Handover Management Scheme in SDN-Based Wireless LAN

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Abstract —Handover of Mobile Equipment (ME) between different Access Points (APs) is an inevitable problem in the wireless network. Mobility of the mobile equipment can cause degradation of Quality of Service (QoS). How to satisfy the user's QoS and achieve seamless handover becomes a very worth of study in the field of wireless communication network. In this paper, we proposed a handover management scheme in the WLAN based on Software Defined Networking (SDN) architecture. In this scheme, the handover decision making process is processed layered and we proposed a multiple attributes handover algorithm based on fuzzy logic (FLMAHA). The algorithm utilizes Received Signal Strength (RSS), forecasting RSS and available bandwidth as parameters to design of fuzzy logic system, using fuzzy logic method to process the parameters, and then obtain the quantized value of each network parameters membership. At last through calculating network performance evaluation values to make handover decision. Finally, the experimental results showed that our proposed handover scheme can avoid the "ping pong" effect and ensure QoS.

Index Terms—SDN, handover, wireless LAN, fuzzy logic

I. Introduction

Now wireless access has become the main way of user access networks, especially the development of 3G, 4G technologies. The MEs have become very popular because of the characteristics of the mobility, and mobile internet is being the trend of future network. At the same time for this characteristic, the mobile communication is not as stable as wired device's. Mobile users want to access to the Internet like other desktop users, sharing the resources, and not limited a fixed area. So user's mobility management is an important challenge for wireless network and needs to maintain the session continuity. More importantly handover as the key technology of mobility management is essential to ensure the QoS when roaming. Handover is a procedure, when ME moves to a region where the signal strength is lower than that of neighboring AP, then the procedure is triggered. Or when ME wants to change the wireless attachment for better radio channel quality, the handover procedure can also be performed.

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Unfortunately, the widely used network communication protocol–TCP/IP was not designed with mobility as a key design requirement. To maintain communication without interruption during roaming, many protocols and specifications have been proposed. Mobile IPv6 proposed by IETF is one of latest versions to guarantee mobility. Mobile IPv6 is responsible for managing the network layer handover between ME and AP. Throughout this protocol, the ME keeps the session continuity when handover. But in the process of handover, the ME cannot be able to receive and send any packets; this can cause high latency and packet loss, especially cause the triangle routing

It's difficult to innovate on the existing network architecture, so this paper used an emerging network architecture–SDN proposed by Stanford University in recent years [1]. The first truthful implementation of SDN concept is the OpenFlow protocol [2]-[3], which is a communication protocol between control plane and forwarding plane. In fact, OpenFlow owning good flexibility and normative has been seen as a de-facto standard communications protocol in SDN architecture, which is similar to the TCP/IP protocol of the Internet as a communication standard. In this paper, we used the SDN technology to implement handover management between different APs. The concept of SDN decouples the control plane from the hardware, and places the control plane on a centralized server called "controller". SDN technologies which based OpenFlow enable network to solve these problem that the high-bandwidth, dynamic nature of applications, adapt the network to ever-changing business needs, and significantly reduce operations and management complexity. The architecture of SDN includes three layers: application layer, control layer and infrastructure layer. Fig. 1 is the logical view of SDN.

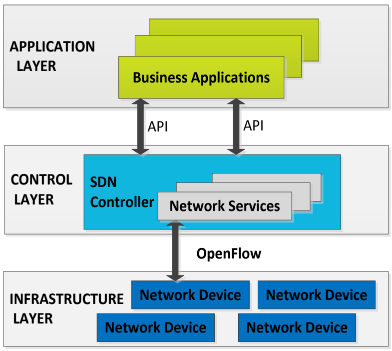

Fig. 1 The logical view of SDN

The network services are centralized at the controller. The controller through OpenFlow protocol manages all the network devices in the infrastructure layer. The network devices controlled by controller only keeps the simple forwarding capability. This makes the operation and design of network simpler and more efficient. The main idea of SDN is to remove the control module from the forwarding devices that makes the network control become directly programmable. And the network devices to be abstracted for network services. Google has been deployed the SDN in data centers worldwide. Through deployment of the traffic engineering and QoS priority scheduling in the network, it makes the utilization of links from an average of 30%-40% to nearly 100%. Google's success stories prove the superiority of the SDN.

