Link Adaptation Strategy for IEEE 802.11 WLAN via Received Signal Strength Measurement

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Abstract— **IEEE 802.11 Wireless Local Area Network (WLAN) physical layers (PHYs) support multiple transmission rates. The PHY rate to be used for a particular frame transmission is solely determined by the transmitting station. The transmission rate should be chosen in an adaptive manner since the wireless channel condition varies over time due to such factors as station mobility, time-varying interference, and location-dependent errors. In this paper, we present a novel link adaptation algorithm, which aims to improve the system throughput by adapting the transmission rate to the current link condition. Our algorithm is simply based on the received signal strength measured from the received frames, and hence it does not require any change in the current IEEE 802.11 WLAN Medium Access Control (MAC) protocol. Based on the simulation and its comparison with a numerical analysis, it is shown that the proposed algorithm closely approximates the ideal case with the perfect knowledge about the channel and receiver conditions.**

I. INTRODUCTION

In recent years, IEEE 802.11 Wireless Local Area Network (WLAN) has emerged as a prevailing technology for the (indoor) broadband wireless access for the mobile/portable devices. The IEEE 802.11 specification was first approved in 1997, and the second edition was published in 1999 [1]. Its specification defined a single Medium Access Control (MAC) and three Physical Layers (PHYs), which provided PHY rates of 1 and 2 Mbps. In 1999, two new high-speed PHY specifications were additionally defined, namely, IEEE 802.11a and IEEE 802.11b [2]. The IEEE 802.11b standard provides 1, 2, 5.5 and 11 Mbps raw PHY transmission rates. With the 802.11, the PHY rate to be used for the transmission of a particular frame is solely determined by the transmitting station (STA). The transmission rate should be chosen adaptively since the wireless channel condition varies over time due to such factors as STA mobility, time-varying interference, and location-dependent errors. In this paper, we present a novel link adaptation algorithm that chooses the transmission rate of frames in an adaptive manner in order to maximize the system throughput.

The link adaptation problem exists in other wireless systems as well [8][9], but in different contexts. For example, in HIPERLAN Type 2, the centralized controller determines the transmission rate to be used by the stations in the network for each single transmission [9]. Link adaptation algorithms for IEEE 802.11 WLAN were also studied by many others [3][4][5][6][7]. However, these existing approaches have some limitations. Some adapt the rate in a heuristic manner so that the system performance is not optimized. For example, the scheme in [7] adapts the rate based on the result of keeping track of a timing function and the number of (un)successful transmissions. This scheme cannot react quickly when the wireless channel condition fluctuates. Most others require some changes in the MAC layer, or assume some kind of communication between the transmitter and the receiver regarding the link condition [3][4][5][6]. These schemes can lead to an optimal solution. However, as the standard does not reflect such an operation, the interoperability between devices from different vendors, which may or may not include such mechanisms, is not achieved. In this paper, we develop a novel algorithm for the dynamic rate adaptation, which basically utilizes the Received Signal Strength (RSS) of received frames, along with the number of retransmissions, in order to determine the channel and receiver conditions in a relative manner. The algorithm does not require any coordination from the receiver, and hence does not require any change in the current MAC operation.

The rest of this paper is organized as follows: Section II introduces the Distributed Coordination Function (DCF) of the IEEE 802.11 MAC and the IEEE 802.11b PHY. The throughput performance for a peer-to-peer communication in the IEEE 802.11 WLAN using 802.11b PHY is derived in Section III. This throughput analysis is used for the comparative evaluation of our proposal. The proposed Link Adaptation algorithm is presented in Section IV. In Section V, we evaluate the performance of the algorithm via simulation. Finally, this paper concludes with Section VI.

II. IEEE 802.11 WLAN

The IEEE 802.11 MAC provides a fair access to the shared wireless medium through two different access mechanisms: a mandatory contention-based access protocol, called the Distributed Coordination Function (DCF), and an optional polling-based protocol, called the Point Coordination Function (PCF). The PCF is very rarely implemented in currently available devices. In this paper, we focus on the link adaptation for an IEEE 802.11b WLAN based on the DCF protocol, which is prevailing in the market today. One should be able to extend the algorithm to other PHYs such as 802.11a PHY easily.

