Integration of SNR, Load and Time in Handoff Initiation for Wireless LAN

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Abstract—The performance of handoff initiation algorithm is one of the key issues for providing roaming capability in wireless LAN (WLAN). In this paper, we propose a new handoff initiation algorithm for data transmitting in WLAN. Our proposal combines association time, system load and signal/noise ratio (SNR) together to decide whether mobile node should handoff or not. The goal is to reduce the number of unnecessary handoff, decrease packet loss and balance the system load. In this way, we can provide Quality of Service (QoS) guarantee. Simulation results show that the proposed handoff initiation algorithm is efficient in WLAN.

I. INTRODUCTION

With the development of high performance portable computers, there are more and more mobile users and wireless data communications. So WLAN is widely deployed in many situations, such as offices, waiting room, meeting room, etc.

But at the beginning, WLAN is designed as nomadic access technology. That is to say, the devices accessing to WLAN are stationary or mobile very slowly when they are working. So people pay little attention to the mobile issues about WLAN, such as handoff. But even we are not mobile, handoff will happen frequently because of the wireless environment variety.

Handoff in WLAN is often occurred in the following conditions: one is channel fading caused by multipath and shadow fading; the other is heavy load of the access point (AP). Channel fading causes degradation of SNR and affects QoS. When the channel cannot provide necessary QoS guarantee, handoff will occur to find another AP. Sometimes if the AP has too many users, there will have too many conflicts because they are sharing the channel. Then the delay will increase and QoS will degrade. In this case, users will also have to handoff.

Research on handoff has mainly focused on real-time services in cellular networks. There are lots of handoff algorithms about how to improve QoS when the users are moving from one cell to another. In another word, we hope users are imperceptible when handoff happens. This is seamless handoff. It requires not only small delay but also few packets loss.

In general, handoff includes two steps, handoff initiation and execution. In initiation phase, the received signal strength is measured according to radio propagation based methods and if necessary, a new candidate station will be chosen. In execution phase, according to traffic control policies, a new radio channel will be assigned.

Many proposals are used to reduce latency, minimize disruption and eliminate packets loss during handoff. Ref. [1] proposed a new handoff method using multicasting to reduce the handoff latency when mobile nodes moving among small wireless cells at high speed in a global cellular system. In [2], a new conception called handoff agents is used to ensure that every packet sent to the mobile user in order. Ref. [3] focuses on dynamic resource reservation to reserved resources needed by handoff calls, thus reducing the probability of block causing by increasing of new calls.

There are also many literatures about handoff initiation algorithm. Handoff initiation phase is defined as monitoring the radio channel, decision for beginning handoff process and selection of new station. So handoff initiation algorithm is very important. It can decrease the number of unnecessary handoff, avoid ping-pong phenomenon and distinguish necessary handoff on time.

Most of the algorithms are mainly based on SNR. And these algorithms can be divided into three categories. The first is based on received SNR from the base station only. This method decides handoff when the SNR from current station is smaller than another station. This kind of method is simple but will take place repeated or unnecessary handoff. The second is based on relative SNR with threshold. In this approach, handoff is initiated when the average SNR falls below a certain threshold value. This method can avoid unnecessary handoff when the current station signal is still satisfactory. The third is relative SNR with hysteresis. In this approach handoff is initiated only if the new station’s SNR is sufficiently stronger by a hysteresis margin than the serving station. This method can prevent from ping-pong effect, which is the scenario of repeated handoff between two stations cause by rapid fluctuations in the received SNR from both the stations. But it cannot distinguish necessary handoff on time and will cause the delay additionally [4].

Although there are so many literatures about handoff, they almost aim at voice service in cellular networks. Up to now, there are few particular algorithms about handoff for data service in WLAN. Due to many differences between telephone networks and WLAN, the algorithms presented in wireless telephone are not applicable to WLAN. In [5], a new handoff algorithm proposed for data service. It develops a new handoff initiation criterion for heavy traffic load. When current traffic load exceeds a specific level, both signal strength and traffic...
load are used to make a decision on handoff initiation. But the proposed algorithm cannot improve the performance of handoff. It is mainly used to balance traffic load of access points (AP).

