An Integrated IP-MPLS Mobility Framework For Next Generation Networks

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Abstract
Next Generation Network (NGN) is an integration of heterogeneous network environment, achieves the vision of next generation services for the delivery of voice, data and video. Researchers have proposed different protocols and architectures for NGN to access heterogeneous networks. Accessing to the devices connected through the NGN with seamless mobility is an important area of research in NGN. Several efforts have been carried out by researchers to integrate MPLS technology into IP networks to provide seamless mobility. But, not much progress has been made so far. Hence, in this paper, a novel framework to integrate IP in MPLS is proposed to achieve seamless mobility with end to end quality of service. The performance of the proposed framework has been tested by establishing a test bed in a simulated environment.

Keywords
NGN, IP-MPLS, Mobility, QoS, MToP.

I. Introduction

The developments of modern communication technologies have paved a way to evolve Next Generation Network (NGN), a user friendly environment to offer better services for the users [1]. The major goal of NGN is integrating heterogeneous networks such as fixed networks, mobile communication networks and Internet which will be operated under the platform of Internet Protocol, to provide next generation services for the users, anywhere, anytime as always connected [2].

NGN is the first full IP-based public telecommunications networks developed by ITU-T coordinated with various Standards Development Organizations (SDOs) such as Automatic Terminal Information Service (ATIS), European Telecommunication Standards Institute (ETSI), Telecommunications Industry Association (TIA) and 3GPP/3GPP2 (Third Generation Partnership Project) [3]. ITU-T defines NGN as, "A packet-based network able to provide telecommunication services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It enables unfettered access for users to networks and to competing service providers and/or services of their choice. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users" [4].

Different existing network technologies in NGN will offer different nature of services and this dynamic nature of heterogeneity causes numerous challenges to manage services like multimedia, voice data, etc [5]. The major concern is the growth of devices, participating in the network which are not able to be located and controlled. These include seamless mobility in mobility management, network administration, security and quality of service [6]. These issues should be addressed, hence researchers put an effort to integrate the above technologies in NGN to resolve the existing problems.

It is a great concern for the network operators to provide high quality transmission and mobility support which will enable the consumers to experience seamless mobility with assured quality of service [7]. For the users, it is an urgent need to access the services like, data, voice and video while roaming, with service continuity and guaranteed QoS at anywhere and anytime [8]. The ever increasing demands from the users and the anxieties of the network operators are the added evidences that seamless mobility is the need of the hour and it is considered to be one of the major challenges in NGN.

There are various mobility management techniques and models were presented by the researchers which enhance the movement of mobile nodes irrespective of the access technologies and transparent to applications and higher layer protocols like TCP. These models support different aspects of mobility management at different levels at different contexts, but none of the models address the issues with regard to seamless mobility in NGN in an unified manner [9]. Designing seamless mobility architecture to seamlessly integrate heterogeneous networks with IP integration is the most challenging issue in NGN and it is a novel area of research. Hence, in this paper, a novel framework has been proposed to design an Integrated IP-MPLS Mobility for NGN.

This paper is organized as follows. Section II briefs the review of literature in the recent development in NGN. Section III presents the proposed framework for seamless mobility. Experimental study in a simulated environment and the performance results are illustrated in Section IV and Section V. Section VI concludes the paper.

II. Related Work

Azita et al. [10] have proposed an architecture for mobility management that integrates the cellular system and the Wireless Local Area Network (WLAN) using Intelligent Mobility Server(IMS). IMS handles the mobility management using a cross-layer mobility management protocol during interdomain roaming. In this domain, traffic load is considered to be an important factor for handoff initiation. This framework is established as a solution for interdomain handoff. Simulation has been done with cellular and WLAN environment. The authours have mentioned that detailed performance analysis are needed with respect to mobility management and efficient Management mechanisms are required to improve the Quality of Service.