A. DCF of IEEE 802.11 MAC

The DCF access mechanism is a distributed medium access protocol based on Collision Sense Multiple Access with

Collision Avoidance (CSMA/CA). Basically, the DCF works as follows: before a station starts a frame transmission, it shall sense the wireless medium to determine if it is busy. If the station detects that the wireless medium has been idle during more than a time interval called Distributed Inter Frame Space (DIFS), the station can transmit the frame immediately. If the medium is sensed as busy, the station waits until the channel becomes idle, then defers for an extra DIFS interval. If the medium remains idle, the MAC starts the backoff procedure by selecting a random backoff count (how to select the random backoff count is detailed below). While the medium stays idle, the backoff counter is being decremented every slot time, and when the counter reaches zero, the frame is transmitted.

Priority access to the wireless medium is controlled by use of Inter Frame Space (IFS) intervals, i.e., time intervals between the transmissions of consecutive frames. The standard defines four different IFS intervals: Short IFS (SIFS), PCF IFS (PIFS), DCF IFS (DIFS), and Extended IFS (EIFS). A basic medium access method is illustrated in Figure 1.

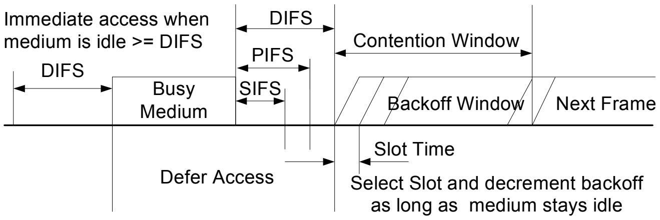

Figure 1. IEEE 802.11 DCF channel access

For each successful reception of a frame, the receiving station immediately acknowledges the frame reception by sending an acknowledgement (ACK) frame. The ACK frame is transmitted after a SIFS interval, which is shorter than the DIFS. If an ACK frame is not received within an "ACK timeout" period after the data transmission, the frame is retransmitted after another random backoff. When the frame is correctly transmitted and the corresponding ACK is received, the station performs a DIFS deference and another random backoff process, which is often referred to as "post-backoff".

To select the random backoff count, each station maintains a contention window (CW) value. The backoff count is determined as a random integer drawn from a uniform distribution over the interval [0,CW]. The CW size is initially assigned a CWmin, and it is increased exponentially when a transmission fails. After any unsuccessful transmission attempt, another backoff is performed with a new CW value determined as follows:

$$CW \Leftarrow 2 \cdot (CW + 1) - 1. \tag{1}$$

Once CW reaches the value of CWmax, it remains at the value of CWmax until it is reset. The CW is reset to CWmin after a successful transmission or after reaching the maximum retry limit.

B. IEEE 802.11b PHY

The IEEE 802.11b PHY [2] is an extension of the original Direct Sequence Spread Spectrum (DSSS) PHY. It operates in the 2.4 GHz ISM band, providing 5.5 and 11 Mbps PHY rates in addition to the 1 and 2 Mbps rates supported by the original DSSS PHY. The PHY rates of 1 and 2 Mbps are based on Binary Phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK) modulations, respectively. Both are encoded using DSSS based on 11-bit Barker chipping sequence that results in a signal spread over a wider bandwidth at a reduced RF power. Each channel occupies 22 MHz of bandwidth, thus allowing three non-overlapping channels in the 2.4 GHz band.

To provide the higher PHY rates of 5.5 and 11 Mbps, the IEEE 802.11b defines a Complementary Code Keying (CCK) modulation scheme [10]. CCK is a variation on M-ary Orthogonal Keying Modulation that uses I/Q modulation architecture with complex symbol structures. It is based on a complex set of 64 eight–bit Walsh/Hadamard functions known as Complementary Codes. For the 5.5 Mbps rate, 4 bits are encoded per word, while for the 11 Mbps rate, 8 bits are encoded per word. Both PHY rates use QPSK as the modulation technique and signal at 1.375 MSps. The spreading maintains the same chipping rate and spectrum shape as the original 802.11 DSSS, hence, occupying the same channel bandwidth.

