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IP Multimedia Subsystem and Its Future Perspectives

Orhan Orhan[1], Cahit Bollu[2], Mehmet Ulvi Agca[3], Selcuk Keskin[4] and Taskin Kocak[5]

[1,2,3] Nokia, R&D Department, Yukari Dudullu 2. Cad. No:17/1, 34776 Umraniye Istanbul, Turkey

[4,5] Bahcesehir University, Department of Computer Engineering, 34353 Besiktas Istanbul, Turkey

Abstract

The 3GPP IP Multimedia Subsystem (IMS) specified as the service delivery platform of 3G networks. Later this aim is updated by 3GPP, 3GPP2 and TISPAN for supporting networks such as WLAN, CDMA2000, fixed line, 4G and 5G networks. This paper explains IMS solution, virtualization of IMS, cloudification of IMS and its usage with 4G and 5G networks. Since the data traffic is increasing very fast, the management of voice network has become heavy and hard since it has too many network elements. Today's broadband technologies (such as LTE) are going to continue to evolve and will provide the backbone of the overall radio-access solution in the future. At that point, IMS relation with LTE, so called VoLTE, becomes much more important. VoLTE provides signaling framework to establish voice calls, media sessions and voice services over IP network. IMS base evolution on voice network as such in LTE will expand over 5G. Virtualization and cloudification of IMS network elements and functions also given in this work.

Keywords: IP Multimedia Subsystem (IMS), 4G, Voice over LTE (VoLTE), 5G, Cloud Computing, Virtualization.

Introduction

Next Generation Networks (NGN) is name of the non-bounded architecture for delivering voice over IP (VoIP), through Session Initiation Protocol (SIP). In frame of NGN each Telecommunication vendor created their own solution with their own interpretation of SIP protocol and as a result operators had to buy complete end to end equipment from one vendor as equipment's are used to be non-compliant with the other vendors' equipment. At the end this led interoperability problems between different Telecommunication vendor devices plus interoperability problems between exchanged messages from one solution to another. In order to solve these problems IP Multimedia Subsystem (IMS) standards are developed. IMS is an architecture to deliver Internet Protocol (IP) Multimedia Services, which is firstly designed by wireless standards body 3GPP. At first it is aimed to evolve mobile networks beyond GSM. In 3GPP release 5 a solution is provided to deliver Internet services over GPRS in the transition from 2G to 3G technology. This aim is later updated by 3GPP, 3GPP2 and TISPAN for supporting networks such as Wireless LAN (3GPP release 6), CDMA2000 (3GPP2) and fixed line (3GPP Release 7 and TISPAN Release 1.1) [1]. IMS is a well-defined standard which enable operators to provide their customers IP multimedia applications such as video sharing, text messaging, VoIP, video streaming and interactive games. IMS explains how to deliver services in a standardized and very good structured way. It provides an architecture that simplifies and speeds up the service creation and provisioning process by enabling legacy inter working. The IMS standard is based on Session Initiation Protocol (SIP) which is widely adopted Internet standard technology. SIP is a text based protocol which gives too many good features to IMS. In IMS, to construct end to end solution operators can choose equipment from multiple different vendors as they are all compliant to IMS standards. IMS operation and maintenance costs (including energy consumption, consumed space and network management) are much lower in comparison to traditional voice networks. By deploying IMS network architecture, service providers can implement new services on existing network infrastructure. IMS provides reliable, easy to use (since it is text based), voice and multimedia services. IMS also give possibility to fixed and mobile convergence.

IMS Architecture

The IMS is an important milestone in Next Generation Networks (NGN) family, it can give services without depending on standard access technology. IMS is responsible to manage all service related issues such as Quality of Service (QoS), Charging, Access Control, User and Services Management, details can be seen in [2,3,4]. For the future telecommunication services the IP Multimedia Subsystem has a great potential to expand and cover all customer needs. IMS has three layers: transport layer, IMS control layer (to construct, modify and finish sessions) - only SIP protocol-, and applications layer as shown in Figure 1.

