Inter-Operator Roaming Scenarios for Third Generation Mobile Telecommunication Systems

J.G.Markoulidakis, G.L.Lyberopoulos, D.F.Tsirkas, E.D.Sykas

National Technical University of Athens
Division of Electrical & Computer Engineering
9 Heroon Polytechniou Str., 157 73 Zographou, Athens, Greece
Tel.: + 30 1 772 2278, Fax.: +30 1 772 2530
e-mail: ymark@telecom.ntua.gr

Abstract

In third generation multi-operator mobile telecommunication systems, terminal operations will allow users to select the desirable operator among the ones available, provided that the user access rights are maintained. In this paper, three alternative (inter-operator) roaming scenarios between public and private operators are proposed. The first scenario considers private operators as autonomous networks (GSM-based approach), the second scenario considers private operators as "domains" of a public operator (DECT-based approach), while the third one considers private operators as extensions of a public operator coverage. Their advantages and disadvantages are highlighted, while particular attention is paid on the implications on access rights management and design issues.

1. Introduction

Third generation mobile telecommunication systems, known as the *Universal Mobile Telecommunication System* (**UMTS**), will be brought into service the early years of the next century [1,2]. UMTS will be a multi-environment, multi-operator and multi-vendor system, enabling mobile users to initiate and receive calls with ***'anyone', 'anywhere'*** and at ***'anytime'*** using a single telecommunication device. UMTS will offer a plethora of mobile telecommunication services (voice, low and high bitrate data, video, etc.) to the user via a range of *Mobile Terminals* (**MT**) operating in both public and private environments (e.g., office areas, residence areas, transportation media, etc.) [3]. In UMTS, universal roaming will be supported by the domain update mobility procedure [1], while MT operations will allow for (possibly with user intervention) the selection of the desirable operator, among the ones available.

In multi-operator systems like UMTS, the access rights management is expected to be of prime importance for both operators and subscribers. The operator requirements include the capability of: (a) adding/deleting subscribers, (b) making contracts with public and private operators, (c) defining within the operator area administrative domains with different access rights, (d) applying charging rules for different subscriber categories, etc. The subscriber requirements may include: (a) the ability of his/her MT to support (both automatically and manually) the user preferences while roaming, (b) the awareness of the user access domain at subscription time and (c) notification of the available/ subscribed services, the relevant charging rates, etc. Issues concerning roaming in mixed public/private environments are presented in [6,7].

From the network performance viewpoint, inter-operator roaming is expected to affect mainly the amount of the distributed database transactions. In GSM, the amount of location registrations due to inter-operator roaming is negligible. On the contrary, the adoption of the GSM approach for UMTS would possibly result in a huge amount of domain updates, mainly due to the expected high subscriber penetration rate (up to 70%) and the high number of network operators (public and private) the user may visit on a per day basis. Therefore, the UMTS network dimensioning should probably consider, among others, inter-operator roaming as a design parameter as well.

In this paper, taking the GSM approach as a basic scenario, we propose and investigate the application of other two alternatives. The analysis concentrates on the way that private environments (*Customer Premises Networks* (**CPNs**)) are treated, since it is expected that

CPNs will be responsible for a remarkable amount of domain updates. The basic scenario (GSM-based approach), considers CPNs as autonomous operators, just like public ones. According to this scenario, MTs which select a CPN operator as more preferable (e.g., due to better coverage) should perform a domain update. In the second scenario (DECT-based approach), CPNs are considered as "domains" of a public operator with specific characteristics (e.g., charging rate, offered services, etc.). According to this scenario, domain update is not mandatory for public operator subscribers when entering/leaving a 'contracted' CPN operator area. The third scenario, considers CPNs as extensions of the public operator radio coverage, forming thus transparent environments. According to this scenario, a domain update is performed whenever the CPN operator is more preferable than the public one.

The material included in this paper is organized as follows. In section 2, we identify the operator types which are expected to form the UMTS multi-operator environment. Section 3 focuses on access rights management aspects, including the user access domain definition, the access information, etc. Section 4 describes the proposed inter-operator roaming scenarios. Finally, the conclusions drawn are summarized in section 5.

