University of Alberta

Master of Science in Internetworking (MINT)

MINT 709
Project Report

An Investigation of CAC in UMTS Cellular Networks

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Abstract

The successful deployment of UMTS (Universal Mobile Telecommunication System) Cellular Network is heavily dependent on CAC (Call Admission Control) which plays a major role in ensuring QoS (Quality of Service) to be achieved. This report is based on the investigation of CAC (Call Admission Control) including the different parameters of RNC (Radio Network Control) Admission Control such as uplink and downlink loading factors, Scheduling Weights, and some attributes of Node-B (Base Station) like Resource Allocation/Retention Priority. Also evaluates the performance of CAC by using the OPNET™ Modeler ver11.5 based on the self made simulation models. And construct the Static Scenario by considering the two QoS traffic classes; streaming and Background. And analyze the relation between offered load and throughput.

Index Terms: *UMTS, CAC, RNC, Loading Factors, Throughput, OPNET™*

Preface

This report is submitted in partial fulfillment of the requirement for the course of MINT (Masters in Internetworking) at the Department of Computing Science and Department of Electrical & Computer Engineering, University of Alberta. The work presented here has been carried out at the Department of Computing Science, during the period from July 2006 to December 2006 under the supervision of Prof. Dr. Ehab S Elmallah.

Production note: This report has been written using Microsoft Word 2003, Microsoft Excel 2003, ACDSee 9.0, Adobe PDF Maker 7.8 and all simulation results were obtained from self-made models using OPNET™ Modeler ver11.5 to design, implement, and test a network system level simulation environment to allow investigators to study the issues.

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Last, but not least, especially I would like to thank my wife Sherene, for her patience and fulltime work at home in supporting my M.Sc. studies. Also love to my dearest son Zain. I feel indebted to my mother for endless love and understanding. My father will feel proud of my Masters that I finally get it. I also thank my brother Maisum and sister Farwa for decades-lasting understanding and support. I devote this report to whole family of mine.

Edmonton, Dec. 2006
Asim Naqvi

List of Abbreviations

3G	3rd Generation
3GPP	3rd Generation Partnership Project
AC	Admission Control
ACK	Acknowledge
AGCH	Access Grant Channel
AP	Access Point
AMR	Adaptive Multi Rate
AUC	Authentication Center
BCCH	Broadcast Control Channel
BLER	Block Error Rate
BR	Blocking Rate
BS	Base Station
BSC	Base Station Controller
BSS	Basic Station System
BSSGP	BSS GPRS Application Protocol
BTS	Base Station Transceiver System
CAC	Call Admission Control
CDMA	Code Division Multiple Access
CIR	Carrier to Interface Ratio
CN	Core Network
CPICH	Common Pilot Channel
CS	Circuit-Switched
DL	Downlink
DTX	Discontinuous Transmission
FTP	File Transfer Protocol
GGSN	Gateway GPRS Support Node
GLR	Gateway Location Register
GMM	GPRS Mobility Management
GMU	Global Management Unit
GoS	Grade of Service
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
GTP	GPRS Traffic Tunneling
GUI	Graphical User Interface
HLR	Home Location Register
HO	Handover
IMEI	International Mobile Station Equipment Identity
IMEISV	IMEI and Software Number
IMSI	International Mobile Subscriber Identity
IP	Internet Protocol
Iu	UMTS interface between Access Network and Core Network
ITMU	Interface Traffic Monitoring Unit
KPI	Key Performance Indicator
LA	Location Area

LAH	Location Area Handover
LC	Load Control
LLC	Logical Link Control
LS	Location Server
MAC	Medium Access Control
ME	Mobile Equipment
MIF	Management Information File
MM	Mobility Management
MMS	Multimedia Message Service
MOC	Mobile Originated Call
MS	Mobile Station
MSC	Mobile Switching Center
MSISDN	Mobile Station ISDN
MT	Mobile Terminal
MTC	Mobile Terminated Call
MU	Mobile User
NPDB	Number Portability Data Base
NRT	Non-real Time
OMC	Operations and Maintenance Center
OVSF	Orthogonal Variable Spreading Factor
P-TMSI	Packet Temporary Mobile Subscriber Identity
PDCH	Packet Data Channel
PDP	Packet Data Protocol
PDU	Packet Data Unit
PS	Packet-Switched
QoS	Quality of Service
RAB	Radio Access Bearer
RACH	Random Access Channel
RAN	Radio Access Network
RLC	Radio Link Control
RMT	Resource Management Technique
RMU	Resource Management Unit
RNC	Radio Network Controller
RNS	Radio Network Subsystems
RRC	Radio Resource Control
RRM	Radio Resource Management
SDCCH	Stand Alone Dedicated Control Channel
SGSN	Serving GPRS Support Node
SIR	Signal to Interference Ratio
SMS	Short Message Service
STS	Simulation Time Step
TBF	Transport Block Flow
TBI	Transport Block Indicator
TCH	Traffic Channel
TCP	Transmission Control Protocol
TDD	Time Division Duplex

TLLI	Temporary Logical Link Identity
TMSI	Temporary Mobile Subscriber Identity
TS	Time Slot
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
USIM	UMTS Subscriber Identity Module
USF	Uplink Stage Flag
UTRAN	UMTS Terrestrial Radio Access Network
Uu	UMTS Air Interface
VLR	Visitor Location Register
W-CDMA	Wideband CDMA
WWW	World Wide Web

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1. Introduction

The mobile communication networks are continuously expanding not only in the terms of size but also in the terms of traffic and services that are provided and supported. Also, the new generation mobile telecommunication platform like the UMTS which are considered to be the fundamental elements for the foreseen 4G (4^{th} Generation) networks with the superior broadband capabilities in data services, will further increase the demand for telecommunication resources and produce new type of traffic profiles. The need for supporting various applications and services in the broadband and complex cellular radio environment like the UMTS (Universal Mobile Telecommunications Systems) is one of the main reasons for introducing much more intelligent and complex CAC (Call Admission Control) techniques.

The goal of 3G (3^{rd} Generation) mobile communication systems is the delivery of multimedia services to the user in the mobile domain. This requires the provision of user data rates that are substantially higher than those provided by today's 2G (2^{nd} Generation) networks.

3G cellular services are now offered in a number of countries around the world. Multimedia applications with various bit rates and QoS (Quality of Service) requirements have steadily become to dominate the wireless communication environment.

UMTS technology has been established as one of the main air interface for 3G mobile systems standardized by 3GPP (3^{rd} Generation Partnership Project). UMTS is envisioned as the successor to GSM (Global System for Mobile Communications). UMTS also referred to as WCDMA (Wideband Code Division Multiple Access), is one of the most significant advances in the evolution of telecommunications into 3G networks. UMTS allows many more applications to be introduced to a worldwide base of users and provides a vital link between today's multiple GSM systems and the ultimate single worldwide standard for all mobile telecommunications, IMT-2000 (International Mobile Telecommunications–2000).

UMTS supports up to 11Mbps data transfer rates in theory, although at the moment users in deployed networks can expect a performance up to 384kbps for R99 handsets, and 1-2Mbps for HSDPA (High-Speed Downlink Packet Access) handsets in the downlink connection. This is still much greater than the 14.4kbps of a single GSM error-corrected CS (Circuit Switched) data channel or multiple 14.4kbps channels in HSCSD (High-Speed Circuit-Switched Data) and in competition to other network technologies such as CDMA-2000, PHS (Personal Handy-phone System) or WLAN (Wireless LAN) offers access to the WWW (World Wide Web) and other data services on mobile devices.

UMTS offers tele-services (like sms or speech) and bearer services, which provide the capability for information transfer between AP (Access Points). It is possible to negotiate and renegotiate the characteristics of a bearer service at session or connection establishment and during ongoing session or connection. Bearer services have different QoS parameters for maximum transfer delay, delay variation and bit error rate. UMTS provides a broad range of network services. Each service is mapped to a certain QoS traffic class, i.e.:

i. **Conversational (voice, video telephony, video gaming)**
ii. **Streaming (multimedia, video on demand, web cast)**
iii. **Interactive (web browsing, network gaming, database access)**
iv. **Background (email, sms, downloading)**

The main describing factor between these QoS classes is how delay sensitive the traffic is: Conversational class is meant for traffic which is very delay sensitive while Background is the most delay insensitive traffic class.

Conversational and Streaming classes are mainly intended to be used to carry real-time traffic flows. The main divider between them is how delay sensitive the traffic is. Conversational real-time services, like video telephony, are the most delay sensitive applications and those data streams should be carried in Conversational class.

Interactive and Background classes are mainly meant to be used by traditional Internet applications like WWW, Email, Telnet, FTP and News. Due to looser delay requirements, compare to conversational and streaming classes, both provide better error rate by means of channel coding and retransmission. The main difference between Interactive and Background is that Interactive class is mainly used by interactive applications, e.g. interactive Email or interactive web browsing, while Background class is meant for background traffic, e.g. background download of Emails or background file downloading. Responsiveness of the interactive applications is ensured by separating interactive and background applications. Traffic in the Interactive class has higher priority in scheduling than Background class traffic, so background applications use transmission resources only when interactive applications do not need them. This is very important in wireless environment where the bandwidth is low compared to fixed networks.

In UMTS radio interface, CAC (Call Admission Control) is a more complex problem than in 2G systems. As a matter of fact, the capacity of each call is not limited by the number of available radio channels, but it depends on the interference levels on each radio link of the network. This allows a more flexible use of radio resources and a dynamic adaptation to different traffic distributions.

In UMTS networks the soft capacity concept applies, each new call increases the interference level of all other ongoing calls, affecting their quality. Therefore it is very important to control the access to the network in a suitable way.

Blocking and dropping are used to prevent the system from an outage situation but their probability of occurrence is greatly reduced. Reserved bandwidth is used thoroughly as a means of improving overall QoS. A CAC mechanism decides whether a RAB (Radio Access Bearer) request should be accepted or rejected.

2. UMTS Architectural Overview

UMTS network based on three major architectural components/interacting domains, which are following; as well shown in Figure 2-1 below;

i. **CN (Core Network)**,
ii. **UTRAN (UMTS Terrestrial Radio Access Network)**, and
iii. **UE (User Equipment)**

And the external networks, it could be traditional PSTN (Public Switched Telephone Network), ISDN (Integrated Services Digital Network), or IP-based network, depending on type of the service.

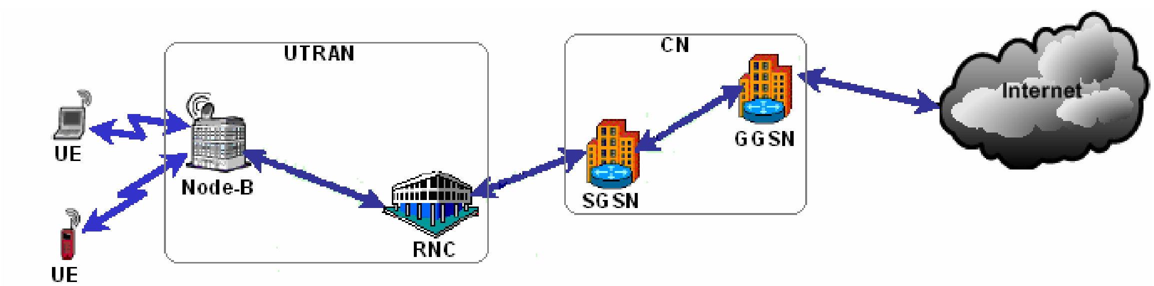

Figure 2-1 UMTS System Overview

The UE (User Equipment) can consist of the MT (Mobile Terminal), the TE (Terminal Equipment), and the SIM (Subscriber Identity Module). The UTRAN is comprised of the Node-B (Base Station) and the RNC (Radio Network Controller). The RNC is in charge of the overall control of logical resources provided by the Node-Bs. The RNC manages the air interface resources between its Node-Bs and their associated UEs. The Node-B provides logical resources, corresponding to the resources of one or more cells, to the RNC. It is responsible for the radio transmission and reception in the cells it controls. A Node-B can control several cells, managing the network air interface for its associated UEs. It is responsible for relaying packets between the UEs and its controlling RNC. The Node-B is also responsible for assisting the RNC with radio resource management through the NBAP (Node-B Application Protocol) signaling messages. The SGSN

(Serving GPRS support node) keeps track of the location of individual UEs and performs security functions and access control. The GGSN (Gateway GPRS support node) encapsulates packets received from external packet networks (IP) and routes them to the SGSN.

It is necessary for a network to know the approximate location in order to be able to page UE. Here is the list of system areas from largest to smallest;

- UMTS systems (including satellite)
- PLMN (Public Land Mobile Network)
- MSC/VLR (Mobile services Switching Center/Visitor Location Register) or SGSN
- Location Area
- Routing Area (PS domain)
- UTRAN Registration Area (PS domain)
- Cell
- Sub cell

2.1 CN (Core Network)

The CN provides mobility management, session management and transport for Internet Protocol packet services in UMTS networks. The CN is divided in CS (Circuit Switched) and PS (Packet Switched) domains.

The ATM (Asynchronous Transfer Mode) is defined for UMTS core transmission. AAL2 (ATM Adaptation Layer type 2) handles circuit switched connection and packet connection protocol AAL5 is designed for data delivery.

Both GSM and UMTS use a common packet domain CN to provide PS services. The packet domain is designed to support several qualities of service levels to allow efficient data transfer of application traffic ranging from non real-time, intermittent and bursty data to real-time voice and video. The SGSN is the node that is serving the UE. It supports GPRS for UMTS via the Iu interface. The SGSN performs location management, security, and access control functions for the UEs. The GGSN provides inter-working with external packet switched networks, and is connected with SGSNs via the ATM-based interface, Gn. It contains routing information for PS-attached users. This routing information is used to tunnel data to the UEs current point of attachment (i.e., the SGSN).

The common CS elements of CN include the MSC/VLR (Mobile Switching Center/Visitor Location Register), the HLR (Home Location Register), the CGF (Charging Gateway Functionality), and the EIR (Equipment Identity Register). The MSC/VLR is used to provide efficient coordination of PS and CS services (i.e., combined GPRS and non-GPRS location updates). The HLR contains GSM and UMTS subscriber information. The CGF collects charging records from the SGSNs and GGSNs. The EIR stores information about user equipment identity.

In order to access the PS services, a UE must make its presence known to the network by performing a GPRS attach. This makes the UE available via the SGSN for notification of incoming PS data. In order to send and receive PS data, the UE must activate the Packet Data Protocol (PDP) context that it wants to use. This operation makes the UE known to its GGSN and to the external data networks through this gateway. User data is transferred transparently between the UE and the external data networks with a method known as encapsulation and tunneling. Data packets are equipped with PS-specific protocol information and transferred between the UE and the GGSN. This transparent transfer method enables easy introduction of additional inter-working protocols in the future.

The architecture of the CN may change when new services and features are introduced. NPDB (Number Portability Data Base) will be used to enable user to change the network while keeping their old phone number. GLR (Gateway Location Register) may be used to optimize the subscriber handling between network boundaries. MSC, VLR and SGSN can merge to become a UMTS MSC.

2.2 UTRAN (UMTS Terrestrial Radio Access Network)

UTRAN has been defined as an access network. It means that the radio interface independent functions, essentially call control and mobility management, are outside the scope of the UTRAN specifications and handled by the core network. UTRAN has inherited its centralized network architecture with a quite complex central RNC (Radio Network Controller) and simple Node-B from the 2G GSM system. A Node-B may serve one or multiple cells.