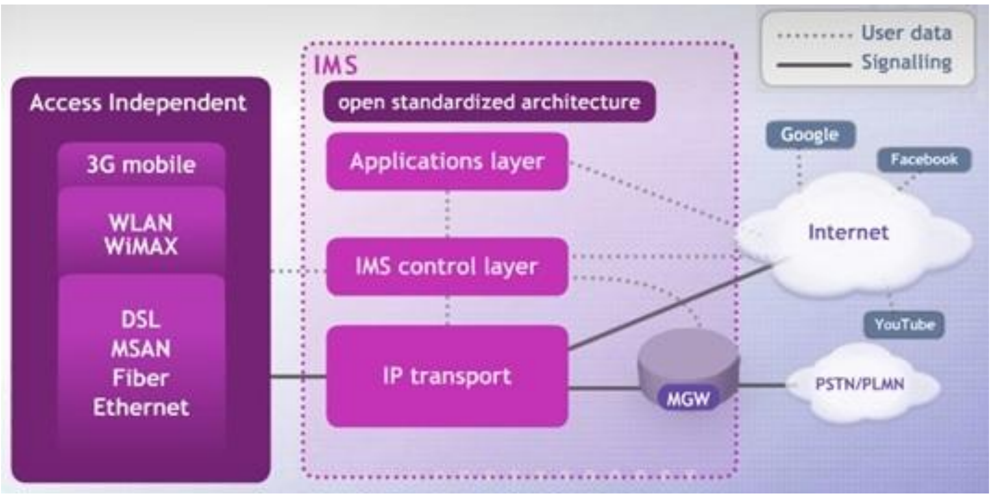

Fig. 1. IMS Layers

IMS offer secure sessions. QoS is enforced from IMS layer to transport layer with COPS. Services are specified but not standardized, instead capabilities are standardized which makes services flexible. Interworking with PSTN is possible. Border Gateway Control Function (BGCF) is introduced to join POTS users with the IPT world offering a smooth migration possibility to become a full IPT user with IMS compliant. POTS users connected to the BGCF are offered identical services available today given by IMS networks [5]. Users can access IMS and the services that are provided by the IMS network through different access technologies. Services can be made available to different types of users as many of these services are developed and available in the IMS network and not related to the access technology. The independence of access technology allows operators and service developers to develop and introduce services that are not dependent on access technology devices. The IMS solution is access technology independent and supports the following wireless and wireline access technologies such as PSTN, Wi-Fi, WiMAX, WLAN, UMTS, 2G and 3G voice and packet data networks, Cable, xDSL, CDMA, LTE, etc..

VoLTE Solution

End-to-End Voice over LTE (E2E VoLTE) brings together the good features of LTE, EPC and IMS portfolios which are optimized for the next generation of IP driven applications and services. The solution has been fully validated through tests spanning the Radio Access Network (RAN), EPC and IMS. The platform for the All-IP 4G broadband wireless networks is used to support voice calls in 4G wireless networks such as Voice over LTE (VoLTE). IMS provides a SIP based signaling framework to establish voice calls and media sessions over IP networks [6]. A cooperative framework have been proposed to balance the load distribution between signaling nodes in the IMS networks. The proposed framework is using the SIP-Specific event notification protocol to exchange load state change notifications among peer P-CSCF nodes and between S-CSCF and I-CSCF nodes [7].

For wireless mobile operators providing voice services are considered as most important use case. IMS with MMTel are the key systems to make voice service possible and provide a required telephony system to LTE [8, 9]. In VoLTE technology, a software upgrade is required to the LTE network and its PS core network (EPC). IMS provides an end to end solution for handling voice over IP wireless networks. VoLTE solution can be considered one of the main and important roles of IMS. Therefore the GSM Association (GSMA) announced that it will consider IMS as a major solution in the one voice profile recommendations in 2010 [10]. To implement a low cost solution to provide VoLTE is important from the operator's point of view [11].

