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3G Networking

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ABSTRACT

3G is the third generation of tele standards and technology for mobile networking, superseding 2.5G. It is based on the International Telecommunication Union (ITU) family of standards under the IMT-2000. 3G networks enable network operators to offer users a wider range of more advanced services while achieving greater network capacity through improved spectral efficiency. Services include wide-area wireless voice telephony, video calls, and broadband wireless data, all in a mobile environment. Additional features also include HSPA data transmission capabilities able to deliver speeds up to 14.4 Mbit/s on the downlink and 5.8 Mbit/s on the uplink.Unlike IEEE 802.11 networks, which are commonly called Wi-Fi or WLAN networks, 3G networks are wide-area cellular telephone networks that evolved to incorporate high-speed Internet access and video telephony. IEEE 802.11 networks are short range, high-bandwidth networks primarily developed for data.

1. IMPLEMENTATION AND HISTORY

The first pre-commercial 3G network was launched by NTT DoCoMo in Japan branded FOMA, in May 2001 on a pre-release of W-CDMA technology. The first commercial launch of 3G was also by NTT DoCoMo in Japan on October 1, 2001. The second network to go commercially live was by SK Telecom in South Korea on the 1xEV-DO technology in January 2002. By May 2002 the second South Korean 3G network was by KTF on EV-DO and thus the Koreans were the first to see competition among 3G operators.The first European pre-commercial network was at the Isle of Man by Manx Telecom, the operator then owned by British Telecom, and the first commercial network in Europe was opened for business by Telenor in December 2001 with no commercial handsets and thus no paying customers. These were both on the W-CDMA technology.

The first commercial United States 3G network was by Monet Mobile Networks, on CDMA2000 1x EV-DO technology, but this network provider later shut down operations. The second 3G network operator in the USA was Verizon Wireless in October 2003 also on CDMA2000 1x EV-DO, and this network has grown strongly since then.

The first pre-commercial demonstration network in the southern hemisphere was built in Adelaide, South Australia by m.Net Corporation in February 2002 using UMTS on 2100 MHz. This was a demonstration network for the 2002 IT World Congress. The first commercial 3G network was launched by Hutchison Telecommunications branded as Three in April 2003.In December 2007, 190 3G networks were operating in 40 countries and 154 HSDPA networks were operating in 71 countries, according to the Global Mobile Suppliers Association (GSA). In Asia, Europe, Canada and the USA, telecommunication companies use W-CDMA technology with the support of around 100 terminal designs to operate 3G mobile networks.

In Europe, mass market commercial 3G services were introduced starting in March 2003 by 3 (Part of Hutchison Whampoa) in the UK and Italy. The European Union Council suggested that the 3G operators should cover 80% of the European national populations by the end of 2005.Roll-out of 3G networks was delayed in some countries by the enormous costs of additional spectrum licensing fees. (See Telecoms crash.) In many countries, 3G networks do not use the same radio frequencies as 2G, so mobile operators must build entirely new networks and license entirely new frequencies; an exception is the United States where carriers operate 3G service in the same frequencies as other services. The license fees in some European countries were particularly high, bolstered by government auctions of a limited number of licenses and sealed bid auctions, and initial excitement over 3G's potential. Other delays were due to the expenses of upgrading equipment for the new systems.By June 2007 the 200 millionth 3G subscriber had been connected. Out of 3 billion mobile phone subscriptions worldwide this is only 6.7%. In the countries where 3G was launched first - Japan and South Korea - 3G penetration is over 70%[2]. In Europe the leading country is Italy with a third of its subscribers migrated to 3G. Other leading countries by 3G migration include UK, Austria, Australia and Singapore at the 20% migration level. A confusing statistic is counting CDMA 2000 1x RTT customers as if they were 3G customers. If using this oft-disputed[by whom?] definition, then the total 3G subscriber base would be 475 million at June 2007 and 15.8% of all subscribers worldwide.

Still several major countries such as Indonesia have not awarded 3G licenses and customers await 3G services. China has been delaying its decisions on 3G for many years, partly hoping to have the Chinese 3G standard, TD-SCDMA, to mature for commercial production. Finally in January 2009, Ministry of industry and Information Technology of China has awarded licenses of all three standardsÿTD-SCDMA to China Mobile, WCDMA to China Unicom and CDMA2000 to China Telecom.

