Deploying IP Multimedia Subsystem (IMS) Services over Next Generation Networks (NGNs): The IU-ATC Integrated Test Bed

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Abstract. The IP Multimedia Subsystem (IMS) is the Third Generation Partnership Project's (3GPP) standardized service platform that enables the deployment of rich and personalized services over fixed and mobile networks whilst allowing end-users ubiquitous access to services such as voice, video, presence and online gaming anytime and anywhere. However, the delivery of these services to the end-users is highly dependent on the available or preferred access network which could range from fixed broadband access to mobile 4G connections. Although the IMS was initially developed as the core network for Third Generation (3G) systems, it has now been adopted as the service platform for the Long Term Evolution (LTE) and System Architecture Evolution (SAE). As this transition of 3G to 4G and beyond evolves, there is an immediate need for a research testbed that facilitates the research, development and early trials of the integration of these technologies. This has motivated us to integrate the IMS based Advanced Next Generation Network (ANGN) testbed at the University of Surrey (UniS), U.K. with the 4G Access Network Testbed at IIT Madras, India via an academic transnational network link to form a fully functional telecommunications mobile network. In this paper, we discuss the rationales, motivations and objectives behind the integrated testbed whilst also investigating how it can be extended to support 4G and future technologies such as LTE/SAE and WiMAX. The testbed as a whole plays a key as role in the future of IMS development as it provides a fully functional platform similar to commercial networks for researchers to investigate and demonstrate the feasibility of their proposal in a realistic environment.

Keywords: IMS, LTE, SAE, NGN, 4G, 3G, WiMAX.

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1 Introduction

Next Generation Networks (NGN) provides the long awaited convergence of the Internet and the cellular worlds, providing ubiquitous cellular access to all the services that the Internet offers and vice-versa [1]. Examples of these services are Voice over IP (VoIP), Instant Messaging, online gaming, video conferencing and presence services. This is achieved by a combination of state-of-the-art access and core technologies providing an access-independent all-IP platform that enables the interconnectivity and interoperability of mobile networks to other heterogeneous networks via packet switched technologies. The development of such an end-to-end all-IP platform for research purposes will facilitate the early trials and development of various new and emerging technologies aimed at NGN platforms. Although various IP Multimedia Subsystem (IMS) testbeds already exist [2-7], our aim in Theme-10 of the IU-ATC UK-India project, is the development of an international research testbed interconnecting key NGN elements in order to emulate an operational and production-level NGN platform. This includes the access, core-network and service platforms.

Such an integrated testbed will help researchers to investigate and demonstrate feasibility of their proposals in a realistic environment. The test-bed will also complement the other analytical and simulation based studies that may be performed in any individual study. In other words, the test-bed will not be considered as a replacement to analytical or simulation based studies but rather to aid the researchers in investigating the practical challenges. Our work in the Theme 10 of the IU-ATC UK-India project will use the existing testbed developed by IITM and UniS as launching pads. This includes the ongoing project in IITM to develop a testbed for research in radio access techniques by deploying a small radio access network with three SDR- based Base Stations (BS) supporting MIMO/OFDM based physical layers [8]. In addition, UniS has an all-IP Advanced NGN (ANGN) testbed [9] that can be configured to provide core service and network infrastructures using both carrier grade IMS platform and the OpenIMS [10] core. Thus, combining these two testbeds, we aim to build a complete platform that can contain different type of virtual mobile networks on a shared physical platform. For example, the physical infrastructure may contain two concurrent virtual WiMAX and LTE mobile networks. A unique feature of the test-bed will be its distributed processing property. While the radio part of the network will be developed and deployed by IITM, the service platform and core network will be hosted by UniS. The two parts of the network will be connected by various academic networks as shown in Fig. 1.

