Case Study

UMTS Network Performance Modeling Service

The UMTS Network can be complex because of its ability to support different traffic bearers, circuit and packet at various bit rates. It is not only difficult to predict the radio environment of such a system, but also the throughput and quality of service available throughout the end-to-end connection including the terminal and core network. Our end-to-end modeling covers radio network layout, radio propagation, radio effects and interferences, user mobility and user application traffic.

INTRODUCTION

This paper presents an executive summary of a UMTS Network Performance Modeling Service delivery. It presents the services which can be offered to UMTS Network operators, including non-Motorola customers. Motorola's network services portfolio supports customers throughout the lifecycle of their infrastructure deployment, from migration study to after-sales development and enhancement. We will describe the offered services along with outstanding benefits backed by simulation results on an example of the network. The service is complementary of the RF planning, as it models the "non-radio" part of the network. It is part of the suite of UMTS Design Services along with UMTS RAN Design and Planning and UMTS Transmission and Signaling Service.

The advent of UMTS technology promises to increase the utilization and usability of wideband mobile data applications in the cellular marketplace. UMTS systems will eventually replace the existing GSM and GPRS systems for wireless voice and data communications after a period of coexistence necessary to assess, perfect and mature the new technology. This UMTS consultancy service has been developed to predict the end-to-end performance at user application levels and utilize an intelligent tool to model and simulate typical scenarios. As it will be explained, all network elements are modeled along with their respective protocol stacks.

We cannot assume that the UMTS network behavior will be similar to GSM in user type or location. Flexibility in the infrastructure design and deployment is a key factor. Motorola provides the solution with the UMTS Network Performance Modeling Service to ensure our customer satisfaction through three key drivers: revenue generation, cost of ownership and quality of service.

UMTS NETWORK PERFORMANCE MODELING SERVICE BENEFITS

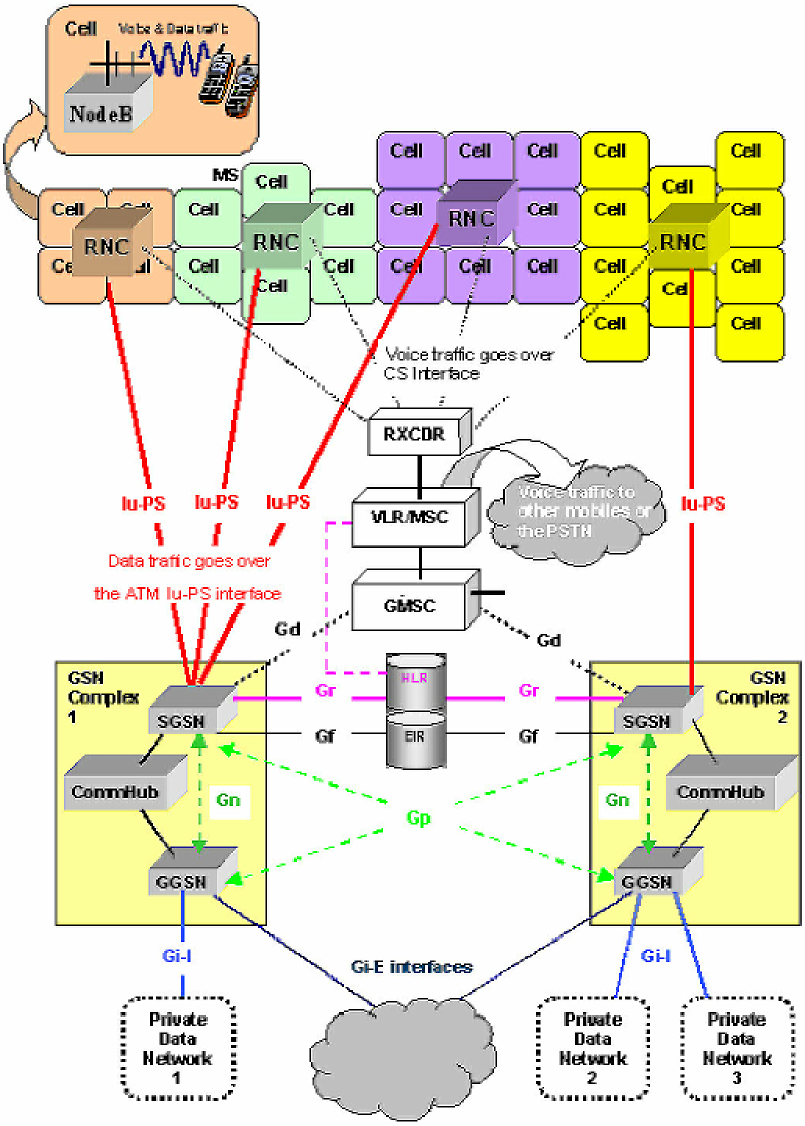
The UMTS technology demands a very high amount of system simulation and modeling work not only because of the involved novelty inherent to the interaction between the traditional IP systems and the new W-CDMA technology used in the air interface, but also because of the complexity of the UMTS radio interface. The new technology offers improvements from a radio resource allocation perspective. A lot of effort is necessary to optimize the main algorithms and to efficiently plan the network to be deployed. The interaction between typical IP and wireless worlds requires simulations of the complete end-to-end system for estimation of application performances and prediction of network behavior under different air interface conditions and traffic loads. Quality of service in UMTS technical specifications is defined as being and end-to-end performance measurement. Therefore, the ability to offer end-to-end system modeling to determine the network performance and quality of service available to UMTS customers at application level is very powerful.