In November 2008, Turkey has auctioned four IMT 2000/UMTS standard 3G licenses with 45, 40, 35 and 25 MHz top frequencies. Turkcell has won the 45MHz band with its €358 million offer followed by Vodafone and Avea leasing the 40 and 35MHz frequencies respectively for 20 years. The 25MHz top frequency license remains to be auctioned.China announced in May 2008, that the telecoms sector was re-organized and three 3G networks would be allocated so that the largest mobile operator, China Mobile, would retain its GSM customer base and launch 3G onto the Chinese standard, TD-SCDMA. China Unicom would retain its GSM customer base but relinquish its CDMA2000 customer base, and launch 3G on the globally leading WCDMA (UMTS) standard. The CDMA2000 customers of China Unicom would go to China Telecom, which would then launch 3G on the CDMA 1x EV-DO standard. This means that China will have all three main cellular technology 3G standards in commercial use.

The first African use of 3G technology was a 3G videocall made in Johannesburg on the Vodacom network in November 2004. The first commercial launch of 3G in Africa was by EMTEL in Mauritius on the W-CDMA standard. In north African Morocco in late March 2006, a 3G service was provided by the new company Wana.Rogers Wireless began implementing 3G HSDPA services in eastern Canada early 2007 in the form of Rogers Vision. Fido Solutions and Rogers Wireless now offer 3G service in most urban centres.

1.1. UMTS Terminals

The technical complexities of a 3G phone or handset depends on its need to roam onto legacy 2G networks. In the first country, Japan, there was no need to include roaming capabilities to older networks such as GSM, so 3G phones were small and lightweight. In most other countries, the manufacturers and network operators wanted multi-mode 3G phones which would operate on 3G and 2G networks (e.g., W-CDMA and GSM), which added to the complexity, size, weight, and cost of the handset. As a result, early European W-CDMA phones were significantly larger and heavier than comparable Japanese W-CDMA phones.

Japan's Vodafone KK experienced a great deal of trouble with these differences when its UK-based parent, Vodafone, insisted the Japanese subsidiary use standard Vodafone handsets. Japanese customers who were accustomed to smaller handsets were suddenly required to switch to European handsets that were much bulkier and considered unfashionable by Japanese consumers. During this conversion, Vodafone KK lost 6 customers for every 4 that migrated to 3G. Soon thereafter, Vodafone sold the subsidiary which is now known as SoftBank Mobile.

The general trend to smaller and smaller phones seems to have paused, perhaps even turned, with the capability of large-screen phones to provide more video, gaming and internet use on the 3G networks, and further fuelled.

1.2. Speed

The ITU has not provided a clear definition of the speeds users can expect from 3G equipment or providers. Thus users sold 3G service may not be able to point to a standard and say that the speeds it specifies are not being met. While stating in commentary that "it is expected that IMT-2000 will provide higher transmission rates: a minimum speed of 2Mbit/s and maximum of 14.4Mbit/s for stationary users, and 348 kbit/s in a moving vehicle," the ITU does not actually clearly specify minimum or average speeds or what modes of the interfaces qualify as 3G, so various speeds are sold as 3G intended to meet customers expectations of broadband speed. It is often suggested by industry sources that 3G can be expected to provide 384 kbit/s at or below pedestrian speeds, but only 128 kbit/s in a moving car. While EDGE is part of the 3G standard, some phones report EDGE and 3G network availability as separate things.

1.3. Network Standardization

The International Telecommunication Union (ITU) defined the demands for 3G mobile networks with the IMT-2000 standard. An organization called 3rd Generation Partnership Project (3GPP) has continued that work by defining a mobile system that fulfills the IMT-2000 standard. This system is called Universal Mobile Telecommunications System (UMTS).

1.3.1. IMT-2000 Standards and Radio Interfaces

International Telecommunications Union (ITU): IMT-2000 consists of six radio interfaces:

- W-CDMA also known as UMTS;
- CDMA2000;
- TD-CDMA / TD-SCDMA;
- UWC (often implemented with EDGE);
- DECT;
- Mobile WiMAX.

1.3.2. Advantages of a Layered Network Architecture

Unlike GSM, UMTS is based on layered services. At the top is the services layer, which provides fast deployment of services and centralized location. In the middle is the control layer, which helps upgrading procedures and allows the capacity of the network to be dynamically allocated. At the bottom is the connectivity layer where any transmission technology can be used and the voice traffic will transfer over ATM/AAL2 or IP/RTP.

