CRITICAL ISSUES FOR ROAMING IN 3G

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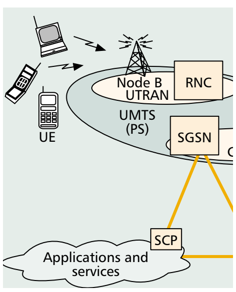

The challenge for the industry cannot be pointed out as one difficult technical issue that needs to be solved to ensure 3G roaming. Instead there many smaller issues with many alternative solutions that need to be solved.

ABSTRACT

Roaming for voice, the ability for a user to make and receive calls when visiting another country, is taken for granted by GSM users today. Currently GSM mobile operators are introducing packet-based data networks (also known as General Packet Radio Service) that bring a huge variety of services. However, this new network also introduces new complexity in the support of the packet-based roaming scenario. Due to the number of services, operators, and users envisaged, it will be impossible for operators to test all services for roaming in all partner networks for GPRS; instead, the capabilities of the network have to be tested. Furthermore, mobile data service developers must be aware that the network capabilities of a visited (GPRS) network might differ from the home network; thus, consideration is required to ensure service continuity. This is especially true as mobile operators start offering 3G networks and support roaming agreements from 3G to 2G networks.

In the continuing development of the mobile network, 3GPP (the international standardization body developing the UMTS standards) has defined the IP Multimedia Subsystem (IMS) as an evolutionary path for basic 3G networks (developing on the already defined Release 99 and Release 4 capabilities). The IMS provides an overlay architecture on top of the basic 3G architecture and implies roaming outside the basic 3G architecture. The resulting 3G-IMS network creates a two-layered roaming architecture, potentially resulting in issues related to optimal routing, QoS, and support of local services. The challenge for the industry cannot be pointed out as one difficult technical issue that needs to be solved to ensure 3G roaming. Instead there many smaller issues with many alternative solutions that need to be solved. Only when operators have a clear view of these issues and their roaming requirements can all issues be solved and roaming agreement negotiations run smoothly. As it looks today, it will be time consuming to establish and conclude the roaming agreements for 3G; thus, delays in the roaming service are expected. When IMS arrives, new addendums will be needed to the roaming agreements, and the same risk for delays exists if the demand issues are not properly addressed before the negotiations.

INTRODUCTION

Roaming, the ability to use a mobile terminal in networks other than the home network, is one of the reasons behind the success of GSM. Citizens of Europe are no longer bound to their country borders for mobile communication. Today roaming is taken for granted, and users demand that the mobile should work and behave in the same way regardless of their physical location. However, the introduction of data services in the mobile network both introduces more possibilities and increases the difficulties to realize the concept of having the same behavior of the terminal wherever you go.

FROM VOICE TO DATA

In the second-generation (2G) circuit-switched environment, the amount of services is limited. An additional important characteristic is that services are fully standardized or use standardized features. This makes it possible to implement and test services in the visited networks and make sure that they function properly. Even so, it is still problematic to make value-added services such as short number dialing work in visited networks. When moving into packet-switched and data-based applications, the problem with roaming increases. Circuit-switched services are very much vertically layered, whereas packet-switched are horizontal, which causes the unpredictability in packet-switched services. Users can specify their own services; new programs that use IP communication are developed every day. All this means it is impossible for operators to predict and test all services that may be used.

Another aspect is that it is no longer obvious how services should act in a roaming situation. For example, a restaurant guide gives the user possibilities to search for a restaurant to meet his/her preferences. Should we expect that a user in a foreign country wishes to find a restaurant in the foreign country, or does he/she want to find one to visit when back home again? In the former case, is such information available? In what language? How is it available? It is obvious that it is very much a service development issue to handle the new roaming problems. The technical challenge left is to make sure that no matter how the service developers expect the service to act, the technology should enable it.

Other aspects that need to be taken into consideration for roaming services are legal aspects.