Generally, handover process includes three phases: (1) The handover trigger phase; (2) The handover decision phase; (3) The handover execution phase. The main work of first phase gathers the network parameter information, which usually includes bandwidth, RSS, the latency and the cost of network and so on. This step of work is done in the ME. The second phase processes these parameters to choose the optimal network, which is completed in the controller. The third phase is that ME access the new network and switches to it all its connection. The handover process determines the performance, not only the network but also the MEs. The selected AP must response to the QoS requirements of applications on the ME.

The handover algorithm can affect the entire handover process. It is very critical that use a good handover algorithm to improve the network performance when roaming. Handover decision algorithm based on RSS threshold can cause "ping pong" effect. And the handover process produces high handover latency. In this paper, we proposed a novel multiple attributes handover algorithm based on fuzzy logic to make handover decision. The algorithm utilizes RSS, forecasting RSS and available bandwidth for parameters to design of fuzzy logic system, through calculating network performance evaluation values to make handover decision. We set up a testbed to validate our handover scheme. The scheme can make the accurate handover decision before reaching the link-down time.

The rest of the paper is organized as followed. We review related work in Section II, and the introduction of the proposed scheme and the FLMAHA algorithm in Section III. In Section IV, we evaluate the performance of the proposed scheme. Finally, we conclude this paper.

II. Related Work

There are many solutions which have been proposed to improve the handover performance. MobilityFirst [4] that supported in part by the US National Science Foundation is a future Internet architecture that committed to a smooth seamless mobility support, which supports communications between the mobile nodes. The architecture has two fundamental goals: mobility and trustworthiness. It uses "global delay tolerant network" (GDTN) to provide communication stability; focus on mobility and scalability of balance. It uses the Globally Unique Identifier (GUID) to mark various objects of the network. For routing, the hybrid routing based on the name and address adopts the Global Name Resolution Services (GNRS) to bind the target GUID latest set of addresses, thus ensuring high scalability. MobilityFirst is good support for mobile computing, but cannot solve traffic surges caused by bandwidth consumption problem. At the same time, designing a massively scalable distributed GNRS is a key challenge that allows tens of billions of endpoint identifiers to update their network addresses many times a day. And, MobilityFirst is still in the research stage, there are still a lot of challenges to be resolved.

Ref. [5] proposed the use of OpenFlow protocol approach as an alternate transport mechanism to execute routing and to provide the connectivity of the network for Mobile IP networks. OpenRoads [6], [7] enables researchers running experiments to demonstrated seamless handover between the WLAN and WiMAX nodes and to improve robustness during handover using multicast in mobile network. OpenRoad redirects the traffic flows dynamically through the network similar to OpenFlow protocol. Peter *et al.* [8] integrated the OpenFlow with wireless mesh network and addressed the problem of host mobility in a wireless mesh network that deal with the handover of host between Mesh Access Points. It only proposed a solution to using OpenFlow to solve the host handover in the context of wireless mesh networks environment, but handover in the context of other network environment didn't mention. They also have a paper about handover management with real-video [9]. In this paper, they proposed a network architecture with the SDN technology and implement handover management of real-time video under this architecture.

