The IMS Service Platform: A Solution for Next-Generation Network Operators to Be More than Bit Pipes

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ABSTRACT

As third-generation (mobile) networks (3G networks) become a commercial reality, strong movements are emerging in the direction of a common infrastructure based on the Internet protocol (IP). The users' mobile devices will be like another IP host connected to the Internet. In such a scenario, the network operator infrastructure will be degraded to bit pipes. To avoid this, the 3G Partnership Project (3GPP) and ETSI TISPAN have designed IP Multimedia Subsystem (IMS), a service platform that aims to place the network operator again in the central role of service provisioning. In this article we examine IMS from a mobile operator's perspective and analyse its possible adaptation to the next-generation networks.

INTRODUCTION

The convergence or, better, migration of the telephone network onto the Internet exists! It is already common to use, over the Internet, traditional services from the telephone network like voice calls. Besides, features such as mobility are ready to be implemented on the Internet. Vinton Cerf's statement during a recent interview for the Spanish journal *Diario el Mundo* [1] supports this view. Due to its relevance, we translated the following excerpt:

Interviewer: "Do you believe that VoIP will replace the telephony we are used to? Do you believe that every information transmission will use the Internet?"
Vinton Cerf: "It makes no sense to keep two different networks if there is enough capacity and quality to merge them."

However, what is the motivation to drive such an important change? We believe it is twofold. First, it will save costs to the network operators because instead of managing two networks, the telephone and data network/Internet, the operators will need to handle only one. Second, we have to consider the enormous user acceptance of Internet applications. Besides, due to the openness of the Internet it is very easy to build more and better services upon it and to offer them (via any access technology) to customers who will then find new opportunities to spend money, thus increasing the operators' revenue. Before proceeding further, we should warn the reader that this last point is also one of the most controversial, as will be seen. The benefits of this migration are clear, but it is also true that such a fundamental change is full of challenges. First, the services offered today in mobile and fixed telephone networks should be mapped — with the same or better performance — to the Internet. This is far from being simple due to the very different technical natures of the telephone and Internet networks. This issue is well known and addressed by the research community [2]. However, the business-related consequences of this convergence are still unclear and this poses serious obstacles towards such a migration. For instance, although the aforementioned openness of the Internet is positively seen as a source for generating increased revenue, network operators fear to loose their central role in the provision of services, particularly in video or audio telephony and SMS services. If care is not taken, the operator networks may become mere "bit pipes" in the business chain and not achieve the proper return of investment.

This risk is one of the most challenging issues to making the migration a concrete reality. Indeed, in new-generation networks, the users' devices will simply be connected to the Internet, and thus for customers, as is the case today with the Internet, it will be easy to employ (e.g., to establish voice calls between them) peer-to-peer communications or applications assisted by proxies with no relation to the network operator. In

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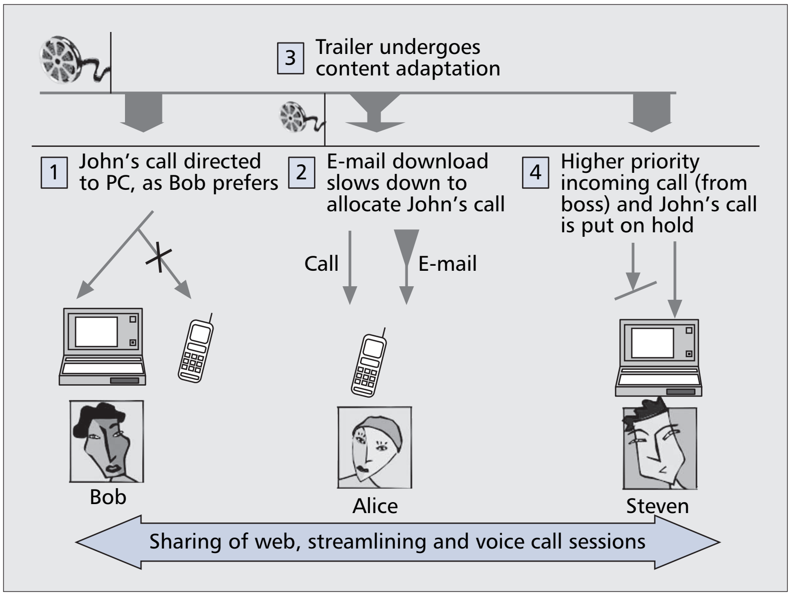