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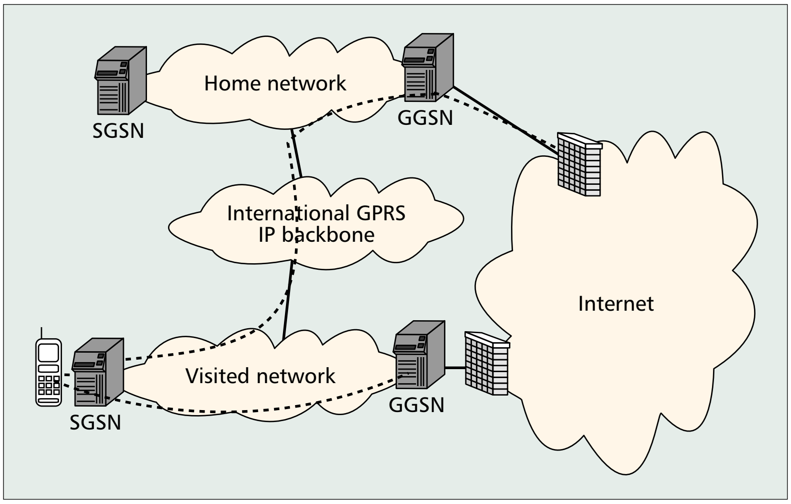


■ Figure 1. *Roaming traffic scenarios in GPRS. In the first scenario (solid line) the traffic is routed back to the home network before leaving the GPRS network. In the second scenario (dashed line) the traffic leaves the GPRS network via a gateway in the visited network.*

The legal situation for using encryption and authentication technologies, for example, varies between countries. It might be a problem to cross the border between some countries with a strongly encrypted data flow. In relation to that, the legal interception demands vary as well. The copyright issue for the content could potentially be a problem as some distribution rights might be limited to certain geographical areas. For example, if an operator in Europe buys the right to broadcast videos from the Olympic games in Europe, does this mean they can make them available to visiting users from other operators? Can they make it available to their own subscribers that are currently visiting the United States?

The main conclusion from this is that the roaming problem is no longer a problem just for technicians in operators' roaming departments; instead, the main responsibilities are transferred to the service developers, who must bear the roaming aspects in mind when designing a new service.

GPRS Roaming

The General Packet Radio Service (GPRS) architecture is not only used for GPRS, but will also be the basis for the Universal Mobile Telecommunications System (UMTS) packet network in the third generation (3G). A clear view of the GPRS roaming architecture is thus fundamentally important to understanding the enablers available to provide roaming capabilities to new GPRS and 3G services.

In GPRS two roaming scenarios can be identified [1]. In the first scenario roaming users make use of the gateway GPRS support node (GGSN) in the home GPRS network. In the second scenario a gateway in the visited network is used. An operator can choose to force all traffic toward the home gateway or allow both scenarios. The choice will have an impact on the operator's network solution as well as the business concept. Using the home gateway, for instance, demands an IP backbone between the home network and other roaming networks, but allows services to work without reconfiguration or packet filter changes when roaming and also enables the use of proprietary service billing solutions.

Using the Home GGSN

The first possibility for connecting roaming users to the home portal is to always use the home GGSN, as shown by the red line in Fig. 1. Here the terminal indicates to the visited serving GPRS support node (SGSN) to which external network it wishes to connect. The SGSN then requires information to identify the home GGSN (HGGSN). This information must be made available from the home network to the visited network, via either normal Internet type protocols or specific information agreed on between the operators in the roaming agreement. This scenario therefore needs the exchange of routing information between networks and the ability to route packets between the networks with the associated security mechanisms satisfied.

The resulting user experience for this configuration is that they experience no change concerning service appearance from when they are in their home network; the only possible impact could come from the quality of service (QoS) level offered by the visited network and the international IP backbone.

Using the Visited GGSN

The second possible case for connecting the roaming user to the home portal is access through the visited GGSN (VGGSN), depicted in Fig. 1 via the blue line. The main advantage of using a visited GGSN is that the inter-public land mobile network (PLMN) backbone is not used; hence, the solution is simpler for the network operator.

