An Integrated IP-MPLS Architecture for Next Generation Networks

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ABSTRACT
Next Generation Networks (NGN) is a strategy to achieve the vision of next-generation services for the delivery of quad play data, voice and video anywhere and anytime virtually across any access technology. It integrates the services of 2G/3G/4G Networks including IPv4 and IPv6 and incorporates the services of traditional networks into a single service platform with the usage of Multi-Protocol Label Switching (MPLS). Much work has been reported by researchers to integrate MPLS technology into IP networks. But, not much progress has been made so far. In this paper, a novel integrated IP-MPLS Architecture is proposed, which provides IP-integration, end-to-end quality of service, security, scalability, resiliency, and management enhancements for deploying data, voice, and video services. Test bed has been established for testing the performance of the proposed architecture.

Keywords
NGN, IP-MPLS, Packet Loss, Jitter, QoS, IPoDWDM

1. INTRODUCTION
NGN is envisioned to be an interworking environment of heterogeneous networks [1] and is a response to network operators and service providers to replace existing telephone networks as well as to introduce a new converged service platform between fixed and mobile telecommunication businesses[2]. It is the movement from separate and vertically integrated application-specific networks to an unified network capable of carrying any services [3]. It integrates services offered by traditional networks and new innovative IP services into a single service platform and delivers new services that are available to any place, at any time, on any device, through any customer-chosen access mechanism.

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" [2].

Telecom operators are merging the transmission and management of a broad range of services deployed on different networks to reduce their Capital Expenses (CapEx), Operating Expenses (OpEx), increase business agility, and more easily deploy Content aware services on to the cloud, IP Multimedia Subsystem services and new 4G/LTE IP-based services. Service providers are increasingly migrating their networks to an IP-based architecture while the overall volume of IP traffic is dramatically growing worldwide [4]. Consumers and Enterprise are using mobile more as an ICT appliance than just a voice device and cautiously advising service providers to upgrade themselves to future trending Next Generation Network (NGN) to keep their subscribers stick to their network, thus preventing revenue loss. Both traditional and new applications are adopting IP such as television, video, and voice as well as music and video podcasting and peer-to-peer (P2P) file sharing [4]. In this scenario, NGN is being considered as a new telecommunication infrastructure replacement for legacy networks.

Next generation networks (NGNs) 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). NGN provides various changes to the telecommunications as consequences by technical features and characteristics of IP. NGN enhances the convergence of voice, data and video networks into a single integrated packet-based multi-service network capable of providing innovative services [5]. Converging facilitates unprecedented cost savings and performance advantages for the Carriers.

This heterogeneous networking environment faces new challenges such as generalized mobility, and network discovery and selection along with the traditional challenges such as security, QoS, and charging. Providing effective, secure and efficient operations and management of the envisioned NGN environment is a huge challenge [6]. It is noted that the NGN standards released by ITU-T at present, just defines an overall framework with its mandatory requirements, but no mandatory network technologies are specified in those standards or recommendations. Even though there has been considerable amount of research work carried out in these areas, there is no concrete proposal offered so far to build an integrated secure architecture for NGN.

This scenario promulgates the need to design an Resilient, adaptive architecture for An Integrated Next Generation Network for Carriers, Enterprise and Consumers with due care on End-to-End security in deployment of Core, Access and consumers to detect or block all types of malicious code or attack patterns with "5-tuple" capabilities (i.e. Source/destination IP address, source/destination port, and protocol) with the ability to allow/deny networking activity based upon the application type and the user's role.

Hence, in this paper, a novel architecture has been proposed to design an Integrated IP-MPLS based secured Architecture for NGN. The proposed "Converged" Next Generation Network will provide a multi-service, multi-domain/Protocol, multi-access (Wireless &Wired), IP (IPV6 & Hybrid) based network which is secured, reliable and trusted Multi-services which are delivered by a common intelligent QoS enabled Core and Access network.