Christian et al. [11] have proposed an Integrated Inter System Architecture (IISA) for Next Generation Wireless Network (NGWN) which guarantees seamless roaming and service continuity in IP-Based NGWN with the use of a third-party entity called Interworking Decision Engine (IDE). The Resource Management Module (RMM) in IDE allows transfer of user profiles, enables QoS mapping and renegotiation between two administrative domains during hand-off. The authors have also proposed a protocol called Handoff Protocol for Integrated Networks (HPINs) which is based on localized mobility management, access networks discovery and enhances fast handoff in IPv6-based heterogeneous wireless environments. Comparing HPIN with other existing IPv6-based mobility protocols, the performance results achieved are better in terms of signaling cost, handoff latency, handoff-blocking probability and packet loss. IISA and HPIN is not validated in a real- time situations.

Han et al. [12] have proposed a method for providing seamless network-based global mobility scheme between the IP based Access Networks. In this method, Mobility Information Control Server (MICS) manages the location information of the mobile nodes. Handover Control Server (HCA) performs the fast location registration through Multi Protocol Label Switching-Label Switched Path (MPLS-LSP) and has the LMA system function to manage the binding entry for the location of mobile node. Packets are transmitted to the mobile nodes through the bidirectional tunneling between HCA. Comparative study with MIPv6 shows that the proposed method achieves higher global mobility and reduces the latency experienced in handover time. The authours have not studied about the transmission time and the processing time for mobile nodes.

Noemie et al. [13] have proposed Virtual Community, a concept which enables dynamic management of various mobility aspects in NGN such as terminal, service, network and user mobility to extend the service continuity with end-to-end QoS. Use cases have been analyzed and experimented on the JXTA platform in a peer-to-peer manner in the service layer of Virtual Community (VC). It has proven that the integration of different Virtual Communities achieves, service continuity within Virtual Private Service Networks (VPSN). Existing JXTA technology does not support to implement this concept to interact at different layers of VC in a real-time environment.

Oleg Berzin [14] proposed Hierarchical Mobility Label Based Network (H-MLBN), a novel approach which involves hierarchical network architecture to obtain optimal traffic delivery between the mobile devices by using MPLS labels associated with control plane and forwarding plane traffic models. This model supports macro mobility and micro mobility for IPv4 / IPv6 mobile hosts and router by using Mobile IP and MPLS respectively. The system model presented provides performance analysis for H-MLBN and compares its performance with the Mobile IP based schemes. This approach overcomes the challenges faced by the triangular routing and bi-directional tunneling. The performance metrics focused in this paper are link count and the hand-off time. The major concerns of latency, jitter, and packet loss are not discussed.

Ping et al. [15] have presented an Identifiers Separating and Mapping Scheme (ISMS) which provides micro mobility, macro mobility and network mobility in NGN environment. ISMS decomposes the IP address into Accessing Identifiers (AIDS) and Switching-Routing Identifiers (SRIDs) to decouple the “locator/identifier overload” of IP address. AIDS are mapped into SRIDs to bridge the customer and the core network. This mapping reduces handoff latency, message overhead and packet overhead. Experimental results have proved that the mobility is achieved in terms of slow handoff, reduced message overhead and packet overhead. The authors have mentioned that this method does not guarantee QoS.

Mani Sekhar et al. [16] have proposed a Configuration Architecture which integrates intelligent network components to achieve global mobility. In this architecture, a Centralized Access Control Unit (CACU), acts as an interface between the different networks and supports multiple bases stations to provide wireless link layer connectivity. They have also proposed Network Switching Decision Mechanism (NSDM) to provide network switching decision which optimizes switching initiation time and selects the most optimal network. This plays a vital role in enhancing QoS, and thereby reducing switching overhead, packet loss rate, and switching blocking probability which in turn improves the performance of the network. Case study has been carried out with WLAN and UMTS integration and simulation results validate their approach with limited number of users.

