IEEE 802.11 Hot Spot Load Balance and QoS-Maintained Seamless Roaming

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[*]Abstract—**This paper presents and evaluates a mechanism for the load control with QoS supported in IEEE 802.11b Wireless LANs. Our mechanism named Enhanced Load Balance (ELB) dynamically adapts load distribution over APs to achieve load balance. The ELB mechanism balances the load by STAs' statistical traffic load. This mechanism also performs admission control to avoid congestion. The ELB mechanism maintains QoS by classifying STAs into three classes and control the traffic flow of every STA. The roaming STAs can get enough bandwidth to maintain the QoS in the new AP by the bandwidth reservation mechanism of ELB. ELB can be used on top of the standard 802.11b access mechanism without requiring any modification or additional hardware. The performance of the IEEE 802.11 protocol with or without the ELB mechanism is investigated in the paper via simulation and implementation. The results indicate that our mechanism can balance the load effectively and the bandwidth can be fully utilized. Therefore, QoS can also be maintained.**

Keywords—load balance; QoS; 802.11; admission control

I. INTRODUCTION

The IEEE organization has approved the 802.11 standard for Wireless Local Area Networks (WLAN) at 1997 [1]. WLAN is now proliferating due to the success of the IEEE 802.11b protocol. With the proliferation of lightweight hand-held devices with built-in high-speed radio access are making wireless access to the Internet the common case rather than an exception. In order to cater to users that typically access the Internet through laptop PCs, tablet PCs and personal digital assistants (PDAs), hot spots are now found in airports, railway stations, hotels, college dormitories, convention centers, coffee shops, apartment complexes and community centers. In these dense areas, due to the characteristics of CSMA/CA, once traffic load is increasing, congestion will be serious and will crash the throughput as known. The hot spot service provider usually solves this problem by adding more Access Points (APs) to increase the capacity of system. This incurs the problem about load balance. In the following sections, we will introduce the background of the IEEE 802.11b WLAN and explain our motivation.

A. Background

1) IEEE 802.11b WLAN architecture [2]

IEEE 802.11 defines two types of wireless networks. One is called as IBSS (Independent Basic Service Set) or ad hoc WLAN. Within an ad hoc WLAN, there is no fixed wired infrastructure to provide STAs to communicate each other. A collection of STAs with wireless network interface may form a network immediately without the aid of any established infrastructure or centralized administration.

The other type is the ESS (Extended Service Set) or infrastructure WLAN. An IEEE 802.11 WLAN is based on a cellular architecture where the system is subdivided into cells, where each cell (called Basic Service Set or BSS) is controlled by a Base Station (called Access Point, or in short AP). The BSS is the fundamental building block of the IEEE 802.11 architecture.

In order to increase the network overage, usually several BSSs are connected via a DS(distribution Systems) which could be 802.x LAN. Each BSS becomes a component of an Extended Service Set (ESS).

Stations within the same BSS can communicate with each other with the help of the AP. STAs can move between BSSs within the same ESS with the help of the Inter Access Points Protocol [3][4]. An ESS can also provide gateway access for wireless users into a wired network such as the Internet.

2) Distribution System Services (DSS)

There are five services provided by the DSS: Association, Reassociation, Disassociation, Distribution, and Integration.

The first three services deal with station mobility. If a station is moving within its own BSS or is not moving, the station's mobility is termed no-transition. If a station moves between

[*] This work was supported under NTPO project NSC 91-2219-E-004-004

BSSs within the same ESS, its mobility is termed BSS-transition. If the station moves between BSSs of different ESSs, it is ESS transition.

A station must affiliate itself with the BSS infrastructure if it wants to use the LAN. This is done by associating itself with an access point. Associations are dynamic in nature because stations move, turn on or turn off. A station can only be associated with one AP. This ensures that the DS always knows where the station is.

Association supports no-transition mobility but is not enough to support BSS-transition. Reassociation allows the station to switch its association from one AP to another. Both Association and Reassociation are initiated by the station. Disassociation takes place when the association between the station and the AP is terminated. This can be initiated by either party. A disassociated station cannot send or receive data.

It must be noted that ESS-transition is not supported by the standard. A station can move to a new ESS but will have to reinitiate connections.