Enterprise WLAN has been rapid growing and also has followed the user scale and traffic load, as well as emerging suffers from poor flexibility and the lack of coordination between APs and wired backbone. Zhao *et al.* [10] took full advantage of SDN architecture then proposed SDWLAN, which was an alternative architecture for enterprise WLAN. Under SDWLAN architecture, the wired backbone and the APs are consolidated to offer a unified network control plane; and the author proposed a client-unaware fast AP handover mechanism. Ref. [11]-[13] studies the seamless handover, optimal access selection and network mobility in different architecture—CCN, CR and High-Speed Rail Networks. They propose various handover schemes. But the handover schemes are restricted to actual environment. Magagula LA *et al.* [14]-[16] employs a handover coordinator between the heterogeneous networks. The proposed handover mechanism utilizes a network-based mobility management protocol. OpenAPI [17] is a system architecture which allows managing and sharing the

WLAN resources. The system defines interfaces between ISP, content provider and end user to enable an open and flexible service quality management. The idea of OpenAPI is pretty good, but in the short run, it is difficult to adapt to this change for equipment vendors that will lose their profit margins.

The handover algorithm determines the performance of the wireless. Therefore, an increasing research effort was absorbed in new handover algorithm. The traditional handover algorithm was based on RSS threshold [18]. The ME would continuously monitors the RSS value of the currently connected AP. And if the RSS value goes under the predefined threshold, the ME triggers the handover process. The algorithm will select the one AP which has the best RSS. This scheme can cause "ping pong" effect and has long handover delay. In addition, it increase the probability of handover failure.

Cost based functions consider several parameters to select the network when roaming. The parameters are usually divided into four categories [19]: network information, service type, terminal capabilities and user preferences. Generally, a weight is assigned to each parameter and a priority is assigned to each application. Ref. [20] proposed a cross layer cost function. The parameters are collected from different layers. The weights of network parameters are assigned based on application and user preferences. The ME utilizes the score that each parameter multiplies the weight to select the network which has the highest score.

III. The Proposed Handover Scheme

Handover management is critical to ensure QoS, and a good handover algorithm can determine the handover management performance. The objective of our handover scheme is to make an accurate handover decision and trigger the handover procedure timely while the ME roaming. We used fuzzy logic system to calculate the values of network performance to determine which AP is chosen as the new link of attachment. Fuzzy logic is a process of decision making that based on the membership function and a group of fuzzy rules. The fuzzy logic system likes the human brain that simulates the interpretation of uncertain sensory information. Based on the traditional fuzzy logic handover algorithm requires defuzzification, which will increase the computing time. This algorithm compares each PEV value of networks, and there is no need for defuzzification. In this paper, according to the current RSS predicts the RSS value of next time moment, and based on the forecasting RSS value to trigger the handover decision-making process, thereby reducing the handover discovery time.

A. Decision Parameters

Each application class has a particular demand on a set of parameters. For example, the interactive application requires a short end-to-end delay and a very low loss rate. The FTP application requires the high bandwidth. RSS has been as one of the most important parameters in the handover algorithm. Because the handover algorithm only based on RSS threshold can cause "ping pong" effect, in this paper, we used the Current RSS (CR), the forecasting RSS (FR) and available bandwidth (B) as network parameters to design fuzzy login system. The forecasting RSS is used to represent the change trend of RSS. The handover discovery time can be shortened according to the forecasting RSS to trigger the handover procedure. In this paper, we use the grey predictive technology [21] to predict RSS value of the next moment. Signal prediction technique as the handover trigger mechanism and judgment parameter can improve the handover discovery speed and accuracy. Equation (1) is the formula for predicting.

$$RSS^{(0)}(n+1) = (RSS^{(0)}(1) - \frac{b}{a})e^{-an}(1-e^{a}) \tag{1}$$

where a represents the development grey number and b represents the internal control grey number. The available bandwidth of network is a reflection network performances important target and also can denote network available bandwidth resource conditions. In addition, using bandwidth as parameters also can improve the load balancing. Each network parameter has different units, in order to make the various network parameters using the same dimension, normalized treatment should be carried out for each parameter.

The normalized processing formula is as follows:

$$V(x) = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \tag{2}$$

where x represents the value of CR, FR and B. $V(x)$ represents the value of normalized processed.

