B-ISDN to the Cell Site Switch versus B-ISDN to the Mobile Terminal[1]

G. Karagiannis[a], J.-P. Katoen[b] and I.G.M.M. Niemegeers[a]

[a] Centre for Telematics and Information Technology
University of Twente
P.O. Box 217, 7500 AE Enschede, The Netherlands

[b] Department of Computer Science
University of Twente
P.O. Box 217, 7500 AE Enschede, The Netherlands

Abstract — This paper addresses in detail two possible scenarios for integrating the future mobile telecommunication system UMTS with the evolving broadband fixed telecommunication system B-ISDN. In the first scenario a mobile-specific access network is envisaged combined with a B-ISDN backbone network. The second scenario uses B-ISDN basic call facilities throughout the entire network, including the mobile access part. The two scenarios are described in detail and a comparison at functional level is made. This comparison is complemented by a performance study of a non-trivial handover procedure in a high-traffic public environment.

I. Introduction

UMTS (Universal Mobile Telecommunications System) is currently being designed and standardized. It is intended to be a system capable of providing a diversity of services (up to 2 Mbit/s). In addition to multi-party and multimedia services, UMTS should integrate services as currently being offered by cordless, cellular, (dedicated) paging and private mobile radio systems which makes it the successor of second generation systems like GSM, DECT, and ERMES. It must be operational in different environments, such as domestic, business, vehicular, and multi-operator public environments (both in rural and metropolitan areas).

UMTS is currently under development both in the Mobile Project Line of the European RACE programme and in the European Telecommunication Standards Institute (ETSI). The results of ETSI are carried over to ITU where standardization activities on the Future Public Land Mobile Telecommunications System, also referred to as IMT-2000, International Mobile Telecommunications – 2000, take place [1]. It is the ultimate goal to obtain a single system, or at least two compatible systems.

In parallel, in the field of fixed telecommunication systems developments in the direction of broadband ISDN (Integrated Services Digital Networks), shortly B-ISDN, are currently ongoing and receive a lot of attention. Though current mobile telecommunication systems are developed (and operating) quite independently from the fixed telecommunication systems, a major goal of the development of UMTS and FPLMTS is to aim towards the integration with B-ISDN. The main advantages of this integration are (i) the avoidance of duplication of common functionality (e.g., call handling, bridging and switching), (ii) the common use of protocols, and (iii) the use of a common infrastructure. These aspects will reduce installation and operational costs, and enlarge the possibilities to satisfy the user's needs [7]. Promising developments in the field of Intelligent Networks (IN), in particular its flexible service combining capabilities, are foreseen to pave the road towards UMTS–B-ISDN integration.

Two major options for integrating UMTS and B-ISDN are identified by [5]: a scenario in which the backbone network is based on B-ISDN and a scenario in which B-ISDN basic call functions are used throughout the entire network, including the radio access network. This paper reviews these two options and studies the impact on the efficiency of treating a non-trivial handover procedure by means of simulation. In particular,

[1] This paper is accepted by the IEEE International Conference on Communication Systems (ICCS'96), November 1996, Singapore.

the relation between handover response time and bearer- and call control execution time is investigated for both scenarios.

II. UMTS Functions and Architecture

The design and standardization of UMTS takes place in a step-wise fashion, starting from user and functional requirements, and finally resulting in an overall architecture, a blueprint for possible realizations of UMTS. The design trajectory of UMTS is an extension of the ITU-T 3-stage method (ITU-T Recommendation I.130). An important step in the design of an UMTS architecture is the specification of mobility procedures and their mapping onto system building blocks and interfaces.

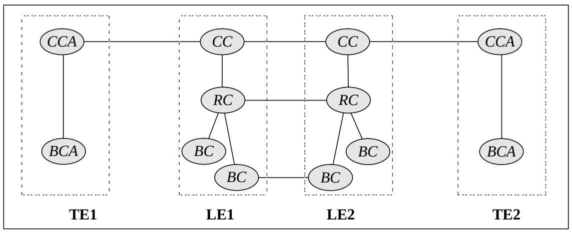

Figure 1: Broadband basic call FM.

