Radio Resource Management Strategies in 3G UMTS Network

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Abstract: *Third generation (3G) mobile communication system, namely Universal Mobile Telecommunication System (UMTS), will support a wide range of applications with different quality of service (QoS) profiles. At present many of these applications are not possible to predict. Also the usage of the different applications are difficult to predict i.e. it is not possible to optimise UMTS to only one set of applications.*

Next generation wireless access system will have features and requirements that are quite distinct from current systems, mostly designed for telephony. Such features include higher bandwidth, mixed, packet oriented and strongly asymmetric traffic patterns as well inhomogeneous network architectures. In this paper we have identified some significant problems in Radio Resource Management (RRM) in future wireless IP based multimedia systems and have proposed some potential solutions.

Key Words: *3G, UMTS, QoS, RRM, FDD, TDD, 3GPP, Admission and Load Control, Handoff.*

1. INTRODUCTION

The delivery of multimedia services to the mobile user is one of the goals of 3rd generation mobile communication system. The use of several different services at the same time raises the demands for mechanisms to guarantee Quality of Service (QoS) for each application. To satisfy the mobile user, UMTS provides several Radio Resource Management strategies.

UMTS is referred as Wideband Code Division Multiple Access (WCDMA) based, because Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are applied to paired and unpaired bandwidth respectively at 2GHz band[1]. As the emerging of Internet and mobile applications, the UMTS users are capable of accessing both telecom and Internet resources. But since historical IP networks provide only best effort service and is not multimedia oriented, QoS becomes a critical issue for the success of UMTS. To provide end users with perspective QoS, the network resources at various nodes must be optimally utilized. Therefore, radio resource management plays an important role in provision of UMTS services, due to the large impact of the "web" and web browser as the common software platform for various IT-applications, provisioning Internet services has become the main design paradigm in defining 3rd and subsequent generations of wireless access systems [2]. 3rd generation wide area access system (e.g. UMTS) currently in the standardization and deployment phase and also deployed in various countries of the world. Multimedia services will be supported by UMTS according to 3rd generation Partnership Project (3GPP) specifications, i.e. the supported bit rates will be at least 144Kbps for rural area, 384Kbps for urban/suburban area and 2Mbps for indoor/low range out door environment [3].

Comparing market estimates for wireless personal communication and considering recent proposals for wide band multimedia services with the existing spectrum allocations for these types of systems show that radio resource management remains an important topic in the near and distant future. Radio Resource Management takes on new dimensions and can no longer be restricted to be matter of spectrum utilization only. Other important components are Medium Access Control (MAC) Transport Format (TF) [4] and mobile equipment power management [5].

This paper investigates some of the new distinctive features of future wireless access systems to see what impact these have on the resource management and planning strategies for future wireless multimedia systems. We will give an outlook over some of the key problems involved in radio resource management and sketch some significant solutions.

2. RESOURCE MANAGEMENT ISSUES IN 3G SYSTEMS

Most of the systems design carries circuit switched traffic of rather moderate data rates (e.g. speech, low rate circuit switch data). Let us now turn to some of the more important features of the traffic expected in future systems and what impact these will have on system design in general and on radio resource management in particular.

2.1 Quality of Service Requirements

As was noted in the introduction, QoS is a critical issue for the success of UMTS. An important feature of the UMTS is that information generated by independent sources can be efficiently multiplexed on the same transmission medium. UMTS supports traffic with very different bandwidth and QoS requirements. Traffic generated by data transfer services and Internet access is essentially bursty and unpredictable. Although data transmission between machines is loss sensitive, it is usually not sensitive to end-to-end delay or jitter. On the other hand, speech (and, more generally, real time applications) requires strict limits on the transmission delay, but can cope with reasonable loss rates. For example end-to-end delay for voice must be less than 400ms.

Table 1. UMTS traffic classes

QoS Class	Transfer delay requirement	Transfer delay variation	Low bit error rate	Guaranteed bit rate	Example
Conversational	Stringent	Stringent	No	Yes	VoIP, Video-conferencing, Audio-conferencing
Streaming	Constrained	Constrained	No	Yes	Broadcast services (audio, video), News, Sport
Interactive	Looser	No	Yes	No	Web browsing, Interactive Chat, Games, m-commerce
Background	No	No	Yes	No	E-mail, SMS, database downloads,

A major challenge for the UMTS infrastructure is to carry various types of applications on the same medium, while meeting the QoS objectives. As well as meeting the needs of the user who is only interested in the end-to-end QoS perceived at application level, it is essential that the system uses the transmission resources efficiently. This requirement applies not only to the scarce radio spectrum, but also to the terrestrial transmission resources, and especially the access part which must provide a cost effective transfer service while minimizing investment and operating costs. Thus it is highly desirable to achieve some statistical multiplexing gain. In particular, transmission links and the radio interface must be loaded as heavily as possible while meeting the QoS requirements. Therefore it is important to identify mechanisms that optimize the load. To meet these requirements, 3GPP has defined four QoS classes (TS 23.107): conversational, streaming, interactive and background. Typical applications and summary of the QoS requirements are given in the Table 1.