About fifteen years ago, this basic architecture was designed for GSM to provide wireless access to the CS, voice-oriented telecommunications network (PSTN). Though in the meantime the network architecture has been extended to packet data services GPRS (Global Packet Radio Service), the provision of IP services over GPRS protocols seems unnecessarily complex. This situation has not improved much by introduction of the 3G UMTS system, since for sake of a smooth migration, the 3GPP standards bodies decided not to change network architectures and protocols dramatically. So it is still up to later releases to cope with the difficulties of evolving 3G networks to optimized IP environments.

As a central instance, UTRAN manages the provisioning of all necessary bearer services for control and user traffic in order to establish the RAB (Radio Access Bearer) between UE and CN.

The UTRAN permits under certain circumstances, the use of multiple radio links across multiple cells in support of a single UTRAN–UE connection (termed soft handover). These links may exist across different Node-Bs in neighboring RNCs, in which case the necessary signaling and data transfers occur across the Iur interface. The Iur also participates in mobility switching (hard handover) where switching between Iu (UMTS interface between Access Network and CN) instances occurs. The figure below shows a simplified version of the protocols running between a UE and the UTRAN. Transport channels carry control plane or user plane data between the UE and RNC, mapping onto physical channels on the air (Uu) interface (allocated by the RRC (Radio Resource Control) layer) and ATM AAL2 connections over the Iub interface.

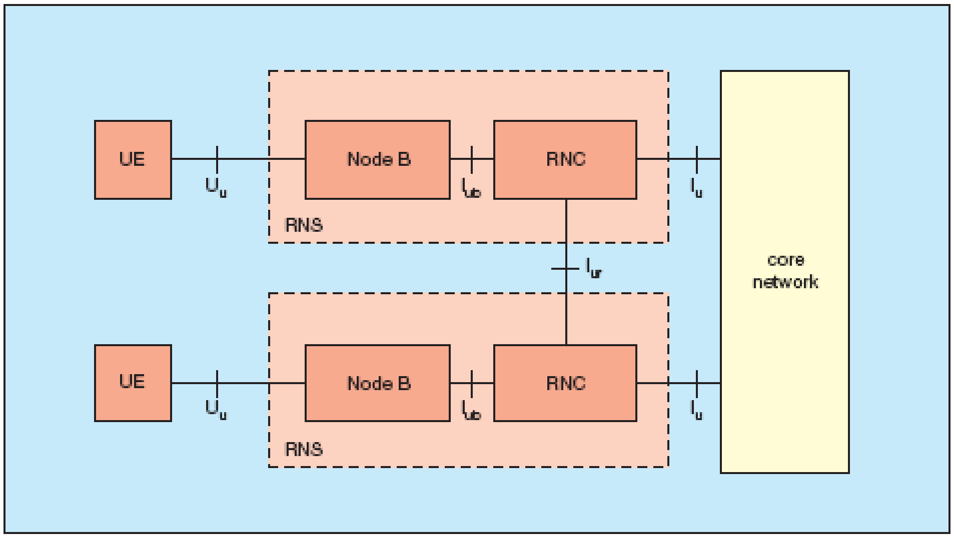

Figure 2-2 UTRAN Architecture

An important point to note is that on the network side the MAC (Medium Access Control) layer and RLC (Radio Link Control) layer reside in the RNC, which is where most of the UTRAN intelligence is concentrated. The FP (Frame Protocol) is responsible for the relaying of transport channels between the UE and the RNC via the Node B.

The main functions of Node-B are:

- Air interface Transmission/Reception
- Modulation / Demodulation
- CDMA Physical Channel Coding
- Micro Diversity
- Error Handling
- Closed loop power control

The main functions of RNC are:

- RRC (Radio Resource Control)
- Admission Control
- Channel Allocation
- Power Control Settings
- Handover Control
- Macro Diversity
- Ciphering
- Segmentation/Reassembly
- Broadcast Signaling
- Open Loop Power Control

2.3 UE (User Equipment)

The UMTS UE is based on the same principles as the GSM MS, the separation between ME and the USIM (UMTS Subscriber Identity Module) card. Beneath Figure 2-3 shows the UE functions. The UE is the counterpart to the various network elements in many functions and procedures.

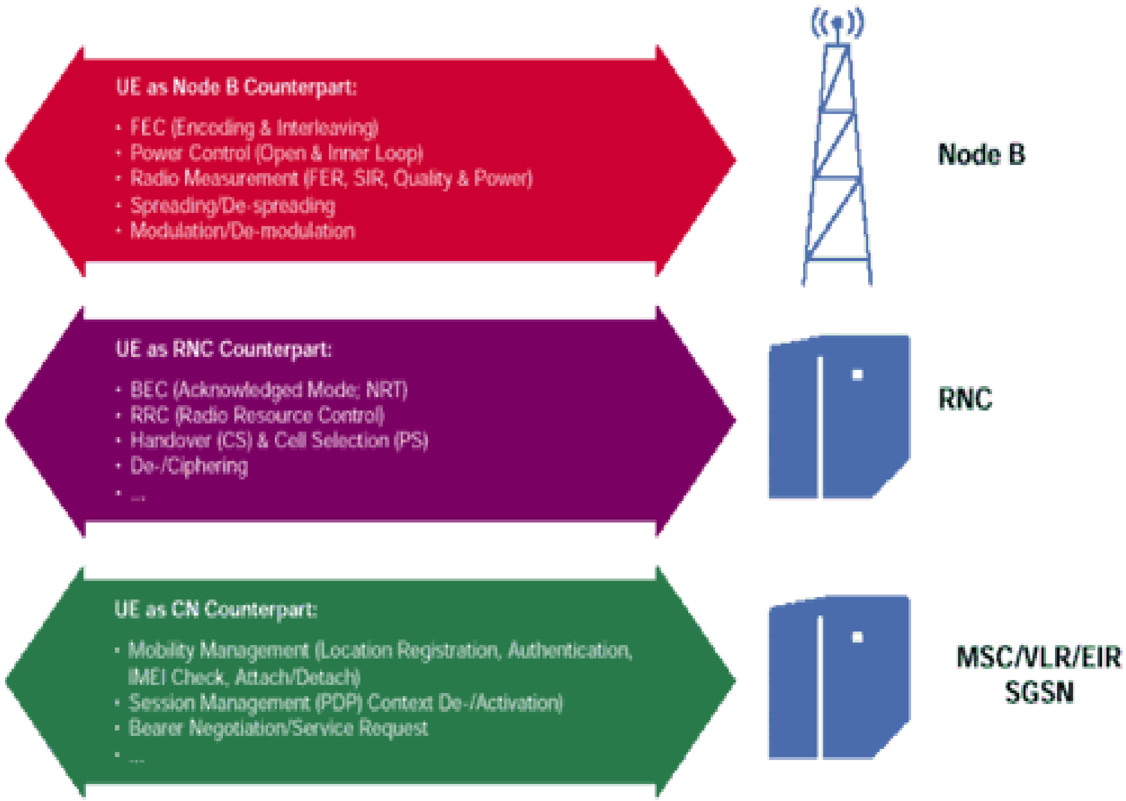

Figure 2-3 UE Functions

UE work as an air interface counter part for Node-B and have many different types of identities. Most of these identity types of UMTS are taken directly from GSM specifications. Here are some:

- IMSI (International Mobile Subscriber Identity)
- TMSI (Temporary Mobile Subscriber Identity)
- P-TMSI (Packet Temporary Mobile Subscriber Identity)
- TLLI (Temporary Logical Link Identity)
- MSISDN (Mobile Station ISDN)
- IMEI (International Mobile Station Equipment Identity)
- IMEISV (International Mobile Station Equipment Identity and Software Number)

UMTS MS or UE can operate in one of three modes of operation:

- **PS/CS mode of operation:** The MS is attached to both the PS domain and CS domain, and the MS is capable of simultaneously operating PS services and CS services.

- **PS mode of operation:** The MS is attached to the PS domain only and may only operate services of the PS domain. However, this does not prevent CS-like services to be offered over the PS domain like VoIP.

- **CS mode of operation:** The MS is attached to the CS domain only and may only operate services of the CS domain.

3. CAC Strategies

As a substantive function of traffic control, CAC has been intensively investigated from both data communication and telecommunication communities. The objective of CAC schemes is to accommodate in an optimal way, a maximum number of connection requests and at the same time, maintain the agreed QoS for existing connections. This is done by managing the available network resources and allocating them according to a particular strategy, among the users [15].

Conventional CAC strategies in wire line networks are complete sharing, complete partitioning and threshold. In the complete sharing strategy, calls of all classes share the bandwidth resources. Whereas in the complete partitioning strategy, bandwidth for each class is exclusively reserved. In the threshold strategy, a newly arriving call is blocked if the number of calls of each class is greater than a predefined threshold [16]. In an IP network CAC could be collectively considered with policing, shaping and resource allocation [18].

For a CDMA based system like UMTS, the CAC strategies can be roughly classified into two approaches as discussed in **Holma, H., Toskala, A. "WCDMA for UMTS**" *Radio Access for Third Generation Mobile Communications*. New York: John Willey & Sons, 2000

- **Measurement-based CAC**: a new call is rejected if the number of ongoing connections has already reached system limit.

- **Interference-based CAC**: a new call is rejected if the observed interference level exceeds a predefined threshold.

The Interference-based CAC uses SIR (Signal-to-Interference Ratio) to ensure that the interference created after adding a new call does not exceed a pre-specified threshold [19, 20], and it is more often adopted in the literature. Usually, the interference from other existing connections within the same cell and the neighboring cells are considered in SIR calculation. One can also consider CAC in a system comprising of hierarchical cells [21].

In order to verify the performance of various CAC strategies, blocking probability for new calls and outage probability of existing calls are commonly used as the criteria for decision making. Since dropping a call is more annoying for a user than being blocked as a new call, GoS (Grade of Service), which is equal to the sum of the blocking probability plus ten times of the dropping probability, is utilized for performance evaluation. More recent work defined a more complex GoS by weighting the blocking probability, handoff failure and QoS loss in the summation [22].

In a practical system, the CAC function involves both UL (uplink) and DL (downlink) interference calculation and decision making. A new call should only be admitted if it passes both DL and UL admission algorithm [23, Chapter 7]. While most CAC schemes appeared in the literature are focusing on UL, research results on downlink CAC schemes are relatively fewer [25]. Like many other studies, the CAC scheme proposed in this thesis also considers only uplink traffic.

As UMTS services are characteristic of high bandwidth, multiple QoS requirements and asymmetric traffic, we have to face a heterogeneous traffic environment. The delay tolerance could also be considered in a CAC scheme. Basically, delay tolerable traffic class can be treated differently from delay stringent traffic class.

3.1 CAC in UMTS Network

CAC and Load Control are processes, which prevent UMTS air interface overloading. In this network, overloading may cause dropping calls, decreasing of QoS, etc.

CAC algorithm is placed in RNC. Its task is to admit or deny new subscriber access into the network. Permit is based on current state of air interface and type of service requested by user.

CAC must be performed for both of uplink and downlink. When both algorithms are passed, new connection can be established.

The CAC algorithm has to estimate the increasing of the resources usage the new user would cause. It is quite difficult, because a new user can also affect the resource consumption of existing users. The more of cell load means the more of load increase by new user. It is illustrated below in Figure 3-1.

3.1.1 Interference based CAC

As discussed above this CAC strategy may be used for both uplink and downlink. However, the directions must be considered separately.

In the uplink a new user is admitted if a new total interference level is under the threshold value:

$$I_{total\_old} + \Delta I < I_{threshold} \qquad \textbf{(1)}$$

Important task is estimation of interference increase ΔI, which is caused by new user. Two different methods of this estimation are shown below. Both take into account the load curve mentioned in Figure 3-1 and load factor of the new connection presented underneath in Equation (2):

$$\Delta L = \ 1 / 1 + (W / (v.\ E_b/N_0\ .\ R)) \qquad \textbf{(2)}$$

Where

- W is the chip rate,
- R is the bit rate of new user,
- E_b/N_0 is the assumed E_b/N_0 of the new connection, and
- υ is the assumed voice activity of the new connection

The first one is the derivative method. It is based on the derivative of uplink interference with respect to the uplink load factor which can be calculated as follows:

$$\text{Noise\_rise} = I_{total} / P_N = 1 / 1- \eta \Rightarrow I_{total} = P_N / 1- \eta \Rightarrow dI_{total} / d\,\eta = P_N / (1- \eta)^2 \qquad \textbf{\textit{(3)}}$$

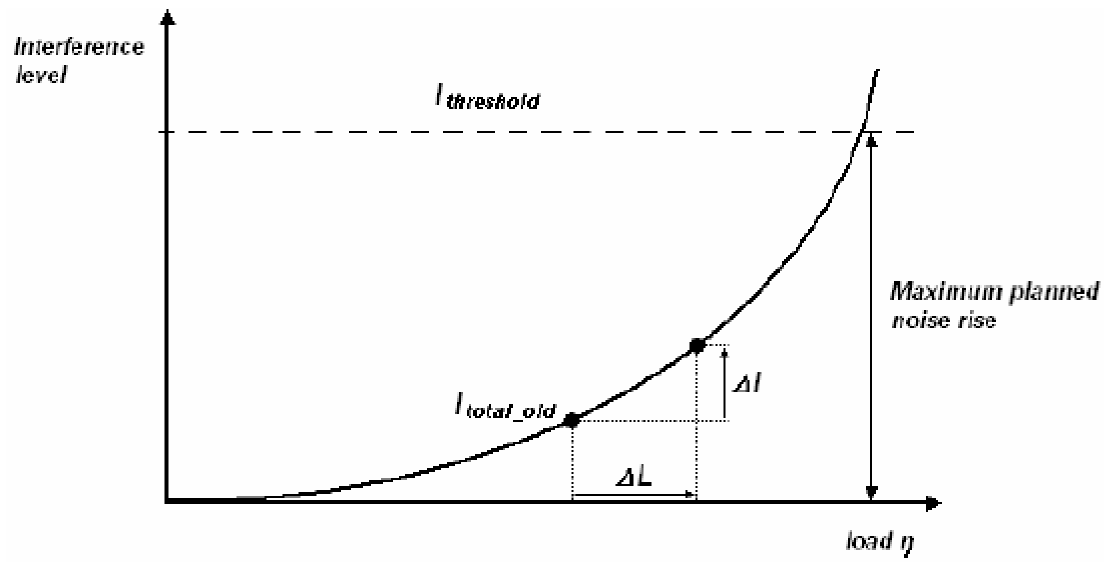

Figure 3-1 Uplink load curve and the estimation of the interference increase due to a new user

The change in uplink interference can be obtained from assumption that the power increase is the derivative of the old uplink interference power with the respect to the uplink load factor, multiplied by the load factor of the new user ΔL:

$$\Delta I / \Delta L = dI_{total} / d\,\eta \Rightarrow \Delta I = P_N / (1- \eta)^2\, \Delta L \Rightarrow \Delta I = (I_{total} / 1- \eta) \qquad \textbf{\textit{(4)}}$$

3.1.2 Throughput Based CAC

With the throughput based CAC method the new user is admitted when the both conditions below in Equations (5) and (6) are valid. Condition for UL:

$$\eta_{UL} + \Delta L < \eta_{UL\_threshold} \qquad \textbf{\textit{(5)}}$$

And the same condition in DL:

$$\eta_{DL} + \Delta L < \eta_{DL\_threshold} \qquad (6)$$

3.2 Load Control in UMTS Network

As discussed above in Section 3.1, CAC and LC (Load Control) are processes, which prevent UMTS air interface overloading. In this network, overloading may cause dropping calls, decreasing of QoS, etc.