For UMTS and B-ISDN mobility and call-handling procedures are specified using *functional models* (FMs), consisting of functional entities (FEs) and relations between them. A procedure is described by a single FM. An FE consists of a subset of the functions needed to offer the procedure at hand. To support their joined operation, interactions between FEs are needed. The information exchange between FEs is described by Information Flows (IFs). E.g., the basic call functions of B-ISDN are organized as in Fig. 1. CC (Call Control) functions respond to the user's request and organise network resources to provide the requested service using the RC entities. They do not include implementation of the network in terms of switches and connections. RC (Resource Control) functions are used to control special resources (such as bridges, splitters, and combiners) which may not be present at each network entity and control BC entities. BC (Bearer Control) functions control the ATM connections which are established, maintained and cleared on demand for the support of services.

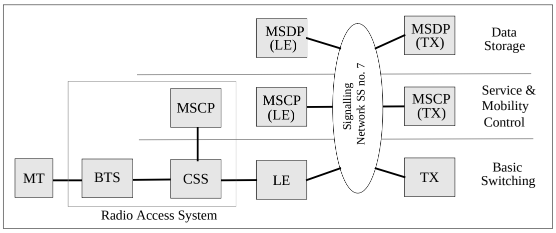

Figure 2: Overview of basic UMTS architecture.

The basic UMTS architecture (Fig. 2) consists of an access network constituted by the BTS (Base Transceiver Station) and CSS (Cell Site Switch), and a backbone network (LE and TX). MT represents the Mobile Terminal. The anticipated UMTS/B-ISDN integration is reflected by the fact that the Local Exchange (LE) and Transit eXchange (TX) are shared. LE and TX perform basic call and connection control. The CSS takes care of basic call control and the connection to the fixed network. The radio access for MTs is provided via BTSs. The Mobility and Service Control Points (MSCPs) comprise the functionality for mobility and service control, whereas the Mobility and Service Data Points (MSDPs) model (distributed) data storage. In order to meet the stringent performance requirements for UMTS the centralized service control of IN has been modified into a distributed service control. This also facilitates local control in private environments such as business and domestic areas. For the different environments for UMTS the system will be configured differently, depending on the requirements of such environment [8]; e.g., in a simple business environment there is no MSCP foreseen in the access network, and for a domestic environment the role of the CSS is minimal, since there is typically a single BTS in such case.

III. Handover Scenarios

Two interesting integration options were identified by [5]: (I) integration in the backbone network, i.e., reuse of B-ISDN basic call functions in the common fixed part of the network with a UMTS-specific RAS (Radio Access System), and (II) full integration, so also reusing B-ISDN basic call facilities in the RAS. (I) is also referred to as B-ISDN-to-the-CSS and (II) is referred to as B-ISDN-to-the MT. Due to the mismatch between e.g. signaling protocols at the access and network side in scenario I, certain interworking functions (like flow control, two-way mapping of radio packets onto ATM cells etc.) are needed in the CSS. In scenario II an MT will have the same basic call facilities (up to a certain limit) as a fixed TE including a direct call control association with the LE. The RAS is designed with B-ISDN functions and protocols as a basis, extending these with UMTS-specific functions when necessary.

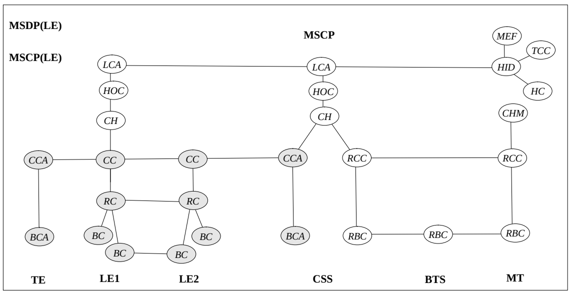

Figure 3: FM for handover (Scenario I).