There will be sufficient flexibility in the topology of the network by means of using configurable switches in both the radio and core sections of the network. In addition, some flexibility will be possible by allowing remote researchers to upload their physical layer and Radio Resource Management (RRM) schemes to the IITM radio network. The core component will be deployed according to the experiment. For instance, an experiment may require LTE network components, whilst another experiment may need a WiMAX network. These experiments can concurrently co-exist on the same physical infrastructures. Both core and radio networks will provide appropriate interfaces for remote researchers and network administrators. Thus, the other partner will be able to remotely deploy their experiment and get back the measurements that they need. As an example, some partners may only need to do experiments on physical and radio parts. Such partners will be able to access the corresponding APIs at the IITM side. Some other partners may be interested in studying some application performance; thus, they could access the application server in UniS to deploy their applications.

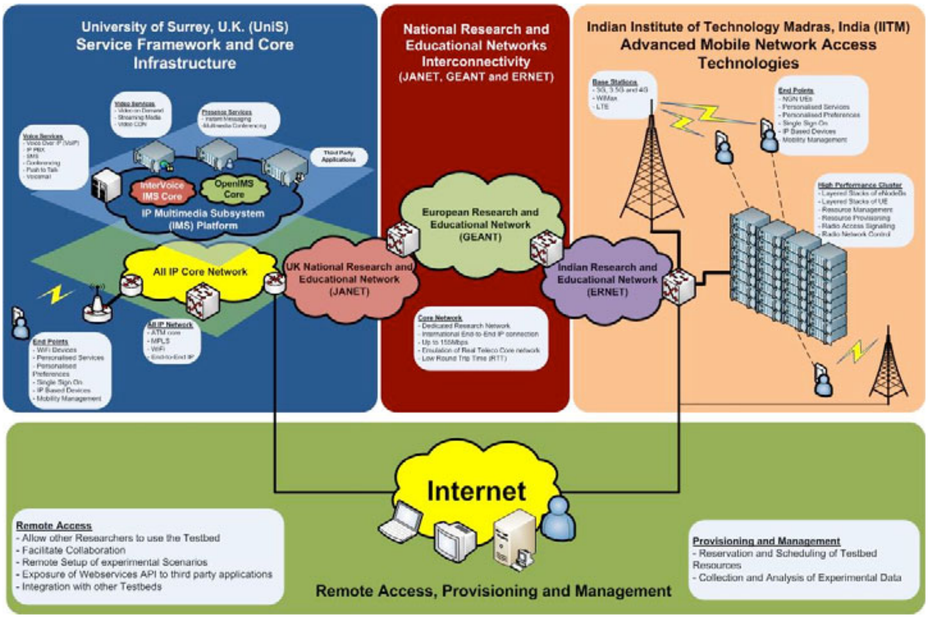

Fig. 1. An Overview of the IU-ATC Integrated Testbed

The rest of this paper is organised as follows: In Section 2, we provide the rationale, motivations and research objectives for the testbed looking at the roles that the testbed can play in the development of the integration of IMS and the advanced access networks. In Section 3, we describe the integrated testbed while pointing out some key features in the respective UniS and IITM the testbed. Finally, conclusions and future work are presented in Section 4.

2 Background

The IMS has been developing rapidly over the years, offering a solution to the all- IP vision of rich, multi-access multimedia services accessible anywhere, at any anytime, with the required quality, and at the right price [11,12]. The IMS is now widely considered as the future service-centric platform of reference, although several researchers are still arguing that the benefits of IMS come with a high cost linked to its layered approach (complexity). Only a large-scale deployment of the IMS and a wide adoption by operators and service providers, will allow a full assessment of its benefits and shortcomings. The enormous interest surrounding the IMS indicates that this may really become the standard framework for deploying advanced, ubiquitous services over converged, all-IP networks, i.e the “Domain of Services”. However, not all the research areas have been fully explored. One of the areas is the deployment of IMS over next generation 4G networks, which explores access technologies such as the LTE and WiMAX. There have been various concerns on the integration of the LTE core, known as the System Architecture Evolution (SAE) with the IMS [13]. Although the functionalities that are proposed in the IMS can be achieved in the SAE, the integration of IMS with SAE provides the major advantage of being a domain of services in which operators can easily bring new services to the market quickly while also exposing various functionalities to third party developers and also charging appropriately for these services. The integration of both the IMS and SAE however currently raises various concerns and it posses as an area worth investigating.

