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Introduction

1.1 What is the Internet Protocol Multimedia Subsystem (IMS)?

Fixed and mobile networks have gone through a major transition in the past 20 years. In the mobile world, first-generation (1G) systems were introduced in the mid-1980s. These networks offered basic services for users. The main emphasis was on speech and speech-related services. Second-generation (2G) systems in the 1990s brought some data services and more sophisticated supplementary services to the users. The third generation (3G and 3.5G) and its evolution (LTE) is now enabling faster data rates and various multimedia services. In the fixed side, traditional Public Switched Telephone Network (PSTN) and Integrated Services Digital Network (ISDN) networks have dominated traditional voice and video communication. In recent years the usage of the Internet has exploded and more and more users are taking advantage of faster and cheaper Internet connection such as Asymmetric Digital Subscriber Line (ADSL). These types of Internet connections enable always-on connectivity, which is a necessity for people to start using real-time communication means – e.g., chatting applications, online gaming, Voice over IP (VoIP).

At the moment we are experiencing the fast convergence of fixed and mobile worlds as the penetration of mobile devices is increasing on a yearly basis. These mobile devices have large, high-precision displays, they have built-in cameras and a lot of resources for applications. They are always-on always-connected application devices. This redefines applications. Applications are no longer isolated entities exchanging information only with the user interface. The next generation of more exciting applications are peer-to-peer entities, which facilitate sharing: shared browsing, shared whiteboard, shared game experience, shared two-way radio session (i.e., Push to Talk Over Cellular). The concept of being connected will be redefined. Dialling a number and talking will soon be seen as a narrow subset of networking. The ability to establish a peer-to-peer connection between the new Internet Protocol (IP) enabled devices is the key required ingredient. This new paradigm of communications reaches far beyond the capabilities of the Plain Old Telephone Service (POTS).

In order to communicate, IP-based applications must have a mechanism to reach the correspondent. The telephone network currently provides this critical task of establishing a connection. By dialling the peer, the network can establish an ad hoc connection

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between any two terminals over the IP network. This critical IP connectivity capability is offered only in isolated and single-service provider environments in the Internet; closed systems compete on user base, where user lock-in is key and interworking between service providers is an unwelcome feature. Therefore, we need a global system – the IP Multimedia Subsystem (IMS). It allows applications in IP-enabled devices to establish peer-to-peer and peer-to-content connections easily and securely. Our definition for the IMS is:

> **IMS is a global, access-independent and standard-based IP connectivity and service control architecture that enables various types of multimedia services to end-users using common Internet-based protocols.**

True integration of voice and data services increases productivity and overall effectiveness, while the development of innovative applications integrating voice, data and multimedia will create demands for new services, such as presence, multimedia chat, push to talk and conferencing. The skill to combine mobility and the IP network will be crucial to service success in the future.

Figure 1.1 shows a converged communication network for the fixed mobile environment. It is the IMS which introduces multimedia session control in the packet-switched domain and at the same time brings circuit-switched functionality in the packet-switched domain. The IMS is a key technology for such network consolidation.