2. RELATED WORK

Peng et al. [7] have proposed a new Adaptive Service Provisioning Architecture (ASPA) which is applicable to Next Generation Network (NGN) and focused only on service adaptability, not on mobility, security and IP compatibility. The architecture was designed with five subsystems namely Available Service List Generator (ASLG), Service Manager (SM), Content Adapter (CA), Network Environment Adapter (NEA) and Reconfigurable Charging (RC) adaptable to user, network and service environment. Several modules of the subsystems of the proposed architecture have been explained. ASLG subsystem generates the adaptive service list for the users and provides an interface for the users to access their profile data. SM subsystem registers a new service and composes a new integrated service in which the modules use agents to communicate with each other, publish, bind, get and register interactions.. The CA subsystem performs content selection and transcoding to overcome the mismatch between user's terminal and service content according to some suitable policy. NEA subsystem collects and abstracts network environment information and guarantees the QoS during the dynamic nature of service initialization and interaction. RC subsystem charges based on current network condition and user preference. An experimental study has been made to test the functionalities of the architecture with PC, laptop, PDA, PSTN devices which are all adaptable to NGN services. The proposed ASPA is only a concept model, further study should be focused on the detailed design of the modules and the definition of the interfaces with IP compatibility, device authentication and security and the integration of the services to solve the very purpose of NGN.

Rudra et al. [8] have proposed a new internetworking architecture, SILO (Services Integration, controL, and Optimization) for the Next Generation Networks which allows applications to work synergistically with the network architecture and physical layers to select the most appropriate functional blocks and tune their behavior so as to meet the application's needs within resource availability constraints. The SILO architecture removes the necessity of having different control and management paradigms or interfaces for routers as opposed to endpoint devices. Different protocols for the same layer and different implementations of the same protocol can be "plugged in and out" without affecting the correctness or functionality of protocols at other layers. The SILO approach can be viewed as "operate in layers, control across layers." The proposed architecture is flexible and extensible so as to foster innovation and accommodate change. It supports a unified Internet, it allows for the integration of security and management features at any point in the networking stack, and it is positioned to take advantage of hardware-based performance-enhancing techniques. This architecture addresses various problems like defining services, constructing and optimizing silos, selecting building blocks and their granularity and guaranteed interaction of nodes in the SILO architecture in NGN environment.

Jialei et al. [9] have proposed a layered architecture for MPLS network itself. In this layered architecture, MPLS area is divided into two independent parts: merging area and core area. Most of the users' data are handled within the merging area, while only a small portion travel through the core area. This makes it possible to decrease the operation needed in the core area and consequently increase the data transferring speed.In this architecture, there are two kind of labels namely local (regular MPLS labels) and global (TE) Labels. Data transportation in the core area consumes global labels, others use re-usable local labels. This labeling strategy effectively eliminates the stress in label consumption for the whole Internet in the future. Data classification and transportation in this layered MPLS architecture happen in the MPLS layer itself, which makes it more controllable and flexible than any other cross-layer operation. The research challenges focused in this paper are the integration of pure IPv6 network in NGN environment, job sequence during the initialization phase, support for multicasting services, mobilized communication scenarios and so on.

Gufang et al. [10] have suggested the access network protocol stack for NGN based on IP over MPLS and compatible with IPv6. This access network protocol stack uses Tunnel Protocol (TP) or Modified Tunnel Protocol (MTP) to realize cooperative working of multiple access networks. And, it integrates the common heterogeneity networks with different architectures by matching in cross layers and optimizing. So, it sets up the access networks protocol stack of the next NGN with information sharing. It uses the Resource ReserVation Protocol (RSVP) to reserve the network resource (bandwidth) for every data stream. Because, RSVP needs the connection setup and release, which will become very frequent, RSVP is not suitable for the NGN.

Sukant K. Mohapatra [11] have proposed an architectural solution for Integrated Network Planning for NGN and provides an overview of market trends on service and network convergence, and reference next generation networks architecture focused on transport stratum. The integrated planning component enables end-to-end seamless planning of next generation networks. This component has three main sub-components: Workflow Engine, Multi-domain/Layer Planning and Multi-domain Reporting. Workflow Engine enables seamless information flow across multiple domains and layers. Multi-domain/Layer Planning enables the planning of the specific domain, which integrates network planning of whole network (end-to-end) with support of capability such as global traffic sensitivity analysis, inter-domain and inter-layer failure analysis. Multi-domain Reporting enables to produce planning reports for end-to-end planning of the next generation networks by interacting with specific domain planning components. The reports could be inter domain and inter layer, as well as covering entire next generation network. This paper focuses on integrated planning aspect of reference solution architecture to meet multitude of network planning challenges, thus enabling cost optimal planning and deployment of next generation networks. This architecture is not implemented in real time.