The disadvantage is that the actual services will differ from network to network (in terms of configuration, packet filtering, etc.). Also, interconnection to private/corporate LANs cannot be integrated as an operator service; the virtual private network (VPN) has to be handled completely by the company, and the user must know the name of the VGGSN to connect to and go through a secondary process of authentication/registration with the external (corporate) data network. Additionally all home services offered by the operator may not be available to the roaming subscriber.

Initially, operators are looking into offering the HGGSN solutions as their only solution. The main reasons behind this are to maintain control of the user by forcing all traffic through their own home network and to provide non-reconfiguration roaming for the user. This methodology would also ensure that the subscriber always uses the home operator's portal, if provided.

The GRX Concept

In order to offer the use of HGGSN routing, there has to be an interconnecting network between the GPRS networks. Within the GSM Association a role model for a common GPRS international backbone, the GPRS Roaming

Exchange (GRX) network, has been worked out [2]. This model is similar to the international carrier model in the fixed IP world today. The carrier makes service level agreements (SLAs) with its customers and other carriers as well. This means the operator is only required to have a business agreement with a single carrier, who will then be responsible for making additional agreements with other similar GRX carriers.

TOWARDS 3G

As the GPRS markets mature and commercial 3G networks are introduced, traffic volume and QoS demands from services will increase. This will create a demand for using the VGGSN since this will minimize or even eliminate the so-called tromboning effect caused by taking the traffic through the HGGSN. Tromboning consumes bandwidth (sending the traffic both back home and then back to the visited network) when the traffic volume is high, and introduces delay that could provide difficulties for some applications. However, as explained earlier, there are several advantages of using the HGGSN. Therefore, a solution where the traffic can be routed through either the VGGSN or the HGGSN, without involvement of the user, depending on the service demands, is needed before the use of VGGSN will be used on a larger scale.

ROAMING BETWEEN 2G AND 3G

When the choice was made to base the 3G Partnership Project (3GPP) core network on the GSM core network, one motivation was to enable roaming between the two technologies. Knowing that subscribers would be used to good coverage, it was predicted that it would be difficult to get understanding of initially poor coverage of 3G. Also, roaming is taken for granted by GSM users today, and as 3G will be deployed at different times in different countries, it will cause 3G roaming to be limited in the beginning. By using GSM as a fallback technology, 3G users will be ensured the same coverage as with GSM, albeit with reduced functionality.

The limited capabilities in 2G compared to 3G raise several problems that must be addressed in order to ensure a working service for end users. First, what is the criteria for switching back a mobile to the 3G network when he/she has been switched to a 2G network due to loss of 3G coverage? Ideally the user should be moved back to 3G as soon as they are back in 3G coverage. However, to avoid oscillation between 2G and 3G networks the switch should not be made until it is ensured that the user's 3G coverage is stable. This estimation is especially hard when the 2G network belongs to a different operator than the 3G operator. So for 3G only operators this is a very important issue to address in national roaming in order to ensure that customers are forced back to their "own" network when available.

To make it even more complicated, it gets even harder as there are several more traffic cases; for example, a roaming user visiting a 3G operator falls back to a 2G network at a third operator (handover between two visited networks). Where can the handover back to the 3G network be controlled? Operators are struggling today with these and several other cases, and currently the standard does not offer them much support.