Figure 1. *An IMS enabled scenario.*

such a scenario the network provider is relegated to just an organizer of "bit pipes." However, we think network operators will not obstruct this migration; as mentioned above, they have strong reasons to favor it. Moreover, they need to take the leading role in this migration; otherwise, they could be surpassed by the events. The economic journal *Cinco Días* [3] pointed out that in 2005 European Telecommunication companies lost 25 percent of their revenues due to voice over IP (VoIP). In next-generation networks, the operators' goal is to play a more important function than "bit pipe" managers. They must offer added-value services to their costumers and entice them to use their service infrastructure and not the application servers (widespread on the Internet) or peer-to-peer communications. The advantages that the network provider could offer to users are either cost saving (paying less) or having "better services." Network operators will prefer the second option, and the potential to offer "better services" is enormous. This ranges from delivering better video quality to more valuable or tailored services, for instance, considering the user's context and location. It also includes service bundling or providing a platform with single sign-on and unified billing to existing client-server or peer-to-peer applications. Third parties will use this platform to build services and offer them to their customers, while the network operator keeps the central role in the business value chain. IP Multimedia Subsystem (IMS) is all about this. This cooperation and a rich service platform are considered to be the main enablers for advanced communication services, which will make possible scenarios such as the one depicted Fig. 1.

John is at home and decides to use his computer to surf the Web. He logs into the computer and into his network operator domain and starts navigating. He sees that, in a movie theatre nearby, an interesting film will be featured soon. He grabs the headset connected to his computer and establishes a multiparty conversation with his friends to see if they would like to join. From his group of friends only three, the ones currently not far away from the cinema and with "available" status, are called. Bob is at home and logged into his computer and mobile telephone (simply termed mobile in the following) and, as he has setup in his preferences, he receives the call via his computer and not his mobile (Fig. 1, scene 1). Alice sojourns in a park and is downloading her e-mails into her mobile while she receives John's call. As the radio link does not have much capacity, the e-mail service slows down to accommodate the call (Fig. 1, scene 2). Finally, Steven is in a café and receives the call in his laptop which is connected to the Internet via WiFi. John proposes that they go to the movie. To convince his friends, he accesses the movie producer's Web page and requests the movie trailer be sent to them. The trailer is multicast to all of them. Alice has a slow connection and a mobile with small screen, so she receives a lower quality video (Fig. 1, scene 3). All of them liked the trailer and agreed to go for it. During the conversation Steven receives a call from his boss. As Steven has set up in his preferences, his boss's calls are high priority and thus the multiparty call is put on hold (Fig. 1, scene 4). Meanwhile, the other three friends agree to buy the tickets and to meet in a café near the cinema. To buy the tickets they create and share a session with the cinema's Web page. None of them needs to provide personal data (such as login or credit card number) in the Web page, because the network operator has it already and the cinema's online booking system is able to reach and use part of it. They send Steven a map with the location of the café and the directions to get there from his current location. They say goodbye and urge Bob to go because his home is a bit far away and he may be late. "No problem" says Bob "I'm already on the bus." Bob has transferred his session from the computer to the mobile.

When John receives his monthly bill from his network operator, he sees that he was correctly charged for the multiparty call, the video trailer, and his cinema ticket. The network operator will divert the money — keeping a percentage of the total amount — to the movie ticket and the movie trailer companies. This single bill, combined with the fact that the friends needed only one log-in (to the network) is called single sign-on and unified billing.

