COMMON CALL ADMISSION CONTROL IN HETEROGENEOUS WIRELESS NETWORK

by

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Submitted to the
Department of Electrical and Electronic Engineering
Faculty of Sciences and Engineering
East West University

In partial fulfillment of the requirements for the degree of
Bachelor of Science in Electrical and Electronic Engineering
(B.Sc. in EEE)

[Summer 2009]

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29/10/2009

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Abstract

In today's world it has become a challenge to provide cellular connectivity as an – "anytime, anywhere and anyhow" basis. Due to the vast increment of number of cellular phone users, multiple radio access technologies (RATs) are coming under same umbrella. Every RAT is allocated with specific radio frequency bands in one core radio network. The purpose of our proposal is to use these RATs in a heterogeneous network on priority basis. This means whenever connectivity is requested by a moving user, he is provided with free channels of the available RATs through sharing radio resources. Through this procedure, maximum quality of service (QoS) can be provided to the users and call blocking probability can be reduced. In our project we have used Common Radio Resource Management (CRRM) algorithms. In our proposed model CRRM has been used for call admission control and vertical hand over functions. Our proposed model is compared with Luo's Joint Scheduling Model. In our proposed model although only GPRS and WLAN have been considered, but our model can be employed for overlapped heterogeneous networks consisting of any wireless communication systems.

Acknowledgements

:most, we would like to thank Almighty for always keeping us blessed and for ɔrating our lives with such opportunities and privileges to reach this level of :ation.

would like to thank our parents and families for always inspiring us with their less support and for providing us with the best of privileges to make us educated and blish in our lives. Without their encouragement it would not be possible for us to :h where we are today.

would like to express our sincere gratitude to our supervisor Mohammad Ghulam ıman, PhD, for the continuous support of our undergraduate thesis study and research, his patience, motivation, enthusiasm, and immense knowledge. His guidance helped in all the time of research and writing of this thesis. We could not have imagined ing such a cooperative and caring supervisor for our thesis study.

sincere thanks goes to our chairperson Professor Anisul Haque for always ouraging us to work harder in developing our knowledge, reading the books roughly to acquire clear concepts and most of all for always encouraging us to elop punctuality and discipline in us.

special thanks go to Dr. Md. Ishfaqur Raza for providing us with the VLSI lab and introducing us with latest electrical engineering softwares which helped us to enrich design knowledge. Without the VLSI lab it was not at all possible for us to work sufficient computer availability and ease.

would like to thank the rest of our faculty members: Dr. Khairul Alam, Ms. Sharmin shan Ara, Ms.Tahseen Kamal, Mr. Emamul Ahsan, Mr. Mohammad Salauddin, Mr. san Ul karim and Mr. Md. Abu Abdullah for their encouragement and insightful nments.

we would like to thank Mr. M A Jobayer Bin Bakkre, VLSI lab officer, for helping vigorously every time we faced problems using computer and softwares throughout thesis work.

tly, we would like to thank all our classmates for sharing their knowledge with us and ping us whenever we were in need.

Authorization page

/e hereby declare that we are the authors of this thesis. We authorize East West niversity to lend this thesis to other institutions or individuals for the purpose of :holarly research.

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Introduction

n a cellular communication system, each service area is divided into number of cells, vhere each cell is served by a base station through radio interfaces. For a user in a nobile wireless system, dropped calls and blocked calls are unacceptable. Users expect o remain connected while travelling through intra and inter cellular service area. Users lso expect to be able to make calls at any time and to have good, clear connections. 'hese user demands can be solved through utilizing the radio resources properly.

'he phenomenon of using radio resources of different Radio Access Technologies RATs) for higher Quality of Service (QoS) is referred to as Radio Resource Management (RRM). There are several elementary functions of RRM those are esponsible for a successful wireless communication system. Efficient radio resource nanagement cost-effectively enhances the capacity which refers to the maximum umber of users that can be supported in a given band, and QoS. RRM functionalities are nportant for call admission control and resource control for a new or ongoing call. Call dmission control involves control of both new calls and handoff calls. Resource control or an ongoing call distributes the radio resources among existing users. In this way atisfactory QoS can be achieved through providing good voice quality and fast data etrieval from the Internet [1].

'wenty first century is the age of knowledge. Better and updated information ensure etter knowledge. Wireless communication is the easiest and rapid way to get nformation. So, people have a great dependency on this technology. The increasing emand urged to ensure the QoS. Limitation of bandwidth, scarcity of channel, shortage f power, mobility of user, fading and interference made it challenging. To overcome his challenge, it can be said that future cellular networks will not consist of just one AT but will contain several different RATs possibly with cells on several hierarchical ayers, for example, macro, micro and pico layers. If a user's cellular device is enabled vith GPRS and WLAN services, then the user can use both the systems' frequency hannels. There are mainly two types of traffic requested by a user: voice call traffic and ata traffic. Successful call admission control can be achieved by vertical channel haring through Common Radio Resource Management (CRRM) functionalities in order to serve maximum number of user traffic requests. When a user in inside a microcell (exp, WLAN) overlapped by a macrocell (exp, GPRS), he is provided with all the GPRS, WLAN and WLAN queuing channels. On the other hand, user in macrocell but outside the microcell can only request for macro-cellular channels which are the GPRS channels. Hence it is more likely that a call request by a user outside the microcell but inside the macrocell will be blocked or dropped if GPRS channels are occupied by users inside the microcell. This phenomenon is unacceptable in case of providing QoS to satisfy all the users.

Previously researches have introduced multimode-devices. These devices are capable of accessing WLAN, GPRS/3G and Bluetooth networks from single device [2]. Through these devices a user can choose channel with higher transmission for faster services. But in these devices the channel utilization is not adaptive, such as for a user inside a microcell, his voice calls and multimedia will be transferred through GPRS and WLAN channels respectively. So it is not possible to free a GPRS channel for a user outside the microcell but inside macrocell.

This research work proposes CRRM for GPRS cell overlapping WLAN access point coverage area and is intended for a multimode device that will be capable to operate both GPRS and WLAN. When a user is inside a building with WLAN access point, his traffic request will be served by the core network in such a way that the voice calls and the muitimedia data will be automatically transferred through GPRS and WLAN channels respectively. As a result, it will be possible to provide another user on a car or outside the building with a free channel to proceed with a voice call or to minimize the possibility of dropping for an ongoing voice call. On the other hand, the user inside the microcell (WLAN coverage area) will be able to transfer his multimedia traffic with higher bit rate. So it will be possible to provide maximum QoS to both the user inside and outside the microcell.

For implementing CRRM functionalities in a heterogeneous network, we considered common call admission control and vertical handover only. According to this technique, the radio network first receives all kind of traffic requests. If all the GPRS channels are occupied, in the microcell it transmits the voice calls through GPRS channels and multimedia data through WLAN channels. So, some GPRS channels are free through which the voice calls outside the microcell are transmitted. As a result the probability of call blocking is minimized. In this paper we considered uniform user distribution over the GPRS cell area the CRRM model is based on load measurement [1]. This means that the voice calls usually are passed through the RAT which has minimum traffic load. In case of simulation purpose the Erlang B formulae of probability of blocking is applied.

Chapter 2 gives an overview of GSM/GPRS system. The features discussed in this chapter comprises general introduction, different elements of the system architecture, frame and time slots structure and different types of channels of GSM/GPRS system.

Chapter 3 presents features of WLAN systems. The topic that have been discussed here are general information and benefits of WLAN systems, the WLAN system architecture, operational principles and elements.

Chapter 4 investigates different elements of radio resource management. The concept of heterogeneous network has been narrated in this chapter. Various functionalities of CRRM have also been discussed in this chapter.

Different scenarios and assumptions of this proposal are elaborated in chapter 5. Simulation results and analysis are also presented in this chapter.

Finally we conclude and provided recommendations and future work in chapter 6.

CHAPTER 2

GSM/GPRS System

2.1 Introduction

GSM stands for Global System for Mobile. GSM was formed in 1982. In 1980s analog cellular telephone systems were growing rapidly in Europe, United Kingdom, Germany and France. Each country was developing its own system, which was different with everyone else's in equipment and operation. This was an undesirable situation, because not only the mobile equipment was limited to operation within national boundaries but also a very limited market for each type of equipment. As a result, it could not bring expected economical earnings. In 1982, the European Conference of Postal and Telecommunications Administrations (CEPT) created the Group Special Mobile (GSM) to develop a standard for a mobile telephone system that could be used across Europe.

