Access Point Selection Algorithm for Providing Optimal AP in SDN-based Wireless Network

DongKyu Lee, Choong Seon Hong
Department of Computer Science and Engineering
Kyung Hee University,
Republic of Korea
{lidoobil, cshong}@khu.ac.kr

***Abstract*—Mobile operators are providing mobile data services through numerous Wi-Fi access points (APs). In such a wireless network, when mobile devices select a APs, recent works only consider to provide guarantee QoS (Quality of Service), however, they ignore the backhaul link limitations which refers to the link between AP and backbone routers. Therefore, even if there exist many APs satisfying the QoS, the mobile devices selects a specific AP, thus, creating congestion on the AP's backhaul link. Therefore, we propose a novel AP selection scheme that classifies mobile traffic by applying a machine learning based scheme and also considers the backhaul link status of APs along with the QoS requirements. Moreover, prior to AP selection, we prioritized the requests and implement an efficient approach that can balance the load between APs. Simulation results state that our proposal is suitable to provide an efficient network environment by distributing the backhaul link load of APs with guaranteed QoS.**

Keywords*—*SDN, Access Point Selection, QoS, Load Balancing

I. Introduction

Recently, mobile traffic in a wireless network is rapidly increasing due to the tsunami of network devices that includes smart phone, sensors and etc. To support the growing demand for mobile traffic, mobile operators offload a significant amount of mobile data through Wi-Fi APs (Access Points) especially in public places or hotspots. Moreover, the number of deployed APs are typically high in a service area, thus, the users have to select the most appropriate AP among the available APs in a service area to obtain connectivity.

According to the current IEEE 802.11 standard, traditionally, the user selects the AP according to the Received Signal Strength Indication (RSSI) value. However, using RSSI-based selection, traffic loads among access-points are often uneven, i.e., a certain access point may have a high number of users, and other points may have relatively few users [1]. Moreover, if high number of users connect to a certain AP, the quality of service (QoS) of a new user's application cannot be guaranteed [2] because the throughput is reduced due to traffic congestion. To solve these problems, recent works are considering the selecting an AP with QoS requirements rather than traditional RSSI value based selection. However, existing works do not consider the backhaul link limitation, thus, there can exist a case in which a number of APs will be satisfying the QoS but the backhaul link of the specific AP may be congested. This will indeed degrade the performance of the network.

In this paper, we address the aforementioned challenges by applying a Software Defined Network (SDN) that can collect the backhaul link information between AP and router of each AP. SDN is known to be an effective way to solve fast handover, frequency selection and power control in Wi-Fi networks [3]. And the enabling of SDN in networks have revolutionized both the wireless and wired networks through which a large number of control tasks can be performed [4]. In this work, we classify user's mobile traffic into an accurate service type through a machine learning algorithm. Then this information is sent to the controller by the APs. Through this, the controller proposes to an optimal AP for the users considering both the backhaul status among the APs and the QoS requirements. As a result, it is possible to make a wireless connection according to the exact service type on the mobile device side. This increases the performance and efficiency of the entire network by distributing the load on all APs in the network. Thus, our key contributions can be summarized as follows:

- We apply the supervised algorithm classification scheme in each AP to classify user's mobile traffic. Through supervised learning more accurate decisions of the service type can be made.
- We propose a novel AP selection scheme in which the SDN controller decides the AP selection based on the bandwidth of the backhaul link.

The rest of this paper is organized as follow. In Section II, we present the related works. We describe the proposed Access Point Selection algorithm for Load Balancing in section III. Then, we demonstrate the evaluation and simulation in section IV. Finally, we conclude the paper and provide the future directions in Section V.

II. Relative Works

A. Supervised learning-based decision tree

$$E(S) = -\sum_{x \in X} p(x) \log_2 p(x) \qquad (1)$$

$$G(S,A) = E(S) - \sum_{t \in T} p(x) E(t) \qquad (2)$$

A decision tree is one of machine learning technique. It is an analysis technique that classifies decision rule for a specific item into a tree form. Data is divided through Entropy (1), which is an information measure of the data set, and Information Gain

(2), which represents the change before and after dividing the data. Decision trees are computationally inexpensive, easy to implementation for learning models.

