Multi-Rate Transmissions in Infrastructure Wireless LAN Based on IEEE 802.11b Protocol

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Abstract-**This paper will discuss the issues of providing multiple data rates (1/2/5.5/11Mbps) over an IEEE 802.11 infrastructure wireless network. With the characteristic of modulation schemes, the data rate of wireless network is inversely proportional with the transmission distance. A moving mobile station needs dynamically adjust the modulation scheme to keep connection alive and to achieve the maximum network throughput. To do this, mobile stations are requested to detect the distance between access point and itself from time to time. In this paper, a simple broadcasting approach will be proposed for mobile stations to detect their locations in wireless network. Based on this information, mobile node can easily determine the proper transmission rate.**

Keywords:CCK, Handshake, Infrastructure, WLAN.

I. INTRODUCTION

Adaptive transmission techniques have been extensively investigated for the improvement of transmission performance in wired and wireless communications. These techniques vary the transmission power [1], transmission packet length [2-4], coding rate/scheme [5], and modulation technology [6] under the time-varying channel. The adaptive modulation technology had been implemented in part of products such as V.34 modem standard [7] to maintain an acceptable bit error rate (BER) over poor quality telephone lines. Similarly, the Asymmetric Digital Subscriber Line (ADSL) [8] uses the DMT (Discrete Modulation Technique) modulation/coding to adaptively allocate more data bits in sub-channel which has a better signal-to-noise ratio (SNR). Besides, the adaptive modulation scheme used in two-way data transmission over cable [9] and the variable-rate QAM has also been proposed in third-generation wireless systems [10]. In summary, all of them are trying to improve the effective data rate under a specified bit error rate (BER).In [11], authors proposed the concept that throughput would be increased by permitting mobile terminal, which nears the central of the cell, to use the high-level modulation scheme. In contract, mobile terminal nears the fringes of cell must use a low level (binary) modulation to cope with the lower SNR. The same concept has also been applied on IEEE 802.11

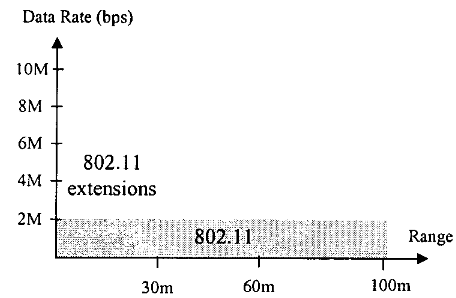

Figure 1. The data rate versus transmission range in IEEE 802.11 standard.

wireless LAN (WLAN) [12-14]. Companies Harris and Lucent have proposed high data rate modulation scheme "Complementary Code Keying" (CCK) [15], which was referred from the "Complementary Code" [16]. The IEEE 802.11 working group finally adopted CCK to support data rate up to 5.5Mbps and 11Mbps. To provide the interoperability for existing 1/2Mbps networks, Harris had proposed a baseband processor, which has the ability to provide four different modulation schemes (DBPSK / DQPSK / CCK / MBOK) and four data rates (1/2/5.5/11Mbps) for IEEE 802.11b WLAN. Intuitively, all mobile stations (MS) should use the highest level modulation scheme with the highest data rate all the time to achieve the maximum network throughput. However, the maximum data rate may not always be obtained since the data rate is inversely proportional with the transmission distance. The general concept is that a higher-level modulation scheme requires a higher SNR to obtain the same specified BER in respect to a lower level modulation scheme. That is, if we only consider the fading caused by the distance, we could find that the SNR degraded with the distance (from the signal power's degradation). As a result, the maximal data rate of a modulation scheme will be obtained only when the distance between two transceivers is not over the transmission distance boundary of the modulation scheme. Furthermore, within this bounded area, data can be transmitted successfully by using the specified modulation scheme. The relationships between data rate and transmission distance in IEEE 802.11 WLAN is shown in Figure 1 [12].

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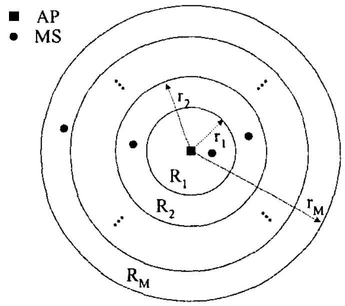

Figure 2. The network architecture of THN

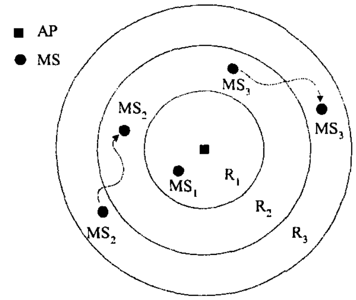

Figure 3. An example of movement problem in THN.