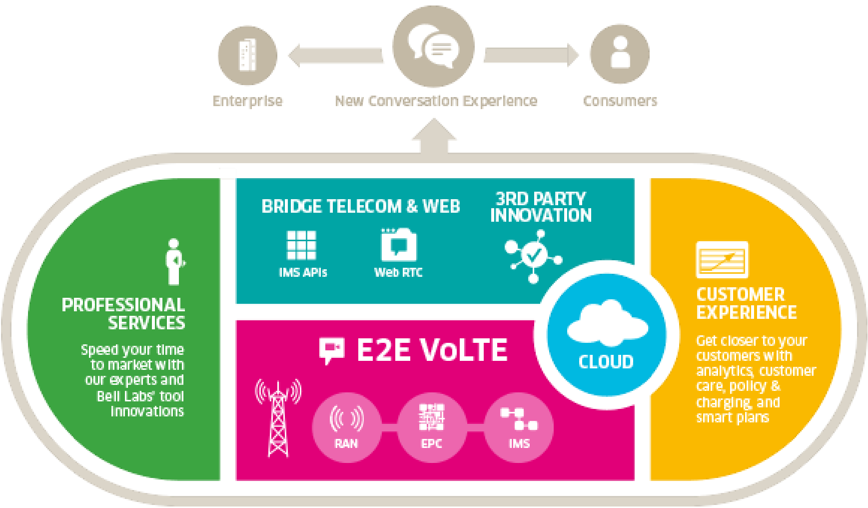

Fig. 2. VoLTE and its usage with Cloud

Figure 2 shows end to end VoLTE solution and its integration with cloud. The VoLTE solution enables subscribers to place IMS based voice calls and send SMS text through LTE personal equipment such as, smartphones, tablets, and laptops. The VoLTE solution provides wide range of voice services to operators. The Single Radio Voice Call Continuity (SRVCC) and enhanced SRVCC features provide handover from LTE VoIP to legacy 2G or 3G circuit-switched (CS) voice, provide emergency services with location information and enable global interoperability of advanced voice services. The service providers can also leverage the same IMS used in the VoLTE solution to partner with OTTs through IMS APIs and Application Enablement. To offer wireless IMS service, carriers must be able to meet regulatory requirements for emergency and lawful intercept, ensure that calls will not be interrupted when a user moves out of LTE coverage, and allow users to originate calls when they are outside of their home network. In addition IMS subscribers in a wireless environment can call other IMS users, other mobile users in the PLMN, fixed IMS users and users in the PSTN.

The 4G LTE is an all IP, packet based, next generation broadband radio access technology for wireless networks. The LTE standards interwork with all wireless network standards supported by both 3GPP and 3GPP2 standard bodies. The LTE network architecture comprises the eUTRAN and EPC components. The evolved Universal Terrestrial Radio Access Network (eUTRAN) is part of the improved and simplified LTE Radio Access Network (RAN). The eUTRAN contains radio frequency transmitters and receivers used to communicate directly with the User Equipment (UE). The eNodeB connects the UE of the subscriber (mobile device) to the LTE network.

The Evolved Packet Core (EPC) is the IP-based packet only Core Network for LTE. The EPC carries all kind of traffic (video, voice, and data) in packet form. All eNodeB data sessions travel through the EPC connecting the UE to various Packet Data Networks (PDNs). Public internet, private data networks, and IMS for communication services are examples of PDNs. The EPC is made up of four major components: Mobility Management Entity (MME), Policy and Charging Rules Function (PCRF), Serving Gateway (SGW) and Packet Data Network Gateway (PGW). The MME provides mobility and session control management and authenticates UEs. It uses S6a interface for user authentication and subscriber data in the Home Subscriber Server (HSS). The PCRF supports network control of Service Data Flow (SDF) detection, gating, QoS and ow based charging and authorization of QoS resources and dynamic policy decision on service data ow treatment in the PCRF (PGW/SGW). The SGW routes and forwards user packets and acts as the mobility anchor for the user plane for LTE handoffs and inter-Radio Access Technology (RAT) handovers. Examples of inter-RAT handovers include handovers from LTE to CDMA or LTE to W-CDMA. The PGW provides UE session connectivity to external packet data networks. The UE may have more than one session active with a PGW for accessing multiple Packet Data Networks (PDN). The PGW also acts as the anchor point for non 3GPP networks such as WiMAX.