Komala et al. [17] have explored the state-of-art development with regard to seamless mobility in 4G heterogeneous wireless networks and presented the mobility management research challenges like self organization, back hauling, handover and interference for the 4G in detail. Enumerating these challenges, the authors have identified that handovers play a major role in providing seamless connectivity. Hence, they have analysed various handover mechanisms with respect to inter-domain and intra-domain handoff and have substantiated their analysis with experimental test bed for the seamless mobility in 4G. Simulation has been carried out with NS-2 simulator between Wireless LAN (WLAN) and Worldwide Interoperability for Microwave Access (WiMax) Networks. The result has proved the efficiency of the mobility aspects with regard to throughput and delay. The authors have concluded that achieving seamless connectivity for a standard 4G is a major concern.

Muhammad et al. [18] have presented Cross Layer Localized Mobility Management Architecture based on Session Initiation Protocol (SIP) and Hierarchical Mobile IPv6 (HMIPv6) in NGN to provide end-to-end QoS, session mobility, bandwidth management and reduce latency. HMIPv6 is hierarchical in structure handles network mobility and SIP manages session mobility. QoS managers in this proposed system are distributed in two levels such as Regional QoS (RQos) Manager and Core QoS (CQoS) Manager. This distribution reduces the traffic load significantly and enhances the quality of service. The proposed system has been analyzed and compared with the integration of SIP and FMIPv6. OPNET simulation tool has been used to test the performance in terms of QoS, packet loss and network mobility. The results show that this scheme is efficient only to the localized Core Network.

Though a considerable amount of research work has been carried out in these areas, there are no concrete proposals offered so far to build an integrated mobility architecture for NGN to provide seamless mobility. Hence, a novel, unique framework called an Integrated IP-MPLS Mobility Framework for Next Generation Networks is designed and proposed in this research.

III. Proposed Framework For IP-MPLS Mobility

IP-MPLS Core designed is the backbone of the proposed framework which provides services to different service providers operating in different networks and the customers by integrating IPv4 and IPv6 for NGN networks. The Core IP-MPLS provides administrative functions such as seamless mobility with guaranteed Quality of Service. This is achieved by interconnecting the enterprise customers over wireless and wired access for Business to Business, Business to Customer and Machine to Machine network. Once the IP-Connection is established, all types of communication media including voice, video, data can be exchanged. This framework interconnects NGN and Non-NGN network via point-of-presence nodes such as Roaming partners, Internet and Private Peering to offer seamless connectivity and services for customers over Virtual Private Network (VPN) and Internet v4/v6 enabled access. Figure 1 depicts the proposed IP-MPLS Mobility framework for Next Generation Networks. This framework interoperates with IPv4 and IPv6 in a hybrid platform which enables easy roaming of users from one network to another. This framework is unique, user-friendly and easily accessible.

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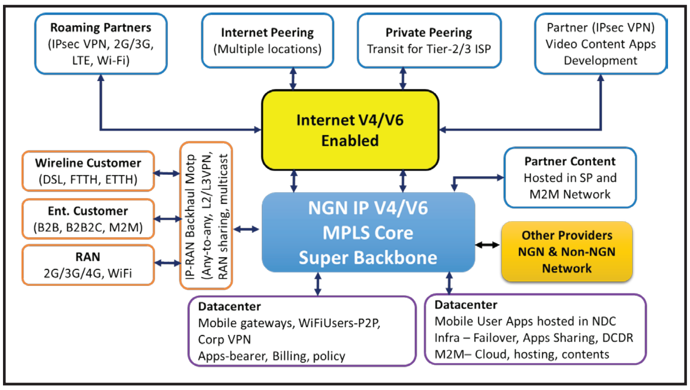

Fig. 1: IP-MPLS Mobility Framework for Next Generation Networks

This framework is based on pseudowires to extend the packet-based core, closer to the edge of the network. The framework integrates the multiple layers of the Radio Access Network (RAN) onto a single MPLS network by encapsulating and transporting time-division multiplexing (TDM), Frame Relay, and ATM traffic over MPLS which makes this design unique, scalable, bandwidth friendly and easily implementable. The MPLS network is extended over point-to-point links from the distribution nodes through Ethernet, serial, microwave, or a Layer 2 access network forming an Access convergence for a perfect Next Generation network Architecture. It supports 2G, 3G, and emerging 4G technologies while continuing to align their network architecture with Third-Generation Partnership Project (3GPP/3GGPP2) recommendations, in particular to provide seamless mobility. To achieve these goals, the proposed framework for mobile service providers evolve their traditional circuit-based transport technology to a packet-based solution by using Mobile Transport over Pseudowires (MToP) and Carrier Ethernet.

