Enhanced Fast BSS Transition on Enterprise WLAN with SDN-based Distribution System

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Abstract— ***One of the challenges in QoS-aware realtime mobile multimedia service provisioning through WLANs is QoS-aware fast BSS (Basic Service Set) transition. Since most WiFi access points (APs) do not provide fast BSS transition (FT), changing currently connected AP to another takes several seconds during which mobile services are disrupted. In this paper, we propose an enhanced fast BSS transition scheme for seamless mobile broadband multimedia service provisioning and load balancing. The proposed scheme is based on i) cognitive management of WLAN ESS with SDN-based distribution system that allows checking for resource availability before selecting a candidate target AP, ii) QoS-aware roaming/handover with resource request over distribution system(DS), and iii) proactive forwarding table updates of SDN-based distribution system. The proposed scheme had been implemented and evaluated in a real IEEE 802.11n testbed environment, and the performance measurements showed enhanced QoS provisioning with minimized service disruption time and packet loss compared with existing approaches.[1]***

Keywords – WiFi handover/roaming, fast BSS transition (FT), mobile broadband Internet access, cognitive management, service disruption, software defined networking (SDN)

I. Introduction

One of the challenges in QoS-aware real-time mobile broadband multimedia service provisioning through WLANs is QoS-aware fast BSS transition and load balancing among BSSs (basic service sets) in the ESS (extended service set) [1-4]. The multiple APs/BSSs in an ESS are, however, mostly installed and operated without careful cell planning and channel allocations to minimize interferences and maximize the overall throughput [5-7]. As a solution to the roaming/handovers for broadband mobile Internet services through multiple APs, IEEE 802.11r fast BSS transition (FT) standard was developed [3]. In IEEE 802.11r FT, the service disruption time is reduced by using message exchanges between the mobile station and the target AP through DS (distribution system) before changing the RF channel from the current AP to the target AP. So, the service disruption time can be minimized.

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The IEEE 802.11r fast BSS transition procedure, however, does not provide the information on the available resources for QoS-aware application to the mobile station [4]. So, the fast BSS transition request from the mobile station to the target AP may not be successfully completed because of the shortage of the required network resource, and disruption of realtime broadband multimedia applications may occur. Moreover, the current IEEE 802.11r does not define any proactive forwarding table updates in the distribution system that can minimize the packet loss during fast BSS transitions.

In this paper, we propose an efficient management of QoS-aware fast BSS transition (QFT) for seamless mobile broadband multimedia service provisioning and load balancing [4]. The proposed scheme is based on i) cognitive WLAN ESS management to allow checking for resource availability before selecting candidate target AP, ii) QoS-aware roaming/handover with resource request over distribution system(DS), and iii) proactive forwarding table updates of SDN-based distribution system.

II. Related Work

A. QoS-aware service provisioning with multiple APs/BSSs in an ESS

Most WiFi networks installed in office building, campus, and public service areas (i.e., airports, terminals, and conference halls) are configured with multiple APs/BSSs in an ESS. The APs are connected through distribution system (DS) from the gateway router, and the RF channels of neighbor APs are configured to be orthogonal in order to minimize the interferences [5-7]. So, when a mobile station roams from a BSS to its neighbors, the RF channel should be changed, and re-association procedure should be executed.

In order to provide the optimal aggregated throughput of the overall APs in the ESS, each AP should be loaded appropriately considering its capacity [5]. Also, the cell coverage of the APs should be carefully configured according to their capacity [6]. For example, IEEE 802.11b WLAN can provide throughput only up to 11 Mbps, while IEEE 802.11n/ac WLAN can provide throughput more than 300/600 Mbps. Since they are using same frequency band, they interfere each other if their channels are not configured with orthogonal channel frequencies; so, the cell size should be carefully adjusted to allow the 802.11n/ac WLAN to cover more stations with limited interference from the 802.11b WLAN.

In current WiFi roaming, most stations are trying to connect to the nearest AP with strongest beacon signal strength without considerations of the traffic load and congestion status of the AP. So, ESS-wide traffic engineering is necessary to enable optimized throughput performance and QoS-aware realtime broadband mobile Internet service provisioning.

