Functional Integration of UMTS and B-ISDN

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Abstract — Nowadays mobile telecommunication systems and fixed telecommunication networks are developed as stand-alone systems and exist as separate and independent systems, interconnected at just a few points. A main objective of third generation mobile systems is to specify mobile-specific functionality as integral part of fixed networks. This paper addresses the (possible) integration of future mobile and fixed systems, UMTS and B-ISDN. It proposes the use of advanced broadband basic call functions for the support of mobile call setup and handover, addresses the common use of a communication infrastructure, and finally, investigates the support of handover by B-ISDN multi-party call capabilities.[1]

I. Introduction

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 of both researchers and industries. In parallel, the design of a new generation mobile telecommunication systems, called UMTS (Universal Mobile Telecommunications System) or FPLMTS (Future Public Land Mobile Telecommunications System) is ongoing. UMTS is currently being standardized by ETSI and FPLMTS by ITU.

Though current mobile systems are developed (and operating) quite independently from fixed telecommunication systems, a major goal of UMTS/FPLMTS is to aim towards integration with B-ISDN. The main advantages of integration are reducing costs and enlarging the possibilities to satisfy the user's needs [13]. Integration could be done by specifying UMTS mobile functionality as integral part of B-ISDN capabilities. In this way, mobility features could benefit from the flexible service combining capabilities in IN (Intelligent Networks [5]) and the advanced B-ISDN multi-party multimedia call and bearer control facilities [4].

II. UMTS

UMTS is aimed to provide a range of services (up to 2 Mb/s) as now being offered by cordless, cellular, (dedicated) paging and private mobile radio systems. In addition, it will offer (part of) the services as offered to users by the fixed networks to the mobile users. UMTS should be operational in different environments such as domestic, business, vehicular, and multi-operator public environments.

By the time that UMTS is operational (in the beginning of the next century), the number of mobile users will be comparable to the number of 'fixed' users. A rough estimate for the year 2000 is that about 50% of all communication will involve at least one mobile party [2]. Currently, this is about 5-10%. Therefore, UMTS will not be a stand-alone network, but will

be integrated with (forthcoming) fixed networks. The extent of integration and implications on UMTS and B-ISDN are, up to now, not clear.

The UMTS architecture [8, 16] consists of three parts:

(i) The *access network* provides mainly radio related functions and some local switching functionality. This part may (partially) reuse functions from B-ISDN and constitutes the wireless access to the network.

(ii) The *core (or backbone) network* provides switching functions, user-data transfer, and interworking functions with other systems. This part will contain minimal UMTS-specific functionality.

(iii) The *mobility network* provides UMTS-specific functions such as location updating, locating, paging, and handover control using IN techniques.

A detailed UMTS architecture (public environment) is given in Fig. 1. Here, the access network is constituted by the BTS and CSS, and the backbone network by the 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 Cell Site Switch (CSS) takes care of basic call control and the connection to the fixed network[2]. The radio access for MTs is provided via Base Transceiver Stations (BTSs).
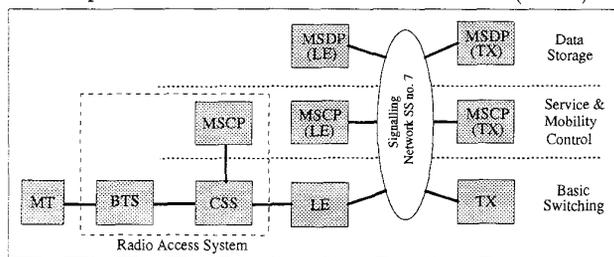

Figure 1: Overview of basic UMTS architecture.

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 the access network they represent the mobility control and data storage, respectively, for 'local' users/terminals (e.g., business users).

III. Integration

The basic idea behind UMTS/B-ISDN integration is commonality of required functions – call handling, transport of

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[1]This paper is an extended abstract of [7].

[2]For large domains (business) this entity is quite similar to a PABX. In small domains (domestic) it may be a simple multiplexer.

user data, switching and bridging are needed in both systems. Integration is a means to avoid the duplication of such functions.

An integrated system will cater for the requirements of both 'fixed' and mobile users. It differs from a system for either fixed or mobile calls. Remark, however, that there will still be a need for stand-alone B-ISDN systems, that is, systems without having the overhead for supporting UMTS. The following aspects could be subject of integration [12].