In GSM, uplink frequency is 890-915 MHz and downlink frequency is 935-960 MHz. To allow maximum number of user access, each band is subdivided into 124 carrier frequencies spaced 200 KHz apart. This frequency band allocation follows FDMA Frequency Division Multiple Access) technique. Each of these carrier frequencies is ubdivided into 8 time slots using TDMA (Time Division Multiple Access) technique. TDMA provides each user with the carrier frequency for approximately 0.577ms. There s also an extension band of 15 MHz in both directions. Frequency hopping may occur in rder to avoid disconnection in the points in some un-overlapped places between two ells and to minimize interference from other signal. The hopping rate is one hop per DMA frame (4.6 μs), or 217 hops per second. The method of modulation used is aussian Minimum Shift Keying (GMSK). GSM has a channel rate of 270.833 kbps and user data rate 22.8 kbps. Figure 1 shows the radio resource allocation of GSM system low:

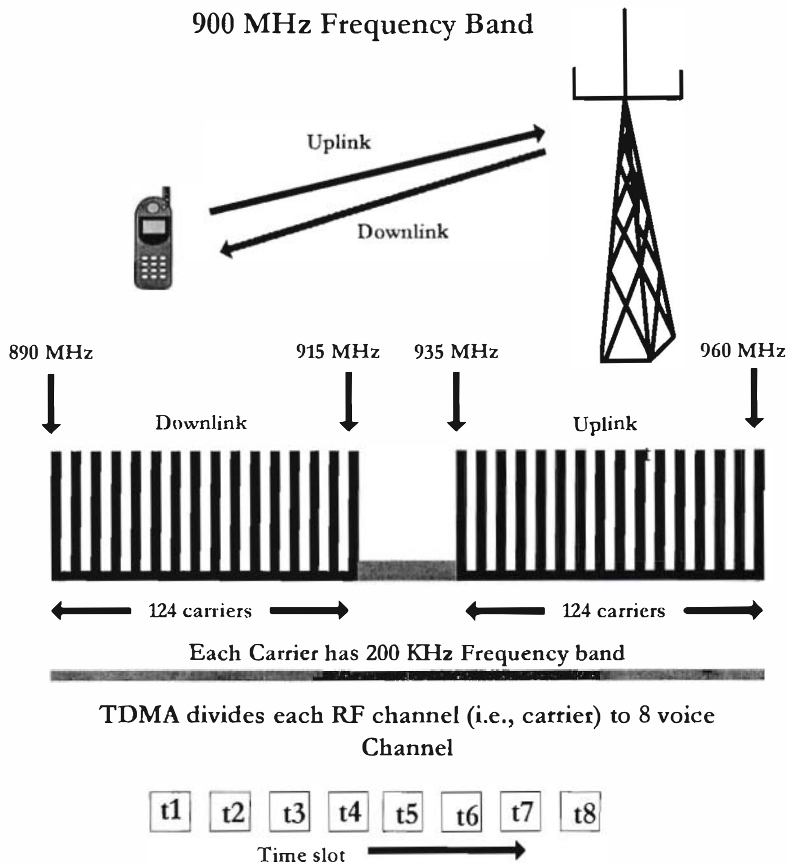


Figure 1: GSM/GPRS Radio Resource Allocation

With emerge of audio, video and text traffic- faster transmission is required. Besides, people need to be connected with the Internet now-a-days. To provide these services besides voice call, GPRS nodes are introduced with GSM. GPRS enables users to get Internet connection anywhere and everywhere they need. Also it gives much higher user data rate, up to maximum 172 kbps. The key element of GPRS technology is that it uses packet switched data rather than circuit switched data, and this technique makes much more efficient use of the available capacity. This is because most data transfer occurring in what is often termed a "bursty" fashion. The transfer occurs in short peaks, followed by breaks when there is little or no activity.

The following parts of this chapter are edited from [3].

2.2 GSM/GPRS System Architecture

The GSM network architecture as defined in GSM specifications can be divided into three main areas:

- Mobile Station (MS)
- Base Station Subsystem (BSS)
- Network and Switching Subsystem (NSS) or Core Network (CN)

Figure 2 shows the GSM/GPRS system architecture

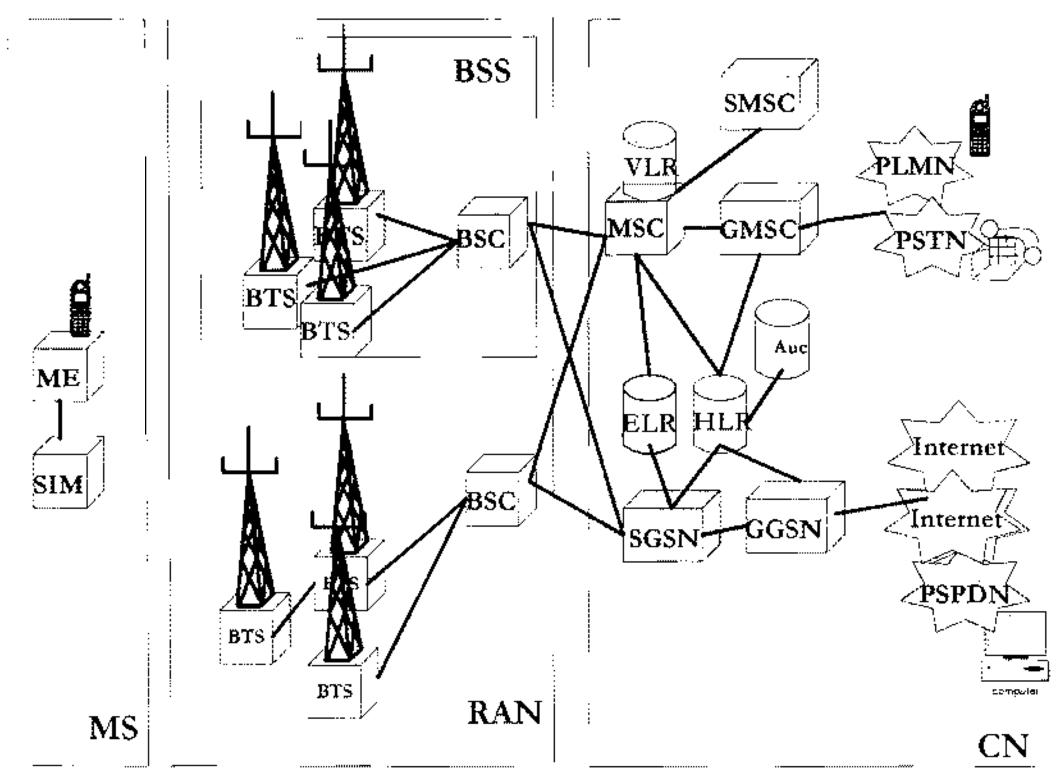


Figure 2: GSM/GPRS System Architecture (Ref: www.everest.ist.upo.es)

2.2.1 Mobile Station (MS)

A mobile station enables user to connect with the base station (BS) through radio interface of a wireless cellular system. A mobile station consists of two components: mobile equipment (ME) and subscriber identity module (SIM).

2.2.1.1 Mobile Equipment (ME)

Mobile equipments (ME), most widely known as cell or mobile phones, are the section of a GSM cellular network that the user sees and operates. In recent years, their size has fallen dramatically while the level of functionality has greatly increased. A further advantage is that the time between charges has significantly increased.

2.2.1.2 Subscriber Identity Module (SIM)

The SIM contains the information that provides the identity of the user to the network. It contains variety of information including a number known as the International Mobile Subscriber Identity (IMSI).

2.2.2 Base Station Subsystem (BSS)

Base Station Subsystem connects mobile station with the core network. It performs the role of radio infrastructure hub. A base station controls from one to eight radio carriers, and each radio carrier provides eight full rate radio channels, transmitting via an Omni-directional or a directional antenna (usually 120° sector). In the cases of sectored coverage, a single site can increase the efficiency of inter-cell hand-over.

The Base Station functions are following:

- Radio transmission in the GSM format, employing frequency-hopping techniques and spatially diverse antennas
- Implementation of equalization algorithms to counter the effects of multiple paths
- Coding and decoding of radio channels
- Encryption of transmission data streams
- Control of the protocols governing messaging into the radio data link layer (LAPDm)
- Measurement of quality and received power on the traffic channels
- Transmission of signaling messages
- Operates and maintenance of the BTS equipment.

SS consists of two elements: Base Transceiver Station (BTS) and Base Station ontroller (BSC).

2.2.2.1 Base Transceiver Station (BTS)

The BTS used in a GSM network comprises of the radio transceiver (transmitter and receivers), and their associated antennas that transmit and receive to directly communicate with the mobiles. BTS communicates with the mobile through radio interface simply expressed as Um interface.

2.2.2.2 Base Station Controller (BSC)

The BSC controls a group of BTSs, manages the radio resources, allocate channels and controls item such as handover within the group of BTSs. BSC communicated with the BTSs through an A-bis interface.

2.2.3 Network Switching Subsystem (NSS)

The GSM/GPRS network subsystem contains a variety of different elements, and is often termed as core network. It provides the main control and interfacing for the whole mobile network. The network switching subsystem (NSS) is responsible for network switching operations. It helps to communicate with other wired and wireless networks as well as support for registration and maintenance of the connection with the MSs. NSS connect a user with other PSTN, PLMN and Internet. The major elements within the core network include mobile switching center (MSC), home location register (HLR), visitor location register (VLR), equipment identity register (EIR), authentication centre (AuC), gateway mobile switching centre (GMSC) and SMS gateway (SMS-G). Three nodes are added to the GSM core network for GPRS system support: serving GPRS support node (SGSN), gateway GPRS support node (GGSN) and packet control unit (PCU).