B. *IEEE 802.11r Fast BSS Transition*

IEEE 802.11r fast BSS transition [4] aims to reduce the length of service disruption time when connectivity is lost between the station (STA) and the distribution system (DS) during the BSS transition. The fast transition (FT) protocols are part of the re-association service and only apply to STA transitions between APs within the same mobility domain which is a set of BSSs within the same ESS, that support fast BSS transitions.

In order to minimize the service disruption time in BSS transitions, the IEEE 802.11r provides "over-the-DS fast BSS transition (FT) with resource request protocol in a robust secure network (RSN) [4].". The fast BSS transition (FT) messages (such as FT request, FT response, FT confirm, and FT ACK) between the current AP and the target AP are delivered through distribution system (DS). The requested network resource for the mobile broadband service is defined in the RIC (resource information container).

III. QoS-aware Fast BSS Transition (QFT) for Seamless Realtime Broadband Multimedia Services

A. *Cognitive WLAN Management with ESS Control and Management (ESS-CM) for Load Balancing and Network-initiated Fast BSS Transitions*

Most mobile Internet terminals with WLAN interfaces are trying to connect to the nearest AP with strongest beacon signal without consideration of the current traffic load of the AP [4]. As a result, in many cases the unbalanced traffic load of BSS within an ESS worsens the overall throughput of the ESS, and deteriorates QoS provisioning. Fig. 1 depicts the centralized control and management architecture for cognitive traffic engineering and QoS-aware service provisioning on WLAN ESS with SDN-based distribution system. In order to provide an effective inter-BSS load balancing in an ESS, we developed a network-initiated fast BSS transition scheme with extended IEEE 802.11r. The BSS agent collects per-STA and per-AC (access category) amount of both upstream and downstream traffic of each station. The aggregated traffic loads of each AP/BSS are collected by the centralized ESS-CM. Based on the collected traffic load information of each BSS, the ESS-CM analyzes the traffic loads in each BSS, considering the capacity of each AP/BSS. This traffic load information is provided to the mobile station which wants to initiate QoS-aware BSS transition. For proactive inter-BSS load balancing, the ESS-CM may select some mobile stations in congested BSS, and ask the selected mobile stations to transit to the less congested neighbor BSS. During these network-initiated fast BSS transition, the required QoS and traffic parameters are considered to provide QoS-guaranteed seamless handover.

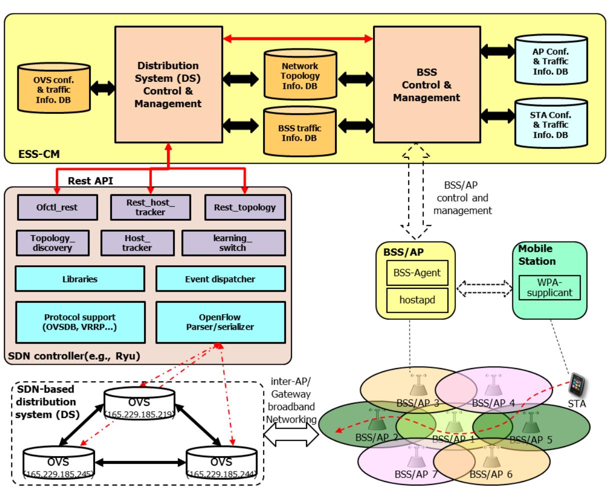

Fig. 1. Control and Management of WLAN ESS with SDN-based Distribution System

B. *Flow-based Traffic Engineering for SDN-based Distribution System*

The APs in WLAN ESS are interconnected by distribution system (DS), and currently gigabit Ethernet hubs/switches are mostly used in enterprise intranet. When the SDN-DS is implemented by OpenFlow switches, each mobile station can be supported with individual flow-based traffic engineering in the enterprise WLAN, and differentiated QoS provisioning is possible. As Fig. 1 depicts, the ESS-CM and the SDN controller are tightly coupled for flow-based traffic engineering for WLAN ESS with SDN-based distribution system.