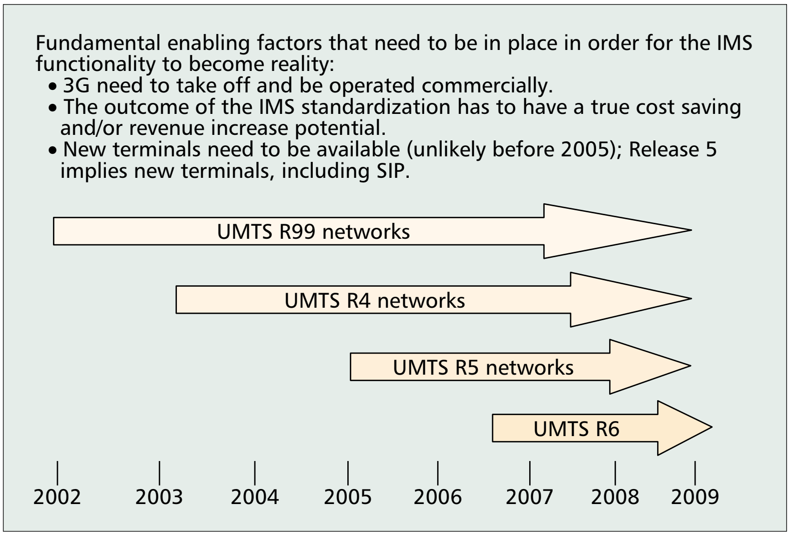


Figure 2. *A high-level timescale for all-IP functionality.*

From a service point of view, roaming between 3G and 2G is more complex. Obviously the capabilities in 2G are more limited than in 3G. The question is, then, how the service should behave when the user enters the 2G network:

- Only 2G services should be allowed; services using 3G enablers should be interrupted.
- The service continues but with lower QoS; for example, for a color video call, only black and white video or sound is retained. However, how the application is made aware of these changes is still undefined.

The next problem that has to be handled is pricing:

- Is the user receiving low-quality service?
- Should the price then be different? What is the motivation for the end user?
- Can the end user understand the price model and the motivation for keeping a price difference?

Initially, the available 3G specific services are limited (i.e., services that use 3G capabilities not available in 2G), and, as discussed, the roaming issue is complex, so we can expect to see a scenario where voice calls are handed over to 2G networks in case of coverage shortage. Video calls are not offered in the 2G network, and Wireless Access Protocol (WAP)/HTML surfing is offered over GPRS at the same volume price as over 3G, but with lower performance when 2G is used as a roaming fallback.

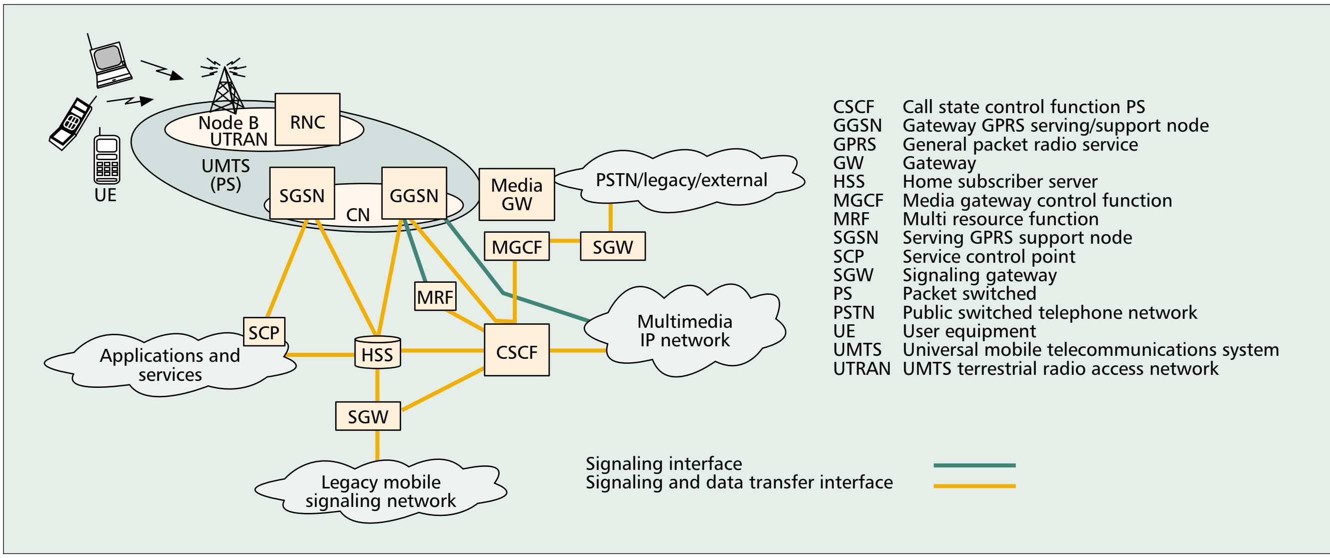
ALL-IP EVOLUTION OF 3G

BACKGROUND

The term *all-IP* has been used extensively in recent years; it often means different things to different people. Here, all-IP refers to the introduction of IP technology in general, beyond Release 99[1] of the 3GPP standards [3].

