IMS Based Fixed–Mobile Network Convergence

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Abstract:
The IP Multimedia Subsystem (IMS) proposed by 3GPP embodies an integration of communications network with the Internet technology and a fabrication of Next Generation Network (NGN) with 3G technology. IMS has been widely acknowledged in both telecom and Information Technology (IT) industries as the core technology for Fixed–Mobile Convergence (FMC). In terms of network convergence, IMS integrates Internet IP, Softswitch and cellular core network technologies. With respect to service convergence, it incorporates open Parlay/OSA technology and web services technology. As to management convergence, it combines management and policy control technologies of telecom network and IP network. To cope with a grim challenge from the Internet, all standardization organizations are interacting to push forward the further development of IMS. A common IMS, proxy service and managed P2P service are important subjects for further research.

At the end of the 20th century, with the rapid growth of the Internet, the communications industry rethought its way of constructing global information infrastructure based on Asynchronous Transfer Mode (ATM) switching technology, and decided to use IP routing technology as the core technology for Next Generation Network (NGN). The fixed communications industry made a breakthrough in Voice over IP (VoIP), introducing Softswitch networking technology and Parlay open service technology; the Internet Engineering Task Force (IETF), taking advantage of the Internet's technical framework, suggested Session Initiation Protocol (SIP) for communication control in IP networks; and the mobile communications industry, represented by the 3rd Generation Partnership Project (3GPP), integrated the above technologies with cellular mobile core network technologies, and proposed IP Multimedia Subsystem (IMS) technology, aiming for multimedia services. After its introduction, IMS was soon widely recognized by the communications industry and Information Technology (IT) industry. It has become the core technology for Fixed–Mobile Convergence (FMC), and is developing as the technology for future information and communications network convergence.

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1 Research of International IMS Standards

3GPP has collaborated closely with other standardization organizations in developing IMS technical standards and improved these standards by teaming up with communications bodies worldwide (see Table 1). Among the collaboration examples, the most important one is that 3GPP and IETF jointly developed the core control protocol, SIP[1], of IMS networks, and studied its extensions and applications. With SIP, future multimedia communications, whether between IMS users or between Internet users, can apply the same control protocol, thus truly realizing convergence of communications network and Internet. Another important example is 3GPP's collaboration with Parlay Group in developing Parlay/Open Service Access (OSA) Application Programming Interface (API) that supports open services, and introducing Parlay technology, which originated from fixed intelligent networks, into OSA architecture[2] of IMS network. As a result, future service development can be based on the same API no matter if the underlying layer is fixed network or mobile network, and no matter how the future network evolves, hence allowing information network and communications network to be converged. Two most important achievements from 3GPP's teamwork with other bodies are: Telecoms and Internet converged Services and Protocols for Advanced Networking (TISPAN) of European Telecommunications Standards Institute (ETSI) and Telecommunication Standardization Sector of International Telecommunication Union (ITU–T) propose the technology that integrates fixed access into IMS[3], and Open Mobile Alliance (OMA) suggests many IMS–based technical specifications[4].

3GPP has made a stage–by–stage evolution plan of IMS[5] based on the

▼ Table 1. Main organizations participating in IMS research

Organization/Forum	Contribution
IETF	SIP and other IP network protocols
3GPP	IMS
3GPP2	MMD
ETSI TISPAN	NGN–related standards
ITU–T	NGN–related standards
OMA	Service specifications for mobile networks
CableLabs	PacketCable2.0 cable multimedia services

IMS: IP Multimedia Subsystem
IP: Internet Protocol
MMD: Multimedia Domain
NGN: Next Generation Network
SIP: Session Initiation Protocol

▼ Table 2. Evolution path of IMS

3GPP Standard Version	Evolution of IMS
R5	IMS framework to support 3G access
R6	Enhanced interfaces and functions, adding WLAN access, flow–based charging and policy–based QoS control
R7	Adding xDSL access, PCC and VCC, integrating TISPAN R1 standard
R8	Adding PBX access, service broker and common IMS framework