The accuracy, versatility and flexibility of the service makes it suitable for a wide range of tasks in the design of a UMTS networks. This service provides quantifiable and direct benefits to our customers. The remaining sections of this paper will demonstrate how this service will optimize specific product parameters as well as the overall network performances on the following:

- Increases UMTS network throughput
- Provides maximum utilization of available capacity
- Optimal bandwidth configuration for terrestrial packet switched links
- Predicts and improves application-level performance
- Utilizes intelligent tools to model and simulate customer network scenarios
- Allows Motorola to provide expert advice on maintaining or improving network capacity and performance

END-TO-END PERFORMANCE ANALYSIS FOR OUR CUSTOMERS

The UMTS Network Performance Modeling Service offers a full end-to-end UMTS network simulation including the major characteristics of the UTRAN transport (see figure 1). Using an end-to-end simulator, it is possible to predict the performance of the complete network under various usage profiles that can range from simple e-mail and game play users to high bandwidth packet video users. The results of the simulations can be used to assess the impact of a new service or network technology deployment. Accurate end-to-end IP network modeling is critical in the cost effective deployment of the innovative new services that will be required to compete for subscribers in the UMTS market place.



(Figure 1) *UMTS Network Elements Modeled*

The UMTS Network Performance Modeling Service offers an approach that is split into modules. Some activities that can be performed are:

RF LINK THROUGHPUT PREDICTION

- Quality of RF plan
- Detection of unacceptable spots
- Application level performance

NETWORK PLANNING

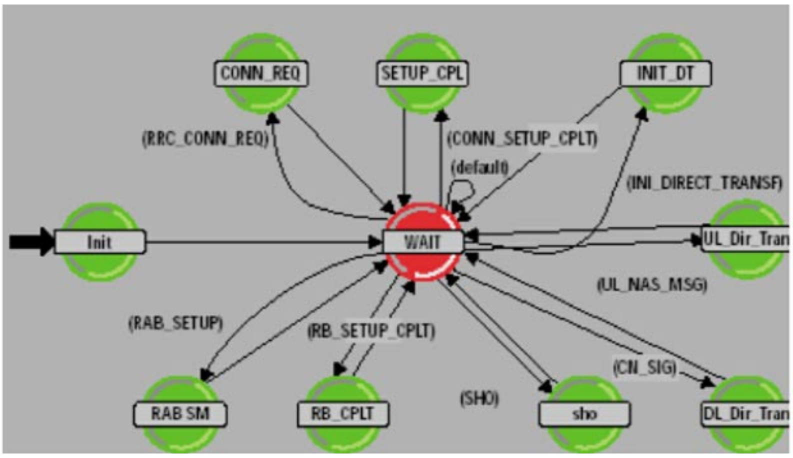
- Planning activities tailored for a specific customer-network configuration and traffic profile
- Terrestrial link dimensioning to achieve the desired end-to-end performances at application level (i.e. Iu-PS dimensioning)
- Air interface dimensioning (channel allocation to different applications for desired QoS levels)

WHAT-IF SCENARIOS

- New user deployment
- Different air interface configuration
- New application introduction
- Network expansion situations
- New technology deployment

ENABLING TECHNOLOGY

The network analysis is conducted using the UPM tool (UMTS Network Performance Modeling Service). It is an end-to-end UMTS network simulator developed to address all the inherent issues to the data modeling activities. The tool utilizes OPNET (simulation modeling tool) as a simulation platform and integrates radio models representing the main features of the UMTS air link interface with the typical core network entities derived from the traditional IP networks. By modeling the full UMTS Protocol stack (see RRC protocol example in figure 2), the tool can be helpful for a variety of activities, such as algorithm testing and optimization, protocol parameter tuning, buffer sizing, network link dimensioning, traffic growth scenarios, performance optimization and bottleneck location.



