A Pricing Proposal for a QoS Enabled UMTS Network

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Abstract— Third generation networks e.g. the Universal Mobile Telecommunications System (UMTS) provide higher data transfer rates which enables the transport of real-time multimedia traffic e.g. streaming video. The cost of Internet access over mobile networks remains high yet user demand for mobile services is increasing rapidly. In order for mobile computing to become viable, the deployment of charging schemes that would see the cost of communication reflect the utilization of resources on the network is necessary. A dynamic charging scheme is an attractive solution. When prices change, users need to indicate their willingness to continue using the service especially when a price increase is beyond the level they anticipated. In this paper we propose a charging scheme that relies on the congestion at the RNC of the UMTS to calculate pricing coefficients, which are in turn used in determining the charge incurred for using the network. The use of user profiles and network agents in the management of the charging scheme is also explored.

Index Terms—Accounting, Billing, Charging, Pricing, QoS[α]

I. INTRODUCTION

Various charging schemes have been proposed for pricing Internet communication services. Flat-rate charging is a scheme that is widely used for the Internet. This is due to its simplicity and also due to the fact that at present the Internet only offers best effort services. Best effort means that all applications compete equally for network resources. In flat rate pricing, subscribers pay for accessing the network (access charge). The charge is independent of the amount of traffic exchanged but may depend on the speed of the access link [1] [15]. Flat rate charging is insufficient for use in multi-service networks where service differentiation is used to provide QoS so as to meet the requirements of specific applications e.g. real-time multimedia.

Usage based charging schemes are needed so as to overcome the limitations of flat rate pricing. Other than making the charges reflect the cost of providing the services, usage based charging schemes can be structured in a way that would give incentives for users to constrain their traffic hence contributing to congestion control.
When users pay according to the perceived QoS, network operators get encouraged to exploit new market scenarios.

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α – The meaning of various terms used in this paper are as given in ref. 18.

The main goals of charging, as given in [15], are stimulating and controlling the use of shared resources, so as to guarantee a *social welfare* that is an acceptable level of service for each user and recovering costs for service providers and network operators.

Charging schemes that aim at reflecting the level of resource utilization have been proposed and researched on widely. The main difference in the schemes arises in the way pricing and accounting for resource usage is done. Table 1, gives a definition of important terms.

Table 1:
Key definitions in billing

Item	Definition
Accounting	The act of collecting accounting data concerning resource consumption
Pricing (or rating)	The process of determining the price for a service unit from both costs and market analysis, and the tariff model to be adopted (flat-rate, per-time, per-volume…)
Charging	The function that computes the costs in monetary units from accounting and pricing data, and the profile of the user to be charged
Billing	The act of preparing and sending the invoices to the users

The following are the details of some of the charging schemes based on the pricing models used.

The *Paris metro pricing* model [14] [15] is based on partitioning resources into different, separate logical channels, each offering a best effort service with different per-packet access price. This implies that channels with a higher price are less loaded and offer a better service.

In the *proportional fairness pricing* approach [16], users declare their willingness to pay, e.g. per time unit. Correspondingly, an amount of resources is allocated to them, in order to maximize revenues for the network and the benefit perceived by users themselves. Otherwise, users may declare their rates, and the network sets the price in order to maximize revenues for the network and the users' benefit.

In the *responsive pricing* model [17], the price explicitly represents a traffic control tool; it is extremely dynamic and increases according to the degree of network congestion, notified by dedicated feedback signals coming from the network.

In the smart market mechanism [15], each packet carries a bid that indicates the user's willingness to pay for the packet to be forwarded. Packets with a bid higher than a threshold price value, which depends on the current traffic load, are admitted into the network. The threshold value is the marginal congestion cost. Its value is zero when the network is not congested, and it increases according to the degree of congestion. Packets are not charged according to their bids, but according to the marginal congestion cost of the current time.

To come up with a comprehensive billing system, proper understanding of the roles played by various network entities is necessary. According to the IETF accounting architecture, network devices and accounting servers are in charge of the accounting procedures [15]. Charging and billing functions are the duty of the billing server. In addition to this, pricing functions and user profile management has to be done. Agents incorporated into the network for that purpose could handle this. Figure 1, illustrates the framework of a comprehensive billing system.

