

SN-FMIA: SDN and NFV enabled Future Mobile Internet Architecture

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Abstract — In this era wireless technology gaining more popularity, people prefer wireless communication over wired communication due to mobility, scalability and ease of access. However, the traditional wireless network is complex, vendor dependent and inadequate feasibility to incorporate new services, protocols, and APIs. The rapid growth in wireless network raises many thoughtful challenges for network and telecom operators. On such grounds, Innovation of Software Defined Network (SDN) and network function virtualization (NFV) for mobile network opens a new arena of research. This research article presents future mobile Internet architecture (FMIA) with the integration of twin technologies, SDN and NFV that enable rapid access to Internet services. Moreover, the network manager can control services provided by ISPs through proposed architecture.

Keywords— *Future Mobile Internet Architecture; Software Defined Network; Network Function Virtualization.*

I. INTRODUCTION AND MOTIVATION

With the rapid growth of mobile users and proliferation of smart applications demand high-end data rate. One survey conducted by CISCO shows that mobile network [1] in the year of 2019 per month overall data traffic will exceed 24.3 Exabyte, also 97% mobile data traffic generate through smart devices. Leading motivation in wireless traffic are multifarious mobile applications, E-Banking, E-agriculture, E-commerce, E-business, etc. These applications force mobile technology to integrate the mobile internet with high volume internet seamlessly that can support in the fifth generation (5G) network. 5G will have extensive data rate up to 10Gb/s, ability to control vast quantity of devices, rapid access to data, almost 99% reliability and expected to deliver gigabit link in crowded areas also.

The current infrastructure is not suitable to support next generation technologies and limited in capacity according to future mobile 5G [1] network traffic demands thousand times greater. Moreover, static nature of current network does not permit heterogeneous services to execute at a real time according to network requirements. In a traditional network each base station consists independent control plane[2], this causes a lack of coordination between neighboring base stations. At present, cellular architecture has particular challenges, consolidated control, global access, centralized monitoring, and quality-of-services. In LTE network all traffic pass via the P-GW, either user on the

same network or another network that produce more complexity inside the cellular network[3]. Extensive tunneling effect data rate that increase the latency rate, multifarious protocols in control plane leads to complex communication at the base station. Moreover, installed equipment interface is available on vendor specifications. Consequently, it is difficult for service operators to deploy new-fangled services in existing network that denigrate the quality of service (QoS).

Mobile carriers declare[4] that the frequency spectrum is not enough for future mobile traffic and may not be able to support high data rate mobile applications that can mitigate mobile network performance. Although researcher and professionals have concurred that the critical cause of spectrum crisis is an inadequate resource allocation.

Virtualization of the wireless network provides[5] promising a solution for service providers (SPs) to extend their network utilization and resource management, furthermore telecommunication operators are pertaining to virtualization techniques. Much research work about network virtualization [5][6][7] has done. However, existing mobile network are not fully capable to support virtualization. LTE network is partially providing virtual network infrastructure for building VPN connection for the user, however not authorize to other service providers to execute their services. The above discussion motivates us to introduce a novel concept of future Internet architecture. We emphasize on specific objectives of proposed architecture.

The first goal, for future mobile Internet architecture, there will need to eliminate the intermediate bases (Middle Box) that make hurdles for smooth delivery of Internet services. We define future mobile Internet architecture FMIA (fig 1) in which Internet access layer next to a physical layer that provides explicit connection to service providers.

The second objective is concerns about network virtualization that leads existing network architecture towards future mobile Internet architecture. This research contributes an idea about a mutual virtual platform for telecommunication operators, and service providers to offer customized services.

The third objective is to improve QoE (Quality of Experience) because at present vendor focus on the quality of services but for the future network we cannot ignore QoE.

The proposed architecture offers to mobile consumers to select their network type whenever the quality of associated network is insignificant. This kind of approach can boost the QoE at the user level.

The fourth objective is converged the layer-based Internet architecture with the plane-based mobile network as illustrated in fig 2. It consists three planes, application plane related to application technologies and provide a management interface to the service operator. SDN control plane perform intermediate control functionalities, and data plane offer direct internet access to user terminal meanwhile for control tasks access to SDN control plane.