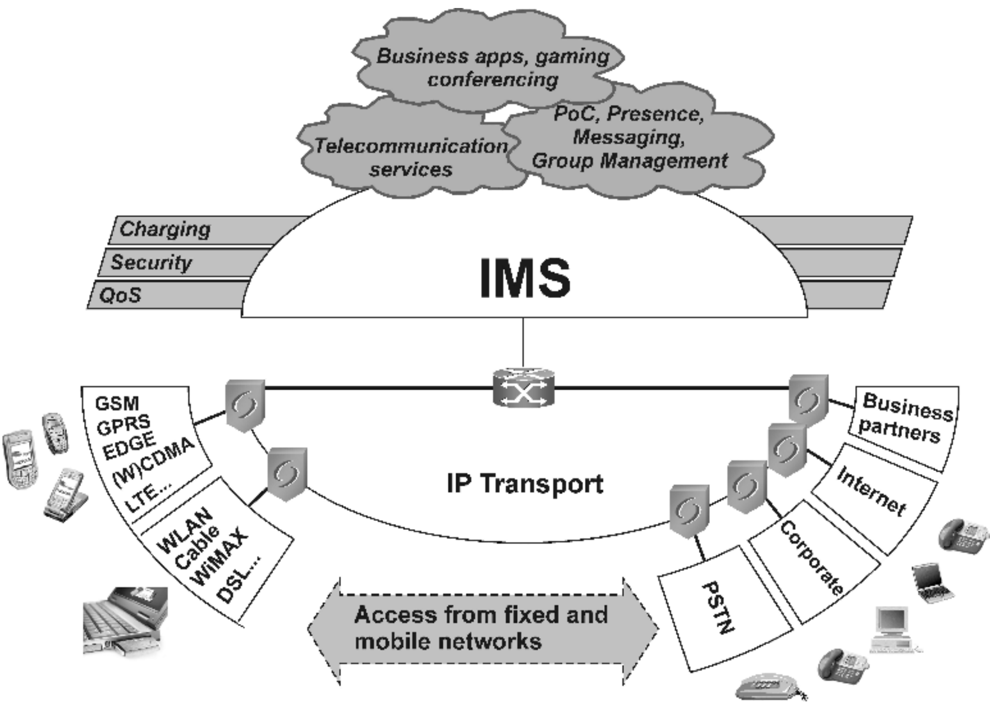

Figure 1.1 IMS in converged networks

1.2 Fixed and Mobile Convergence

Since the IMS architecture integrates both wireless and wireline networks, the IMS becomes an inexpensive medium for Fixed to Mobile Convergence (FMC). It is currently one of the crucial strategic issues in the telecommunications industry. Trends in different regions and countries are different, but on a global level operators are facing increasing competition and declining prices for voice traffic, fixed lines and fixed minutes. At the same time, mobile voice traffic is growing rapidly and substituting that of voice traffic over fixed lines. End users now expect high quality with reliable mobility and are using the Internet more as the penetration of broadband grows rapidly. Now, Voice over IP (VoIP) is starting to substitute PSTN. Meanwhile, key enabling technologies, such as smart phones, wireline and wireless broadband and IMS for seamless service over different access types are readily available. Combined, this means that operators are looking for long-term evolutionary strategies towards converged, access-agnostic networks, with service integration and interoperability across domains and devices. From the end user's perspective this delivers seamless end user experience across multiple locations, devices and services. Convergence can be viewed from three separate angles:

- convergence of networks
- convergence of services
- convergence of devices

Convergence of Networks

Network convergence simplifies the end user experience and dissolves the barriers and complexities that separate today's network islands. The same services are available across all networks and, in an ideal world, appear and perform in exactly the same way, making usage easy, transparent and intuitive.

From an operator's perspective, the goal of network convergence is to migrate today's separate PSTN, PLMN, backbone and IP networks to a fully converged network that supports any access technology. The full evolution includes a cost effective migration to an All-IP network using IMS as the unifying platform, allowing all new services to be accessed in a standard and consistent manner as shown in Figure 1.2 manner. Advancing in this evolution will be the key to an operator's ability to reduce OPEX and CAPEX, and increasing competitiveness and profitability.

Many locations, such as homes, enterprises and public places already have access networks available (xDSL, WLAN, cable etc.). When operators launch new services such as video streaming or hosted email they can take advantage of these existing networks, extending service access to more potential subscribers. In turn this will mean launching services to new market segments for new revenue opportunities. With multiple access networks operators can attract existing and new customers with an enhanced convergence service portfolio using unified billing.

A converged core network is the key enabler for converged networks. Multi-access to a common, converged core network enables cost optimization for both mobile and hybrid operators. Re-use of existing access network infrastructure and integration with the service infrastructure results in both OPEX and CAPEX savings. And multi-access enables operators to introduce end-to-end quadruple-play services (voice, data, video/TV and mobility), to new customers.