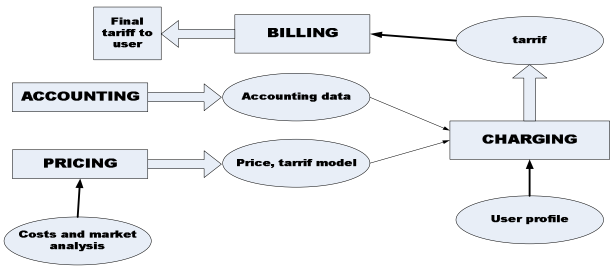

Fig. 1: Main functions of a usage based charging architecture

Mobile communications came due to the need for users to access information "anywhere, anytime" [2]. 3G networks offer higher bit-rates (up to 2Mbps), more flexibility, multiple simultaneous services for one user, and different quality-of-service classes. This creates a platform for providing sophisticated services over mobile networks [6]. Multimedia services e.g. video conversations and streaming services are now supported. Such services demand strict QOS guarantees e.g. low delay, low jitter and steady bandwidth [3].

In the UMTS, the core network is to be made IP based. The Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN) form the entry and exit points to the core network. The 3GPP and other task forces are working on having an all-IP mobile network. While this is the case, the properties of the core network would render it feasible for the use of QoS provisioning schemes like the Diffserv architecture [4], which have been proposed for the Internet.

The available network resources in mobile networks are limited. The 2Mbps bandwidth of the UMTS is generally an instantaneous rather than a guaranteed steady rate [3] [6]. It is therefore necessary to enforce an effective QoS provisioning scheme to manage the resources of the UMTS.

The mobile Internet connectivity and multimedia technologies are progressively merging in a single paradigm of personal communications. Features like roaming between various operator networks enable users to stick to the same mobile unit always [6]. This calls for the exchange of charging and network management information between the different operators involved in the end-to-end service delivery. The user is interested in a comprehensive bill that is easy to understand and accurately reflects the service used. There are cases when a user's bill would arise from the purchase of content that is delivered across networks owned by different operators. An example is the case of a roaming user accessing premium services. It would be very inconvenient for the user to, directly, pay every party involved in service delivery. Service providers come in as a bridge between the user and the other parties so as to provide convergence of the user's bill.

In this paper, we propose a charging scheme that takes QoS issues into consideration. In section II, we explore QoS in wireless networks and look at the possibility of classifying the traffic at the SGSN into classes where their network characteristics, e.g. tolerable delay, are similar. Section III brings out the technical details of the proposed charging scheme. It utilizes the considerations and ideas presented in section II. In section IV, we explore the design of an implementation test-bed carried out on a local area network. Section V presents the results and section VI finalizes the paper with the conclusions.

II. QOS IN UMTS WIRELESS NETWORKS

Quality of service entails the capability of providing resource assurances in a network. The need for QoS provisioning arises because the Internet communications media is shared by traffic generated by different applications. The applications have diverse requirements and some are sensitive to latency and loses [3]. These applications, which include multimedia, get corrupted when the latency and loss rate exceeds certain levels. On the other hand, some applications e.g. TCP services can tolerate significant delay and loss without degrading the perceived performance. QoS provisioning, as proposed by IETF, can be done using IP service differentiation (Diffserv) and integrated services.

The traffic requirements in a network can be characterized by four main parameters: reliability, delay, jitter and bandwidth. Table 2: shows the performance characteristics of a wireless WAN (3G) network with different applications [3].

The UMTS/3GPP defines four basic QoS classes of service (CoS):

- Conversational
- Streaming
- Interactive
- Background file transfers

These classes are mainly distinguished by their sensitivity to delay and packet losses [3].
The conversational and streaming classes form the group of real-time applications e.g. control traffic, IP telephony, videophone etc.