LC guards the overloading in the network. When the congestion occurred, LC executes action, which decreases the interference level.

This rule of LC tries to settle the problems with network overloading. Its process seems to be the same as the AC. The difference is that LC takes place after overload occurs and AC tries to prevent overload situation.

If the system is good planned and AC and packet scheduling algorithms works sufficiently, overload situations should be exceptional. But absolutely effective AC is a very complicated task. In addition interference level in the cell may change over time and fast moving user cause more interference than a stationary or slow moving user.

If congestion occurs, the LC must decrease the load to the limits defined by network planning. There are several methods for load reduction.

First two possibilities are UL fast power control and DL fast load control. In DL it means prevention of power-up commands from mobile. These actions are done within a Node-B. It is fast prioritization of the different services. These actions only decrease the rate of services which are not sensitive to delay and maintain the quality of the conversational services.

The other LC possibility is slower and reduces the throughput of packet data traffic. This action is provided by packet scheduler, which is discussed in above mentioned Holma's book.

LC Algorithm can also decrease bit rates of real-time users. One example of this is AMR (Adaptive Multi Rate) speech codec.

Last possibility is the dropping of existing calls. This action is supposedly last chance for reduce overload of network and must be performed in a controlled manner.

4. UMTS Environment for CAC Analysis in OPNET™ Modeler ver11.5

The purpose of this project report (as mentioned earlier) is to develop a network system level simulation (shown in Figure 4-1 below) to allow investigators to study the effects of the UMTS. OPNET™ Modeler ver11.5 is chosen as the simulation environment for its flexibility and extensive model library sets. This simulation effort leveraged the existing OPNET™ model libraries, specifically the UMTS model sets. Several assumptions are necessary to limit the scope of the problem. The intent of these limiting assumptions is to keep the simulation complexity manageable, while still meeting the goals.

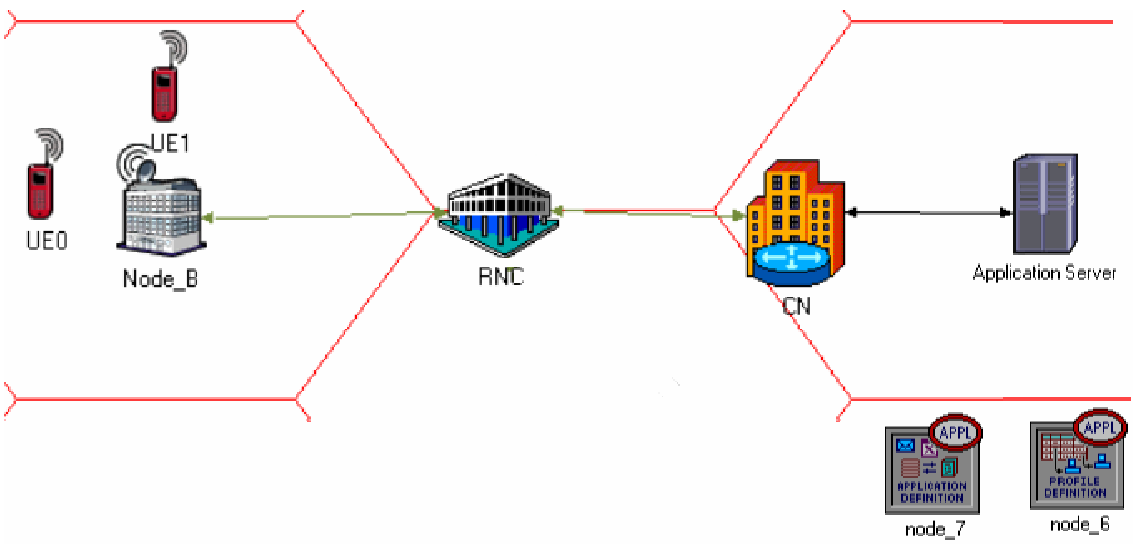

Figure 4-1 UMTS Network System Level Simulation

4.1 UMTS Model Assumptions for OPNET™

The UMTS simulation environment designed in the research leveraged the OPNET™ UMTS model set. The underneath following detail describes the assumptions of this model set.

The OPNET™ UMTS simulation environment models the UMTS architecture domain of the 3GPP Release 1999 UMTS standard. The main system components of the UMTS architecture, described in detail in Section 2 above, are modeled as the following OPNET™ node parameters:

4.1.1 Basic CAC Control Parameters

Among other parameters OPNET™ allow us to control the following:

- **CN (Core Network)**, simple CN node has core network functionality, but does no IP routing. Routes packets to and from umts_station nodes, exclusively. The CN models the GMM/SM layer protocol interaction with the UE, handles GPRS attach, PDP context activation, and Service requests, and provides both an IP interface to the Internet and ATM interfaces to multiple RNCs. It models the CN functionality in the SGSN.

- **RNC (Radio Network Control)**, this node consists of a single processor module that runs a process that performs the functionality of the RNC. It has the ability to support and manage up to 8 Node-Bs. It handles both UE admission control and RB (Radio Bearer) assignment, and provides the ATM interfaces to the Node-B and SGSN.

- **Node-B (Base Station)**, it serves as a Node-B node, models the radio interface (physical/air-interface) with 3 sectors that handles the connection of the UEs in it own coverage area with RNC and the rest of the UMTS network.

- **UE (User Equipment)**, general client node that includes UE and generic traffic generation functionality. This node can only send traffic to (and receive traffic from) other umts_station nodes. The UE node models the full TCP/IP stack with both data/multimedia application models and hi-fidelity TCP/IP layer models, the GMM/SM layer, the RLC/MAC layer, and the physical/air-interface layer. The GMM/SM layer handles both mobility management and session management. The RLC/MAC layer models the three transport modes, the four transport channels, and the segmentation and reassembly of higher layer data.

- **Application Server**, umts_server represents a server node with server applications running over TCP/IP and UDP/IP over UMTS like Ftp server.

4.1.2 System Performance Parameters

There are the following system performance parameters which are evaluated in this report:

- **Dropping Performance**, it is the arrival intensity for each service and it compares the dropping results for those real time service types.

- **Termination/Blocking Performance**, the basic function of CAC is to make the decision whether a new user should be allowed to enter into the system of be rejected when making a service request.

- **Absolute Throughput Performance**, the best performance in terms of number of users allowed transmitting anything in real time traffic.

4.1.3 Traffic Parameters

The traffic conditioning is performed by policing or/and by traffic shaping. This report proposed traffic conditioning scenario in radio access network, i.e., how we employ traffic shaping at each individual UE and traffic policing at the RNC.

4.1.4 Mobility Parameters

This parameter includes the mobility from one cell to another in between UE with the handover decisions. Handover polices handle the mobility of the user when the user is moving from one cell to another. There are three types of handover supported:, hard, and softer.

- **Soft**, in a soft handover, the UE is temporarily connected to multiple Node-Bs. The “Active Set Size” parameter determines the maximum number of Node-Bs during the soft handover process. Soft handovers consume resources of multiple cells.

- **Hard**, a hard handover results in the UE being disconnected from one Node-B and connected to another Node-B.

- **Softer**, in softer handover, the UE is connected to multiple sectors in the same Node-B. The advantage of a soft handover is that it is more reliable at the cell edges and it requires less power.

We’re not experimenting this in subject of unavailability of time.

4.2 Model Attributes

These are the local attributes apply to individual nodes in OPNET™ of the UMTS network model. This section lists the most important model attributes for the CN, RNC, Node-B, and UE node models. Rest of all other UMTS Model Attributes are available in Appendix B for further reference.

4.2.1 RNC Attributes

There are the following RNC (Radio Network Control) parameters:

- **UMTS Handover Parameters**, it configures the RNC to support hard or soft handovers and the parameters used in handover decisions. It is based on TR 25.922.

- **UMTS RNC Admission Control Parameters**, it specifies parameters (such as uplink and downlink loading factors and maximum available power) used to compute uplink and downlink capacity in the admission control algorithm.

  The load factor may vary a lot between uplink and downlink, capacity is allocated separately for both directions.

- **Scheduling Weights**, it assigns weights to each QoS class for use in the FACH's Weighted Round Robin (WRR) scheduling algorithm.

  Scheduling mechanism controls the UMTS packet access, which is part of RRM functionality in RNC. It is executed each time a packet is sent or received. This algorithm also decide when and which packet to send first.

  It is obvious that due to the different delay sensitivity levels, four UMTS service classes should be assigned priority levels from 1 to 4, in which 1 is the highest.

Normally it chooses WRR scheduler, because the relative importance of each class can be modified easily according to the change of traffic mix, hence it is more flexible.

4.2.2 Node-B Attributes

There are the following Node-B parameters for current consideration;

- **Allocation/Retention Priority**, (sub-attribute of QoS Profile Configuration) it configures parameters for the allocation and retention of a RAB during admission control. We use this attribute to enable queuing for the RAB request, and to specify if the RAB request can preempt or be preempted by other requests.
  Allocation/Retention priority specifies the relative importance compared to other UMTS bearers for allocation of the UMTS bearer. The Allocation/Retention Priority attribute is a subscription attribute which is not negotiated from the MT.

  This priority is used for differentiating between bearers when performing allocation and retention of a bearer. In situations where resources are scarce, the relevant network elements can use the Allocation/Retention Priority to prioritize bearers with a high Allocation/retention Priority over bearers with a low Allocation/Retention Priority Admission Control.

5. Examining the Effect of loading factor on System Performance

Loading factor is an important parameter of system. To evaluate the performance of CAC by using loading factor, we are using OPNET™ as discussed earlier.

To demonstrate the alternative, Throughput-based, RNC Admission Control Algorithm and compare its performance by choosing loading factors on different levels for the network used in the scenario.

5.1 Model the UMTS Network Environment

As illustrated in Figure 5-1 below, we are configuring the UMTS network model to use the following configuration:

- UMTS workstation nodes routing application traffic (ftp) through two CN (SGSN-GGSN) nodes to other UMTS workstation and server nodes.

  Where a typical cell that consists a set of two UEs and a single Node-B connected to the RNC through an ATM link. Then the RNC connected to the CN using Ethernet links. This is then connected to ftp Application Server through Ethernet links using hub.

- UMTS station nodes sending generic data traffic to other UMTS station nodes through CN nodes.

- Now by using the UMTS workstation nodes use the application server to generate traffic as required for any workstation node.

5.2 Model the Effects using Static Scenario

For modeling the effects of loading factor on system showing in Figure 4-1, we're considering the following steps:

- The two QoS traffic classes; which are Streaming and Background.
- Users are stationary.
- Set the loading factor on different levels and analyzing the percentage of accepted and percentage of rejected or dropped UL and DL capacity.
- Analyzing the percentage of accepted sessions that are admitted in the system.
- Investigating the impact of loading factors on the throughput level and percentage of rejected connections.
- Analyzing the relation between Offered Load and Throughput, along with the relation between DL Rejection Capacity and Offered Load.

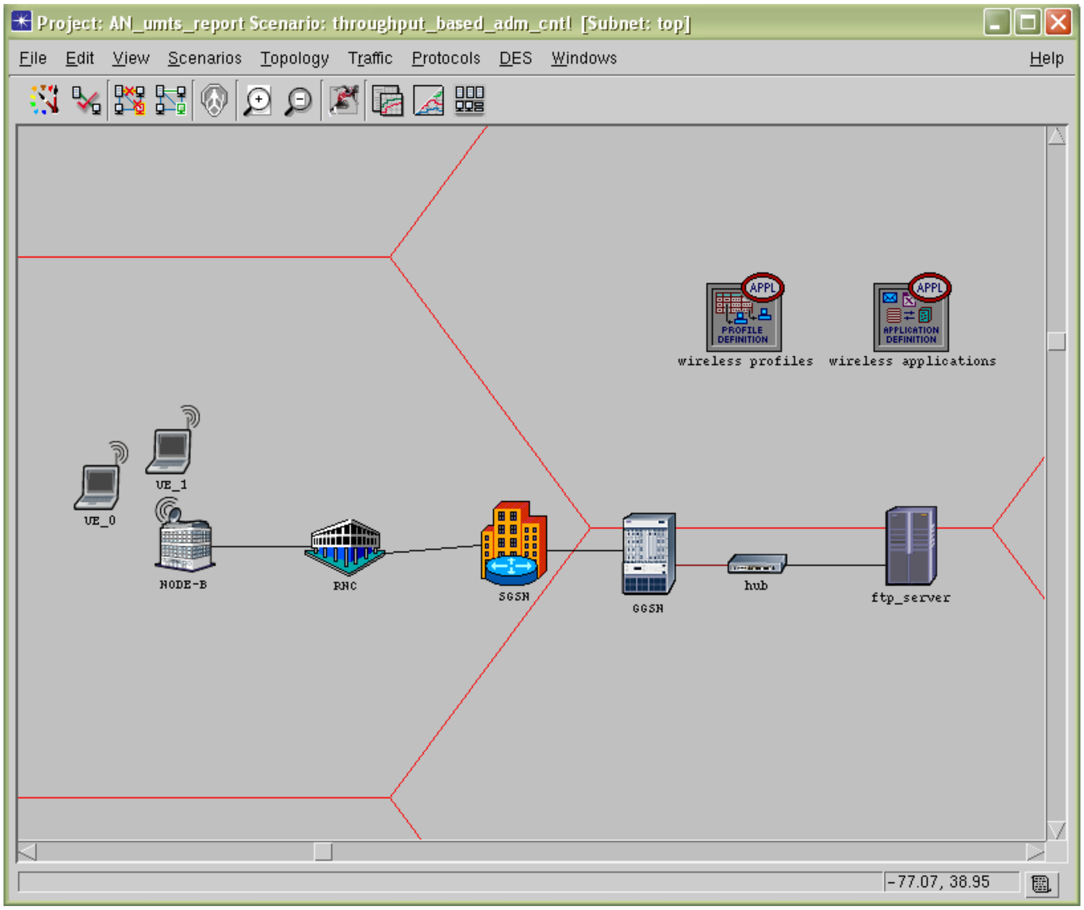

Figure 5-1 UMTS Network Scenario Simulation

5.3 Run the Simulation

At this point, we have modeled contending traffic and applications, and tuned all radio parameters. Record the application response time, the response time may be higher as the application is now running over a UMTS network. View the simulation logs. There are some logs indicating failed application connections, check the distance between the UE and the Node-B. And make sure the distances are within the expected range as showing parameters in both Figures 5-3 and 5-4 below.

Admission Control Algorithm is invoked from ADM_CNTL state of the RNC process. Set the Throughput based RNC Admission Control algorithm parameters and assign the UL Load factor and DL Load factor 1.5 initially and then keep increasing for getting better and significant results. Also assigned the Scheduling Weight to both QoS traffic classes (Streaming and Background), showing in Figure 5-2.