European Union 7th Framework Program have proposed Service-Oriented Architectures for All (SOA4ALL) [12] which aims at providing a comprehensive framework for NGN that integrates four complementary and evolutionary technical advances (SOA, context management, web principles, Web 2.0 and semantic technologies) into a coherent and domain independent service delivery platform. SOA4ALL integrates the most recent and advanced technologies into a comprehensive framework and infrastructure to provide an efficient web of billions of services through SOA4ALL Studio, Distributed Service Bus, SOA4ALL Platform Service, and Business Services (third party Web services and lightweight processes). Research challenges include the openness of the future web communities, IP addressing and mobility which pave the way towards a real explosion on the NGN platform.

3. PROPOSED INTEGRATED IP-MPLS ARCHITECTURE

This proposed design is based on heterogeneous network convergence with high capacity and interoperability, granular end- to-end Quality of Service (QoS), intelligent structured IPv6 & Hybrid (IPv4/v6) architecture with mobility and security. This design inherits the prospective attributes such as high availability and resiliency, predictable network behavior, scalable and consistent deployment model, quick service deployment, easy management, reliable service delivery and lower total cost of ownership.

The architecture defines the structure of components, their interrelationships, the principles and guidelines governing their design and evolution over time. Fig.1 depicts the proposed architecture which consists of the core IP-Multi Protocol Label Switch (MPLS), the components of Integrated IPv4/IPv6 services with access network. The core IP-MPLS is composed of core switch, softswitch, content storage, service control engine, IP class 4/5 switch, edge router, Unspecified Bit Rate (UBR) and Digital Subscriber Line Access Multiplexer (DSLAM). The core switch is a high capacity switch, placed within the backbone of the network and acts as a gateway to provide aggregation point for the heterogenous network.

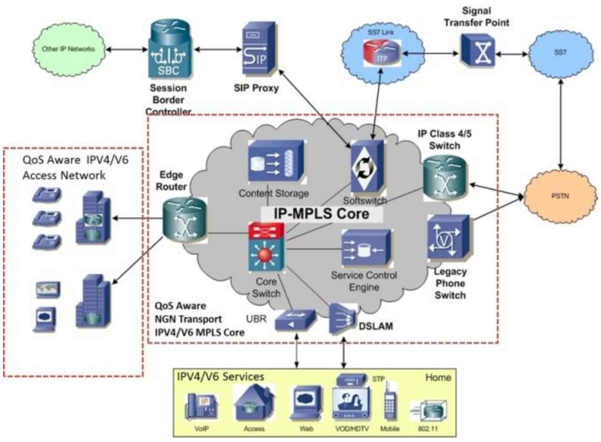

Fig.1 : Integrated IP-MPLS Architecture for NGN

Softswitch is a programmable switch, creates interface to the legacy networks through Signaling Gateways (SG) and Media Gateways (Access Gateway). The softswitch, is the core device in the integrated NGN which is recognized as Media Gateway Controllers (MGC). It is located in the service provider's network and handles call control and signaling functions. It keeps track of every call in the network and maintains the call state. It interacts with the application servers to provide services that are not directly hosted on softswitch. The important functions executed by the soft switch are media gateway access control, signaling gateway control, border gateway control, resource allocation, protocol processing, routing, authentication and charging.

The signaling interface between the IP network and the PSTN signaling network is provided by the Signaling Gateways (SG). It terminates Signaling System 7 (SS7) links and provides Message Transport Part (MTP) level 1(Physical) and level 2 (Data link) functionality. Each SG communicates with its associated circuit switch to support the end-to-end signaling for calls. Access Gateway refers to devices that either originate or terminate traditional landline phone calls. It acts as the line side interface to the core IP network and connects subscribers with analog subscriber access, Integrated Services Digital Network (ISDN) subscriber access, V5 subscriber access, Private Automatic Branch Exchange (PABX) and x Digital Subscriber Line (xDSL) access.

