J Inf Process Syst, Vol.13, No.2, pp.236~255, April 2017
https://doi.org/10.3745/JIPS.03.0069

ISSN 1976-913X (Print)
ISSN 2092-805X (Electronic)

JOURNAL OF INFORMATION PROCESSING SYSTEMS JIPS

Mobility Scenarios into Future Wireless Access Network

Syed Mushhad Mustuzhar Gilani*, Tang Hong*, Qiqi Cai*, and Guofeng Zhao*

Abstract
The rapid growth of smart devices demands an enhanced throughput for network connection sustainability during mobility. However, traditional wireless network architecture suffers from mobility management issues. In order to resolve the traditional mobility management issues, we propose a novel architecture for future wireless access network based on software-defined network (SDN) by using the advantage of network function virtualization (NFV). In this paper, network selection approach (NSA) has been introduced for mobility management that comprises of acquiring the information of the underlying networking devices through the OpenFlow controller, percepts the current network behavior and later the selection of an appropriate action or network. Furthermore, mobility-related scenarios and use cases to analyze the implementation aspects of the proposed architecture are provided. The simulation results confirm that the proposed scenarios have obtained a seamless mobility with enhanced throughput at minimum packet loss as compared to the existing IEEE 802.11 wireless network.

Keywords
Access Point (AP), Internet Architecture, Network Function Virtualization (NFV), Seamless Handover, Software-Defined Network (SDN)

1. Introduction

In the modern era of technology, wireless technology is gaining more popularity compared to the wired technology due to mobility, scalability, and interoperability. The tremendous growth in wireless Internet has raised several contemporary challenges to mobile operators. The first challenge is the rapid growth of data traffic, according to a survey [1], by 2019, mobile network data traffic will exceed 24.3 exabytes per month, and 97% of the traffic will come from smart devices. Nonetheless, the existing wireless infrastructure is insufficient to support next generation technologies and to fulfill the demands of future Internet traffic. The second challenge is the fixed and tight-coupled data and control planes in the current wireless network which is hard to execute multifold services at the real time. In a traditional network, each base station consists of independent control plane [2] which may cause a lack of coordination among neighboring base stations. Consequently, it is uphill battle for mobile operators to deploy innovative services on existing wireless network. The third challenge is deployment cost of new network equipment such as routers, switches, access points (APs), and middleboxes to fulfill the demands of the massively increasing population of Internet user.

Manuscript received January 25, 2017; first revision February 13, 2017; accepted March 04, 2017.
Corresponding Author: Syed Mushhad Mustuzhar Gilani (mushhad@hotmail.com)
* Future Internet Research Group, Chongqing University of Posts and Telecommunication, Chongqing, China (tanghong@cqupt.edu.cn, 77caikiki@gmail.com, zhaogf@cqupt.edu.cn)

In common, networking devices are being designed by multiple vendors with different benchmark and configuration procedures which makes the network management more complex for the network operators. The fourth challenge concerned with the frequency spectrum [3] that is insufficient for the future mobile data traffic and it may not be able to support future Internet applications. The researchers and professionals have realized that the critical cause of the spectrum crisis is the poor resource allocation. The aforementioned challenges motivate the researchers and mobile operators to consider and take over the existing wireless Internet architecture with an innovative one [4].

On such grounds, innovation in software-defined network (SDN) and network function virtualization (NFV) for wireless network opens a new arena of research. SDN [5] has emerged as a key technology for future Internet architecture. The provision of simple network configuration, the centralized control, global view of the entire network, and a platform for the innovative network services and applications are aims of the SDN paradigm. The SDN paradigm has been adopted by the data center, and wired networks, especially the Google's B4 network is a successful example of the SDN implementation. SDN approach addressing the wireless network has also brought several benefits such as mobility management, load balancing, routing, policy management, and radio resource management [6]. NFV [7,8] has been considered to perform a significant role in the development of future Internet architecture. Virtualization of the wireless network provides a promising solution for the service providers (SPs) to enhance their network utilization and resource management [9,10].

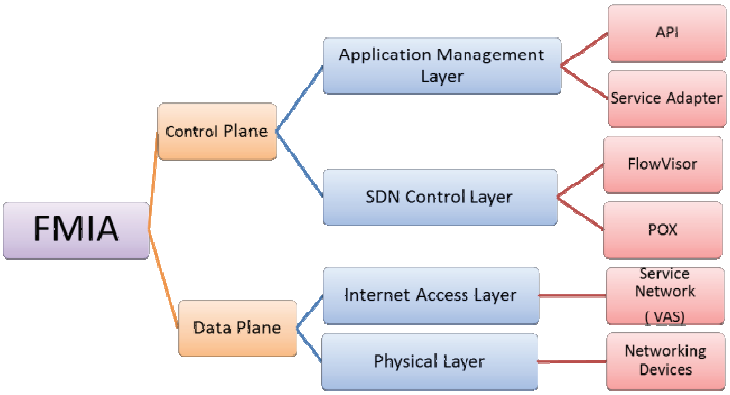


Fig. 1. Illustration of SDN and NFV enabled future mobile internet architecture (SN-FMIA).

In order to describe how to design a future Internet architecture using SDN and NFV, we proposed an innovative SDN and NFV enabled future mobile internet architecture (SN-FMIA) [4]. Our proposed architecture consists of four layers inheriting the concept from SDN to make control plane and data plane separated, as illustrated in Fig. 1. The control plane provides the global view of the entire network with service APIs (application program interface) at the northbound interface (Fig. 1). The purpose is to provide a unique platform for virtual service providers (vSP) to offer network services, network management, and analyze the running network applications and protocols. Open API for APs can permit deployment of context and application aware control algorithms [11]. The data plane defines data path on wireless infrastructure devices as per controller instructions. In a dense-deployed WiFi environment, a controller is insufficient to handle all control requests which would deteriorate the network performance.

Contrarily, user demands a dedicated resource for better performance that would be an expensive solution for the service providers. In order to resolve the above-discussed issues, it is a necessity to share data plane networking devices into logical slots with isolation approach that can be achieved through NFV. FlowVisior [12] is an example of slicing network resources, in which a separate rule is defined for each slice to restrict the overlapping among the slices. The proposed architecture reduces the implementation cost of middleboxes (CAPEX & OPEX) with replacing NFV technology paradigm. It also provides fine-grained packet control with OpenFlow [13] which acts as a communication protocol.

1.1 Contribution

Specifically, following contributions are made by our work.