2.2.3.1 Mobile Switching Center (MSC)

The main element within the core network area of the overall GSM network architecture is the Mobile switching Services Centre (MSC). The MSC acts like a normal switching node within a PSTN or ISDN, but also provides additional functionality to enable the requirements of a mobile user to be supported. These include registration, authentication, call location, inter-MSC handovers and call routing to a mobile subscriber. It also provides an interface to the PSTN so that calls can be routed from the mobile network to a phone connected to a landline. Interfaces to other MSCs are provided to enable calls to be made to mobiles on different networks.

2.2.3.2 Home Location Register (HLR)

This database contains all the administrative information about each subscriber along with their last known location. In this way, the GSM network is able to route calls to the relevant base station for the MS. When a user switches on his phone, the phone registers with the network and from this it is possible to determine which BTS it communicates with, so that incoming calls can be routed appropriately. Even when the phone is not active (but switched on) it re-registers periodically to ensure that the network (HLR) is aware of its latest position. There is one HLR per network, although it may be distributed across various sub-centers for operational reasons.

2.2.3.3 Visitor Location Register (VLR)

This contains selected information from the HLR that enables the selected services for the individual subscriber to be provided. The VLR can be implemented as a separate entity, but it is commonly realized as an integral part of the MSC, rather than a separate entity. In this way access is made faster and more convenient.

2.2.3.4 Equipment Identity Register (EIR)

The EIR is the entity that decides whether given mobile equipment may be allowed onto the network. Mobile equipments have a number known as the International Mobile Equipment Identity (IMEI). This number is installed in the equipment and is checked by the network during registration. Depending upon the information held in the EIR, the mobile may be allocated one of three states - allowed onto the network, barred access, or monitored in case it has problems.

2.2.3.5 Authentication Center (AuC)

The AuC is a protected database that contains the secret key also contained in the user's SIM card. It is used for authentication and for ciphering on the radio channel.

.2.3.6 Gateway Mobile Switching Center (GMSC)

'he GMSC is the point to which a call is initially routed, without any knowledge of the 1S's location. The GMSC is thus in charge of obtaining the MSRN (Mobile Station .oaming Number) from the HLR based on the MSISDN (Mobile Station ISDN number, ıe "directory number" of a MS) and routing the call to the correct visited MSC. The MSC" part of the term GMSC is misleading, since the gateway operation does not equire any linking to an MSC.

.2.3.7 SMS Gateway (SMS-G)

iateways defined in the GSM standards. The two gateways handle messages directed in ifferent directions. The SMS-G or SMS Gateway is the term that is used to collectively escribe the two Short Message Services. The SMS-GMSC (Short Message Service Gateway Mobile Switching Centre) is for short messages being sent to an ME. The SMS-IWMSC (Short Message Service Inter-Working Mobile Switching Centre) is used or short messages originated with a mobile on that network. The SMS-GMSC role is imilar to that of the GMSC, whereas thc SMS-IWMSC provides a fixed access point to he Short Message Service Centre.

2.2.3.8 Serving GPRS Support Node (SGSN)

'he SGSN or Serving GPRS Support Node element of the GPRS network provides a ariety of services to the mobile such as packet routing and transfers, mobility nanagement, attach/detach logical link management, authentication and finally charging lata. There is a location register within the SGSN and this stores location information exp, current cell, current VLR). It also stores the user profiles (exp, IMSI, packet ddresses used) for all the GPRS users registered with the particular SGSN.

2.2.3.9 Gateway GPRS Support Node (GGSN)

'he GGSN, Gateway GPRS Support Node is one of the most important entities within he GPRS network architecture. The GGSN organizes the networking between the GPRS etwork and external packet switched networks to which the mobiles may be connected. 'hese may include both Internet and X.25 networks.

e GGSN can be considered to be a combination of a gateway, router and firewall as it les the internal network to the outside. In operation, when the GGSN receives data dressed to a specific user, it checks if the user is active, then forwarding the data. In opposite direction, packet data from the mobile is routed to the right destination twork by the GGSN.

2.3.10 Packet Control Unit (PCU)

e PCU or Packet Control Unit is a hardware router that is added to the BSC. It ferentiates data destined for the standard GSM network (circuit switched data) and ta destined for the GPRS network (Packet Switched Data).

3 GPRS Frame and Slot Structure

ain the GRPS air interface employs the same basic structure as that adopted for GSM. e overall slot structure for this channel is the same as that used within GSM, having same power profile, and timing advance attributes to overcome the different signal vel times to the base station dependent upon the distance the mobile is from the base tion. This enables the burst to fit in seamlessly with the existing GSM structure. But RS two time slots are used at a same time for data transmission and internet nnection. Figure bellow shows the GPRS slots showing offset between transmit d received.

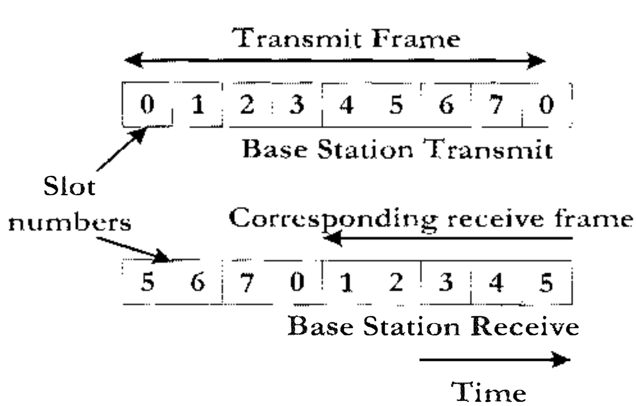


Figure 3: GSM/GPRS Slots Showing Offset Between Transmit and Received

2.4 GPRS Burst Structure

Each GPRS burst of information is 0.577 mS in length and is the same as that used in GSM. A GSM/GPRS burst structure is shown in Figure 4. The GPRS burst carries two blocks of 57 bits of information in line with a GSM burst, giving a total of 114 bits per burst. It therefore requires four GPRS bursts to carry each 20 mS block of data, i.e. 456 bits of encoded data. Slots can be assigned dynamically by the BSC to GPRS, depending upon the demand, the remaining ones being used for GSM traffic.

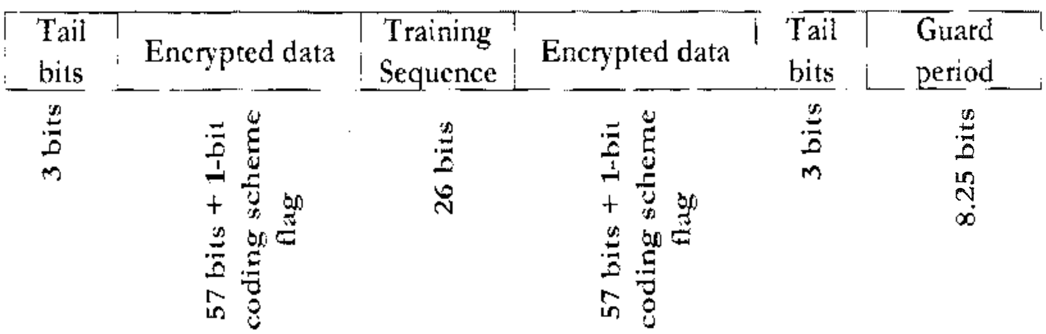


Figure 4: GSM/GPRS Burst Structure

2.5 GPRS Channel Allocation

Although GPRS uses only one physical channel (PDCH) for sending data, it employs several logical channels that are mapped into this PDCH to enable the GPRS data and facilities to be managed. As the Data in GPRS is handled as packet data, rather than circuit switched data which is used in GSM TDMA slots. Hence GPRS data formation is different than that of a standard GSM link. Packets of data are assigned a space within the system according to the current needs, and routed accordingly.

2.5.1 Physical Channels

GPRS builds on the basic GSM structure. GPRS uses the same modulation and frame structures that are employed by GSM, and in this way it is an evolution of the GSM standard. Slots can be assigned dynamically by the BSC to GPRS calls depending upon the demand, the remaining ones being used for GSM traffic.

There is a new data channel used for GPRS and it is called the Packet Data Channel (PDCH). The overall slot structure for this channel is the same as that used in GSM, having same profile and timing advance attributes to overcome the different signal travel times to base station depending upon the distance the mobile is from the base station. This enables the burst to fit in seamlessly with the existing GSM structure.

2.5.2 Logical Channels

There is variety of logical channels used within GPRS, and they can be set into groups depending upon their nature of use, whether common or dedicated. Naturally the system does use the GSM control and broadcast channels for initial set up, but all the GPRS actions are carried out through the GPRS logical channels carried by the PDCH [4].