We consider a handover between two CSSs controlled by the same MSCP (inter-CSS handover) initiated due to reduced quality of radio connections. MT performs measurements and when certain criteria are met it initiates a handover. Function LCA (see Fig. 3) checks whether or not an indicated handover can be executed at the level of the network the LCA entity is allocated. If it is able to handle the request it initiates HOC (Handover Control) which is responsible for the handover execution; if not, it passes the request onto a LCA entity at a next higher level in the network. During handover execution a new connection is established (while the 'old' connection is still present) and a bridge is temporarily established (on both the network and terminal side) between these two paths. As opposed to GSM the call is not simply relayed but the call is rerouted to optimize the use of fixed network resources [2].

IV. Performance Assessment

To get more insight about the differences in efficiency between the two handover options we investigate the impact on handover response time. Since the main differences between the two scenarios concern the basic call functionalities we determine (by means of simulation) the influence of the execution time of CC and BC entities on the handover response time.

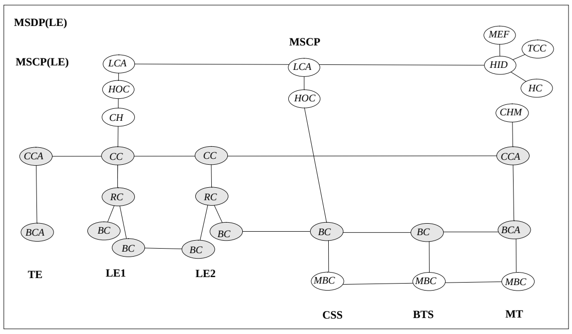

Figure 4: FM for handover (Scenario II).

We consider a public high traffic environment; that is, the RAS is configured as in Fig. 2. The physical distances between the network entities are: BTS_{new} - MT and BTS_{old} - MT approx. 500 m, LE-CSS approx. 50 km, and all other distances approx. 25 km. The propagation delay for radio connections is 3 μs/km, for fixed connections this is 5 μs/km; this last value is adopted from ITU-T recommendation G.114. The following execution times for functions are used: BC entities 3 ms, CC entities 1 ms, and LCA+HOC+CH 1 ms. The services times of these functions are distributed according to a 10-stage Erlang distribution, i.e., almost a deterministic distribution. For the fixed connections it is assumed that a message can be mapped onto a single ATM cell. Based on mobility models—that model the movement of users during the day—developed within the MONET project, it is assumed that handover requests are generated according to a Poisson arrival process with a total average rate λ of 2400 request/per cell/per hour. The inter-CSS handover rate equals 0.23λ. The total background load, i.e., the load due to other activities, is assumed to be 80% of the total capacity of the system. The handover requests are imposed on this background load.

The simulation method we use is adopted from [3] and is strongly related to [10]. The approach is based on those FMs and information flows that are of significance to the concerned performance measures. For each network entity a queuing network is developed and these queuing networks are connected via queues, the service time of which models the propagation delay (depending on distance and type of media) between the network entities at hand. Traffic generator processes generate customers according to a specified arrival process. In our case these customers are abstractions of handover requests. Handover response times are now directly determined by the sojourn times of the customers in the composite queuing network.

Two examples of the queuing networks used are given in Fig. 5 and Fig. 6; we refer to [4] for a full treatment. Fig. 5 depicts the queuing network model of the CSS used for the B-ISDN-to-the-CSS scenario; the related FM is shown in Fig. 3. Fig. 6 shows the same for the B-ISDN-to-the-MT scenario; this model is related to the FM of Fig. 4. The model of Fig. 5 is composed of 2 parts: the CSS fixed part and the CSS mobile part. The CSS fixed part models the communication between the CSS and LE and between the CSS and the MSCP in the RAS. During the simulation multi-media connections are considered up to a maximum of K connections at the same time. We used $K = 2$ for the simulation. The protocol