The ESS-CM is composed of two important functional blocks: i) distribution system control and management (DSCM), and ii) BSS control and management (BSS-CM). The DSCM provides control and management functions for distribution system. For SDN-based distribution system, a SDN controller is tightly coupled with the DSCM. In this paper, we implemented the distribution system with Open vSwitch (OVS) and the Ryu [16] SDN controller, where the Ryu SDN controller is connected via RESTful API to the ESS-CM. The SDN controller firstly collects the network topology of Open vSwitches, and configures the necessary paths for control messages of IEEE 802.11r fast BSS transitions. The SDN-DS network topology information is shared with ESS-CM, and is used in the calculations of shortest paths for attached mobile stations.

Before fast BSS transition, the mobile station performs smart channel scanning [9], and provides the scanning results to the ESS-CM which is selecting the most appropriate target AP for the mobile device to make fast BSS transition.

C. *QoS-aware IEEE 802.11r Fast BSS Transition over the SDN-based Distribution System*

In order to support QoS-aware fast BSS transition, we added the request/response procedure of traffic load information between the mobile station (QSTA) and the ESS-CM if there is a necessity of BSS transit. The mobile station which wants to initiate fast BSS transition, firstly monitors its neighbor APs by smart scanning [9]. The mobile station sends the request message with the list of its neighbor APs with their channel scanning results, and the required network resource (i.e., required bandwidth for QoS-aware broadband multimedia service). The ESS-CM checks the availability of requested network resources at the neighbor APs in the received list, and sends response messages of traffic load information of the recommended neighbor APs through DS

The mobile node selects the most appropriate neighbor AP, and sends FT request through the currently connected AP which forwards the FT request message to the target AP. When the target AP accepts the FT request and provides its information, the mobile station sends FT confirm message with RIC (resource indication container) that specifies the required network resource for the QoS-aware broadband multimedia service. When the target AP can provide the requested network resource, it sends FT ACK to the mobile station through the current AP.

Since message exchanges of the request/response of traffic information of neighbor APs, the FT request/response and FT confirm/FT ACK, are performed through the currently connected AP, upstream/downstream multimedia service data packets are continuously delivered without any service disruption.

D. *Proactive Forwarding Table Updates at SDN-DS*

The proactive forwarding table updates at OpenFlow switches of SDN-based WLAN ESS distribution system is very important in the performance of the QoS-aware fast BSS transition over the SDN-based distribution system. When the mobile station is associated with a new AP after a successful fast BSS transition, the route for the packets/frames destined to the terminal should be updated immediately. If the forwarding tables in the OpenFlow switches of SDN-DS are not updated promptly, packets/frames will be delivered to the previous AP that transmits uselessly.

E. *Overall Procedure of QoS-aware Fast BSS Transition*

Fig. 2 depicts the overall procedure of QoS-aware fast BSS transition (QFT) that is proposed in this paper. At the initialization stage, each QAP initializes BSS-agent and hostapd process, configure internal socket, and establish connection to ESS-CM. Each QAP continuously measures per-station / per-AC traffic load data, and periodically reports the measured results to ESS-CM.