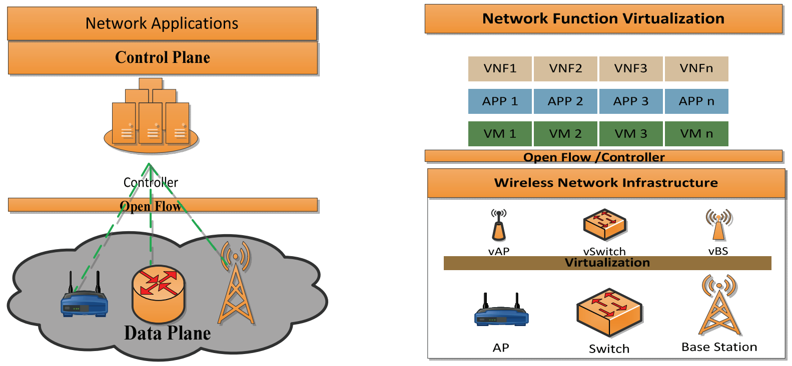
- We presented mobility related scenarios and use cases to analyze the implementation aspects of our proposed architecture SN-FMIA.
- We consolidate network selection approach (NSA) into SN-FMIA to enhance the mobility performance. The fundamental purpose of NSA is to acquire data from the SDN control layer to predict the network behavior and then forward to other layers for appropriate action or network selection.
- We consider network connectivity function as a service that is handled by service adapter at application management layer as illustrated in Fig. 1. It reveals how SDN/NFV incorporates the data plane functions for the smooth running of Internet architecture according to the service-oriented point of view which enables top-level abstraction for a network with various benefits. In order to take advantage, we design service-based mobility scenario for connectivity, identification, and categorization of network services.
- An interactive mobile application for WiFi consumers to select best available network has developed. In the existing WiFi network, the user can select a network only based on fixed parameter such as received signal strength indicator (RSSI) which could lead to poor QoE and load imbalance. By taking advantage of the centralized logical control plane, our application offers a customized network selection at the station/mobile terminal (MT) on the basis of information provided by NSA.
- In the proposed architecture, each AP contains an agent to perform local network tasks that are assigned by SDN controller. The agent is responsible for delivering the local network information to SDN control layer to minimize the burden of SDN controller. Further, with the provision of SDN and NFV, we construct virtual APs (vAPs) to release the management complexities of AP. Such as transfer the IEEE 802.11 protocol stack operations to application management layer, establish the connection abstraction between MT and AP, handles migration of MT across different APs without connection re-establishment procedure. Our method supports MT connection with multiple APs simultaneously in the signals overlapping area to manage the seamless handover. With the advent of agent and vAP abstraction, we design seamless mobility application on the top of the controller.
- We evaluate the feasibility of SN-FMIA by conducting several mobility experiments through simulated WiFi environment.

The rest of the article as follows. Section 2 describes the background and significant role of SDN and NFV in wireless networks. Section 3 elaborates SN-FMIA architecture and its layers functionalities.

Section 4 provides SN-FMIA applications scenarios and use cases that could deploy to enhance the mobility performance. In Section 5, we evaluate the performance of seamless mobility application and makes a comparison with traditional mobility approach. Finally, the conclusion of this research work draws in Section 6.

2. Background and Related Work

Software-defined network: is a programmable scheme that applied to network devices to make them more intelligent, dynamic and manageable [14]. The SDN divides the control plane for wireless network applications configuration and management as shown in Fig. 2(a). It also provides a global view of the entire network to organize the routing and packet flow control. The SDN separates the data plane for forwarding the traffic rules using OpenFlow protocol [13]. In addition, SDN is also used to apply the network infrastructure and manage data path accessible for programmers and mobile operators [15]. The wired network has been successfully implemented the SDN-based solutions to achieve more accurate performance compared to a traditional infrastructure [5]. The revolutionary outcomes of the SDN motivate the researchers, industrialists and network operators to pay more attention for the implementation of SDN in the wireless network [16].



(a) (b)

Fig. 2. Programmable wireless network environment. (a) SDN architecture and (b) an example of NFV.

Network function virtualization: In the domain of wireless network virtualization, tremendous work has already been done [7-10,12]. However, the existing wireless network is still not capable of supporting virtualization techniques such as the LTE network provides partially virtual network infrastructure for creating VPN connection. Also, the LTE network does not authorize to other service providers to execute their services. The common networks contain middleboxes to perform network functions. For example, network address translation, access control, load balancer, flow manager and firewall features that require independent hardware (middlebox) which is an expensive and lengthy solution. The idea of NFV is to replace these middleboxes to reduced the network equipment cost.

We highlight some key advantages of twin technologies, SDN and NFV. (1) Virtualization with SDN offers an economic interpretation to vendors to extend their network, adopt wide-ranging technologies and well-organized mobile network. (2) Multiple APIs can execute on the top of SDN controller that make easy to incorporate numerous applications at the higher level of the logical controller. However, the traditional network is required for enhancements at the hardware level. (3) The programmable interface for network operators enhances the active flow control to reduces error probability. (4) The SDN controller provides services execution platform for various services such as flow handler, security services, IPS/IDS, policy QoS, and mobility management can be managed by a network manager using the logically centralized controller. (5) Independent control plane can allow multiple operators to execute their applications to build a logical control that can manage through OpenFlow protocol and wireless network virtualization. (6) Resource utilization, as mentioned above SDN and NFV, provide network resource sharing to extends the network logically that reduces energy consumption and network operating cost.

2.1 SDN/NFV Research Contribution

SDN and NFV challenges in the prospects of the wireless network have considered by several researchers and working groups of the Internet Research Task Force (IRTF). OpenRoads [15] has initiated OpenFlow in the wireless network testbed at Stanford University. In the proposed architecture, mobility manager includes hard handover, informed handover, n-casting and Hoolock, which enables the user to move freely on existing wireless infrastructure but with limited support of the cellular network. There is an example of video streaming using n-casting approach built on NOX controller, where client utilizes WiFi and WiMax interface. NOX [17] is an open source-based controller that provides a broad view of the network. An integration of WLAN and cloud networks introduce in CloudMAC [18] architecture which partially transfers the MAC layer processing to the cloud (virtual machines at data centers) to reduce the overall network management complexity. CloudMAC consists of virtual APs to handle MAC frames processing, although in-depth processing has raised packet delay issues at MAC layer. In [19], the authors present a framework to mitigate interference in WLAN through centralized SDN controller to take advantage of OpenFlow. Odin [20,21] is a SDN-based framework for enterprise WLAN to simplify the management complexities and mobility issues. It introduces the concept of the light virtual access point (LVAP) to handle seamless handover, but the lack of load balancing among APs, and do not offer integration with cellular networks. LVAP concepts are further extended in [22] to familiarize the programmable abstraction into a wireless network for resource management, network monitoring, and management. The architectures are mentioned above address the particular problems of the wireless network to exploit the idea of SDN and NFV. They mainly targeted on abstracting the technicalities of physical layer technologies and transfer the intelligence functionalities to the center of the wireless network. In the case of additional processing, the tasks need execution in less capable networking devices. However, the centralized SDN controller might slow down the response to MAC layer that shortened the throughput of the wireless network.

In [23], the authors presented OpenRadio as programmable wireless data plane with an extensive feature of modular programming for the entire wireless stack. It mainly targets the NFV functionalities into the multi-core architecture. However, OpenRadio does not define network controller that can lack the whole network management. OpenRan [24] introduces the SDN into radio access network (RAN) with the concept of virtualization under the SDN controller to achieve resource virtualization, programmable and flexible control plane. SoftRAN [2] architecture has been introduced to handle the base station as a radio element under the virtual big base station. The SoftRAN centralized controller provides a platform for soft decoding to manage data plan activities and handover management. However, it does not address the detail functionalities of NFV for big base station abstraction. MobileFlow [25] has been introduced as the SDN-based future mobile network architecture to enable blueprint for flow-based forwarding model. The purposed model provides the flexibility to mobile carriers regarding the configuration of radio coverage, gateway location, control and examining of network resources.