The service platform supporting such a scenario must be open enough to offer any kind of service. Moreover, it must offer them with the best possible quality considering that, in next-generation networks, the users may employ very different devices and access technologies to access these services. Yet, it must be simple enough to require few managing costs from the operator and not demand any knowledge from the user. This article examines the IMS service platform focusing on the above criteria.

Other architectural solutions exist such as Open Service Architecture (OSA) and NTT DoCoMo's i-mode. We describe IMS because it is more representative than these solutions. IMS directly targets user-to-user communications, the traditional service of network operators, while other platforms focus more on "content services" such as downloading songs or purchasing tickets. Since IMS targets multimedia communications which demand strong QoS requirements, the QoS interfaces to the network are an important part of the IMS design. As we discuss in this article, this interaction with the network's QoS mechanisms is one of the most interesting and distinctive features of IMS, as compared to OSA or i-mode. Moreover, IMS is also better suited to be extended to next-generation networks than OSA or i-mode: IMS is based on IP (version 6) and on open IETF standards, and its goal is to be integrated in any access network, not only UMTS. IMS and the other solutions are not incompatible but complementary.

The main part of this article is divided into three parts: first we present the IMS service platform; then we focus on one of its more important characteristics, the design necessary to achieve application and network level interactions; in the third part, we focus on the business model behind IMS and how the IMS platform can be exported to next-generation networks. In the conclusion, we emphasize how the IMS solution deals with the problems highlighted in this introduction and outline potential research avenues.

THE IMS SERVICE PLATFORM

IP Multimedia Subsystem (IMS) [4, 5] was introduced in the 3GPP [6] architecture release 5 and is being updated in releases 6 and 7. The IMS "service platform" is designed to assist and control (multimedia) sessions established between peers, for instance, our scenario where some friends set an appointment for seeing a movie together. The peers that are willing to involve IMS in their sessions must use some of its nodes as proxies for their session signaling. IMS only deals with the session signaling and control; it does not tackle the actual transport of data or media flows of the sessions, for example, the voice traffic in our scenario. Indeed, these flows do not even need to traverse the IMS platform. Still, the main characteristic of IMS is that it can interact with the elements from UMTS or GPRS networks, for instance, with the gateway GPRS support node (GGSN) routing the flows and then, for example, influence the QoS that each flow will receive. Next we describe the main protocols and components that form the IMS platform.

PROTOCOLS

IMS uses Session Initiation Protocol (SIP) [7] for the control and signaling of sessions. SIP is a protocol designed by the IETF that is currently widespread on the Internet. To transport media data, the peers will use two other IETF-designed and very popular protocols: Real-Time Protocol (RTP) and Real-Time Control Protocol (RTCP). Finally, IMS uses IPv6 as the network protocol.

COMPONENTS

Since IMS is based on SIP, its main elements are SIP proxies/servers, known in the IMS platform as Call Service Control Functions (CSCFs). To interact with these proxies, the user devices must