CHAPTER 3
WLAN

l Introduction

Wireless LAN (WLAN) is a data transmission system designed to provide location-ependent network access between computing devices by using radio waves rather n a cable infrastructure. In the corporate enterprise, WLANs are usually implemented the final link between the existing wired network and a group of client computers, 'ing these users wireless access to the full resources and services of the corporate :work across a building or campus setting. The widespread acceptance of WLANs ɔends on industry standardization to ensure product compatibility and reliability ıong the various manufacturers.

e major motivation and benefit from Wireless LANs is increased mobility. Undeterred ɔm conventional network connections, network users can move about almost without striction and access LANs from nearly anywhere.

e other advantages for WLAN include cost-effective network setup for hard-to-wire cations such as older buildings and solid-wall structures and reduced cost of 'nership-particularly in dynamic environments requiring frequent modifications [5]. LANs liberate users from the dependency on hard-wired access to the network ckbone, giving them access to network anytime, anywhere. This roaming freedom fers numerous benefits to user for a variety of work environments, namely:

- Immediate bedside access to patient information for doctors and hospital staff
- Easy, real-time network access for on-site consultants or auditors
- Improved database access for roving supervisors such as production line managers, warehouse auditors, or construction engineers
- Simplified network configuration with minimal MIS involvement for temporary setups such as trade shows or conference rooms
- Faster access to customer information for service vendors and retailers, resulting in better service and improved customer satisfaction

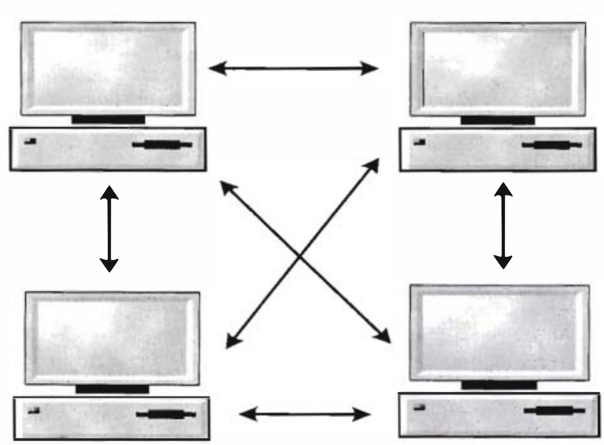
- Location-independent access for network administrators, for easier on-site troubleshooting and support
- Real-time access to study group meetings and research links for students

3.2 WLAN System Architecture

Each device, mobile, portable or fixed, is referred to as a station in 802.11 WLAN. The difference between a portable and mobile station is that a portable station moves from point to point but is only used at a fixed point. Mobile stations access the LAN during movement. When two or more stations come together to communicate with each other, they form a Basic Service Set (BSS). The minimum BSS consists of two stations. 802.11 LANs use the BSS as the standard building block.

3.2.1 Basic Service Set (BSS)

A BSS that stands alone and is not connected to a base is called an Independent Basic Service Set (IBSS) or is referred to as an Ad-Hoc Network. Ad-hoc networks are spontaneous and can be set up rapidly. Figure 5 shows a WLAN BSS model



Independent Basic Service Set (IBSS)

Figure 5: WLAN BSS Model

When BSS's are interconnected, the network becomes one with infrastructure. Two or more BSS's are interconnected using a Distribution System or DS.

3.2.2 Distribution System (DS)

The concept of DS increases network coverage. Each BSS becomes a component of an extended, larger network. Entry to the DS is accomplished with the use of Access Points (AP). An access point is a station, thus addressable. So, data moves between the BSS and the DS with the help of these access points [5, 6].

Creating large and complex networks, using BSS's and DS's leads us to the next level of hierarchy, the Extended Service Set or ESS. The beauty of the ESS is the entire network looks like an independent basic service set to the Logical Link Control layer (LLC). This means that stations within the ESS can communicate or even move between BSSs transparently to the LLC [6].

Figure 6 is showing a WLAN infrastructure model.

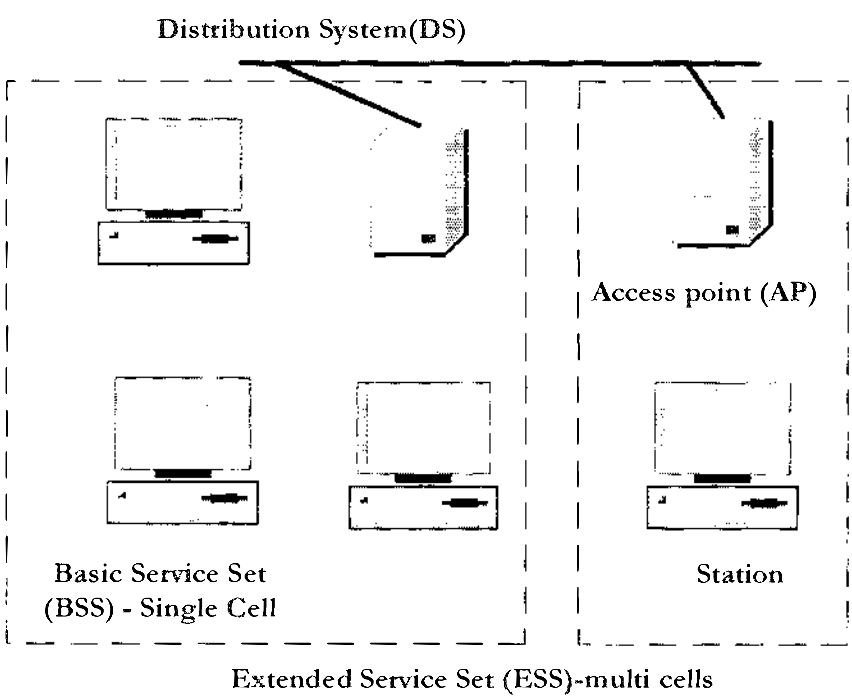


Figure 6: WLAN Infrastructure Model

CHAPTER 4
Radio Resource Management (RRM)

4.1 Introduction

Radio Resource Management is the system level control of co-channel interference and radio transmission characteristics in wireless communication systems. RRM techniques are used to improve the utilization of radio resources of the wireless network. The main objectives of radio resource management are to:

- Maximize the performance of all users with coverage and capacity
- Guarantee the quality of service for different applications
- Maintain the planned coverage
- Optimize the system capacity

The main functions of radio resource management are as follows:

a. Power Control
b. Handoff Control
c. Congestion Control
   i) Call Admission Control
   ii) Load Control
   iii) Packet Scheduling Control

There are different algorithms for RRM functions. RRM algorithms mostly consist of mechanisms for efficient power control, handoff control, admission control, load control, and packet scheduling functionalities.

4.2 Power Control

Power control is the most important and critical function of RRM. Power control is very essential for radio communication due to the interference nature of cellular systems and responsible for adjusting the transmit powers to minimum level, required to ensure the maximum expected QoS limitations. The main objectives of power control are to:

- Provide sufficient power for each user equipment
- Control interference

- Overcome the near- far effect
- Maximize the battery life of the user equipment

4.3 Handoff Control

The mechanism that transfers an active call from one cell to one of its neighboring cell with subscriber's movement is called handoff. Handoffs are very important in cellular architecture. Handoff provides freedom of mobility within the boundaries of the cellular system. But this mobility can cause some problems related to link quality and interference level during communication. So, a mechanism to control this procedure is necessary in order to cope with the problems, which are referred to as handoff. The cell in which MS is currently connected is known as active cell and the neighbor cell in which MS can connect after handoff is known as candidate cell [7]. Each handoff requires network resources in the candidate cell in order to transfer the ongoing call with QoS requirements.

Main objectives of handoff control are to:

- Ensure the stability of ongoing call with required
- Guarantee the stability of service
- Minimize the interference level of whole wireless system
- Load balancing in wireless systems

4.3.1 Types of Handoffs

Handoff control can be divided into the following four types: Intra system handoff, Inter system handoff, hard handoff and soft handoff.

4.3.1.1 Intra System Handoffs

Intra system handoffs occur within the cellular system. There are further two types of intra system handoff.

Intra Frequency Handoff- Intra frequency handoff occurs between the cells having same carrier frequency.

Inter Frequency Handoff-Inter frequency handoffs occur between cells having different carrier frequency.

4.3.1.2 Inter System Handoff

Inter system handoff is the process of transparently handing off a call in progress from one wireless system to a neighboring wireless system, like between GSM and UTMS or IS-95. This process is made possible because of an MSC to MSC link between the neighboring wireless systems.

4.3.1.3 Hard Handoffs

Hard handoff is a handoff procedure in which all previous radio links of user equipment are released before new radio links will establish. Hard handoff is lossless for Non Real Time (NRT) connections but for Real Time (RT) connections, it is just a short disconnection, which is usually not recognizable.