The rest of the article as follows. Section II describes the significant role of SDN and NFV into mobile networks according to requirements of the future network. Section III concisely present research work about future mobile architectures, Section IV elaborate architecture description and its inside components functionality and at final Section V reveal challenges and future work.

II. SDN & NFV HIGHLIGHTS

Software defined network (SDN): for the mobile network has launched new research arena for network operators, developers, and researchers. SDN is a programmable scheme that applied to network devices to make them more intelligent, dynamic and manageable [8]. The fundamental approach in SDN is dividing the control plane for applications configuration and management. It provides a programmable interface (APIs) to the top level controller rather than low-level functions have produced complexity in the traditional network. The network operator can access the whole network and set instructions regarding for example packet flow, routing and load balancing using SDN controller. The second approach is data plane forward the traffic rules using open flow protocol [9] which can apply to the network infrastructure Open flow manage data path that is accessible to researcher also[10].

Network Function Virtualization (NFV): Traditional network contains middleboxes to perform network functions. For example Network Address Translation (NAT), access control, load balancer, flow manager and firewall features that require independent hardware (middlebox) which is expensive and lengthy solution. The idea of virtualization replaces these middleboxes with (NFV) that is a requirement of future mobile Internet architecture.

The wired network had successfully implement SDN [9] based solutions and achieved more accurate performance as compared to a traditional network. After this milestone researcher, industrialist and network operators are paying more attention for implement of FMIA. We discuss some main advantages of FMIA with NFV.

- **Virtualization with SDN** offers an economical interpretation for vendors to extend their network, adopt wide-ranging technologies and well-organized mobile network.

- **Multiple APIs execute on the top of SDN controller.** It is easy to incorporate numerous applications at the higher level of the logical controller, however in the traditional network need to change at the hardware level.
- **Programmable Interface** for network operators enhances agile flow control that reduces error probability.
- **Diverse Services Platform** provide by centralized SDN controller. Various services for example flow handler, security services, IPS/IDS, policy QoS, mobility management can manage by a network manager using the logically centralized controller.
- **Independent Control Plane** can allow multiple operators to execute their applications and build logical control that can manage through open flow protocol and wireless network virtualization
- **Resource Utilization**, as mentioned above SDN and NFV, provide physical resource sharing that extends the network logically also reduce energy consumption and network operating cost

III. RELATED RESEARCH

Various network operators, researchers focused on SDN challenges and prospects. OpenRoad [10] initiate open flow into the mobile network. OpenRoads introduce a test bed OF wireless which control WiFi and WiMax base stations. In the proposed architecture, mobility manager including hard handover, informed handover, n-casting and Hoollack, which offer the user to move freely on existing wireless infrastructure.

One example of video streaming using n-casting approach built on NOX controller, where client utilizes WiFi and WiMax interface. NOX[11] is an open source-based controller provide a broad view of the network, although a standalone platform to run diverse experiment separately. OpenRoad project successfully demonstrates test on wireless network infrastructure in which cellular network not included.

OpenRan [12] introduce radio access network (RAN) with SDN that can be more flexible, controllable, programmable and virtualized platform for the mobile network. Cloud computing resource pool(CCRP) consist of a physical processor, Virtual baseband units (vBBUs). Virtual base station controllers (vBSCs) and wireless spectrum resource based on heterogeneous wireless stations and virtual radio resource unit(VRRU) of two different kinds of protocols that are handled by SDN controller. This architecture has four virtualization levels 1.Application level 2.Cloud Level 3.Spectrum Level 4.Cooperation Level.

SoftRAN architecture[2] handle all physical base station as a radio element under the virtual big base station. Advantages of SoftRAN are Resource Management, Network Management, and Effective Handover.