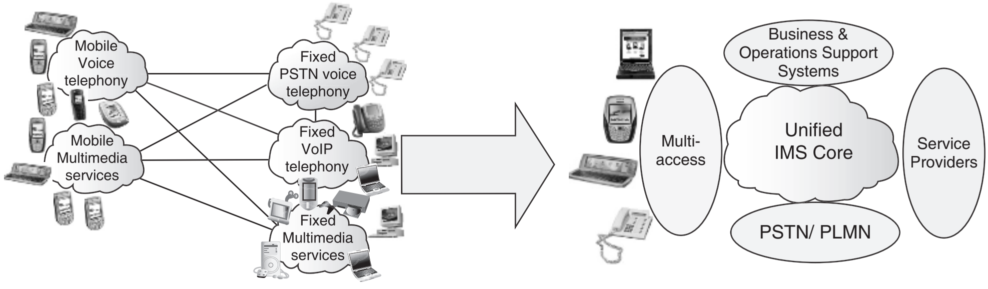

Figure 1.2 Convergence of networks

IP-based access connection using the SIP protocol between the device and the converged core network – so called 'Native IP access' – allows voice, video and other multimedia applications over any access network. Native IP access supports a wide variety of applications in different devices, including mobile handsets, PC clients and SIP desktop phones. POTS phones too, can also be supported, via a connection to an SIP-capable DSLAM or analog terminal adapter (ATA). Native IP access architecture allows the introduction of new rich IP multimedia services through IMS functionality, such as presence, media push, multimedia telephony, games and various other SIP enabled applications, furthering revenue streams for operators.

Device Convergence

Typically, a device is only used – in the main – for a single purpose and the support for its other functions is limited. PSTN phones, low end mobile phones and set-top boxes are good examples. Consumers use these devices for a single purpose. When they change tasks they change device and access network. This means service islands, which lead to mis-matched user experiences from different public and private networks. What's needed are unifying devices that can access services in a similar and easy way.

Smart phones are serious contenders for voice-plus multimedia services in a truly mobile environment. Multiple radio interfaces provide access over circuit and packet-switched networks (cellular, WLAN etc) and IMS allows services and applications to traverse different IP networks. Mobile phone development has been rapid in the last decade and new models take increasing advantage of new technologies. They incorporate the enhanced colour displays and high quality imaging features needed to support service consumption and the creation of own content. Plus the exponential growth of memory capacity and processing power means that smart phones can now replicate the applications currently employed in notebook PCs and PDAs.

Consumers want the quality of fixed services with the flexibility of mobile and convergence lets this happen, by allowing service access through the most suitable access network, and by letting consumers choose the best device for the service. In many cases that device will be a smart phone, but it could just as easily be a PC or laptop with VoIP software or converged fixed clients who can share IM, presence etc with mobile devices, a fixed VoIP phone or even a TV with a set-top box.

Service Convergence

The mobility model has become 'me-centric', with my phone book, my contact information, my agenda, my messages, my availability and preferred communication method, my Internet, my pictures and video clips (received and shared), my personal and business email, my wall-paper, my music and so on. Multimedia services, such as Presence, Push-to-talk, messaging, interactive applications, data or video sharing plus streaming, browsing and downloading, are being delivered over fixed and mobile packet networks. To launch new services and applications quickly, operators can use IMS to eliminate the complexity of different service platforms in the network. Standards based Service Delivery Framework (SDF) provides comprehensive lifecycle management, making the launch of new services and applications quicker and easier to integrate and operate; delivering solutions more speedily to market and reducing the total cost of ownership. In effect the operator can provision – and the end-user quickly and conveniently self-provision – the new services.