2. Description of the UMTS environment

UMTS will be a multi-service, multi-environment, multi-operator mobile telecommunication system. Apart from the coexistence of various public operators, it is envisaged that indoor environments may be covered by specific subsystems, the so-called CPNs [1]. CPNs, depending on the "environment" they operate, are distinguished into: (a) *Business CPNs* (**BCPN**s) e.g., companies, industries etc. (b) *Domestic CPNs* (**DCPN**s) and (c) *Mobile CPNs* (**MCPN**s) e.g., buses, trains, airplanes, ships etc. From the operational viewpoint, UMTS can be regarded as a mixture of UMTS subsystems, assuming B-ISDN as the backbone network [1].

UMTS operators, according to their functionality, fall into five categories (see Table 1). Regarding private operators (CPNs), four classes can be identified. CPNs of classes A, B and C do not support full UMTS functionality and therefore, their operation requires the "assistance" of a public UMTS operator. Although CPNs of class D have full UMTS functionality, the public UMTS operator "co-operation" is necessary, so as to enable CPN subscribers to initiate/receive calls to/from users subscribed to other UMTS operators (e.g., support of calls between BCPN subscribers located in different countries). The public UMTS operator which "assists" the CPN operations is called **Host Public Operator**.

	Public UMTS	CPN Class A	CPN Class B	CPN Class C	CPN Class D
Bearer Control	√	√	√	√	√
Call Control	√		√	√	√
Mobility Control	√			√	√
Data Management	√				√
Example	*Any public UMTS operator*	*DCPN, Simple MCPN*	*Small BCPN, MCPN*	*BCPN*	*Large BCPN*

Table 1: Classification of UMTS operators according to their functionality

3. Roaming in UMTS

3.1. Access rights management and user access domain

Mobile services become available to a user as soon as a subscription with the so-called **Home Operator** (either public or private) is established. More than one subscriptions per user are allowed, each corresponding to a single Home Operator. The location of a user having multiple subscriptions is tracked by all the corresponding Home Operators. Inter-operator roaming is enabled via 'contracts' established between operators. The set of the operators, within which a UMTS user preserves the access rights, forms the *User Access Domain* **(UAD)**. An example of a UAD is shown in Fig. 1.

Inter-operator contracts refer to the agreed set of services and the relevant charging rates. Concerning the offered services, two approaches can be envisaged:

- A pre-determined set of services (e.g., voice and short messaging) is provided to all subscribers of the contracted operator(s).
- The contracted operator fully supports the subscriber service profile defined in the Home Operator.

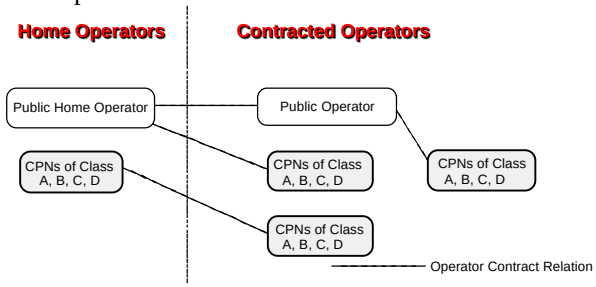

Fig. 1: An example User Access Domain (UAD)

3.2. Access information

While roaming, the MT operations enable the terminal to identify whether an operator that provides coverage at the present location belongs to its UAD. This is achieved by examining the *Access Information* **(AI)** the operators' BTSs periodically broadcast (Fig. 2). 'Restricted Access' implies that only the specific operator subscribers are allowed to access operator resources. Contracts with other operators do not exist. 'Unrestricted Access' denotes the existence of contracts with other operators enabling thus the subscribers of the 'contracted' operators to roam inside their coverage area.

Operator type *(e.g., BCPN)*	**OPid** *(Operator identity)*	**Access type** *(e.g., restricted, unrestricted)*	**LAI** *(Location Area Identity)*	**Other Info** *(e.g., charging info)*

Fig. 2: Access information elements

Table 2 illustrates the relation between the operators' functionality and the access types they may provide. Functionally independent operators (e.g., public, CPNs of class D) are free to negotiate with other operators in order to offer access to their subscribers. On the other hand, functionally dependent operators (i.e., CPNs of class A, B and C) may offer access to subscribers of the Host Public Operator only and, possibly to subscribers that the Host Public Operator maintains contracts with.