B. FLMAHA Alogrithm Description

In this paper, the handover decision making process is processed layered. We set up a RSS threshold, in the handover decision phase only to meet the RSS threshold can enter into the fuzzy logic decision phase, otherwise, the ME continues to monitor the current link. This step can effectively reduce the amount of data into the fuzzy logic system and unnecessary overhead. The second layer is fuzzy decision, using multiple parameters of network makes handover decision in the FLMAHA algorithm.

The process of fuzzy logical decision as follows: 1) multiple network attribute parameters processed by fuzzy logical controller, so that obtain fuzzy set and membership function of the network parameters. 2) Membership functions of network parameters were normalized process, and then obtain the quantized value of each network parameters membership. 3) Calculate the optional network Performance Evaluation Value (PEV) in the fuzzy logic system, and select the optimal network PEV. Then the PEV of the optimal network compared with the PEV of current connection, if meet the handover conditions, then the selected AP will be as the new link of attachment for the ME. The FLMAHA algorithm flow block diagram shows in Fig. 2. The first layer of the processing is done in the ME. The second layer of handover judgment is completed in the controller.

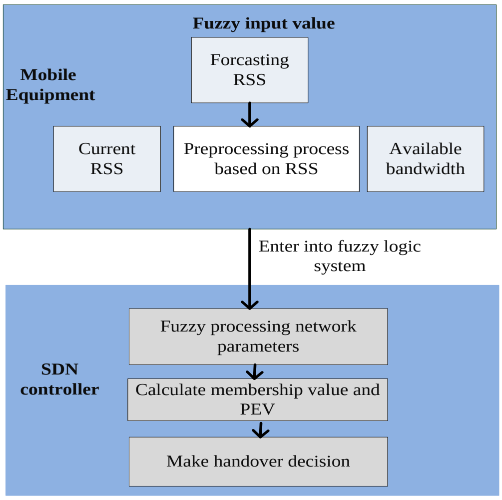

Fig. 2. Flow block diagram of HLMAHA

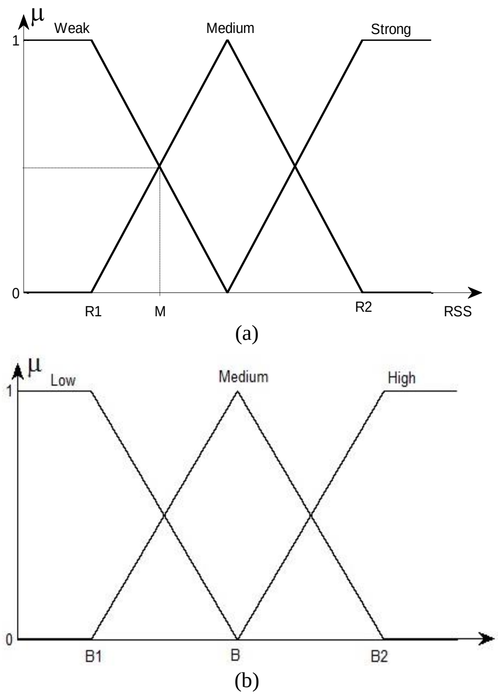

Fig. 3. Membership function for network parameters: (a) Membership function for current RSS and forecasting RS and (b) Membership function for available bandwidth

C. *Fuzzy Processing Network Parameters*

In this paper select three network parameters for fuzzy processing, respectively, the CR value, FR value and B. The essence of fuzzy processing is the numerical mapping to the membership function. The Fig. 3(a) shows the membership function of current RSS and forecasting RSS. And the Fig. 3(b) shows the membership function of available bandwidth.

We use the (Weak (W), Medium (M), Strong (S)) three fuzzy sets to describe the CR and FR status value for each AP. Expressed as $\mu_i^{CR}(W,M,S)$ and $\mu_i^{PR}(W,M,S)$. And using the (Low (L), Medium (M), High (H)) three fuzzy sets to describe the available bandwidth statue value for each AP. Expressed as $\mu_i^{B}=(L,M,H)$. As shown in Fig. 3(a), when RSS=M, then $\mu_{i-L}^{CR}=0.5$, $\mu_{i-M}^{CR}=0.5$, $\mu_{i-H}^{CR}=0$. Therefore the membership vector is represented as $(\mu_{i-L}^{CR},\mu_{i-M}^{CR},\mu_{i-H}^{CR})=(0.5,0.5,0)$.