Distribution and Integration are the remaining DSSs. Distribution is simply getting the data from the sender to the intended receiver. The message is sent to the local AP (input AP), then distributed through the DS to the AP (output AP) that the recipient is associated with. If the sender and receiver are in the same BSS, the input and output APs are the same. So the distribution service is logically invoked whether the data is going through the DS or not.

The Integration DSS takes place when the output AP is a portal. Thus IEEE 802.x LANs are integrated into the IEEE 802.11 DS.

B. Motivation

As we explained earlier, installing several APs in a dense area will cause load balance problem. Some researches have proposed the solutions for load balancing in the IEEE 802.11b infrastructure environment [5][6]. Most of them tried to balance the number of STAs attached to the different APs. However, balancing only the number of STAs attached to the different APs can not solve the problem [7]. This is because these control mechanisms don't consider the access behaviors of the STAs over different APs. One AP encounters the bandwidth overuse problem because its STAs access data frequently while other neighboring APs remain idle because their STAs don't access data. In this case, the transmission bandwidth over all APs can't be fully utilized and thus load is not balanced among these APs.

There are also two Quality of Service issues in the IEEE 802.11b WLAN [8][9][10][11]. (1) In the traditional IEEE 802.11b WLAN which does not support QoS, the APs always permit the association of users. In the heavy load area, as the number of STAs increase, the channel will be overcrowded with STAs and the QoS will be deteriorated. As most of users are transmitting data, each user can share only a portion of bandwidth and suffers multi-access problem. Therefore, QoS is hard to be satisfied. In order to control the use of bandwidth effectively and provide differential service, we need a mechanism to differentiate between users according to their bandwidth requirement. (2) Because of the mobility of the STAs, they sometimes go beyond the scope of the coverage area of the associated AP and roam to other APs. The QoS both before and after roaming should be maintained.

In this paper, we propose a balance control mechanism with QoS supported to solve the above problems. We will consider the dynamic access behaviors of all STAs and the load of all APs, and let APs control the balance procedure and the admissions. With this new control mechanism, the total throughput of all APs can be better utilized. To achieve the transparency of STAs, all control mechanisms will be implemented on AP.

C. Related work

1) Traditional Approach

In the traditional approach proposed by IEEE 802.11 [1], the procedure for the association of a STA to an AP is as follows:

The STA sends Probe Request to all channels, and listens for the Probe Response or Beacon Frames from APs. The STA store the Received Signal Strength Indicator (RSSI) of Probe Response or Beacon and other information, as ESSID, WEP, etc. After finishing scanning procedure, the STA selects the AP with maximum RSSI from the available lists that list all the APs have the same ESSID and WEP as the STA. When the RSSI between the STA and AP is getting lower than a threshold, the STA will restart this procedure and reselect the AP.

This procedure can let STAs associate with the AP with best channel state. However, this procedure does not consider the load distribution over APs. Some AP may be overloaded while others having light load. The overloaded AP will lead to performance degradation.

2) Dynamic Load Balance Algorithm (DLBA)

In [5], the authors presented a load balance approach based on the modification of the Beacon and the Probe Response Frames. In this approach, the STAs get information of the number of station associated, RSSI value, and mean RSSI value for the STAs already associated from AP. From these information, STAs can calculate and determine which AP to association in order to make the number of STAs for all APs balance and the mean RSSI value be maximum.

In [6], the authors propose another dynamic load balance algorithm. This algorithm acts in three different levels: 1) The AP Channel Autoselection Level aims at the best distribution of the AP to the available channels. 2) The Station Join Decision Level determines the manner that the STA selects the AP to associate with it. 3) The Link Observation Level determines when the STA leaves the AP and the roaming function are performed. This approach shows a balanced distribution of the number of STAs to the APs and an improvement in the overall network performance.

In [5] and [6], the authors tried to achieve the load balancing by distributing all STAs to all APs in different approaches. However, these approaches balance only the associated client of all APs. They don't consider the access behaviors of STAs and the traffic load of all APs. In [7], the authors found that even though the number of users associated to each AP during the day is roughly the same, the offered load in terms of bandwidth at the APs varies considerably. This indicates that offered load is more sensitive to individual user bandwidth requirements rather than just the number of users.

In this paper, we propose a QoS supported approach focused on the load of the AP instead of the number of users of the AP to achieve load balancing.