UMTS Operator		**Access Type**	***Example Operators***
Public UMTS Operator		Restricted	*An operator serving only its own subscribers*
		Unrestricted	*An operator also serving other operators subscribers*
CPNs of Class A	DCPN	Restricted	*A CPN covering the user residence*
	MCPN	Restricted	*A CPN covering e.g., a sailing boat*
		Unrestricted	*A CPN covering transport. media (e.g., metro)*
CPNs of Class B, C, D	BCPN	Restricted	*A CPN covering private companies*
		Unrestricted	*A CPN covering banks, hotels, shopping centres*
	MCPN	Restricted	*A CPN covering e.g., cruise ships*
		Unrestricted	*A CPN covering trains, airplanes, etc.*

Table 2: The relation between the UMTS operator's functionality and the access type

3.3. Mobile terminal operations while roaming

The roaming process may be initiated: (a) automatically: the MT periodically checks for new operators and (b) manually: whenever the user himself wishes to select an operator.

The MT stores two lists: the *User Preference List* (**UPL**) and the *Available Operators' List* (**AOL**). The UPL contains an OPid for each user subscription. The AOL contains (see Table 3):

- pairs of OPid(s) and frequency identities,
- a *Priority Number* (corresponding to the user preference priority) and
- an *Access Flag* which indicates whether this operator is accessible or not.

Operator Identity	**Frequency Identity**	**Priority Number**	**Access Flag** (Yes/No)

Table 3: Information stored in an entry of the AOL

The first phase of the MT roaming operation is the **scanning phase**. The output is an AOL[1]. Initially, the AOL is being reset i.e., all entries with Access Flag "YES" are deleted. In this way, 'not accessible' operators are not deleted, and the MT will not try to access them in the future[2]. Next, the MT scans the frequencies available to UMTS until an 'active' BTS is detected. If so, the MT stores the OPid and the access type (e.g., restricted) the BTS broadcasts. Then, it checks whether the corresponding OPid belongs to the UPL. If so, a priority number is assigned to it and it is added in the AOL. Otherwise, it is firstly checked whether the access type of the OPid is restricted and if the OPid appears in the AOL with access flag "NO". If one of those comparisons is positive then the MT scans for the next 'active' frequency. Otherwise, the OPid is added in the AOL.

After the completion of the scanning phase, the MT enters the **operator selection phase**. The outcome of this phase is the selection of the most preferred operator (with *access flag* "YES") stored in the AOL. If the MT operates in "automatic mode", the most preferred operator is chosen from the AOL without any user intervention[3]. In "manual mode" operation, the AOL is displayed on the MT screen and the user himself chooses the most preferred operator. If no operator is accessible, the MT falls into the **limited service mode**, where only emergency calls are allowed [4]. In this mode, the MT periodically initiates the scanning phase to check for new operators.

[1] A typical AOL will contain on the top the currently available Home Operators, whereas all other operators are put at the end of AOL, possibly in a random order.

[2] In GSM, a separate list (the list of forbidden environments) is utilised for this purpose. However, the use of a unique list is more flexible and reduces the MT storage requirements.

[3] Alternatively, the user confirmation could be requested whenever a new operator is selected by the MT.

The next MT roaming phase is the **cell selection phase**. The MT is first synchronized with the BTS that operates in the frequency identity of the selected operator. During this phase, the complete access information is collected (see Fig. 1), forming the basis of the next phase (**decision phase**). In the latter phase, the MT checks whether a location management procedure (domain update, location update, attach) should be initiated. The decision is based upon the selected operator access information and the previous information details stored in the MT (e.g., the "previous OPid", the previous LAI, etc.). In particular: The MT checks whether the "new OPid" differs from the "previous OPid". If so, a domain update procedure is performed. If "not", the MT processes the location information, to realize whether a change of the LAI occurred. If so, a location update procedure is initiated. If the MT is still inside the same location area, an attach procedure is performed if the previous MT status was "detached" i.e., the MT has just switched-on. Based on the result of the decision phase, the **execution phase** is then employed, so as to apply the selected location management procedure. After the successful completion of the selected procedure, the MT stored information is updated. If the execution phase fails, then the MT returns to the scanning phase.