D. *Memberships Value*

In order to calculate the membership value of CR, FR and B, the network parameters that through the fuzzy processing must be assigned a specific effect value. CR and FR normalized quantization rule is calculated as follows:

$$(J_{i-W}^{x},J_{i-M}^{x},J_{i-S}^{x})=(\frac{V_i(x)-R_1^x}{R_2^x},\frac{V_i(x)-R_1^x}{R_2^x-R_1^x},\frac{V_i(x)}{R_2^x}) \quad (3)$$

In (3), x represents the value of CR and FR. The R1 and R2 respectively correspond to the R1 and R2 on the axis in the figure.

The available bandwidth B normalized quantization rule is calculated as follows:

$$(J_{i-L}^{B},J_{i-M}^{B},J_{i-H}^{B})=(\frac{V_i(B)-B_1^B}{B_2^B},\frac{V_i(B)-B_1^B}{B_2^B-B_1^B},\frac{V_i(B)}{B_2^B}) \quad (4)$$

Membership values of each network parameter are calculated as follows:

$$\begin{aligned}M_i^x &=(J_{i-W}^{x},J_{i-M}^{x},J_{i-S}^{x})(\mu_{i-W}^{x},\mu_{i-M}^{x},\mu_{i-S}^{x})^T\\ &=(\frac{V_i(x)-R_1^x}{R_2^x},\frac{V_i(x)-R_1^x}{R_2^x-R_1^x},\frac{V_i(x)}{R_2^x})(\mu_{i-W}^{x},\mu_{i-M}^{x},\mu_{i-S}^{x})^T \quad (5)\end{aligned}$$

where x represents the CR and FR, i represents the candidate AP, μ represents membership vector.

$$\begin{aligned}M_i^B &=(J_{i-L}^{B},J_{i-M}^{B},J_{i-H}^{B})(\mu_{i-L}^{B},\mu_{i-M}^{B},\mu_{i-H}^{B})^T\\ &=(\frac{V_i(B)-B_1^B}{B_2^B},\frac{V_i(B)-B_1^B}{B_2^B-B_1^B},\frac{V_i(B)}{B_2^B})(\mu_{i-L}^{B},\mu_{i-M}^{B},\mu_{i-H}^{B})^T \quad (6)\end{aligned}$$

where i represents the candidate AP, μ represents membership vector.

After these calculations, obtained judgment matrix M as follows:

$$M=\begin{bmatrix} M_1^{CR} & M_1^{PR} & M_1^{B}\\ M_2^{CR} & M_2^{PR} & M_2^{B}\\ \vdots & \vdots & \vdots\\ M_i^{CR} & M_i^{PR} & M_i^{B}\end{bmatrix} \quad (7)$$

Each row represents one AP various network parameters attribute value after fuzzy processed in matrix M. The number of rows of matrix M represents the number of networks, namely the number of AP.

E. *Handover Decision*

After calculating the membership values of parameters in the network, we utilize the matrix M carries out the handover decision. Due to different network parameters having different effects on the handover decision, it need weighted processing on each network parameters. In this paper, the weight of each network parameter set as follows:

$$W = (\omega^{CR}, \omega^{PR}, \omega^{B}) = (0.2, 0.45, 0.35) \quad (8)$$

In (8), $\omega^{CR} + \omega^{PR} + \omega^{B} = 1$. Then calculates the network performance evaluation value according to the matrix M and W:

$$PEV_i = W \times M^T = (\omega^{CR}, \omega^{PR}, \omega^{B}) \times (M_i^{CR}, M_i^{PR}, M_i^{B})^T \quad (9)$$

The mobile handover decision is based on different PEV and chooses the maximum value (PEV_{max}) as the target network for handover. The handover decision rule as follows:

(a) When selecting the PEV_{max} is greater the current PEV (PEV_{cur}), namely $PEV_{max} > PEV_{cur}$, then perform the handover process.