The MToP provides lower-cost transport, switching, routing and quality of service. The MToP integrates multiple layers of the RAN onto a single IP MPLS network by encapsulating and transporting TDM, Frame Relay, and ATM traffic over IP MPLS. Thus all protocols and its associated access layers gets integrated and converged to a single Core architecture. The data are transmitted over the network through pseudowires. The pseudowire is an emulator, emulates as an Virtual circuit (VC) from one location to another and the necessary Virtual Routing and Forwarding (VRF) configurations are done at the Provider edge network. VRF populates the virtual routing and forwarding in the Core and establish the end to end IP connection. This helps in integrating the Mobile network as a packet Network to the core. Fig. 2 illustrates the MToP Establishment of MPLS in a Mobile Network.

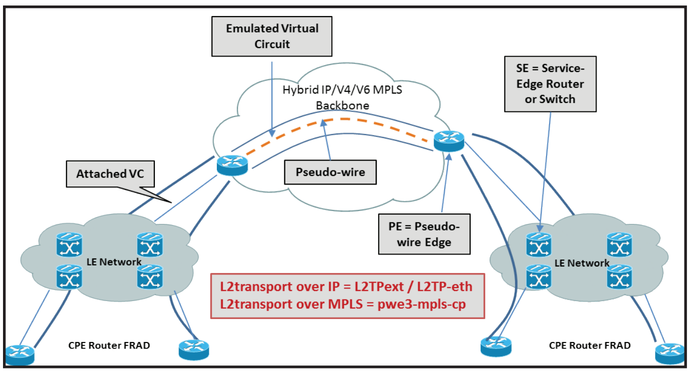

Fig. 2: MToP Establishment of MPLS in a Mobile Network

MToP is integrated in Carrier Ethernet Design using Circuit-Emulation-over-Packet (CEoP) Shared Port Adapters (SPAs) that work with traditional 2G and 3G networks. Mobile services are complemented by the IPv6 enabled Core platform, supporting trouble-free expansion to support emerging 4G technologies. CEoP enhances the Pseudowire portfolio for Time-Division Multiplexing (TDM) and ATM transport over packet. With CEoP-Enabled MToP, Mobile Service Providers (MSPs) can reduce operating expenses (OpEx) and enhance flexibility while offering greatly improved performance to their customers with seamless mobility and guaranteed QoS. Thus the integration from Access to Core is seamless and makes this design flexible for implementation in NGN.

This proposed framework enables the users from one domain to access their data from another domain based on the seamless integration. Therefore IPv4 networks are allowed to have IPv6 network nodes and IPv6 networks are allowed to have IPv4 network nodes. This forms a complete integration of heterogeneous network.

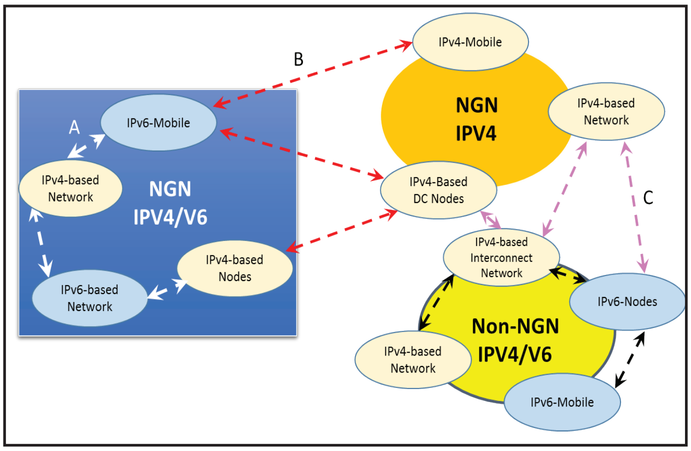

Fig. 3: IPv4/IPv6 Interaction of Mobile Nodes for NGN and Non-NGN

The possible communications are denoted by the alphabets A, B and C. A denotes Intra-NGN communication within NGN network, B denotes Inter-NGN communication within NGN networks and C denotes Inter-NGN communication in a NGN and Non-NGN networks. The flow of IPv4/v6 interaction of mobile nodes for NGN and Non-NGN is depicted in fig. 3.