IMS: IP Multimedia Subsystem
PBX: Private Branch Exchange
PCC: Policy and Charging Control
QoS: Quality of Service
VCC: Voice Call Continuity
xDSL: Digital Subscriber Line family

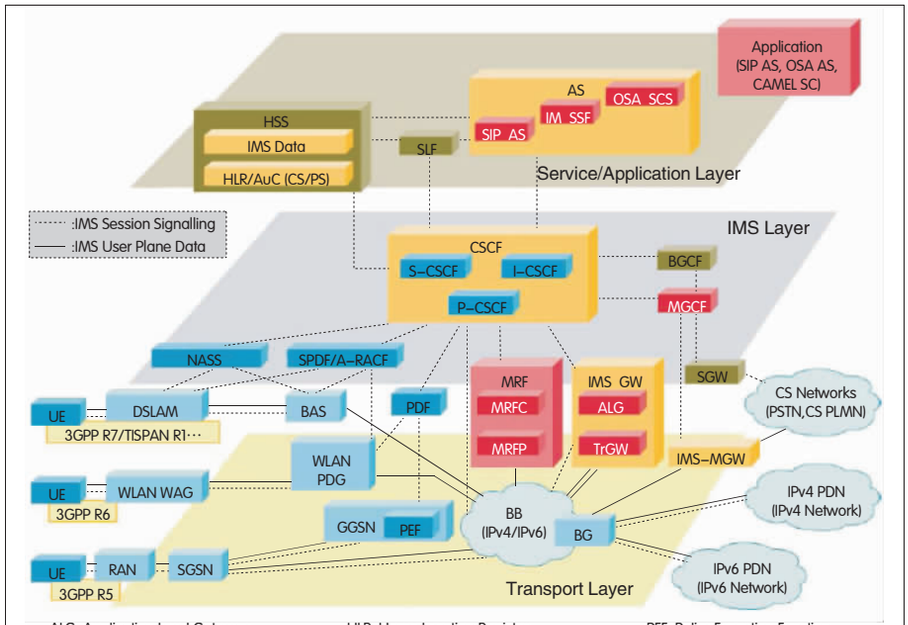
versions of Universal Mobile Telecommunications System (UMTS)'s 3G mobile communications system standards, as shown in Table 2. Among these standards, R5, which was developed in 2002, is the first standard for all–IP mobile networks. Treating the core network as a unified, IP–based Packet Switched (PS) domain, it can provide QoS guarantee and offer various types of value–added multimedia services. The core technical standard in R5 is IMS. R6 improves the interfaces and functions of IMS, supporting access to Wireless Local Area Network (WLAN), and studying charging and QoS control technologies for IMS. Integrating the NGN–related standards developed by TISPAN into IMS, R7 supports access to Digital Subscriber Line family (xDSL) and introduces Policy and Charging Control (PCC) technology as well as Voice Call Continuity (VCC) technology for WLAN/3G continuous voice communications. R8, which is still under research, will focus on proxy technology, which is for integrated services, and common IMS framework. 3GPP will work with different standardization organizations in the research of R8.

2 IMS–Centric FMC Technology

Based on the ideas discussed above, a layered network structure of IMS is proposed, as shown in Figure 1. This figure illustrates the evolution of different standard versions.

The underlying one is the transport layer, which core technology is IPv4/IPv6. At this layer, all media streams, including voice, video and text, access the network using access technologies of either 2G/3G mobile networks or fixed broadband networks (e.g. Wireless Fidelity (Wi–Fi) and DSL). But all media streams are transmitted in the form of IP packets. The network operators construct unified IP broadband network to serve all users, reflecting the IP–based network convergence.

The upper layer is the service/application layer, which uses information technology as the core technology. At this layer, the service operators offer value–added services to end users via service logic units deployed in various application servers, and the service provisioning is independent of user access technologies which reflects the Information and Communication Technology (ICT)–centric service convergence and the characteristic of invoking converged communications network capabilities via API.