In this paper, we introduce a new handoff initiation algorithm. We combine association time, system load and SNR together to decide whether mobile node should handoff or not. The goal is to achieve minimum number of handoff, reduce number of unnecessary handoff and balance the system load. In section II, we describe the system model of WLAN briefly and introduce the process of handoff. Then we describe our proposed algorithm to reduce the number of handoff and decrease the packets loss in WLAN in section III. Section IV presents the simulation results. Finally we conclude the paper in section V.

II. System Model

In this paper, we focus on the IEEE 802.11 WLAN [6]. Since a WLAN relies on a share transmission medium, the transmissions of the stations must be coordinated by the Medium Access Control (MAC) protocol. This coordination is achieved by means of control information, such as ACK messages and CTS/RTS, or can be provided by the channel itself, which is active or idle, by means of carrier sensing.

The 802.11 MAC layer protocol provides asynchronous, time bounded, and contention free access control on a variety of physical layer. The basic access method in the 802.11 MAC protocol is the Distributed Coordination Function (DCF) which is a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) MAC protocol. In additional to the DCF, the 802.11 also incorporates an alternative access method known as the Point Coordination Function (PCF).

In IEEE's proposed standard for wireless LAN (IEEE 802.11), there are two different ways to set up a network using different access protocol respectively: ad-hoc and infrastructure. In the ad-hoc network, computers are brought together to form a network by means of DCF. There is no structure to the network; there are no fixed points; and usually every node is able to communicate with every other node. Another type of network structure used in wireless LAN is the infrastructure. This architecture works under PCF protocol and uses fixed network access points (AP) with which mobile nodes can communicate. These network access points are sometime connected to landlines to widen the LAN's capability by bridging wireless nodes to other wired node. If service areas overlap, handoffs can occur. This structure is very similar to the present day cellular networks around the world. Our algorithm is proposed for this condition.

When using DCF access method, a station will senses the channel to determine whether the channel is idle when it has packets to send. If the channel is idle, the station begin to transmit data. If not, the transmission will be deferred until the channel is idle. Control messages or data packets will retransmit due to collision. But if the times of retransmission exceed the maximum, the packets will be discarded. So if there are too many stations communicating through an AP, there will be too many contentions. And the packets loss and delay will increase greatly. If the channel fading changed greatly, the handoff will occur. The station, which initiate handoff process, must reassociate with a new candidate AP. During this process, the communication have to be interrupted and the packets will be discarded. As we all know, the data transition is delay insensitive, but loss sensitive. So we want to decrease the packet loss. The most fundamental method is decrease the number of unnecessary handoff. So our idea is to design a proper handoff initiation algorithm to reduce the number of handoff. This perhaps causes the delay of the algorithm, but we think it is worthy.

The traditional handoff initiation algorithm is depend on SNR only, as shown in Fig. 1. When a station needs connection to a network, it first execute a full sweep, and select AP with best communications quality, then send ”Association Request” and AP enters the station in its association table. After these process, the station can communicate with other nodes

Fig. 1. Traditional handoff initiation algorithm.

Fig. 2. Standard handoff process in WLAN.
through AP. During the transmission, the station monitors the communications quality (CQ) of the link to "its" Access-Point. When station moves away from Access-Point or the channel fading changes dramatically, the CQ drops greatly. When CQ drops below a setted threshold value, the station enters Cell-Search state. In this state, the station will inform current AP to buffer traffic and block its own transmissions during sweep. Then it scans multiple channels using a "channel-list" that contains the channels to scan and sends probe requests. At last, the station uses SNR of probe responses compared to SNR of current AP. When CQ drops below "Cell Search Threshold", new Access-Point should already been identified and the station start the handoff process. The station retrieves buffered frames from current AP. Then it re-associates with new AP. usually, the network uses Inter Access Point Protocol (IAPP) to connect between the APs. The new AP informs old AP to change the association table and updates filter tables in intermediate bridges. IAPP uses UDP/IP, so can work over routers, but if the station roams over routers, it requires Mobile IP. This process has been shown in Fig. 2.