Virtualization in IMS networks

Virtualization in Telecommunication industry has become popular in recent years. Moving operating system instances from one physical host to another is one of the most important characteristic of this technology. This feature gives opportunity to network administrators to resolve serious problems both in hardware and software in a short time frame. A high availability solution which is giving opportunity to avoid performance degradation described in [14]. In this work when introducing the migration technique within the IMS architecture overload problem resolved and Quality of Service (QoS) for IMS client guaranteed. The use of migration reduces considerably the delays by 40% for registration and by 38% for session setup. As a result acceptable values in comparison to the threshold values obtained. In [13], a virtualization-based cloud platform for the IMS core network, with a novel load balance and disaster recovery policy proposed. Experimental results indicate that the proposed mechanism improves system performance by dynamic allocating resources according to current load. The proposed cloud infrastructure is able to recover from a disaster in seconds by using live migration of virtual machines. The cloud infrastructure offers the services of dynamic resource allocation, load balancing and disaster protection. In this work VM-PM matching algorithm for load balancing offered. Using the algorithm and live migration, a mechanism of overload control and consolidation to achieve high utilization of the physical resources provided. Experimental results indicate that the proposed mechanism improves system performance by dynamic allocating resources according to current workload. The proposed cloud infrastructure is able to recover from a disaster in seconds by using live migration of virtual machines.

There is few comparable research related to combining cloud infrastructure with IMS core network. Chen et al. made the first attempt to combine cloud computing with IMS access network [14]. In the study, the IMS QoS policies of three wireless accessing technologies, 3G, Wi-Fi and WiMAX, are integrated in cloud computing environment to provide different services such as VoIP services and video streaming service. The main reason why Telecom core network still not integrating cloud computing is that the main characteristic of the cloud computing is to provide best services as it can, lacking assurance of the Telecom level QoS. Since the Telecom level reliability of the core network is extremely important for Telecom industries. The cloud of Telecom core network should be transformed from the traditional one to the platform that can effectively use of the shared resources to provide Telecom level reliable services. The solutions must incorporate virtualization technologies such as the reliability and live migration. Amazon's EC2 (Elastic Compute Cloud) is based on Xen [12] virtualization technology. Through dividing each region into Availability Zones, EC2 can complete disaster recovery into the Amazon cloud. However, the accidental failures of the hardware and software could still cause serious influence of large-scale cloud services. Reliability and disaster recovery solutions in cloud computing are two main challenges. Kangarlou et al. proposed GENI-VIOLIN, a distributed snapshot mechanism that operates exclusively at the network level and provides fault tolerance for stateful services provisioned over multiple VMs (Virtual Machines) [15]. The GENI-VIOLIN approach is applicable to a variety of virtualization platforms (e.g., VMware ESX, Xen, and KVM [16]) and only requires live VM migration support from the underlying virtualization platform. Live migration is a core technique of virtualization. Xen hypervisor fully supports live migration. Using live migration, a VM can be relocated in the physical machine cluster, without disconnecting the clients' applications. Cully et al. presented a transparent, comprehensive and high available solution, Remus, for Xen hypervisor [17]. It maintains a completely up-to-date copy of a running VM on a backup server. The copy will be activated automatically if the primary server fails and this protection is transparent to the guest OS. Remus is designed to protect a VM by high frequency checkpoints from active host to backup host, asynchronously propagating changed state to a backup host at frequencies as high as forty times a second and using speculative execution to run the active VM slightly ahead of the replicated system state concurrently. The image file of the VMs is protected by DRBD [18]. Unlike traditional backup solutions, Remus is based on Xen hypervisor and does not require additional dedicated hardware. As long as the physical architecture supports Xen hypervisor, it can be used as Remus backup hardware without modification. In brief, live VM migration mechanism can synchronize states of the VMs in different physical host at a relative low cost. Different from the traditional disaster recovery mechanism based on proprietary devices, live VM migration has no additional requirement for physical hardware, also without any modification of software. However, although in the recently work, disaster recovery based on live migration has not yet been applied to Telecommunication field [19]. This needs to fully consider Telecom characteristics of the core network. The mainly Telecom characteristics of the core network which should be taken into full account in the disaster recovery exist in two respects. First, the physical servers which used in Telecom core network are heterogeneous. To ensure compatibility with all physical servers, the virtualization platform is needed to provide a cross-platform data monitor of heterogeneous physical servers and a set of common VM operation API. Next, to reduce cost, Telecom operator needs the physical servers run at higher load. The data provided by Telecom operator indicate that, running at 80% load, the physical servers in core network will reach the best energy consumption performance. Algorithm must be designed to match the VMs and physical machines. When the running load is low, the system will first integrate physical servers, and then sleep idle servers. When the system is overloaded, VMs should be migrated to load balance the physical servers.