D. Organization

The rest of this paper is organized as follows. In Section II, we describe the architecture and operations of an enhanced load balance approach. In Section III, we describe the simulation environment and evaluate the performance. In Section IV, we implement our approach on a Linux based notebook and discuss the implementation issues. In Section V, we conclude our work and then discuss the issues to be addressed in the future.

II. ENHANCED LOAD BALANCE

A. Overview

The QoS supported Load Balance mechanism that we propose here will control the action of STAs from their entering the network to leaving the network.

As STAs enter the network, they must first establish their identities in order to gain access to the network. Before a station is acknowledged and allowed to participate in the traffic, it must first pass a series of tests to ensure its identity. That is the meaning of authentication. Once a station has been authenticated, it may then associate itself. It tries to association to the AP which has the maximum RSSI in the network. In this stage, this AP determines whether the client can enter the network or not by exchange the load situation with other APs. If the network is overloaded, the STAs will be rejected in this stage.

After successful association, the STAs can access network through the BSS now. In order to control the traffic load of each user and provide QoS, we classify the STAs into three classes. Each class has a bandwidth limit, and all the STAs can only transmit data under the limited speed.

In order to evaluate the influences of our approach on the users, we define a metric "SA" to indicate the satisfaction of user. We assume that users can always transmit their data at the limit of their class. If the users can transmit data at this expected speed, we say that the satisfaction (SA) of this user is 100%. As the BSS is overloaded, or there is traffic congestion at the BSS, users can't transmit their data at the expected speed. Then the SA can be calculated as the following formula.

$$SA = \frac{\text{User BW used}}{\text{Allowed BW Limit of User's class}} \cdot 100\%$$

The APs monitor the traffic load in period. If the traffic load is over a threshold, or the SA is lower than a threshold, the AP initiates "load balance" with other APs. By this method, we can maintain the satisfaction of user and balance the load between the APs.

Because of the mobility of the STAs, they sometimes go beyond the scope of the coverage area of associated AP and roam to other APs. To maintain the SA during the roaming and prevent the user's communication from breaking off, we will reserve some bandwidth for the roaming user.

B. Architecture

Considering the compatibility with co-existed systems and STAs, we only add new features into the traditional AP functions without making any modification to the STAs. So, we can easily add the new features to any existing IEEE 802.11b WLAN without changing the users' equipment.

There are four major components and one minor component in our AP. The major components are BW Management, Admission Controller, Inter-AP Management, and the Load Balance Controller. The minor component is User Space Control and Monitor Program. As shown in the Figure 1, each component is in charge of one of the features in our system. The BW Management observes the usage of the bandwidth, and calculates the load and the SA. Then, it reports the result to the Admission Controller and the Load Balance Controller. The Admission Controller controls the admission of the STAs by the information reported by the BW Management. As the BSS is overloaded, it will reject the STAs to enter the network to maintain the QoS. The Load Balance Controller gets the load and SA situations from the BW Management and decides balanced or not by this information and our rules. The Load Balance Controller also checks the load of other APs reported by the Inter-AP Management. The Inter-AP Management communicates with other APs' Inter-AP Management components to collect the whole ESS's load situations, and then reports to the Load Balance Controller. Through this component, every AP can know the situation of other APs, and they can adjust the load distribution. The last component, the User Space Control and Monitor Program, is used to control the mechanism and monitor the status of the AP.

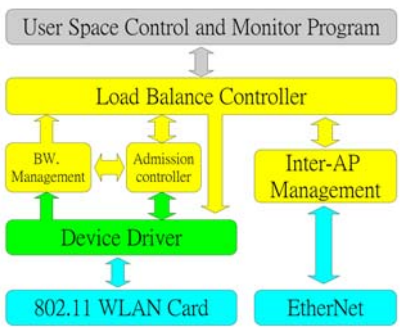

Figure 1: Software Architecture.

1) Classification

To obtain differentiated services, we classify the users into three different service levels. Every user in each class has their own bandwidth limit, and they can only transmit data at this rate at maximum.

In the experiment of [3], the authors found that the light, medium, heaving user's data rate was less than 60Kbps, 60~175Kbps, and over 175Kbps. Respectively, referring to this result, we separate the STAs into three classes, namely GOLD, SILVER, and COPPER.

The GOLD class has highest bandwidth provisioning. Each STA of GOLD class can transmit/receive through AP at 512Kbps at most. The second and third class, SILVER and COPPER class, has 128Kbps and 64Kbps, respectively.