(b) When selecting the PEV_{max} is lower the PEV_{cur}, namely $PEV_{max} < PEV_{cur}$, then handover process is not performed. Stay on the current network, can effectively reduce the handover frequency.

F. Handover Management Process

When mobile equipment moves in a network coverage, it will detect a new wireless link or cut off the current connection when the signal severely degraded. In this paper, the handover process is processed with layered manner. The first layer is preprocessing process based on RSS threshold. The RSS threshold should be relaxed on the preprocessing process, and only meeting the RSS threshold of the network can enter into the fuzzy logic decision phase, otherwise the ME will continue to monitor the current connection. The second layer is fuzzy decision, which utilizes the FLMAHA algorithm to make a rational decision.

When the forecasting RSS is larger than the threshold value, the ME will send the HANDOVER_REQUEST message to the controller, and the message includes the information about network interface, IP address, MAC address, and the parameter information of network and the forecasting information and so on. Then SDN controller makes decision based on FLMAHA algorithm. If SDN controller decides to handover, then it send the HANDOVER_REPLY message to the ME, the message includes the new AP information; meanwhile SDN controller establishes a new path from the server to the new AP. When the ME receives the HANDOVER_REPLY message, perform the handover process. If there is not meet the requirement of handover, then it sending the HANDOVER_NOACTION message to the ME, and the ME do noting action. So the SDN controller is mainly response to handover control, such as when to trigger the handover, and how to route the ME's packets to the new AP and when to release the resources occupied by the previous path. The handover management process is shown in Fig. 4.

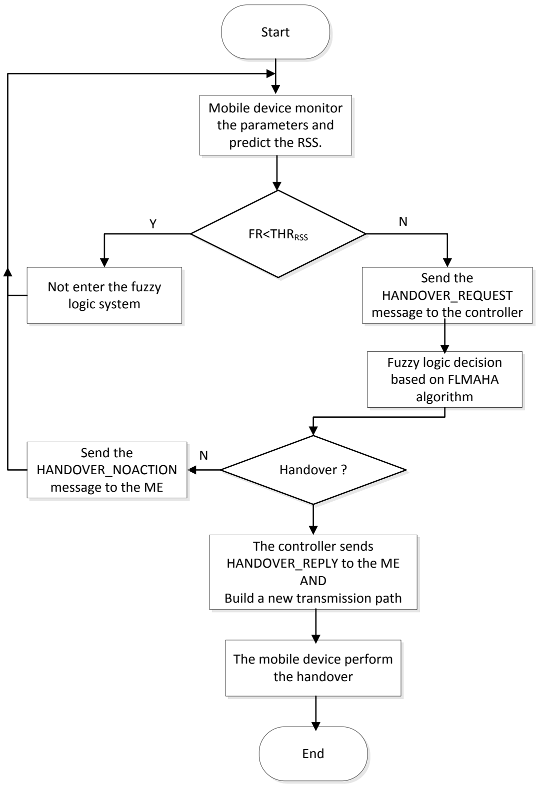

Fig. 4. The flow chart of handover

IV. EXPERIMENT ANALYSYS

In order to evaluate the feasibility and effectiveness of the proposed handover scheme and algorithm, we build a SDN testbed. We deployed our testbed in the corridor and placed thirteen APs with different distance intervals. OpenFlow switches are hosts equipped with four Ethernet ports. The host system is Linux12.04 which downloaded the OpenFlow 1.0 and compiled the source code on it, so that the host has the function of OpenFlow. We use the POX controller, which is modular programming and add modules that we need easily. The FLMAHA algorithm modular is added into the POX controller. While the script that preprocessing process written in Python language on the ME, when the preconditions are met, the ME sends a HANDOVER_REQUEST message to the controller.

