# SIMULATION METHODOLOGY FOR ASSESSING MXRAN ARCHITECTURE PERFORMANCE

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**Abstract[1]:** Product life cycles in communications and other technology related industries are getting shorter and shorter. Consequently the performance of such systems must be evaluated early in the architecture design stage. In the wireless networks area new radio access technologies are applied and form a multistandard radio access network (MxRAN) which denotes an evolution of the current UMTS (Universal Mobile Telecommunications System) architecture defined by standards bodies. The MxRAN is a main part of the IPonAir [IPonAir homepage] project. For this project several network architecture options and protocol stacks must be assessed. This makes the availability of an easy to use performance evaluation tool indispensable. In this paper the requirements and the modeling concept of a flexible signaling performance model are depicted. Thereby a use case approach starting with a description in Message Sequence Charts (MSCs) is applied. This set of MSCs is then converted automatically to a generic model that can be executed in an event driven environment.

*keywords: Network Performance Models, Queueing Systems*

## 1. INTRODUCTION

In the IPonAir project a new flexible radio access network (RAN) architecture supporting existing and future IP-based protocols is conceived. Starting from the UMTS Release 5 (R5) RAN architecture new architecture options of the above mentioned type are evolved. Several different solutions must be compared to derive an optimal architecture with respect to protocol processing cost and signaling delay. Therefore a performance assessment in an early stage of the software design is needed to detect the most advantageous architectures and avoid capital investment in technologies which are not efficient. This is why a flexible signaling performance assessment methodology for decision support is provided and implemented in a tool chain. Thus the methodology can be applied easily for the comparison of different MxRAN architectures.

The paper is organized as follows. First the requirements for the envisaged performance tool are identified. Then after a short overview on UMTS R5 the main scenarios (use cases) of the MxRAN control plane are listed. MSCs [SDL Forum 2001] are used for the specification of the use cases. The MSCs are annotated with additional processing related information. From the set of MSCs a table related representation is derived automatically. This representation of the use cases is transferred into an event driven simulation tool. Predefined generic modules are used in the network nodes of the event driven system. The modeling concept and the node internal generic modules applied are described. Then the realization within an OPNET event driven environment is explained by means of two architecture examples. The paper closes with a summary of the simulation methodology and some remarks concerning the future development and implementation of this simulation methodology.

## 2. REQUIREMENTS

In this paragraph the requirements that have to be met by the envisaged simulation methodology are described.

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- The focus is to evaluate MxRAN architecture alternatives by simulation with regard to performance in terms of signaling load, processing and memory capacity as well as delays assuming different traffic loads and mobility models.
- The evaluation of architecture variants shall be performed easily and efficiently.
- The bundling of protocol entities to network elements and the mapping of protocol entities to processors shall be possible in a flexible manner.
- The modeling concept shall support the separation of functions belonging to different planes, e.g. user plane and control plane.
- Main focus of the intended investigations is the signaling traffic load.

In order to meet these requirements, a generic and flexible modeling approach for the intended simulation study is needed.

## 3. UMTS R5 MODEL

As the future MxRAN architecture evolves from the current UTRAN R5 architecture, a short overview of the latter architecture is given hereafter.