According to network operator point of view, Radio Network divides into 3D grid under the single base station. It provides a global view of the network that enables to implement multiple control algorithms. "Single base station" control method not very efficient for the client due to traditional handover between new and old base station. Meanwhile author proposes that some of the issues can control like handover latency, interference and stability within the same pair of the base station. SoftRAN central controller provides a platform for soft decoding and manages data plane activities. This architecture set the boundaries of a big base station, reduces the number of handoff and gets benefits of the centralized control plane. This research claims that SoftRAN easily incorporate LTE Standards within existing base stations. However need to evaluate SoftRAN at hardware and software territories.

MobileFlow [13] article about the implementation of SDN based architecture that enables blueprint for flow-based forwarding model. The purpose of this model provides the flexibility to mobile carriers in terms of configuration, radio coverage, gateway location, control and examining of network resources, etc.

CellSDN[3] introduce software-defined approach in a cellular network. First install network operating system to allow supervision of access and core network, and then configure the switch with local agents that handle fine-grained packet control, slicing of radio resources and mobility management.

IV. ARCHITECTURE DESCRIPTION

Future Mobile Internet Architecture (FMIA) established on four logical layers shown in fig.1 that provide a single virtual platform to execute heterogeneous service offered by diverse service providers.

It has three interfaces: Service Operator Interface, Northbound Interface, and Southbound Interface. This section describes architecture components, interfaces and distribution of layers

A. Application Management Layer and Service Operator Interface

We suppose one unified operator interact with service operator interface and can control network in a better way and allow others virtual service provider to execute their service virtually. Through service adapter, the unified operator can globally access of each service for deployment and management at SDN controller. Unified operator concept relate to China tower[14] that will combine base stations like China Mobile, China Unicom, and China Telecom.

Numerous applications implement for network management, network monitoring, network security, network access, network virtualization and control policies through service controlling API which is accessible to unified operator for organizing services that enlighten below:

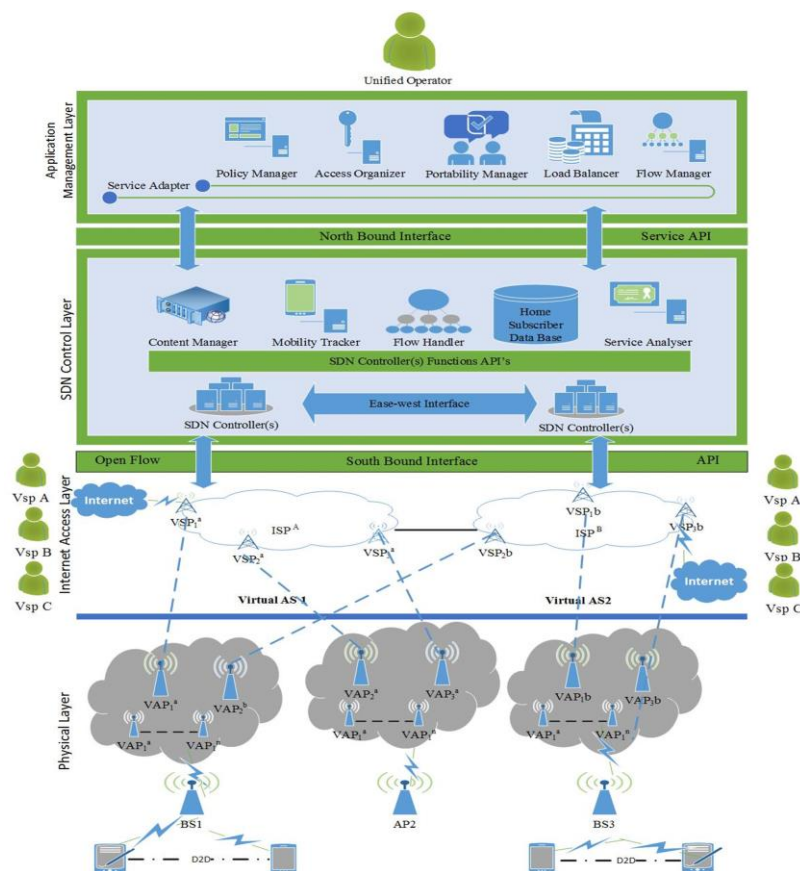


Figure 1. Future Mobile Internet Architecture

- 1) **Virtual AS Manager:** Provide access to control VSP, keep track of controllers, switches and have a global view of Internet services and applications under the umbrella of each virtual autonomous system (VAS).
- 2) **Portability Manager:** Allow user to turn one service to another service during execution. In case of service portability, it defines rules for user portability matters and forward to SDN controller. It is intelligent service that can execute multiple applications through different operators for a single user.
It also refers as software portability where one type of software/application is running on diverse environments, then represent as a logical entity between them and interact with control API [15]. Currently many mobile devices have the ability of application portability [16] through the various mobile market applications framework. In future network privation to append portability features at the top level layer. We adopt this approach as service portability where service with the same functionality can interchange between ISP operators. However, it will face some challenges like service level agreements.
- 3) **Flow Manager:** Each VSP performs different flow control for the different behavior of applications. This component provides a global view of network flow and in future will be discussed how to optimized flow control at a global level. There is a need to adopt algorithm allocation (For example Dijkstra algorithm) for the packet flow and find the shortest path.
- 4) **Service Adapter:** Service adapter deploy at the top of the controller instead of single adapter for separate virtual autonomous systems. It is a logical entity that can be incorporated with service providers to deliver service inside one autonomous system. Service adapter has four components: service category, service session, service protocols and packet forwarding services.

Firs component is declared to network management services, user-oriented services, global services and application services. The second component is about the connectivity of service, start to end service positions and service lifetime. The third component contains information of active protocols that incorporate with services like ICMP, BGP, OSPF, TCP, UDP and OVSDB protocol. Fourth component relates to flow handler that keeps a record of separate flow control of each service.

B. SDN Control Layer

Multilayer management tasks accomplished at this layer. It enables the full control of the network and also supports virtualization on different layers. Get information to Internet access layer and physical layer either IP address-based locations, subscriber information, policy parameters through SDN local agent installed with a physical access point. SDN control layer performs as intermediate role

between the upper layer and lower layers as illustrated in fig. 1. It also receives open flow rules parameters from the application layer and applies an action to lower layers.

For deployment of SDN controller (NOX)adopt FlowVisor [6] that create Isolation between each controller. FV make a slice of data paths according to network administrator requirements and runs multiple hosts guest controllers. Why FlowVisor (FV) incorporate OpenFlow (OF)? Because there are some reasons to join OF and FV, 1) OF manages the physical Network. 2) OF offers a programmable interface of the switch. 3) Multiple OF controllers can host by FV. FV ensure that packet flow control is accurate and forward to the appropriate destination.

- 1) **Autonomous System Manager:** Each Virtual Autonomous System (VAS) connects using service API with the northbound interface. It handles interior and exterior routing updates. Keep a record of switches and routers of the autonomous system and provide information to the network administrator.
- 2) **Service Analyzer:** This module is responsible to examine the mobile user profile for match policy actions from available services. It interacts with policy manager and forward rules to a southbound interface. Each autonomous system policy tracking may be modifying according to consumption of the network, distinct applications and number of connected users.
- 3) **Mobility Tracker:** Provide mobility tracking inside the autonomous system and also synchronized with another autonomous systems. It handles inter-autonomous system handover and intra-autonomous system handover, also involved authentication process with the incorporation of HSS. This module provides a control function interface to the northbound interface for handover between service operators. Keep the record of the mobile user whenever handover occurs through tagging, home location register and visitor location register.

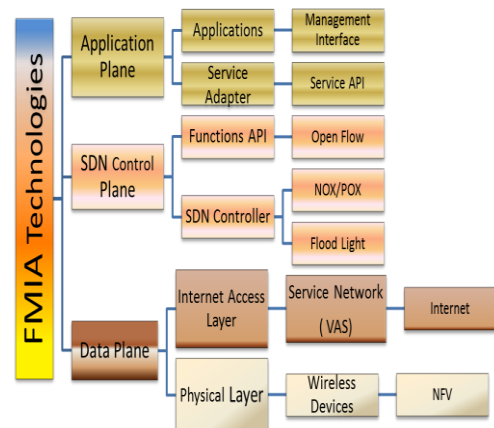


Figure 2. Illustration of FMIA Technologies

- 4) **Home Subscriber Server:** HSS is a centralized database that contains information about all ISP operators. User authentication, the authorization will be performing at this level. It also interacts with the mobility manager control plane for providing access information for the mobile user.
- 5) **Content Manager:** execute content delivery services in the virtual autonomous system and provide local contents at access point level. An agent installed at access point keeps track of service and is synchronized with the content manager of offer the contents. The same contents can easily be available for another connected access point inside the autonomous system.