III. ALGORITHM DESCRIPTION

Our proposal combines association time, system load and SNR together to decide whether mobile node should handoff or not. Association Time is time period during which mobile mode keep communicating with an AP and without handoff. System Load is occupation percentage of AP’s channel. It can be calculated by measuring the ratio of the busy times and total times of the AP’s channel during a proper period.

In general, channel fading caused by multipath is frequency-selective fading and it is not changing with time. But shadow fading is time-selective and perhaps can recover after a little time. So if mobile nodes have fine channel gain for a long time, then we can think the abrupt fading is temporary and perhaps recover some seconds later. For data transportation, delay is insensitive, but packet loss is sensitive. So we must reduce the number of handoff as possible as we can. Waiting appropriate period can avoid unnecessary handoff efficiently.

Balancing traffic load can provide QoS guarantee. If there are too many users sharing an AP’s channel, then channel cannot transmit data normally. When the network provide QoS guarantee, the handoff call may be blocked because of too heavy load of the AP. So it is proper to take traffic load into account when handoff initiate.

The way we combining the association time and system load is using them as the weight of received SNR. We design the weighting functions, then multiply the SNR. Our handoff strategy is designed as following:

At first, we track the change of the SNR of current channel. When the SNR is above threshold H, handoff will not occur. If the SNR is below threshold h, we will begin handoff execute immediately. In other case, when the SNR is between the two thresholds, we will use our handoff initiation algorithm to make a decision. We define a new function named ISLT(t) (Integrated SNR and Load and Time), and calculate function values of both the current AP and the candidate AP. When the discrepancy of the two values is bigger than a certain value I, the handoff execution will start and the mobile node will handoff to the candidate AP.

Now, it is the description of our handoff initiation algorithm:

The function which decides whether handoff or not is named ISLT(t) (Integrated SNR, Load and Time):

\[
ISLT(t) = SNR(t) \times f_L(l) \times f_T(t)
\]

where \( f_L(t) \) is the function of system load and \( f_T(t) \) is the function of association time:

\[
f_L(l) = \exp(k_2 l^{k_1}) + k_3
\]

\[
f_T(t) = \exp(k_5 t^{k_4})
\]

\( SNR(t) \) represents signal noise ratio value, which can be calculated by mobile node.

\( T \) is the association time between AP and mobile node. \( f_T(t) \) is the association time weighting function which is used to improve handoff decision strategy. \( k_1 \), \( k_2 \) and \( k_3 \) are function parameters which is tunable and can be optimized during simulation. In our consider, the association time is longer, the weight is bigger. When \( t \) trends to zero, the function trends to one. This is mean the mean the parameter \( t \) having nothing on our algorithm. When we calculate the \( ISLT(t) \) of the candidate AP, the association time is zero and the \( f_T(t) \) equals to one. But when the association time trends to infinite, the function trends to a certain value. We hope the affect to the algorithm becomes more and more smaller with the time goes by. By adjusting function parameters, the function curve can be revised more suitable for expectation. During the implementation, we will set a timer to record the association time. After the mobile node have received association response message from the AP, we will start to count the association time.

\( l \) is system load calculated by AP and transmitted to mobile node. \( f_L(l) \) is system load weighting function, which we are using to improve handoff decision strategy. \( k_4 \) and \( k_5 \) are function parameters which are also tunable during simulation. Comparing the two AP’s system load, the mobile node will prefer handoff to the light one. That is to say, the value of \( f_L(l) \) will decrease with the increase of \( l \). When the system load trends to full usage, the function trends to one. This means it has no affect to the algorithm.

In one word, our idea is taking into account two more parameters: association time and system load, as well as SNR for decision on handoff initiation process. The purpose considering association time parameter is to avoid repeat or unnecessary handoff. And the system load is used to decrease the handoff dropping probability and provide QoS guarantee.