The initial 3G all-IP architecture [4] was orig-

[1] The 3GPP Release 99 architecture includes two separate switching domains: a circuit-switched domain designed to support voice and circuit-switched data, and an IP-based packet-switched domain (GPRS) for efficiently transporting packet data.



■ Figure 3. *The 3GPP Release 5 and 6 architecture; circuit-switched domain not included. Note that the PSTN/legacy interworking and associated nodes are not included in the Release 5 specifications.*

inally branded a simple step and envisaged to be finished within the year 2000. This step turned out to be not quite so simple, and the all-IP functionality was split into several standards sets called Releases: Release 4 [5] is defined to facilitate the evolution of the Release 99 circuit-switched architecture into an IP transport development with a separation of control and bearer planes easing the introduction of packet-switched backbone technology in the circuit-switched domain. Release 5 [6] introduces the first step toward using IP session control mechanisms in the packet-switched domain, called the IP Multimedia Subsystem (IMS) [7], enabling flexible session negotiation for multimedia. Finally, a Release 6 [8] is currently being defined to incorporate enhancements and corrections to Release 5.

Given that the network is essentially unchanged from an external perspective for roaming in Release 4, the focus here is on IMS roaming for Release 5 and later. The reader is assumed to be familiar with the Release 99 and 4 architectures and functionality; see [3, 5].

The development of IMS has focused on the following three major elements:

- Introduction of an IP-based session control based on Session Initiation Protocol (SIP), allowing the setup, modification, and teardown of various types of IP sessions including voice over IP (VoIP), video, and instant messaging
- Support of end-to-end QoS, interacting with the call control mechanism
- Interworking with packet- and circuit-switched networks

Another item that introduces major problems is mandatory IPv6 [9] support.

One of the objectives of the all-IP architecture in general is to enable both real-time and non-real-time services to be carried in a homogenous packet-switched IP network. This will reduce costs for the operator, thanks to the efficiencies of a packet-based network for data transmission. In particular, the IMS is regarded as enabling potential increased revenue due to its coherent application environment for integrating voice, multimedia, and Internet services through control mechanisms based on SIP [10]. Another driver for operators to adopt IMS deployment is to increase the possibility of successful communication (via negotiation of supported capabilities of end-user devices) and enhance the relation to end users. Furthermore, IMS introduces certain levels of control for the network operator within an IP environment.