The IEEE 802.11 defines two types of wireless network [17]. One is called as IBSS (Independent Basic Service Set) or *Ad Hoc* WLAN. The other is the ESS (Extended Service Set) or *Infrastructure* WLAN (IWLAN). In *Ad Hoc* WLAN, a collection of MSs can quickly form a network without the aid of any pre-established infrastructure or centralized administration. An IWLAN connects MSs to a wired network via access point (AP). Basically, the AP is a fixed station that provides MSs the access to the Distribution System (DS). That is, an IWLAN extends MS's communication range and is often used in realistic wireless networks. However, in the case of two MSs desire to communicate with each other, their data packets must be relayed via AP no matter how close they are. Moreover, since different kinds of modulation schemes (with different data rates) can only be used in their transmission ranges, when an active MS moves around the AP's coverage area, the modulation scheme must be adjusted according to the distance. Besides, it will also incur unfairness since the MS locates within outer area will share a lower bandwidth quota than the others within inner area. Unfortunately, these problems are not considered or solved by the IEEE 802.11 standard. Thus, it is desired to design an efficient protocol to inform MSs about its location and to equally allocate bandwidth for every MS.

Recall that a modulation scheme with shorter (longer) transmission distance will provide a higher (lower) data rate. An MS in IWLAN network may change its modulation scheme according to the distance between AP and itself. Such kind of network is somewhat like the 'Tower of Hanoi' if we consider the 'size' and 'height' of plates as the 'coverage range' and 'data rate' of modulation schemes. In the 'Tower of Hanoi', the height (coverage range) and the size (data rate) of plates are gradually reduced and increased respectively from inner to the outer. For simplicity to identify the characteristics of IWLAN, we call such multi-rate IWLAN as 'Tower of Hanoi' Network (THN) throughout this paper. We note that, in THN, the inner side always provides a higher data rate than the outer side. The rest of this paper is organized as follows. The system model is described in Section 2. In Section 3, we will introduce an interesting problems of THN. The designed protocol and the frame format of it are addressed in Section 4. Section 5 describes the state diagrams of AP and MS in the THN. Finally, some conclusions are given in Section 6.

II. SYSTEM MODEL OF THN

Without loss generality, we assume there are N reachable MSs in the THN. Suppose the WLAN adapter can support M modulation schemes. The THN can be logically segmented into M concentric circles surrounded with AP as shown in Figure 2. Let TR_i denote the maximal transmission rate of the i-th modulation scheme with the distance restriction r_i ($1 \leq i \leq M$). We have $TR_m > TR_n$ and $r_m \leq r_n$, $\forall 1 \leq m < n \leq M$. To precisely derive the maximal data rate in any distance, we divide the THN into M disjoint regions: the innermost circle and $M-1$ 'doughnut' like regions. The former is denoted as R_1 and the other $M-1$ regions are numbered as $R_2, R_3, \ldots, R_M$ from inner to outer. The innermost region R_1 is the area which radius is smaller than or equal to r_1 and the 'doughnut' like region R_j ($2 \leq j \leq M$) is the area where the radius is larger than r_{j-1} and smaller than or equal to r_j. Let $l(i)$ denote the location of MS_i in THN. If MS_i locates in region R_j, we have $l(i)=j$ if $r_{j-1} \leq d_i < r_j$, where d_i is the distance between MS_i and AP. Here, we let $r_0=0$.

In this paper, we assume the transmission condition in the THN is symmetry. For each MS locates in R_j, it can transmit/receiver data to/from AP with the transmission rate TR_k if $r_k \geq r_j$ (or $k \geq j$). In other words, MS in R_j has the ability to transmit data by using the transmission rate TR_k ($j \leq k \leq M$). Therefore, we define a Boolean function $g(j,k)$ to indicate whether range R_j supporting transmission rate TR_k :

$$g(j,k) = \begin{cases} 1 & \text{if } r_j \leq r_k \\ 0 & \text{otherwise} \end{cases}$$

Figure 3 shows an example of THN where M=3, r_1=30m, r_2=60m, r_3=100m, TR_1=11Mbps, TR_2=5.5Mbps and TR_3=2Mbps. From mentioned above, we know that MS in R_j can transmit data using the transmission rate TR_k where $j \leq k \leq M$. The maximal network throughput will be derived only when all MSs in R_j transmit data in data rate TR_j. Under this assumption, the transmission rate of MS_1 should be TR_1. When MS_2 moving from R_3 to R_2, it must upgrade its transmission rate from TR_3 to TR_2. Contrarily, when MS_3 moves from R_2 to R_3, it must reduce the data rate from TR_2 to TR_3 to keep the connection alive.

So far, we only discuss the scenarios that all MSs support all modulation schemes. However, the real situation is that an MS may only support one or some kinds of modulation schemes due to the considerations of downward compatibility and production cost. Hereafter, we define a Boolean function $m(i,k)$ to indicate whether MS_i is capable of supporting TR_k. If MS_i supports TR_k, we let $m(i,k)=1$; otherwise, $m(i,k)=0$. Now, we can define the Boolean function $h(i,k)$ to indicate whether MS_i can use the transmission rate TR_k by considering both its location and transmission ability. Thus, we have

$$h(i,k) = g(l(i),k) \times m(i,k).$$

If $h(i,k)=1$, MS_i is allowed to transmit data in transmission rate TR_k.