4.3.1.4 Soft Handoffs

Soft handoff is a handoff procedure in which a MS is connected and controlled by more than one cells simultaneously. These cells can belong to the different BTSs of same BSS or same BTSs of different BSS. If participating cells belong to the same BTS then this type of soft handoff is a special case of soft handoff and known as Softer Handoff.

4.3.2 Handoff Procedures

Handoff procedure can be divided into following three phases:

- Measurement
- Decision
- Execution

In ***measurement*** phase the necessary required information to make a handoff decision is measured. For downlink, typical measurement is energy per bit to total interference ratio (Ec/Io) estimation. In other measurements, intra frequency measurements, inter frequency measurements; inter RAT measurements, traffic volume measurements, quality measurements and MS positioning measurements are performed in wireless network.

In ***decision*** phase, a decision is made on the basis of measurements done in the measurement phase. The measurements are compared with the predefined target values and a decision is made on the result of this analysis. These target values are different for different systems and technologies.

In ***execution*** phase (final phase), handoff procedure is completed and relative parameters are changed according to the handoff type, for example a BTS is added or released, power of different channels involved in handoff adjusted etc [8].

4.4 Congestion Control

Congestion control is important to keep the radio interface load under predefined thresholds to guarantee the availability of required resources for a call. Overloading cause problems in terms of lower capacity, quality of service degradation or unavailability of services in the planned coverage area or simply unstable the network.

4.5 Call Admission Control

Call Admission Control (CAC) is the function to regulate and provide resources for new call request or already going call. CAC also ensure the QoS for the calls in terms of required radio resources. The location of admission control is BSS, where load information of several cells can be obtained.

The main objective of a admission control is to ensure the free radio resources fro a new or handoff call with required Signal to Interference Ratio (SIR) and bit rate. CAC ensure that the admittance of new connection will not sacrifice the planned coverage area or the QoS of the existing connections. Admission control always initiates when a MS starts communication with a BTS either through a new call or handoff call or makes a new service request.

Admission control takes the decision of acceptance or rejection of a new call or the modification in an ongoing call. Whenever a MS wants to establish a connection with BTS, it sends request for resource allocation. Admission control at BSS, handles that request. For real time (RT) services, if connection causes excessive interference to the system, request will be denied. Otherwise resources will be allocated for that connection.

For non real time (NRT) connection request, the optimum scheduling of the packets must be determined after the admission of the call [7].

4.6 Load Control

Load control maintains the radio resources of the network within the given limits of QoS [9]. The main objective of load control is to ensure that the network is not overloaded and remains stable. If network becomes overloaded, then load control performs some actions to quickly decrease the load to the limits to decrease the interference and maintained the QoS and planned coverage. Load control is functional on both BTS and BSS. The main actions of load control to prevent congestion in BTS are:

- Manage transmit power control (TPC) up commands by overwriting them for uplink direction or deny power up commands for downlink direction
- Use a lower target SIR for uplink inner loop power control to reduce interference

Basic load control actions taken place in BSS are:

- Interact with packet scheduler and restrict the use of packet data traffic
- Degrade the real time users in terms of bit rate
- Dropping of calls by using dropping strategy defined during planning
- Manage intra frequency or inter system handoffs to prevent interference in terms of load

4.7 Packet Scheduling Control

Packet scheduling control is done by BSS in GPRS with functionality to control the packet access. Packet scheduling control provides appropriate radio resources for data calls. Packet scheduling control algorithms work with call admission control and load control algorithms in order to prevent the radio network from congestion and maintain the QoS. GPRS guarantee the availability of required resources for the real time services. Packet scheduling control mainly deals with the NRT traffic without disturbing real time traffic.

The main objectives of packet scheduling control are:

- Finding and splitting accessible radio resources for NRT connections

- Monitoring of NRT allocations
- Monitoring of system load
- Executing the load control actions for NRT connections when required

4.8 CRRM Functional Model

Common Radio Resource Management (CRRM) refers to the set of functions that are devoted to ensure an efficient use of the available radio resources in heterogeneous network scenarios by means of a proper coordination between the different radio access networks [10]. The functional model for CRRM operation considers the total amount of resources available for an operator divided into radio resource pools. Each radio resource pool consists of the resources available in a set of cells. Two types of entities are considered for the management of these radio resource pools, as shown in Figure 7 below:

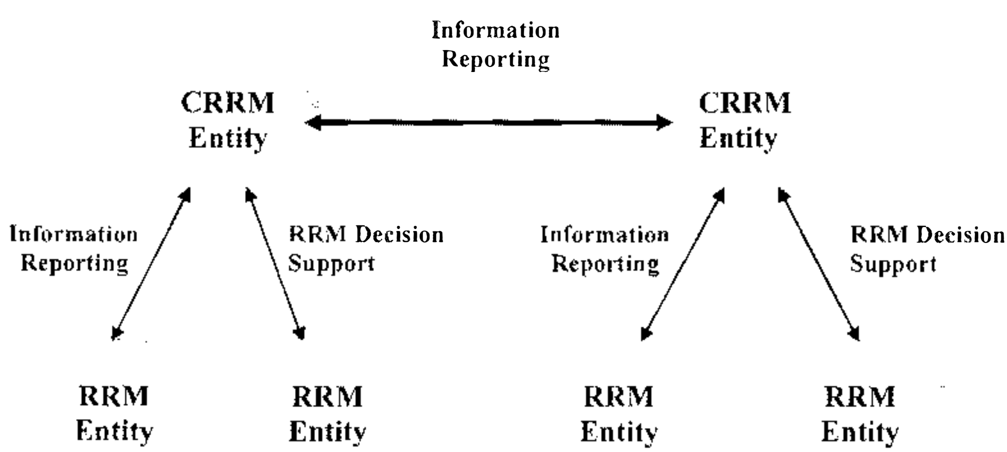


Figure 7: CRRM Functional Model

4.8.1 RRM Entity

The RRM entity carries out the management of the resources in one radio resource pool of a certain radio access network. This functional entity involves different physical entities in the RNS (Radio Network Subsystem) or BSS (Base Station Subsystem) depending on the specific functions [11]. Different RRM entities do not necessarily belong to different radio access technologies.

4.8.2 CRRM Entity

The CRRM entity is involved in coordinated management of resource pools under different RRM entities. In this way, decisions on radio resources usage may take into account the resource availability in several RRM entities. Each CRRM entity controls a number of RRM entities and may communicate with other CRRM entities as well, thus collecting information from other RRM entities that are not under its direct control.

4.9 CRRM Functions

Interaction between RRM and CRRM entities involve mainly two types of functions

a) Information reporting function

b) RRM decision support function

4.9.1 Information Reporting Function

The information reporting function allows the RRM entity to report relevant information to its controlling CRRM. The reporting can be performed periodical or event-triggered, or even at given instant, and it is totally up to CRRM entity's request. The exchange of information is also possible between different CRRM entities in order to know the status of their corresponding RRM entities. There are mainly two types of information to be reported to the CRRM entity from RRM entities:

- Dynamic common measurements on cells controlled by a distant RNC (radio network controller) or BSC entity. These measurements include cell load both in circuit switched (CS) domain and packet switched (PS) domain, information such as the transmitted carrier power, the received total wideband power, interference measurements, etc.

- Static information on cells controlled by a distant RNC or BSC entity. This includes the knowledge about the cell relations, the cell capacities in the CS and PS domains (e.g. the number of available time slots) or the available QoS (e.g. maximum bit rate for a given service or average buffer delay).

4.9.2 RRM Decision Support Function

This function describes the way how the CRRM and RRM entities interact for taking decisions. For example, it is possible that the CRRM simply advises the RRM entity, so that the RRM remains as the master of the decisions, and, on the contrary, it is also possible that the CRRM is the master so that its decisions are binding for the RRM entity.

4.10 CRRM Functionalities

CRRM is designed to coordinately manage resource pools over the heterogeneous air interface in an efficient way. This efficiency depends on how to construct its functionalities. There exist a range of possibilities for the set of functionalities that CRRM entity may undertake, which mainly depend on the following two factors:

- RRM or CRRM entity is the master to make RRM decisions
- The degree of interactions between RRM and CRRM entities

The RRM functionalities arising in the context of a single RAT, are the admission and congestion control, the horizontal (intra-system) handover, the packet scheduling and the power control. It is worth mentioning here that, when these functionalities are coordinated between different RATs in a heterogeneous network environment, they can be denoted as "common" (i.e. thus having the common admission control, common congestion control [12].

In turn, when an heterogeneous network environment is considered, two specific additional functionalities arise, namely the initial RAT selection (i.e. the functionality devoted to decide to which RAT a given service request should be allocated) and the Vertical (inter system) handover (i.e. the functionality devoted to decide a seamless RAT switching for an on-going service) [10]. Then, the different possibilities that are envisaged when considering the operation between RRM and CRRM entities are the following.