Application	Required Reliability	Tolerable delay	Tolerable Jitter	Bandwidth Requirement
E-mail & file transfer	Low	High	-	High
Web access	Low-medium	Medium	-	Medium
Control	Null	Low	-	-
Voice and Video telephony	Low-medium	Low	Low	Medium-high
Streaming video and audio	Low-medium	Low	Low-Medium	Medium-High

Table 2:
Common wireless WAN (3G) network performance characteristics

These applications require strict resource guarantees. The interactive and background classes form the non-real-time group of applications, which include web browsing, database retrieval, e-mails and file transfers. The main requirement for this group is data integrity, although considerable throughput is necessary. The level of bandwidth in the UMTS is adequate to support various multimedia applications.

Considering all network applications, when the number of simultaneous sessions increases to high levels the resultant throughput would degrade. By using Diffserv to provide traffic differentiation, a system that would ensure fair sharing of the available network resources by different applications can be achieved. In Diffserv the edge routers classify the traffic by marking the Diffserv code-point (DSCP) of every packet with a code that would be mapped to per-hop-behaviors (PHBs) by the routers in the core network [8]. The PHBs enable the core routers to perform traffic management quickly. The expedited forwarding (EF) and assured forwarding (AF) PHBs are the main characteristics used. From the layout of the UMTS network, we model a network where all traffic transferred across the core network traverses a VPN with a specified amount of resources. These are the resources to be shared by the traffic on that section of the UMTS network.

Connection admission control can be used to control the number of simultaneous communication sessions through the VPN so as to improve the QoS. For instance, in the real-time group of applications, only a certain number of sessions may be allowed on the network at a given time. Exceeding that number would lead to degraded service e.g. poor video clips etc. Defining and restricting the maximum allowable number (***N***) of simultaneous sessions on the network can lead to achieving an acceptable minimum level of service quality [8].

In the UMTS, the SGSN and GGSN would be the ideal ingress/egress points of the Diffserv implementation. The UMTS core network routers would then implement the PHBs. The first step would be to classify the traffic according to the UMTS/3GPP basic QoS CoS. The admission control strategy for each class will then admit up to the maximum allowable number of simultaneous sessions ($I \leq N$). After an existing session is closed, a new request may be admitted. The RNC is a good position for the admission control strategy. This is because the RNC controls all the nodes Bs under its service; hence all traffic to and from users served by its base stations will be routed via the RNC. Figure 2, shows the possible QoS layout of the UMTS data network employing the scheme described above.

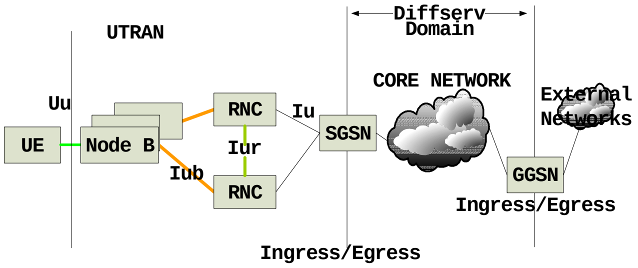

Fig. 2: Layout of the UMTS implementing Diffserv

III. THE PROPOSED CHARGING SCHEME

The state of Internet traffic varies rapidly; in order to effectively control congestion; a mechanism that works on low time-scales, i.e. on the order of round-trip-times is needed [7]. The control of Congestion in the UMTS networks can be achieved by the use of the QoS provisioning mechanism discussed above. Charging for the use of the UMTS resources will be done by using pricing parameters generated as explained in this section. By keeping track of the number of established sessions, a coefficient that corresponds to the demand for network resources at a particular time can be calculated. The coefficient would then be used to adjust the price of the network resources hence reflecting the changing congestion state across the links being monitored. In the UMTS, the RNC is considered as the right point to perform accounting for resource usage since all traffic to and from the node Bs converges here. Due to the detailed nature of the accounting information that would be collected, placing the accounting function at the edge of the Access and core network would alleviate possible scalability problems that would have occurred if it were located in the core network as it is in GSM.

We define the maximum number of permissible end-to-end communication sessions per Diffserv CoS as ***N*** *(section II)*. Using this value as a reference, the formula for adjusting the price for service units on the network can be derived. The number of active sessions will keep on increasing and decreasing, as some sessions are closed and new ones admitted. Referring to the number of active sessions at any time as ***I*** then the following relation applies:

$$C_v = k_c \, (I/N) \qquad \text{(I)}$$

K_c is a constant related to a particular class of service. C_v would then be the applicable cost of service at the particular instant when the number of established connections equals ***I*** for that class of service. The assumption made here is that all connections have approximately the same bandwidth requirement.