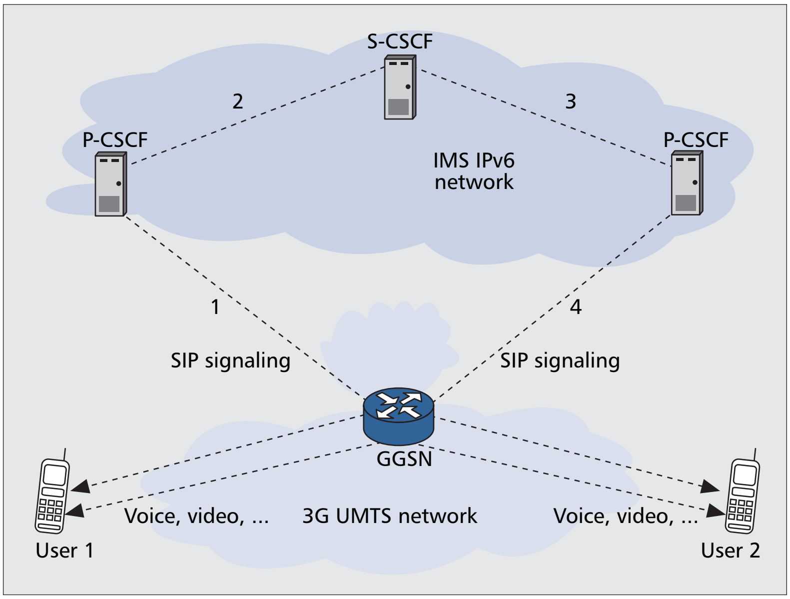


Figure 2. *IMS SIP signaling path (non-roaming scenario).*

implement the functionality of a SIP user agent (SIP-UA). The CSCFs handle all the SIP session signaling, but they do not take part and neither are they on the path of the application data. The IMS proxies are hierarchically divided in two categories (Fig. 2):

- The proxies-CSCFs (P-CSCFs) are the IMS contact points for the SIP-user agents (SIP-UAs).
- The serving-CSCF (S-CSCF) is the proxy server controlling the session.

In some topologies, there is a third type of CSCF, the interrogating-CSCF (I-CSCF). The I-CSFC is an element used mainly for topology hiding (THIG) purposes between different operators and also, in the case of having several S-CSCFs in the domain, to assist in selecting the appropriate one.

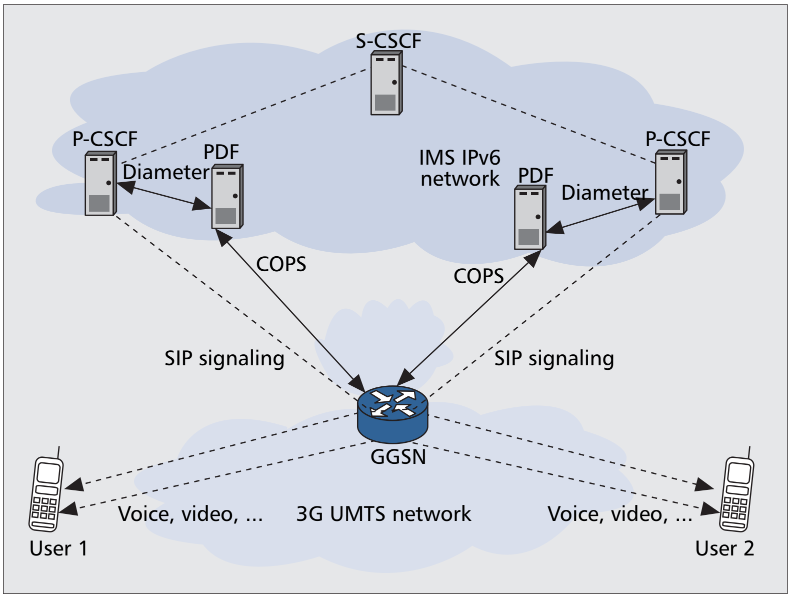
SIGNALING PATH

The basic SIP-signaling path will be illustrated by describing a simple scenario with two non-roaming users in the same domain. Suppose there is only one S-CSCF in this domain and that the P-CSCF serving user 1 (P-CSCF A) is different than the P-CSCF serving user 2 (P-CSCF B). The SIP messages will follow the path shown in Fig. 2:

- User 1 SIP-UA to P-CSCF A
- P-CSCF A to S-CSCF
- S-CSCF to P-CSCF B
- P-CSCF B to user 2 SIP-UA

In roaming scenarios, the P-CSCF is located in the visited domain, while the S-CSCF is located in the home domain.

Although IMS offers many services by itself, it is also designed to interact with third-party service providers via application servers (AS). The most common alternative to achieve this interaction is via the S-CSCF. The S-CSCF controls the session and could, for instance, divert some of the SIP signaling to the appropriate AS. Then, the AS could modify this signaling, for



■ **Figure 3.** *IMS–network interworking: QoS and policy aspects.*

example, to direct the call to the Voice Box service that it provides.