C. Internet Access Layer

- 1) **Virtual Autonomous System (VAS):** is a pool of routing and Internet protocols under the umbrella of SDN controller that depicts mutual, dynamic, pre-defined routing policies to connect with Internet and service operators.

In this architecture, numerous protocols execute for smooth running of the network. Two routing protocols espoused here; the first one is Border Gateway Protocol, which is used to provide the connection between autonomous systems and establish the link to the Internet. The second one is Open Shortest Path First that is implementation inside the VAS. Some objectives of VAS enlisted below.

- a) The purpose of VAS in proposed architecture is to provide independent controllers for service providers and unified operator for an assortment of master controllers on the basis of availability, cost, traffic and Quality of service parameters.
- b) Inter-AS Communication, in which ISP^A consist multiple VSP shown in fig 1, have related to same ISP however they can vary network performance and traffic load.
- c) Inside the autonomous system where master controller computes the flow process and pass through the link to the Internet.
- 2) **Virtual Service Providers (VSP):** connect with VAS and offer Internet service without the interception of the middlebox that make Internet connection more fast and reliable. The concept of the virtual base station, SoftRAN[2] focused on resource allocation and load balancing. However, proposed architecture provides a link to virtual service provider inside the autonomous system for fine-grained packet control, centralized management, and resource optimization.

D. Physical Layer

Access Point performs like an OpenFlow-based switch in proposed architecture and provides control plane to the southbound interface for channel allocation, power consumption, bandwidth management, and virtualization.

- 1) **Virtual Access Point:** Virtualize Access point characterizes for different kind of service operators[15] which emulate physical access point for multiple VSP as shown in fig 1. Multiple physical access points are providing the internet, and each access point has a multiple virtual access point with unique identities and independent frequency band. CAPWAP is a protocol offered by CISCO that enable communication between access point and controller, hypervisor implement on the access point to build virtual access point.
- 2) **Mobile Terminal:** is responsible to select the best available network according to information provided by a controller. Therefore mobile terminal can choose different VSP, however, flow demand, QoE is handled at the user terminal.

V. CHALLENGES AND FUTURE WORK

We explore that software-defined network and network function virtualization provide new services, rapid Internet access, ease of use, resource optimization and centralized control for future mobile Internet architecture. We furnish a conceptual sketch of FMIA, however, for successful deployment of proposed architecture need to address some challenges that enlisted below:

- 1) **Global Service Management:**
For the implementation of FMIA, it is essential to develop an interface for service management. The interface present a global view of network services that can supervise by the unified operator (Network Manager).
- 2) **OF API with Services API:**
Moderately support each other for packet categorization, flow control, defining actions and rules, however, necessitate to develop OF API for heterogeneous mobile network services. New API should be flexible and can incorporate new services originating from any VSP.
- 3) **NFV and VSP:**
Network function virtualization assists VSP to deploy network services in the large-scale network that incorporate multiple network function and services in terms of virtualization on manufacturing standard hardware. It is a challenge to design new mobile network services that can act as a bridge between virtual functions and network services.

The purposes of new services are resource optimization, enhance the performance of the network, increase the reliability and reduce the infrastructure budget.

4) **Physical Layer Multi-dimension virtualization:**

Multiple service providers are available in the same geographical area to provide different services. Thus, multifarious devices at the physical layer can provide virtual connectivity to all of them as illustrated in fig 2. However, the challenge is how to slice them according to different characteristics, for example, frequency spectrum, channel allocation, available bandwidth, etc.

5) **Customized Network Selection:**

This challenge relates with end user terminal, smart mobile can be able to select best available network at real time on the basis of intelligence algorithm.

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