IPv4/IPv6 services are integrated with DSLAM which connects multiple customer DSL interfaces to a high-speed digital communications channel using multiplexing techniques. UBR plays a crucial role in this proposed architecture to avoid transmission delays of the packets and to ensure quality of service. Edge router routes the data packets between Ipv4 and IPv6 Networks. The connectivity between the customer premises equipment and the access gateways in the service provider's network is provided by the access network and IPv4/v6 services are availed through IP Terminals. The IP terminals refer to IP phones, IP PBX and software phones which are intelligent terminals based on either H.323 or SIP protocol.

The SCE (Service Control Engine) platform makes a distinction between identical IP addresses that come from different VPNs, and maps them into subscribers according to the MPLS labels attached to the packets. The SCE also performs deep packet inspection, identifies the users, stores the data in the Content Storage through Core Switch and generates the report data records. Session Border Controller (SBC) is located at the administrative boundary of the Core IPv4/v6 network for enforcing policy on NGN Network. Session policy may be defined to manage security, service level agreements, network device resources, network bandwidth, inter-working Inter and Intra NGN and protocol interoperability between NGN and Non-NGN networks. The functions provided by the Session Border Controller (SBC) are Connectivity / Inter-working, Security, Service Assurance, Lawful Interception, Protocol Translation and Call accounting and Regulatory compliance.

To provide Transport Services, the network protocols IP and Transport/Generalized-MPLS (T/G-MPLS) are used with the optical fibre transport technology IPoDWDM. This optical transport aggregation integrates the IP NGN Carrier Ethernet design through IPoDWDM interconnections. The integration of IP and DWDM in the core and aggregation networks reduces the need for transponders and allows signals to stay in the optical domain. The signals remain to be the same without electrical conversion. IP-MPLS core network offers routing and transports IP packets by adapting packet switching technology and provides various services such as voice, video and data to the subscribers with a common and integrated platform. It ensures high reliability, availability, security and quality of service.

The main feature of IP-MPLS Architecture is to switch applications between IPv4/v6-enabled devices and to establish peer-to-peer and peer-to-content connections easily and securely. The various modes of communication between IPv4/IPv6 could be (i) IPv4 node initiated communication with IPv6 destined node; (ii) IPv6 node initiated communication with IPv4 destined node, where the source and the destination nodes roaming in different IP version networks; (iii) the IPv4 initiated communication with IPv4 destined node and (iv) the IPv6 initiated communication with IPv6 destined node, where the source and destination nodes are in the same networks. Once the IP connection is established, all types of communication including voice, video, data can be exchanged. The Core IP-MPLS provides a full suite of network capabilities for authentication of clients, network-to-network interfaces and administrative functions such as monitoring, charging etc. The proposed architecture makes the design unique, scalable, bandwidth friendly and easily accessible.

4. EXPERIMENTAL STUDY

The main focus of the experimental study is to test the functionalities of IP-MPLS architecture for NGN with the integration of IPv4/IPv6. The performance of the proposed integrated IP-MPLS architecture for next generation network is tested in a service provider lab environment in terms of jitter and packet loss during the data transmission from NGN to non-NGN and vice-versa. Fig.2 depicts the sample test bed. The IPv6 enabled MPLS core test bed consists 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.

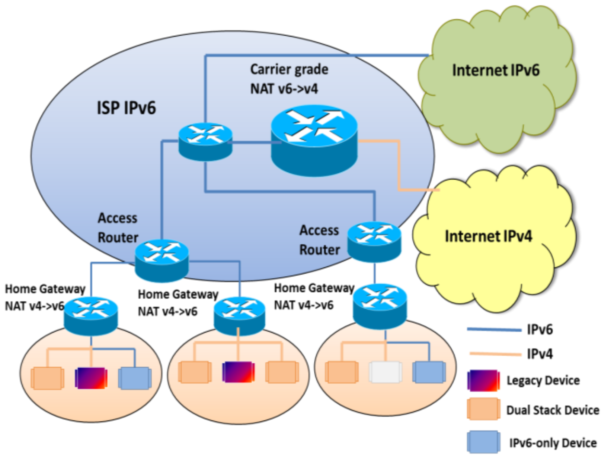

Fig.2 Sample Test Bed

The test bed is studied under four categories of communication (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). The results of the experiments are tabulated and depicted.