VoIP and Instant Messaging are two developments that helped kick-start service convergence. VoIP has had a seismic impact on telephony within enterprises and, as the penetration of broadband access increases, so does the availability of this transport mechanism within the home. Users also benefit from personalized VoIP, including same number, same contacts and the same supplementary services like call barring, call waiting, ring back tones, one voice mail, option for one postpaid bill or prepaid account, etc through any access network. IP DSLAMs are letting operators offer both DSL access and traditional two-wire POTS connections using a SIP client in the DSLAM. This development and others like fixed VoIP phones, Analog Telephony Adapters (ATA) and fixed soft switches place fixed line operators in an excellent position. They can offer multimedia services via DSL and attractive tariffs for analog POTS connected to an IP network, thereby maintaining existing services where required and evolving the core network to an IP-based solution. Smart phones, on the other hand, have WLAN interfaces so they can access fixed broadband networks. This allows the mobile phone to be used as an IP phone and users to continue employing their personalized services at home, or via WLANs, connected to DSL, in hot spots or offices. Convergence in this case enables a practical combination of cellular and fixed broadband access. The user experience doesn't change: the same voice and multimedia services are used in the same way. Fixed to Mobile Substitution and fixed VoIP are gradually replacing PSTN voice telephony. Multimedia services are being delivered over fixed and mobile packet networks. Operators must now decide on the kinds of services they wish to provide by themselves or by partners, to whom and in which regions. And what they might offer is no longer limited to traditional telecom services only, but perhaps entry into new businesses.

1.3 Example of IMS Services

Switching on my Internet Protocol Multimedia Subsystem (IMS) enabled device, it will automatically register to the IMS network using information in the identity module (such as USIM). During registration both device and network are authenticated and my device will get my user identities from the network. After this single registration, all my services will be available, including push to talk, presence, voice and video sessions, messaging and multiplayer games. Moreover, my availability information is updated at the presence server as being "online" and listing my current applications.

When I need to contact my friend Bob, I select Bob from my device's phone book and, based on his presence information, I see immediately that he is available. After pressing the 'green button' on my device it will place an 'ordinary' call to him. The IMS network will take care of finding and setting up a Session Initiation Protocol (SIP) session between our devices, even though Bob is currently abroad. When my call reaches Bob's terminal he will see that the call is coming from me and, additionally, he sees a text string inserted by me ('Free tickets to movie next Wednesday'). Bob answers, but tells me that he's not sure whether he is able to come. We decide to check the issue again on Sunday. Before hanging up, Bob says to me, 'You won't believe what I saw today but just wait a second, I'll show you.' Bob starts streaming a video clip to me, and while I'm watching the video, Bob keeps explaining what happened in the zoo earlier that day.

Mike realizes that today is the birthday of his good friend Jill. Although he's travelling and can't meet her today, he wants to send Jill a personal birthday message. While Mike is sitting in a local coffee shop enjoying coffee and reading the latest news from the Internet using his brand-new Wireless Local Area Network (WLAN) device, he decides to send her a video clip as a birthday greeting. Jill is having a bath when she hears her phone ringing. She sees that she has received a message and checks it. She saves the video clip and decides to send something in return. Knowing that Mike knows her weird sense of humour, she sends a picture of herself taking a bath (Figure 1.3).

Peter Simpson is a Londoner and a die-hard Arsenal fan. With sheer luck he has managed to get tickets to an Arsenal–Tottenham derby and sets off to see the game. There he is, sitting at the stadium during the match, when suddenly he gets an irresistible urge to make his friend envious. He gets his mobile phone and makes a call to his friend John Clark, a Tottenham supporter. John is sitting at his desk and receives an incoming call pop-up on his PC screen, informing him that Peter is calling. He answers and they start to talk. Peter can't contain himself and starts the video-sharing application while zooming onto the field. John receives an incoming video request and accepts the stream. The PC client starts to show the game, and with a pang of jealousy and disappointment John watches Arsenal score. 'Nice goal, huh?' asks Peter. 'It ain't over yet,' says John, gritting his teeth, and ends the video stream. They continue to argue good-naturedly about the game and their teams over the phone.