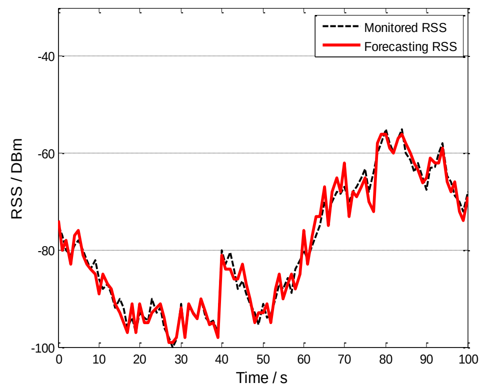

Fig. 5. Compare with CR and PR

Fig. 5 is comparison with the forecasting RSS and the monitored RSS. The grey predictive technology can get a good prediction of RSS value. The error value of the forecasting RSS and the monitored RSS is in the acceptable range. Using the forecasting RSS can make accurate prediction to the tendency of RSS value change, which plays a very important role for the preprocessing process. And it can shorten the handover discovery time.

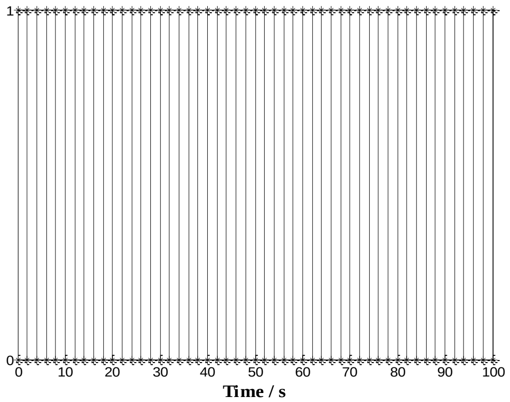

Fig. 6. Without preprocessing into the fuzzy logic of sampling points

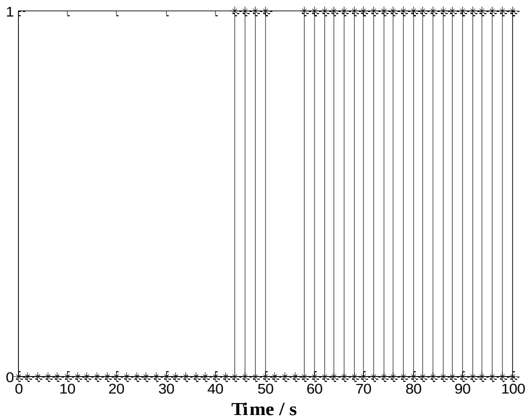

Fig. 7. After preprocessing into the fuzzy logic of sampling points

The Fig. 6 and Fig. 7 illustrate the difference between the handover management without preprocessing process and the handover management with preprocessing process on the amount of data that entered into fuzzy logic system. In the Fig. 6, the fuzzy logic system is making calculation of handover decision at each time point. Fig. 7 is the number of the monitored network parameters data through preprocessing process enter into the fuzzy logic system. As can be seen from the comparison of the two figures, the preprocessing process can significantly reduce the amount of data and the amount of calculation, in addition, improving the performance of system. With the preprocessing process also can reduce the number of handover.

The Fig. 8 compares the handover number of the handover algorithm based on RSS threshold and the FLMAHA algorithm. In 210 seconds, the handover process trigged by the algorithm based RSS threshold is more frequency, because of it only considered the condition of the current network channel, not overall consideration of the target network status. The proposed algorithm takes into account the overall performance of the network, and uses the SDN architecture which knows the whole network status information can make accurate decision, reducing the handover frequency. And also can avoid the "ping pong" effect.