ALG: Application Level Gateway
A–RACF: Access–Resource Access Control Facility
AS: Application Server
AuC: Authentication Center
BAS: Broadband Access Server
BB: Broadband
BG: Border Gateway
BGCF: Breakout Gateway Control Function
CAMEL SC: Customized Applications for Mobile Network Enhanced Logic Service Control
CS: Circuit Switched
CSCF: Call Session Control Function
DSLAM: Digital Subscriber Line Access Multiplexer
GGSN: Gateway GPRS Support Node
GW: Gateway
HLR: Home Location Register
HSS: Home Subscriber Server
I–CSCF: Interrogating–Call Session Control Function
IM SSF: IP Multimedia Service Switching Function
IMS: IP Multimedia Subsystem
MGCF: Media Gateway Control Function
MGW: Media Gateway
MRF: Media Resource Function
MRFC: Media Resource Function Controller
MRFP: Media Resource Function Processor
NASS: Network Attachment Subsystem
OSA: Open Service Access
P–CSCF: Proxy–Call Session Control Function
PDF: Policy Decision Function
PDG: Packet Data Gateway
PDN: Packet Data Network
PEF: Policy Execution Function
PLMN: Public Land Mobile Network
PS: Packet Switched
PSTN: Public Switched Telephone Network
RAN: Radio Access Network
SCS: Service Capability Server
S–CSCF: Serving–Call Session Control Function
SGSN: Serving GPRS Support Node
SGW: Signalling Gateway
SIP: Session Initiation Protocol
SLF: Subscription Locator Function
SPDF: Service Policy Decision Function
TrGW: Transition Gateway
UE: User Equipment
WAG: Wireless Access Gateway

▲ Figure 1. Layered network architecture of IMS.

The middle layer is IMS layer which takes SIP as its core technology. For the lower layer, i.e. transport layer, this layer controls and manages calls in IP multimedia communication, while for the upper layer, i.e. the service/application layer, it provides open interfaces to invoke communications network capabilities. In this way, the service layer is separated from the network layer, and service operators are independent of network operators, reflecting the control and management convergence of multimedia services.

2.1 Network Convergence Technology

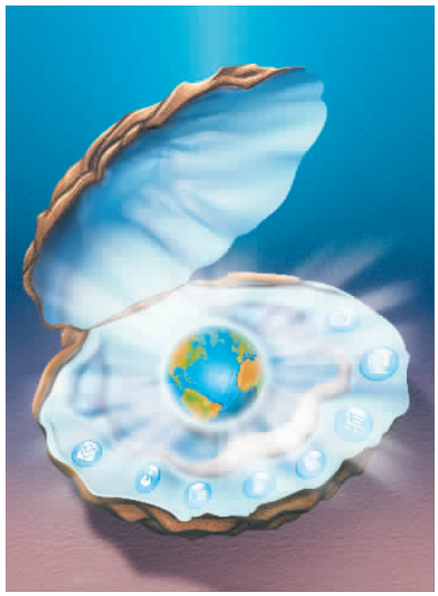
The basic idea in IMS–based network convergence is to effectively integrate IP technology of Internet, Softswitch technology from fixed networks and core network technology in mobile networks to achieve the goal that fixed and mobile communications networks converge.

In the bearer layer, seeing the successful application of VoIP, IMS abandons the Circuit Switched (CS) domain, which has been dominant in traditional communications networks for quite a long time, but adopts IP–based Packet Switched (PS) domain to transmit various types of media and signaling streams. It for the first time applies all–IP bearer network in the communications system and makes it the foundation for communications network convergence.

As to service networking, IMS inherits network technologies specific to cellular mobile communications systems. It continues to use the concept of home network and visiting network, extended mobility management technology and centrally–configured network database to support subscriber's roaming and handover. In addition, based on Home Location Register (HLR) in 2G networks, the Home Subscriber Server (HSS) is developed, which is a critical network element to IMS. The HSS is used to store user information required for processing multimedia sessions, including location, authentication and authorization, user profile and home SIP server. As a result, IMS system can flexibly offer IP multimedia services while retaining all characteristics of mobile communications. This fully reveals the convergence of mobile communications technologies with Internet technologies.