IMS and 5G Networks

The wireless standards with high data throughput such as LTE and 5G use the Evolved Packet Core (EPC) which supports multiple heterogeneous access. The fundamental functionalities of LTE Network Architecture are illustrated in Figure 3. ETC aims to hand over IMS architectures to efficiently access to different type of services. Instead of voice based wireless communication, IP-based systems of data communication will be imitated by EPC technology which is recently developed for wireless systems. The voice-centric system is detached by at network architecture from the network. EPC is attributed by this approach.

With the increasing of using network by many platforms, management of network objects has become harder with unwieldy voice-centric architecture. To handle with that problem, the packets can be separated too much simplified network sequences with different types like voice or data [21]. With the decrease the count of hops in the communication system, data peregrinates more expeditious between end points, greatly reducing the network latency to avail support real-time applications such as video-conferencing, gaming and voice over IP (VoIP). The at IP architectures have come out with WiMAX, and future LTE networks will be at by illustration [20,21,22]. 5G, in proportion to 4G, should be more massive and scalable to allow for a wider range of services and scenarios. In particular, the radio access 5G must provide consequential performance improvements in terms of system capacity and transmission speed of the user data [23]. There are two rudimentary evolution paths that can be taken to fortify incipient system capabilities for 5G, i.e., a step-by-step evolutionary path fixating on further LTE enhancements and/or a revolutionary path utilizing a pristinely incipient radio access technology (RAT) that may include major changes that are non-rearward compatible with LTE [24].