The C5.0 algorithm [5] used in this paper is a one of Machine Learning Algorithms based on decision trees. It means that the decision trees are built from list of possible attributes and set of training cases, and then the trees can be used to classify subsequent sets of test cases. C5.0 has several features such as boosting which can generate and combine several decision trees to improve prediction. C5.0 makes it possible to avoid errors which can result in a harm and supports sampling and cross-validation. In addition, C5.0 can handle attributes that are not related to classification, and can solve over fitting and error pruning problems [6].

B. Access Point Selection Algorithm

The conventional AP search process selects one of neighboring APs using only received signal strength indication (RSSI). However, in this case, since the state information of the network is not considered, QoS (Quality of Service) for the application of the mobile device is not guaranteed. Therefore, many studies on efficient AP Selection have been conducted to solve the problem by introducing the concept of SDN. In [7], the SDN controller considers the bit rate in addition to the RSSI value or the AP-to-client downlink control in Access Point selection. However, if the backhaul link condition of the AP is not taken into account, QoS can be assured on the downlink side, but the backhaul may be congested. In addition, if all the neighboring APs guarantee QoS, then the users connect to only one AP that is typically with the highest RSSI value, thus, the efficiency of the whole network may degrade.

To solve this load balancing problem, in the case of [8], they propose an algorithm that selects the least loaded AP among the APs with RSSI values satisfying the QoS requirements. In addition, for papers that propose the AP Selection Algorithm with SDN, there is a big overhead problem as all processing is performed at the controller. Therefore, in order to solve these problems, this paper reduces the overhead by classifying the service through the mobile traffic analysis in the wireless AP instead of the controller. Here, we propose an algorithm that allows the user to select an AP that takes into account the QoS requirements of the service and the backhaul load condition of the AP.

III. PROPOSAL

A. System Architecture

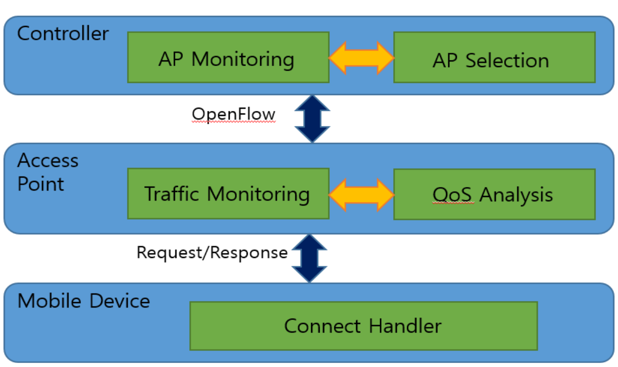

Fig. 1. System Architecture.

Figure 1 shows the system architecture of this paper. The mobile device establishes a connection with the AP through the Connect Handler. The Access Point classifies the service of incoming traffic through Traffic Monitoring and AP confirms that it can provide QoS requirement for services classified through Service Analysis. If the current access point cannot satisfy the QoS requirement, it informs the controller through the Openflow protocol. The controller also collects network information of neighboring APs of mobile devices through Access Point Monitoring function. Then, the AP selection module selects an optimal AP by using the information of neighboring APs and the QoS requirement of the device. The result of AP selection is then informed.

B. System Designs

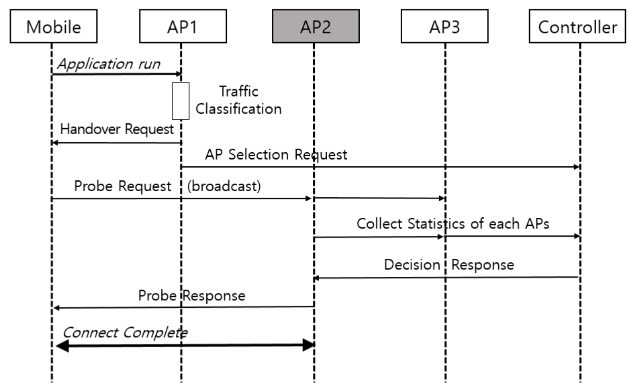

Fig. 2. Sequence Diagram

Figure 2 shows the sequence diagram for our novel AP selection procedure. Consider that a user already connected to an AP 1 executes a new application. Then, AP 1 analyzes the incoming mobile traffic and classifies the application traffic as a service and confirms whether it can provide the required QoS for this service or not. If AP 1 can provide the QoS requirement, the connection continues otherwise a handover will take place through the AP selection algorithm. The AP 1 informs the user and the SDN controller that it cannot satisfy the requirement for the service, and proceeds the handover. Then, the controller collects and analyzes the information of neighboring APs to determine the appropriate access point in the service area with available QoS capability and enough backhaul bandwidth. This allows the mobile device to connect to an access point that can meet the requirements for application services.