In terms of heterogeneous network interconnection and heterogeneous terminal access, IMS takes advantage of Softswitch technology to connect itself to traditional fixed and mobile networks via gateways. Like those traditional networks, it configures such network elements as Signalling Gateway (SGW), Media Gateway (MGW) and Media Gateway Control Function (MGCF). Moreover, H.248 protocol, which was jointly developed by IETF and ITU–T, is used between MGCF and MGW. By setting related gateways and servers, IMS can support the access of not only mobile terminals, but also fixed terminals, multimedia terminals and PCs. The access can be done via cellular Radio Frequency (RF) interface or through WLAN and Worldwide Interoperability for Microwave Access (WiMAX) in wireless network or using Local Area Network (LAN), DSL and coaxial cable in case of wired networks. Therefore, IMS system is applicable to both mobile networks and fixed networks, reflecting the convergence of fixed and mobile networks.

Referring to switching control technology of communications network, IMS introduces a call/session control layer (i.e. IMS layer) above the IP bearer layer. As the underlying layer is not traditional circuit switched network but IP–based packet switched network, IMS no longer uses traditional communications network signaling but applies Internet technologies and protocols as much as possible. In particular, it gives up the matured H.323 protocol suite, which was defined and developed by ITU–T based on Integrated Services Digital Network (ISDN) signaling, but chooses SIP protocol for control, which is not so mature but simpler and more scalable. The core network element, i.e. Call Session Control Function (CSCF), acts as a SIP proxy server, which not only forwards SIP messages, but is also responsible for call control in multimedia communication. For the routing of SIP messages, the Domain Name System (DNS) protocol is used for address resolution, while for the terminal users assigned with traditional telephone numbers, Telephone Number Mapping (ENUM) protocol developed by IETF is



used for address resolution. Because most of its network interfaces use Internet protocols, IMS system not only supports IP network–based multimedia communications between 3G users, but also supports communications between 3G users and Internet users without difficulty.

2.2 Service Convergence Technology

Service convergence is a higher–level convergence of IMS, playing a more important role in future heterogeneous information and communications network. To ensure graceful evolution of existing networks, IMS supports three service provisioning modes.

In the first mode, the fixed and mobile intelligent network technologies are used, allowing network operators to provide contracted intelligent services through Service Control Points (SCPs), and ensuring the converged network to provide all value–added services of existing networks. In terms of technical update, this mode simply separates Service Switching Function (SSF), which was originally a part of a switch, from CSCF and makes it independent IP Multimedia SSF (IM–SSF).

In the second mode, service technologies of SIP–based networks are used. With SIP protocol being adopted in the IMS layer, IMS can naturally offer the users various services or applications by setting various SIP servers and using the technologies that are widely used in

Internet, such as Common Gateway Interface (CGI), Servlet, JavaBean and Call Processing Language (CPL). This service provisioning mode employs many computer network technologies, and directly uses SIP as the interactive interface between the service layer and IMS layer. As a result, the networking scheme is the simplest and easiest to converge with Internet, but is subject to SIP protocol.

The third mode is called Parlay/OSA service architecture. It applies Parlay technologies that have been used in Softswitch–based networks, and offers services in an open way through API, the interface jointly developed by 3GPP and Parlay Group for invoking IMS network capabilities. The services and applications are offered by OSA Application Servers (ASs) at the service layer, which are from either network operators or independent third–party service operators. In this way, the communications network is changed into an open network, separating the service layer from the network control layer. Moreover, 3GPP has defined Web Services interfaces against common APIs, allowing IMS services and applications to be easily integrated with Web Services of Internet, thus realizing the convergence of communications networks' services and Internet services. Therefore, Parlay/OSA represents a development trend of IMS, and will be the core technology of service convergence.

2.3 Management Convergence Technology

With respect to service/operation management, IMS exploits Operations Support System (OSS) and Business Support System (BSS) technologies of communications networks. In network management, it refers to access authentication and security technologies of IP networks, and in QoS control and charging, it introduces PCC technology.