In CellSDN [26], the SDN approach has been implemented to offer centralized control plane and fine-grain packet control for a cellular network. The extensive features of the CellSDN architecture are the installation of network operating system for supervision of access and core network, the configuration of the switch with local agents to handle packet control, slicing of radio resources to get flexible data plane functionalities, and support for virtualized wireless resources. However, the CellSDN does not provide the precise implementation procedures and also does not specify the RAN concepts. The integration of cellular network and WLAN network are exposed in [27], the architecture provided network-based mobility between WLAN and evolved packet core (EPC) without any amendments in the user/MT. However, the authors did not address the WLAN management issues. The work in the same direction presents in Aurora [28], an architecture for the wireless and mobile network to support multi-perspective technologies. Aurora-AP performs as virtualized agent for AP to enable resource management and configuration of additional technologies in the virtualization plane. Nevertheless, the mobile network technologies did not discuss in more detail.

In conclusion, the available architectures have some limitations and are dependent on industry-developed solutions. In contrast, we proposed a novel architecture SN-FMIA in Section 3, different from aforementioned architectures. SN-FMIA can integrate various mobility scenarios into WLAN and provides a unique operator interface to the service providers.

3. SN-FMIA Architecture

SN-FMIA presents the integration of twin technologies, the SDN and the NFV. This integration enables rapid access to the Internet services and synchronizes the programmable control plane and data plane with future technologies. This research focuses on programmable AP that can deliver future Internet services, intelligent network selection, and seamless mobility. We introduce the SN-FMIA with the following objectives.

The first objective is to eliminate the intermediate bases (middlebox) that cause hurdles in smooth delivery of Internet services. In our proposed architecture (Fig. 3), Internet access layer is next to a physical layer to provide an explicit connection to service providers. The second objective is a concern with NFV that contributes an interactive virtual platform for telecommunication operators, and service providers to offer customized services. This will help to lead the existing network architecture towards future Internet architecture. The third objective is to improve QoE because at present vendors focus on the quality of services, but in the future network, we cannot ignore QoE. The proposed architecture offers mobile consumers to select their network type whenever the quality of the associated network is insignificant. This kind of approach can boost the QoE at the user level. The fourth objective is to converge the layer-based Internet architecture with the plane-based mobile network. It consists of three planes, application plane related to application technologies that provide a management interface to the service operator. The SDN control plane performs standard control functionalities, and data plane offers direct Internet access to the user terminal. Meanwhile, control tasks can be accessible through the SDN control plane. The fifth objective is to enhance the mobility functions according to the demand of the future Internet applications.

In SN-FMIA, different types of mobility scenarios will be defined that are appropriate according to the demands of future network and user: (1) service-oriented mobility, (2) user-defined mobility, and (3) seamless mobility, which will be further discussed in Section 4.

SN-FMIA divides into four logical layers to provide a virtual platform for the various type of services as shown in Fig. 3. It has three interfaces: service operator interface, northbound interface, and southbound interface. In next subsections, we describe the SN-FMIA with four layers in detail.

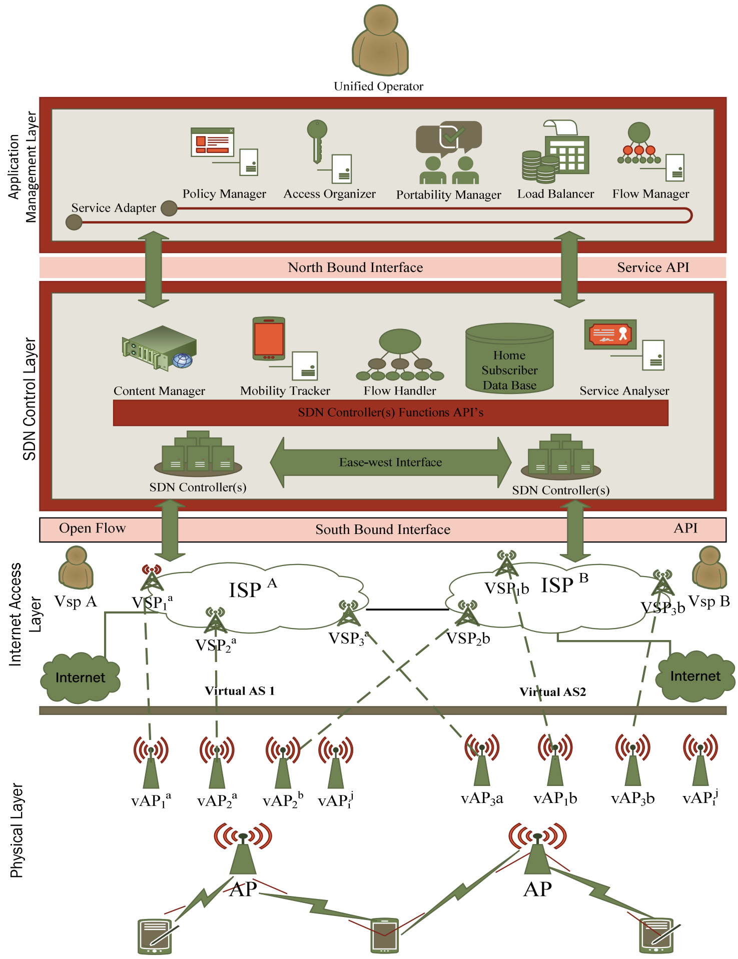


Fig. 3. SDN and NFV enabled future mobile internet architecture (SN-FMIA).

3.1 Application Management Layer

It is argued that one unified operator interacts with service operator interface and able to control network in a better way and also allows others vSPs to handle their services virtually. With service adapter, the unified operator access and manage the individual network services using SDN controller. Unified operator concept relates to the China Tower [29] that will operate multiple base stations (China Mobile, China Unicom, and China Telecom) through a unified interface. Network management related applications can execute separate services to accomplish the network tasks. These network services can be managed through service controlling API that is accessible to the consolidated operator. Different key APIs for organizing services will also be highlighted.

Portability manager: It defines the rules for the user portability matters and forwards to the SDN controller. It is an intelligent service that can execute multiple applications through different operators for a single user. It also refers as software portability where one type of application can work in diverse environments, and also represents as a logical entity that interacts with control API. Presently, mobile devices have the ability of application portability with the support of different available frameworks. The requirements of the future Internet architecture is to append the probability features at top layers. We adopt this approach as service portability where service with the same functionality can be interchangeable amongst ISP operators. However, the key challenge is service level agreements.

Flow manager: Each vSP performs different flow control for the different behavior of applications. This component provides a global view of network flow and can optimize the flow control at a global level. There is need to adopt allocation algorithm (for example Dijkstra algorithm) to find the shortest path for the packet flow.

Service adapter: It is installed 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 services inside the autonomous system. Service adapter has four components: (1) service category, (2) service session, (3) service protocols, and (4) packet forwarding services. The first component is for 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 existing protocols (ICMP, BGP, OSPF, TCP, UDP, OVSDB) to incorporate with services. The fourth component includes the flow handler to keep separate records of flow control of each service.

3.2 SDN Control Layer

The SDN control layer can accomplish multilayer management tasks. It enables the full monitoring of the network and also supports virtualization on different layers. It gathers information from Internet access layer and physical layer such as IP-based locations, subscriber information, and policy parameters. SDN control layer acts as liaison layer between the upper and lower layers as illustrated in Fig. 3. It also receives OpenFlow rules from the application layer and applies actions to lower layers. For the deployment of SDN controller (NOX) we adopt FlowVisor [12] to create isolation between different controllers. FlowVisor enables slicing of data paths and hosts multiple guest controllers as per network administrator requirements. There are some explanations to join OpenFlow with FlowVisor: (1) OpenFlow manages the traffic path of the physical network. (2) It enables programmable interface into networking devices, (3) and it ensures the accurate packet flow control to the appropriate destination.