4.10.1 No CRRM Functionalities

In this case, it is considered that, although different RATs operate in a heterogeneous network environment no coordination among them is carried out and, consequently, no specific functionalities are associated to CRRM level. In this case, and as shown in Figure 8, the Initial RAT selection and Vertical Handover algorithms are associated with RRM entities, so that the decisions are taken without any knowledge from the radio network conditions in other RATs [13].

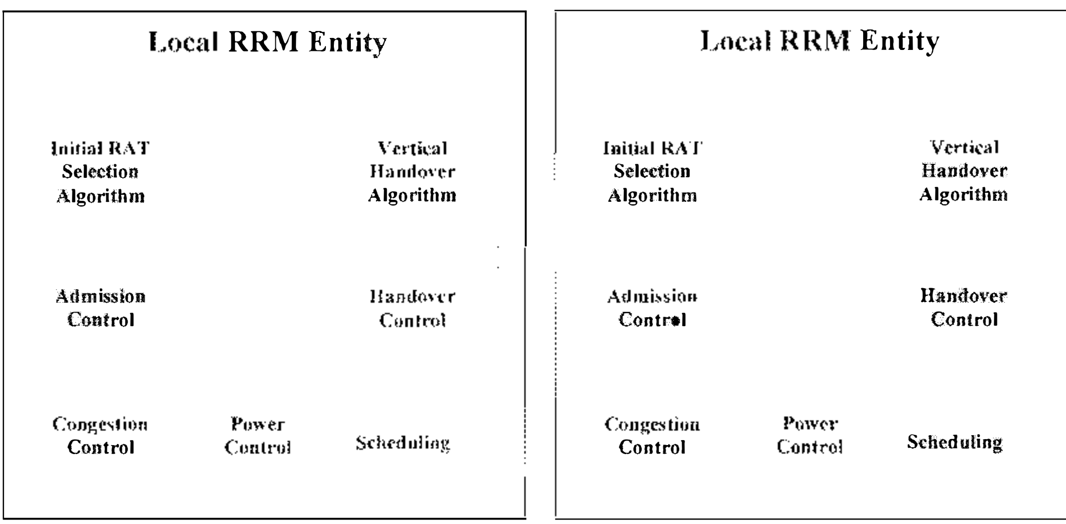


Figure 8: No CRRM Functionalities

4.10.2 Initial RAT Selection and Vertical Handover

Another approach is based on associating the Initial RAT selection and Vertical Handover algorithms with the CRRM entity, as depicted in Figure 9. The local RRM entities provide RRM measurements including the list of candidate cells for the different RATs and cell load measurements, so that the CRRM can take into account the availability of each RAT for the corresponding mobile terminal. Clearly, such algorithms may be more sophisticated and take more information into account, so that a more suitable behavior may be obtained. Nevertheless, once the RAT has been selected, the local RRM algorithms deal with the specific admission control and intra-system handovers. Similarly, fast resource allocation by means of scheduling algorithms is also handled by the local RRM to ensure the specific QoS requirements.

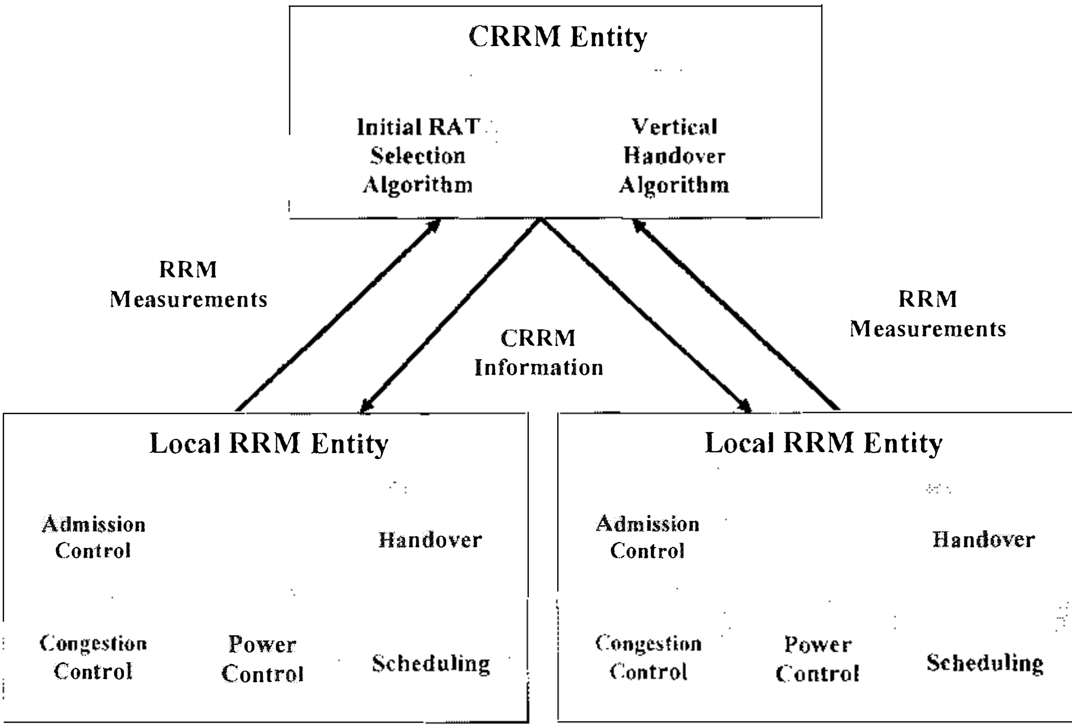


Figure 9: CRRM Carrying Out Initial RAT Selection and Vertical Handover

4.10.3 Common Admission Control

Another envisaged approach is to move to the CRRM entity those local functionalities that operate on a long-term basis, like the admission and congestion control algorithms, while keeping in the local RRM entities the functions that operate at the radio frame level or below, like the packet scheduling or the power control, which would require a very, frequent exchange of information between RRM and CRRM entities. This approach is depicted in Figure 10. This allows more efficient management by executing the algorithms jointly for the different RATs. For example, the common congestion control may take decisions at CRRM level by having the information about the system status in all the involved RATs [14]. Similarly, the cell selection in the Horizontal Handover procedure may be done according to load measurements in the different cells and RATs, so that cells to be avoided (e.g. a Horizontal Handover to a highly loaded cell) can be better anticipated. In this way, handover functionality (either Vertical or Horizontal) can be undertaken from a common perspective. In this case all the decisions regarding admission and congestion are taken by the CRRM entity, and can be undertaken from a common perspective. In this case all the decisions regarding admission and congestion are taken by the CRRM Entity, and executed by the RRM Entity.

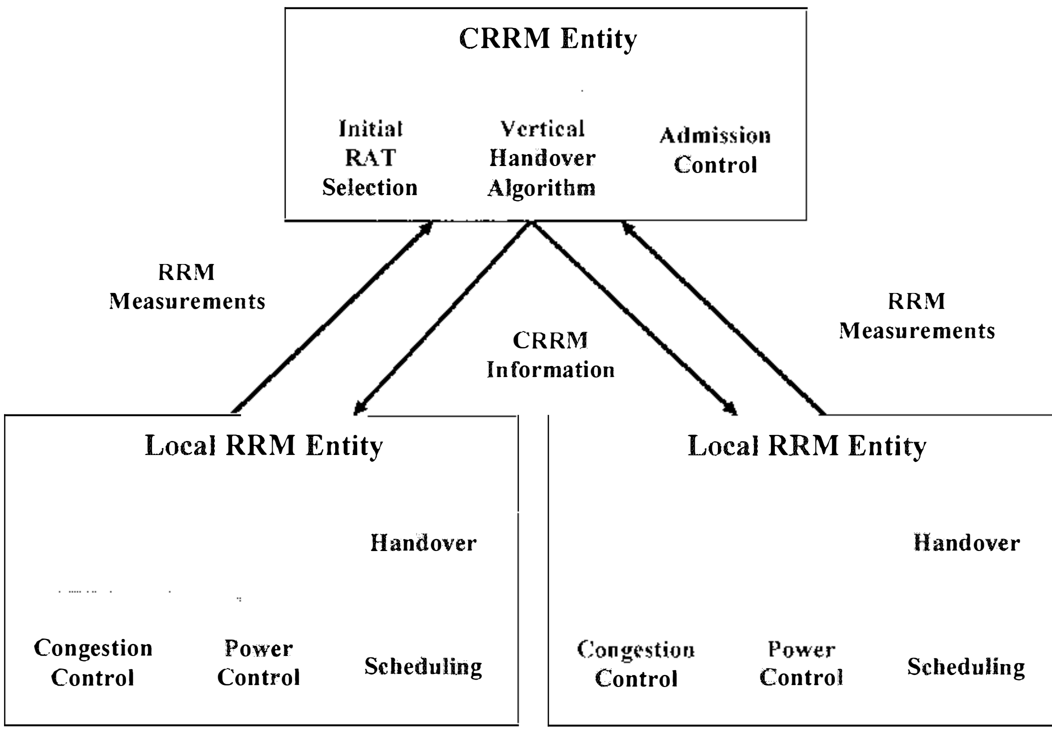


Figure 10: CRRM Carrying Common Admission Control

CHAPTER 5

Simulation and Analysis

5.1 System Model

In this research work overlapped radio networks (GPRS and WLAN) integrated with vertical channel sharing are considered. It proposes a joint admission and scheduling scheme where both GPRS and WLAN radio interfaces can serve the basic data stream. The proposed JRRM scheme tries to minimize blocking probability due to GPRS resource scarcity and improves QoS of applications by allocating multiple RATs, whenever possible. A simulation approach supported by mathematical analysis is given to justify the benefit of the proposed strategy.