In the traditional 802.11 network, when there exist both GOLD STAs and COPPER STAs transmitting data, the GOLD STAs' data rate will be reduced first. The SA of the GOLD STAs will be much lower than the COPPER STAs'. In our approach, we apply the Weighted Round Robin (WRR) to ensure the STAs not to overuse their bandwidth and improve the fairness. As the total bandwidth is more than the capability, the system will not only reduce the bandwidth of STAs that have higher class, all STAs bandwidth will be reduced in the same ratio and the SA can be maintained fairly.

2) Inter Access Point Communication

In the design of our approach, every AP has to exchange the AP information with each other. Each AP maintains an AP_Info table. This table contains the information about other AP's SSID, IP, MAC address, Channel, backbone bandwidth, number of attached STAs, and a list of STAs' Table. The following data structure defines an AP_Info table's entry which records an AP's information.

The Data Structure for an AP_Info Table's Entry: (AP_ID, AP_IP, MAC_Addr, Channel)

The STA_Info of an AP contains the information of STAs attached to this AP. It contains the information about the STA's IP, MAC address, class, active time, transmitted data, and history load.

The Data Structure for an STA_Info Table's Entry: (STA_IP, MAC_Addr, Active_Time, Transmit_Data)

The "Active_Time" field records the time that a STA transmit data during the balance trigger period. The "Transmit_Data" field records the size of data that transmitted during the balance trigger period. We can calculate the SA easily by the above two fields use following formula.

$$SA = \frac{DATA\_Size/ACT\_TIME}{MAX\_Rate} \cdot 100\%$$

ACT_TIME: The duration that the STA transmit data during the balance trigger period.
DATA_Size: The data size that the STA transmit during the balance trigger period.
MAX_Rate: The max data rate of the STA defined by the STA's class.

The "History_Load" field records the ratio of total Active_time to the duration that the STA attached the ESS.

Periodically, each AP sends AP_Info and the STA_Info messages to other APs. The messages are sent as the broadcast packets. When an AP receive the message, it updates its AP_Info tables and STA_Info tables immediately.

C. Admission Control

Too many STAs associated to one AP will degrade the performance, and will influence the satisfaction of the STAs. We propose an admission control scheme as follows to prevent this situation.

As a client wants to access the network through the APs, it first tries to associate with one AP with highest RSSI value. When the AP with highest RSSI received the association request, it checks the load of the AP. There will be two cases.

First case, the load of the AP is under threshold. This AP will accept the association request, and set the bandwidth limit according to this user's class. Second case, the load of the AP is over the threshold. It will reject the association request.

D. Load Balance

As the AP accepts the user's association, the user will start to access the network through the AP. The AP monitors the load in period. As the load increases to the trigger threshold, the load balance method starts. In this section we describe the mechanism of our history-based load balance method.

1) Trigger Condition

In normal situation, the STAs can usually transmit their data at expected speed. The APs need not balance their load. If we balance the load in a fixed period, that would be an overhead to the network. We should set a trigger condition, and check whether the load violate the condition.

We also keep the satisfaction (SA) of user in an acceptable range. Therefore, we use two indexes to determine whether the balance should be triggered or not. First index is the traffic load, and another is SA. When the total traffic load is over the threshold or SA is under acceptable, we should try to start load balance.

2) Load Balance Method

As the load balance starts, the relevant APs first collect and exchange the STAs' information in their overlapped area. The information includes the STAs' average load in this period, the STAs' class, and the STAs' history. Then the AP initiates the balance procedure according to the information. The balance steps are as follows. 1) Sort the STAs by their history. 2) After sorted, calculate the difference of the load between APs. 3) Moving or changing STAs with other APs from light load to heavy load.

By these steps, we change the light load STAs first. This will let the heavy users become stable, and the traffic load will become stable, too.

E. User Mobility

One of the design requirements for our mobility management scheme was its integration with QoS support. As a STA roam from one BSS to another, we don't know if the destination BSS have enough bandwidth for this handoff user or not. Somehow, we should make sure the new BSS has enough bandwidth to achieve seamless QoS support.

The idea is we should reserve appropriate bandwidth for possible roaming-in STAs from neighboring APs. In order to estimate the bandwidth, we propose the mechanism of our user mobility management mechanism with QoS supported below.