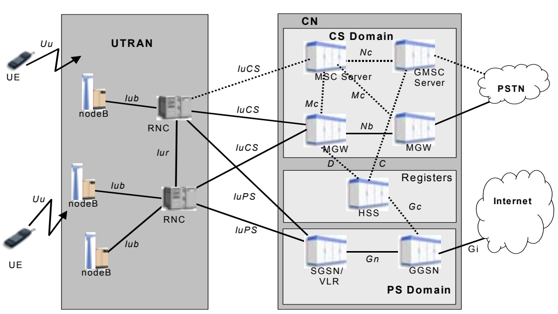


Fig. 3.1: UMTS Schematic R5 Architecture

Figure 3.1 depicts a simplified picture of the UMTS R5 architecture as defined by 3rd Generation Partnership Project (3GPP). Three different domains are depicted. First there is the UMTS Radio Access Network (UTRAN) consisting of base transceiver station (Node B) and Radio Network Controller (RNC) network elements. Second there exists the Circuit Switched (CS) domain of the Core Network (CN) consisting of a Media Gateway (MGW) for voice user data, the Mobile Switching Center (MSC) server for signaling purposes and the Gateway MSC (GMSC) server for connection to external networks. It must be noted that unfortunately inside the CN of the UMTS system the term MSC denotes Mobile Switching Center, but in the rest of this paper an MSC denotes a Message Sequence Chart. The third domain is the Packet Switched (PS) domain within the CN comprising the Serving GPRS Support Node (SGSN) which is comparable to the Mobile Switching Center but for PS connections and the Gateway GPRS Support Node (GGSN) for connection to external packet data networks. The UTRAN handles all radio specific functionality. The CS domain handles all circuit switched sessions and connects the UTRAN to the Public Switched Telephone Network (PSTN) while the PS domain handles the packet switched sessions and connects the UTRAN to the public internet. Also depicted is the user equipment (UE) handling the user traffic in the cellular system and the Home Subscriber Server (HSS) storing the relevant user data. In UMTS R5 there are some more network elements performing call control and other signaling functions as well as multimedia resource functions. Those are not shown here for shortness sake. In Figure 3.1 dotted lines denote pure signaling links. Solid lines can transport signaling as well as user traffic.

The current UMTS architecture originates from the second generation (2G) GSM (Global System for Mobile communications) voice network. In GSM the PS domain was added later on in the form of the General Packet Radio Service (GPRS) subsystem. All this clarifies the fairly complex 3G architecture today and also in R5 as well as the permanent process of enhancing and optimizing these architectures. The further development of such 3rd generation networks and the finding of new improved architectures with regard to performance is a topic of active research just now [Uskela, 2003], [Yungsoo et al, 2003].

Certainly such rather complex networks impose strict delay requirements both on user and signaling traffic handling. Those requirements have to be met by the architectures under consideration and are one criterion for assessing these architecture options by simulation. In order to investigate this criterion, traffic has to be imposed on the simulation system. The traffic modeling concept and the traffic flows of interest as well as their derivation and adaptation to the overall simulation modeling concept are the main focal point now. To impose load on the modeled network elements, traffic must be generated inside the system. Within the traffic modeling concept the focus is on the signaling traffic, i.e. the control plane of the MxRAN. With regard to the signaling traffic the following use cases are of interest:

- CS Mobile Originated (MO) and Mobile Terminated (MT) Call Setup and Release
- PS MO and MT Call Setup and Release
- Intra- and Intersystem Handover
- Location Update procedure

- Paging procedure.

The first two procedures indicate the main activities of a user in a cellular network. Those are starting or receiving a voice call and using packet switched services by reading e-mail or surfing the web. The others are mobility related procedures involved when a user transits to a new cell or cell area or when the UE has to be located by the system when receiving a call.

These use cases can be described in the form of high level MSCs as specified in [3GPP TSG RAN, 2002] and [Kaaranen et al, 2001] where those MSCs are used to describe important UTRAN functions. The dominant signaling load is generated by these MSCs. In Fig. 3.2 the "RRC Connection Setup" procedure which is part of the CS MO Call Setup scenario is taken as an example. A Radio Resource Control (RRC) Connection is a point-to-point bi-directional connection between RRC peer entities on the UE and the UMTS RAN side, respectively. An UE has either zero or one RRC connection. The "RRC Connection Setup" procedure is used in several basic signaling traffic procedures to set up a signaling channel between a mobile terminal (UE) and the corresponding RNC via a base station (Node B).

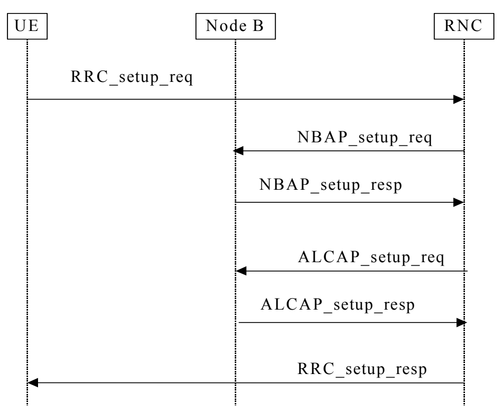

Fig. 3.2: High Level MSC for "RRC Connection Setup"

In the developed modeling concept the relevant network elements and protocol entities are identified from the MSCs given in the appropriate standards documents, e.g. [3GPP TSG RAN, 2002]. Considering the "RRC Connection Setup" procedure as an example, the relevant network elements which can be identified from Fig. 3.2 are the

- UE with the protocol entity RRC
- Node B and the protocol entities Access Link Control Application Protocol (ALCAP) and Node B Application Part (NBAP)
- RNC with the protocol entities ALCAP, NBAP and RRC.