A. Services

Integration of services comprehends that UMTS services and B-ISDN services (partially) overlap (e.g. the plain-old telephone service). With integrated services the user will not notice the difference between services offered by either UMTS or B-ISDN. Though UMTS and B-ISDN have common services, UMTS will not be able to provide B-ISDN services that require a higher bandwidth than available on the radio path (2 Mb/s). In addition, due to bandwidth differences efficient source coding and compression mechanisms are needed implying the need for 'transcoding' for connections between fixed and mobile terminals. These bandwidth limitations should not be considered as a difference between UMTS and B-ISDN but rather as a restriction caused by the terminal capabilities.

B. Functions

For the support of UMTS and B-ISDN a number of similar functions are needed. In fact fixed telecommunication needs a subset of the functions of mobile telecommunication – e.g., UMTS call and bearer control can be considered as a true superset of the B-ISDN alikes, and B-ISDN resource control can be seen as the support for the bridging and switching of connections in case of a handover. Functional integration has a large impact on the integration of protocols and infrastructure. Integration of call and bearer control functions enables the use of common network entities. In addition, when common functions are used the same protocols can be used to control and access these functions.

C. Infrastructure

The most obvious form of integration is achieved when UMTS and B-ISDN use common physical components and concrete interfaces. Integration of infrastructure is essential to reduce costs – both implementation and operational costs – and could be established by e.g. connecting BTSs (which will be present at high volume) and B-ISDN terminals (TE1 and TE2) to the same fixed backbone network, see Fig. 2.
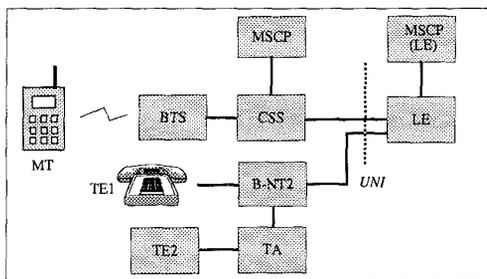

Figure 2: Integrated UMTS/B-ISDN infrastructure.

D. Protocols

Integration of protocols is the reuse of B-ISDN protocols for UMTS. This can be viewed in different ways – UMTS might reuse ATM protocols as a basis for application protocols or B-ISDN call and bearer control protocols can be reused on top of UMTS-specific lower layer protocols.

Protocol integration is directly related to the use of common concrete interfaces via which protocols are used and accessed. At the NNI (Network-Node Interface) the broadband protocol architecture provides sufficient flexibility to add UMTS-specific protocols, for example, in the INAP (IN Application Part) framework. At the UNI (User-Network Interface) the Q.2931Ext protocol architecture[3] would require the same flexibility.

Currently, much research is going on to investigate how and to what extent B-ISDN and UMTS should and can be integrated [9, 10, 12, 13, 16, 18]. This paper contributes to this investigation by proposing an integration at the functional level (with direct implications for integrated infrastructure and protocols) of UMTS call handling and handover procedures and B-ISDN basic call facilities.

IV. TWO FUNCTIONAL INTEGRATION SCENARIOS

This section treats the functional integration of mobile call setup (fixed to mobile basic telephone call), handover, and broadband call, bearer, and resource control. Two integration scenarios are discussed.

I *Functional integration in the backbone network*
 Reuse of B-ISDN call control and bearer control functions in the common fixed part of the network, with a completely UMTS-specific access network.

II *Maximal functional integration*
 Complete reuse of B-ISDN basic call facilities for UMTS, also in the access network.

Scenario I has a UMTS-specific access network, thus facilitating efficient control of scarce radio resources. BTSs are connected to a CSS via a UMTS-specific interface whereas the CSS is connected to the fixed network via a standard B-ISDN UNI. Due to the mismatch between e.g. signaling protocols at the access and network side, certain interworking functions (like flow control, two-way mapping of radio packets onto ATM cells etc.) are needed in the CSS.

Scenario II anticipates full integration. This means that e.g. 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 access network is designed with B-ISDN functions and protocols as a basis, extending these with UMTS-specific functions when necessary. This scenario results in minimal interworking requirements.

UMTS and B-ISDN functional specifications are developed using the Functional Model concept [4, 17]. A *Functional Model* (FM) consists of Functional Entities (FEs) and relations between them. The necessary functions for a service are described by a single FM. An FE consists of a subset of the functions needed to offer the service at hand. In order to

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[3]One of the important candidates for B-ISDN Capability Sets 2 and 3 which also offers some necessary functionality needed for UMTS [14].

support their joined operation interactions between FEs are needed. The information exchange between FEs is described by Information Flows (IFs).