4.1 Performance Testing for Packet Loss

Network performance is analysed by network traffic measurement in a test bed network, using Ixia network traffic generator. The traffic generator sends dummy packets with a unique packet identifier. The data packets are analysed with all the possible communications: IPv4-IPv4, IPv6-IPv6, IPv4-IPv6 and IPv6-IPv4. The entire testing process was carriedout within the GNS3 emulation environment using a virtual topology for packet loss rate analysis. It is always envisaged to have packet loss less than 1% in a NGN network because all the applications used under NGN are time sensitive and need to be treated as premium as possible. In the packet loss rate analysis, the packet size is varied in the range (64,512,1024….16384 in bytes), to measure the corresponding change in the loss rate. Table 1 shows the simulated results in milliseconds for the packet loss rate analysis.

Table 1–Simulated results for the packet loss rate analysis

Packet Size (byte)	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 Fig.3, the packet loss rate observations are made for all possible four types of communications which include (i) IPv6 to IPv6 Communication, (ii) IPv4 to IPv4 Communication, (iii) IPv6 to IPv4 Communication and (iv) IPv4 to IPv6 Communication. 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 with lesser delay.

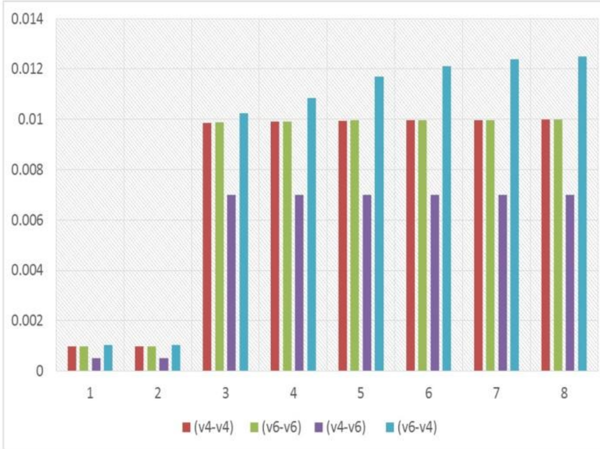

Fig. 3: Packet loss rate for all possible communications

In an intra-NGN communication between IPv6 to IPv4 device nodes , a minor delay is observed since, IPv6 packets contain huge data during the communication from the IPv6 source node to the IPv4 destined node and vice-versa. Moreover, 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.

4.2 Performance Testing for Jitter

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.4, the jitter rate observations are made for all possible four types of communications with IP integration.

Table 2 – Simulated results for jitter rate analysis

Packet Size (byte)	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

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 for jitter rate for communication between IPv6 device nodes to another IPv4 device node in hybrid IPv4-IPv6 intra NGN network communication observed to be equal.

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.

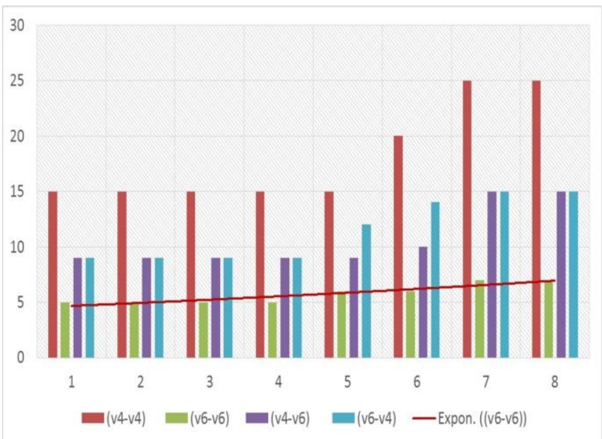

Fig.4: Jitter rate for all possible communications

5. CONCLUSION

The proposed IPv4/IPv6 integrated IP-MPLS architecture for NGN is to realize the idea of next-generation services for the delivery of quad play data, voice, and video anywhere, anytime, any device across virtually any access technology. The proposed architecture is unique one, which is scalable, bandwidth friendly and easily accessible for the implementation in next generation networks. The proposed architecture is tested and the results are presented. Further study is also undertaken for testing the quality of service of the proposed architecture.

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