A pricing system of this type is bound to be hysterical due to the erratic nature of data traffic on large networks. For this reason, a smoothing function can be applied by defining steps of ***I*** for which a price update is necessary. It is worth noting that price updates would have to be done frequently hence integral price updates is necessary. When using integral price updates, the delay in transmitting the new price information to the accounting point must be minimized. To achieve this, the entities of the billing system must be within close proximity.

The accuracy of the accounting data is very important. In accounting, metering is done so as to collect the usage data. The metering process either determines the volume of data transferred or the duration (time) over which the transfer occurs. The collected usage data (time and volume) would be used in the charging process by applying the pricing algorithm.

When a new communication session is authorized, a value (equivalent to Cv) representing the current unit price for network resources in a given class of service would be associated with the service delivered during that session. When a price update is done, a new value would be used. The same value would be used for traffic transmitted in the CoS by all users during the applicable session. Usage data will be collected and this will be associated with the Cv value used at the time of service. The product of this association is the accounting data, which will be used at the billing center to calculate the charge incurred by the user. For some classes of service e.g. where the bit-rate is approximately constant, the duration (time) of the session may be used for calculating the charge. While the volume of data transferred would be used for other classes. Thus we come up with two charging formulae:

$$C1 = C_vV = k_c\ (I/N)\ V \qquad \text{(II).}$$

$$C2 = C_vT = k_c\ (I/N)\ T \qquad \text{(III).}$$

C1 applies to variable bit-rate traffic while C2 is for constant bit-rate traffic, where V is the volume of traffic in bytes and T is the duration in seconds.

The charging scheme being proposed in this paper would determine the communication costs of using the network and hence it does not consider the application level costs of the content the user might purchase from another provider.

In order for this complex process to be accomplished, intelligent network agents would be incorporated in the system. A comprehensive explanation on the role of network agents is given in [1]. We notice that an agent is needed at the RNC to oversee the process of connection admission control. The output of this agent would be the number of active sessions (***I***). Another agent would calculate the pricing coefficients ***Cv*** and send this information to the agent responsible for the accounting of resource usage. The accounting agent depends on information from the metering agents so as to accurately associate particular sessions with the applicable network prices. Some users may wish to only use the network when the prices for the resources are below certain figures. For this to be accomplished, an agent that interprets user requests as 'bids' with a monetary value should be incorporated. This agent would check the profile specified by the user at the start of the session so that when the price of network resources reaches a level that violates the specifications, the admission control function would be triggered for the necessary action. (Figure 3) illustrates the functions of the various agents.

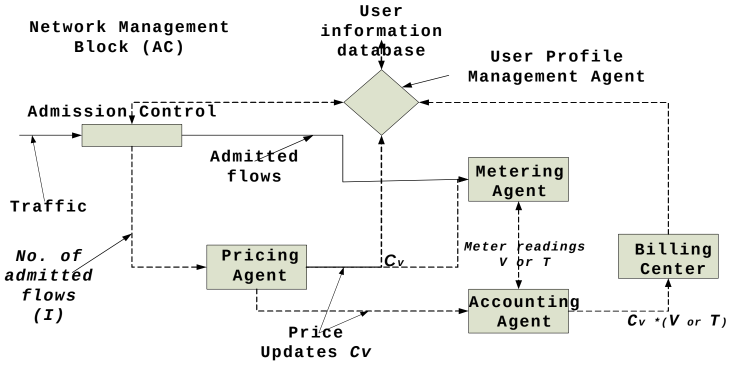

Fig. 3: Network management agents

IV. IMPLEMENTATION

In this section we present a description of the test-bed for simulating the billing scheme described in this paper. The objective of the simulation is to investigate the practicability of the billing scheme discussed in this paper.