Two basic approaches of JRRM are joint session admission control (JOSAC) and joint resource scheduling (JOSCH) [6]. In JOSAC approach, the incoming traffic can be admitted to any of the sub-networks in an heterogeneous cooperative environment. Selecting the RAT may depend on the sub-network load, quality of service (QoS) requirement of application or user's preference. But the limitation of this approach is that it does not support the sharing of multiple RATs by the same traffic stream. Conversely, the JOSCH scheme allows the incoming traffic to be split and transported over cooperating sub-networks based on the available capacity and QoS requirement. This results in significant capacity gain [15].

If the mobility behavior of users is considered, we note that a large number of users covered by the WLAN usually stay in their office or home, most of the time. This mobility behavior motivates us to modify Luo *et al.*'s JRRM scheme [16, 17]. Hence, in this paper, the proposed scheme is a joint admission control and scheduling scheme. In the proposed JRRM scheme, selection of the primary RAT depends on the radio interface availability and user or operator's preference.

For simplicity we considered that all GPRS cells are statistically identical and so is the consideration for all WLAN access point coverage area. So that analysis can be done by focusing on one coverage area of GPRS cell and WLAN access point. The system is operating under steady-state condition. One GPRS cell (macrocell) of area A^M overlaps with n WLAN non overlapped cells (microcells) m_1, $m_2 \ldots m_n$. The sum of microcell areas is A^M.

5.2 Simulation Scenario 1: User Inside Microcell Overlapped by Macrocell

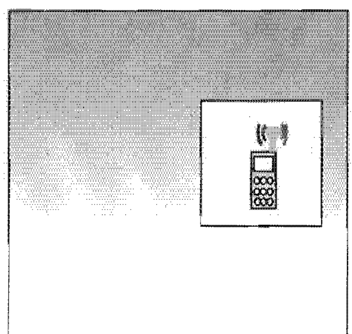


Figure 11: Simulation Scenario 1

When the MS is inside the microcell (WLAN coverage area) overlapped by macrocell (GPRS coverage area), as shown in Figure 11, all GPRS traffic channel, WLAN channel and WLAN queuing channels are available to support its call. In this case, total number of GPRS, WLAN and queuing channel are indicated by C_M, C_m and C_Q respectively. The traffic intensity (A), which is the ratio of the number of call requested per minute (λ) to the mean call duration (μ). As per Erlang B formulae the call blocking probability for MS in this scenario is given below

$$P_b(m) = \frac{\dfrac{A^{C_M+Cm+C_Q}}{C_M+Cm+C_Q\,!}}{\displaystyle\sum_{i=1}^{C_M+Cm+C_Q} \frac{A^i}{i!}} \quad \ldots\ldots\ldots\ldots\ (1)$$

5.3 Simulation Scenario 2: User in Non-Overlapped Macrocell without Vertical Handover

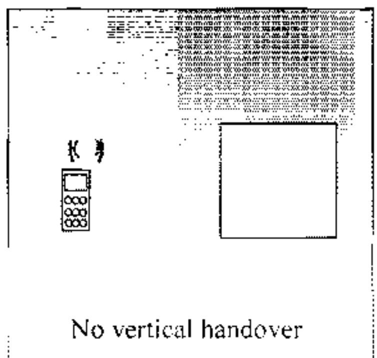


Figure 12: Simulation Scenario 2

When the MS is outside the microcell (WLAN coverage area) but inside the macrocell (GPRS coverage area), as shown in Figure 12, only GPRS channels are available to support its call. If no vertical channel sharing is considered then there will no channel freed from the microcell but user in overlapped area may already in use of some of the GPRS channels. Hence the call blocking probability for the user in non-overlapped macrocell area will be for only GPRS channels and the call blocking probability for the MS in non-overlapped macrocell area is given by:

$$P_b(M) = \frac{\dfrac{A^{C_M}}{C_M!}}{\sum_{i=1}^{C_M} \dfrac{A^i}{i!}} \qquad \text{.............. (2)}$$

5.4 Simulation Scenario 3: User in Non-Overlapped Macrocell with Vertical Handover

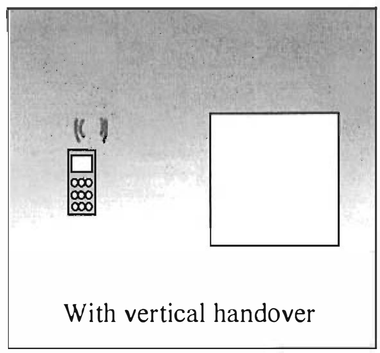


Figure 13: Simulation Scenario 3

The scenario is the same as scenario 2. The only difference is that when there is call congestion for the user in non-overlapped macrocell region, then one of the GPRS channels that are being used by the users of overlapped area (of marocell and microcell coverage area) will be freed and handed over to the user in non-overlapped macrocell coverage. The ongoing call of overlapped area (that is freed for non-overlapped user) will be vertically handed over to WLAN channels unless all the WLAN channels are allocated. This phenomenon is referred to as vertical channel sharing. So the voice call request for a user outside the microcell but inside macrocell will be served through GPRS channel. Channel rearrangement is necessary after vertical handover. In case of only one channel vertical sharing failure, the blocking probability is given by:

$$P_v = (1 - P_r) * [1 - P_b(m)] \qquad \text{............ (3)}$$

Where Pr = probability of successful channel rearrangement and is given by

$$P_r = (1 - \frac{1}{\frac{A^m * C_M}{A^M}}) \qquad \text{................. (4)}$$

So the overall call blocking probability is the joint blocking of the call blocking probability without vertical sharing and probability of vertical sharing failure:

$$P_b = P_b(M) * P_v \qquad \text{.................. (5)}$$

5.5 Simulation

For the simulation purpose it is assumed that the users are uniformly distributed over the whole coverage area of macrocell. We did not consider any Horizontal handoff for simplicity. Also for simplicity we consider cell structure as square. Here, WLAN coverage area is considered as 200 m X 200 m. and GPRS coverage area is considered as 2 km X 2 km square. Omni-directional antenna is considered within the cell. User mobility is considered for pedestrian case only. Finally, in this proposal it is assumed that single channel is utilized by a user. All the simulations have been performed on MATLAB 7.0.