C. Traffic Monitoring & Service Analasis

Access Point monitors the incoming mobile traffic and analyzes the services through which they decide whether they can satisfy the QoS requirements or not. The mobile applications generally use the HTTP / HTTPS protocol for communication and thus can be classified into these categories.

Application	Data rate [kbps]	Delay [ms]	PER
HD video streaming	**800**	**2000**	**0.05**
VoIP	**512**	**150**	**0.01**
Audio streaming	**320**	**200**	**0.08**
File download	**200**	**3000**	**0.1**

Fig. 3. QoS Requirements for Application Type.

Moreover, existing traffic classification methods are difficult to classify applications that run on the HTTP protocol [9]. Therefore, this paper applies the C5.0 algorithm to classify HTTP traffic by service [10]. We classify the mobile HTTP traffic into AUDIO / FILE / VOIP / VIDEO and implement the classifier in the Traffic Monitoring module of each Access Point. The Service Analysis component applies the QoS requirements which are classified as shown in Figure 3[11]. If the access point cannot satisfy the QoS, it makes a request to the controller for AP selection. Other services are categorized as Web class and have the lowest priority in AP selection.

D. Service-Aware Access Point Seclection Algorithm

The controller receiving the request monitors the neighboring APs for connection with the new AP that can satisfy the QoS requirements and the optimal AP is proposed to the mobile device through the proposed AP selection algorithm. Figure 4 shows the pseudo code for request selection among the algorithms proposed in this paper. Because the controller manages a large number of APs, the priority of AP selection requests within a given window size must be considered. Therefore, the controller stores incoming requests in S_{Req}. Then, the controller prioritizes through the service type of each request and performs AP selection from the highest priority P_{Req} to the next. Because the AP selection algorithm proposed in this paper considers the load distribution at each AP, if the service type of the request requires a large bandwidth such as video, AP selection should be considered first.

Algorithm 1 : *Request Selection*

Input: S_{Req} ***(Set of Requests from devices)***

Output: P_{Req}(Prioritized Device)

Prioritize devices
    for Request ∈ S_{Req} **do**
        L_{Req} = get ***traffic_Service*** of Request
    end if
    Sort L_{Req} with ***traffic_Service*** priority
    $\boldsymbol{P_{Req}}$ = ***Request*** *with* L_{Req}.get(0)

Fig. 4. Pseudo code for Request Selection Algorithm

Figure 5 shows the pseudo-code for the algorithm that selects APs suitable for the service through the backhaul link and downlink status information of the neighboring APs to satisfy the request of P_{Req} determined previously. First, the controller defines the requirements for the corresponding service type classified by the AP. Second, it collects downlink bit rate ($R_{AP_{down}}$) information of each AP from APs around the mobile device. The collected bit rates are compared with the QoS requirements and the appropriate APs are stored in the list (L_{down_AP}). The controller collects the backhaul link bandwidth status of APs belonging to L_{down_AP} and stores them in the list (L_{Up_AP}). Then, the AP with the best bandwidth condition is selected as the optimized AP (O_{AP}) in the list (L_{Up_AP}), and the mobile device is connected. After the AP selection for one request is completed, the controller again processes the request of the next priority of L_{Req}.

