Demo: SDN-based Seamless Handover in WLAN and 3GPP Cellular with CAPWAN

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***Abstract*—Many protocols and architectures have been proposed to approach the seamless convergence of Wireless Local Area Network (WLAN) and the 3rd Generation Partner Project (3GPP) cellular, such as Long Term Evolution (LTE). However, a universal, medium-independent protocol for implementing the seamless convergence architecture in heterogeneous wireless networks is still missing. This paper proposes a Centralized and Programmable Wireless Wide Area Network (CAPWAN) protocol to fill the vacancy and presents a demo of performing seamless handover in WLAN and 3GPP cellular, such as LTE, by implementing CAPWAN protocol. The demo setup consists two parts. The first part comprises an Access Point (AP), a soft base station connecting via an openflow-enabled switch to the centralized server playing a role as a Software Defined Network (SDN) controller. We will demonstrate performing seamless handover between the AP and the soft base station with CAPWAN protocol. The other part of our demo replaces the soft base station with an AP and adds a video web server via the switch. We have developed a video living server, a video living client and a web server managing the WLAN. In our video living test, approximately ten-megabits uplink bandwidths of broadcasting the live video stream can be guaranteed during the handover in WLAN.**

I. Introduction

As it is addressed by many mobile operators [1], the 5th Generation mobile networks (5G) communications would involve a combination of Radio Access Network (RAN) technologies. The RAN technologies involve 3GPP mechanisms (e.g., LTE) and non-3GPP mechanisms. Among those non-3GPP technologies, Wi-Fi technology has lots of new enhancements by using the 802.11ac MIMO technology, increasing the Wi-Fi speed to hundreds of Mbps. Beside from this, the widespread deployment of WLAN is expected to drive further convergence of RAN, especially in the heterogeneous wireless network which is composed of WLAN and LTE network. Thus, Wi-Fi technology occupies an important position in the non-3GPP mechinisms.

Various works have been done to study the convergence of WLAN and LTE networks. To approach seamless handover in WLAN, a SDN-based WLAN framework has been proposed, managing and controlling the virtual resources of APs [2]. A SWAN protocol is used in [2] to manage virtual resources and achieve mobility management in WLAN. Based on the SWAN framework, [3] proposed a seamless convergence approach of WLAN and LTE networks with a middle box architecture. In addition, many advanced approaches have been proposed to reduce the traffic pause time caused by a host-initiated layer-2 handover (e.g., OpenFlow). Although many works have been done, performing seamless handover between WLAN and LTE network is still a great challenge because that User Equipment (UE) will change the interfaces during handover procedure, causing the reconnection of layer-3. And the challenge is monumental in guaranteeing the Quality of Services (QoS) especially the QoS of live video stream while performing handover between WLAN and LTE network.

In this demo, LTE network is regarded as a typical example of 3GPP cellular. The presented demo brings out two contributions: (1) A design and implementation of the SDN-based converged architecture in WLAN and LTE with the new CAPWAN protocol is presented, supporting an uninterrupted video living system. (2) Although many advanced approaches to reduce the traffic pause time caused by a host-initiated layer-2 handover (e.g., OpenFlow) and technologies to virtualize access equipments in WLAN or LTE network [2] [3], a universal, medium-independent protocol for the virtual resources management and achieving the seamless handover in heterogeneous wireless networks is still missing. Thus, CAPWAN protocol is proposed in this paper to fill the vacancy of such protocol by reporting the status informations measured in the access equipment. The rest of the paper is organized as follows. Section II presents the SDN-based convergence framework and the design of CAPWAN protocol. Section III presents the details of the architecture implementation. In section IV, we present the demonstration details about what would be demonstrated and how the attendees would be able to interact.

II. Demo Architecture and CAPWAN

A. Demo Architecture

In this demo, our previous works are reviewed, SWAN [2] and Seamless Convergence Architecture. [3]

Firstly, a brief introduction of the key technologies in SWAN framework will be presented. We construct a Virtualized Access Point (VAP) to abstract the association between a physical AP and UE. The physical AP implementing the CAPWAN protocol is denoted as a Soft Access Point (SAP). A SDN controller is built to manage the VAPs inserted in