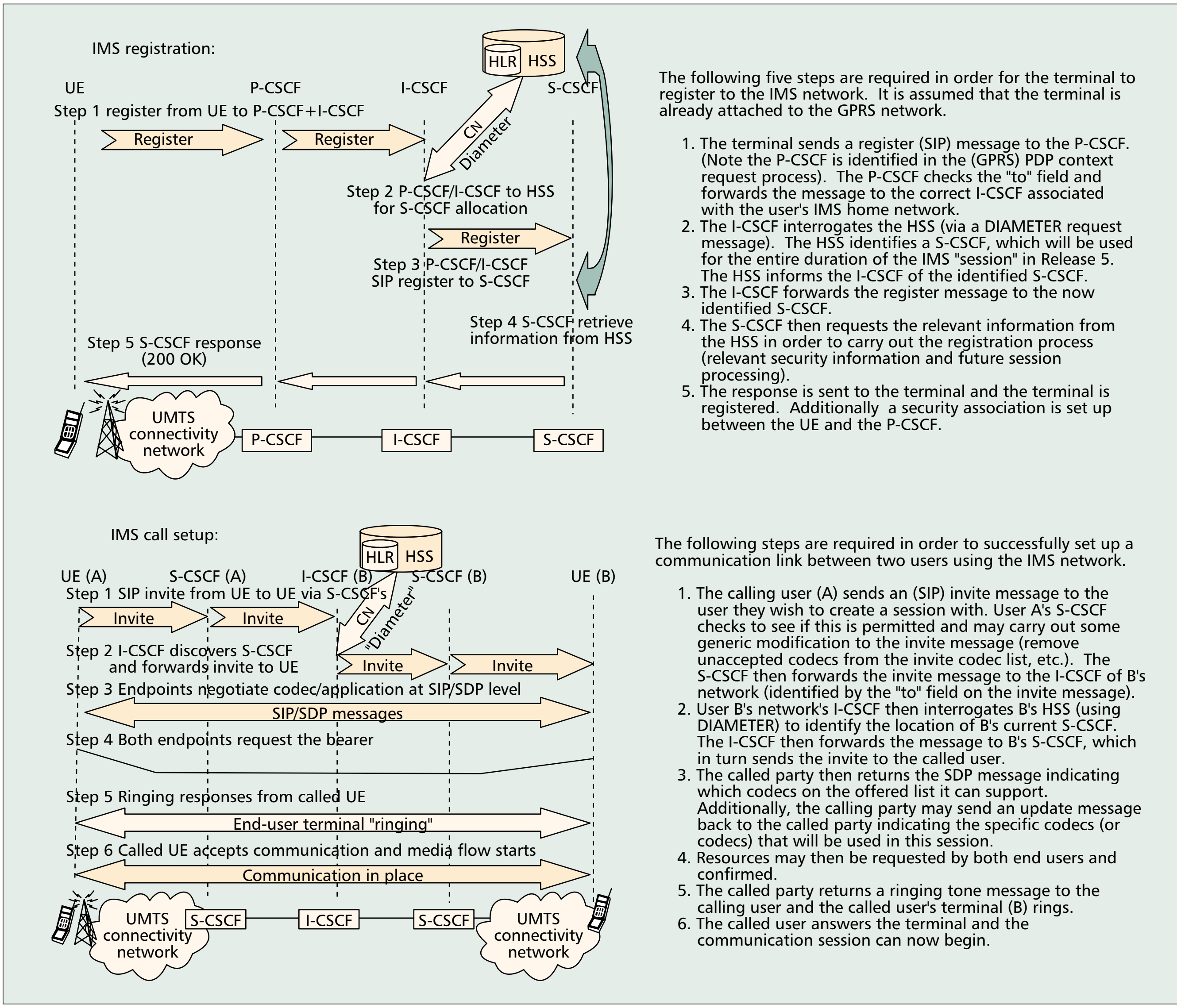
Regarding the timescale for introduction of all-IP functionality in commercial products, there are several factors that will influence the timescale. An estimate of when these stages will occur is shown in Figure 2.

The IP Multimedia Subsystem (IMS)

The basic introduction of the IMS network arrives in the 3GPP Release 5 set of standards, while enhancements such as PSTN and IPv4 interworking are added for Release 6 (Fig. 3). As can be seen from the figure, IMS is an overlay control network that reuses the packet domain of the Release 99/Release 4 networks. IMS nodes are colored in yellow. For details, see [7].

The heart of IMS is the call state control function (CSCF) that performs session control services — the central connection control point behind SIP negotiation. In fact, there are three different CSCFs in the network with different roles:

- Proxy-CSCF (P-CSCF) is the first contact point within IMS, acting as the proxy between the user equipment (UE) and the S-CSCF. It is closely associated with the GGSN for policy control and resource allocation, and is always located in the same network as the GGSN.
- Interrogating-CSCF (I-CSCF) is the contact point from any external network to the home network operator for an incoming session or due to interactions from a visited network when roaming.



■ Figure 4. *High-level registration and call setup flows in IMS.*

- Serving-CSCF (S-CSCF) performs the session control services for the IMS subscriber.