IV. Experimental Study

The main focus of the experimental study is to test the functionality of heterogeneous IPv4/IPv6 based NGN network with respect to IPv4/IPv6 core transition/coexistence, mobility between IPv4 and IPv6 nodes, core and access protection, and to measure the performance of these mechanisms on a network, including nodes and routers that support dual IPv4/IPv6 stacks, Tunneling, and IPv6 implementation using the existing IPv4 infrastructure. The entire testing process was carried out within the Lab Environment using a virtual topology. The performance of the proposed system was investigated in terms of any time, any device mobility, QoS and Security. The results of the experiments are tabulated and graphically presented in the following sections.

A. Experimental Set-up Test Bed

The proposed framework of heterogeneous IPv4/IPv6 based NGN network is tested in a service provider Lab Environment. Figure 4 illustrates the sample test bed for inter and intra NGN mobility testing.

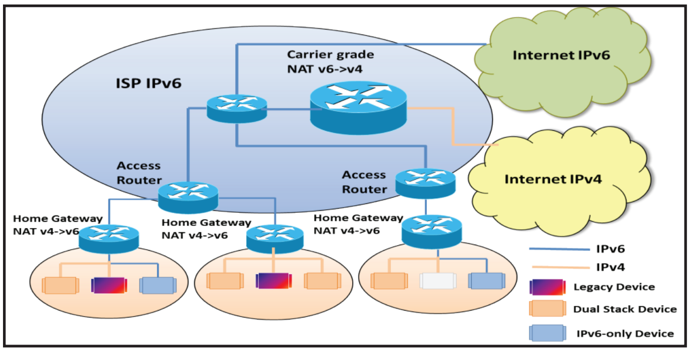

Fig. 4: Sample Test bed for Inter/Intra NGN Mobility Testing

The IPv6 enabled MPLS core test bed consist of Dual Stack Routers connected back to back to simulate a Pseudowire MPLS network environment; it also houses a soft switch for PSTN simulation. Both the MPLS core platform consists of Web service enabled PC and Standalone PC for mobility testing. The Test Bed used for Mobility is studied under four categories (i) IPv4 device node to another IPv4 device node in IPv4 network (IPv4-IPv4) , (ii) IPv6 device node to another IPv6 device node in IPv6 intra NGN network communication (IPv6-IPv6), (iii) IPv4 device node to another IPv6 device node in Hybrid IPv6-v4 network communication (IPv4-IPv6), (iv) IPv6 device node to another IPv4 device node in Hybrid IPv4-v6 inter NGN network communication (IPv6-IPv4).

V. Performance Analysis

Network performance is analysed by network traffic measurement in a test bed network, using Ixia network traffic Generator. The traffic generator sends dummy packets, often with a unique packet identifier. The entire testing process was carried out within the GNS3 Emulation Environment using a virtual topology for the four categories of communication.

A. Packet Loss/Data Loss Rate Analysis

Packet Loss is referred to as the ratio between the numbers of bytes received at the receiving node to the total number of bytes transferred from the source node. It is always envisaged to have packet loss less the 1% in a NGN network because all the applications used under NGN are time sensitive.