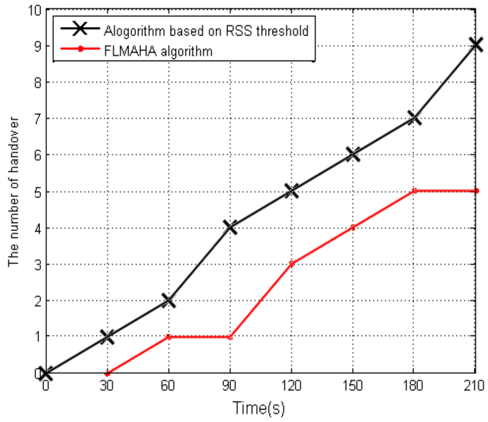

Fig. 8. The handover number of algorithm based on RSS threshold and FLMAHA comparison

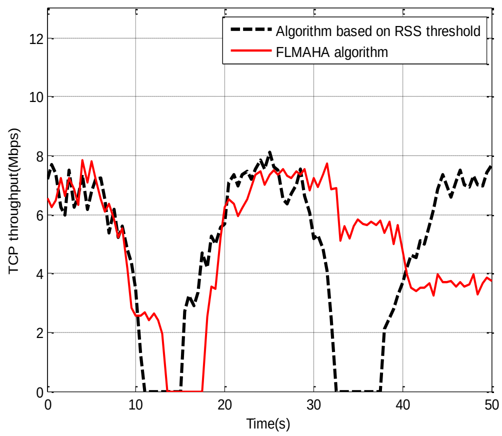

Fig. 9. Comparison of throughput

Fig. 9 shows the comparison of two algorithm throughput in the 50 seconds. We collected the throughput data each 0.5 second. The ME switches between APs brings degradation of end-to-end throughput. From Fig. 9, The algorithm based on RSS switches more frequency, the second handover is unnecessary. Although the RSS value decreased, the network can still meet the needs of application. It affects the performance of the network. The FLMAHA algorithm avoids the situation. Because the handover condition didn't meet, the FLMAHA algorithm didn't make handover decision at the 32nd seconds. Though the throughput is decreased, it is little effect on application, the network still can meet the needs of the application for QoS. So the FLMAHA algorithm can make accurate handover decision based on network performance parameters. In addition, it can reduce the unnecessary system overhead. The FLMAHA algorithm plays an important role in improving the performance of the handover.

We also evaluated the influence of the FLMAHA algorithm to balance the network load. Due to the FLMAHA handover algorithm employed the available bandwidth as one of the handover parameters, so the algorithm can balance the entire network load. The Fig. 10 is the surrounding seven network load comparison of two algorithms after handhelds go back and forth for ten minutes. The FLMAHA algorithm can select the nearest performance network to handover, so that it can make full use of the network resource. While the algorithm based on RSS threshold only according to the RSS to make decision, network load of some AP is heavy, and some is little load. This will lead to the degradation of the QoS.

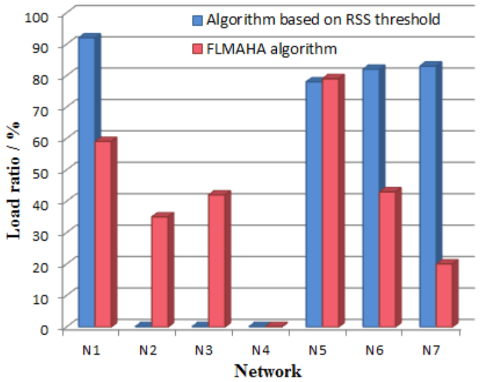

Fig. 10. Network load ratio after handover

V. Conclusions

This paper proposed a scheme of handover management in SDN-based WLAN, and proposed the FLMAHA algorithm which utilizes the fuzzy logic method to calculate the performance evaluation values of network to make handover decision. The algorithm improves the precision of handover decision. Meanwhile, layered processing reduces the unnecessary data volume and signaling overhead. Experimental results show that the proposed handover management scheme can avoid the "ping pong" effect, while ensuring the QoS when the ME perform the handover procedure, achieving the a better user experience.

The next phase of the mission is based on the existing work optimize handover algorithm, making the handover process more smooth and effective. For the current testbed environment is in the same kind of network technology, we need to consider increasing handover support for heterogeneous networks.

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