Many of the characteristics offered by IMS are just achieved by the use of the SIP framework; for instance, in our scenario, ending the call on Bob's PC and not on his mobile and, afterwards, when he leaves, transferring the session from his PC to his mobile. Any other service platform using SIP could provide the same results. However, the unique features offered by IMS are achieved thanks to the interaction between the IMS platform and the network operator, as described in the next section.

AN IMS KEY POINT: INTEGRATION WITH THE NETWORK PLATFORM

QOS AND POLICY

In our scenario, as in any IMS-enabled scenario, the different services may have different qualities, depending on user profile, location, access network and devices, and so forth. The IMS platform controls the session but the actual application flows are completely "out of its reach," as they do not even traverse the IMS nodes. Namely, they will go through the network routers or the GGSN in 3GPP networks. Thus, to achieve QoS for the flows of the IMS-controlled applications, IMS must interact with the network elements that transport them. The IMS entity in charge of this interaction is the policy decision function (PDF). The PDF is "aware of the application-level details" of the session being established, such as codecs and requested bandwidth for the media flow(s). It is the P-CSCF that takes part in the application control, which instructs the PDF about these details. The protocol between the P-CSCF and the PDF is Diameter. On its side, the PDF provides (using the COPS protocol) the network nodes with the characteristics of the media flow(s). In summary, the PDF is, for the service quality (QoS), like an intermediary between the QoS defined at the application-level (IMS) and its actual enforcement at the network level (in 3G networks in the GGSN nodes). The P-CSCF, PDF, and GGSN interaction is depicted in Fig. 3.

IMS has a dedicated node to do transcoding and content adaptation: the multimedia resource function processor (MRFP), which behaves like and endpoint in the communication. Combining this transcoding and QoS-based network interaction, IMS can support scenarios like the movie trailer adaptation and e-mail download speed adjustment described in our scenario. An overview of what happens in such a scenario is that the PDF instructs the GGSN serving Alice to reduce the bandwidth of the Packet Data Protocol (PDP) context created to transport the e-mail flow. Then, when the network creates the multicast tree to distribute the movie trailer, IMS should divert the "branch" going to Alice to the MRFP that will transcode the flow and forward it to Alice.

AAA AND CHARGING

Another important aspect present in our scenario is the concept termed single sign-on, which includes unified billing. As we will discuss below, it is not new to IMS and it is a fundamental concept in the IMS business value chain. Here we will just describe the mechanisms employed by IMS to achieve this single sign-on. We will divide them according to authentication, authorization, and accounting (AAA) and charging.

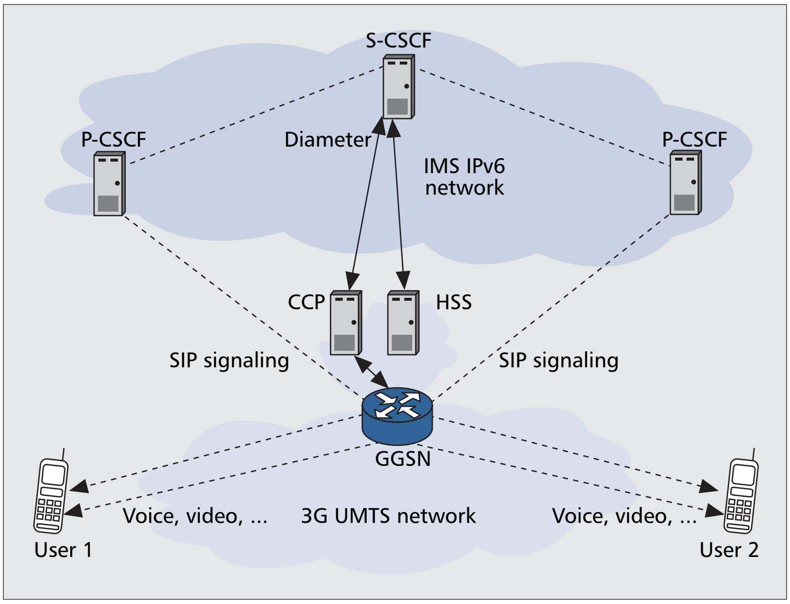
When a user gains access to UMTS networks, an authentication process is performed with the network operator's home subscriber server (HSS), which holds user data (including context information such as his location) and credentials. When IMS (which does not hold the user credentials) needs to authenticate a user, it delegates and depends on the HSS and the previous authentication of the user to this system. In IMS, the S-CSCF is the node responsible to interact with the HSS (Fig. 4). This interaction is done following the IETF Diameter base protocol [8] and some extensions for this specific application [9] defined jointly by the 3GPP and the IETF. In our scenario, the friends needed to log-in only once to the network operator and, afterwards, no sign-on was needed to enjoy the different services. The interaction here described is the basis for enabling such a feature.