This has been one of the key motivations to combine the existing test-beds of IITM and UniS into an integrated test-bed that can be used to prototype and test advanced protocols developed within the framework of the IU-ATC project. This will help researchers and the IMS community as a whole to investigate/demonstrates feasibility of their proposals in a realistic environment. The test-bed will complement the other analytical and simulation based studies that will be performed in individual areas. In other words, the test-bed will be one of the many tools for IMS based analytical or simulation studies. It will also help the researcher to investigate the practical challenges as we have outlined in the following objectives.

First, a fully operable end-to-end system and corresponding performance- monitoring tools will be developed. In order to achieve this, the Indian portion of the test-bed will be dedicated to the radio-related technology aspects of the next generation of mobile networks, from the air interface, physical, Multiple Access scheme. For research on higher level networking features at the network level and above, e.g., Mobility support for IP networks, Multicast support, Service platform for future mobile networks, and IP Multimedia Subsystem, the UniS segment of the testbed will be used. The most powerful capability of the integrated test-bed will come into play when research is carried out employing both segments simultaneously, interconnected across the continents, using the transnational academic network, which provides higher bandwidth and fewer routes as compared to the public Internet. As an example, a scenario for establishment of an end-to-end multimedia service session between two User Equipments (UE), one in the UniS and other in IITM segments of the testbed. The IMS core and required CSCF (Call Session Control Functions) are provided and maintained within the UniS ANGN, and radio part research scenarios are tested within IITM testbed. This will allow possible interoperability issues to be identified and solutions developed. Key performance indicators (KPI) encompassing application, radio and network protocols will also be identified. Software modules for capturing of KPIs and their post-processing will also be developed.

Another key objective that would be facilitated by the testbed will be the ability to develop, analyse and optimise novel mobility management protocols enabling fast and reliable horizontal and vertical handover. In order to achieve this the UniS ANGN will be enhanced with development and evaluation of new advanced mobility management and network/user security protocols. The advanced mobility management will be based on multi-layered mobility management protocol concepts which require cooperation between application layer, network layer and handover at layer 2 using respectively SIP, MIPv4/6 and layer 2 handover algorithms respectively. The multi-layered mobility management protocol will be optimized with a fully integrated context transfer protocol for fast and reliable and secure handover involving AAA for user authentication. We will also be developing and analyzing various sets of cross-layer link adaption, resource management, admission control, packet scheduling and routing algorithms to provide QoS guarantees for a variety of services and application. We also aim to investigate

Other research objectives that can be investigated on the testbed include Advanced MIMO Schemes including various BS co-operation techniques and establishing their respective performance parameters, NGN charging mechanisms and inter-domain presence management to mention a few.

3 The Integrated Testbed

The "End-to-End Transnational Wireless Network Testbed" is based on Software Defined Radio (SDR) network elements, a High Performance Computing (HPC) cluster, and an IP-based network nodes with IP Multimedia Subsystem (IMS) service development platform. In this section we provide a brief overview of the existing facilities and their current status, at both IITM and UniS, an interworked architecture together with selected advanced research ideas to be tested and optimized utilizing the testbed. The testbed will provide real-time and non real-time (depending on algorithm complexity) emulation of a 4G network, providing researchers with an insight into how their ideas perform and how different techniques interact. Part of the testbed is proposed to be located on the campus of Indian Institute of Technology, Madras in order to leverage the significant physical resources already available and interconnected through various academic networks with niversity of Surrey (UniS) existing Advanced Next Generation Network (ANGN) testbed. The capabilities of the UniS platform will be significantly augmented with all-IP based mobility management protocols with context-transfer techniques for fast and reliable handover employing a novel multi-layered mobility management technique. It will also be enhanced with new integrated Resource Management, MAC and routing protocol as well as a new cross- layer control plane functionality enabling cross-layer operation. The capability of the IITM platform will be significantly enhanced with proposed advanced MIMO and Air- interface techniques enabling full cross-layer operation between Physical layer and the higher layers in the protocol stack, resulting in power and bandwidth efficient air- interface solutions for the future 4G systems. This cooperative experimental based research project aims at leveraging on existing testbeds in the UK and India and enhance them with advanced Physical layer techniques, MAC, RM, MM and Network layer and SIP protocols together with cross-layer control plane techniques for efficient 4G all-IP network.