The building blocks of the test-bed are as follows:

Computers with wireless connection to access points are used as mobile units. The access points act as the base transmitting stations (node B) and are managed by a custom system embedded on a Linux PC (Access gateway). The access gateways are connected to a central management server known as the access controller (AC) which acts as the RNC. It is necessary to store and maintain profiles posted by the registered users. In the UMTS, the Home Location Register (HLR) and the corresponding Visitors Location register (VLR) – for roaming users [11] carry out this function. A database server connected to the access controller would serve this purpose; however in this test-bed the database services are provided by the AC.

The access controller when compared to the UMTS system would correspond to the radio network controller (RNC). The functions of each block in the simulation test bed will be explained in this section. Figure 4, shows the layout of the test bed.

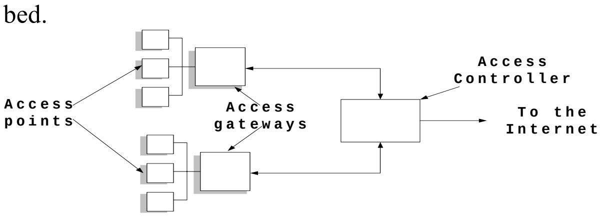

Fig. 4: Layout of the simulation test bed

The links between the AGs and the AC form a structure similar to the UTRAN. In the provisioning of QoS, the access controller handles the admission of connection requests from authenticated users and it also handles traffic control. Details on implementing Diffserv on Linux may be found in [12] & [13]. The aim of this charging scheme is to determine the cost of using the 'UTRAN' and the core network resources. An uplink connection from the access controller to the Internet has limited bandwidth (***B***). The limited bandwidth is shared by all connections to and from the 'UTRAN'. Regarding QoS provisioning, we make a general assumption that traffic is handled according to the appropriate Diffserv PHBs on the Internet.

a. Mobile Units

The main function of the mobile units is enabling the user to access the network services. The applications investigated include: web browsing (e.g. HTTP), file transfer (FTP), Linux *SSH* services and email. As a requirement, the mobile users would register with the network prior to service use. To uniquely identify each mobile unit, the Ethernet hardware (MAC) address is used as a component of the user registration. More advanced WLAN authentication schemes are discussed in [9]. For flexibility and extensibility of the system, an additional user identification scheme is used. Once a mobile unit is configured with an IP address, the user can logon to the network through a special interface by supplying a login ID, domain details and a password. This information is transmitted to the access controller for processing by contacting the database of the specified domain for the user's credentials. A user interaction page can be accessed from the mobile units and it enables them to update their service usage profiles.

b. Access Gateways

The access gateways (AG) are part of the whole system management setup. The single access gateway used in the simulation was implemented on the Linux operating system platform. The AG offers physical network connectivity to the mobile units via a radio interface that is provided by a D-Link access point that is connected to it. The following are some of the functions done by the access gateway:

Performs the dynamic IP configuration of the wireless client network interfaces, provides a login page and a link to the page where users specify their profiles. A web server and scripts written in PHP were installed on the system so as to process the web interface for the users. In the network management hierarchy, the access gateway is under the control of the access controller.

The process of user authentication and authorization is done as follows:

After a new user is detected by the access gateway, the DHCP server issues an IP address (Network Access Identifier) from a predefined pool of IP addresses. The user would input some credentials i.e. ID and password which will be transmitted to the AC, using a UNIX socket, for processing. The AG, as a default mechanism, transmits the MU's MAC address and the assigned network access identifier (NAI) to the AC. If this information is inadequate for the authentication, then the user's credentials would be required. If the authentication is successful, the AG will be instructed to authorize the user, allowing him access to the network; otherwise the user is denied access to the network. The authorization is done by adding the user's IP address (NAI) and the corresponding MAC address to an IPTABLES firewall list on the AG.

c. Access Controller

The center for the management of the system is the access controller (AC). All the network management roles e.g. authentication, authorization and accounting are either handled here or another network entity e.g. the AG is triggered to perform the function. In the authentication of users, the AC receives requests from the various access gateways. It then queries the database where the users' information is stored. The right database is indicated by the domain value in the information submitted by the user. Hence the domain value is used to determine whether to search in the home (local database – this is used in the default authentication mechanism) or in the visitors (another domain) database.