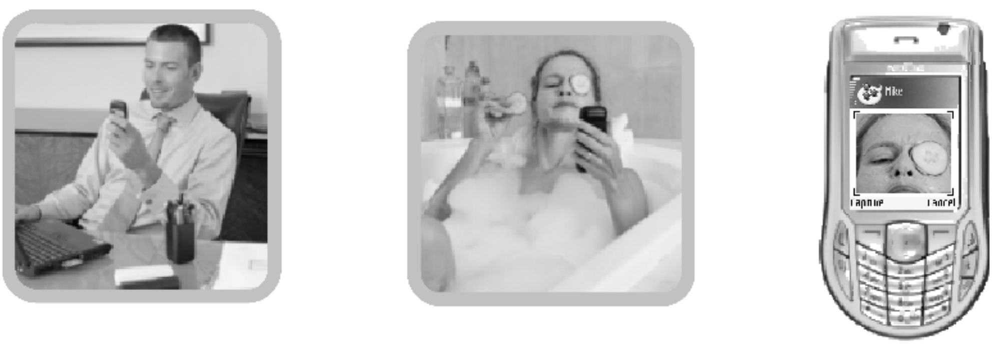

Figure 1.3 Multimedia messaging

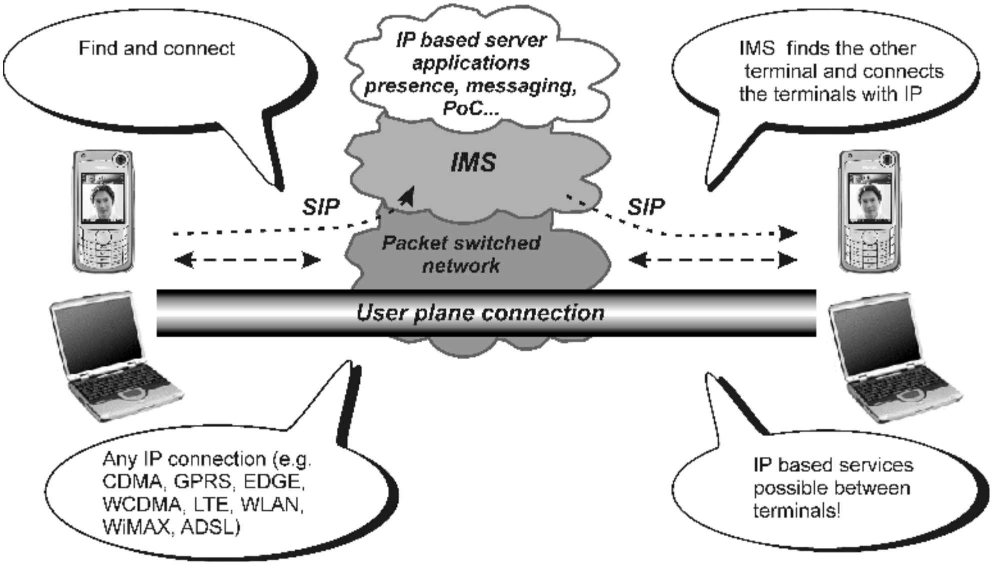

Figure 1.4 The role of the IMS in the packet switched networks

All the required communication takes place using the IP connectivity provided by the IMS as shown in Figure 1.4. The IMS offers the capability to select the best and most suitable communication media, to change the media during the session spontaneously, and use the preferred (SIP-capable) communication device over any IP access.

1.4 Where did it come from?

The European Telecommunications Standards Institute (ETSI) was the standardization organization that defined the Global System for Mobile Communications (GSM) during the late 1980s and 1990s. ETSI also defined the General Packet Radio Service (GPRS) network architecture. The last GSM-only standard was produced in 1998, and in the same year the 3GPP was founded by standardization bodies from Europe, Japan, South Korea, the USA and China to specify a 3G mobile system comprising Wideband Code Division Multiple Access (WCDMA) and Time Division/Code Division Multiple Access (TD-CDMA) radio access and an evolved GSM core network (www.3gpp.org/About/3gppagre.pdf). Most of the work and cornerstone specifications were inherited from the ETSI Special Mobile Group (SMG). The 3GPP originally decided to prepare specifications on a yearly basis, the first specification release being Release 99.