1.4. 3G Evolution (pre-4G)

The standardization of 3G evolution is progressing in both 3GPP and 3GPP2. The corresponding specifications of 3GPP and 3GPP2 evolutions are named as LTE and UMB, respectively. Development on UMB has been cancelled by Qualcomm as of November 2008. 3G evolution uses partly beyond 3G technologies to enhance the performance and to make a smooth migration path.

There are several different paths from 2G to 3G. In Europe the main path starts from GSM when GPRS is added to a system. From this point it is possible to go to the UMTS system. In North America the system evolution will start from Time division multiple access (TDMA), change to Enhanced Data Rates for GSM Evolution (EDGE) and then to UMTS.

In Japan, two 3G standards are used: W-CDMA used by NTT DoCoMo (FOMA, compatible with UMTS) and Softbank Mobile (UMTS), and CDMA2000, used by KDDI. Transition for market purposes to 3G was completed in Japan in 2006.The first introduction of 3G (UMTS/HSDPA) technology in the Caribbean (2007) was done by SETAR in Aruba in December 2007. The Implementation phase of this network was carried out by Alcatel-Lucent. SETAR had also implemented a 3G network based on CDMA 1X EV-DO in April 2007.Not just broadband internet can be exploited from multi megabit speeds. Video calling and VOIP. HSDPA (High Speed Data Packet Access) has capabilities of bringing 14.4 Mbit/s downstream; this is faster than most standard lines, and even some in cities in well developed areas. Not to mention capabilities of 5.8Mbit/s uplink that is more than ten times standard ADSL, and almost seven times the leading cable provider; Virgin Media.

There are now around 400 3G and HSDPA networks around the world in a quarter of the world's countries. The migration of global subscribers to 3G has passed 15%, and in countries where 3G has been launched, the migration rate is over 35% by the end of 2008. Many operators have launched low cost or fixed rate data plans for 3G data use which has increased usage and lowered costs. At the launch of 3.5G HSDPA, in many markets this technology is provided as a portable "broadband" modem connection for laptop and even desktop computer users and priced at the low end of broadband pricing. 3G data is however expensive when roaming, with the average cost per megabyte is still in the £5.00/mb range. It would be hard to use many megabytes due to the undeveloped speeds that many networks provide.

In the UK the mobile network 3 (Three) boasts that 90% of the UKs population is covered with 3G, and 99% with the standard talk and text network (2G/2.5G/EDGE)As anticipated, if stationary, or walking slowly you can expect a minimum of 2Mbit/s. but if in a car doing average city speeds, this falls to 348kbit/s. 3G networks in Britain offer a variety of packages. Going up from 1.8Mbit/s on networks such as T-Mobile and right up as far as 7.2Mbit/s; the same speed as a fixed line within a few hundred metres from its exchange is possible in urban areas of London taking the whole concept of fast easy mobile broadband up to a whole new level. The packages they offer however cannot give you that sustained 7.2Mbit/s, a typical 3GB (3072megabytes) plan costs between £15 and £20 a month. Three is offering 15GB for a record breaking £30 a month or £15 if you have a contract with them already. Three however does not give such headline speeds as Vodafone.

3G is still in its early years, high prices are to be anticipated because of high fees for frequency licensing and the sheer cost of employing dozens and dozens of teams of engineers to implement a nationwide network and then to maintain it. Canada, for example, boasts some of the highest data access fees in the world for subscribers. Without a data contract 1KB of data is charged at $0.05, translating to $50 per megabyte used on Canada's GSM providers Rogers and Fido. A 4G network is in the pipe line, capable of speeds of 100Mbit/s while moving and 1Gbit/s stationary. This however will not see the light of day until at least four, or even eight years time when they have the right equipment to use it. By that stage, bandwidth will be all around us to take advantage of.

2. EVOLUTION FROM 2G TO 3G

2G networks were built mainly for voice data and slow transmission. Due to rapid changes in user expectation, they do not meet today's wireless needs. Evolution from 2G to 3G can be sub-divided into following phases:

- 2G to 2.5G;
- 2.5G to 2.75G;
- 2.75G to 3G.

2.1. From 2G to 2.5G (GPRS)

The first major step in the evolution to 3G occurred with the introduction of General Packet Radio Service (GPRS). So the cellular services combined with GPRS became 2.5G.