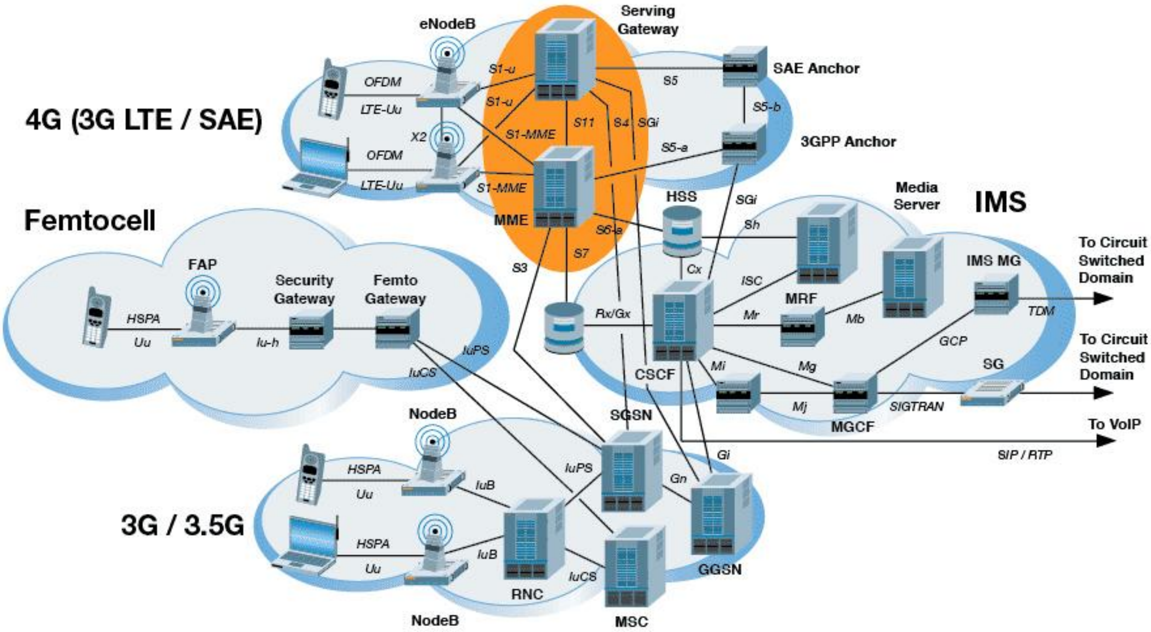

Fig. 3. LTE Network Architecture Diagram

However, a range of scenarios (e.g. wireless backhauling, device-to-device (D2D), multi-hop, etc.) should be supported by the new RAT [25]. Therefore, the RAT will be developed with downlink and uplink symmetry. The utilization of massive MIMO technology in coalescence with an immensely colossal number of antenna elements is a potential solution to exploit higher frequency bands. However, the technologies of mass antenna have several technical problems to be solved, such as how to achieve accurate beam forming, how to circumvent impairments radio frequency and how to provide control signaling for mobility and connectivity of links highly directive. Non-Orthogonal Multiple Access (NOMA) is a multiplexing scheme multiuser intracellular domain that makes use of a supplemental incipient domain, i.e. power domain. As opposed to earlier generations such as 2G (Time Division Multiple Access), 3G (Code Division Multiple Access) and 4G (Orthogonal Frequency Domain Multiple Access) systems do not utilize the power domain in their communication systems. Current mobile broadband technologies such as HSPA and LTE will perpetuate to evolve and provide the backbone of the global solution of the future radio access. By 2020 and beyond, much more spectrum and higher bandwidths will be needed to promote the expected increase in traffic and data transfer rate in higher frequency ranges. There is an effort on finding more spectrums for current's LTE technology [26].

Conclusion

In this paper, the IMS solution explained and its conversion with new virtualization and cloud solutions analyzed. As IMS is access independent it will be key technology in the future together with simplifications on hardware platform requirements by virtualization. IMS solution is highly flexible to easily be adapted on rapidly evolving Telecommunication technologies where data consumption is already the key factor in Telecommunication world. As Telecommunication technologies goes all IP based, IMS will be important standard for new coming Telecommunication technologies such as 5G. IMS voice centric architecture offers a standardized model which makes the market as vendor independent for service providers. The standardization of IMS model with architecture on 3 layer bases which is supported by the wide range of wireless and wire line protocols allow us to develop services and implement solution which are not dependent on access technology devices. Together with new concepts of virtualization and cloudification; IMS solution is less complex to implement, largely scalable and cost effective. Since IMS has simplistic model in terms of network entities, the orchestration of voice network becomes more manageable within this topology. In order to manage service quality and reduce the interoperability problems on voice delivery which makes it cost effective as well. VoLTE architecture mix together the best features of LTE, EPC and IMS standards and these are optimized for next generation of IP driven applications and services. The VoLTE solution enables large scale of IMS based voice services for service operators. And the future of Telecommunication will require larger bandwidths to support expected traffic and related services. As IMS is placed in the core of Telecom network and interacts with very diverse access technologies, the administration of the IMS core network is crucial. 5G systems with IMS feature can be achieved either by following LTE enhancements or new RAT technology. It is more desirable to have new RAT as in the future more bandwidth will be required. IMS solution is flexible to easily be adapted on evolving Telecom technologies in order to meet the quality expectations in voice network during the competition in the market.

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