Concerning authorization, this is done by the IMS/S-CSCF itself but is based on the user profile and context obtained, also using the Diameter protocol, from the HSS. Note that IMS may also employ this data for refining the services delivered to the user. Referring to our scenario, there will be a decision for an adequate content adaptation of the multicast flow. Or, also in our scenario, the IMS decision to let John's call proceed to only some friends is based on a user-context composition done via IMS obtaining some information (such as user location) from the network operator's HSS.

The main characteristic of the IMS accounting and charging architecture is the capacity of correlating charging at the network and service levels. Charging in IMS supports both offline and online charging. In offline charging, the amount due is deducted from the user's account after the end of the session while in online charging, the amount is progressively deducted during the session. An example of online charging is prepaid mobile-phone service. An example of offline charging is phone service with a contract.

The charging collection function (CCF) is the central point in the offline charging architecture. It receives information from several IMS and UMTS networks entities (Fig. 4) and processes, correlates, consolidates, and records the relevant parts of this information and generates call detail records (CDRs) for the UMTS billing system. IMS entities communicate with the CCF following the Diameter base protocol [8] with 3GPP specific extensions, which are not yet standardized in the IETF. IMS entities, namely, the CSCFs (both P-CSCF and S-CSCF), interact with the CCF module to charge the session in the application plane. CSCFs can instruct the CCF about the type of session (audio or audio and video call), its duration, or the number of participants. The interaction between the GGSN and the CCF — via the charging gateway function (CGF) — is also defined to charge the session in the network plane (e.g., number of bytes sent and received). CSCFs, GGSN, and CCF will share the same charging identifier (CID) for the same session and for the PDP context(s) transporting the session's media flow(s). Therefore, the CCF can correlate charging at the application and network levels in the same session.

The online charging architecture is far more complex, but its main characteristic is also that it can correlate charging at application and network planes. Online charging follows the Diameter credit-control application [10]. This extension to Diameter is precisely done so as to support online charging.



■ **Figure 4.** *IMS–network interworking: AAA and charging aspects.*

Analysis of IMS

While the two previous sections were mainly descriptive, the goal of this last part is to analyze the IMS aspects discussed in the introduction. We first examine the IMS technical approach, then we consider the IMS business model, and finally we evaluate the IMS suitability to be ported to next-generation networks.

IMS is a complicated framework. Or, at least, it is far more complicated than other SIP-based solutions offering similar services. Let us analyse whether this complexity brings any added value. First, IMS has specific nodes designed to make it interact with non-IP networks. This aspect, which has not been analyzed in this article, is a surcharge that any IP-based system wanting to interact with other networks must pay. Second, to handle the SIP sessions, IMS employs different types of proxies (CSCFs). But this, rather than being a drawback, is an advantage since it improves scalability. This improvement is achieved because the IMS design allows having several S-CSCFs per domain to control the session of the domain's users. The P-CSCF, another type of SIP proxy, leverages some of the tasks that need to be done by the S-CSCF. The third aspect making IMS complicated is the interaction with the network operator infrastructure. IMS works at the application signaling level while the network operator focuses on a very different layer: data transport. But thanks to this interaction, as we have seen earlier, IMS achieves negotiation with the network operator, on a per session basis, of the transport-level parameters so that they match the application-layer ones. This is a great advantage compared to current systems that cannot influence the parameters of the transport service provided by the network operator. Nevertheless, similar results (at least where QoS is concerned) could be achieved with a simpler system and by pushing the complexity to the terminals. In [11] the authors compare both approaches: the proxy or the mobile node undertaking the QoS negotiation with the network infrastructure. Other advanced features surcharge IMS complexity, like its capability to do content adaptation, as briefly described above. Nevertheless, the added value they bring to the whole IMS system pays for this extra complexity.