GPRS could provide data rates from 56 kbit/s up to 114 kbit/s. It can be used for services such as Wireless Application Protocol (WAP) access, Short Message Service (SMS), Multimedia Messaging Service (MMS), and for Internet communication services such as email and World Wide Web access. GPRS data transfer is typically charged per megabyte of traffic transferred, while data communication via traditional circuit switching is billed per minute of connection time, independent of whether the user actually is utilizing the capacity or is in an idle state.

GPRS is a best-effort packet switched service, as opposed to circuit switching, where a certain Quality of Service (QoS) is guaranteed during the connection for non-mobile users. It provides moderate speed data transfer, by using unused Time division multiple access (TDMA) channels. Originally there was some thought to extend GPRS to cover other standards, but instead those networks are being converted to use the GSM standard, so that GSM is the only kind of network where GPRS is in use. GPRS is integrated into GSM Release 97 and newer releases. It was originally standardized by European Telecommunications Standards Institute (ETSI), but now by the 3rd Generation Partnership Project (3GPP).

2.2. From 2.5G to 2.75G

GPRS networks evolved to EDGE networks with the introduction of 8PSK encoding. Enhanced Data rates for GSM Evolution (EDGE), Enhanced GPRS (EGPRS), or IMT Single Carrier (IMT-SC) is a backward-compatible digital mobile phone technology that allows improved data transmission rates, as an extension on top of standard GSM. EDGE can be considered a 3G radio technology and is part of ITU's 3G definition, but is most frequently referred to as 2.75G. EDGE was deployed on GSM networks beginning in 2003—initially by Cingular (now AT&T) in the United States.

EDGE is standardized by 3GPP as part of the GSM family, and it is an upgrade that provides a potential three-fold increase in capacity of GSM/GPRS networks. The specification achieves higher data-rates by switching to more sophisticated methods of coding (8PSK), within existing GSM timeslots. EDGE can be used for any packet switched application, such as an Internet, video and other multimedia.

2.3. From 2.75G to 3G

From EDGE networks the introduction of UMTS networks and technology is called pure 3G. 3G Bandwidth 5 MHz

2.4. Migrating from GPRS to UMTS

From GPRS network, the following network elements can be reused:

- Home location register (HLR);
- Visitor location register (VLR);
- Equipment identity register (EIR);
- Mobile switching centre (MSC) (vendor dependent);
- Authentication centre (AUC);
- Serving GPRS Support Node (SGSN) (vendor dependent);
- Gateway GPRS Support Node (GGSN).

From Global Service for Mobile (GSM) communication radio network, the following elements cannot be reused

- Base station controller (BSC);
- Base transceiver station (BTS).

They can remain in the network and be used in dual network operation where 2G and 3G networks co-exist while network migration and new 3G terminals become available for use in the network.

The UMTS network introduces new network elements that function as specified by 3GPP:

- Node B (base station);
- Radio Network Controller (RNC);
- Media Gateway (MGW).

The functionality of MSC and SGSN changes when going to UMTS. In a GSM system the MSC handles all the circuit switched operations like connecting A- and B-subscriber through the network. SGSN handles all the packet switched operations and transfers all the data in the network. In UMTS the Media gateway (MGW) take care of all data transfer in both circuit and packet switched networks. MSC and SGSN control MGW operations. The nodes are renamed to MSC-server and GSN-server.

3. SECURITY

3G networks offer a greater degree of security than 2G predecessors. By allowing the UE to authenticate the network it is attaching to, the user can be sure the network is the intended one and not an impersonator. 3G networks use the KASUMI block crypto instead of the older A5/1 stream cipher. However, a number of serious weaknesses in the KASUMI cipher have been identified.

In addition to the 3G network infrastructure security, end to end security is offered when application frameworks such as IMS are accessed, although this is not strictly a 3G property.

4. ISSUES

Although 3G was successfully introduced to users across the world, some issues are debated by 3G providers and users:

- Expensive input fees for the 3G service licenses & agreements;
- Numerous differences in the licensing terms;
- Large amount of debt currently sustained by many telecommunication companies, which makes it a challenge to build the necessary infrastructure for 3G;
- Lack of member state support for financially troubled operators;
- Expense of 3G phones;
- Lack of buy-in by 2G mobile users for the new 3G wireless services;
- Lack of coverage, because it is still a new service;
- High prices of 3G mobile services in some countries, including Internet access (see flat rate);
- Current lack of user need for 3G voice and data services in a hand-held device.