Autonomous system manager: Each virtual autonomous system (VAS) connects with the northbound interface using service API to handle the interior and exterior routing protocol updates. It keeps a record of AS internetworking devices for providing information to the network administrator.

Service analyzer: This module is responsible for examining the user service profile to identify the service category (shown in Fig. 4). It interacts with policy manager and forwards the rules to a southbound interface. The rules can amend as per the current state of the network that includes network consumption, distinct applications, available services and connected users.

Mobility tracker: It provides mobility tracking inside the AS and also synchronizes with other available AS. It handles inter-autonomous and intra-autonomous system handover and performs an authentication process with the incorporation of HSS (home subscriber server). This module offers a control function interface to the northbound interface for handover among service operators. It maintains the tagging record of each MT whenever handover occurs from home location to visitor location or vice-versa.

Home subscriber server: This is a centralized database that contains information of ISP operators. User authentication and authorization performs at this level. It also interacts with the centralized control plane for providing access information to MTs.

Content manager: It executes content delivery services in the VAS and also can handle local contents at AP level. SDN agent is installed at AP for synchronization with the content manager to offer the available contents. The same contents can readily accessible for other APs inside the AS.

3.3 Internet Access Layer

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 SN-FMIA, various protocols can execute for the smooth running of the network. Two routing protocols are espoused here: (1) border gateway protocol (BGP), which provides the connection between autonomous systems and establishes the link to the Internet, and (2) Open Shortest Path First (OSPF) that is implemented inside the VAS. Some objectives of VAS are enlisted underneath.

- It gives an abstraction of independent controllers to service providers and unified operator on the basis of service availability, network cost, current traffic, and QoS parameters.
- Inter-AS communication, in which ISP^A consists of multiple vSP having access of individual virtual operators as shown in Fig. 3. However, the connection between vSP and operators can vary according to the current network performance.
- Inside the AS, the master controller computes the flow process and passes through the Internet.

Virtual service providers: It connects with VAS to offer Internet service without the interception of the middlebox to make Internet connection more fast and reliable. The concept of the virtual base station is introduced by SoftRAN [2], which mainly focused on resource allocation and load balancing in the cellular network. In contrast, our proposed architecture provides a link to virtual service provider inside the AS for fine-grained packet control, centralized management and resource optimization of the wireless network.

3.4 Physical Layer

In our proposed architecture, AP perform like an OpenFlow-based switch to empower the control plane at the southbound interface for channel allocation, power consumption, resource management, and function virtualization.

Virtual access point: It is characterized by different kinds of service operators [30] that can emulate AP for many vSP as shown in Fig. 3. APs are used to access the Internet, and each AP has a multiple vAPs with a unique identity and independent frequency band. CAPWAP [31] is a protocol introduce by CISCO to enable communication between APs and controller. The virtualization of network functions can enable by the hypervisor.

Mobile terminal/user: It is responsible for selecting the best available network according to information provided by the controller. However, traffic flow direction, QoE, and service type are handled at the user terminal.

3.5 Network Selection Approach

The proposed architecture SN-FMIA is overture the SDN centralization control layer to perceive real-time network traffic flow without the duplication of the total traffic. So, it is necessary for the SDN controller to provide global information of underlying physical networks that includes networking devices status, end-to-end statistics, network service behavior, and traffic monitoring. This information can be supportive for all stakeholders including network operators, users and service providers who can predict current network situation. With the advent of this information, we introduce NSA into the SN-FMIA to enhance the performance of the overall network. The NSA performs the following steps in sequence to detect the traffic flow and network statistics.

- The first step is related to the perception of the current network, to accomplish this task the SDN controller sends a periodic request message to underlying networking devices such as OpenFlow-enabled switches and APs. In order to respond the requests, the NSA collects information about AS topology, switch port number with traffic flows, APs information including radio communication with MT, user equipment information including location information, and network service behaviors.
- In the second step, the SDN controller stores the collected information into a table and then performs processing to make a reasonable representation of the current network statistics.
- In the third step, the prediction of the future network behavior can accomplish on the basis of OpenFlow data table. The controller can publish the precise information in response to query messages for further action or network selection.

Initially, NSA can divide into three categories: (1) NSA for service-oriented mobility, (2) NSA for user-based mobility, and (3) NSA for seamless and load-inform mobility. In next section, we will discuss in detail how NSA could be useful in different use cases.

4. SN-FMIA Mobility Scenarios

In this section, we investigate and propose particular applications and use cases related to our proposed architecture having the advantage of a centralized controller.

4.1 Service-Oriented Mobility

The basic concept of service can refer to a pattern that can deal with the particular problems, such as web service, API service, and other workflows. However, all services do not have similar goals and functions; it can categorize by functionality, reusability and integration dependency. According to the proposed SN-FMIA, a case study to represents service components functionality and service behavior will be discussed as an example. In this section, we highlight network services function of the proposed architecture and elaborates how the SDN will incorporate these features for the smooth running of Internet architecture. First, services will be categorized according to functionality point of view. Second, outlines a set of duties for each category that also belongs to different layers such as in TCP/IP model, each layer has its protocols and functions. This case study defines the mobility by service discovery process as shown in Fig. 4. The further functionalities of service modules with complete sequences of service components are given below.

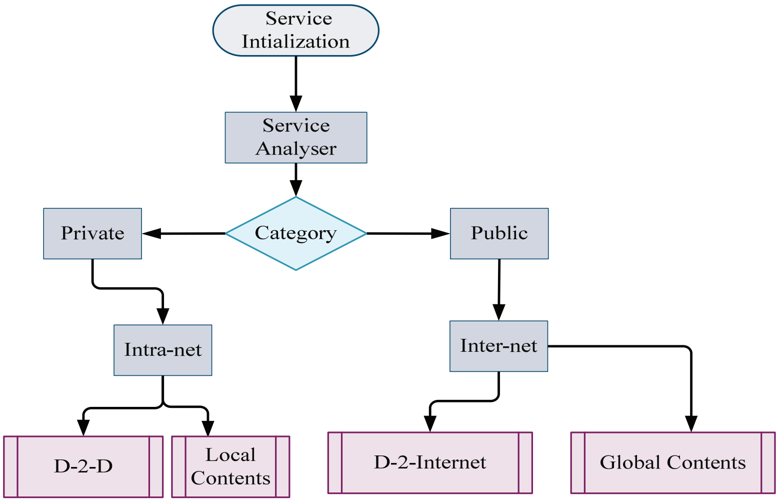


Fig. 4. Service discovery process.

Service initialization (origination): It is a high-level management interface for different services offered by various vSP. However, it administrated through a unified operator. There are different types of services like network control services, system services, and security services. Service adapter communicates with service unit through the SDN controller, it receives rules from the unified operator and applies them to lower level layers and also responsible for pre-defined allocation policies. Service adapter receives information about service category from the SDN controller and then set instruction as per requirements of the network manager.

Services terminal: It is the primary platform for services utilization that narrates the physical layer and can access services through the Internet access layer. The MT can request for a service subscription, utilization, and service migration. For example, AP selection, network registration, and user identification services are executed whenever MT activates the service reusability features. On service invoke the first parameter, service analyzer, which investigates the service category either is it public service or private service as depicted in Fig. 4.

Services unit: There are two types of service units. First one is for handling the vSP services inside the AS are called it as a local service unit that controls the private service category. The second one applies to outside the AS to get Internet services name as a global service unit that can handle the public service category as exhibited in Fig. 4.