The testbed at IITM will have four BS radio-nodes and 12 UE radio-nodes in the coverage area of the BS nodes. Each BS node will have four antennas while a UE node will have two antennas. BS and UE nodes will have transmit power of 5 W and 250 mW respectively. Testbed is designed for a transmission bandwidth of 20 MHz. All the protocols of MAC and PHY (as well as applications, in other layers) will be run in the cluster and the digitized samples of the signal that has to be transmitted/received on air will be communicated to/from BS nodes as Ethernet packets over optical fibre links. Cluster has 16 nodes and each node has 8 processors. Applications could be run in real-time or near real-time depending on the degree of parallelisation achieved. BS as well as UE nodes will be synchronised to the GPS clock to enable coordinated transmission. Ethernet packets will be time stamped to ensure transmission in the intended frame.

The test bed at the University of Surrey provides an end-to-end all-IP platform for the delivery of NGN services using the standardised IP Multimedia Subsystem (IMS) service framework. These services include Voice over IP, video streaming and multimedia conferencing to mention a few. The testbed is also made up of state-of-the- art network and service elements that allow various forms of research to be carried out on both fixed and wireless network domains. The service domain is made up of an open source IMS core and also an industry standard IMS platform harnessing the advantages of IMS SIP profiles that are used in live environments by various telecommunications providers. The UniS testbed is developed using a layered approach allowing for either each layer to be individually extended or allowing for cross layer research and extensions to be achieved. The layers are mainly divided into the access technologies, the IP core and the service domain.

At the access level, the testbed provides a platform to study concepts such as mobility management, vertical and horizontal handovers, new communication technologies, signalling effects on the integration of mobility and security and secured communications over public infrastructures to mention a few. Although converged networks already have some mechanisms in place to enhance the deployment of mobile services [2,11,14], the test bed provides the opportunity to research these technologies in real environments using standardized protocols and applications. Furthermore, based on the technologies available on the testbed, significant attention has been devoted to individual studies of mobility at the access network level in converged networks investigating specifically the integration of mobility and security. This is has led to the development of a wide range of access technologies and protocols such as RMA controlled Soft Radios, Mobile IP and Mobile IPv6. Other research areas that a closely related with the access layer include AAA Context Transfer, Dynamic Configuration of Access Networks and Sensor Environments.

The IP core network provides a flexible, re-configurable network platform, capable of supporting an extensive range of networking and service provisioning scenarios. It can also be used to set up protocol stack functionalities in a flexible manner in order to support adaptive quality of service for multi-media communications in mobile environments. The IP core also contains almost all the essential constituents of the public Internet. It can be configured to support both IPv4/IPv6 and has the ability to undertake research in every area of fixed and mobile communication such as Mobility support for IP networks, Service Discovery, Location and Routing in MANETs/PANs, Terminal and network reconfigurability, Quality of Service (QoS), Network and data security and Multicast support.