5. 3GP

3GP is a multimedia container format defined by the Third Generation Partnership Project (3GPP) for use on 3G mobile phones but can also be played on some 2G and 4G phones.

5.1. Technical Details

3GP is a simplified version of the MPEG-4 Part 14 (MP4) container format, designed to decrease storage and bandwidth requirements in order to accommodate mobile phones. It stores video streams as MPEG-4 Part 2 or H.263 or MPEG-4 Part 10 (AVC/H.264), and audio streams as AMR-NB, AMR-WB, AMR-WB+, AAC-LC or HE-AAC. A 3GP file is always big-endian, storing and transferring the most significant bytes first. It also contains descriptions of image sizes and bit rate. There are two different standards for this format:

- 3GPP (for GSM-based Phones, may have filename extension .3gp);
- 3GPP2 (for CDMA-based Phones, may have filename extension .3g2).

Both are based on MPEG-4 and H.263 video, and AAC or AMR audio.

When transferred to a computer, 3GP movies can be viewed on Linux, Mac, and Windows platforms with MPlayer and VLC media player. Programs such as Media Player Classic, Totem, RealPlayer, QuickTime, and GOM Player can also be used. Some cell phones use the .mp4 extension for 3GP video.

5.2. Device Support

Most 3G capable mobile phones support the playback and recording of video in 3GP format (memory, maximum file size for playback and recording, and resolution limits exist and vary). Some newer/higher-end phones without 3G capabilities may also playback and record in this format (again, with said limitations). In iMovie ’08, a movie exported using the “Tiny” setting is saved as a .3gp file and can be played on a Mac, an iPhone (as well as any other handset able to load and play the file), an iPod touch or using Apple’s .Mac Web Gallery service. Audio imported from CD onto a PlayStation 3 when it is set to encode to the MPEG-4 AAC codec will copy onto USB devices in the 3GP format.

6. DIGRF V3

DigRFSM

The DigRFSM WG was formed as a MIPI Alliance (MIPI) working group in April 2007. The group is focused on developing specifications for wireless mobile RFIC to BBIC interfaces in mobile devices.

The group’s current charter is split into short and long term development efforts. The short term development will focus on a specification targeted for completion by end of 2007 for LTE and WiMax air interface standards. The longer term development will focus on future air interface standards which promise further improvements in high speed, data optimized traffic. In addition, the future work will seek to harmonize efforts with the MIPI’s PHY and UniPro Working Groups. These specifications will describe the logical, electrical and timing characteristics of the digital RF-BB Interface with sufficient detail to allow physical implementation of the interface, and with sufficient rigor that implementations of the interface from different suppliers are fully compatible at the physical level.

7. IP MULTIMEDIA SUBSYSTEM

The IP Multimedia Subsystem (IMS) is an architectural framework for delivering internet protocol (IP) multimedia services. It was originally designed by the wireless standards body 3rd Generation Partnership Project (3GPP), as a part of the vision for evolving mobile networks beyond GSM. Its original formulation (3GPP R5) represented an approach to delivering "Internet services" over GPRS. This vision was later updated by 3GPP, 3GPP2 and TISPAN by requiring support of networks other than GPRS, such as Wireless LAN, CDMA2000 and fixed line. Notably though, as of now, many (most) companies do not use IMS to deploy these services.

To ease the integration with the Internet, IMS uses IETF (i.e., Internet) protocols wherever possible e.g. Session Initiation Protocol (SIP). According to the 3GPP[1], IMS is not intended to standardize applications but rather to aid the access of multimedia and voice applications from wireless and wire line terminals, i.e. create a form of fixed mobile convergence (FMC). This is done by having a horizontal control layer that isolates the access network from the service layer. From a logical architecture perspective, Services need not have their own control functions, as the control layer is a common horizontal layer. However in implementation this does not necessarily map into greater reduced cost and complexity.

Alternative and overlapping technologies for access and provisioning of services across wired and wireless networks include combinations of Generic Access Network, soft switches and "naked" SIP. This contributes to making the business case for the use of IMS less appealing. It is easier to sell services than to sell the virtues of "integrated services", but additionally the task to sell an IMS based on a service is also difficult as there are often (cheaper) alternatives to creating and deploying that service. Since IMS was conceived years ago, it is becoming increasingly easier to access content and contacts using mechanisms outside the control of traditional wireless/fixed operators, and so those operators are likely to reconsider their strategies. It is unclear how much of the 3GPP/3GPP2/TISPAN IMS specifications as exist today will ever be implemented or deployed.