1.4.1 3GPP Release 99 (3GPP R99)

It took barely a year to produce the first release – Release 1999. The functionality of the release was frozen in December 1999 although some base specifications were frozen afterward – in March 2001. Fast completion was possible because the actual work was divided between two organizations: 3GPP and ETSI SMG. 3GPP developed the services, system architecture, WCDMA and TD-CDMA radio accesses, and the common core network. ETSI SMG developed the GSM/Enhanced Data Rates for Global Evolution (EDGE) radio access.

WCDMA radio access was the most significant enhancement to the GSM-based 3G system in Release 1999. In addition to WCDMA, UMTS Terrestrial Radio Access Network (UTRAN) introduced the Iu interface as well. Compared with the A and Gb interfaces, there are two significant differences. First, speech transcoding for Iu is performed in the core network. In the GSM it was logically a Base Transceiver Station (BTS) functionality. Second, encryption and cell-level mobility management for Iu are done in the Radio Network Controller (RNC). In GSM they were done in the Serving GPRS Support Node (SGSN) for GPRS services.

The Open Service Architecture (OSA) was introduced for service creation. On the service side the target was to stop standardizing new services and to concentrate on service capabilities, such as toolkits (CAMEL, SIM Application Toolkit and OSA). This principle was followed quite well, even though the Virtual Home Environment (VHE), an umbrella concept that covers all service creation, still lacks a good definition.

1.4.2 3GPP Release 4

After Release 1999, 3GPP started to specify Release 2000, including the so-called All-IP that was later renamed as the IMS. During 2000 it was realized that the development of IMS could not be completed during the year. Therefore, Release 2000 was split into Release 4 and Release 5.

It was decided that Release 4 would be completed without the IMS. The most significant new functionalities in 3GPP Release 4 were: the Mobile Switching Centre (MSC) Server–Media Gateway (MGW) concept, IP transport of core network protocols, Location Services (LCS) enhancements for UTRAN and multimedia messaging and IP transport for the Gb user plane.

3GPP Release 4 was functionally frozen and officially completed in March 2001. The backward compatibility requirement for changes, essential for the radio interface, was enforced as late as September 2002.

1.4.3 3GPP Releases 5 and 6

Release 5 finally introduced the IMS as part of 3GPP specifications. The IMS is supposed to be a standardized access-independent IP-based architecture that interworks with existing voice and data networks for both fixed (e.g., PSTN, ISDN, Internet) and mobile users (e.g., GSM, CDMA). The IMS architecture makes it possible to establish peer-to-peer IP communications with all types of clients with the requisite quality of services. In addition to session management, the IMS architecture also addresses functionalities that are necessary for complete service delivery (e.g., registration, security, charging, bearer control, roaming). All in all, the IMS will form the heart of the IP core network.

The content of Release 5 was heavily discussed and, finally, the functional content of 3GPP Release 5 was frozen in March 2002. The consequence of this decision was that many features were postponed to the next release – Release 6. After freezing the content, the work continued and reached stability at the beginning of 2004. The Release 5 defines a finite architecture for SIP-based IP multimedia service machinery. It contains a functionality of logical elements, a description of how elements are connected, selected protocols (see Chapter 2) and procedures (see Chapter 3). In addition, it is important to realize that optimization for the mobile communication environment has been also designed in the form of user authentication and authorization based on mobile identities (see Chapter 11), definite rules at the user network interface for compressing SIP messages (see Section 3.18) and security (see Section 3.21) and policy control mechanisms (see Section 3.10.3) that allow radio loss and recovery detection. Moreover, important aspects from the operator point of view are addressed while developing the architecture, such as the charging framework (see Section 3.11) and policy (see Section 3.10), and service control (see Section 3.13).