3 Challenges from Internet

With the rapid expansion of Internet applications and continuous update of Internet technologies, IMS is suffering great challenges from Internet due to conflicts between their design concepts.

Firstly, Internet's applications are directly developed at the network layer. It generally adopts Browser/Client/Server (B/C/S) architecture, and its service provisioning mode depends on servers and intelligent terminals. As a result, there is no network control layer. The basic design concept of Internet is to simplify the network as much as possible to ensure its scalability. According to Internet researchers, there is no distinctive difference between IMS and traditional telephone networks, except that the bearer layer of traditional telephone network is replaced by the IP–based layer in IMS. They even predict that IMS will eventually collapse under their own weight.

Secondly, the Internet focuses on contents from the very beginning. Connection is only regarded as a basic function that a network must be equipped with. The network operators should cooperate with the content providers and make profits from back–end services, such as advertisements attached to the contents, rather than from connections. Some IT leading enterprises even advocate network neutralism[6]. That is to say, networks should be treated as public resources in the information society, and should be fairly provided to the content providers. These enterprises understate the roles of operators and neglect the operation and charging management technology, which is exactly one of the most important technologies in IMS.

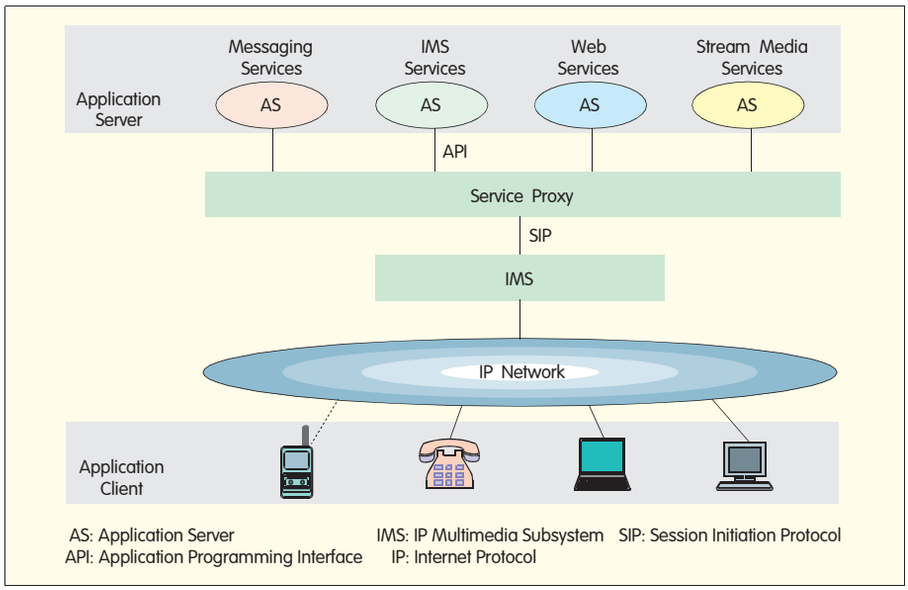
Thirdly and more importantly, the quick development of P2P services in recent years has become a direct threat to IMS[7]. P2P is a self–organizing technology in the application layer. It takes advantage of teamwork of computer terminals to obtain required services under the circumstance of insufficient bandwidth. It does not require any central network infrastructure as well as interventions from the IMS control layer. Although P2P services consume lots of network resources, and there are many problems to be solved, for example, security and intellectual proprietary rights, this creative technology has been widely recognized by many users, especially the young ones. The development of P2P cannot be ignored.

In sum, IMS has to find its position as well as its development direction in such a challenging environment.

4 Development Direction of IMS

From the perspective of either technology or application, IMS should be first an FMC technology. Therefore, the first thing that should be considered is how to integrate it with NGN so as to support multiple accesses, especially fixed access technologies. The problems to be solved include network traversal in case of fixed terminal access, Service Border Controller (SBC) technology, authentication and authorization of different types of terminals, roaming management of mobile terminals, nomadic management of fixed terminals, and domain–based routing mechanisms. So far, many solutions have been brought forward. The research of these problems is led by TISPAN and ITU–T.