The physical parameters of the 802.11b modulations are summarized in TABLE I.

TABLE I. IEEE 802.11B PHY PARAMETERS

Parameter	Value	Comments
aSlotTime	20μsec	Slot Time
aSIFSTime	10μsec	SIFS time
aDIFSTime	50μsec	$aDIFSTime = aSIFSTime + 2 \times aSlotTime$
aCWmin	31	Minimum contention window
aCWmax	1023	Maximum contention window
tPLCPPreamble	144 μsec	PLCP Preamble Duration
tPLCPHeader	48 μsec	PLCP Header Duration

Figure 2 shows the Bit Error Rate (BER) curves vs. Signal to Noise Ratio (SNR)[1] for the IEEE 802.11b PHY modes. These curves could be derived theoretically. However, for the purpose of this paper and to achieve a link adaptation solution close to the reality, we have used empirical curves provided by Intersil for its chip called HFA3861B [11][2]. These curves have been used to estimate the BER in both the analysis and the simulation results shown in the following sections.

The frame format of an IEEE 802.11b frame is shown in Figure 3. When a frame (or MAC Service Data Unit, i.e., MSDU[3]) arrives at the MAC layer from the higher layer, it is encapsulated in a MAC Protocol Data Unit (MPDU) by adding 24 bytes for the MAC header, and 4 bytes for the Frame Control Sequence (FCS). The MPDU is then passed to the PHY layer, which will attach the Physical Layer Convergence Protocol (PLCP) header and preamble. The PLCP overhead takes 192 μsec in total.

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[1] The SNR is measured at the antenna of the receiver, before decoding the spread signal.

[2] The BER curves for the HFA3861B are measured in an AWNG environment.

[3] An MSDU is the unit of data arriving at the MAC from the higher layer.

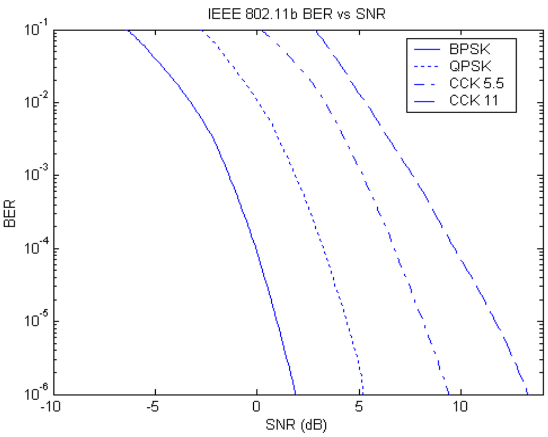

Figure 2. IEEE 802.11b BER vs. SNR

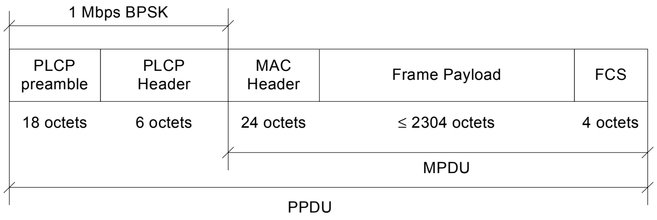

Figure 3. PLCP Protocol Data Unit (PPDU) format[4]

III. IEEE 802.11B THROUGHPUT PERFORMANCE

In this section, we analyze the throughput performance of an IEEE 802.11b WLAN. Our objective is to calculate the maximum throughput achievable with an 802.11b WLAN at the MAC layer for a given SNR by taking into consideration of MAC, PHY and retransmission overheads. To simplify our analysis we make the following assumptions: (1) there is only one sender and one receiver running in the DCF mode with no interfering stations nearby. Therefore, there are no collisions on the wireless medium; (2) the sender generates, at an infinite rate, L-byte long data frame (or MSDU), where $L = 1500$ bytes; (3) the MSDU is not fragmented; (4) there is no retry limit for each frame, and (5) the propagation delays are neglected. A detailed analysis for IEEE 802.11a including fragmentation can be found in [3][4]. With these assumptions, recall from Section II, a transmission cycle is composed of the following phases that are repeated over time: (1) DIFS deferral phase; (2) Back-off/contention; (3) Data (or MPDU) transmission phase; (4) SIFS deferral phase; and (5) ACK transmission phase.