As a consequence of this identification procedure, the MSCs provided by standards documents are refined as illustrated in Fig. 3.3 where the MSCs are extended by additional trigger messages to model the exchange of messages between protocol entities.

In the refined MSC (see Fig. 3.3) the relevant protocol entities explicitly communicate with each other while this communication is only implicitly modeled by the high level MSC illustrated in Fig. 3.2.

In the modeling concept the relevant protocol entities are modeled as stateless Functional Entities (FEs). This implies that a full functional model based on extended finite state machines (EFSMs) for the protocols is not needed. Hence the presented modeling approach is not state based. The reason for this design decision is that the modeling approach has to meet the requirement of a quick and easy evaluation of MxRAN architecture options.

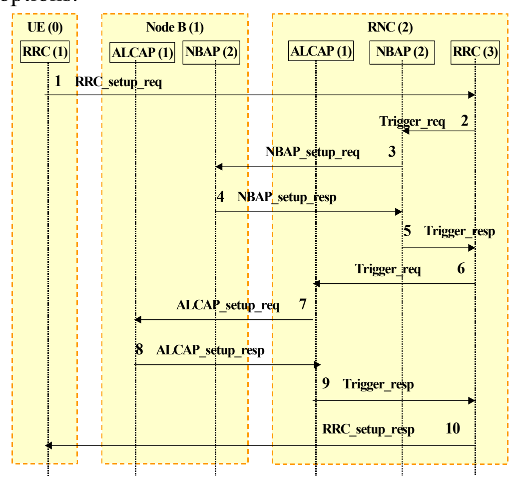

Fig. 3.3: Refined MSC

The context of FEs, MSCs and signaling traffic can be described as follows: FEs exchange specific sequences of signaling messages which are provided in the form of refined MSCs and model the use cases of interest described above.

## 4. MODELING CONCEPT

In order to set up network elements, a generic and modular node modeling concept is used. This is depicted in Fig. 4.1 and described subsequently.

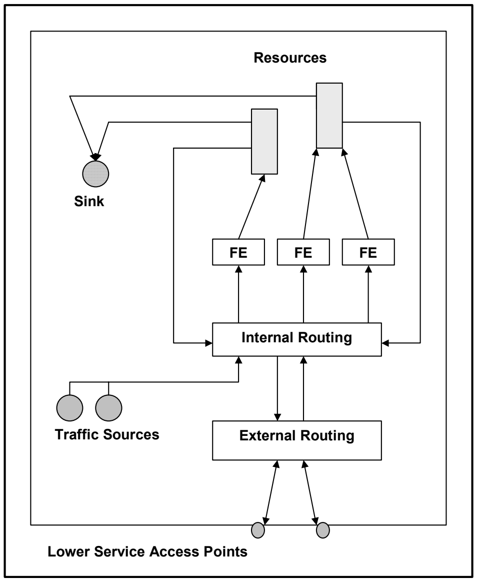


Fig. 4.1: Generic Node

Each network element consists of:

- One or more Lower Service Access Points (LSAPs)
- External Routing (ER) module
- Internal Routing (IR) module
- (Multiple) Functional Entities (FEs)
- One or more resource modules
- Sink module
- Optionally one or more traffic source modules.

Network elements which initiate signaling traffic contain *traffic sources* to model user (outgoing) and network generated (incoming) traffic. All sources starting a specific signaling sequence (e.g. all users in a cell starting an outgoing call) are aggregated. In a first step, the signaling sequences are triggered independently from each other and a statistical mix of signaling procedures derived from measurement data is used. One of the current activities is to refine the traffic model in order to model correlation among signaling procedures (e.g. setup and release of calls) without having to explicitly model every single traffic source.

An *LSAP* transparently interconnects the elements within the network. The LSAP can also be used as an interface to lower layer protocol stacks.