Table 1: Simulated Results for the Packet Loss Rate Analysis

Packet Size (bytes)	IPv4-IPv4 (ms)	IPv6-IPv6 (ms)	IPv4-IPv6 (ms)	IPv6-IPv4 (ms)
64	0.0009863	0.0009883	0.0005	0.0010248
128	0.0009863	0.0009883	0.0005	0.0010248
512	0.009863	0.009883	0.007	0.010248
1024	0.009912	0.009912	0.007	0.010849
2048	0.009937	0.009956	0.007	0.011683
4096	0.009958	0.009961	0.007	0.012114
8192	0.009973	0.009967	0.006999	0.012387
16384	0.009998	0.009982	0.006997	0.01249

In the packet loss rate analysis, the packet size is varied in the range (64,128,512,1024….16384 in bytes), to measure the corresponding change in the loss rate. Table 1 shows the simulated results for the packet loss rate analysis for all possible communications.

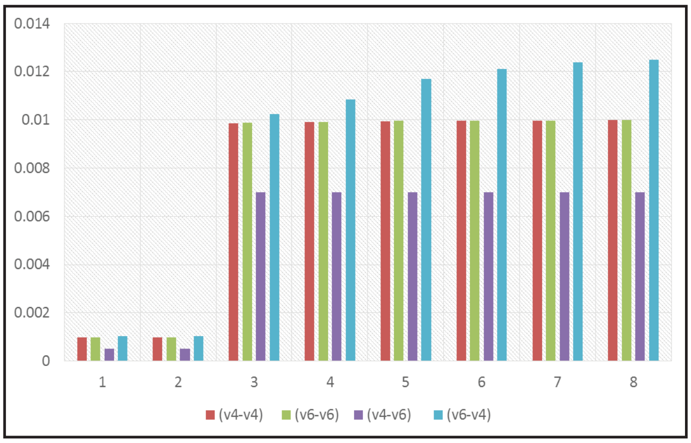

Fig. 5: Packet Loss Rate for All Possible Communications

In fig. 5, the packet loss rate observations made for all possible four types of communications are presented. The packet loss rate for the communication between IPv4 only nodes; and the communication between IPv6 only nodes are found apparently equal. IPv4 packets are successfully sent from IPv4 source node to the IPv6 destined node and the data loss rate for the communication from IPv4 node to IPv6 node is very less. IPv6 packets are successfully sent from the IPv6 source node to the IPv4 destined nodes in an Intra NGN communication.

However, a minor delay is observed since it is an Intra NGN communication between IPv6 to IPv4 device nodes as the IPv6 packets contain huge data during the communication from the IPv6 source node to the IPv4 destined node and vice-versa as the IPv4 router buffer size is lesser than the IPv6 router buffer size. However the lost packets are retransmitted successfully. Overall the Packet loss is observed to be less than 1% which is the primary requirement for any NGN communication.

B. Jitter with QoS

Jitter is often defined as the variance in network latency. Thus if the average latency is 100 ms and packets are arriving between 95 ms and 105 ms, the peak-to-peak jitter is defined as 10 ms. NGN network application are highly sensitive to Jitter, as such, has an end-to-end jitter target to be less than 50ms Jitter Rate for the NGN communication is studied. In the Jitter rate analysis, the packet size is varied in the range (64,128,512, 1028,...16384 bytes), to measure the corresponding change in the loss rate. Table 2 shows the simulated results for the jitter rate analysis. In Fig. 6, the jitter rate observations made for all possible four types of communications are presented.

The Jitter rate for the communication between IPv4 only nodes found to be increased with the increase in bandwidth and usage. The Jitter rate for the communication between IPv6 only nodes found apparently equal and shows very minor variance with increase in bandwidth and usage. The Jitter rate for the communication between IPv4 to IPv6 Hybrid IPv6-IPv4 network communication observed to be equal with increase in bandwidth and shows very minor changes, also jitter rate for communication between IPv6 device nodes to anotherIPv4 device node in a hybrid IPv4-IPv6 intra NGN network communication observed to be equal.