CHALLENGES OF THN

In THN, MSs may move all the time and the distance between MS and AP may change from time to time. This implies the network performance and transmission quality become quite unpredictable than traditional network. How to maximize both network throughput and connection quality is an open issue in THN. In the following subsections, we will discuss the interesting problem: location detection problem (LDP) in THN.

A. Location Detection Problem (LDP)

In THN, once MS moves from one region to another region, it needs adjust its modulation scheme. By this way, the network throughput can be further improved (when move toward AP) and the connection quality can be maintained (when move away from AP). Unfortunately, the 802.11 standard does not define any function to support it. Therefore, it is desired to design a method to inform MSs where they are. Basically, the broadcasting approach is the simplest way can be used to solve the location detection problem (LDP).

B. Broadcasting Approach

In IEEE 802.11 standard, the Beacon (*B*) is generated periodically by AP and every MS must hear it to perform timing synchronization or to make the joining decision. In our broadcasting approach, a number of *M* Sub-Beacons (*SB*), which are distributed between two consecutive beacons, will be broadcast. These *M SB*s are broadcast by using different kinds of modulation schemes (one for each

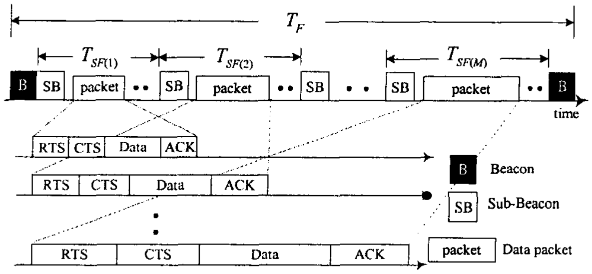

Figure 5. The frame format of THN

modulation scheme) and in the order from the highest transmission rate to the lowest transmission rate. MS locates in R_j will detect the *SB* in TR_k ($j \le k \le M$) if we do not consider the packet loss caused by the channel noise. By this methodology, MS can easily detect its location and employ the best modulation scheme.

THE FRAME FORMAT OF THN

Assume the channel is divided into frame *F* of duration T_F as shown in Figure 5. Each frame *F* is composed of one beacon *B* and *M* sub-frames (each sub-frame starting by sub-beacon *SB*). The beacon *B* carries the duration of each sub-frame and other network parameters. The beacon *B* is transmitted in the lowest transmission rate TR_M to make sure all MSs can receive the information.

Now, we will discuss the way of one MS accesses sub-frame. Here, we define a Boolean function $\xi(j,k,s)$ to indicate whether the MS in R_j is able to transmit data with TR_k in sub-frame SF_s. We have

$$\xi(j,k,s) = \begin{cases} 1 & \text{if MS in } R_j \text{ is allowed to transmit data with } TR_k \text{ in } SF_s \\ 0 & \text{otherwise} \end{cases}$$

We also define another Boolean function $\eta(i,k,s)$ to indicate whether MS_i can transmit data with transmission rate TR_k in SF_s. That is, we have $\eta(i,k,s) = \xi(l(i),k,s) \times h(i,k)$. In this paper, we only permit MSs in R_j to access SF_j with the transmission rate TR_j. Thus, we let $\xi(j,k,s)=1$ for all $j=k=s$.

III. THE STATE DIAGRAMS OF AP AND MS IN THN

A. The State Diagram of AP

When AP powers on, it will keep broadcasting the *Beacon* and *Sub-Beacon* signals periodically. When AP has data to transmit and the receiver is listening in this sub-frame, it will contend the channel by CSMA/CA protocol. If the AP gets the access right, it will use the hybrid handshake protocol to transmit data. When the AP finds that the reason of transmission failure is channel noise, it will retransmit the data in the same data rate. On the contrary, if the transmission error is caused by MS's movement, it will update the MS's location table in order to transmit packets by attempting the lower transmission rate. In the receiving part, AP will receive data from MS only when its buffer is not full. When receive is successful, it will transmit the ACK signal to the MS and update the MS's location table according to the current transmission rate.

B. The State Diagram of MS

When MS powers on, it will first listen to the *Beacon* signal. After acquiring the network parameters from the *Beacon* signal, it will join to network and listen to the *Sub-Beacon* signal to obtain its location related to the AP. After then, it will start to contend channel in the allowed sub-frame period. The transmission and reception processes are similar as the AP excepting maintaining the location table and checking the receiver's location. Another difference is that when the MS detects that its transmission error is caused by its movement (no matter the movement occurs before sending RTS packet or during the receiving data period), it will retransmit packets in the next frame. This will avoid the MS retransmits packets in the same transmission rate to waste the bandwidth. Therefore, the STA would retransmit it again by using a lower transmission rate in the next super-frame period.

CONCLUSIONS

In this paper, we pointed out the potential problem, named as the location detection problem (LDP), in the IEEE 802.11 infrastructure wireless networks while supporting multiple data rates. In this paper, we proposed a broadcasting approach for solving the LDP problem. Our future work is to simulate and evaluate the proposed protocol.

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