We define the handoff rate σ as follows:

$$\sigma = \text{the handoff rate of client every minute.}$$

For example σ = 0.1, means that on the average, each user have 10% probability roaming out its AP every minute. According to this mobility model and the number of users of other APs, we can reserve some bandwidth for roaming users. By collecting the statistical bandwidth usage, we can calculate the mean bandwidth needs for possible roaming-in STAs. That is, we reserve:

$$\text{Bandwidth} = \text{number of user} \cdot \sigma \cdot \text{mean bandwidth needs}$$

III. SIMULATION RESULTS

We now investigate the performance of our algorithms proposed in Section 2. In our simulation, we create seven simulations.

A. Environment

We assume that there are only two APs in the scenario even though our approach can work well at the environment with more than two APs. Each AP has independent backbone bandwidth at 1.544Mbps. Their coverage areas are exactly the same but work in different channel. In order to avoid the interference problem, we assume the channel of AP1 is 1 and the channel of AP2 is 11. In the coverage area, there are several STAs accessing the network through the two BSSs. These STAs are distributed into three classes and in the ratio 1:3:2. We also assume that the ratio of STAs class distributions is always 1:3:2 even though the new STAs are entering and old STAs are leaving the network as the time goes by. The traffic type in the simulation scenario is exponential on/off with 0.7 as mean on/off period ratio. As the STAs transmit data, they always transmit at constant bit rate as their class limited at the on period and silent at the off period.

B. Simulation Examples

1) Admission Control

In this simulation, we randomly generate the network association request and apply into our admission control mechanism. With different mean traffic load in the BSS, we use eight kind of different admission control condition and observe the SA. As the traffic load is over the threshold, the new users will be rejected.

In Fig.2, each line stands for the relationship between the SA and the admission condition as the AP was under the mean traffic load. As we wish to maintain the SA more than 90%, we should set the admission control condition at 80% load when the BSSs' mean traffic load is 90%. And, as the BSSs' mean traffic load is 70%, we should set the condition to 90%.

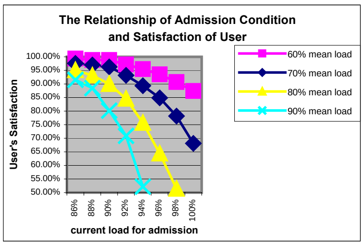

Figure 2: Admission Condition vs SA

2) *Load Balance*

In this simulation we evaluate the influence of trigger threshold to the satisfaction (SA) of user. We use the simulation environment as we describe before and the result is shown in the Figure 3. Figure 3 shows the relationship between the load balance trigger threshold and the satisfaction of user. As we want to maintain the satisfaction more than 90%, according to the result, we should set the trigger threshold at 90%.

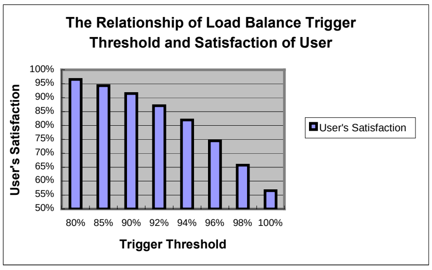

Figure 3: Trigger Threshold vs SA.

To demonstrate the effect of load balance, we compare four kind of load balance schemes with the no load balance scheme and measure (i) the percentage of load balance occurrence, (ii) SA, and (iii) the total number of STAs that have been force to move to other AP. The real-time-traffic-based, and the number-of-STAs-based load balance methods monitor the real time traffic load, and balance the load according to real-time traffic and the number of associated user of the APs, respectively. The hybrid method mixes the two methods above. The history-based load balance method balances the load by the history load situation of STAs as we described before.

By the simulation result before, as we want to maintain the satisfaction to 90%, we set the trigger threshold to 90%. In Figure 4, we can see that we can't only balance according to the number of STAs without considering the user behavior. Comparing the real-time-traffic-based method with the hybrid method, we can see that the SA and the balance ratio are almost the same, but the hybrid method moved more STAs than the real-time-traffic-based method. In comparison with our history-based method, the real-time-based method is is too sensitive and may influence by the peak traffic easily.

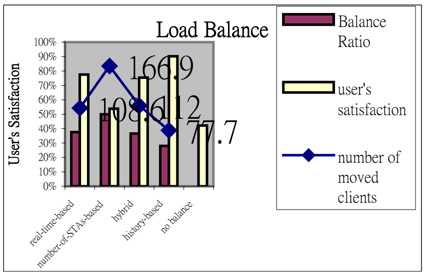

Figure 4: Load Balance.