As the degree of integration is such a basic design decision with a large impact on the total design of an integrated system, a FM is developed per integration scenario. These FMs are based on material independently developed within RACE 2066 Monet [17] and RACE 2044 Magic [4]. In the sequel the FMs are introduced and their mapping onto the UMTS architecture is addressed. For simplicity, neither management nor security aspects are considered.

A. Basic Call Functions

For both scenarios the three levels of the B-ISDN specific part are Bearer, Resource, and Call Control (BC, RC, and CC) (Fig. 3). CC functions respond to the user's request and organize network resources to provide the requested service using the RC entities. It does not include implementation of the network in terms of switches and connections. RC 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 functions control the ATM connections which are established, maintained and cleared on demand for the support of services. Broadband FEs will be indicated grey, dashed boxes indicate network entities, bubbles represent FEs, and relations between FEs are indicated by solid lines.
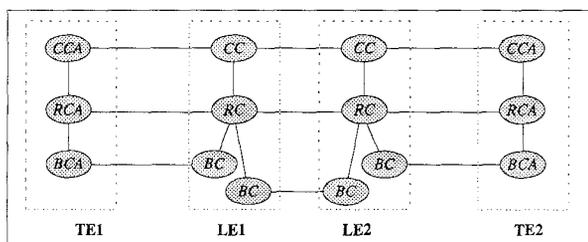

Figure 3: Broadband basic call FM.

Scenario I introduces UMTS-specific FEs in the access network, RCC and RBC which are capable of managing radio calls and bearers. Interworking between the fixed and radio-specific entities for call and bearer control is performed by a mobile call handler (CH).

For scenario II in the access network B-ISDN functions are maximally reused; only the additional functionality to the broadband BC entities needed for setting up, maintaining and clearing mobile bearers is introduced (MBC). The resulting bearer functionality (MBC+BC) will be similar to RBC entities in scenario I.

B. Mobile Call Setup

The FMs for mobile call setup for both scenarios are depicted in Fig. 4 and 5. The call establishment from TE to MT goes globally as follows. The original call setup request of the calling user is received by the CCA in the TE and is directly forwarded to the CC entity in LE1. This entity recognizes that the request concerns a mobile call and passes it onto CH. This entity first initiates a locating procedure, controlled by LH, of the called user. First, the current location area is determined from the database (LD) after which
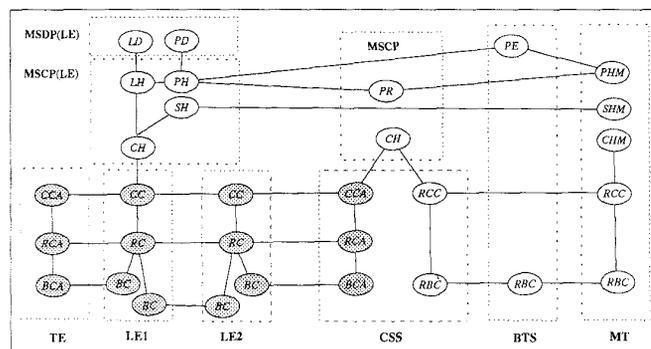

Figure 4: Integrated FM for mobile call setup (I).

a paging procedure is initiated (PH). Paging is assumed to be performed in an intelligent way[4]. PH requests the appropriate PE to initiate paging in its coverage area. Once an MT replies (via PHM) the reply is passed on via some FEs to CH. As the precise location of the called user is known, a session can be established. (A session is a trusted association between a user and a service provider.) This is performed via SH and SHM. Finally, CH requests the CC FE in LE1 to set up the call to the called user.
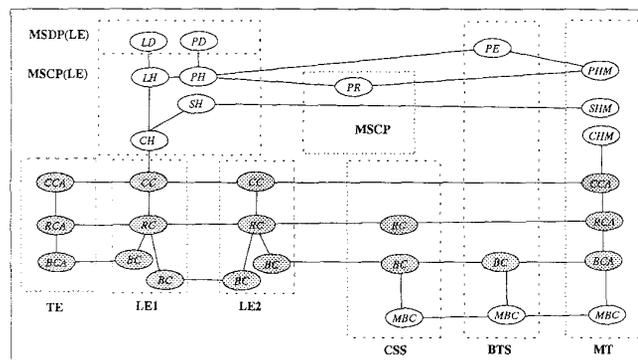

Figure 5: Integrated FM for mobile call setup (II).

