fully cater for the volume charging, thus saving processing power at entities that would perform volume accounting. From the figure, it may be suggested that calls using PCMU and PCMA codecs be charged at a 5 times higher rate than GSM codec calls.

VI. CONCLUSIONS

Without optimized IP-CANs calls will only be admitted to the network if the required call quality can be met; other calls get rejected. This would happen regardless of the possibility of such calls achieving a (lower) performance level that may be satisfactory to the caller. Rejected calls translate to lost income opportunities, a situation that may degenerate into network churn. By supporting calls of different qualities, the IP-CAN may reduce the number of blocked calls. For VoIP and IPTV, as mentioned earlier, this may be achieved by supporting lower quality codecs through the creation of logical IP-CANs. This mechanism will allow IP-CANs like future LTE RAN based networks to attract users who would normally seek public wireless hot spots to make VoIP calls or watch TV channels. Optimized IP-CANs will support the provisioning basic communication services (e.g., VoIP) on networks in a manner that low budget users want, resulting in an increase in the usage of other services and further boost revenue. IPTV creates an avenue for advanced advertisement scenarios on IMS networks.

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