Systems with intermittent data transmission, will also suffer from a different kind of problem. Since there are no continuous transmissions, good link quality estimates cannot be made at will but only when there actually is a transmission in progress. In particular when the traffic is very "bursty", the statistical estimates of the link quality parameters can degrade considerable since the terminal may move a considerable distance between transmissions. This affects all type of RRM decisions, e.g. channel allocation, power control and hand-off decisions. In these situations channel allocation decisions and power control has to be made on estimated average link qualities rather than on instantaneous values. In these cases, the concept of a "hand-off" looses it meaning in the physical sense and one may instead consider different "connection-less" schemes where any Radio Access Port (RAP) or base station in some area may receive messages from a mobile terminal without the explicit establishment of a logical/physical connection [6]. Another possibility considered (particularly in CDMA-type systems) is to "artificially" maintain a physical link even when there are no data to transmit by prescribing a minimum "idle" power level. These trade-offs are, of course, the more important, the more rapidly the terminals are allowed to move relative to the duration of these "idle periods" [7].

2.2 QoS and the Radio Interface

To cope with a certain QoS a bearer service with clearly defined characteristics and functionalities must be setup from the source to the destination of the service, maybe including not only the UMTS Terrestrial Radio Access Network (UTRAN, plus Core Network) but also external networks [8]. Within the UMTS bearer service, the role of the radio bearer service is to cover all aspects of the radio interface transport over the UTRAN. RRM strategies will be responsible for assuring the defined QoS in this segment.

The radio interface of the UTRAN is layered into three protocol layers; the physical layer (L1), the data link layer (L2), and the network layer (L3). Additionally, L2 is split into two sublayers, radio link control (RLC) and medium access control (MAC). On the other hand, the RLC and L3 protocols are partitioned in two planes, user and control. In the control plane, L3 is partitioned into sublayers where only the lowest sublayer, denoted radio resource control (RRC), terminates in the UTRAN [8].

Connections between RRC and MAC as well as RRC and L1 provide local interlayer control services, and allow the RRC to control the configuration of the lower layers. In the MAC layer, logical channels are mapped to transport channels. A transport channel defines the way in which traffic from logical channels is processed and sent to the physical layer. The smallest entity of traffic that can be transmitted through a transport channel is a transport block (TB). Once in a certain period of time, called a transmission time interval (TTI), a given number of TBs will be delivered to the physical layer in order to introduce some coding characteristics, interleaving, and rate matching to the radio frame. The set of specific attributes are referred as the transport format (TF) of the considered transport channel. Note that the number of TBs transmitted in a TTI indicates that different bit rates are associated with different TFs. As the user equipment (UE) may have more than one transport channel simultaneously, the TF combination (TFC) refers to the selected combination of TFs. The list of allowed TFCs to be used is referred to as the transport format combination set (TFCS) [8].

2.3 Asymmetric Traffic

Current mobile communication systems are mainly geared for speech traffic and operate in symmetric full duplex fashion. Data rates and other quality of service parameters in these systems are the same in the uplink and the downlink. In 3rd generation systems, data traffic, as generated by IP-based information retrieval applications, is expected to dominate. In many of these applications an increasing fraction of the total offered traffic, is expected to load the downlink segment of the system.

Typically, the World Wide Web traffic is highly asymmetric (i.e., the user is downloading data from the network, and only some acknowledgements or commands are transmitted from the terminal to the network).

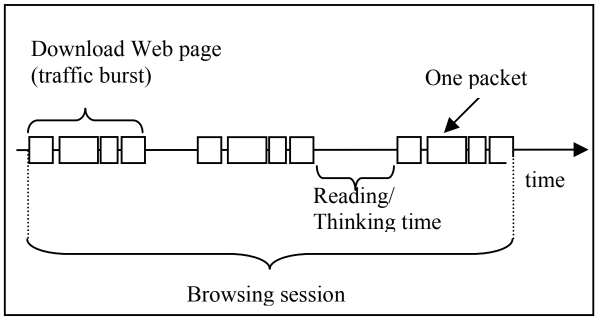

Figure 1. World Wide Web Traffic Characteristics.

Understanding the nature of the traffic is critical for a good system design. Between the transmission pauses, the system can either keep the radio connection, or release it and then establish it again when there is new data. This is a tradeoff between spending radio resources to keep the connection alive and spending radio resources to reestablish the connection. Furthermore, the access time will be longer if the connection is released and the reconnected. The question is how the timers should be set to minimize the consumption of radio resources and the access delay for a user.