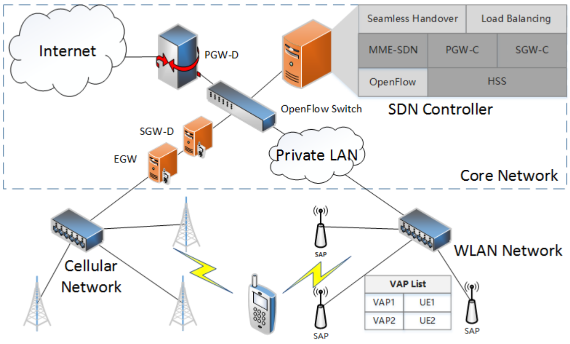

Fig. 1. The Convergence Architecture in LTE and WLAN

the SAP by implementing the CAPWAN protocol. The VAP holds the status informations, such as BSSID, MAC address, SSID, UE IP address. The WLAN part of Fig.1 demonstrates the proposed SWAN framework. The basic infrastructures in WLAN are SAPs and a SDN controller. Each UE will be assigned a unique VAP when it connects to the network, and a SAP will reserve certain VAPs.

Fig.1 demonstrates the seamless convergence architecture. The key technologies in this architecture include two parts: one is that we decuple the traditional SGW and PGW into the control plane SGW-C, PGW-C which are responsible for the control functions, and data plane SGW-D, PGW-D which only focus on forwarding data. The other part is the middle box architecture in UE presented in Fig.2. The middle box consists of a virtual interface, an agent and a bridge. The agent is used to communicate with the controller in the core network and the bridge is expected to sustain a connection between interfaces in terms of the flow tables. The service layer connects to the network through the virtual interface added to the bridge, while the traffic is routed to either LTE or WLAN interface according to the flow tables configured by the agent.

B. Signaling Messages of CAPWAN

1) Online Update: When an AP or Evolved NodeB (eNodeB) is online, it sends Online Update to the controller periodically. This message contains a WLAN/LTE indication and its IP address. The indication means that ”W” represents WLAN while ”L” is referred to LTE.

2) Read/Write Profile: When the controller detects Online Update from an AP, it sends Read Profile to the AP which will send back profile informations. Then, the controller sends Write Profile predefined in the controller to the AP. The message contains a WLAN indication plus profile informations which involve beacon_interval, transmit_power, channel and AP's capabilities for WLAN.

3) Subscribe/Publish Status: When the controller detects Online Update from AP/eNodeB, having sent Read/Write Profile messages, it sends Subscribe Status to the AP/eNodeB. After that, the AP/eNodeB sends Publish Ststus to the controller whenever the status meets the subscription received from the controller. The subscription consists of status and relations(e.g., greater/less than, equal). The status involves UE's statistics such as the association state, the Received Signal Strength Indication (RSSI) and the current transmission rate for AP. For eNodeB, it contains RSSI, Modulation and Coding Scheme (MCS) of UE and the load of eNodeB.

4) Heterogeneous Handover Notification: When the controller determines a heterogeneous handover, it sends Heterogeneous Handover Notification to eNodeB. Then, the eNodeB forwards this message to the agent located in UE. This message includes UE IP address and the direction of handover.

5) Probe MAC: When an AP detects a probe request frame from UE, it sends Probe MAC message to the controller containing the MAC address of UE.

6) Add/Delete/Update VAP: The controller sends Add VAP to the AP, allocating the VAP resources in the AP. A VAP profile, which consists of MAC address, BSSID, SSID, connecting state, authentic request frame and associate request frame, is included in this message. AP uses the Update VAP message to send a update about the connecting state of UE to controller. The controller will send Delete VAP to the AP to free the resources which have been allocated in the AP.

C. Handover Procedures with CAPWAN

The seamless handover mechanism in WLAN relays on the migration of VAP resources. When UE associates an AP for the first time, the AP sends Probe MAC message to the SDN controller. The controller will set a VAP profile to the AP using Add VAP message. When another AP detects that the UE is moving into its coverage and sends a Probe MAC message to the controller, the controller is responsible for the migration of VAP resources using a combination of Delete VAP and Add VAP messages. This network-based handover, trigged by the controller, will not lead to a perceptible impact on UE.

When it refer to the handover procedure between WLAN and LTE network, the controller and the middle box architecture in UE are responsible for the whole procedure. To illustrate this mechanism, we take an example scenario that UE hands off from LTE to WLAN because of the similarity between those two scenarios that the other handover scenario is in the opposite direction. Assuming a UE has connected to the LTE network and the agent has connected to the controller. A channel between the virtual interface and the LTE interface on the bridge has been established. When the handover is triggered by controller, the controller sends Add VAP message to the target AP and Heterogeneous Handover Notification message to the eNodeB. The eNodeB forwards the message to the agent in UE, directing the agent to install new flow tables that route the traffic from virtual interface to Wi-Fi interface. During the handover procedure, the flow tables in SDN switches located in the core network would be adapted according to the controller using OpenFlow protocol.