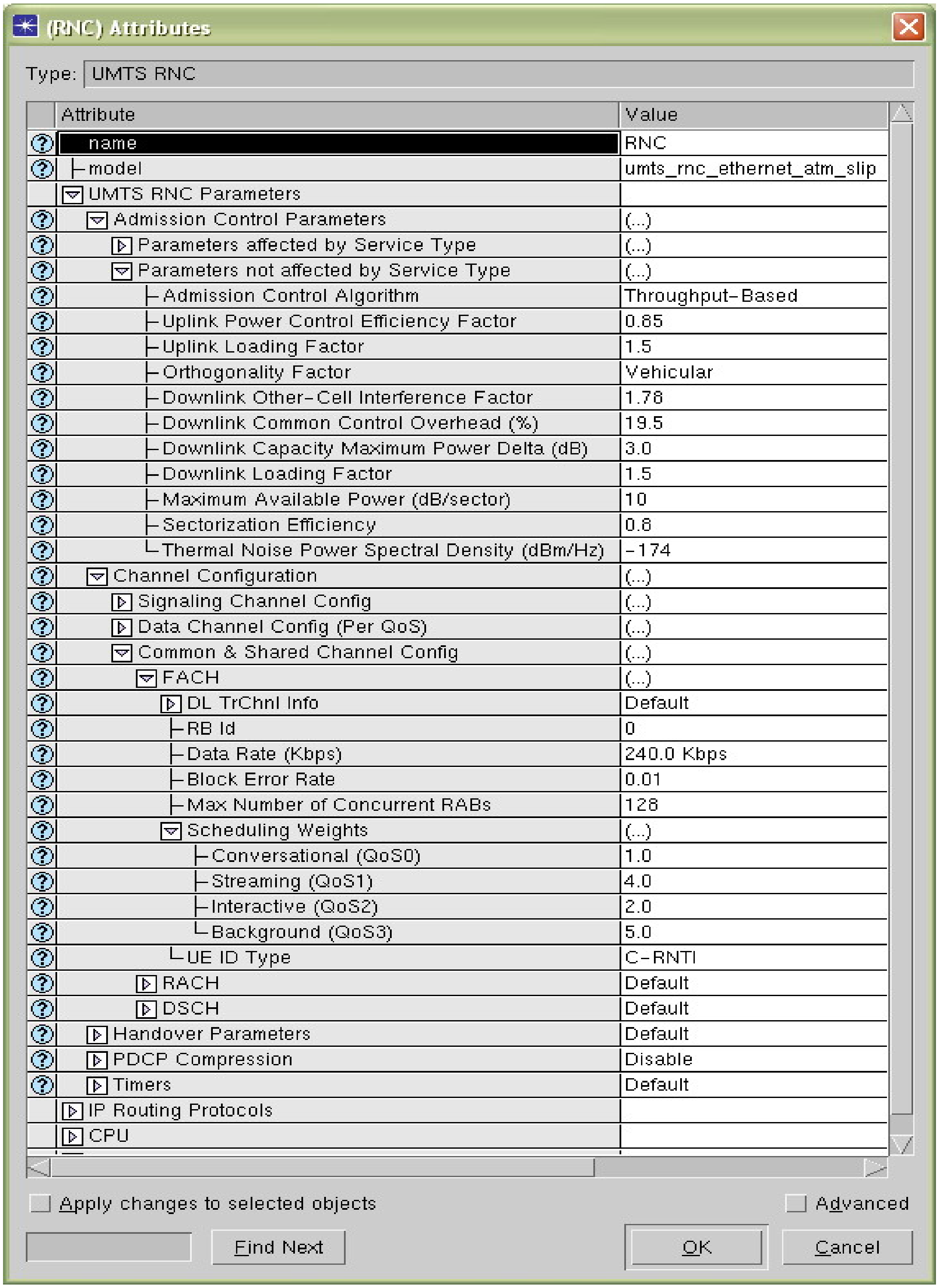

Figure 5-2 UMTS RNC Parameters

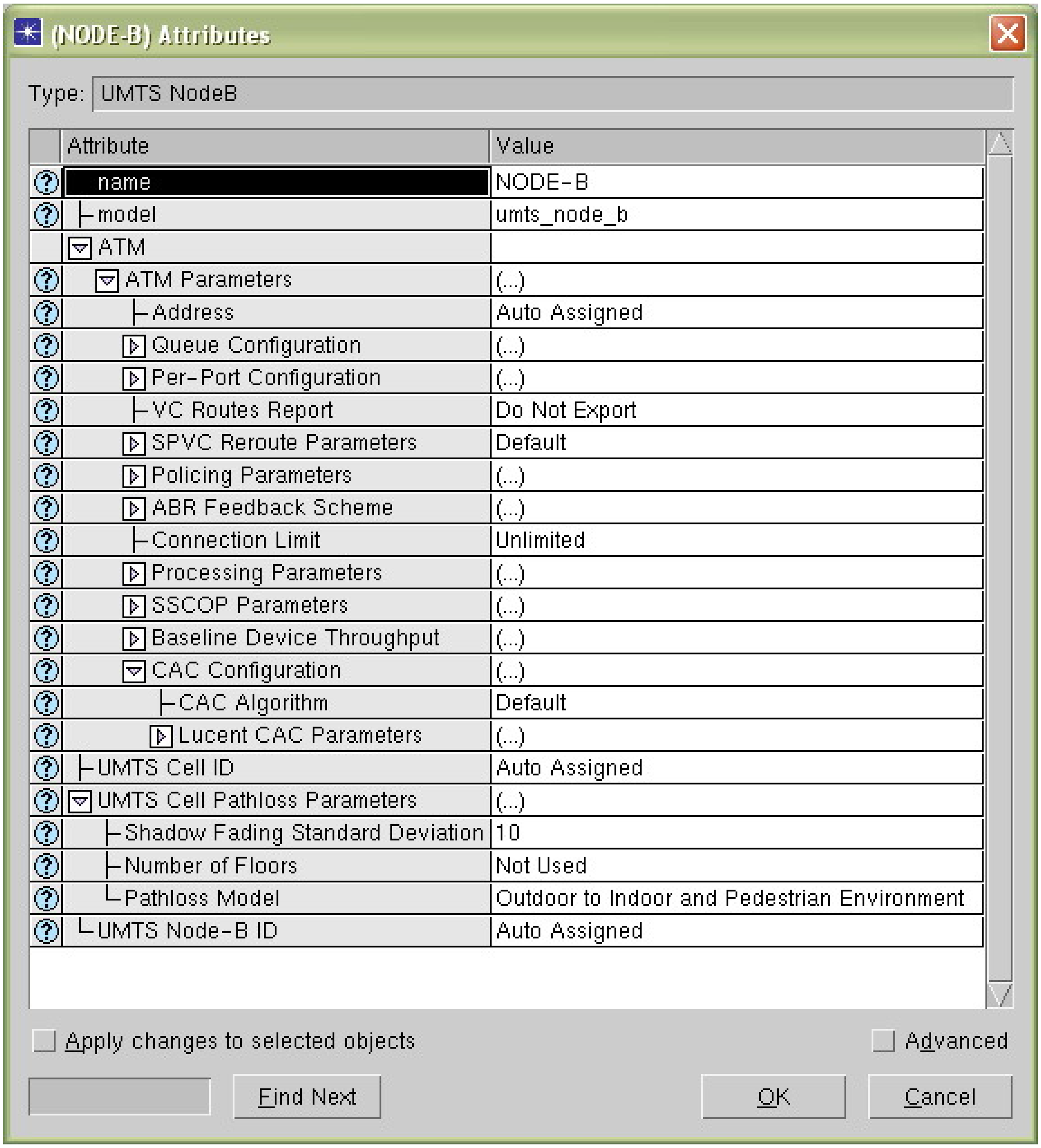

Figure 5-3 UMTS Node-B Parameters

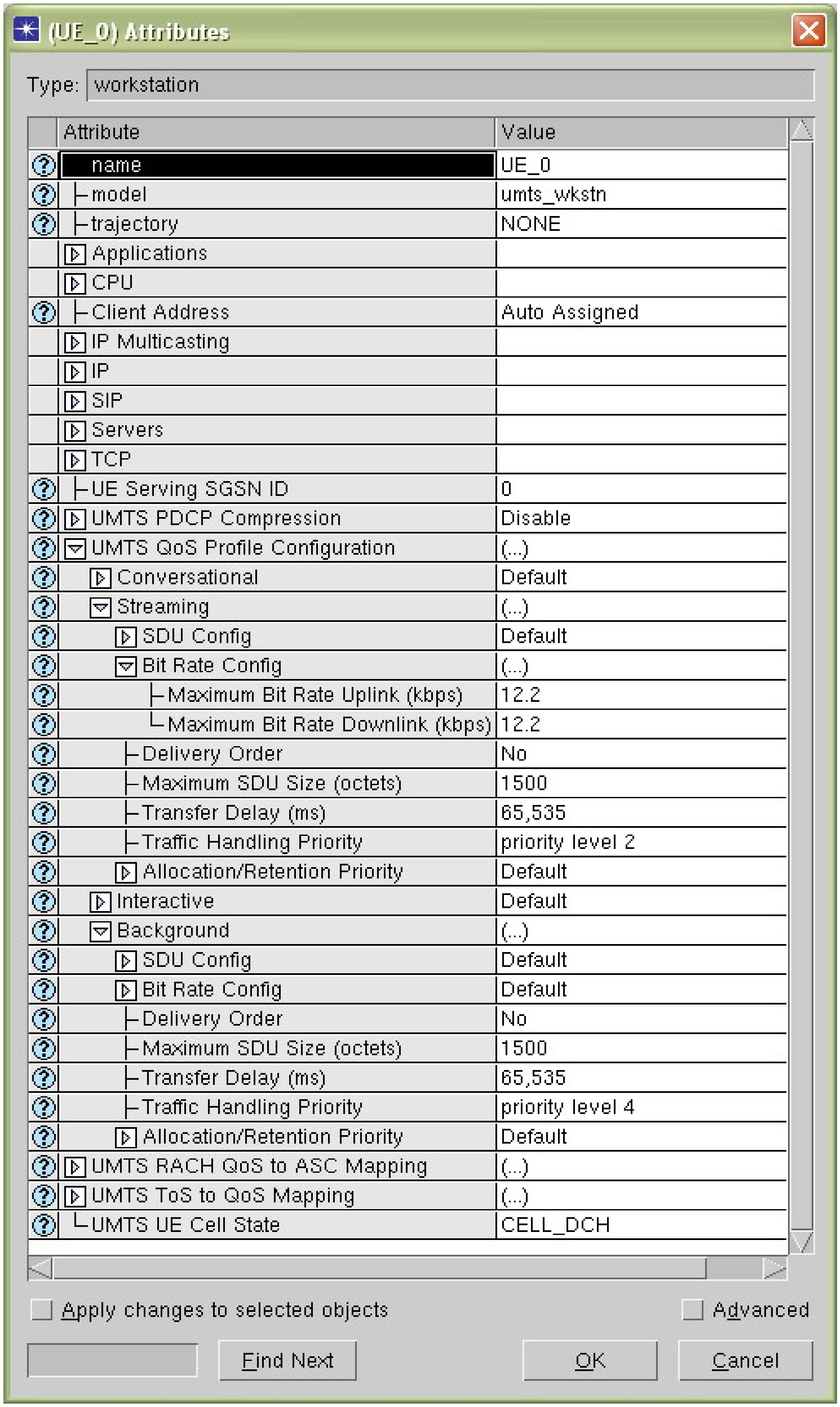

Figure 5-4 UMTS UE Parameters

5.3.1 Opting Statistics

OPNET™ is flexile in opting different statistics for both UMTS RNC and UMTS Node-B. There are different statistics can choose able, in which global statistics, node statistics and link statistics are for viewing and analyze results after running the simulation. OPNET™ has different options of choosing from the list of statistics or customizing them and reporting specific results according to the requirement. Underneath Figure 5-5 illustrates the standard list of statistics.

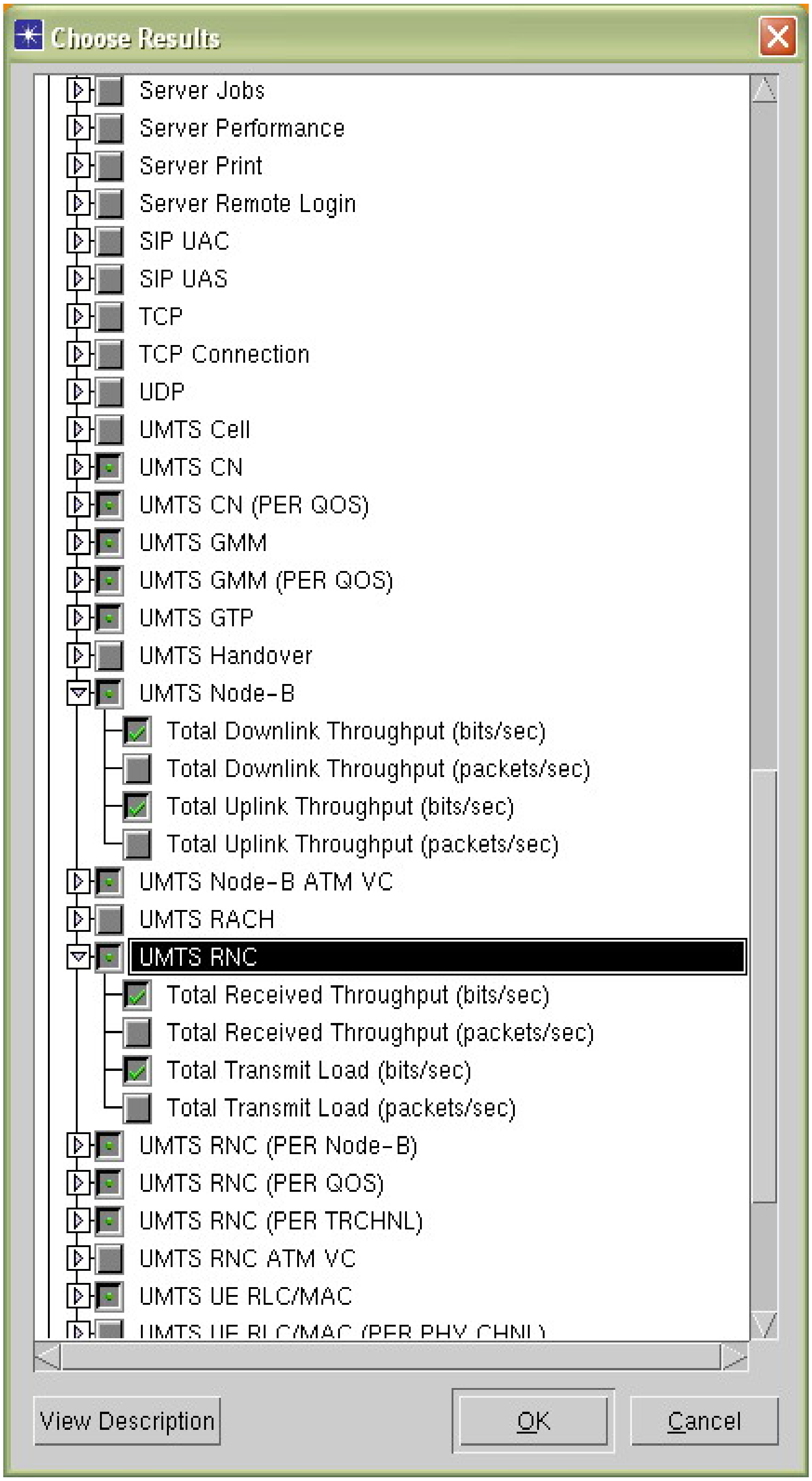

Figure 5-5 UMTS Choosing Result Parameters

5.4 Analyze Results

After given network and configuration, run the simulation for achieving the results and compare the application response times and application traffic throughput with and without contending traffic.