7.1. History

IMS was originally defined by an industry forum called 3G.IP, formed in 1999. 3G.IP developed the initial IMS architecture, which was brought to the 3rd Generation Partnership Project (3GPP), as part of their standardization work for 3G mobile phone systems in UMTS networks. It first appeared in release 5 (evolution from 2G to 3G networks), when SIP-based multimedia was added. Support for the older GSM and GPRS networks was also provided. 3GPP2 (a different organization than 3GPP) based their CDMA2000 Multimedia Domain (MMD) on 3GPP IMS, adding support for CDMA2000. 3GPP release 6 added inter working with WLAN. 3GPP release 7 added support for fixed networks, by working together with TISPAN release R1.1, the function of AGCF (Access Gateway control function) and PES(PSTN Emulation Service) are introduced to the wire-line network for the sake of inheritance of services which can be provided in PSTN network.

7.2. Architecture 3GPP / TISPAN IMS Architectural Overview

The IP Multimedia Core Network Subsystem is a collection of different functions, linked by standardized interfaces, which grouped form one IMS administrative network. A function is not a node (hardware box): an implementer is free to combine 2 functions in 1 node, or to split a single function into 2 or more nodes. Each node can also be present multiple times in a single network, for load balancing or organizational issues.

7.2.1. Access Network

The user can connect to an IMS network in various ways, all of which use the standard Internet Protocol (IP). Direct IMS terminals (such as mobile phones, personal digital assistants (PDAs) and computers) can register directly on an IMS network, even when they are roaming in another network or country (the visited network). The only requirement is that they can use IPv6 (also IPv4 in early IMS) and run Session Initiation Protocol (SIP) user agents. Fixed access (e.g., Digital Subscriber Line (DSL), cable modems, Ethernet), mobile access (e.g. W-CDMA, CDMA2000, GSM, GPRS) and wireless access (e.g. WLAN, WiMAX) are all supported. Other phone systems like plain old telephone service (POTS — the old analogue telephones), H.323 and non IMS-compatible VoIP systems, are supported through gateways.

7.2.2. Core Network

7.2.2.1. Home Subscriber Server

The Home Subscriber Server (HSS), or User Profile Server Function (UPSF), is a master user database that supports the IMS network entities that actually handle calls. It contains the subscription-related information (user profiles), performs authentication and authorization of the user, and can provide information about the user's physical location. It is similar to the GSM Home Location Register (HLR) and Authentication Centre (AUC).

A Subscriber Location Function (SLF) is needed to map user addresses when multiple HSSs are used. Both the HSS and the SLF communicate through the Diameter protocol. This Diameter is also called as AAA protocol i.e Authentication, Accounting and Authorization

7.2.2.1.1 User identities

Normal 3GPP networks use the following identities:

- International Mobile Subscriber Identity (IMSI).
- Temporary Mobile Subscriber Identity (TMSI).
- International Mobile Equipment Identity (IMEI).
- Mobile Subscriber ISDN Number (MSISDN).

IMSI is a unique phone identity that is stored in the SIM. To improve privacy, a TMSI is generated per geographical location. While IMSI/TMSI are used for user identification, the IMEI is a unique device identity and is phone specific. The MSISDN is the telephone number of a user. IMS also requires IP Multimedia Private Identity (IMPI) and IP Multimedia Public Identity (IMPU). Both are not phone numbers or other series of digits, but Uniform Resource Identifier (URIs), that can be digits (a tel-uri, like tel:+1-555-123-4567) or alphanumeric identifiers (a sip-uri, like sip:john.doe@example.com). There can be multiple IMPU per IMPI (often a tel-uri and a sip-uri). The IMPU can also be shared with another phone, so both can be reached with the same identity (for example, a single phone-number for an entire family).

The HSS user database contains the IMPU, IMPI, IMSI, and MSISDN and other information.

7.2.2.2. Call/session Control

Several roles of Session Initiation Protocol (SIP) servers or proxies, collectively called Call Session Control Function (CSCF), are used to process SIP signaling packets in the IMS.