After years of exploration, the telecom industry comes to an agreement that network evolution should be based on service–driven policies, and service convergence should be the most important goal of IMS–based network convergence. More attention should be focused on the research of system architecture and platform that can flexibly create services rather than just looking for the so–called "killer" services that can bring the operators huge profits. It must be noted that the control principle of IMS is basically originated from traditional communications networks although the services that are supported by SIP–based IMS have been expanded from voice services to broadband multimedia services. Hence, IMS is most suitable for offering real–time session services such as VoIP, trunking voice and trunking video, rather than pure data services such as Web and electronic commerce. As for other promising services, for instance, media streaming services, Internet Protocol Television (IPTV) and messaging services, IMS has proposed or is studying the provisioning methods, but these services have already been provided by other non–IMS methods. Therefore, IMS is by no means an all–inclusive technology. Specifically speaking, IMS is a network convergence



▲ Figure 2. A service proxy platform supporting service convergence.

technology put forward by the communications industry, so it lays emphasis on offering services similar to traditional communications services. In order to enable IMS to play an important role in future converged information and communications networks, the researchers should actively study how to extend IMS' service capabilities on the one hand, and develop new architecture for IMS on the other hand to include both IMS and non–IMS services, with an ultimate objective of creating a converged, open service platform. This IMS–based comprehensive service platform is also called service broker technology, which is one of hot research topics. Figure 2 illustrates such a platform. This platform can provide at least 4 categories of services as well as any combination of these categories: IMS, messaging, media streaming and Web. In other words, in addition to SIP and API of IMS system, the platform should have the capabilities of supporting other non–IMS system protocols and interfaces so as to form an integrated service layer. IMS is an important part of this platform, serving for communications network convergence.

Currently, all standardization organizations closely cooperate in promoting the research of a common IMS. Based on SIP–based IMS, they try to extend IMS to include other interfaces and protocols, thus supporting various accesses and network interconnections, and integrating different service provisioning methods. Their final goal is to make IMS the foundation of information and communications network convergence. They all agree that 3GPP takes the leadership in this research, i.e. Release 8, which is still in its infancy.

The last point that needs to be emphasized is that the advantage of IMS lies in its reliability and QoS guarantee, which are important characteristics distinguishing communications networks from Internet. Therefore, in the research of IMS, more attention must be paid to management technologies convergence, ensuring IMS network to be operable, manageable and profitable. As for the Internet–specific service model such as P2P, which develops quickly but is found serious security and network scalability problems, the communications industry has changed its approach. It no longer takes the action of containments, but begins to introduce P2P into communications networks, studies manageable P2P service technologies and has proposed IMS–based P2P management framework and technologies.

5 Conclusion

IMS is a technology proposed by the communications industry. Its direct goal is to support fixed–mobile convergence, while its long–term goal is to support information and communications network convergence. The IMS–based convergence involves three aspects: IP–based network convergence, SIP–based control convergence and API–based service convergence. Among them, service convergence is the most important. The important characteristics of IMS network, which distinguish it from Internet, are QoS guarantee and reliability. However, the development of IMS should not be limited to SIP and API–based service provisioning mode. It should not only support various access technologies, but also include other control protocols and service interfaces to support diversified service provisioning modes. A common IMS architecture suggests a research subject oriented to IMS–based future information network convergence.

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Biography

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Mi Zhengkun is a professor at the College of Telecommunication & Information Engineering, Nanjing University of Posts and Telecommunications, and a fellow of China Institute of Communications. He was granted one second–class Science and Technology Advancement Award by Jiangsu Provincial government, one second–class and one third–class Science and Technology Advancement Awards by the Ministry of Information Industry. His current research interests lie in the study of NGN technologies and heterogeneous network convergence technology. He has published over 30 journal papers collected by SCI and EI, and 8 widely circulated books. He has also applied for 5 patents of invention.