Algorithm 2 : *Access Point Selection*

Input: S_{AP} ***(Set of Aps)***, $\boldsymbol{P_{Req}}$

Output: O_{AP}(Optimized AP)

set R_{req} based ***traffic_Service*** of $\boldsymbol{P_{Req}}$
AP selection for QoS requirement
    for ap ∈ S_{AP} **do**
        $R_{AP_{down}}$ = get ***DownLink*** bit rate of ap
        if $R_{AP} > R_{req}$ **then**
            Append(L_{down_AP}, ap)
        end if
    end for
AP selection for Load balancing
    for ap ∈ L_{down_AP} **do**
        Thr_{AP} = get ***Backhaul link*** current Throughput of ap
        Append(L_{Back_AP}, Thr_{AP})
    end for
    Sort(L_{Back_AP})
    $\boldsymbol{O_{AP}}$ = ***AP*** *with* L_{Back_AP}.get(0)

Fig. 5. Pseudo code for Access Point Selection Algorithm

IV. Evaluation

A. Simulation Scenario

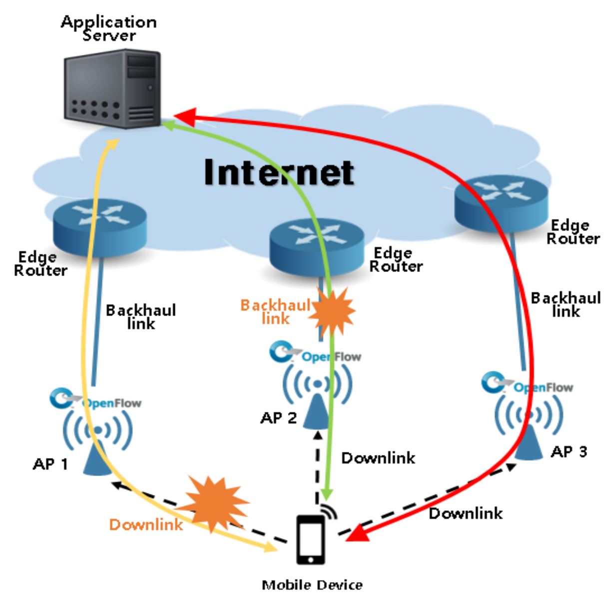

Fig. 6. Simulation Scenario

In order to validate our proposal, we perform the simulations. Figure 6 shows the considered scenario topology for testing the AP Selection algorithm proposed in this study. The AP 1, which is currently connected to the mobile device, determines that the device has executed the video streaming service through traffic monitoring and service analysis. However, since AP1 does not satisfy the QoS for the corresponding service in the downlink, the device searches for a new AP to be connected. At this time, when AP2 and AP3 both satisfy QoS, existing works on AP selection always selects AP2 based on only RSSI value and ignore all other constraints. However, in this case, the load on the backhaul will increase on the AP 2 link creating congestion. However, our proposed algorithm will take into account the bandwidth of the backhaul link during the AP selection process and will distribute the load among all APs.

First, the controller checks whether downlink information of neighboring APs that have received the probe request can satisfy the QoS for the service being executed in the device. Then, an optimal AP is determined so that congestion does not occur on the APs and the QoS can be maintained. That is, when all of the surrounding APs meet the QoS requirements, the proposed algorithm causes the mobile device to select AP3 to distribute the load of the backhaul link of AP2 as shown in the figure. The Access Point was implemented using Raspberry Pi 3, and OpenFlow protocol was used for communication with the SDN Controller. AP also monitors traffic through pcap library and classifies it by service using C5.0 algorithm. Performance evaluation confirms that the load distribution of APs is better than that of existing algorithms.

B. *Simulation Result*

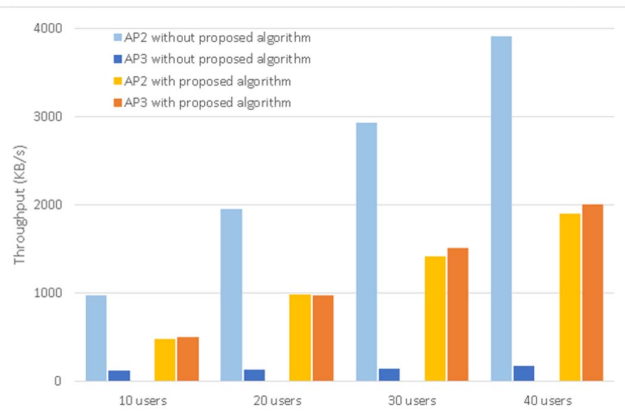

Fig. 7. Comparison of Backhaul link bandwidth of APs with existing algorithm and proposed algorithm

Figure 7 shows the comparison of the backhaul link bandwidth of each AP according to the number of users when applying the existing algorithm and the proposed algorithm in the above scenario. Since the existing algorithm selects the AP based on the RSSI value, even if both AP2 and AP3 satisfy the QpS requirement, the new mobile device is only connected to AP2. Therefore, as shown in the figure, the load on the backhaul link of AP2 occurs, which reduces the efficiency of the entire network. However, in the proposed AP selection, if AP2 and AP3 satisfy the QoS requirements, the AP is selected considering the backhaul link condition of each AP. Therefore, as shown in the figure, it is possible to increase the efficiency of the entire network by distributing the load on the backhaul link.