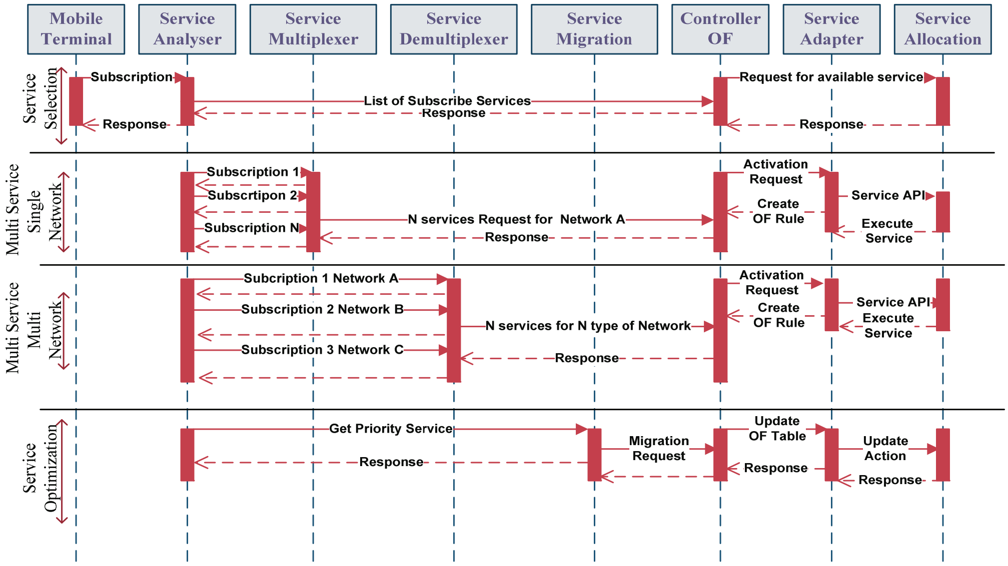


Fig. 5. Sequence diagram of service interaction modules.

Service selection: In the first step, MT invokes services for subscription, second, service analyzer examines the requests and third, acquires service subscription parameters and sends for availability check and permission. If the required service is available on the current network, then its permission is granted through service adapter, otherwise, forwards the request to the SDN controller for further action as depicted in Fig. 5. It also makes sure that available services are available at Internet access layer through vSP.

Multi services single network: In this situation service analyzer examines *N* number of requests receives from vSP as shown in Fig. 5. It multiplexes the *N* services and forwards to service adapter for activation. If the service related API is available then grant access for the execution of that services at Internet access layer.

Multi services multi networks: This situation represents a many-to-many relationship, *N* type of service request for *N* type of networks. In this case, if one MT, m1, simultaneously send two subscription requests, one for vSPA and second for vSPB then service analyzer forwards the request to DE-multiplexer which transfer that request to the connected network.

Service optimization: The first objective is to improve the QoE of the available services. If quality decreases for any reason, this function will be enabled and switch service network to other best available network. The second objective, if service analyzer receives some high priority services then migrates the running service into a waiting queue and executes the high priority-based service. The same concept has been used in the operating system (e.g., Windows, Linux, etc.), in which high priority process replaces with low priority process, further detail service sequence is shown in Fig. 5.

4.2 User-Based Mobility

The network selection can improve at client side using the SDN controller that send precise information of a global network including device status, service quality, and network behavior. This case study relates to end user terminal such as smartphones or laptops that can receive real-time information through NSA for the selection of a best available network. The smart network selection decision is either done by SDN controller or by the user. In this section, we implement a case study of network selection through the user interface with predefined parameters of network selection algorithm such as RSSI, current traffic intensity, bandwidth estimate and channel types.

We develop an API named as WiFi-collector [32] for the smart network selection as illustrated in Fig. 6. The core functions of smart network selection API are listed underneath.

(1) In the startup of the application, a list of APs are displayed, then capture the list of APs on the MT and pop-up a dialog for synchronization as shown in Fig. 6(a). In the capture list of each AP is displayed with three different states that are given below:
   - AP is secured with "WEP" or "PSK" appears as "secured."
   - Open AP with no encryption is displayed as "open."
   - AP with the association to be displayed as "connected."

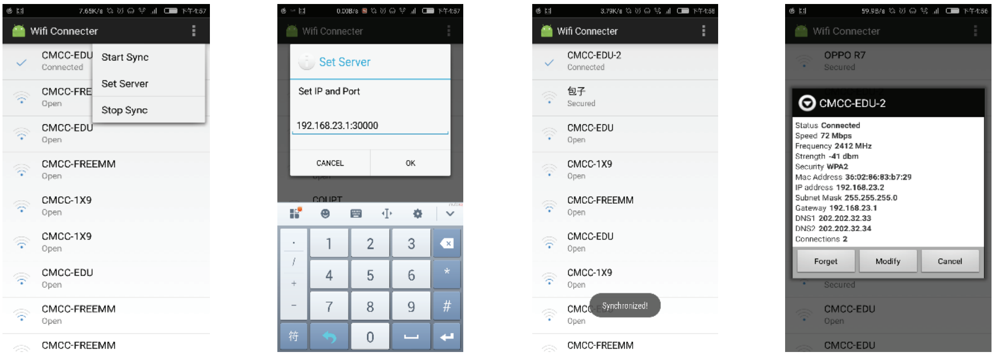
   The user can select maximum three APs from the list, and then starts the sync with selected APs.

(2) Prompt for selection mode that is default mode or customized mode. In the customized mode, the user can select parameters for the selection of a network. Once clicks on the list item of the AP, the user is connected to, and a popup window is displayed with configuration parameters of the acquired connection.

(3) The SDN agent collects the user's input and forwards to the SDN-controller. When a user clicks the "Start Sync" option, it starts sending the parameters of each AP to the selected server after every 10 seconds (time can be varied). On the other side, the SDN server receives the info, stores the info into a.CSV file and upgrades accordingly.

(4) The controller makes available the requested information of users through NSA. Meanwhile, the SDN server accomplished the processing of the CSV file. It also processes the client statistics on each AP, and sends the result back to the client the information is "synchronized!".

(5) After the synchronization, the user would associate with the AP.



(a) (b) (c) (d)

Fig. 6. Interface of WiFi connector. (a) Synchronization (b) Server selection (c) Connection established (d) Current connection status.

4.3 Centralized Mobility

As mentioned in the Subsection 3.4, vAPs are identified by BSSID that provides an abstraction to handle the association and handover procedures of MTs. The total bandwidth of the AP divides according to the number of vAP so that each user can avail equal distribution of bandwidth. When a new MT sends a probe request to the AP, the installed SDN agent on the AP forwards the request to the SDN controller for assigning vAP with unique BSSID. During handover, the centralized SDN controller handles multiple tasks such as authentication, re-association, assigning ID, and spawning of vAP to other AP without connection break off. The seamless and load-inform mobility can be achieved after collecting necessary parameters information through the NSA.

The first parameter is RSSI of associated MTs which receives at the AP and compares with a pre-defined threshold to detect mobility. The SDN agent acquires the RSSI values and forwards to the controller if the obtained value of associated MT is less than a pre-defined threshold which means MT is moving from associated AP to others. Simultaneously, the controller transfers the associated vAP to the target AP (shown in Fig. 7) that one receives RSSI value is greater than the threshold. However, RSSI-based mobility can generate load-imbalance situation and unnecessary handovers in WLAN [33]. In the current research, we take advantage of the centralized SDN controller to collect network state information through the NSA for seamless and load-inform mobility.