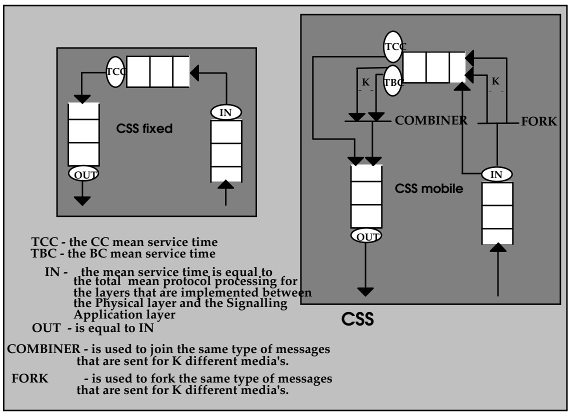

Figure 5: Queuing network of the CSS for B-ISDN-to-the-CSS.

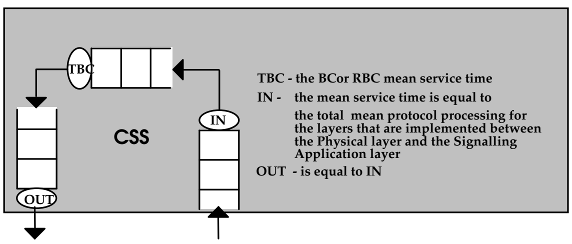

Figure 6: Queuing network of the CSS for B-ISDN-to-the-MT.

processing of the layers in between the Physical and Application layers is modeled by 2 queuing network models. The service times of these networks, IN and OUT, are assumed to have a constant service time distribution of 1 ms.

CC execution time (ms)	conf. interval B-to-the-CSS	conf. interval B-to-the-MT
1	0.3748	0.3977
5	0.6864	0.4319
10	0.9254	0.6760
20	1.159	0.3727
30	2.863	0.5960
40	5.108	0.7466

Table 1: Confidence intervals.

Simulations of the composed queuing network have been performed using the QNAP2 (Queuing Network Analysis Package) tool [9]. The results have been obtained using standard techniques for analyzing simulation results, such as the approach of independent replications, see, e.g., [6]. Fig. 7 shows the sensitivity of the mean execution time of CC entities on the mean response time for handover requests for both scenarios. The BC time was fixed to 3 ms. The 95% confidence intervals for these simulations are given in Table 1; for the sensitivity of the BC execution time we refer to Fig. 8 and Table 2 (where the CC time is fixed to 1 ms).

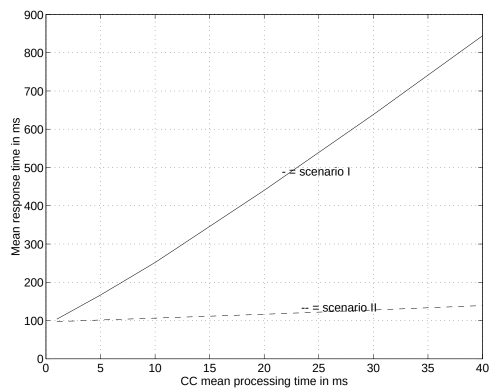

Figure 7: Response time vs. CC execution.

Fig. 7 shows that HO execution mean response time for the B-ISDN-to-the-CSS scenario is more sensitive to variations of the CC mean service time than for the B-ISDN-to-the-MT option. The HO execution mean response time is for all the CC mean service times larger for the B-ISDN-to-the CSS integration scenario. The reason for this difference is that the B-ISDN-to-the-MT option

BC execution time (ms)	conf. interval B-to-the-CSS	conf. interval B-to-the-MT
3	0.3748	0.3977
9	2.024	1.882
15	1.247	1.649
21	1.406	2.266
27	2.465	3.946
33	4.130	4.959

Table 2: Confidence intervals.

does not require any call associations to be set-up or released. The only call control messages required are used for the communication between the HOC-CH, in the MSCP, with the CC, in the LE.