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Table 2: Simulated Results for the Jitter Rate Analysis

Packet Size (bytes)	IPv4-IPv4 (ms)	IPv6-IPv6 (ms)	IPv4-IPv6 (ms)	IPv6-IPv4 (ms)
64	15	5	9	9
128	15	5	9	9
512	15	5	9	9
1024	15	5	9	9
2048	15	6	9	12
4096	20	6	10	14
8192	25	7	15	15
16384	25	7	15	15

It is observed that the Jitter Rate between Intra NGN communication and Inter NGN communication involving IPv6 nodes seems to perform better than IPv4 only nodes due to the fact that IPv6 supports refined NGN QoS parameters. Overall the jitter is observed to be less than 25ms which is the primary requirement for any NGN communication.

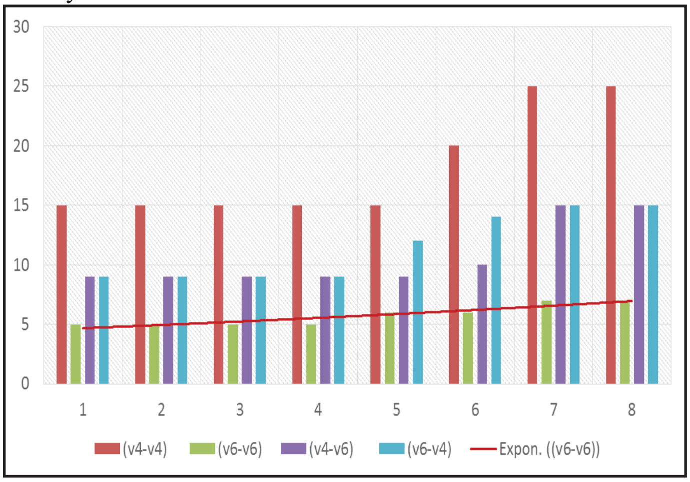

Fig. 6: Jitter Rate for All Possible Communications

C. Latency Analysis between IPv4 and IPv6 Communications

Transmission delay or the latency is the amount of time taken to transmit all the packets from source to the destination. Latency analysis for NGN network is studied by sending different size packets (64,128,512, 1028, ...16384 bytes). The latency is measured by varying the packet size from 512 bytes to 16384 bytes. The latency/delay measured for all possible four communications are recorded into the Table 3. The graph presented in fig. 7 indicates the output observed for all possible four cases of communications.

Table 3: Simulated Results for the Latency Analysis

Packet Size (bytes)	IPv4-IPv4 (ms)	IPv6-IPv6 (ms)	IPv4-IPv6 (ms)	IPv6-IPv4 (ms)
64	5	3	10	10
128	20	3	20	20
512	25	5	15	15
1024	30	8	20	20
2048	30	10	25	25
4096	33	10	30	30
8192	40	10	30	30
16384	45	10	30	30

It is observed from fig. 7 which clearly indicates that the delay for the IPv4 to IPv6 communication is less when compared with IPv4 to IPv4 communication and also the delay in IPv6 to IPv4 communication is low when compared with IPv4 to IPv4 communication. This is due to the optimization of the routes received from the Non NGN neighbors routing table size in the Intra NGN communication. In IPv4 to IPv6 communication, at the receiving end, the IPv6 router buffer size is greater, hence the IPv4 packets are easily processed.