A Proxy-CSCF (P-CSCF) is a SIP proxy that is the first point of contact for the IMS terminal. It can be located either in the visited network (in full IMS networks) or in the home network (when the visited network isn't IMS compliant yet). Some networks may use a Session Border Controller for this function. The terminal discovers its P-CSCF with either DHCP, or it is assigned in the PDP Context (in General Packet Radio Service (GPRS)). it is assigned to an IMS terminal during registration, and does not change for the duration of the registration it sits on the path of all signaling messages, and can inspect every message.

It authenticates the user and establishes an IPsec security association with the IMS terminal. This prevents spoofing attacks and replay attacks and protects the privacy of the user. Other nodes trust the P-CSCF, and do not have to authenticate the user again.

It can also compress and decompress SIP messages using SigComp, which reduces the round-trip over slow radio links.

It may include a Policy Decision Function (PDF), which authorizes media plane resources e.g. quality of service (QoS) over the media plane. It's used for policy control, bandwidth management, etc. The PDF can also be a separate function.

It also generates charging records.

A Serving-CSCF (S-CSCF) is the central node of the signaling plane. It is a SIP server, but performs session control too. It is always located in the home network. It uses Diameter Cx and Dx interfaces to the HSS to download and upload user profiles — it has no local storage of the user. All necessary information is loaded from the HSS.

It handles SIP registrations, which allows it to bind the user location (e.g. the IP address of the terminal) and the SIP address it sits on the path of all signaling messages, and can inspect every message it decides to which application server(s) the SIP message will be forwarded, in order to provide their services it provides routing services, typically using Electronic Numbering (ENUM) lookups it enforces the policy of the network operator there can be multiple S-CSCFs in the network for load distribution and high availability reasons. It's the HSS that assigns the S-CSCF to a user, when it's queried by the I-CSCF.

An Interrogating-CSCF (I-CSCF) is another SIP function located at the edge of an administrative domain. Its IP address is published in the Domain Name System (DNS) of the domain (using NAPTR and SRV type of DNS records), so that remote servers can find it, and use it as a forwarding point (e.g. registering) for SIP packets to this domain. The I-CSCF queries the HSS using the Diameter Cx interface to retrieve the user location (Dx interface is used from I-CSCF to SLF to locate the needed HSS only), and then routes the SIP request to its assigned S-CSCF. Up to Release 6 it can also be used to hide the internal network from the outside world (encrypting part of the SIP message), in which case it's called a Topology Hiding Inter-network Gateway (THIG). From Release 7 onwards this "entry point" function is removed from the I-CSCF and is now part of the Interconnection Border Control Function (IBCF). The IBCF is used as gateway to external networks, and provides NAT and Firewall functions (pinholing).

7.2.2.3. Application Servers

Application servers (AS) host and execute services, and interface with the S-CSCF using Session Initiation

Protocol (SIP). An example of an application server that is being developed in 3GPP is the Voice call continuity Function (VCC Server). Depending on the actual service, the AS can operate in SIP proxy mode, SIP UA (user agent) mode or SIP B2BUA (back-to-back user agent) mode. An AS can be located in the home network or in an external third-party network. If located in the home network, it can query the HSS with the Diameter Sh interface (for a SIP-AS) or the Mobile Application Part (MAP) interface (for IM-SSF).

SIP AS: native IMS application server.

IP Multimedia Service Switching Function (IM-SSF): an IM-SSF interfaces with Customized Applications for Mobile networks Enhanced Logic (CAMEL) Application Servers using Camel Application Part (CAP)

Open Service Access-Service Capability Server (OSA-SCS): Interface to the OSA framework Application Server [3]

7.2.2.4. Media Servers

The Media Resource Function (MRF) provides media related functions such as media manipulation (e.g. voice stream mixing) and playing of tones and announcements.Each MRF is further divided into a Media Resource Function Controller (MRFC) and a Media Resource Function Processor (MRFP).

The MRFC is a signalling plane node that acts as a SIP User Agent to the S-CSCF, and which controls the MRFP across an H.248 interface

The MRFP is a media plane node that implements all media-related functions.

7.2.2.5. Breakout Gateway

A Breakout Gateway Control Function (BGCF) is a SIP server that includes routing functionality based on telephone numbers. It is only used when calling from the IMS to a phone in a circuit switched network, such as the Public Switched Telephone Network (PSTN) or the Public land mobile network (PLMN).