The second parameter relates to traffic load status of AP that is further divided into sub-parameters such as a number of connection, associated MTs throughput, and uplink traffic percentage.

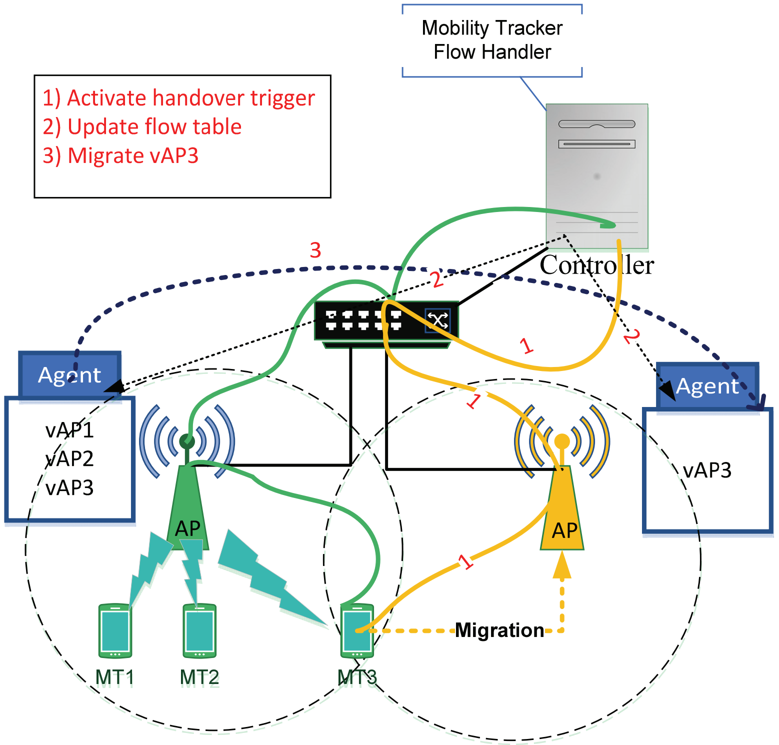


Fig. 7. Migration of virtual access point (vAP) during seamless handover.

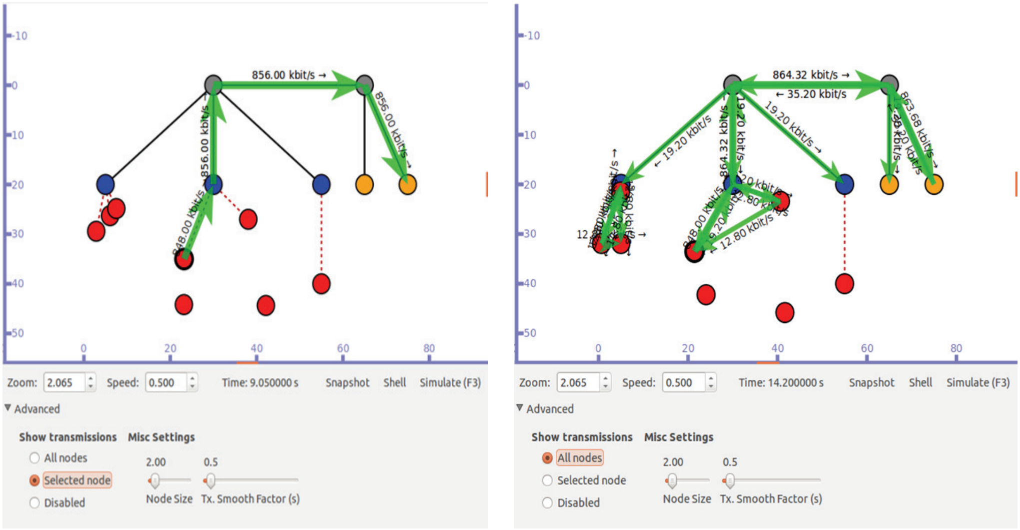
5. Evaluation and Results

5.1 Simulation Environment

This section explores the implementation of SN-FMIA mobility scenario through a simulated environment supported by NS-3 [34]. We implemented significant functional parts based on the reference case and built a prototype to evaluate the performance of proposed architecture. The detail procures of building simulation topology (Fig. 8) is given underneath.

- Node 0, 1: The top two nodes in the GRAY color represents two OpenFlow-enabled switches.
- Node 2, 3, 4: The three BLUE color nodes in a line represent three OpenFlow-enabled APs.
- Node 5, 6: The two ORANGE color nodes, in which one of node acts as the UDP (in current simulation) or TCP server.
- Node 7, 8, 9: The three RED color nodes represent the stations/MTs in association with node 2
- Node 10, 11, 12, 13: The four RED color nodes below the node 3 are four MTs in association with node 3.
- Node 14: The RED color node below the node 4 represents the only station in association with node 4.

It can be seen (Fig. 8) that the black straight line represents the wired links and the dotted line exhibits the wireless links. In WIFI networks, the dotted wire between the MT and the AP, that means that they have been associated. Otherwise, they are not associated because the distance between the two nodes is out of the range of the signal.



(a) (b)

Fig. 8. Simulation topology. (a) Demonstrate traffic of selected node and (b) demonstrate traffic of all connected nodes.

In PyViz [35], there are two options for the users to display the traffic, "Selected node" and "All nodes." If the option "Selected node" is chosen, in the path from the source (node 10, the one with a black circle) to the destination (node 6, the ORANGE one), the traffic sent by the selected node could be observed only, i.e., the source. As illustrated in Fig. 8(a), the link throughput from the RED node to the BLUE node is 848.00 kbit/s, while the throughput of the other three links is same, 856.00 kbit/s. This is because that the throughput in wired links is stable, and packets loss was not found. Afterward, the "All nodes" option was selected to analyze the throughput of all node traffic in the topology as shown in Fig. 8(b). The link throughput from node 3 to node 0, from node 0 to node 1, and from node 1 to node 6 has changed because traffic was sent by other nodes that were all joined together.

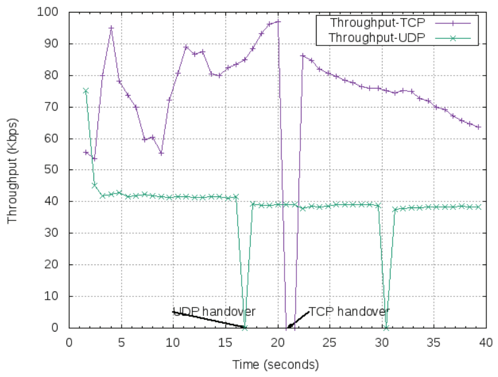
5.2 Simulation Results

In a comparison of existing with proposed approach, we present experimental results about mobility performance in SN-FMIA. We consider two different scenarios to evaluate the performance. First, measure the TCP throughput of MTs during handover among adjacent APs. Second, the same experiment performed using the UDP protocol to analyze the packet loss ratio.