C. Handover

The mapping of handover FEs depends on the type of handover. For a handover in which MT changes from BTS1 to BTS2, both controlled by the same CSS (intra-CSS handover), the handover control function must be present in the access network, whereas for a handover between two BTSs controlled by different LEs (inter-LE handover) it should be present in the fixed network. Here, we consider inter-LE handover as this case involves moving CC entities.

It is assumed that a handover procedure is initiated only due to the quality of radio connections. MT performs measurements and when certain criteria are met it initiates a handover. Finally, the handover request is sent to the 'old' BTS to which the MT is linked. This BTS initiates a request for setting up a new connection.

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[4]E.g. paging could start in the paging area where the user has last been spotted (as indicated by PD); with these techniques up to 60% of paging signaling traffic can be saved while the average call setup delay increases only marginally.

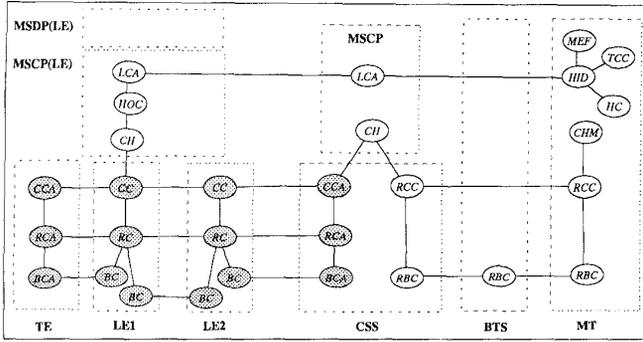Figs. 6 and 7 show the integrated handover FMs.

Figure 6: Integrated FM for handover (Scenario I).

Handover performs globally as follows. The MT estimates the actual quality of the connection in progress (MEF), at the same time keeping track of the available radio and network resources (TCC). Once certain criteria are met (HC) a handover is decided and initiated (HID).
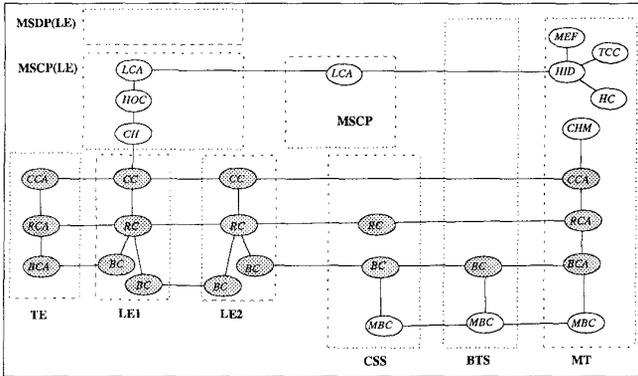

Figure 7: Integrated FM for handover (Scenario II).

Handover control phase: on receipt of a handover request the LCA checks whether or not an indicated handover can be executed at the level of the network the LCA entity is allocated. If it is unable to handle the request it passes the request onto a LCA entity at a next higher level in the network. If it is able to handle the request it initiates HOC which is responsible for the handover execution.

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 connections. Opposed to GSM the call is not simply relayed but the call is rerouted to optimize the use of fixed network resources.

Different approaches can be defined for handover execution. A possible way is to view a handover as the addition of a third party to a two-party call, and subsequently the removal of the original called party. The exchanged messages for such type of handover are indicated in Fig. 8. Here, it is assumed that the originating exchange (LE3) is responsible for adding the new party to the call. For efficiency reasons this could also be the terminating LE. Initially there is a two-party call between the TE and MT which is in the coverage area of BTS1 (controlled by LE1). Then the MT roams to BTS2 (controlled by LE2).
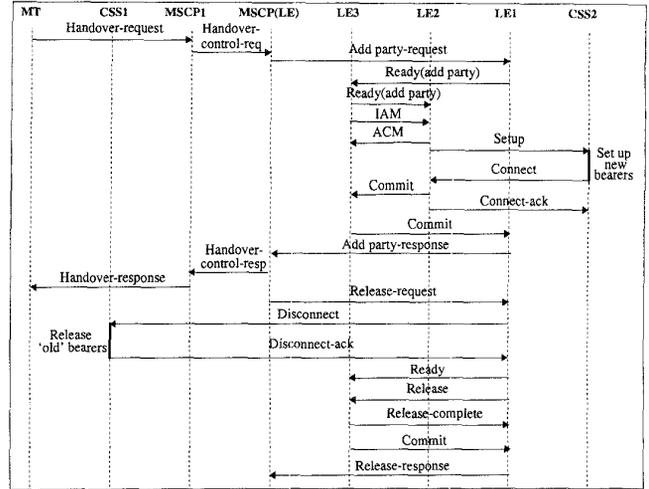

Figure 8: Information Flows for inter-LE handover using third-party calls (IAM = Initial Address Message; ACM = Address Complete Message).