V. CONCLUSION

AP selection process of existing studies only considers the downlink condition of neighboring APs in order to guarantee QoS for services of mobile device when selecting AP. However, even if all of the surrounding APs satisfy the QoS, the backhaul link may get congested due to establishment of new connection to a single AP based on RSSI, which ultimately deteriorates the efficiency of the network. Therefore, we propose a novel algorithm in which the SDN controller considers the backhaul link of each AP along with the QoS requirements for providing service. In particular, in this process, among many requests coming in at the same time, a service having a high QoS requirement is processed first so that efficient load balancing between APs can be achieved. Simulation results reveal that the proposed algorithm can provide fair distribution of load among the AP along with the required QoS. Moreover, considering the feature that most mobile traffic is HTTP, mobile traffic is classified into service type through decision tree. Future studies will extend the study to include more accurate and efficient AP selection with additional parameters such as delay or latency.

ACKNOWLEDGMENT

This research was supported by the MSIT (Ministry of Science and ICT), Korea, under the ITRC (Information Technology Research Center) support program (IITP-2017-2013-0-00717) supervised by the IITP (Institute for Information & communications Technology Promotion). *Dr. CS Hong is the corresponding author.

REFERENCES

[1] Tomotaka Kimura, Kouji Hirata, et al., “Dynamic access-point selection method using Markov approximation” International Conference on Information Networking (ICOIN), pp. 332-337, January 2017.

[2] Dongkyu Lee and ChoongSeon Hong, "Handover Algorithm for QoS Guarantee in SDN based IoT Wrieless Environment," Proc. of the 43th KIISE Winter Conference, pp. 942-944, December 2016.

[3] Alessandro Raschella, Faycal Bouhafs, et al., "Quality of Service Oriented Access Point Selection Framework for Large Wi-Fi Networks" IEEE Transactions on Network and Service Management, pp. 1-14, May 2017.

[4] Choong Seon Hong, SM Ahsan Kazmi, et al., "SDN Based Wireless Heterogeneous Network Management." AETA 2015: Recent Advances in Electrical Engineering and Related Sciences, pp. 3-12, March 2016

[5] Tomasz Bujlow, Tahir Riaz, et al., “A method for classification of network traffic based on C5.0 Machine Learning Algorithm” IEEE International Conference on Computing, Networking and Communications (ICNC), pp. 237–241, January 2012.

[6] Pandya, Rutvija and Pandya, Jayati, “C5.0 Algorithm to Improved Decision Tree with Feature Selection and Reduced Error Pruning” International Journal of Computer Applications, vol. 117(16), pp.18-21, May 2015.

[7] Jeongkeun Lee, Mostafa Uddin, et al., “meSDN: Mobile Extension of SDN” International Conference on Mobile Systems, Applications, and Services (MobiSys), pp. 1-8, June 2014.

[8] Keshav Sood, Shigang Liu, et al., “Dynamic Access Point Association Using Software Defined Networking” International Telecommunication Networks and Applications Conference (ITNAC), pp. 226-231, November 2015.

[9] Shuaifu Dai, Alok Tongaonkar, et al., “NetworkProfiler: Towards Automatic Fingerprinting of Android Apps” IEEE International Conference on Computer Communications (INFOCOMM), pp. 809-817, April 2013.

[10] Tomasz Bujlow, Tahir Riaz, et al., “Classification of HTTP traffic based on C5.0 Machine Learning Algorithm”, IEEE Symposium on Computers and Communications (ISCC), pp. 882-887, July 2012

[11] Pantisano, Francesco, et al., "Matching with externalities for context-aware user-cell association in small cell networks," IEEE Global Communications Conference (GLOBECOM), pp. 4483-4488, December 2013