(Figure 2) *RRC Protocol Modeling*

A discrete event approach is adopted to model all the protocols in UPM. This means that each packet is explicitly created, manipulated and sent from one protocol to another, in order to reproduce the actual path followed by the packets in the real systems. Most of the user plane protocols are modeled, along with the most important features of the control plane protocols. The signaling messages related to radio and CN (Core Network) resource management, radio admission and load control, mobility management (soft and hard handover), power control, state management are considered. All network entities except the traditional GSM ones, such as MSC/VLR, HLR, and EIP are modeled.

A generic snapshot of UPM is depicted on Figure 3. UMTS Network Performance Modeling simulation:

- The full UMTS network architecture is extremely complex
- Network components simulated: UEs, Uu , Node-Bs, RNC, Iu-ps, SGSN, Gn, GGSN, Gi, External PDN
- UMTS protocol stack from end-to-end (user plane & control plane)

A wide range of statistics can be collected from across the network or from individual entities:

PROTOCOL STATISTICS

- TCP packet retransmissions
- RLC AM protocol behavior

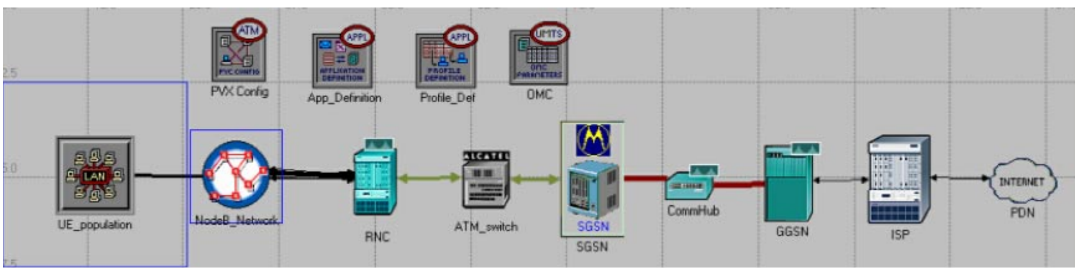
INTERFACE STATISTICS

- Load and throughput
- Number of packets dropped
- Uu interface: Tx/Rx power, SIR, Block Error Rate

APPLICATION STATISTICS

- Successful FTP downloads
- Applications response time
- Overall throughput

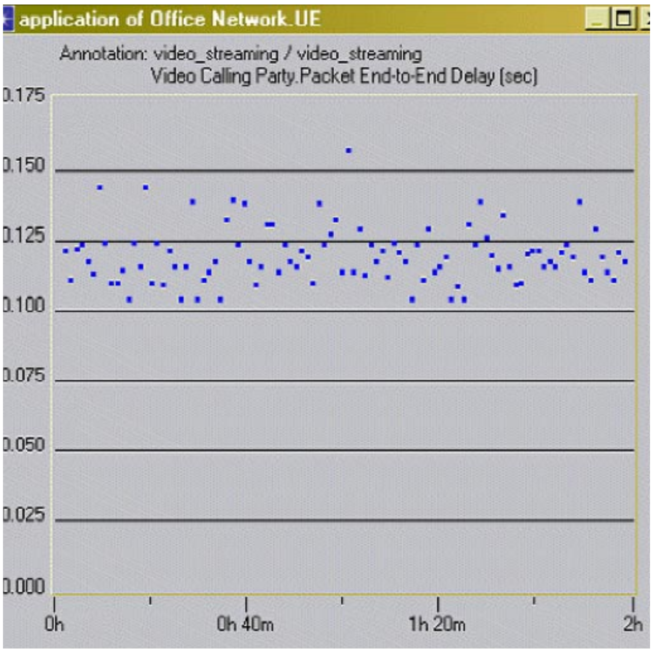
(Figure 3) *UMTS Network Elements Modeled in OPNET*



Network Performance Benchmarking:
End-to-End Packet Delay and Application Throughput

- End-to-end packet delay: usually tested with an UDP application.
- Maximum data throughput achievable; Uplink and Downlink tested with a streaming application (such as video conference) over UDP protocol.
- Application performances: the response time of typical Interactive and Background applications such as e-mail, FTP and HTTP were tested.