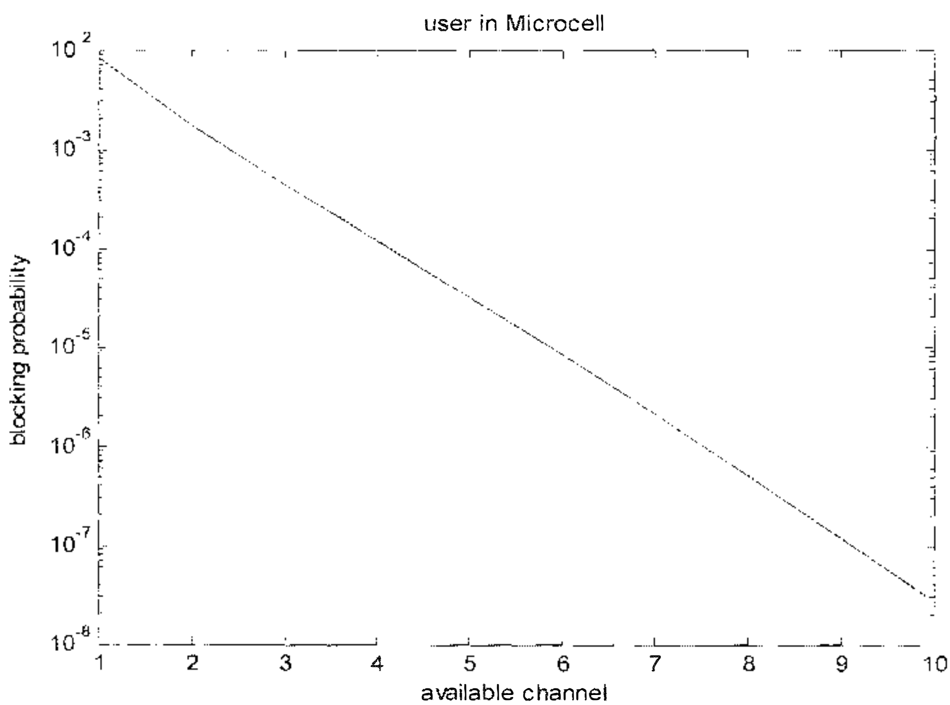


Figure 14: Blocking Probability vs. Available Channels for Scenario 1

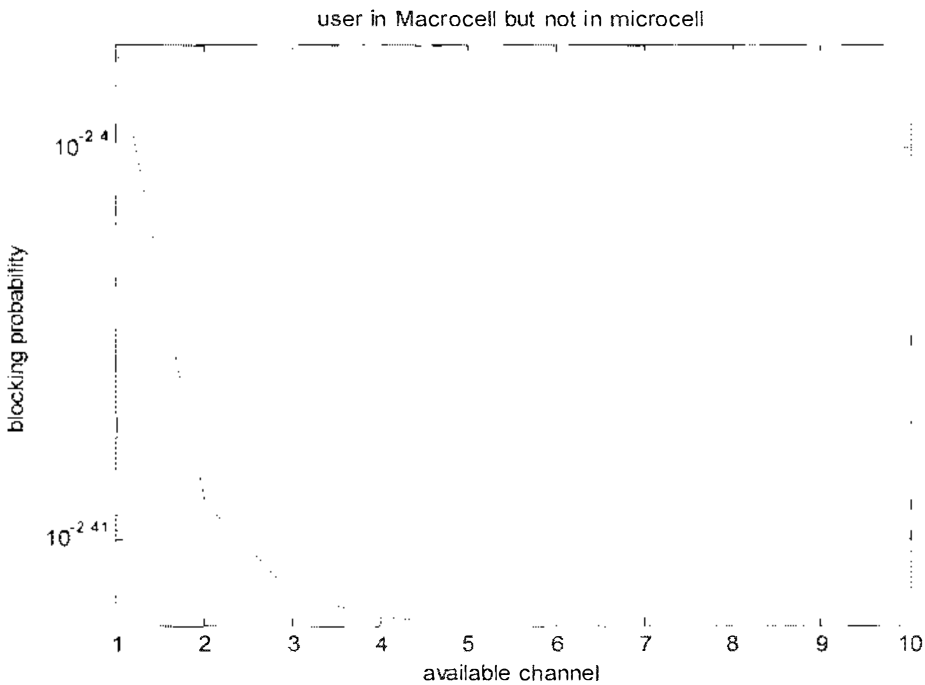


Figure 15: Blocking Probability vs. Available Channels for Scenario 2

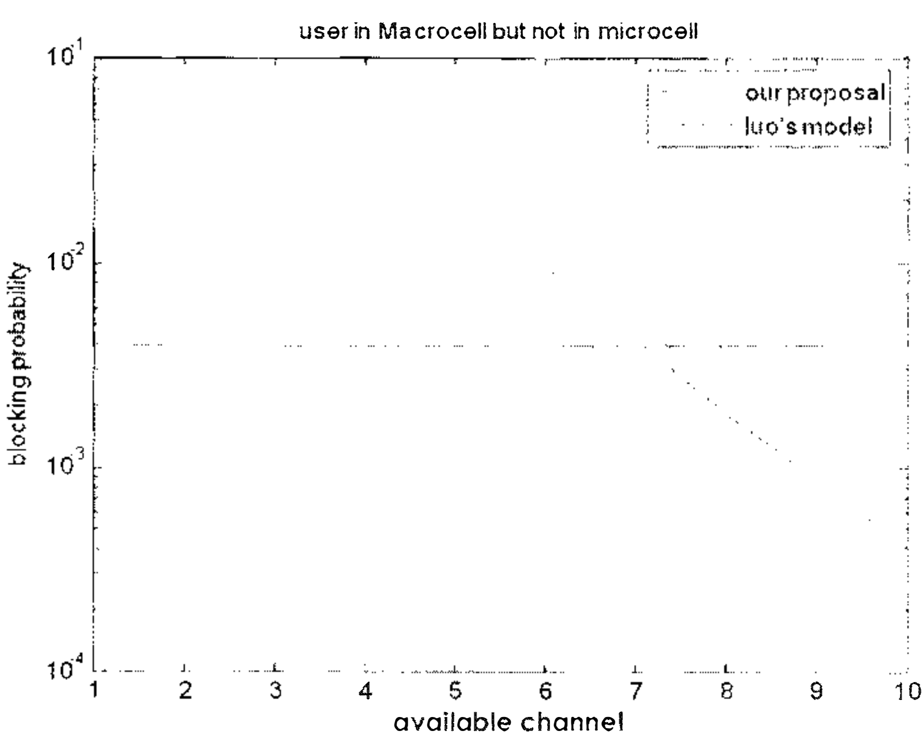


Figure 16: Our Model vs. Luo's Model

5.6 Simulation Analysis

Figure 14 shows the call blocking probability when the user is inside microcell. Similarly, Figure 15 shows the call blocking probability when the user is outside microcell but inside macrocell. In this case, vertical channel sharing is considered. The probability of call blocking decreases gradually in Figure 15 as the number of available channel increases. This states that the more GPRS channel is being shared, the more it is possible to serve a user's request outside microcell. In this way the maximum QoS can be achieved.

For verifying our proposed model, we have compared our simulation with Luo's joint scheduling model [15, 16]. In Figure 16, we can see that our proposed model shows much reduced blocking probability than the Luo's proposed model up to 7 available channels. After that our model shows degradation because we could not perform operation more than 25 channels in MATLAB 7.0. So the result could not be obtained with the actual available channels. Here, as the blocking probability is very small than the range of Luo's blocking probability range, our simulation is showing almost a straight line. Moreover, Luo's model follows the state model [16], according to which, six different combinations are used in case of number of channel sharing. These combinations are based on the user's location inside and outside the microcell and macrocell. In our model we have followed the traffic model in which the vertical sharing occurs whenever a user demands a channel outside a microcell but inside macrocell.

CHAPTER 6

Conclusion and Recommendation

From the simulation we have seen that our proposed model shows much reduced call blocking probability than Luo's joint scheduling model. So we can conclude with the view that our proposed model can improve the QoS in a heterogeneous network incorporating GPRS and WLAN. During the simulation we could not take all the actual number of channels in GPRS, WLAN and Queuing channels as the limitation of MATLAB 7.0 software. Although the actual result could not be shown in the simulation, but our model is applicable for all available channels in a heterogeneous network. So vertical channel sharing can provide satisfactory QoS through common radio resource management.

Our model is recommended for any kind of cell structure such as hexagonal, circular etc. Also a user can utilize multiple channels to fulfill his requirement by multiple channels sharing. Although in the simulation we have only shown vertical handover but in real perspective our model is applicable for horizontal handover with cell sectoring.

In our proposed model we have used a combination of GPRS and WLAN but this model can be applied for any other combinations; for example WLAN in WMAX in recent perspective. Our model enables the operator to build a network using a common core of infrastructure for network and subscriber management, billing and login for all their wireless access networks (i.e. CDMA, GPRS, 3G and WLAN). This will enable users to logon to both a GPRS/3G and WLAN network transparently using one sign-on, similar to the method used today with GSM phones. From a user's point of view, they are able to use WLAN and GPRS/3G services transparently and receive one bill. From an operator's point of view, they are able to offer an integrated set of services, providing more freedom for users and enabling them to access their services using whichever network makes sense at the time. This provides greater flexibility and freedom for both the operator and user

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Appendix

```
%This code is used to find the blocking probability for three different simulation
%scenario mentioned in chapter 5
clear all
clc
Cm=1:10;
Clan=5;
Cq=5;
C1=(Clan+Cq);

lambda=0.25;
meu=0.05;

A=lambda/meu;
sum=0;
for i=1:length(Cm)
   C(i)=C1+Cm(i);
   p(i)=(A^C(i))/(factorial(C(i)));

   for j=1:C(i)
      q(j)=(A^j)/factorial(j);
      sum=sum+q(j);
   end
   sum1(i)=sum;
   Pbm(i)=p(i)/sum1(i);
end


PbM=0.02;
CM=124;
AM=2000*2000;
Am=200*200;
```

```
r=CM/(AM/Am);
Pr=1-(1/r);
for k=1:length(Pbm)
    Pv(k)=(1-Pr)*(1-Pbm(k));
    Pb(k)=PbM*(1-Pv(k));
end

% To plot graph of our proposal vs. Luo's model we plotted using the collected data
% from reference [16]

axis([0 10 10e-3 10e-0]);
xd=[1 2 4 6 8 10];
pbl=[0.028 0.02 0.018 0.0095 0.0018 0.0004];

figure(1);
semilogy(Cm,Pbm);
Title('available channel vs. blocking probability');

figure(2);
semilogy(Cm,Pb,'r-');
Title('available channel vs. blocking probability');

figure(3);
semilogy(Cm,Pb,'r-',xd,pbl,'k');
legend('our proposal', 'luo''s model');
Title('available channel vs. blocking probability');
```