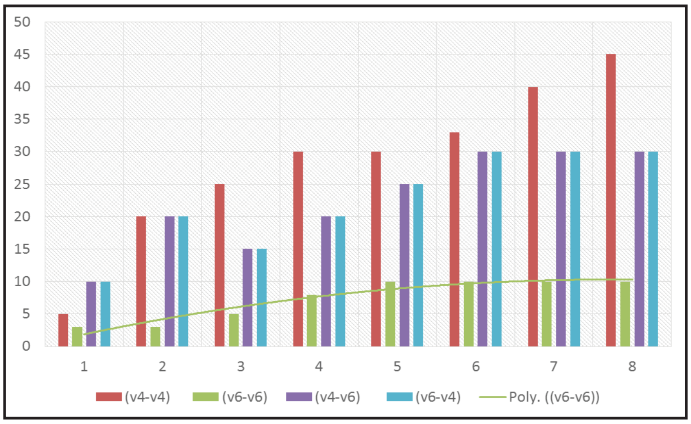

Fig. 7: Simulated Latency Analysis for All Possible Communications

Fig. 7 indicates that the transmission of packets from IPv4 network node to IPv6 network node has low latency and vice versa in an intra NGN communication. This is due to the fact that NGN QoS of prioritizing scheduling and queuing helps in optimization of packet size and routing. Whenever it receives larger packet size, IPv6 router needs to retransmit packets with smaller MTU discover packets until the IPv4 router is capable of receiving the packet without any loss. Hence there is no such a delay for the communication from IPv6 node to IPv4 node. However, all the IPv6 packets were transmitted to the destined IPv4 nodes. Also, in the IPv6 to IPv6 communication, the latency is observed to have maximum 10ms throughout which is negligible. Dual Stack mechanism was found to have lower latency in all of the packet size tests. Consistency of latency was also found to be better in comparison to Tunnel mechanism. The overall delay is observed to be less than 50 ms which is good for best customer experience.

D. Mobility Testing - Machine to Machine (M2M) Test Results

Machine to Machine (M2M) refers to technologies that allow both wireless and wired systems to communicate with other devices of the same type. The M2M traffic has its own specific characteristics, such as low mobility and offline and online data transmission, which create new challenges for dimensioning the network. Testing is done by customizing networks to support traffic generated from residential and enterprise customer premises equipment (CPE). M2M analysis for NGN network is studied by sending 64 bytes size packets communication between PC to PC, Mobile to Mobile and Mobile to PC VoIP for the four categories of transmission. The Reachability Convergence measured for all possible four communications are recorded in Table 4. Fig. 8 indicates the output observed for all possible four cases of communications.

Table 4: Simulated Results for Reachability Convergence

Convergence (ms)				
M2M Testing	IPv4-IPv4	IPv6-IPv6	IPv6-IPv4	IPv4-IPv6
PC-PC-Datacenter	20	6	10	11
Mobile –PC VOIP	30	15	15	23
Mobile –Mobile	15	6	10	13

It is observed from Figure 8, that the Convergence of packets from Mobile to PC VoIP, PC to PC, Mobile to Mobile is lower in IPv6-IPv6 and IPv6-IPv4 communication confirming the working of the Granular configured QoS from CPE to CPE. Also the IPv4-IPv4 is higher in all case of combination which confirmed the need of the NGN network.

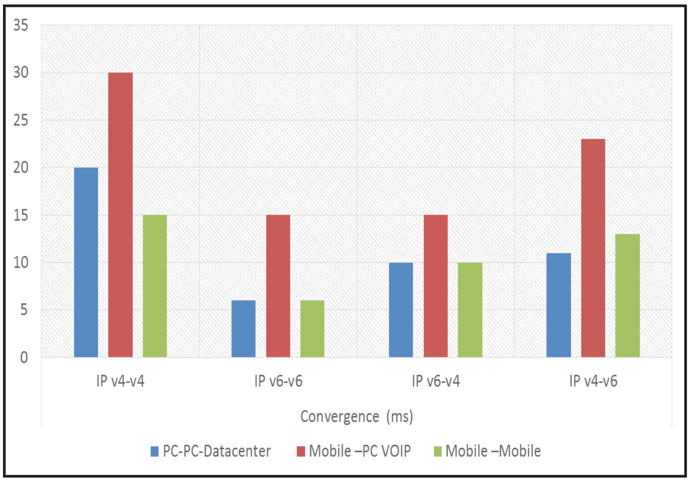

Fig. 8: Reachability Convergence for All Possible Communications

VI. Conclusion

The proposed integrated IP-MPLS mobility framework for NGN is an approach to realize the idea of next-generation services for the delivery of quad play data, voice, and video anywhere, anytime. It provides a migration path to an integrated framework and supports NGN and Non-NGN interoperability to achieve seamless mobility, better control and greater network efficiencies. The simulated results prove that the proposed framework provides seamless mobility with end-to-end QoS, scalability, resiliency, and management enhancements for deploying data, voice, and video services.

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