Based on obtained results, here are some graphs and tables citied below, also refer to Appendix A for detailed results in Web Generate Report of OPNET™.

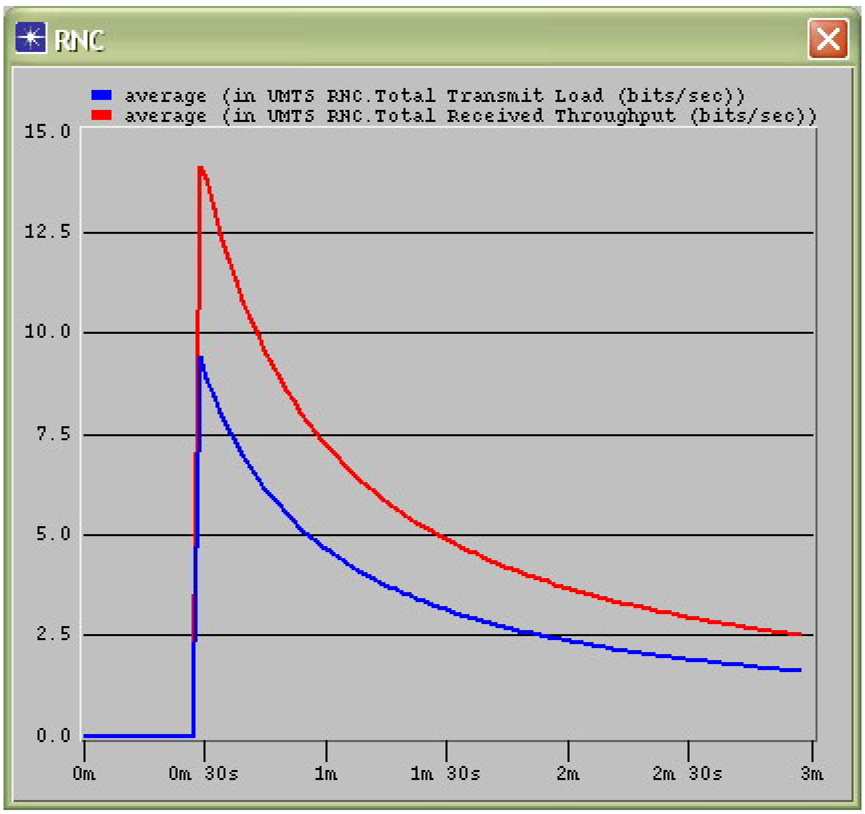

Figure 5-6 RNC Statistics with Offered Load 1.5

In above Figure 5-6, showing the comparison of RNC node in between Total Transmit Load (bits/sec) and Total Received Throughput (bits/sec). This particular statistic is based on the Offered Load assigned to 1.5 for both UL and DL, and simulation run for 3mins. It is not showing any significant difference.

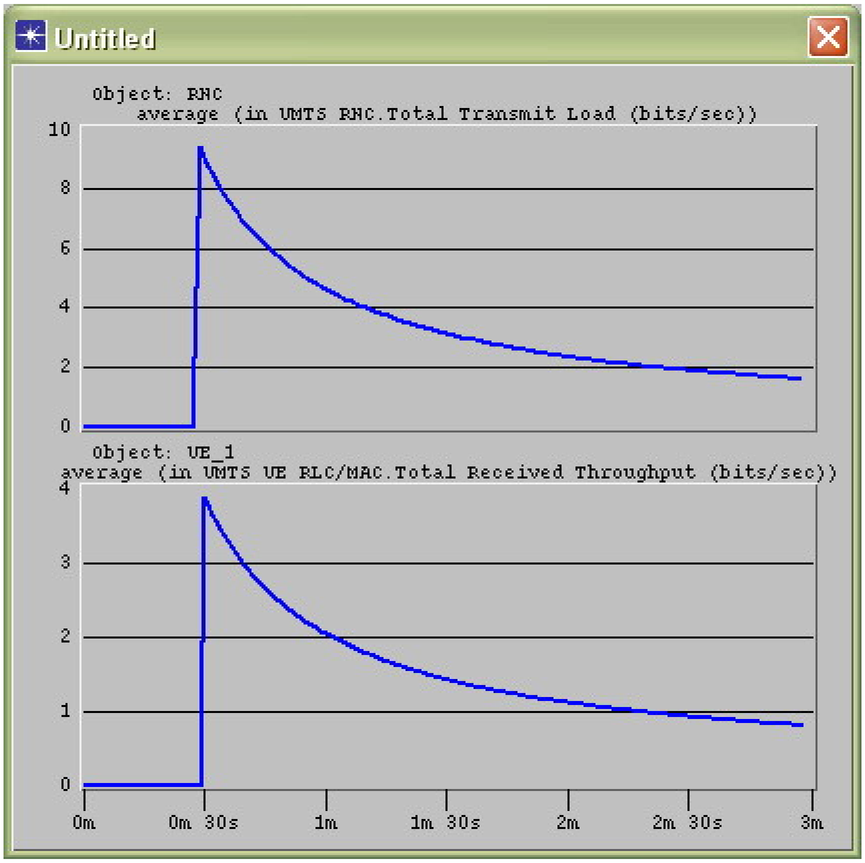

Figure 5-7 RNC and UE_1 Statistics

Above Figure 5-7 mentioning the graph of RNC Total Transmit Load (bits/sec) and UE_1 Total Received Throughput (bits/sec). This statistic is again based on the Offered Load assigned to 1.5 for both UL and DL, and simulation run for 3mins.

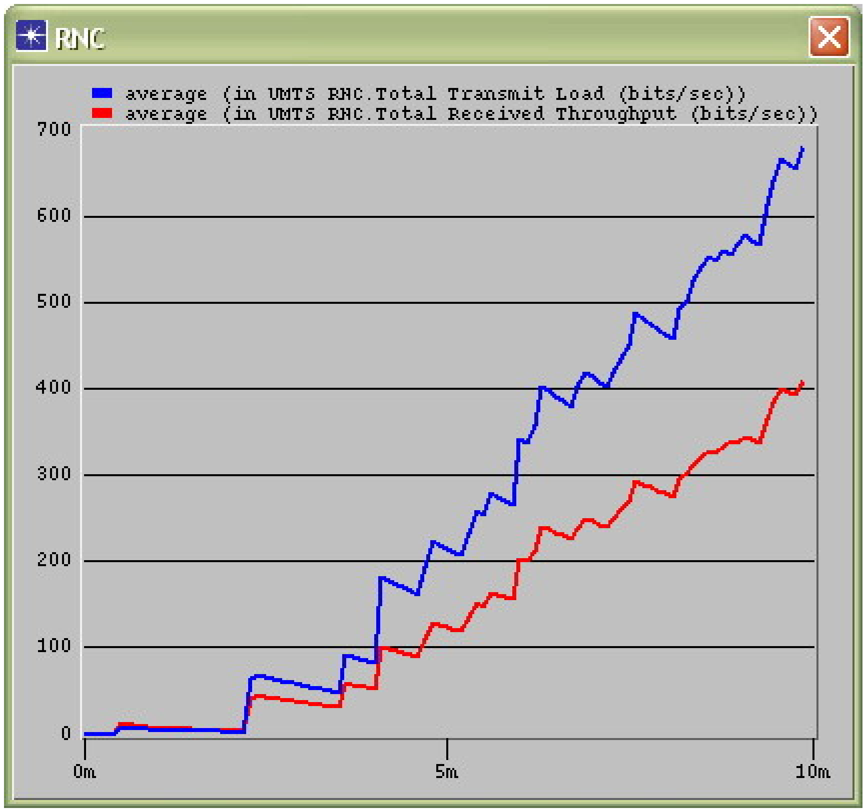

Figure 5-8 RNC Statistics with Offered Load 3.0 and running duration 10mins

In Figure 5-8, RNC statistics making some comparison between Total Transmit Load (bits/sec) and Total Received Throughput (bits/sec) after running for longer time with UL and DL Load Factor of 3.0. Both are slightly making difference, that transmitting load bits/secs are comparatively higher then receiving throughput bits/secs.

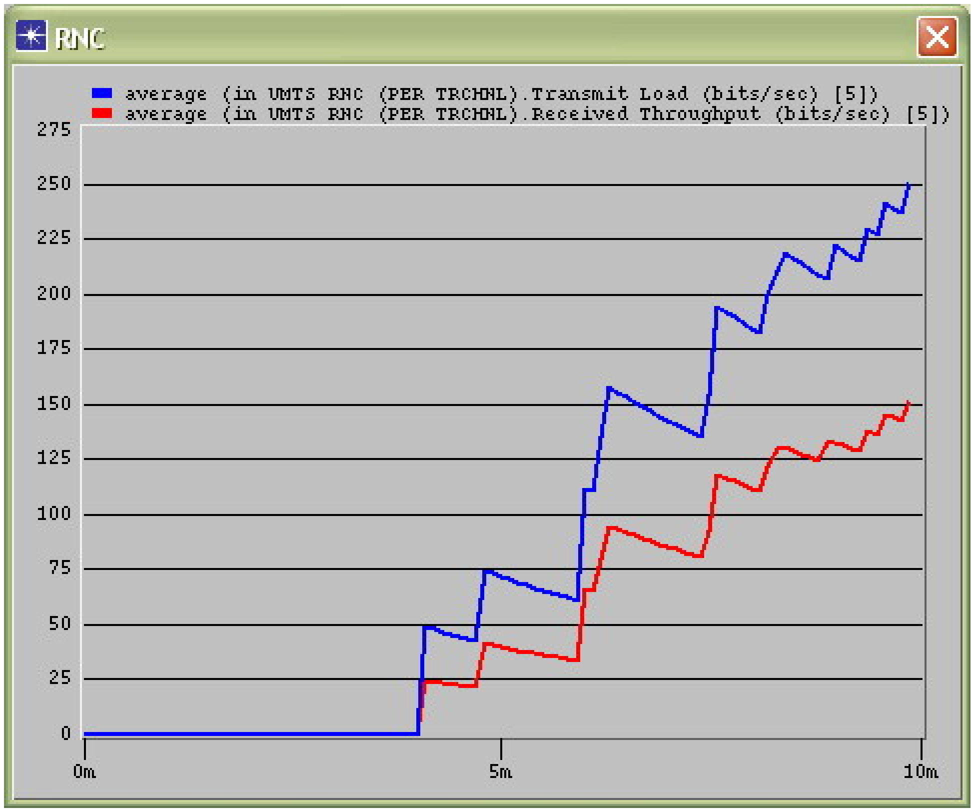

Figure 5-9 RNC Statistics per TRCHNL

In Figure 5-9, RNC statistics per TRCHNL making some difference between Transmit Load (bits/sec) and Received Throughput (bits/sec), both started increasing after 4mins and Transmit Load made huge difference as compare to Throughput in UMTS RNC (Per TRCHNL).

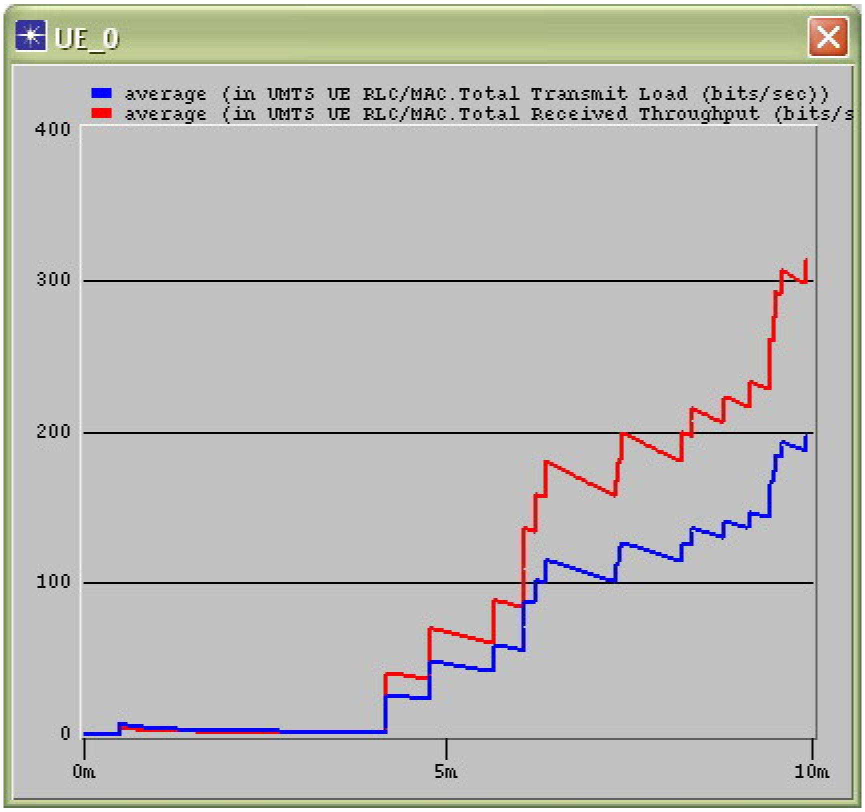

Figure 5-10 UE_0 Statistics

In above Figure 5-10, UE_0 statistics making some significant change between Total Transmit Load (bits/sec) and Total Received Throughput (bits/sec) after running for longer time with UL and DL Load Factor of 3.0. At UE_0 receiving throughput is higher and fast as compare to transmit load.

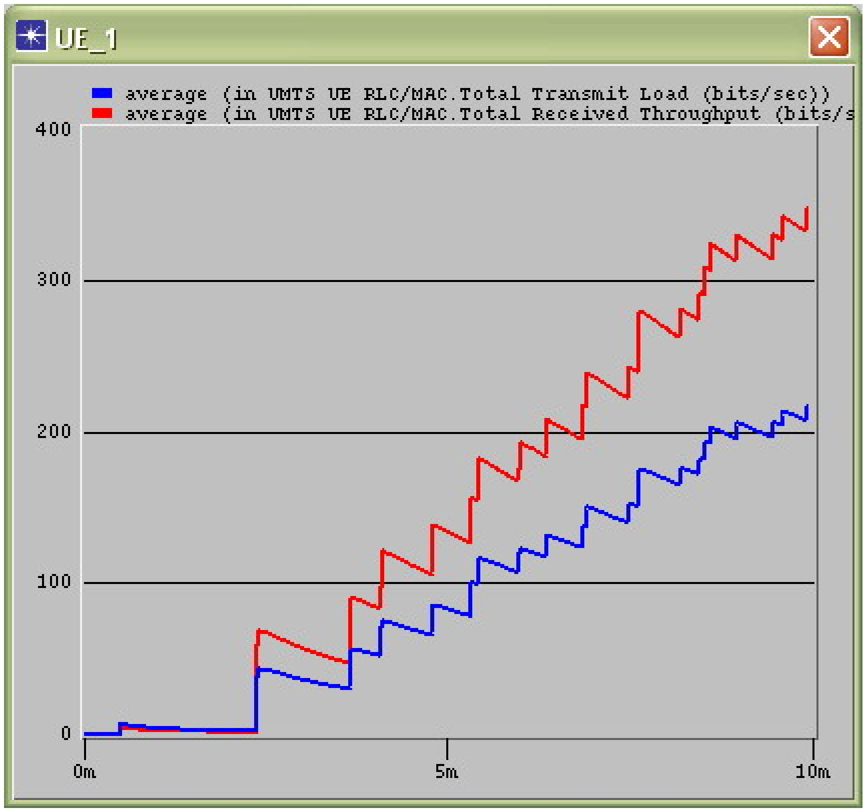

Figure 5-11 UE_1 Statistics

In above Figure 5-11, UE_1 statistics showing comparison with UE_0, the ratio of receiving throughput is higher at this equipment and ratio of transmitting is gradually higher.