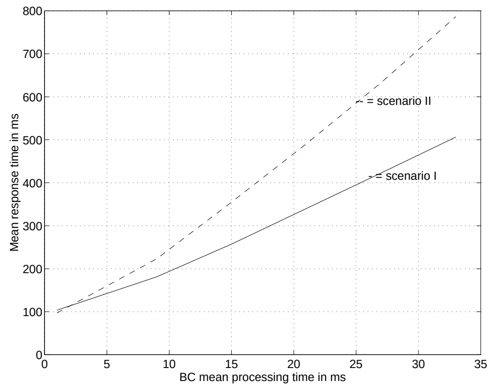

Figure 8: Response time vs. BC execution.

From Fig. 8 it can be seen that the mean response times obtained for the B-ISDN-to-the-CSS scenario are smaller than the mean response times obtained for the B-to-the-MT option when large BC mean service time values are used. As the BC mean service time is increased to a certain value (in the simulation approximately 4 ms) the mean response time obtained for the B-ISDN-to-the-MT option becomes smaller than the mean response time obtained for the B-ISDN-to-the-CSS option. The reason for obtaining these results is that the number of the messages being processed (see the message flows in [4]) by the BC FE's for the B-ISDN-to-the-MT option is greater than that of the B-ISDN-to-the-CSS option.

V. Conclusions

We conclude that for approximately equal CC and BC mean service times the HO execution mean response times are larger for the (see Fig. 7) B-ISDN-to-the-CSS integration scenario compared to the B-ISDN-to-the-MT scenario. The B-ISDN-to-the-MT scenario is more sensitive regarding mean response times for variations on the BC mean service time than the B-to-the-CSS scenario (see Fig. 8) while the B-ISDN-to-the-CSS scenario is more sensitive regarding mean response times for variations on the CC mean service time than the B-ISDN-to-the-MT scenario (see Fig. 7).

Acknowledgment: This work has been partially funded by the CEC RACE II project MONET (MObile NETwork) in which the authors participated. The views expressed in this paper are those of the authors and do not necessarily represent those of a project as a whole. The members of the MONET project, in particular, Toon Norp and Gary Fleming are acknowledged for their help and discussion. Phil Chimento is thanked for comments and discussion.

References

[1] M. Callendar. Future public land mobile telecommunication systems. *IEEE Pers. Comm.*, pages 18–22, 1994.

[2] G. Colombo and H. Hegeman. Network architecture and functionalities for UMTS. In J. Weber, J. Arnbak, and R. Prasad, editors, *Proc. Wireless Comm. Networks*, volume 3, pages 844–851, 1994.

[3] X. Hou, N. Kalogeropoulos, M. Lekkou, I. Niemegeers, and I. Veniers. A methodological approach to B-ISDN signalling performance. *Int. J. of Comm. Systems*, 7:97–111, 1994.

[4] G. Karagiannis. UMTS and B-ISDN service and functional integration. Technical Report 96-05, Centre for Telematics and Information Technology, 1996.

[5] J.-P. Katoen. Functional integration of B-ISDN and UMTS. In *Proc. 45th IEEE Vehicular Technology Conference*, pages 160–165, 1995.

[6] I. Mitrani. *Simulation Techniques for Discrete Event Systems.* Cambirdge University Press, 1982.

[7] T. Norp and A. Roovers. UMTS integrated with B-ISDN. *IEEE Comm. Mag.*, pages 60–65, November 1994.

[8] W. van den Broek and J.-P. Katoen. Reference configurations for UMTS. In *Proc. 2nd Int. Workshop on Mobile Multi-Media Comm.*, 1995.

[9] M. Veran, B. Sems, and D. Potier. QNAP2, a portable environment for queueing systems modelling. In D. Potier, editor, *Modeling Techniques and Tools for Performance Analysis*, pages 25–63. North-Holland, 1985.

[10] G. Willmann and P. Kühn. Performance modelling of Signalling System No. 7. *IEEE Comm. Mag.*, 28:44–56, 1990.