We think that the complexity of IMS will not be the key factor to its success or failure. Other aspects such as the acceptance of its business model or the added value that IMS can offer to customers — by itself or interacting with third parties — will be much more important. However, we need to design smart user interfaces. On the one side, they must provide a friendly user interface, enabling easy control of the IMS advanced features. On the other side, this interface has to profit from simple access to the applications that IMS enables thanks to service bundling and single sign-on.

IMS defines a network-provider-centric business model, just like i-mode or 3GPP's OSA. The user's profile and charging are controlled by the network operator, and IMS (or third-party entities interacting with IMS) depends on the network operator's AAA services to control their users. Users trust and pay the network operator who, in its turn, trusts and pays (retaining, for example, 10 percent of the total amount) the IMS and third-party entities related to the IMS (Fig. 5). Indeed, IMS is designed to be part of

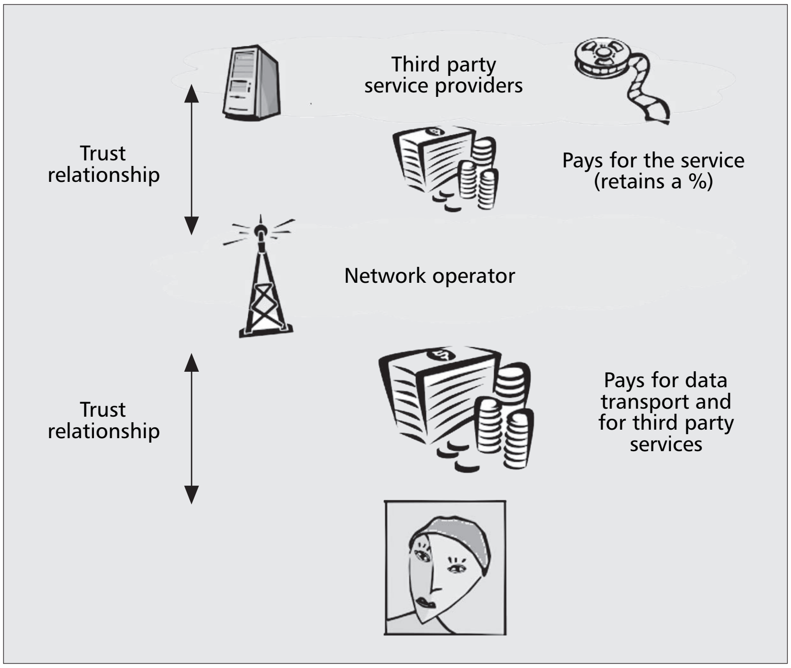


Figure 5. *Network-operator-centric business model.*

the network operator architecture and to be controlled and owned by it. This fact does not reduce the validity of our discussion. It is clear that for network operators the key point is that IMS places them in the core of the business value chain. But what are the advantages for the users? We discuss this next.

There is an excellent chance that customers will accept the IMS-based model, since most of the control will be given to the operator while at the same time the customer will receive all services (e.g., QoS [12]). This also includes the creation of an operator-driven "trust" center: the operator will become the account holder for the customers by mercenarily offering various services and service bundles with single sign-on support. Users are normally reluctant to spread their data and to have to trust several identities, so the operator-driven "trust" center has a good chance of being accepted. Besides, customers are used to perceiving the network operator as a trustable entity. The success of i-mode in Japan shows that the network-operator-centric business model can be successful. Together with OSA, i-mode focuses on "content services," unlike IMS, which targets user-to-user communication services. This aspect is a fundamental IMS feature. Of course, the different platforms can complement each other. Keeping this in mind along with the fact that the network operator can act as a customer-related data broker against third parties, new tailored and advanced service bundles can be delivered to customers. IMS can help achieve the network-operator-centric business model, but it cannot be a guarantee that this business model will prevail.