The authorization of a user is done in two parts. The first part (global authorization) grants him access to the core network. While the second part (session authorization) is performed when the user requests for a particular service and there are enough network resources to service the request. This means that, global authorization can be granted, allowing them to request services e.g. file transfer, and yet the request may still be denied due to lack of enough network resources.

The must determine in real time the availability of resources on the network. The charging scheme depends on the QoS provisioning scheme which guarantees resources for traffic in the different CoS. In the implementation test-bed three traffic classes were created. Bandwidth was allocated to the classes as a percentage of the total capacity of the network. The AC is a network management center that has various agents incorporated in it. By performing traffic control, it acts like the SGSN of the UMTS. We did not go into the details of setting up the core network to handle the Diffserv PHBs. For information on traffic engineering, see reference [13], which presents this explicitly well.

After a user receives 'global' authorization, he may request services from the network. For instance if a user tries to access a web page, the access controller filters the request into the *http* CoS. It then checks if the defined maximum number of admissible connections ***N*** for that class has not been exceeded. If the active sessions are less than ***N***, i.e. ***(I < N)*** then the sync packet i.e. the packet attempting to establish the new connection is allowed to proceed to the destination host otherwise it is dropped. It is necessary, in the event of unavailability of resources, to instruct the mobile client to differ the attempt for some time. If the destination host receives the sync packet, then an *ack* packet would be sent to the mobile client, who would finish the handshake process and the stream of data from the web server will begin flowing to the user terminal.

The profiles set by the users define the quality of the service that will be delivered to the user when network conditions dictate so. In this simulation, one of the network conditions that lead to the use of the profiles is the increasing value of the pricing coefficients. Three profiles have been defined, i.e. platinum, gold and silver.

The profile information submitted by the user after authentication is temporarily stored in a database. The profile management agent uses this information in conjunction with the changing resource prices in order to ensure that the wishes of the user are not violated. The example mentioned earlier where network prices may rise above the level for which the user willing to pay is a clear illustration. The network management system requires an indication from the user showing acceptance to continue using the service at the new, higher, price or a default indication would be assumed. Considering the nature of network communications, it is difficult to get a timely response from the user. The user profile management agent becomes useful in this case since it is readily available with the service usage profile specified by the user.

Metering is done to generate the resource usage data. As explained in section III, the usage data is associated with the applicable price coefficients. During specific intervals e.g. 10 ms and also when the user stops accessing services on the network, the total charge incurred is calculated and updates are made to the billing database.

V. RESULTS

The simulations are still underway but the results and observations made in the initial stages have been analyzed and important conclusions can be made as follows:

An important observation was made with regard to the rapid change of the values of the pricing coefficients for the various classes of traffic. The only feasible solution to this behavior is to synchronize the resource usage accounting process with the network resource pricing process. When the value of the pricing coefficient changes, the usage data collected for the period before it changed should be send to the charging system. The charging system should keep track of the changing values of the pricing coefficients and associate them with the service usage data it receives. To ensure accuracy in the association of service usage data and the pricing coefficients, both the new and old values of the pricing coefficients should be sent to the charging function alongside the usage data.

Interaction between the user and the system needs to be enhanced. Information should be send to the user whenever necessary, for example when a request for services is denied or when a change in the quality of the service to be delivered to the user is about to occur – due to the profile submitted by the user and when the network conditions dictate so. To reduce the volume of bandwidth and other network resources that are needed in sending the reports to the user, coded information values should be used. The meaning of each information code would be interpreted by custom software resident on the user terminal – such software should be downloaded to the user terminal upon registration.

Several tests are yet to be done on the simulation test-bed. Some tests call for modifications in the original design. Among the tests to be carried out is one that would determine which profiles mobile service users prefer most.

VI. CONCLUSION

A QoS dependent charging scheme is necessary for use in the billing of the UMTS services in the view of the new applications that require special resource guarantees. User participation in controlling the service quality and cost relationship is important since it would bring a balance between the service provider's and the user's interests. The incorporation of intelligent agents in the management of the network is crucial so as to absorb the complexity of the dynamic billing system.

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