3) *User Mobility*

In the previous simulation, we didn't consider about the user's mobility. In this simulation, we will focus on the QoS maintain of the mobile user. In the scenario, there are forty STAs and two APs with the same coverage area. All STAs moves randomly and there are σ percentage of users will move near one AP to another AP. We simulate two bandwidth reservation methods with three kind of σ. In the simulation, we calculate the satisfaction of the handoff STAs and the satisfaction of the original STAs. Then we sum up the two satisfaction values with their weight and shown as Figure 5. The result shows that the satisfaction of the method that reserve the mead load of the STAs grows as the user mobility grows, and the satisfaction of the method that reserve the total load of the STAs is getting lower as the user mobility grows. By this result, we can know that we needn't reserve all bandwidth for the mobility user. As we reserve all bandwidth for them, the bandwidth for the original user seems not enough so that the satisfaction of original users is getting lower more than the increase of the satisfaction of handoff user.

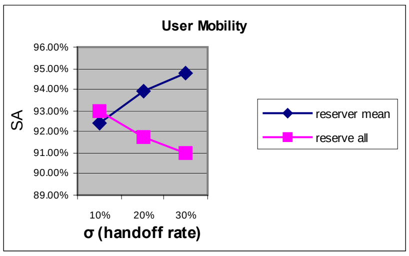

Figure 5: User Mobility.

4) *Admission Control with Load Balance*

In this simulation, we demonstrate the load balance with admission control in two parts. In the first part, as our previous results, we can maintain the satisfaction of user more than 90%, by setting the admission control threshold to 90% and set the load balance threshold to 90%, too. We randomly add new STAs into the BSS as time goes by and evaluate the influence of Admission Control. The other environment settings are the same as we described in the load balance section.

Because of the combination of Load Balance and Admission Control, we separate the overloading case of admission control into two conditions. First, the neighboring APs are overloading, we still reject the association request. The second, the load of the neighboring APs is light. Thus, we can initiate load balance to solve the overloading problem. So we can accept the association request.

The result is shown in Figure 6. Comparing with the result shown in Figure 4, we notice that after adding the admission control method, we get a notable improvement at every method especially for the number-of-STAs-based method. And, as we expected, the satisfaction of user by the history-based method is more than 90%.

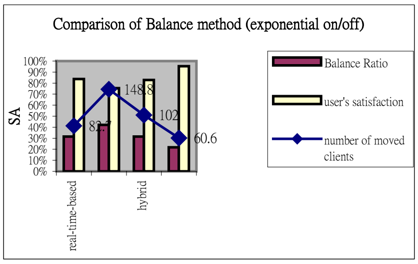

Figure 6: SA vs Balance methods(1)

In the second part of the simulation, we generate another traffic type called uniform on/off to compare with the previous traffic type called exponential on/off. The uniform on/off traffic's probability is 0.7 as mean on/off period ratio, the same as the exponential on/off. The Figure 7 shows that the result is similar to the exponential on/off case. That means even in different traffic type, the history-based load balance scheme also works well.

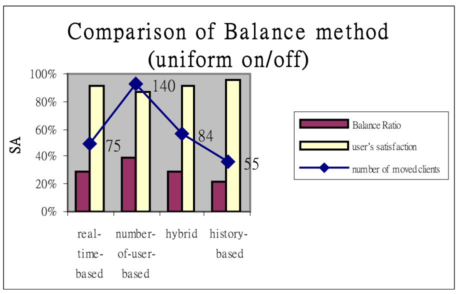

Figure 7: SA vs Balance methods(2)

5) User Mobility with Admission Control

In this simulation, we randomly add new STAs into the BSS as time goes by and evaluate the influence of Admission Control. The result is shown in Figure 8. According to the figure, we can see that as we add admission control to the user mobility scheme, because we reject the user's association request as load was getting heavy, we have an improvement of the satisfaction of user. And we also can see that the greater user mobility is the better improvement the admission control performs. That is because as the user mobility is getting higher, the condition of admission will achieve more easily.