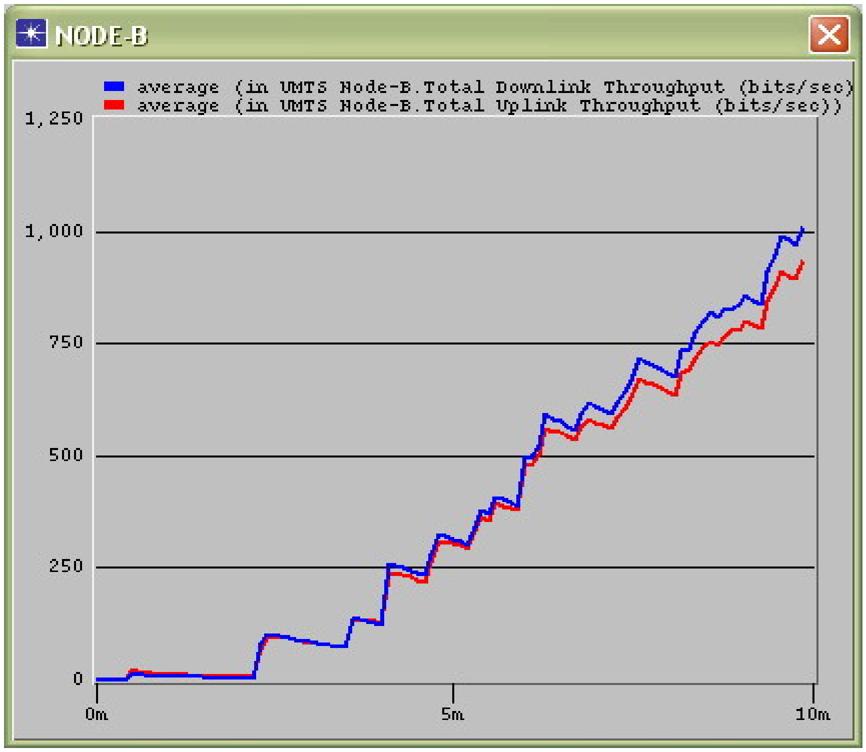

Figure 5-12 Node-B Total DL and UL Throughput (bits/sec) Statistics

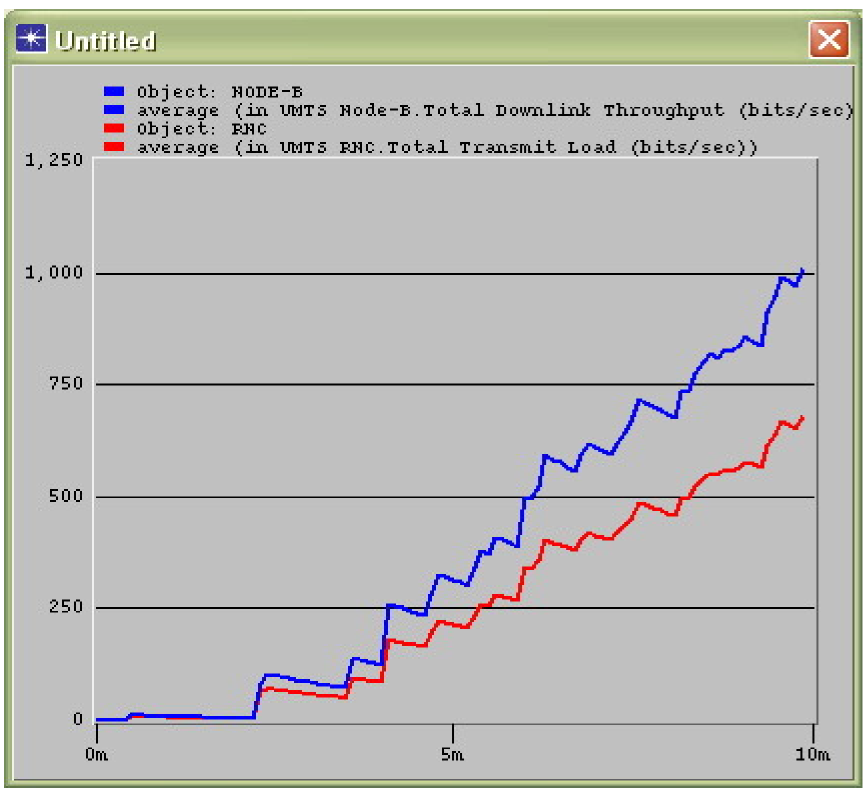

Figure 5-13 Node-B DL Throughput (bits/sec) vs. RNC Transmit Load (bits/sec)

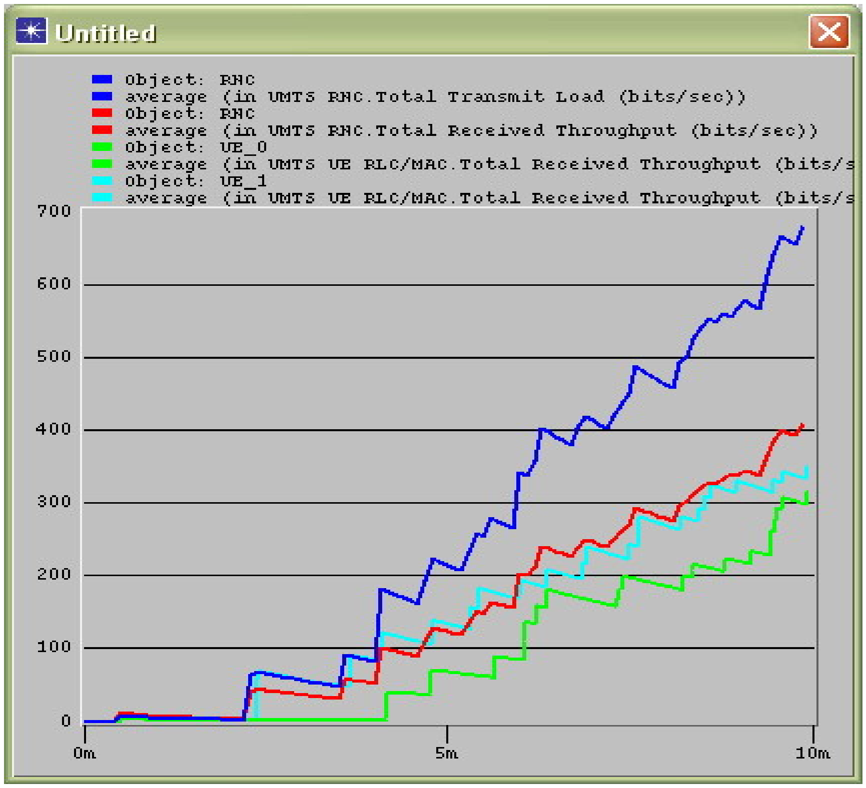

Figure 5-14 RNC Total Transmit Load (bits/sec), RNC Total Received Throughput (bits/sec), UE_0 Total Received Throughput (bits/sec), and UE_1 Total Received Throughput (bits/sec)

In above Figure 5-13, we can see the RNC Total Transmit Load compare to RNC Received Throughput, and UE_0 statistics for Received Throughput compare to UE_1 statistics. Object UE_0 is receiving more throughput compare to object UE_1.

Figure 5-15 UE_0 (Per QoS) End-end end Delay (sec) and RAN DL Delay (sec)

In above Figure 5-14 illustrate the average graph of End-to-end and RAN DL Delay basis on per QoS for UE_0, having very slightly difference in delay.

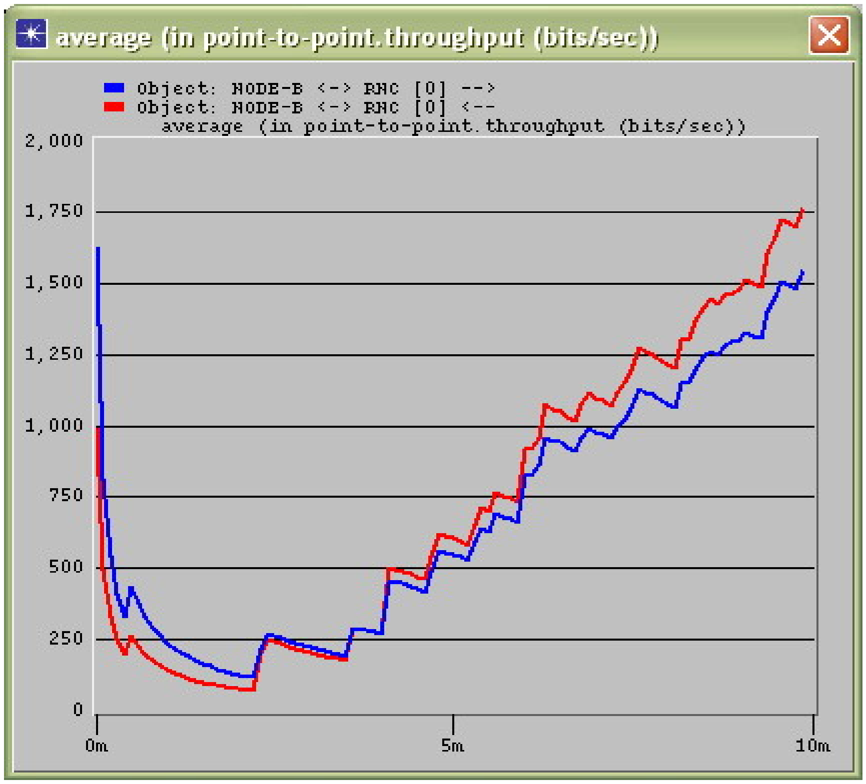

Figure 5-16 Node-B to RNC point-to-point throughput (bits/sec) for UL and DL

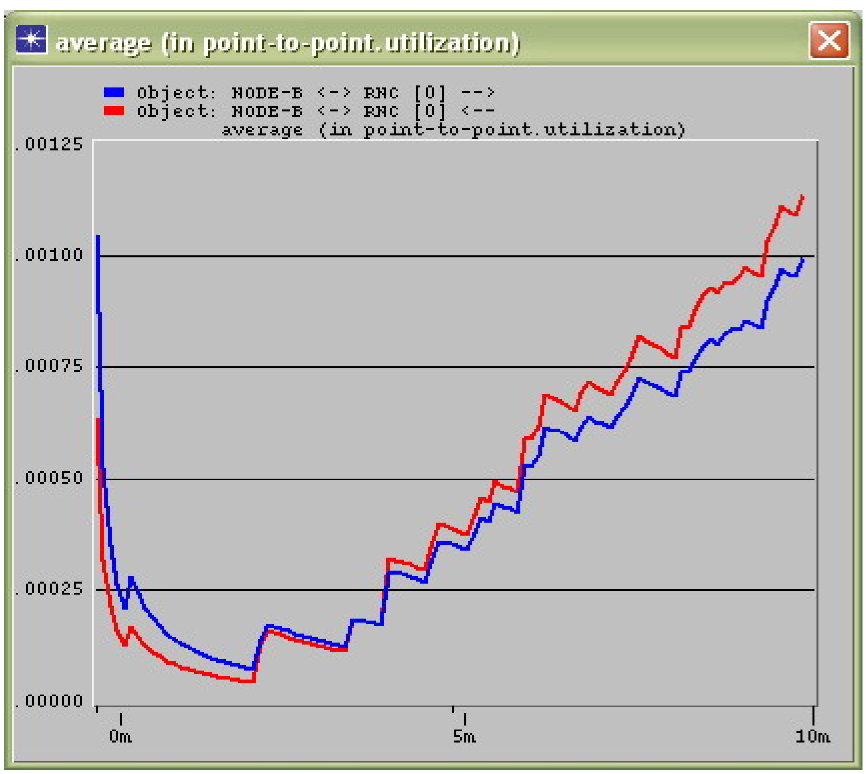

Figure 5-17 Node-B to RNC point-to-point Utilization

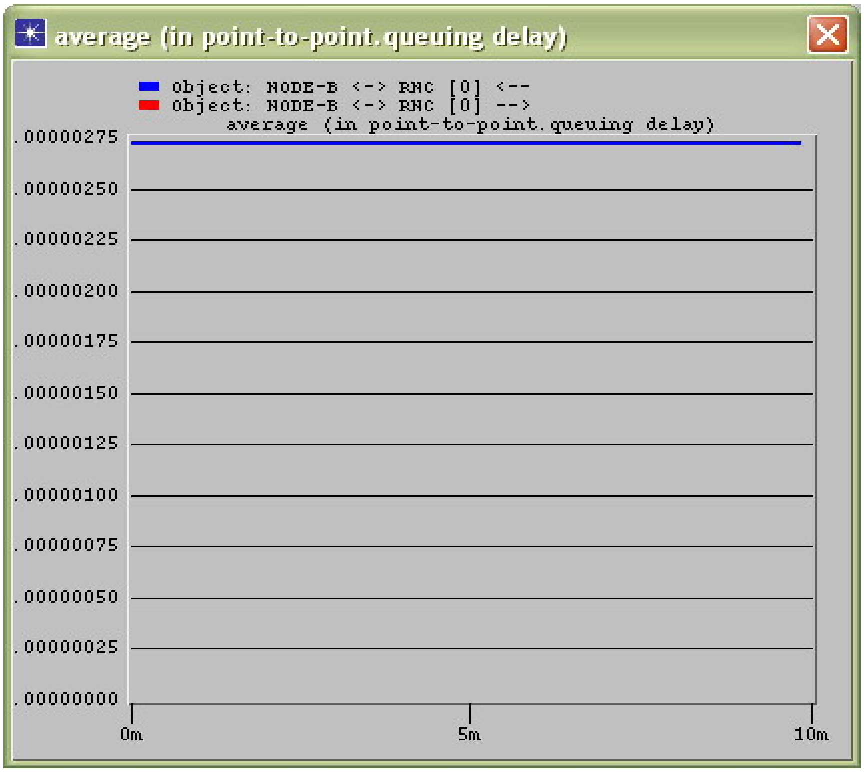

Figure 5-18 Node-B to RNC average in point-to-point queuing delay

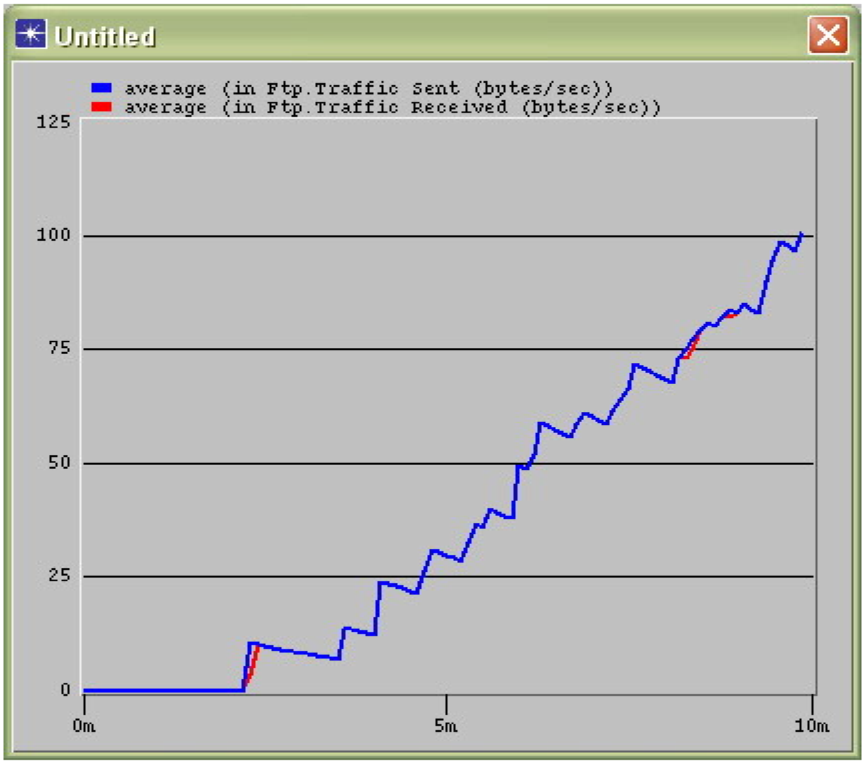

Figure 5-19 FTP Traffic average sent and received (bytes/sec)