The *ER* and *IR modules* realize the routing functionality between network elements and within network elements, respectively. If a message reaches the ER module it is checked whether the message is addressed to the local node or not. If it is addressed to the local node the message is passed to the IR module, otherwise it is sent to the LSAP in direction to the addressed node which means that the message is just relayed by the ER module (e.g. in Fig. 3.2 the "RRC Setup Request" within the "RRC Connection Setup" procedure is sent by the UE, addressed to the RNC and relayed by the ER module of Node B).
The *IR module* forwards an incoming message to the addressed FE.

*FEs* logically process incoming messages (e.g. convert them to another message type and provide new addresses) and pass the processed message to the *resource module* which models time consumption and resource contention. In reality FEs are located on physical processors which are modeled by the resource in this case. On a single processor one or more FEs can be located.

The resource forwards the last message of a signaling sequence to the *sink module* so that the End-to-End delay of the signaling procedure can be measured. Other messages are forwarded to the IR module which determines whether the message is addressed to a FE within the local node or not. If the message is addressed to a FE within the local node, the IR module sends the message to the addressed FE, otherwise the message is passed to the ER module. In this case the ER module sends the message to the LSAP in direction to the addressed node.

According to this generic node modeling concept and using the "RRC Connection Setup" procedure (see Fig. 3.2 and 3.3) as an example, the network element RNC can for example be modeled as illustrated in Fig. 4.2. Here the three FEs depicted in the RRC Connection Setup procedure are located on two resource modules. The ALCAP FE runs on the first resource while the NBAP and the RRC entities run on the second resource.

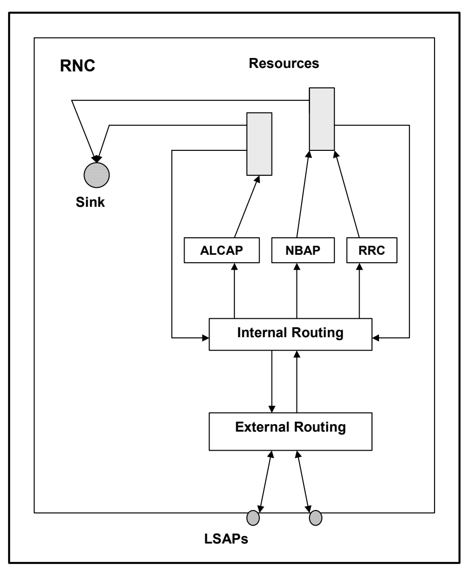


Fig. 4.2: Network Element RNC Modeled According To Generic Node Modeling Concept

## 5. REALIZATION

As far as an implementation of the simulation methodology is concerned, the OPNET Modeler environment was chosen to execute the simulations and analyze the results. OPNET is a quasi standard event-driven simulation environment provided by OPNET Technologies [OPNET homepage]. Despite the fact that OPNET provides a huge set of libraries for many well-known protocols, e.g. from the TCP/IP suite, the implementation of the methodology presented here does not necessarily make use of those OPNET built in protocol stacks. However, from the OPNET event driven environment the traffic generation package, queuing modules, links, graphical network editor and the analysis tool are used.

The refined MSCs (cf. section 3) that describe relevant signaling procedures are noted down in Microsoft Excel and automatically loaded into the OPNET simulation model via a Visual Basic for Applications (VBA) transformation algorithm. This VBA script generates the tables that can be imported directly into the OPNET environment. Extensible Markup Language (XML) or simple ASCII tables are used to specify and interchange the data. The network elements within the OPNET simulator are designed according to the generic node modeling concept (cf. Fig. 4.1). A simple RNC model with seven FEs mapped onto one resource is shown in Fig. 5.1 as an example for the OPNET node model of the network element RNC. The generic modules which build up the network elements (cf. section 4) are interconnected by packet streams, which is the mechanism for the exchange of messages between node internal modules provided by OPNET.