The roles of the different CSCFs are further shown by the registration and call setup signaling diagrams depicted in Fig. 4.

There are several considerations for the support of roaming for IMS. First, 3G packet roaming must be in place since the IMS relies on the packet domain as its packet bearer. Next, the S-CSCF is currently (according to Release 5 and 6 specifications) only present in the IMS subscriber's home network. The I-SCSF is also associated with the home network, whereas the P-SCSF may be located in either the visited or home network, depending on which GPRS roaming scenario is used (i.e., HGGSN or VGGSN above).

IMS Roaming

Home or Visited GGSN When Roaming? — When the IMS becomes commercially deployed in mobile networks, UMTS should have been operating for approximately two to three years in its Release 99 and Release 4 form. The packet-switched (GPRS) roaming solutions already in place at that time will set the prerequisites for roaming with IMS services. As discussed earlier, this is likely to mean that IMS roaming will be carried out through the GRX, using the SGSN located in the visited network and the GGSN located in the operator's home network. Furthermore, in this setup all IMS affected nodes are now located only in the home network, which would make IMS roaming available in networks that did not support IMS. Still, this gives no guarantee that suitable QoS is in place in the visited network.

Nevertheless, 3GPP allows for both the HGGSN and VGGSN approaches to support roaming for IMS. In particular, it is muted that the use of a VGGSN introduces advantages for the subscriber; the IMS principle of separation of control signaling and user data will enable support of optimal routing and potentially lower transmission delays of user data in certain call scenarios.

To illustrate the above-mentioned wish to separate signaling and user data, we can look at

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the example where two users (Mary and John), belonging to a U.S. operator, roam to Australia. If John were to call Mary the potential delays for their real-time IMS session, would depend on which roaming mechanism had been chosen by their operator. If the operator has adopted the HGGSN approach, this would carry the user data from Australia to the United States and back, causing an intercontinental transfer delay as well as potentially unnecessary costs for the involved parties. If the VGGSN were used, the user data path would remain locally in Australia with only the IMS signaling being brought back to the home network (due to the home control associated with the IMS). This scenario also implies that the visited operator supports IMS functionality and has an IMS roaming agreement in place with the home operator.

While this example shows the potential rationale for introducing VGGSN roaming for IMS, there are some considerations to take into account. How often will this scenario actually occur? Normally when users are roaming they call their colleagues, family, and friends in their own "home" country; thus, the actual occurrence of the above example is reduced.

Quality of Service — QoS is crucial for IMS type traffic since it has to cope with various QoS requirements that may vary significantly depending on the type of service (real-time, non-real-time, jitter-free, sensitive bit error rate, etc). Consequently, 3GPP has put significant effort into standardizing means for enabling the IMS network to support the needed level of QoS. For the IMS system 3GPP has introduced mechanisms to identify, authorize, and allocate resources before the receiving end user is alerted to the session being established. Enhanced mechanisms to authorize resources between the IMS network and the UMTS core network are in place for Release 5, while mechanisms to control resources between the IMS network and external networks are currently being discussed for inclusion in Release 6.

Additional QoS considerations for the support of roaming will depend clearly on the case using VGGSN or through a GRX using the HGGSN. The use of the HGGSN ensures that the home operator maintains the authorization of the bearer resources of the data path however this provides further burden on the support of the required QoS over the GRX. Whichever mechanism is used, the resulting QoS for the end user will be dependent on the weakest QoS link in the data path.

Even in the case of roaming on the IMS level, using the VGGSN, there has to be a QoS-enabled network in place that unifies the IMS operators and connects to external networks. Such a network will most likely be based on the GRX infrastructure, meaning that potential QoS problems are independent of whether roaming is performed using the VGGSN or HGGSN. Still, operators face the challenge of upgrading the GRX network and roaming agreements to support dual service roaming. This means that the operators need to identify and incorporate the needed requirements into their SLAs, with both roaming partners and GRX carriers.