IV. NUMERICAL RESULTS

With the advent of wireless devices, there is great deal of interest in characterizing radio propagation indoor. The indoor radio channel differs from the traditional mobile radio channel in two aspects: the distances covered are much smaller, and the variability of the environment is much great.
indoor radio propagation is dominated by the same mechanisms as outdoor: reflection, diffraction and scattering. However, conditions are much more variable. For example, signal levels vary greatly depending on whether the doors are open or not inside a building. The field of indoor radio propagation is relatively new, but it is more suitable to the WLAN environment. So we select a Log-distance Path Loss Model to simulate our algorithm.

Indoor path loss has been shown by many researchers to obey the distance power law in equation:

\[ PL(dB) = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right) + X_\sigma \]

where the value of \( n \) depends on the surroundings and building type, and \( X_\sigma \) represents a normal random variable in dB having a standard deviation of \( \sigma \) dB.

Using this indoor path loss model, we simulate two kinds of handoff initiation algorithms: one is the traditional algorithm, the other is our proposal. We compare some performance of the two systems, such as the number of handoff, the throughput etc.

In our simulation topology, there are two APs and some mobile nodes. The AP has its own coverage, which is about 300 meters according to the standard. And the mobile nodes move continuously during the simulation. With the mobile nodes moves, the channel fading changes, too. When the SNR decreases greatly, the mobile node has to handoff to another AP. Generally, we set a value of SNR, below which we think the QoS is unbearable. But it is difficult to set this value. If the value is too high, the handoff will occur frequency even the QoS is good enough. That is to say, there will be many unnecessary handoff. On the other hand, if the value is too low, the number of handoff can reduce, but mobile nodes cannot determine handoff on time. This will cause degradation of the QoS.

So the traditional handoff algorithm using two thresholds: one is to start the handoff initiation algorithm; the other is to decide handoff execution. When the SNR is lower than the first value, the mobile node begins to scan the channel and calculate the candidate channel’s SNR. When the SNR of new AP is big enough, the handoff will happen. This method can avoid unnecessary handoff when the SNR can satisfy the QoS. But sometimes there are burst channel fading and can recover after a while, in this condition, if we can wait some seconds, the channel gain can recover and the unnecessary handoff can avoid. So we design the new handoff initiation algorithm integrating of SNR, Load and Time for Wireless LAN.

The change of the SNR is caused mainly by the movement of the mobile nodes, as shown in fig. 3. The mobile nodes move randomly and the channel fading will decrease and increase with the distance changes between the mobile nodes and the AP. Form the figure, we can see that the SNR of the two APs change up and down. If we use the traditional algorithm, the will be some unnecessary handoff. But if use our algorithm, the number of handoff will reduce greatly.

The result has been shown in fig. 4. We can see that our algorithm is efficient. It can reduce the number of handoff when the channel fading changes greatly in a short time. This can be used to combat the deep fading. And we all know, in WLAN environment, the deep fading happens frequently because of the variety of the surroundings. This can be cause by the movement of the people, the change of the furnishings etc. Especially in the large auditoria, the number of people changes greatly and the movement is frequent. So the channel fading may change with these varieties. On the other hand, in this condition, we often use several AP to satisfy the need of the capacity. Too many users will cause large delay and packet loss. So the load balance is an issue we focus on.

In terms of the shown Fig. 5, we can see that the packet loss is reduced greatly using our algorithm, nearly fifty percent. Because our handoff algorithm take the load balance into
consider, it can decrease the number of conflicts in the share wireless channel, especial in heavy traffic. When the conflicts happen, the packets will be retransmitted and if the retransmission number of a packet reach the maximum, the packet has to discard. So our algorithm improves the system throughput, which is the number of packets transmitted successfully, as shown in Fig 6.

V. CONCLUSION

In this paper, we have proposed a handoff initiation algorithm integrated of SNR, Load and Time in Wireless LAN. The goal is to achieve minimum number of handoff, reduce number of unnecessary handoff and balance the system load. Simulation results have shown that our algorithm is efficient. To compare with the conditional handoff initiation algorithm, it can reduce the number of handoff, combat the deep fading, decrease the packets loss and balance the system load. In the other hand, it add the complexity of the algorithm and may cause additional delay, but we think the cost is worthy for the data transmission in WLAN.

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