D. Comparison

Both scenarios strive for maximal reuse of broadband functions. This facilitates that UMTS has a minimal impact on broadband protocols. This is beneficial as standardization in this field is already emerging, and, on the other hand, fixed network operators which would like to operate plain broadband systems are not burdened by the overhead caused by UMTS.

The main advantage of scenario I is that the CSS-LE interface is a standard B-ISDN UNI. Requirements on the broadband protocols to support UMTS are limited. In addition, UMTS interfaces in the access network can be developed independently from B-ISDN, enabling the optimal use of radio resources. Compared to scenario II the CSS contains some more functionality (CC and RCC) which may impose additional call setup delays (due to interworking) and increases the cost of such entities. In addition, there is no direct call control association between MT and LE which implies that in case of an intra-LE handover a new call control association between MT and the 'new' CSS is needed.

Scenario II does not suffer from both disadvantages of scenario I. However, severe requirements on B-ISDN on the CSS-LE interface are needed to support UMTS. E.g. either protocol separation has to be introduced or a separate protocol stack for UMTS has to be included in the LE (e.g. on a dedicated UMTS signaling virtual circuit [3]). As BC entities can only be controlled via CC FEs, the HOC function must control bearers indirectly. This imposes extra delays in case of intra-CSS handovers as the HOC is quite 'on distance' of the actual point of handover. Performance assessment is needed to compare the two scenarios in this respect. An alternative would be to allow direct HOC-BC associations, putting some more requirements on B-ISDN.

E. Requirements on B-ISDN

In existing ISDN systems there is a one-to-one mapping between a call and a connection – no signaling information can be exchanged without establishing a physical connection. Compared to fixed terminals, mobiles have a greater

possibility of being incapable to accept a call (e.g. detached or out of radio coverage). To avoid bandwidth wastage, the control of the call and the control of connections should be separated [1]. Thus, negotiations on call acceptance can be completed before the actual connections are set up. This separation not only embodies a functional distinction, but also the distinction between CC and BC messages in the signaling protocols.

A broadband exchange must be able to pass a call to another exchange while still retaining an acceptable QoS and without the need to release the call in an end-to-end fashion. It is therefore required that an LE which is part of an end-to-end call path maintains its own local view of the call. This local view will contain relevant bearer and call status data, charging information, and so on. During handover such local views need to be transferred.

A number of important performance requirements can be put on the efficient support of handover. In UMTS the idea is to keep handovers transparent for the users (seamless handover). In order to do so HOC must be able to set up bearers and release ones efficiently, and the execution time of adding a third party to a call (in case of handover) should be minimized. Also RC entities must be able to efficiently handle resources. For this purpose a means should be included in B-ISDN multi-party call functions/protocols to indicate that adding a third party is caused by a handover.

The broadband call control process (CC) should be able to identify that a call is destined to a UMTS user. Then, it can trigger CH to further handle the call and initiate a locating and paging procedure. The call state model defining the CC FE should cover the identification and adequate treatment of mobile calls.

Different BTSs may be connected to a single CSS using different topologies (ring, star) [11]. Similarly, several CSS network entities may be connected to the same LE. Such configurations require to correctly route signaling messages to the right CSS, BTS, MT, and user. This requires the existence of adequate addressing mechanisms at the UNI.

In UMTS signaling takes place that is not directly related to call control (e.g. paging, location updating). IN facilities and the associated INAP protocol will be used for this purpose. The B-ISDN UNI should support this non-call related signaling.

V. Conclusions and Further Work

This paper proposed two scenarios for the functional integration of UMTS mobile call setup, handover, and B-ISDN basic call functionalities. A scenario has been given to illustrate how third party capabilities could support (inter-LE) handover. To the best of our knowledge this is the first proposal of a detailed integrated *functional* perspective of B-ISDN and UMTS. With respect to B-ISDN interfaces it is observed that the requirements for the NNI have been achieved, while for the UNI a number of requirements have to be met.

Several areas require further work. To mention a few:

- Investigation of how to extend functions to support multimedia multi-party calls [6] with UMTS mobility.

- Definition of other handover execution scenarios and a performance assessment of these scenarios (e.g. execution time).

- Including Customer Premises Networks (CPNs) [8, 15] in the integrated models.

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