As an example, figure 4 shows the instantaneous packet end-to-end delay with a 64kbps RAB in the DL direction. This RAB uses the RLC Transparent Mode. The average delay figure obtained was 119.175ms, which is very close to the theoretical estimation of 117.15ms. If the end-to-end delay were higher than expected, the analysis of the different component delays could provide the point in the network where there is a potential bottleneck. For instance, PDU transferred delays can be assessed at PHY Layer, but also at MAC, RLC layer. After the system evaluation and through simulation of different scenarios with different protocol parameter settings, the user could determine which parameter setting is causing the poor end-to-end delay behavior.



(Figure 4) *Packet Video End-to-End Delay*

SERVICE DELIVERY

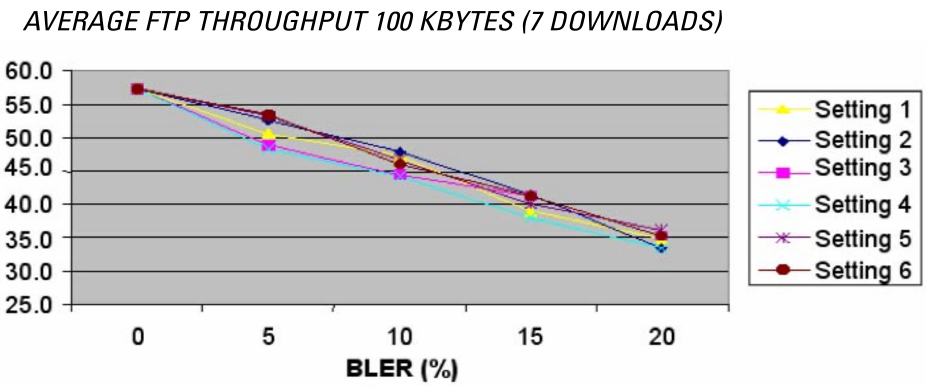
In the following section, we use the service to optimize the product's parameters as well as performing network analysis. The GSM-version of this tool has produced similar results to customers.

Product Optimization

This section describes some performance simulation results obtained using the service enablers at application level in terms of KPIs (Key Performance Indicators) achieved. It accounts for the impact of key variables such as BLER or file sizes for single scenarios.

Database Parameter Optimization

The developed tool is also able to predict the performance achieved at application level for a set of parameters defined in the network. Through simulations of several groups of settings for the RLC protocol (6) with different values (timers, windows sizes, etc.), one can choose the best parameter configuration that maximizes the network performance capability that optimizes the network. The following two examples clarify this idea. As illustrated in figure 5, the performances achieved are shown for 6 settings. The analysis reveals that after running the simulations, the 6th combination optimizes the performance behavior because it maximizes the system performance in terms of throughput achieved and packets lost.



(Figure 5)
RLC Performance - Retransmission

Network Analysis

The service is not only used to assess specific product parameters such as RLC timers, but also determines the performance of the network under different conditions. For instance, we can assess the network performance under different load or type of traffic mix. In this particular case study, a network loaded at 10% is assessed. The configuration mix is as follows:

- Voice users (AMR) at 12.2Kbps
- Data users downloading/uploading FTP files with DCH 64Kbps assigned
- Data users downloading/uploading FTP files with DCH 144Kbps assigned
- Data users downloading/uploading FTP files with DCH 384Kbps assigned

The voice users have an activity factor of 0.5, and they are continuously active (session of infinite duration). The FTP users download a constant file of 48Kbytes every 43.2 seconds. In total, 40% of traffic is due to voice users and 60% to data. The traffic is dimensioned according to the equivalent Kbps generated. Table 1 provides more details on the scenario considered for the simulations. All simulations were run on a 25 omni-cells configuration.

Scenario Nº	Nº of Voice kbps users	Nº of 64 kbps users	Nº of 144 kbps users	Nº of 384 kbps users	Nº of users
1	14	14	2	1	31
2	28	28	3	1	60
3	40	41	4	1	86
4	55	56	5	1	117
5	70	71	6	1	148

(Table 1) *Configurations Scenario Used in the Simulations*

The service enabler is a very powerful analysis tool because of its ability to collect a wide range of statistics. Every single unit (protocol, node, algorithm) has its own KPIs list assigned in order to evaluate the achieved performances. For instance, the average values for traffic received are shown in table 2. As expected, the uplink traffic is lower than the downlink traffic, representing the 68.5% and 65.8%, respectively for MAC and PDCP layers. These numbers represent the average traffic at network level for all the users in the simulation.