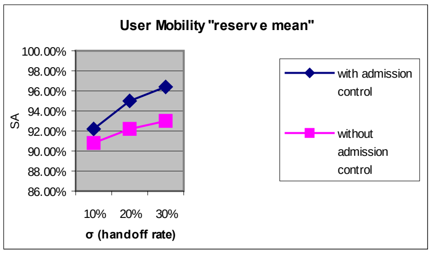

Figure 8: User Mobility with Admission Control.

6) Load Balance with User Mobility

Here we add the User Mobility property into our history-based load balance simulation. The user mobility vector σ is set to 20% and assumes that there are no new arrivals to the network. We notice that the satisfaction of user degrades a little bit in the mobility case. That's because after applying the mobility support, the total bandwidth for non-mobile users is reduced.

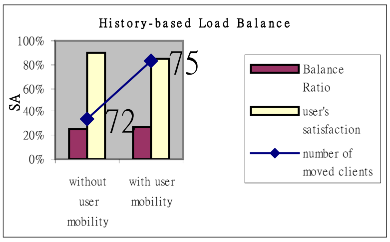

Figure 9: SA vs Mobility (History-based)

7) The full scenario simulation

In this simulation, we combine the simulations done before, and compare their delay time with these simulations. The total simulation time is ninety-five seconds. In this duration, we randomly add heavy load STAs into simulation environment every five minutes. There are two APs in the simulation environment.

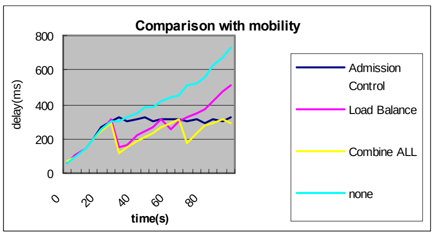

Figure 10: Comparison with mobility.

C. Discussion

In the above simulations, we can see that our mechanisms can achieve load balance with QoS support based on the history based scheme and admission and bandwidth control scheme. Comparing with other dynamic load balance schemes, our mechanism is more stable and effective. By adjusting thresholds of admission control and load balance trigger, we can maintain the satisfaction of user to what we expected.

IV. IMPLEMENTATION

We have also implemented the ELB mechanisms on Linux notebooks that use a Intersil Prism II based 11 Mb/s 802.11b wireless interface with the Host AP project [12] as the AP and an Ethernet interface connected to the backbone. We use the MAC filter to implement the admission control mechanism and CBQ (Class Based Queueing) to implement the classification.

Thus, we can control the number of users in the system and the usage of the bandwidth. Besides, there are three more modules we implemented in the platform. Those are bandwidth monitoring module, load balance module, and inter-access points communication module.

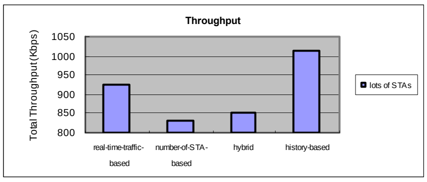

Figure 11: Experiment 2 of Implementation

In the bandwidth monitoring module, we monitor the state of the AP itself and the STAs associated to it. We collect the STAs situation every second and count the size of data they sent and received. We also record the AP's information with above data and store in the AP_info and STA_info field described previously. In the load balance module, we check the load situation every five seconds. As the load is over the threshold we proposed before, and then this module will start to balance the load. When a STA is forced reassociated to be moved to other APs, this module disconnects the STA voluntarily. In the inter-access points communication module, every five seconds, we broadcast the information generated from bandwidth monitoring module to the Ethernet interface. This module also listens to the broadcast packets that contains the information of other APs from port 2313 and store those for the usage of admission control. The result in Figure 16 is similar to previous cases.

V. CONCLUSION

In this paper, we have described and evaluated a new approach for providing load balance solution while maintaining QoS. These algorithms accommodate more users and improve network utilization by making more efficient use of deployed resources. We describe an admission control protocol that enables the capacity control of an AP. Finally, we describe a unified QoS management architecture that provides differentiated service and maintains the QoS of mobile users.

We evaluate the benefit of the load balance algorithm, admission control, and QoS support for user mobility using simulations. The simulation results show that our algorithms perform well in a variety of user configurations. We use a parameter called satisfaction of user to evaluate our algorithms. Our algorithms can maintain the satisfaction of users over 90%, while existing schemes can offer little or no load balancing. We implement our algorithms on the existed 802.11b wireless LAN. Based upon our results, we conclude that such networks would benefit greatly from the use of these algorithms.

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