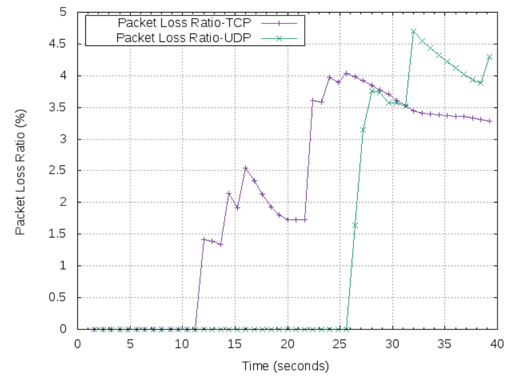
The maximum range that the AP's signal can cover is 100 m. The transmit power of AP1, AP2, and AP3 configures at 90 dBm, 100 dBm, and 90 dBm, respectively. Each AP does not have an IP address, like a layer2 device. It just forwards the frames that receive from the wireless interface card to the CSMA Ethernet interface card and vice versa. A fixed SSID “SSID-default” has been set for APs, and a fixed IP address range has been assigned to stations, so there is no DHCP. The link bandwidth between the switch1 and switch2 is 100 Mbps. The link bandwidth between each AP and switch1 is 30 Mbps. The link bandwidth between each host and switch2 is 30 Mbps. The TCP packet size was fixed at 1024 bytes with 5 Mbps data rate, and the UDP packet size set to be the same as the TCP. The interval between two packets has been set as 0.2 second for simulating the throughput. If the interval value has been set too high, which means the wait time is too long, in results few packets are transmitted, and consequently decrease the throughput. Contrarily, if this value has been set too low, which means the interval time between two packets is too short, there is enormous packet loss, therefore the throughput is still low. Initially, we set the sampling period too long; there were not enough points in the diagram for observing the handover process. If the sampling period set too short, there could be more dropping points at zero in the diagram that creates confusion about the actual handover processing time and other irrelevant time. Therefore, an optimal value for the sampling rate is selected as 0.8 second, which is clearer to observe.

Fig. 9(a) plots the TCP and UDP throughput of stations during the handover amongst adjacent APs. The node 7 is initially associated with AP3, and as it moves, after stepping into the common signal interference area of AP1 and AP2, it chooses the AP2 for the association, which has a higher RSSI than AP1 does, though more loaded. The moving station does not perform active probing, which means it does not actively scan the available APs. Instead, the deployed APs issue the beacons to inform the stations in-range for the later association. In traditional handover procedure, packet loss ratio also increases gradually as the user activates handover procedure as shown in Fig. 9(b). In results, throughput degrades and reaches at 0 levels that could lost the connection for a short period of time.

Fig. 10(a) plots the throughput during handover amongst the adjacent APs, the handover process is controlled by the SDN controller, and in results, throughput has improved as compared to previously serving AP. Using SDN centralized control mechanism the packet delay ratio is also reduced as illustrated in Fig. 10(b).

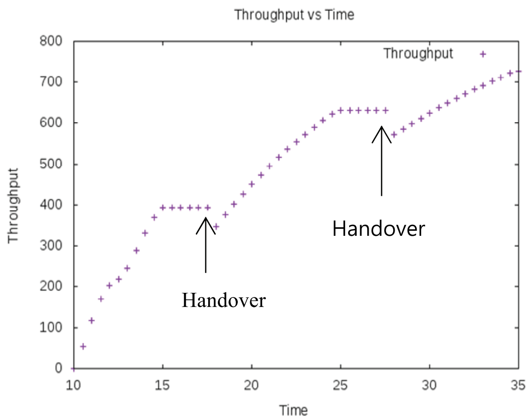


(a)

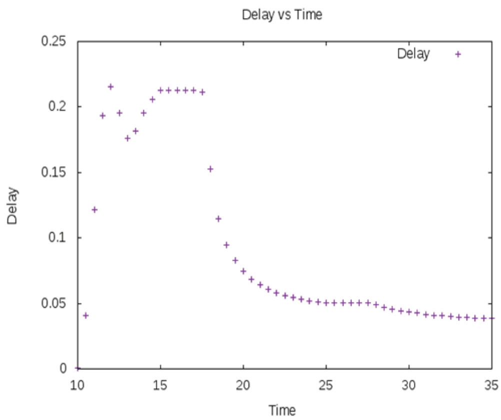


(b)

Fig. 9. Traditional handover using TCP and UDP. (a) Throughput during handover and (b) packet loss ratio.



(a)



(b)

Fig. 10. Handover performance in the SN-FMIA. (a) Throughput during handover and (b) packet delay.

6. Conclusions

The emergence of the SDN and the NFV into the wireless network architecture provides the ability to execute multiple mobility scenarios according to the future Internet demands. In current research work, we proposed the SN-FMIA architecture to handle the traditional wireless network mobility issues. Furthermore, three mobility scenarios are discussed in this research. First, service-oriented mobility that carries on service management platform for handling the mobility service operations with OpenFlow. Second, WiFi connector API has developed that offers customized network selection at user-end terminals. Third, in the case of centralized mobility, the SDN controller can take a decision regarding association and re-association of the MTs. This approach enables the features of seamless mobility amongst the WLAN stations without throughput degradation.The evaluation results confirm that the proposed mobility scenarios can achieve good throughput at the minimum cost of packet loss in comparison with the traditional mobility schemes.

Acknowledgement

This paper is a revised and expanded version of a paper entitled "SN-FMIA: SDN and NFV enabled Future Mobile Internet Architecture" presented at 2015 17th IEEE International Conference on Advanced Communication Technology (ICACT) (pp. 341-346). This work was supported by Prospective Research Project on National Nature Science Foundation (No. 61402065, 61501075), Future Networks (No. BY2013095-2-03) fund by Jiangsu Future Networks Innovation Institute and Project Foundation of Chongqing Municipal Education Committee (No. KJ1500429).

References

[1] CISCO, "CISCO Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021," 2017 [Online]. Available: http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.pdf.

[2] A. Gudipati, D. Perry, L. E. Li, and S. Katti, "SoftRAN: software defined radio access network," in *Proceedings of the 2nd ACM SIGCOMM Workshop on Hot Topics in Software Defined Networking*, Hong Kong, 2013, pp. 25–30.

[3] B. X. Chen, "Carriers warn of crisis in mobile spectrum," April 17, 2002 [Online]. Available: http://www.nytimes.com/2012/04/18/technology/mobile-carriers-warn-of-spectrum-crisis-others-see-hyperbole.html.

[4] S. M. M. Gilani, T. Hong, and G. Zhao, "SN-FMIA: SDN and NFV enabled future mobile internet architecture," in *Proceedings of 2015 17th International Conference on Advanced Communication Technology (ICACT)*, PyeongChang, Korea, 2015, pp. 341–346.

[5] D. Kreutz, F. M. Ramos, P. E. Verissimo, C. E. Rothenberg, S. Azodolmolky, and S. Uhlig, "Software-defined networking: a comprehensive survey," *Proceedings of the IEEE*, vol. 103, no. 1, pp. 14–76, 2015.

[6] A. Hakiri, A. Gokhale, P. Berthou, D. C. Schmidt, and T. Gayraud, "Software-defined networking: challenges and research opportunities for future internet," *Computer Networks*, vol. 75, pp. 453–471, 2014.

[7] C. Cui, H. Deng, D. Telekom, U. Michel, and H. Damker, "Network functions virtualisation: an introduction, benefits, enablers, challenges & call for action," 2012 [Online]. Available: https://portal.etsi.org/NFV/NFV_White_Paper.pdf.

[8] Open Networking Foundation "OpenFlow-enabled SDN and Network Functions Virtualization," 2014 [Online]. Available: https://www.opennetworking.org/images/stories/downloads/sdn-resources/solution-briefs/sb-sdn-nvf-solution.pdf.

[9] A. Fischer, J. F. Botero, M. T. Beck, H. de Meer, and X. Hesselbach, "Virtual network embedding: a survey," *IEEE Communications Surveys & Tutorials*, vol. 15, no. 4, pp. 1888–1906, 2013.