IMS is currently at the final stage of standardization. At the same time, new architectures are appearing in the framework of 4G (or next-generation) evolution. Most probably, in 4G networks, nearly all functionality will be pushed into the common network layer with IP as the convergence protocol. This is a major difference with 3G networks, where, for instance, all the UMTS Terrestrial Access Networks (UTRANs), until the GGSN, behave as 'single hop' at the IP layer. IMS, since it is purely based on IP and IETF protocols, is a good step towards the 4G infrastructure. However, several issues not covered in IMS must be solved before deployment.

A very short review of the main research trends for adapting IMS to 4G networks is given next. The first thing to deal with is the extension of IMS to networks other than UMTS. Although the goal is to have IMS integrated in every kind of network, currently its design covers only UMTS ones. Some of the aspects to be solved are related to QoS interaction. As discussed in this article, this interaction depends on mechanisms proprietary to UMTS networks, such as PDP context activation. Another issue to be solved is its integration with Mobile IP. Although SIP is independent of the IP-based mobility management (layer 3 is responsible for this and SIP is located at layer 5), it is still under discussion whether the terminal should provide its IP Home Address or/and its (interface) IP Care of Address in the SIP registration. The best solution, according to [13], would be to provide the Home Address, but that would require the P-CSCF to support Mobile IP. Third, the anonimization of the user is also a very interesting research topic, since it aims to satisfy two contradictory requirements. On the one side, users are very pleased with the single sign-on feature provided by IMS; on the other side, they do not want to be tracked in their various activities (services consumption). Multicast integration in IMS is also under research. Multicast can be achieved as an IMS application overlay or by taking advantage of native multicast capabilities in next-generation networks.

These are only some of the many issues the research community is addressing. Much effort is being made with regard to urgent problems, as in [13], and broader aspects [14, 15].

Conclusion

This article has presented the IMS service platform designed by 3GPP for UMTS networks, which can be easily exported to next-generation networks. The business model proposed by IMS and its original design, separating application and transport layers but making them interact, centers the network operator again in the core of the business chain. Thus, it minimizes the risk that next-generation network operators will become mere bit pipes. Adding to this the fact that IMS is open to third parties, IMS can offer very rich scenarios that will entice users to employ this platform.

In the coming years, the telecommunications world will surely undergo fundamental changes; hence, the future is open. However, some trends have been identified. On the one side, there is the dilution of the network. Two examples support this forecast. First, large areas in city centers have WiFi coverage from private-owned WiFi access points. Second, in the operator-owned CDMA radio systems, the capacity of the network may increase and depend on the users' terminals collaborating with each other, informing themselves of the interferences they are generating. On the other side, the rise of service bundling is forecasted. IMS is designed to make the network operator profit from this, placing it the core of the business chain. However, this "bundling" may be carried out by other entities, thus relegating the network to a bit pipe; for instance, one may think of buying a bouquet of roses and including a greeting MMS to the beloved person. The MMS will just increase the price of the flowers.

With such a broad range of possibilities, it is very difficult to forecast the future of the IMS service platform. However, it will be the customers' acceptance that will determine its success. For this, IMS must propose more than what standalone non-network-operator-partnered service platforms offer. We think IMS is a good platform to achieve this, but finding and developing the services that match users' demand will be the key point for the success of IMS.

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With such a broad range of possibilities, it is very difficult to forecast the future of the IMS service platform. However, it will be the customers' acceptance that will determine its success. For this, IMS must propose more than what standalone non-network-operator-partnered service platforms offer.