IV. Performance Analysis

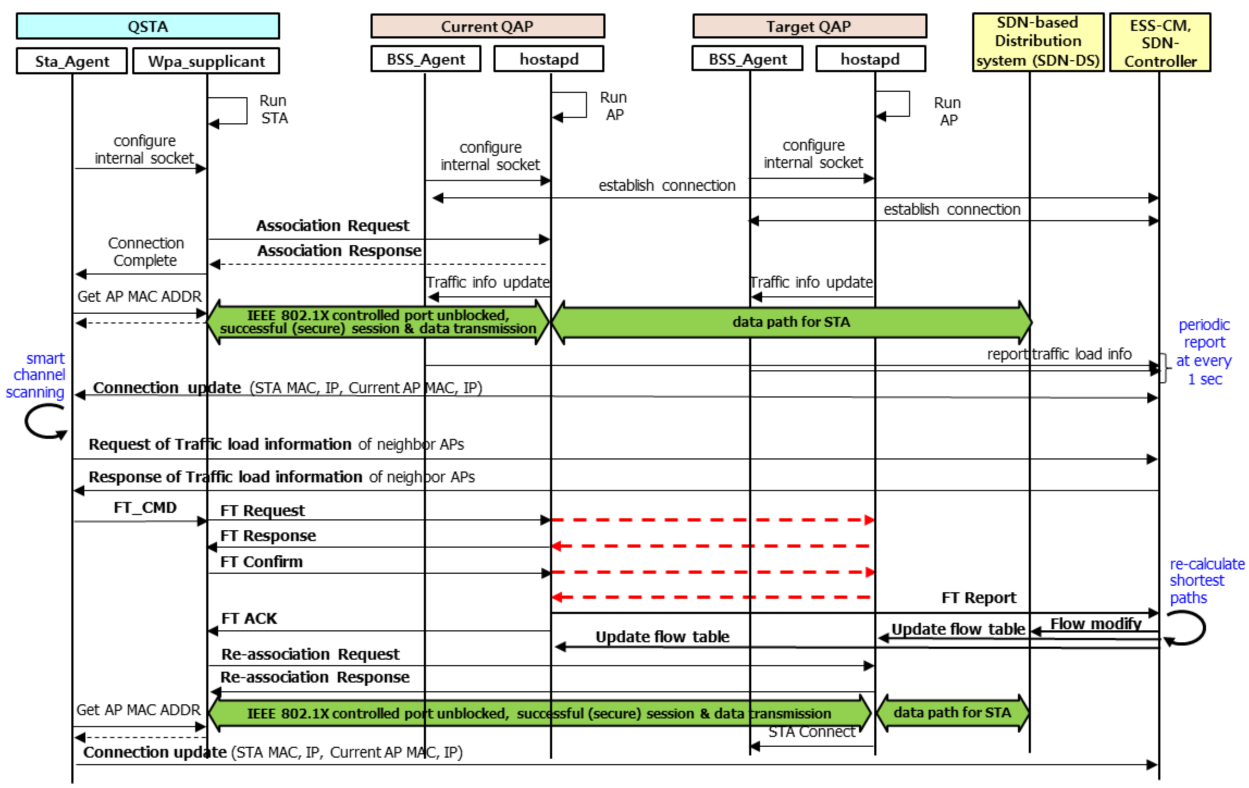

Fig. 2. Overall Procedure of QoS-aware Fast BSS Transition on WLAN ESS with SDN-based Distributed System