7.2.2.6. PSTN Gateways

A PSTN/CS gateway interfaces with PSTN circuit switched (CS) networks. For signalling, CS networks use ISDN User Part (ISUP) (or BICC) over Message Transfer Part (MTP), while IMS uses Session Initiation Protocol (SIP) over IP. For media, CS networks use Pulse-code modulation (PCM), while IMS uses Real-time Transport Protocol (RTP).

A Signalling Gateway (SGW) interfaces with the signalling plane of the CS. It transforms lower layer protocols as Stream Control Transmission Protocol (SCTP, an Internet Protocol (IP) protocol) into Message Transfer Part (MTP, an Signalling System 7 (SS7) protocol), to pass ISDN User Part (ISUP) from the MGCF to the CS network.

A Media Gateway Controller Function (MGCF) does call control protocol conversion between SIP and ISUP and interfaces with the SGW over SCTP. It also controls the resources in a Media Gateway (MGW) across an H.248 interface.

A Media Gateway (MGW) interfaces with the media plane of the CS network, by converting between RTP and PCM. It can also transcode when the codecs don't match (e.g. IMS might use AMR, PSTN might use G.711).

7.2.2.7. Media Resources

Media Resources are those components that operate on the media plane and are under the control of IMS Core functions. Specifically, Media Server (MS) and Media gateway (MGW)

7.2.3. NGN Interconnection

There are two types of Next Generation Networking Interconnection:

Service oriented Interconnection (SoIx): The physical and logical linking of NGN domains that allows carriers and service providers to offer services over NGN (i.e. IMS and PES) platforms with control, signalling (i.e. session based), which provides defined levels of interoperability. For instance, this is the case of "carrier grade" voice and/or multimedia services over IP interconnection. "Defined levels of interoperability" are dependent upon the service or the QoS or the Security, etc.

Connectivity oriented Interconnection (CoIx): The physical and logical linking of carriers and service providers based on simple IP connectivity irrespective of the levels of interoperability. For example, an IP interconnection of this type is not aware of the specific end to end service and, as a consequence, service specific network performance, QoS and security requirements are not necessarily assured. This definition does not exclude that some services may provide a defined level of interoperability. However only SoIx fully satisfies NGN interoperability requirements.

An NGN interconnection mode can be direct or indirect. Direct interconnection refers to the interconnection between two network domains without any intermediate network domain. Indirect interconnection at one layer refers to the interconnection between two network domains with one or more intermediate network domain(s) acting as transit networks. The intermediate network domain(s) provide(s) transit functionality to the two other network domains. Different interconnection modes may be used for carrying service layer signalling and media traffic.

7.2.4. Charging

Offline charging is applied to users who pay for their services periodically (e.g., at the end of the month). Online charging, also known as credit-based charging is used for prepaid services, or real-time credit control of postpaid services. Both may be applied to the same session.

Offline Charging: All the SIP network entities (P-CSCF, I-CSCF, S-CSCF, BGCF, MRFC, MGCF, AS) involved in the session use the Diameter Rf interface to send accounting information to a Charging Collector Function (CCF) located in the same domain. The CCF will collect all this information, and build a Call Detail Record (CDR), which is sent to the billing system (BS) of the domain.

Each session carries an IMS Charging Identifier (ICID) as a unique identifier. Inter Operator Identifier (IOI) parameters define the originating and terminating networks.

Each domain has its own charging network. Billing systems in different domains will also exchange information, so that roaming charges can be applied.

Online charging: The S-CSCF talks to a Session Charging Function (SCF) which looks like a regular SIP application server. The SCF can signal the S-CSCF to terminate the session when the user runs out of credits during a session. The AS and MRFC use the Diameter Ro interface towards an Event Charging Function (ECF).

When Immediate Event Charging (IEC) is used, a number of credit units is immediately deducted from the user's account by the ECF and the MRFC or AS is then authorized to provide the service. The service is not authorized when not enough credit units are available.

When Event Charging with Unit Reservation (ECUR) is used, the ECF first reserves a number of credit units in the user's account and then authorizes the MRFC or the AS. After the service is over, the number of spent credit units is reported and deducted from the account; the reserved credit units are then cleared.

8. SECURITY ASPECTS OF EARLY IMS SYSTEMS

It is envisaged that security defined in TS 33.203 may not be available for a while especially because of the lack of USIM/ISIM interfaces and prevalence of devices that support IPv4. For this situation, to provide some protection against the most significant threats, 3GPP defines some security mechanisms, which are informally known as "early IMS security," in TR33.978.

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