In the early days of IMS, when IMS roaming will probably not be carried out using the VGGSN, there may be a lack of explicit real-time capability requirements from the operator community, implying that GRX networks may not support real-time transmission, and roaming with IMS may lead to poor QoS for certain services.

Local Services — The support of local services (i.e., services specific to the location of the user) are not included in Release 5. Nevertheless, the support of local services for roaming users raises several issues that need to be solved for Release 6. Examples of such services are location-based services in combination with local content, local advertising, IMS versions of short numbers, and so on.

An objective within 3GPP is to define standardized means to access local services that will be the same for users located in their home network as well as users roaming into that network. One obvious issue with this scenario is how local services are adapted to the roaming user (e.g., with respect to language); another is how a user identifies that the local service they wish is the local service in their visited network and not the one in their home network.

Given the Release 5 home control, any support of local services for roaming users will have to be carried out via the supervision of the home network's CSFC. One approach would be to let the end-user device indicate to the S-CSCF that a local service is requested. The S-CSCF would then route the session directly to its end destination (e.g., a server in the visited network providing the local service).

This solution implies that the user must determine him/herself when a service is local or not, which seems to be a tough requirement on the user and not user-friendly enough: a local service may or may not lack a corresponding service in the home network. In the former case the question is how the user can obtain the knowledge of the presence of the service in the first place. In the latter case the question is how the user knows that the particular service is local. In conclusion, this is an issue that will require an innovative effort to solve in a manner that results in a user-friendly solution. Experience shows that non-user-friendly solutions are a huge threat to the mobile industry. The support of local services is currently identified to be included in the Release 6 set of standards.

Conclusion

Due to the success of roaming support for GSM voice, roaming is seen as an essential service capability for any further developments on the mobile network. The evolution from voice to data-based services introduces a more complex roaming situation. The huge variety of services and the possibility for operators to differentiate based on services makes it impossible to test all services in all roaming partners' networks. Security, QoS, bandwidth, and allowed traffic will all affect how the services behave in different networks. Service developers must also be aware that services may behave differently in different networks. It might also be necessary that services themselves behave differently or use different content to make sense in a roaming situation. Other factors that may impact service continuity during roaming include legal issues like copyright and legal interception.

3G roaming will require using 2G as a fallback roaming solution but will involve substantial planning efforts to make sure that the behavior of the services make sense to the users. 2G–3G roaming also includes problems with handling handovers and traffic cases with a third operator (i.e., one operator without its own 2G network uses national roaming for 2G fallback; visiting users to the 3G operator will then use a third operator's network for 2G fallback).

As an evolution path for the basic 3G networks, 3GPP has defined IMS for support of new multimedia services based on SIP, combining voice, data, and Internet services, all built on a packet-based architecture. Roaming within the IMS will partly depend on the GPRS roaming solution adopted by the operator (VGGSN or HGGSN use). The most likely solution will be the support of HGGSN by emerging IMS operators given the general HGGSN deployment for pre-IMS networks and the fact that the HGGSN approach allows operators to offer IMS roaming in networks with no IMS infrastructure. However, operators may need to restudy their service level agreements to ensure interconnecting networks and roaming operators are able to support the QoS required. There are thus a number of roaming issues foreseen related to optimal routing, QoS, and support of local services that have been discussed in this article.

As discussed here, roaming-related problems will be much more widespread in the network. This means that more types of staff within operators and suppliers than today need to involve the roaming problem in their daily work (e.g., when developing new services).

The challenge for the industry cannot be pointed out as one single difficult technical issue to solve to ensure 3G roaming. Instead there are many smaller, and technically not so difficult, issues that need to be solved. In addition, these issues have many alternative solutions. The main challenge is to get a wider group of people involved to understand and address the roaming issue in their particular fields so that the best alternatives can be identified. Only then will the operators be able to have a clear view of their roaming requirements so that issues can be solved smoothly and addressed in roaming agreements. As it looks today it will be time consuming to establish and conclude roaming agreements; thus, delays in roaming service are expected.

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