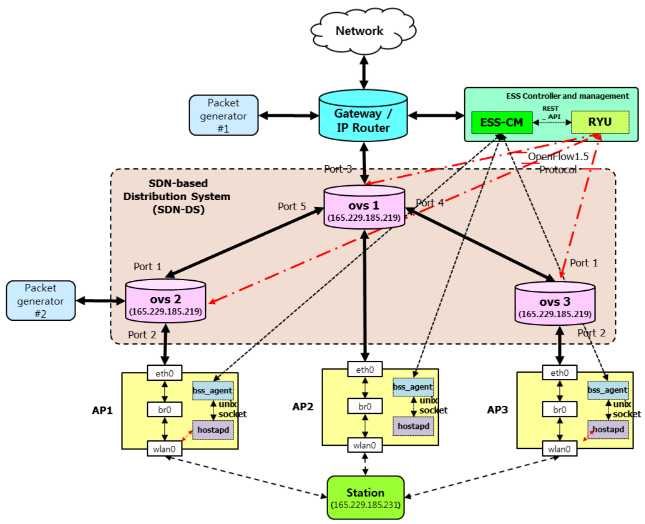

Fig. 3. QoS-aware Fast BSS Transition Scenario

A. *Scenario to Evaluate the Performance of QoS-aware Fast BSS Transition*

Fig. 3 shows the scenario to evaluate the performance of QoS-aware fast BSS transition. The QSTA is initially associated to QAP/BSS1, and broadband downstream data flow of real-time multimedia service (e.g., HD Video-on-Demand) is configured. The QSTA is assumed to move from BSS1 to BSS2, and from BSS2 to BSS3. When the WiFi channel condition becomes poor at the boundary of the BSS1 service range, the QSTA performs smart channel scanning for its neighbor QAPs, provides the scanning results to the ESS-CM, and obtains the traffic information of its neighbor QAPs from ESS-CM. Then it selects one of the most appropriate neighbor QAP, and performs "over-the-DS fast BSS transition with resource request."

In order to measure the real-time service disruption during the fast BSS transition, the elapsed time of each FT message exchanges were measured in micro-second unit. The broadband real-time multimedia service traffic was emulated with 6 Mbps UDP packet stream (1500 Bytes packets delivery at 2 ms interval).

B. *Performance of QoS-aware Fast BSS Transition*

Table I compares the service disruption time without IEEE 802.11r and with IEEE 802.11r fast BSS transition using SDN-DS with Open vSwitch and packet buffering. When the distribution system is implemented with Open vSwitch, the service disruption time is on average 16.93 ms, and the maximum disruption time is 20.09 ms.

From the experimental results, we can confirm that the proposed QoS-aware fast BSS transition can be executed in less than 50 ms. As explained in Section III-B, FT-Confirm/FT-ACK message exchange is used to proactively check the availability of the requested network resources for QoS-aware broadband multimedia service, using RIC, through

TABLE I. Service Disruption Time

	Without IEEE 802.11r		With IEEE 802.11r using SDN-DS with Open vSwitch	
	Service Disruption time[ms]	**Packet loss**	**Service Disruption time[ms]**	**Packet loss**
min	30.88	42	13.72	19
avg	48.86	66	16.93	23
max	89.95	122	20.09	27

the current QAP. Another key factor to minimize the service disruption in QoS-aware fast BSS transition is proactive forwarding table updates in SDN-DS [11-13].

From the experimental results of measurements on real IEEE 802.11n testbed, we can conclude that the proposed QoS-aware fast BSS transition over SDN-DS can guarantee minimized service disruption (less than 25 ms) when the QSTA performs QFT with i) obtaining traffic load information of neighbor QAPs from the ESS-CM, ii) FT-Confirm/FT-ACK message exchange to check the availability of required network resource in advance, and iii) proactive forwarding table updates in SDN-DS when the QSTA is successfully re-associated.

V. Conclusion

In this paper, we proposed a QoS-aware fast BSS transitions (QFT) for seamless mobile broadband multimedia service provisioning on enterprise WLAN ESS with SDN-based distribution system. The proposed scheme is based on i) cognitive management of WLAN ESS with SDN-DS that allows checking for resource availability before selecting candidate target AP, ii) QoS-aware roaming/handover with resource request over the SDN-DS, and iii) proactive forwarding table updates at the OpenFlow switches in the SDN-DS and APs. The proposed cognitive WLAN ESS management system has been evaluated with prototype implementation of real WLAN ESS with SDN-DS. The proposed QoS-aware fast BSS transition scheme has been implemented with hostapd 2.6 and wpa-supplicant 2.6 on Ubuntu 14.04 (Linux 3.16.0 kernel) with ath9k IEEE 802.11n WLAN driver. And, the SDN-based distribution system was implemented with Open vSwitch 2.5.2 and Ryu 4.14 SDN controller.

From the experimental results of measurements on real testbed of IEEE 802.11n ESS with SDN-based distribution system, we can conclude that the proposed QoS-aware fast BSS transition can guarantee minimized service disruption (less than 20 ms) when the QSTA performs QoS-aware fast BSS transition (QFT) with i) obtaining traffic load information of neighbor QAPs from the ESS-CM, ii) FT-Confirm/FT-ACK message exchange to check the availability of required network resource in advance, and iii) proactive forwarding table updates in SDN-Ds and APs when the QSTA is successfully re-associated.

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