III. Demo Implementation

This demo consists three core parts. The implementation of SDN-based WLAN architecture is more inclined to be adopted in industry while the implementation of programmable LTE architecture tends to make contributions in experimentally-driven research area towards 5G communications.

A. The Implementation of Controller

The operating system of our controller is Ubuntu 12.04 LTS. The controller mainly includes two parts, a SDN controller and some programmable LTE control plane equipments such as Mobility Management Entity (MME), SGW-C, PGW-C and HSS.

The floodlight1.2 is adopted as our SDN Controller because of its special platform, such as offering a module loading system that make it simple to extend and enhance the features. Upon the basic developments of floodlight, some applications such as Master module is inserted into the module system to manage and control the WLAN/LTE network. The controller takes the CAPWAN protocol as the south protocol. In addtion, the OpenFlow protocol is enabled in floodlight to make dataplane programmable. The relevant REST API of Master module is also developed to supply high usability and feasibility for those researchers and consumers who only want to use the API to create innovative applications. Meanwhile, there is an apache web server to manage the WLAN/LTE using the REST API and floodlight module. The implementation of this programmable LTE architecture is an open source project which can be referred to [4].

B. The Implementation of Access Point/Evolved NodeB

The Access Point takes OpenWrt 14.07 as the operating system which is widely deployed in industry and some services(e.g., hostapd, OpenVSwitch) is enabled in the OpenWrt. Our core implementation is constructing an agent communicating with the controller. The main work of the implementation is that an agent builds VAP resources when triggered by the controller using the Multi-SSID technique [5] and reports some status informations, such as BSSID, MAC address, SSID, UE IP address to the controller. The works mentioned here only updates hostapd which can be easily reproduced in Linux distribution by implementing the CAPWAN protocol.

A majority of the implementation in the eNodeB has been done by OpenAirInterface (OAI) open source project [4]. What we have done is implementing an agent, while the agent reports some status informations of UE, such as MCS and RSSI. The function of the agent is monitoring and reporting status informations, executing the command delivered by controller. The eNodeB developed by OAI is a soft base station and all the capabilities of eNodeB are software-implemented on a universal hardware platform. Thus, the work can be easily reproduced using the OAI platform.

C. The Implementation of User Equipment

The key work of user equipment is to overcome the problem that UE has to switch the working network interface, which causes a reconnection of layer-3. Thus, we construct an agent to communicate with the SDN controller and adopt the OpenVSwitch (OVS) as the core part to adapt the connection between virtual interface and LTE/WLAN interfaces. The agent would install different flow tables into OVS achieving the seamless traffic handover between two physical interfaces according to message from the controller.

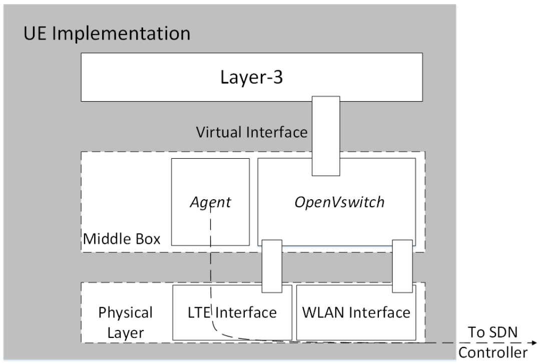

Fig. 2. The Implementation of UE

IV. DEMONSTRATION

The demo includes two parts. One of them is demonstration of performing **seamless handover between WLAN and LTE networks**, and the other part is demonstration of VAP managements in WLAN and **seamless handover in WLAN**, guaranteeing a video living service with approximately 10Mbps upstream rate. A video is available at YouTube[1] website.

In the first part, the demonstration would present the seamless mobility of a UE which has been registered in the system between an access point and a soft base station. A traffic stream would be guaranteed during the seamless handover between WLAN and LTE network.

In the second part, two APs would be included. And we would show the VAP managements and a uninterrupted live video stream service broadcasting from the user equipment during the mobility between those APs. In addtion, the attendees could register their own UE by providing the mac address of the physical wireless card. Thus, those registered attendees can enjoy the seamless handover between those APs.

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