4. Inter-operator roaming scenarios

4.1. 1st scenario: GSM-based approach

According to this scenario, every UMTS operator (public or private) is assigned a unique identity (OPid) and is regarded as an autonomous operator. Operators (public or private) are free to make contracts other operators, applying special charging rates for visitors. When a user enters a 'contracted' visited operator, a domain update will be performed if the new operator is more preferred (see terminal operations). In case of an incoming call to an MT roaming within a visited operator, the called MT is paged utilizing the visited operator resources.

4.2. 2nd scenario: DECT-based approach

The DECT-based approach makes use of the advantages offered by the access rights management scheme followed by DECT. According to DECT specifications, the DECT base station broadcasts the so-called *Access Rights Information* (**ARI**), which corresponds to both OPid and LAI. The terminal, on the other hand, stores the ARI (that corresponds to a user subscription) and an identifier called *Portable Access Rights Key* (**PARK**) [5]. The PARK indicates the number of the most significant bits of ARI. A DECT terminal while roaming, compares the stored and detected ARIs using their most significant bits, indicated by the PARK. The less significant bits of the ARI are used as LAIs. Another characteristic of DECT is that BTSs are able to broadcast a set of ARIs which correspond to contracted operators.

The DECT-based scenario proposed in this paper for UMTS, adopts a similar but more flexible technique. At subscription time, the MT is provided with a pair of identifiers: an OPid and a *Mask*. The OPid uniquely identifies a set of "domains". A domain may either cover a part of a public operator service area or a CPN operator hosted by a public operator (see Fig. 3). In this scenario, CPNs can be regarded as domains of the Host Public Operator with specific characteristics (e.g., charging rates, service availability, etc.).

An MT while roaming, compares the stored OPid with a broadcast OPid, after filtering the second one via the Mask, as shown in Fig. 3. The Mask technique may provide means to discriminate between different subscriber classes as far as the set of accessible domains is concerned. For example, a subscriber class may have access to the public operator service area including contracted CPNs, while another one is allowed to roam in the public operator service area only.

One of the major advantages of this scenario is the fact that MTs subscribed to the Host Public Operator of a CPN, when entering/leaving this CPN area they do not perform domain updates. Simply, the MT upon detecting that the access rights are maintained, it just performs a cell selection. Due to the lack of the domain update, the public operator is not able to determine whether an MT roams inside its service area or within a CPN. As a result, to enable incoming calls inside CPNs, the CPN BTSs should transmit all paging messages of the Host Public Operator.

Note: The CPN should broadcast the Host Public Operator LAI to avoid also the employment of the location update procedure.

Note: MTs roaming inside CPNs utilize the CPN radio resources for both incoming and outgoing calls.

Note: The DECT feature, according to which a BTS broadcasts more than one OPid(s) is not proposed for UMTS since, the list of contracted operators can be very long and thus, the resulting MT effort for processing the corresponding OPid(s) will become quite heavy; affecting possibly the MT stand-by period.

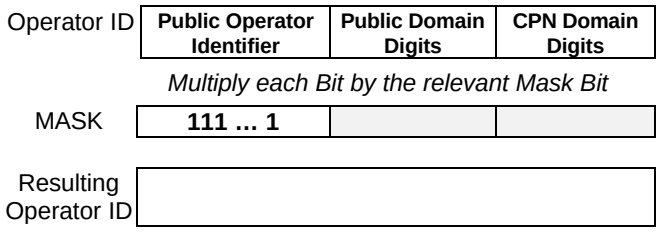

Fig. 3: The application of the mask technique

4.3. 3rd scenario: CPNs as extensions of a public operator radio coverage

According to this scenario, the CPN operator area is regarded as an extension of some public contracted operator(s), offering thus access to the corresponding public operator(s) subscribers. The CPN operator may establish 'contracts' with overlaid public operators only. From the implementation viewpoint, the CPN BTSs act as repeaters of the public operator BTSs, so as to guarantee that the coverage of the public operator is adequate within the CPN. However, this is expected to be the common case in high user density environments where signalling and traffic requirements are significant (e.g., a city centre).