Node	UMTS CN Total Number Requests Granted	UMTS CN Total Number Requests Released	UMTS GMM GPRS Attach Delay (sec)	UMTS GMM PDP Context Activation Delay (sec)	UMTS GMM Service Activation Delay (sec)	UMTS GMM (PER QOS) End-to-End Delay (sec) [3]	UMTS GMM (PER QOS) RAN Downlink Delay (sec) [3]
GGSN	-	-	-	-	-	-	-
NODE-B	-	-	-	-	-	-	-
RNC	-	-	-	-	-	-	-
SGSN	11.6	10.6	-	-	-	-	-
UE_0	-	-	0.35942	0.55771	0.13785	0.18179	0.1811
UE_1	-	-	0.36364	0.56266	0.13759	0.18135	0.18064

Table 5-1 Average summary of Node Statistics (part 1)

Node	UMTS GTP DL Traffic Received (bits/sec)	UMTS GTP DL Traffic Sent (bits/sec)	UMTS GTP Downlink Tunnel Delay (sec)	UMTS GTP Uplink Tunnel Delay (sec)	UMTS Node-B Total Downlink Throughput (bits/sec)	UMTS Node-B Total Uplink Throughput (bits/sec)	UMTS RNC Total Received Throughput (bits/sec)	UMTS RNC Total Transmit Load (bits/sec)
GGSN	646.4	678.72	-	4.9E-05	-	-	-	-
NODE-B	-	-	-	-	1,011.56	935.87	-	-
RNC	701.52	658	1.85E-05	-	-	-	408.45	680.45
SGSN	690.32	701.52	3.19E-05	2.41E-05	-	-	-	-
UE_0	-	-	-	-	-	-	-	-
UE_1	-	-	-	-	-	-	-	-

Table 5-2 Average summary of Node Statistics (part 2)

Node	UMTS RNC (PER QOS) RAN Uplink Delay (sec) [3]	UMTS RNC (PER TRCHNL) Downlink Retransmission Delay (sec) [4]	UMTS RNC (PER TRCHNL) Downlink Retransmission Delay (sec) [5]	UMTS RNC (PER TRCHNL) Received Throughput (bits/sec) [3]	UMTS RNC (PER TRCHNL) Received Throughput (bits/sec) [4]	UMTS RNC (PER TRCHNL) Received Throughput (bits/sec) [5]
GGSN	-	-	-	-	-	-
NODE-B	-	-	-	-	-	-
RNC	0.10817	0.28828	0.23028	2.9733	252	151.2
SGSN	-	-	-	-	-	-
UE_0	-	-	-	-	-	-
UE_1	-	-	-	-	-	-

Table 5-3 Average summary of Node Statistics (part 3)

5.5 Summary

The UMTS simulation environment successfully modeled a UMTS network. The enhancements to the OPNET™ model library created an environment to investigate the issues and tradeoffs for the CAC in UMTS networks. The model worked well for investigating UMTS offered load and throughput.

The model has a limitation in the way the UMTS network allocates DCH channels. The RNC allocated only one DCH channel for a data session, even when it was the only data session in progress, thus wasting available resources.

The model worked well for studying application performance. It provided an environment for studying application performance for a variety of traffic loads. The model demonstrated that the users accessing the UMTS access network experienced significantly reduced application delays for a range of normal operating conditions. It demonstrated that the UMTS access network scaled well for both DL throughput and offered load.

6. Conclusion

In 1990s the telecommunications industry in North America experienced significant growth for both cellular telephone and internet usage. In consequence both Internet access and cellular telephones have become common household commodities. Attempts to integrate data services into cellular networks have brought the limitations of both the internet and the cellular network into sharp focus. The Internet's best effort model cannot support the real time constraints of a voice conversation. While, the low data rates of cellular telephone network are not sufficient for web-browsing or large file transfers.

Research is in process to improve both the cellular telephone network and the internet. Emerging 3G Wireless Networks will focus on supporting data traffic with increased data rates. The report and simulation presented in this document focused on investigating the CAC in UMTS Networks.

6.1 Significant Results

The purpose of this report effort is to design, implement, and test a network system level simulation environment to allow investigators to study the issues for CAC into UMTS. The key contribution of this report is to augment the current OPNET™ model library by creating Throughput based Admission Control in UMTS.

The simulation environment was designed in OPNET Modeler™ ver11.5 using a top-down design approach. The UMTS Network was designed at the node level using both built-in OPNET™ and user-defined processes, the details of this design were covered in Section 4 above. The validation process compared simulation and theoretical results to ensure that the simulation environment was representative a real system. The simulation environment was tested under different scenarios, as described in Section 5.

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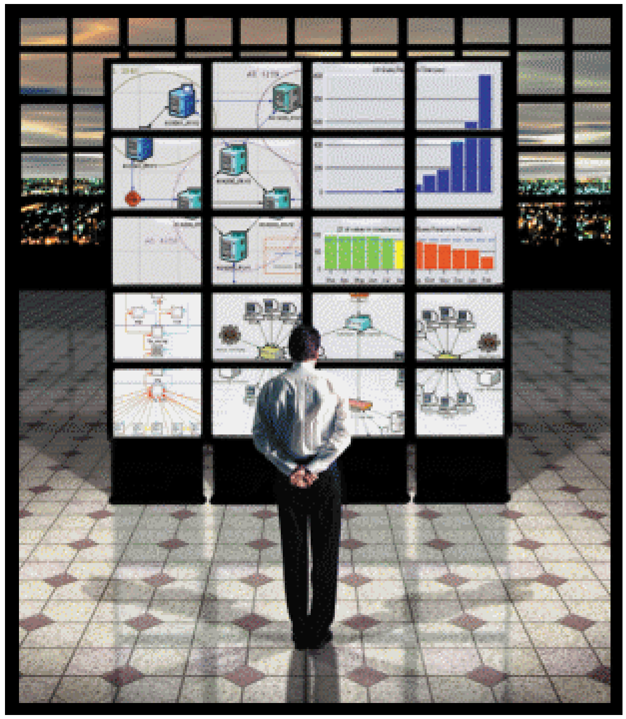
Appendix A Simulation Web Generate Report



OPNET Simulations Results

Reports are available for the following projects:

- **AN_umts_adm_cntl**

Reports for the following scenarios of the project "AN_umts_adm_cntl" are available:

- **throughput_based_adm_cntl**

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Global Statistics Summary**

Ftp

Statistic	Average	Maximum	Minimum
Ftp Download Response Time (sec)	0.9684	1.3027	0.7126
Ftp Traffic Received (bytes/sec)	100.80	756.00	0.00
Ftp Traffic Sent (bytes/sec)	100.80	756.00	0.00

UMTS GMM

Statistic	Average	Maximum	Minimum
UMTS GMM GPRS Attach Delay (sec)	0.35942	0.36364	0.35942
UMTS GMM PDP Context Activation Delay (sec)	0.55888	0.56266	0.55771
UMTS GMM Service Activation Delay (sec)	0.13798	0.14835	0.13021

UMTS GMM (PER QOS)

Statistic	Average	Maximum	Minimum
UMTS GMM (PER QOS) End-to-End Delay (sec) [3]	0.17780	0.25768	0.07459

Project: AN_umts_adm_cntl
Scenario: throughput_based_adm_cntl

Report: User Selected
Title: Top Links Summary

Average Values

Link	low-level point-to-point bit error rate	low-level point-to-point bit errors per packet	low-level point-to-point packet loss ratio	point-to-point queuing delay	point-to-point throughput (bits/sec)	point-to-point throughput (packets/sec)	point-to-point utilization
GGSN <-> SGSN [0]	0	0	0	0.00007942 --> 0.00003096 <--	777.75 -->	0.4067 <--	0.0017385 --> 0.0012498 <--
NODE-B <-> RNC [0]	0	0	0	0.00000273 -->	1,768.08 <-- 1,545.48 -->	4.1700 <-- 3.6450 -->	0.0011369 <--
SGSN <-> RNC [0]	0	0	0	0.00000273 -->	990.04 --> 799.95 <--	2.3350 --> 1.8867 <--	0.0006366 -->
ftp_server <-> hub [0]	0.002451	1.4118	0.002451	0.00020855 -->	723.45 -->	0.4050 <--	0.0072345 -->
hub <-> GGSN [0]	0.002451	1.4118	0.002451	0.00012460 <--	723.20 -->	0.4050 <--	0.0050604 <--

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Top Objects for point-to-point**

point-to-point queuing delay

Statistic sampling period is 6 seconds.

Sort By Link	Sorted By Average	Sort By Peak
ftp_server <-> hub [0] -->	0.00020855	0.00025680
hub <-> GGSN [0] <--	0.00012460	0.00019253
GGSN <-> SGSN [0] -->	0.00007942	0.00010772
GGSN <-> SGSN [0] <--	0.00003096	0.00004632
NODE-B <-> RNC [0] -->	0.00000273	0.00000273

point-to-point throughput (bits/sec)

Statistic sampling period is 6 seconds.

Sort By Link	Sorted By Average	Sort By Peak
NODE-B <-> RNC [0] <--	1,768.08	12,720.00
NODE-B <-> RNC [0] -->	1,545.48	10,600.00
SGSN <-> RNC [0] -->	990.04	7,137.33
SGSN <-> RNC [0] <--	799.95	5,441.33
GGSN <-> SGSN [0] -->	777.75	5,788.00

point-to-point throughput (packets/sec)

Statistic sampling period is 6 seconds.

Sort By Link	Sorted By Average	Sort By Peak
NODE-B <-> RNC [0] <--	4.1700	30.000
NODE-B <-> RNC [0] -->	3.6450	25.000
SGSN <-> RNC [0] -->	2.3350	16.833
SGSN <-> RNC [0] <--	1.8867	12.833
GGSN <-> SGSN [0] <--	0.4067	3.000

point-to-point utilization

Statistic sampling period is 6 seconds.

Sort By Link	Sorted By Average	Sort By Peak
ftp_server <-> hub [0] -->	0.0072345	0.054240
hub <-> GGSN [0] <--	0.0050604	0.037520
GGSN <-> SGSN [0] -->	0.0017385	0.012938
GGSN <-> SGSN [0] <--	0.0012498	0.009281
NODE-B <-> RNC [0] <--	0.0011369	0.008179

Project: AN_umts_adm_cntl

Scenario: throughput_based_adm_cntl

Report: User Selected

Title: Top Objects for UMTS CN

UMTS CN Total Number Requests Granted

Statistic sampling period is 100 seconds.

Sort By Node	Sorted By Average	Sort By Peak
SGSN	11.60	24.00

UMTS CN Total Number Requests Released

Statistic sampling period is 100 seconds.

Sort By Node	Sorted By Average	Sort By Peak
SGSN	10.60	22.00

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Top Objects for UMTS GMM**

UMTS GMM GPRS Attach Delay (sec)

Sort By Node	Sorted By Average	Sort By Peak
UE_1	0.36364	0.36364
UE_0	0.35942	0.35942

UMTS GMM PDP Context Activation Delay (sec)

Sort By Node	Sorted By Average	Sort By Peak
UE_1	0.56266	0.56266
UE_0	0.55771	0.55771

UMTS GMM Service Activation Delay (sec)

Sort By Node	Sorted By Average	Sort By Peak
UE_0	0.13785	0.14835
UE_1	0.13759	0.14731

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Top Objects for UMTS GMM (PER QOS)**

UMTS GMM (PER QOS) End-to-End Delay (sec) [3]

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
UE_0	0.18179	0.29369
UE_1	0.18135	0.24968

UMTS GMM (PER QOS) RAN Downlink Delay (sec) [3]

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
UE_0	0.18110	0.29294
UE_1	0.18064	0.24894

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Top Objects for UMTS GTP**

UMTS GTP Downlink Traffic Received (bits/sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
RNC	701.52	5,232.00
SGSN	690.32	5,168.00
GGSN	646.40	4,848.00

UMTS GTP Downlink Traffic Sent (bits/sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
SGSN	701.52	5,232.00
GGSN	678.72	5,088.00
RNC	658.00	4,928.00

UMTS GTP Downlink Tunnel Delay (sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
SGSN	0.000031931	0.000062753
RNC	0.000018534	0.000028908

UMTS GTP Uplink Traffic Received (bits/sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
SGSN	464.00	3,408.00
GGSN	441.92	3,312.00
RNC	410.24	3,056.00

UMTS GTP Uplink Traffic Sent (bits/sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
RNC	464.00	3,408.00
SGSN	448.96	3,344.00
GGSN	403.20	3,024.00

UMTS GTP Uplink Tunnel Delay (sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
GGSN	0.000048953	0.000064098
SGSN	0.000024064	0.000030756

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Top Objects for UMTS Node-B**

UMTS Node-B Total Downlink Throughput (bits/sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
NODE-B	1,011.56	7,729.33

UMTS Node-B Total Uplink Throughput (bits/sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
NODE-B	935.87	6,736.00

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Top Objects for UMTS RNC (PER QOS)**

UMTS RNC (PER QOS) RAN Uplink Delay (sec) [3]

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
RNC	0.10817	0.26616

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Top Objects for UMTS UE RLC/MAC**

UMTS UE RLC/MAC Total Received Throughput (bits/sec)

Statistic sampling period is 1 second.

Sort By Node	Sorted By Average	Sort By Peak
UE_1	347.69	18,563.29
UE_0	313.08	18,975.82

UMTS UE RLC/MAC Total Transmit Load (bits/sec)

Statistic sampling period is 1 second.