The Service domain on the test bed is made up of a back-end infrastructure enabling a converged architecture which can provides personalized services to end users and devices. It uses the service framework known as the IP Multimedia Subsystem (IMS), which is the Third Generation Partnership Project (3GPP) standardised core network for the all-IP convergence of fixed and mobile networks. The core signalling protocol in the IMS is the Session Initiation Protocol (SIP), a lightweight standardised protocol for creating, modifying and terminating multimedia sessions over the Internet and also in converged networks. The UniS testbed is made up an open source IMS core known as the FOKUS OpenIMS platform and also a carrier-grade IMS core developed by InterVoice, which is used in live telecommunication networks. Based on the two IMS core, services such as Voice over IP (VoIP), Video on Demand (VoD), Presences Services and a combination of these services can be provided to both fixed and mobile end users using the testbed. The service domain has motivated various research in the field of Sensor Networks, Charging and Billing in converged networks, Service Management and Quality of Experience (QoE) to mention a few.

4 Future Work and Conclusions

The IMS as a whole has great potential and has been developing rapidly over the years, offering a solution to the all-IP vision of rich, multi-access multimedia services accessible anywhere, at any anytime, with the required quality, and at the right price. The IMS is now widely considered as the future service-centric platform of reference, although several researchers are still arguing that the benefits of IMS come with a high cost linked to its layered approach (complexity). Only a large-scale deployment of the IMS and a wide adoption by operators and service providers, will allow a full assessment of its benefits and shortcomings. These will hopefully be unveiled in the next few years. The enormous interest surrounding the IMS indicates that this may really become the standard framework for deploying advanced, ubiquitous services over converged, all-IP networks, i.e the “Domain of Services”. However, not all the research areas have been fully explored as yet especially in the area of distributed session management. Many approaches have been developed to eliminate (or reduce) the number of centralized servers from the IMS, aiming at a better level of scalability.

Furthermore, as the IMS is paving way for the introduction of the next generation 4G networks, which explores access technologies such as the LTE and the WiMAX. There have been various concerns on the integration of the LTE core, know as the System Architecture Evolution (SAE) with the IMS. As most of the functionalities that are proposed in the IMS can be achieved in the SAE, the IMS still provides the major advantage of being a domain of services in which operators can easily bring new services to the market quickly while also exposing various functionalities to third party developers while also charging appropriately for these services. The integration of both the IMS and SAE at the moment raises various concerns and it posses as an area worth investigating.

Another promising area of research is that of the deployment of peer-to-peer services in the IMS. This requires coming up with solutions as to how SIP sessions can be managed via distributed signalling protocols. Before this vision can become a reality, a number of issues still need to be tackled. P2P overlays do not map well onto physical networks, since P2P systems optimize IT resources but neglect the network. There is a fundamental clash between current P2P and network architectures. P2P architectures were designed to bypass the network operator, limiting its ability to control and influence the P2P application overlay. On the other hand, fundamental operations such as charging, security, quality control, and location management are hard to realize without the operator’s collaboration. P2P services in the IMS, bring them into the operator’s realm, creating the preconditions for a richer P2P service. If placed in perspective, P2P services in the IMS have the potential to address problems that have so far remained unresolved. Current P2P systems are increasingly faced with the problem that they do not offer a sound digital rights management solution. Privacy and data retention legislation is also bound to curb the further development of current P2P systems. There is also the major issue of how to cater for national security requirements, given that it is not currently possible to perform legal intercepts on P2P communications and data flows. P2P is now a service in high demand which requires an immediate, fundamental redesign. The IMS may be the next P2P provisioning platform, provided that the IMS itself evolves towards a more decentralized architecture. All in all, facilitating P2P services in the IMS will enable the deployment of new and exciting services, achieving what the IMS was initially designed for i.e. a platform of services.

Finally, the UK-India transnational testbed is just one many steps in the various approaches in the IU-ATC to continually contribute the development of the digital economies of both countries specifically focussing on the rural and remote areas. As the testbed evolves, various technologies and concepts will be developed and added to it in order to continually support the research aims and challenges faced by the IU-ATC research Themes and applications as well as a facility for industry to showcase and test future products.

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