It should be stressed here that this technique may introduce problems in the synchronization between the MT and the BTS. In DECT, for example, the use of repeaters located at the edge of a cell (to extend the radio coverage), result in a transfer rate reduction. This is due to the fact, that the delay introduced by the repeater is high, compared to the guard time. However, for UMTS we may assume that the CPN BTSs will not be located at the edge of the public operator cells, and therefore synchronization between the MT and the public BTS can still be maintained [8].

According to this scenario, whenever an MT enters a CPN area, it detects that the public BTS is still reachable, although a new CPN BTS is identified. If the CPN OPid is more preferable, the MT will perform a domain update otherwise, no mobility procedure will be performed (not even cell selection). Note that in this case, an MT roaming inside a CPN utilizes the public network resources for both incoming and outgoing calls.

Note: This scenario cannot support either the discrimination of different subscriber classes nor the application of some extra charging policy, since CPN BTSs act as passive repeaters.

5. Conclusions

In this paper, three alternative inter-operator roaming scenarios have been described. The first scenario (GSM-based approach), considers CPNs as autonomous operators. According to this scenario, MTs which select a CPN operator as more preferable, perform a domain update. The second scenario (DECT-based approach), regards CPNs as "domains" of the Host Public Operator. According to this scenario, domain update is not mandatory for the Host Public Operator subscribers when entering/leaving a 'contracted' CPN. The third scenario, considers CPNs as extensions of the 'contracted' public operator(s) radio coverage, provided that their service areas overlay. According to this scenario, a domain update is performed if the CPN operator is more preferable than the public one.

The above scenarios have been investigated from both the operational and functional viewpoints. Their salient characteristics are summarized in Table 4.

	1st Scenario (GSM-based)	**2nd Scenario** (DECT-based)	**3rd Scenario** (CPNs as extensions of public operator)
Contracts with other public operators	*Unlimited*	*Unlimited (CPN is considered as a domain of the Host Public Operator only)*	*Limited (Overlaid Public Operators only)*
Domain update execution	*Based on the UPL*	*Based on UPL (Not applicable for Host Public Operator subscribers)*	*Based on UPL (Not applicable for 'contracted' operator(s) subscribers)*
The public operator radio link is involved in paging	*Incoming Calls for MTs registered to Public Operator*	*As scenario 1, including MTs roaming in CPNs hosted by Public Operator*	*As scenario1, including portion of the MTs[4] roaming in 'contracted ' CPNs*
Charging Policies for Visitors	*Yes*	*Yes*	*No*
Discrimination of Subscriber Classes	*No*	*Yes*	*No*

Table 4. Inter-operator roaming scenarios characteristics

[4] MTs that have performed a domain update receive the paging messages via the CPN BTSs.

References

[1] S.T.S.Chia, "The Universal Mobile Telecommunication System", *IEEE Comms Mag.*, Vol. 30, No. 12, Dec. 1992.

[2] J.Rapeli, “UMTS: Targets, System Concept, and Standardisation in a Global Framework”, *IEEE Personal Communications*, Feb. 1995, pp. 20-28.

[3] ETSI Technical Report, Draft-ETR/SMG50301, "*Framework of network architecture, interworking and integration for the Universal Mobile Telecommunications System (UMTS)*", Version 0.3.3, February 1993.

[4] Michel Mouly, Marie-Bernadette Pautet, *The GSM System for Mobile Communications*, 1992.

[5] ETSI/RES-03(91)61 "*DECT System Description Document*", version 3.4, June 1992

[6] H.Maab, O.Schreyer, M.Stahl, “Directory Services for Mobility Management in Private Telecommunication Networks”, *Proc. IEEE Intern. Conf. on Comms. ICC93*, Geneva, May 1993, pp. 1252-1256.

[7] M.Ohta, J.Yamagishi, K.Tanaka, T.Ogusu, “A Next Generation Private Personal Communication System”, *Proc. XV International Switching Symposium ISS’95*, Vol. 1, Berlin, April 1995, pp. 129-133.

[8] G.MacNamee, “Reducing the Cost of DECT Coverage”, *Mobile Comms. International*, Issue 31, May 1996.