Sort By Node	Sorted By Average	Sort By Peak
UE_1	216.76	11,046.87
UE_0	196.95	12,063.89

Project: AN_umts_adm_cntl	Report: User Selected
Scenario: throughput_based_adm_cntl	**Title: Top Objects for UMTS UE RLC/MAC (PER TRCHNL)**

UMTS UE RLC/MAC (PER TRCHNL) Number Uplink Transmissions Required

Sort By Node	Sorted By Average	Sort By Peak
UE_0	1.00	2.00
UE_1	1.00	2.00

UMTS UE RLC/MAC (PER TRCHNL) Received Sequence Number

Sort By Node	Sorted By Average	Sort By Peak
UE_1	47.248	127.00
UE_0	31.425	103.00
UE_0	21.789	54.00
UE_1	14.774	32.00

UMTS UE RLC/MAC (PER TRCHNL) Received Throughput (bits/sec)

Statistic sampling period is 1 second.

Sort By Node	Sorted By Average	Sort By Peak
UE_1	339.36	18,563.29
UE_0	307.04	18,975.82
UE_1	8.33	345.97
UE_0	6.04	344.70
UE_1	0.00	0.00

UMTS UE RLC/MAC (PER TRCHNL) Transmit Load (bits/sec)

Statistic sampling period is 1 second.

Sort By Node	Sorted By Average	Sort By Peak
UE_1	213.79	11,046.87
UE_0	194.67	12,063.89
UE_1	2.97	208.06
UE_0	2.28	208.03
UE_1	0.00	0.00

UMTS UE RLC/MAC (PER TRCHNL) Uplink Retransmission Delay (sec)

Statistic sampling period is 6 seconds.

Sort By Node	Sorted By Average	Sort By Peak
UE_1	0.27973	0.27973
UE_0	0.20974	0.21973

Appendix B OPNET™ Modeler ver11.5 UMTS Attributes

UMTS Model Attributes

These are the local attributes apply to individual nodes in the network model. This Appendix lists the most important model attributes for the CN, RNC, Node-B, and UE node models.

CN Attributes

There are the following CN (Core Network) parameters, which we can consider:

UMTS CN ID, it defines the CN identifier, which is used by IP Auto-Addressing to ensure that the UEs connected to this CN are in the same IP subnet. All nodes bearing the same CN ID or UE CN ID are assigned to the same IP subnet. Note that each CN must have a unique CN ID.

UMTS CN Timer, it specifies timer used in the operation of the CN.

T3350, (sub-attributes of UMTS CN Timer) it specifies the length of the GPRS attach timer.

TRABAssgt, (sub-attributes of UMTS CN Timer) it specifies the length of RAB assignment timer.

T3385, (sub-attributes of UMTS CN Timer) it specifies the length of the PDP activation timer.

Processing Time, (sub-attributes of UMTS CN Timer) it specifies the processing time of data services, transcoding, and so on

Maximum Retry on Timer Expiry, (sub-attributes of UMTS CN Timer) it specifies the maximum number of times a signaling message is sent after the RAB assignment timer expires.

UMTS CN ToS to QoS Mapping, it specifies the UMTS QoS class (conversational, streaming, interactive and background) used for each IP application ToS class (best effort, background, standard, ...) for traffic arriving at the SGSN from higher IP layer and destined to UEs.

RNC Attributes

There are the following RNC (Radio Network Control) parameters, which we'll consider:

UMTS Handover Parameters, it configures the RNC to support hard or soft handovers and the parameters used in handover decisions. It is based on TR 25.922.

UMTS RNC Admission Control Parameters, it specifies parameters (such as uplink and downlink loading factors and maximum available power) used to compute uplink and downlink capacity in the admission control algorithm.

UMTS RNC Timer, it configures RNC Timers

Processing Time, (sub-attribute of UMTS RNC Timers) it specifies how long packets are delayed for processing at the RNC. This attribute does not include the time required for buffering on a transmission time interval. It is based on 3GPP TR 25.853.

Tinactivity, (sub-attribute of UMTS RNC Timers) it specifies the maximum length of time a radio bearer can be inactive before it is released.

Tqueuing, (sub-attribute of UMTS RNC Timers) it specifies the maximum time a RAB assignment for setup can be queued during the admission control. If the assignment is not served within this time, it is discarded.

UMTS RNC Channel Configuration, it configures dedicated, common, and shared transport channels carrying data and signaling traffic. For data channels, we can configure channel parameters for each UMTS service class. The main transport channel attributes are described below. Note that the configurable transport channel parameters depend on the channel type. For example, RB Mapping info does not apply to common channels because it is specified on a per-UMTS-class basis for the UEs in CELL_DCH state.

RLC Info, (sub-attribute of UMTS RNC Channel Configuration) it configures the parameters for radio link control operations.

UL RLC Mode and DL RLC Mode, (sub-attributes of RLC Info) it specifies the RLC mode used on the uplink (UL) and downlink (DL) channels. Because retransmissions triggered by TCP can incur larger delay in the unacknowledged mode, using an RLC in the acknowledged mode may reduce response times when TCP is running over a noisy channel.

Transmission Window Size and Receiving Window Size, (sub-attribute of RLC Info) it specifies the number of RLC PUs that can be sent or received without an acknowledgement. This attribute applies only to the RLC Acknowledged Mode.

RLC Discard Info, (sub-attribute of RLC Info) it specifies the timers used to determine when and how packets in the transmitter's RLC buffer are discarded.

In-Sequence Delivery, (sub-attribute of RLC Info) it specifies if the RNC preserves the order of packets received from higher layers. When this attribute is set to "No", the RNC forwards packets to the SGSN as they are received. When this attribute is set to "Yes", the RNC will only send packets to the SGSN in sequenced order. That is, if the RNC receives packet 21 but has not received packet 20, it will hold packet 21 until it receives and forwards packet 20 to the SGSN or until it realizes that packet 20 will never be fully received and sent to the SGSN.

DL RLC Status Info, (sub-attribute of RLC Info) it specifies how often downlink status reports are sent from the RNC to the CN. When the Missing PU Indicator sub-attribute is set to "True", status reports are sent out each time a missing PU is detected, subject to the maximum and minimum intervals permitted between status reports. These maximum and minimum values are specified by the Timer Status Periodic and Timer Status Prohibit sub-attributes, respectively.

Timer Status Prohibit, (sub-attribute of DL RLC Status Info) it specifies how often the RNC checks to see if it should send status reports to the UEs. Once the time specified by this attribute has elapsed, the RNC determines if it needs to send status reports to UEs. If a status report is required, the RNC sends the report and resets this timer.

Missing PU Indicator, (sub-attribute of DL RLC Status Info) it specifies if a missing PU triggers the RNC to send a status report to the UEs. After the Timer Status Prohibit timer elapses, the RNC checks to see if a missing PU was detected. When this attribute is set to "True", the RNC will send a status report to the appropriate UEs if it detects a missing PU. When this attribute is set to "False", missing PUs do not trigger a status report.

Timer STATUS Periodic, (sub-attribute of DL RLC Status Info) it defines how often the RNC sends status reports to UEs if it detects missing PDUs. The RNC starts this timer when it receives its first AM packet and the timer is continually reset after expiration. Upon detection of a missing PDU, this timer triggers a status report to be sent at the end of the current Timer Status Prohibit timer.

RB Mapping Info, (sub-attribute of Transport channel Parameters) it configures the parameters required to map the radio bearers to different channel types for the UEs that are in CELL_DCH state. The radio bearers for UEs in CELL_FACH state are mapped to FACH and RACH for down link and uplink, respectively.

UL TrChnl Info and DL TrChnl Info, (sub-attribute of Transport channel Parameters) it defines parameters required to compute the channel data rate from the information rate based on the channel coding employed. Currently, the model supports convolution channel coding types, with puncturing.

UMTS to ATM QoS Mapping, it defines the QoS of each ATM SVC that carries a particular class of UMTS traffic.

Scheduling Weights, it assigns weights to each QoS class for use in the FACH's Weighted Round Robin (WRR) scheduling algorithm.

UE ID Type, it specifies the format of the UE identification number used over FACH communications. Both C-RNTI (16-bit) and U-RNTI (32-bit) are supported.

ASC Parameters, it configures the RACH access service classes that define the level of service for RACH procedures.

AICH Transmission Timing, it sets the timing relation between PRACH and AICH channels.

Node-B Attributes

There are the following UE (User Equipment) parameters, which we'll consider:

UMTS CPICH Transmission, it specifies the transmission power of the Node-B common pilot channel in Watts. This is a key parameter of cell evaluation (and consequently handover procedures).

UMTS Cell Pathloss Parameters, it specifies the environment around the Node-B. The environment settings determine how the model computes cell pathloss. (Based on UMTS 30.03 TR 101 V3.2.0)

Shadow Fading Standard Deviation, (sub-attribute of UMTS Cell Pathloss Parameters) it specifies the standard deviation of the log normal distribution used to model shadow fading of the antenna signal. Typical attribute values are 12dB for indoor environments and 10dB for outdoor and vehicular environments.

Pathloss Model, (sub-attribute of UMTS Cell Pathloss Parameters) it specifies the surrounding environment (Vehicular, Pedestrian, Indoor Office, ...), which defines the path loss model used for the cell.

Number of Floors, (sub-attribute of UMTS Cell Pathloss Parameters) it specifies the number of floors when using Indoor office Environment in the Pathloss Model. Set this attribute to Not Used for other path loss models.

UMTS FACH Transmission, it specifies the FACH transmission power of the surrounding Node-B. The FACH transmission power can be explicitly configured in watts or it can be computed as distance-based to cover an imaginary circle of the specified radius around the Node-B.

UMTS Node-B Cell ID, it specifies an identifier for the Node-B and the cell that it is associated with, which can be useful to identify the cells in the debugger.

UMTS to ATM QoS Mapping, it defines the QoS of each ATM SVC that carries a particular class of UMTS traffic.

UE Attributes

There are the following UE (User Equipment) parameters, which we'll consider:

UE CN ID, it is CN identifier of CN node that the UE should attach to (applies (applies only to workstation and server UE nodes). When auto-assigning IP addresses, the model uses this attribute value to ensure that the UE is in the same IP subnet as the CN node. If the network modeled contains only one CN, no configuration is necessary since the default value of all CN IDs and UE CN IDs is 0.

UE IMSI, it specifies the International Mobile Subscriber Identity of the UE. You should set this attribute if you need to specify a source and destination for traffic that is going to be generated between station UE nodes.

QoS Profile Config., it configures each UMTS service class (conversational, streaming, interactive, and background). The majority of UMTS QoS profile configuration attributes are described below.

Bit Rate Config., (sub-attribute of QoS Profile Config.) it specifies the expected maximum bit rates for the uplink and downlink communication, these values need to be specified carefully. A too low value may cause consistent saturation of the QoS buffer and hence the loss of communication. A too high value would cause resource wastage in the cells with which the UE has established radio links.

Allocation/Retention Priority, (sub-attribute of QoS Profile Configuration) it configures parameters for the allocation and retention of a RAB during admission control. We use this attribute to enable queuing for the RAB request, and to specify if the RAB request can preempt or be preempted by other requests.

Allocation/Retention priority specifies the relative importance compared to other UMTS bearers for allocation of the UMTS bearer. The Allocation/Retention Priority attribute is a subscription attribute which is not negotiated from the MT.

This priority is used for differentiating between bearers when performing allocation and retention of a bearer. In situations where resources are scarce, the relevant network elements can use the Allocation/Retention Priority to prioritize bearers with a high Allocation/retention Priority over bearers with a low Allocation/Retention Priority Admission Control.

UMTS RLC Processing Time, it specifies the reliable Link Control processing time, which is primarily due to software processing and information transfer within nodes. The default value is 15ms for uplink and downlink communication.

UMTS ToS to QoS Mapping, it specifies the UMTS QoS class (conversational, streaming, interactive and background) used for each IP application ToS class (best effort, background, standard, ...). It is also available on workstation and server UEs.

UMTS UE Cell State, it specifies the state the UE is in, CELL_FACH or CELL_DCH.

UMTS Simulation Attributes

Unlike local attributes, which apply to individual nodes, simulation attributes apply collectively to all nodes in the network. The UMTS model suite has the following simulation attributes.

UMTS UE Mobility Distance Threshold, this attribute defines the shortest (distance) movement of a UE that triggers an update of the tables tracking UE location and related parameters. In other words, the UE is considered to be in the same location as long as it does not move more than the threshold distance away from its last recorded location. This attribute does not affect simulations that use only fixed nodes.

UMTS Sim Efficiency Mode, there are two simulation efficiency modes:
None - efficiency mode is not active, Constant BLER - disables outer loop power control and uses the initial BLER negotiated for each radio link (at the start of the connection) for the remainder of the simulation. This mode reduces simulation run times avoiding repeated power and interference calculations.

UMTS Statistics

To analyze the performance of your UMTS network, you can collect several statistics during the simulation.

Node Statistics

There are following UMTS node statistics are available. For details on a particular statistic, see its description by right-clicking on the statistic name in the Choose Results dialog box and selecting View Description from the pull-down menu.

UMTS CN,
Total Number of Requests Granted
Total Number of Requests Queued
Total Number of Requests Released

UMTS CN (per QoS),
CN-CN Delay
Number of Requests Granted
Number of Requests Queued
Number of Requests Released
Total UTRAN-CN Delay
UTRAN_CN Delay per ATM Link per QoS

UMTS CN ATM VC,
Load
Throughput
Utilization

UMTS GMM,

GPRS Attach Delay

PDP Context Activation Delay

Service Activation Delay

UMTS GMM (per QoS),

End-to-End Delay

RAN Downlink Delay

UMTS Handover,

Active Set Cell Count

Cells Added to Active Set

Cells Removed from Active Set

UMTS Node-B,

Cell Active Data DCH count

Total Cell Downlink Throughput

Total Cell Uplink Throughput

UMTS Node-B ATM VC,

Load

Throughput

Utilization

UMTS RACH,

Access Delay

Acknowledgments Received

Acquisition Indicators Received

Messages Sent

Negative Acknowledgments Received

Preamble Cycles Per Message

Preamble Power Level

Preambles Sent

Preambles Sent Per Message

Unsuccessful Contentions

UMTS RNC,

Total Received Throughput

Total Transmit Load

UMTS RNC (per Node-B),

DSCH Number of Active RABs

FACH Number of Active RABs

UMTS RNC (per QoS class),

CN-UTRAN Delay

RAN Uplink Delay

UMTS RNC (per transport channel),

Downlink Retransmission Delay

Number of Downlink Transmissions Required

RAN Uplink Delay

Received Sequence Number

Received Throughput

Transmit Load

UMTS RNC ATM VC,

Load

Throughput

Utilization

UMTS UE GMM (per QoS class),
End-to-End Delay
RAN Downlink Delay

UMTS UE RLC/MAC,
Total Received Throughput
Total Transmit Load

UMTS UE RLC/MAC (per physical channel),
Uplink Actual Eb/No
Uplink Average Interference
Uplink reception Power
Uplink Target Eb/No
Uplink transmission Power

UMTS UE RLC/MAC (per transport channel),
Number of Uplink Transmissions Required
Received Sequence Number
Received Throughput
Transmit Load
Uplink Retransmission Delay

Global Statistics

There are following UMTS global statistics are available. For details on a particular statistic, see its description by right-clicking on the statistic name in the Choose Results dialog box and selecting View Description from the pull-down menu.

UMTS GMM,
GPRS Attach Delay

PDP Context Activation Delay

Service Activation Delay

UMTS GMM (per QoS),

End-to-End Delay