[10] C. Liang and F. R. Yu, "Wireless Network virtualization: a survey, some research issues and challenges," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 1, pp. 358-380, 2015.

[11] H. Moura, G. V. Bessa, M. A. Vieira, and D. F. Macedo, "Ethanol: software defined networking for 802.11 wireless networks," in *Proceedings of 2015 IFIP/IEEE International Symposium on Integrated Network Management (IM)*, Ottawa, ON, 2015, pp. 388–396.

[12] R. Sherwood, G. Gibb, K. K. Yap, G. Appenzeller, M. Casado, N. McKeown, and G. Parulkar, "FlowVisor: a network virtualization layer," 2009 [Online]. Available: http://archive.openflow.org/downloads/technicalreports/openflow-tr-2009-1-flowvisor.pdf.

[13] A. Lara, A. Kolasani, and B. Ramamurthy, "Network innovation using OpenFlow: a survey," *IEEE Communications Surveys & Tutorials*, vol. 16, no. 1, pp. 493–512, 2014.

[14] Open Networking Foundation "ONF SDN Evolution," 2016 [Online]. Available: https://www.opennetworking.org/images/stories/downloads/sdn-resources/technical-reports/TR-535_ONF_SDN_Evolution.pdf.

[15] K. K. Yap, M. Kobayashi, R. Sherwood, T. Y. Huang, M. Chan, N. Handigol, and N. McKeown, "OpenRoads: empowering research in mobile networks," *ACM SIGCOMM Computer Communication Review*, vol. 40, no. 1, pp. 125–126, 2010.

[16] N. A. Jagadeesan and B. Krishnamachari, "Software-defined networking paradigms in wireless networks: a survey," *ACM Computing Surveys*, vol. 47, no. 2, pp. 1–11, 2014.

[17] The NOX controller [Online]. Available: https://github.com/noxrepo/nox/.

[18] P. Dely, J. Vestin, A. Kassler, N. Bayer, H. Einsiedler, and C. Peylo, "CloudMAC: an OpenFlow based architecture for 802.11 MAC layer processing in the cloud," in *Proceedings of 2012 IEEE Globecom Workshops*, Anaheim, CA, 2012, pp. 186–191.

[19] D. Zhao, M. Zhu, and M. Xu, "Leveraging SDN and OpenFlow to mitigate interference in enterprise WLAN," *Journal of Networks*, vol. 9, no. 6, pp. 1526–1533, 2014.

[20] L. Suresh, J. Schulz-Zander, R. Merz, A. Feldmann, and T. Vazao, "Towards programmable enterprise WLANs with Odin," in *Proceedings of the 1st workshop on Hot Topics in Software Defined Networks*, Helsinki, Finland, 2012, pp. 115–120.

[21] J. Schulz-Zander, C. Mayer, B. Ciobotaru, S. Schmid, and A. Feldmann, "OpenSDWN: programmatic control over home and enterprise WiFi", in *Proceedings of the 1st ACM SIGCOMM Symposium on Software Defined Networking Research*, Santa Clara, CA, 2015, pp. 1–12.

[22] R. Riggio, M. K. Marina, J. Schulz-Zander, S. Kuklinski, and T. Rasheed, "Programming abstractions for software-defined wireless networks," *IEEE Transactions on Network and Service Management*, vol. 12, no. 2, pp. 146–162, 2015.

[23] M. Bansal, J. Mehlman, S. Katti, and P. Levis, "OpenRadio: a programmable wireless dataplane," in *Proceedings of the 1st workshop on Hot Topics in Software Defined Networks*, Helsinki, Finland, 2012, pp. 109–114.

[24] M. Yang, Y. Li, D. Jin, L. Su, S. Ma, and L. Zeng, "OpenRAN: a software-defined ran architecture via virtualization," *ACM SIGCOMM Computer Communication Review*, vol. 43, no. 4, pp. 549-550, 2013.

[25] K. Pentikousis, Y. Wang, and W. Hu, "Mobileflow: toward software-defined mobile networks," *IEEE Communications Magazine*, vol. 51, no. 7, pp. 44-53, 2013.

[26] L. E. Li, Z. M. Mao, and J. Rexford, "CellSDN: Software-defined cellular networks," 2012 [Online]. Available: https://pdfs.semanticscholar.org/1431/9018fc6d26d690c4a771a08634bc77306188.pdf.

[27] D. Roeland and S. Rommer, "Advanced WLAN integration with the 3GPP evolved packet core," *IEEE Communications Magazine*, vol. 52, no. 12, pp. 22–27, 2014.

[28] H. Wen, P. K. Tiwary, and T. Le-Ngoc, "Multi-perspective virtualization and software-defined infrastructure framework for wireless access networks," *Mobile Networks and Applications*, vol. 20, no. 1, pp. 19-31, 2015.

[29] S. Kinney, "Telecom infrastructure: China carriers create tower company," December 4, 2014 [Online]. Available: http://www.rcrwireless.com/20141204/cell-tower-news/telecom-infrastructure-chinese-carriers-create-tower-company.

[30] G. Bhanage, D. Vete, I. Seskar, and D. Raychaudhuri, "SplitAP: leveraging wireless network virtualization for flexible sharing of WLANs," in *Proceedings of 2010 IEEE Global Telecommunications Conference (GLOBECOM)*, Miami, FL, 2010, pp. 1–6.

[31] D. Stanley, P. Calhoun, and M. Montemurro, "Control and provisioning of wireless access points (CAPWAP) protocol specification," 2009 [Online]. Available: https://tools.ietf.org/html/rfc5415.

[32] "Collecting WiFi info in physical environment," 2016 [Online]. Available: https://github.com/caiqiqi/wifi-collector.

[33] D. Gong and Y. Yang, "On-line AP association algorithms for 802.11 n WLANs with heterogeneous clients," *IEEE Transactions on Computers*, vol. 63, no. 11, pp. 2772–2786, 2014.

[34] NS-3.26 [Online]. Available: https://www.nsnam.org/ns-3-26/.
[35] PyViz [Online]. Available: https://www.nsnam.org/wiki/PyViz.

Syed Mushhad Mustuzhar Gilani
He is currently a PhD Scholar in the School of Computer Science at Chongqing University of Posts and Telecommunication (CQUPT), China. He obtained M.S. (Computer Science) degree from IQRA University Islamabad, Pakistan in 2008. He joined University Institute of Information Technology, PMAS-AAUR, where he is serving as Assistant Professor. His research interests include software-defined networking (SDN), wireless networks and future Internet architecture.

Hong Tang
She received her M.E. degree and Ph.D. degree from the Chengdu University of Technology in 1985 and 1993, China. Now she is a Professor of computer science at School of Telecommunications and Information Engineering, CQUPT. Her research interests are in future Internet, mobile Internet, network management, etc.

Qiqi Cai
He is currently a Master Candidate in the School of Computer Science at CQUPT, China. He obtained Bachelor's degree at CQUPT, too. His research interests include software-defined networking (SDN), future network architecture and cyber security.

Guofeng Zhao
He received his M.E. degree from Northwest Polytechnic University in 1996, China, and Ph.D. degree from the University of Chongqing in 2003, China. Now he serves as a Professor in the Institute of Information and Network Engineering, and the director of the Research Center of Future Internet (RFI) at CQUPT. He has published more than 120 papers and held six patents and has been the TPC member of ICC 2014, ICC 2015, NSFP 0215, etc. His research interests are in future Internet, mobile Internet, network management, network security, etc.