Release 6 IMS fixes the shortcomings in Release 5 IMS and also contains novel features. Release 6 was completed in September 2005. If Release 5 created the IMS machine we call Release 6 as the IMS application and interworking release. The Release 6 introduced standardized enhancements for services such as routing and signalling modifications e.g. Public Service Identity (see Section 3.5.5 and Section 12.11), sharing a single user identity between multiple devices (see Section 3.7). Improvements in routing capabilities smoothed the road to complete new standardized services such as presence (see Chapter 4), messaging (see Chapter 7), conferencing (see Chapter 8), PoC (see Chapter 6). In addition, IMS-CS voice interworking and WLAN access to IMS were completed. Moreover, improvements in security, policy and charging control and overall architecture were also completed.

1.4.4 IMS Development in other Standardization Development Organizations

While 3GPP has finalized its Release 5 and Release 6 other standardization development organizations have done parallel developments to define their IMS variants. Most notable development organizations having own variants are ETSI Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN), Third Generation Partnership Project 2 (3GPP2) and Cablelabs.

TISPAN is the outcome of the merger of two ETSI bodies and it is building specifications to enable migration from fixed circuit switched networks to fixed packet-based networks with an architecture that can serve in both, also known as Next Generation Network (NGN). December 2005 TISPAN declared that they have completed the first NGN release (Release 1) that contained IP multimedia component. This IP multimedia component was based on 3GPP Release 6 and 7 IMS with TISPAN specific extensions and modifications. Since 2005 TISPAN has been working with its Release 2 which is expected to be completed during 2008.

3GPP2 created its IMS variant to support CDMA2000 access. This IMS variant is also known as Multimedia Domain (MMD). 3GPP2 has used 3GPP IMS specification as a starting point and at the time of writing 3GPP2 has three MMD releases: MMD-0, MMD-A, MMD-B.

Cablelabs is a development consortium that is defining specification for cable operators. An IMS like building block is present in their PacketCable 2.0 release. Again Cablelabs is using 3GPP IMS as a baseline.

Figure 1.5 depicts major development paths of IMS standards. This figure clearly reveals that there exists fragmentation in the IMS standardization arena. Luckily the industry has taken decisive steps towards harmonized IMS, the common IMS. Common IMS technology in all mobile and fixed ecosystems provides economies of scale to both the operators

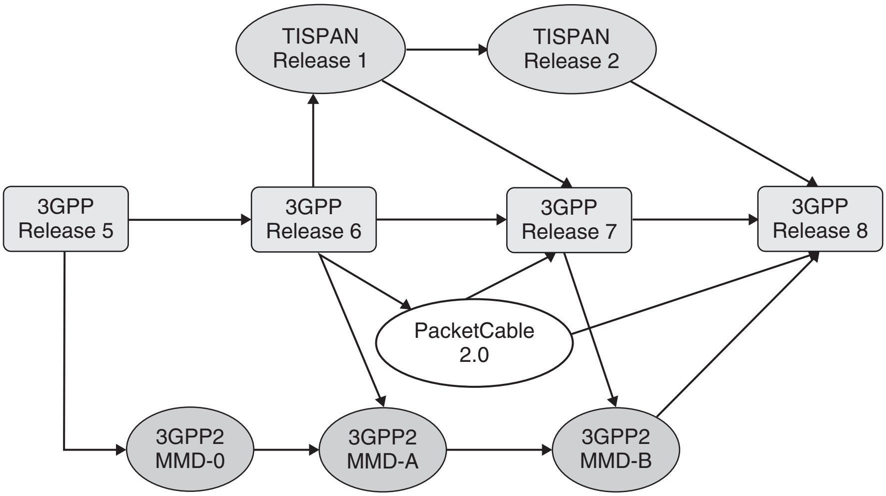

Figure 1.5 Road to standardized common IMS standards

and vendors in different ways. IMS vendors will be able to create the functionality once, and reuse it later. This means faster time to market, lower research and development cost due to eliminated replication effort. From an operator and service provider point of view it means that they will have a larger choice of vendors to select from and procurement cost of IMS products is lower. During 2007 3GPP and TISPAN made an agreement to stop IMS related development in TISPAN and focus all IMS development to 3GPP. Based on this agreement lot of functions and procedures developed in TISPAN Release 1 were included in 3GPP Release 7. TISPAN Release 2 is expected to be the last TISPAN release on IMS matters and functions and procedures are expected to be harmonized in 3GPP Release 8. Some Packetcable 'IMS' features were already included in 3GPP Release 7 and additional features and procedures originating from cable operators will be addressed in 3GPP Release 8. Harmonization of 3GPP2 MMD and 3GPP IMS is starting in Release 8. Due to late start full harmonization will probably happen in future 3GPP IMS releases.