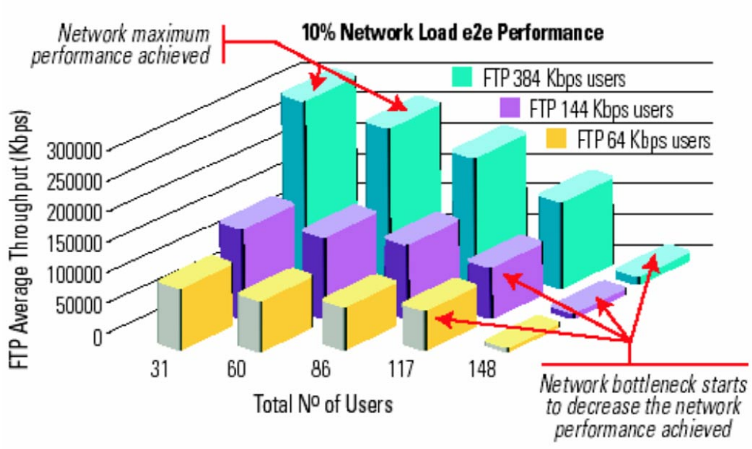
These statistics collected within this group fully detail the amount of traffic running across the MAC and PDCP protocols, a layer 2 and 3 UTRAN protocols at the UE side. It's very important to verify the first protocol layers show traffic activity. Otherwise, it would mean that there is a concern at the end-to-end pipe.

Layer	Average Traffic Received (bytes/sec)
MAC DL	48318.2
MAC UL	33085.15
PDCP DL	43052.2
PDCP UL	28351.73

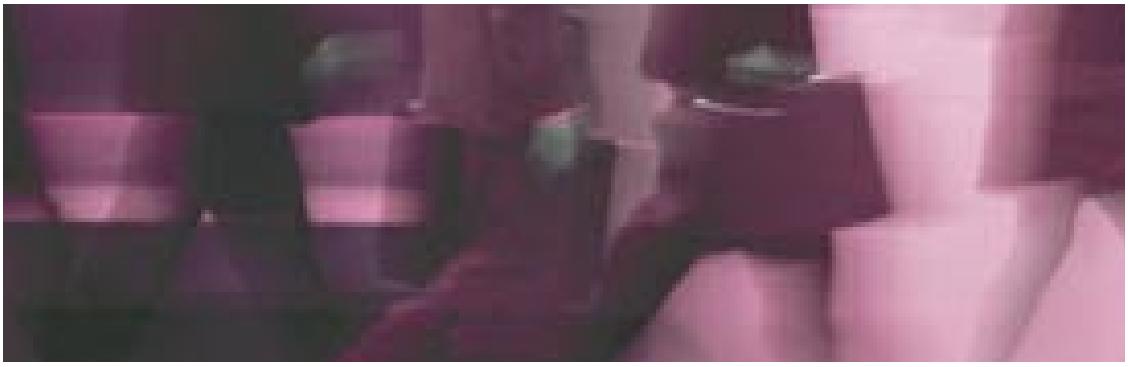
(Table 2) *MAC/PDCP Protocol Activity*

Figure 6 shows the collected results for the scenarios 1 to 5. Obviously, as the number of users increases, the performances achieved decreases. Through this service, we are able to analyze high loaded network scenarios and determine whether the loaded network with a determined user profile is going to have a good performance at application level or not. In this situation, with the user profile configuration given in scenario 1, the performance achieved is good for all the cases until 117 users is reached. The throughput obtained clearly decreases after this number of users and for 148 users, the performance is worse. Further studies will show that the bottleneck is located on the Gn interface, between the GGSN and the SGSN.

This network scenario is an example of the use of this service. It is possible to determine and localize possible bottlenecks along the UMTS chain by analyzing and studying the implemented statistics, the performance of the different network nodes and entities within it.



(Table 6) *Packet Video End-to-End Delay*



CONCLUSION

Motorola's UMTS Network Performance Modeling Service is driven by our unique modeling, which is a valuable asset when optimizing an existing UMTS network or when introducing enhancements in the design and deployment phase. This includes increasing the number of subscribers and application usage, introduction of new applications and new features, optimizing terrestrial links bandwidth, and increasing throughput - network balancing. By simulating the entire protocol stack, accurate figures of the typical application performances that can be achieved with UMTS networks, can be estimated. The figures account for the interaction between higher layer (i.e. TCP) and lower layer protocols (i.e. RLC/MAC). It provides secured performance, offers the capability to plan the introduction of UMTS applications and new features in a phased manner, allows for understanding the potential impacts affecting the performance of existing applications and voice traffic. It provides valuable data to support decision-making when balancing costs, revenue and customer satisfaction.

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