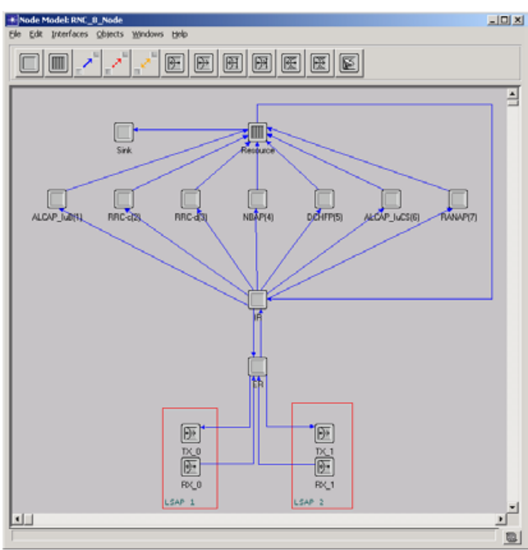


Fig. 5.1: Simple RNC Node Architecture Implemented in OPNET

Within the OPNET simulation model the MSCs are represented by a C code data structure within the FE modules. The FEs process incoming messages according to the MSC logic. Messages are annotated using complexity factors in order to specify the amount of processing time spent in the resource module. Thereby a higher complexity factor denotes more processing time in the resource. Moreover each message between two FEs is annotated with its message length. This determines the transport delay between two FEs. Within the current simulation model each signaling sequence is triggered by a single traffic source. Different traffic scenarios can simply be created by changing the simulation parameters of the traffic sources.

The OPNET implementation of the simulation concept at hand in particular fulfils the requirements presented in section 2. A flexible grouping of protocol entities to network elements and resources is easily possible by adding and removing FE modules and resources to and from network elements and re-interconnecting them by packet streams. For example the RNC illustrated in Fig. 5.2 contains seven FEs mapped onto two CPU (Central Processing Unit) resources. By doing so it is easily possible to set up different MxRAN architecture alternatives of interest for evaluation within simulation scenarios and assess them by means of performance figures (e.g. utilization of single resources, End-to-End delays of signaling sequences) provided by simulation runs.

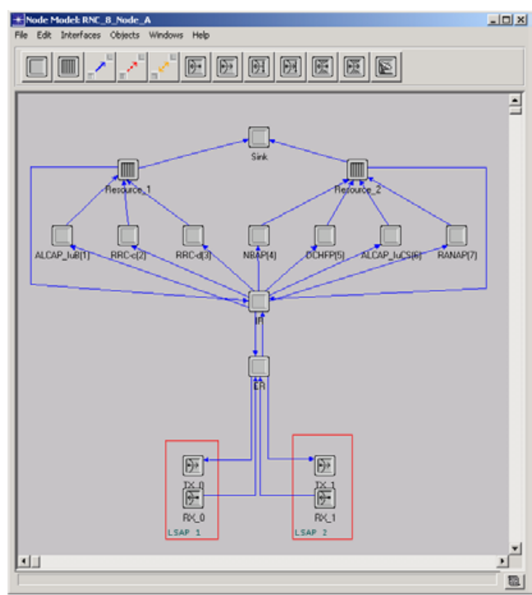


Fig. 5.2: Alternative RNC Node Architecture Mapping of FEs to Resources in OPNET

A detailed description about the implementation of the modeling concept using the OPNET Modeler simulation toolkit is provided in [Frangiadakis et al, 2002].

## 6. CONCLUSION

This paper introduces a general simulation methodology for the evaluation of different signaling architectures with respect to their performance. The approach is characterized by the automatic conveyance of the use cases under study to an event driven simulation environment.

There are many benefits of the proposed methodology. On the one hand the error prone transfer of MSCs into a simulation model is bypassed and a refinement of the use cases under study is assisted. On the other hand the approach is flexible and alternative MxRAN architectures under study can be modeled easily. Particularly the relocation of functional entities within one node is performed at the OPNET graphical user interface without difficulty. Thus the derivation of an optimized system architecture can be tackled in an iterative way and in a very early design stage so that the risk of capital investment into a suboptimal architecture is considerably reduced.

In the future the relocation of functional entities between different nodes is envisioned for the tool chain. Moreover it is intended to integrate and correlate all traffic sources within a Central Intelligent Traffic Control node. Inside this central traffic source node also additional information on occupied resources like radio channel elements or links can be kept. Besides the modeling of thousands of nodes will be incorporated as signaling background traffic by means of a stochastic process that switches ON and OFF the related resources. For this reason processing resources are available for processing foreground traffic only in ON mode. In the same way user traffic shall be supported as background traffic. Moreover the incorporation of resource specific state information for scarce resources like maximum number of channels is envisaged.

In general the devised approach and tool implementation helps to design complex next generation communication systems. This pertains to an optimized architecture choice in terms of signaling overhead, scalability and performance.

## 7. ACKNOWLEDGEMENTS

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