1.4.5 3GPP Release 7 and common IMS

3GPP Release 7 functional content was frozen in March 2007. It introduces two more access technologies (Data Over Cable Service Interface Specification (DOCSIS)[1] and xDSL[2]) and features and procedures originating from those and other general improvements. This can be considered as a step towards the ultimate goal of single common IMS. Major new features in Release 7 are: IMS multimedia telephony including supplementary services (see Chapter 9 and Chapter 12), SMS over any IP access (see Chapter 7, Section 7.4), Voice Call Continuity (see Section 3.20 and Chapter 13), local numbering (see Section 3.16), Combining CS calls and IMS sessions (see Section 3.19), Transit IMS (see Section 3.15), Interconnection Border Control Function (IBCF) (see Section 2.2.6.2),

[1] Access technology of Cablelabs.
[2] Access technology of TISPAN.

Globally Routable User Agent's URI (see Section 3.5.6 and Section 12.10), IMS emergency sessions (see Section 3.17), Identification of Communication Services in IMS(see Section 12.3.9) and new authentication model for fixed access (see Section 3.21.2.3).

1.4.6 Insight to 3GPP Release 8

Standardization work on Release 8 is ongoing at the time of writing and work is expected to be completed by the end of 2008. This release will introduce a number of novel IMS features such as IMS centralized services which enables the use of IMS service machinery even though devices are using CS connection (GSM/3G CS radio) towards the network; multimedia session continuity which would improve the voice call continuity feature to enable continuity of multimedia media streams when IP access is changed; corporate access to IMS, a feature that enables integratation of IP-PBX to the IMS network; service level interworking for messaging and number portability.

1.5 Why a SIP Solution Based on 3GPP Standards?

IETF is the protocol factory for Internet world and it is doing great work in this space but it does not define the ways that they are used, especially in the mobile domain. 3GPP is the body that took Session Initiation Protocol (SIP) as the control protocol for multimedia communication and 3GPP has built a finite architecture for SIP-based IP multimedia service machinery (the IMS). It contains a functionality of logical elements, a description of how elements are connected, selected protocols and procedures. 3GPP standardized solutions are needed to provide: interoperability between terminals from different vendors, interoperability between network elements from different vendors, interoperability across operator boundaries. The following advantages of 3GPP IMS against a pure IETF SIP service model can be listed:

- optimization for wireless usage:
  - SIP compression (see Section 3.18);
  - implicit registration (see Section 3.3);
  - network initiated re-authentication (see Section 11.14.2);
  - network initiated deregistration (see Section 11.15.3);
- authentication:
  - GPRS-IMS-Bundled Authentication (see Section 11.16);
  - NASS-IMS-Bundled Authentication (see Section 3.21.2.3);
  - ISIM/USIM authentication (see Section 11.6);
- policy control (see Section 3.10):
  - policy control and policy enforcement functions;
  - Rx and Gx reference points;
  - quality of Service (QoS);
- charging (see Section 3.11):
  - charging correlation (online and offline charging);
  - charging entity information;

- services and application server interfaces:
  - ISC interface (see Section 2.3.3);
  - Initial Filter Criteria (see Section 3.12.4);
- access network information available in IMS (see Section 11.11.1);
- mobility and roaming models defined (see Section 2.1.7);
- visited network identification (see Section 11.11.2);
- regulator requirements specified:
  - emergency call (incl. location information) (see Section 3.17);
  - legal interception;
  - number portability.