The average transmission rate depends on the packet length and the time intervals between packets (Figure 1). If the packets are large and the time interval between packets is short, capacity requirements will be much higher. The same applies for reading time between Web pages. The reading time depends on the contents of the page. For example, a page that needs some information to be filled in (e.g., address and credit card information for on-line shopping) requires more time than a page that just contains a simple greeting and a command to continue to the next page.

3. NETWORK MANAGEMENT

From the mobile telephony operator point of view, radio resource managements are bottleneck in most situations. On the other hand, network performance depends mostly on radio part of the network, so good radio resource management is essential. Management in UTRAN is done with admission and load (congestion) control.

3.1 Admission and Load Control

The purpose of admission control is to ensure that there are free radio resources for the intended call with required SIR and bit rate. The purpose of load control is to maintain the use of radio resources of the network within the given limits of QoS. Admission control is always performed when a mobile station initiates communications in a new cell, either through a new call or handoff. Furthermore, admission control is performed when a new service is added during an active call. In general, the admission control procedure ensures that the interference created after adding a new call does not exceed a prespecified threshold.

Moreover, handoff procedures have a strong impact on the overall RRM, so it is mandatory to develop RRM strategies that take this influence into account. Handoff management is in charge of allowing the continuity of the call in progress when the mobile moves from one cell to another and still guaranteeing its QoS.

3.2 Load Factor

Load factor η is used to measure the network congestion. Load factor for the reverse link can be defined as follows:

$$1-\eta = \frac{SIR_{loaded}}{SIR_{empty}} = \frac{\frac{S}{I_{tot}}}{\frac{S}{I_o}} = \frac{N}{I_{tot}} \Leftrightarrow \eta = 1 - \frac{N_o}{I_{tot}} \qquad (1)$$

where
N_o is the thermal noise spectral density;
I_{tot} is the total interference plus noise spectral density;
S is the received power at the base station from each user;
SIR is the signal-to-interference ratio.

When the system is fully loaded then the load factor is one. Because a fully loaded system might get into an unstable state and drive the powers of all users to a maximum, a safety margin is required. Therefore, the load factor should be in the order of 0.4 to 0.8.

In the forward link, the load factor can be defined as the ratio of the maximum base transceivers station (BTS) transmission power to the predefined threshold value [3].

3.3 Admission Control Principles

The principle of the admission control algorithm is shown in figure 2.

Admission control needs to be done separately for uplink and downlink. This is specially important if the traffic is highly asymmetric. Typical criteria for admission control are call blocking and call dropping. Call dropping is more annoying than blocking.

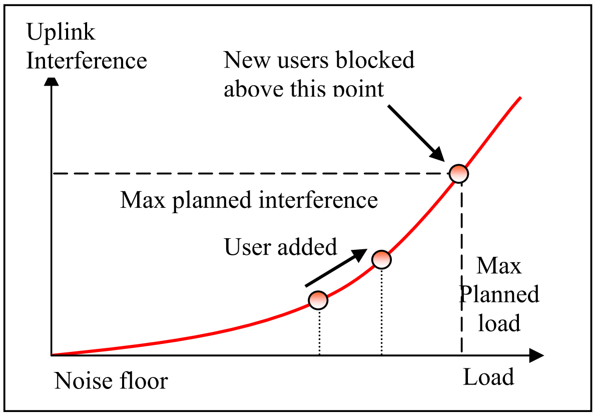

Figure 2. Admission Control in UTRAN

The nature of downlink is different, since users are located at different locations and control channels are not power controlled. Because of that, noise rise is not appropriate for downlink control. As it was shown before, downlink is limited with base station transmit power, so downlink control is done with intelligent base station transmission power allocation.

3.4 Load Control Principles

The basic principle of load control is the same as admission control. While admission control is carried out as a single event, load control is a continuous process where the interference is monitored.

Load control measures the load factor, and, if the predefined load factor is exceeded, the network either reduces the bit rates of those users whose service contract allows it to be done, delays the transmission of those users without delay requirements, or drops low priority calls. If there is an under load, load control increases the bit rates of those users who can handle higher bit rates. The increase and decrease of the bit rates can be performed with priority order.

4. CONCLUSION

Considering the phenomenal growth in mobile wireless communications, both for speech and data services, providing end-to-end quality of service to support a variety of applications has become of key importance for both operators and users. So the RRM and QoS have a major impact on subscriber satisfaction. In this paper, we have investigated some of the new distinctive features of future wireless access systems to see what impact these have on the resource management and planning strategies for future wireless multimedia systems.

Acknowledgement

Authors are grateful to the Higher Education Commission (HEC) who has provided funding under Endowment Scheme for sponsoring research work. The technical and useful suggestions and discussions with Dr. Hanzo Lajos Prof. of Communication, School of Electronics & Computer Science (ecs) University of Southampton are greatly acknowledged.

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