A. *Probability of Successful Transmission*

Assume that an L-byte long frame has to be transmitted using PHY mode m, where m=1, 2, 3, and 4 for 1, 2, 5.5, and 11 Mbps PHY rates, respectively. Then, the probability of a successful transmission can be calculated by:

$$P^m_{success}(L) = (1 - P^m_{e\_data}(L)) \cdot (1 - P^m_{e\_ack}), \qquad (2)$$

where $P^m_{e\_data}(L)$ and $P^m_{e\_ack}$ are the error probabilities for an L-byte long data frame and ACK frame, respectively. An ACK frame is transmitted at the rate equal to or lower than the data frame rate, and is 14 bytes long, which is usually much shorter than the data frame. Therefore, the error probability of the ACK frame is very low compared to the error probability of the data frame, and hence we can approximate the probability of successful transmission as:

$$P^m_{success}(L) \approx (1 - P^m_{e\_data}(L)). \qquad (3)$$

Now we can derive the probability of error for an L-bytes long data frame transmitted at PHY mode m. Based on Figure 3, the probability of error of a data frame is given by:

$$P^m_{e\_data}(L) = 1 - (1 - P^1_e(24)) \cdot (1 - P^m_e(28 + L)), \qquad (4)$$

where $P^1_e(24)$ is the probability of error of the PLCP preamble/header transmitted using PHY mode 1, and $P^m_e(28 + L)$ is the probability of error of the MPDU including the MAC overhead. Further, the $P^m_e(L)$ can be expressed in terms of BER P^m_b as:

$$P^m_e(L) = 1 - (1 - P^m_b)^{8L}, \qquad (5)$$

where the P^m_b is estimated for each PHY mode m using the empirical curves shown in Figure 2.

B. *Throughput Analysis*

In this section, we calculate the average throughput considering the assumptions made above. Each successful frame transmission duration is equal to the data frame transmission time, plus the ACK transmission time, plus one SIFS. However, if the data transmission fails, the station has to wait for an ACK timeout period[5], execute a backoff and retransmit the frame. Therefore, the average transmission time for a single frame is given by (6) in the next page, in which $T^m_{data}(L)$ and T^m_{ack} are the durations to transmit a data frame and an ACK frame as shown below.

$$T^m_{data}(L) = \text{tPCLPreamble} + \text{tPLCPHeader} + \frac{(28 + L) \cdot 8}{tx\_rate(m)}, \qquad (7)$$

$$T^m_{ack} = \text{tPCLPreamble} + \text{tPLCPHeader} + \frac{14 \cdot 8}{tx\_rate(m)}. \qquad (8)$$

Here, the transmission rate *tx_rate(m)* for PHY mode m is given by *tx_rate(m)*=1, 2, 5.5, 11 Mbps for m=1, 2, 3, 4, respectively. $\overline{T}_{bkoff}(j)$ is the average backoff interval in µsec, after i consecutive unsuccessful transmission attempts given by

$$\overline{T}_{bkoff}(i) = \begin{cases} \dfrac{2^i \cdot (CWmin + 1) - 1}{2} \cdot aSlotTime & 0 \le i < 6, \\ \dfrac{CWmax}{2} \cdot aSlotTime & i \ge 6, \end{cases} \qquad (9)$$

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[4] The MAC header size becomes 28 bytes if address 4 is used. However, address 4 is used only for the wireless AP-to-AP communication, which is not common, and hence we assume that it is not used. The frame payload can be up to 2312 if encryption is used, but we assume that encryption is not used.

[5] According to IEEE Std. 802.11-1999, the ACK timeout is defined as SIFS time, plus ACK transmission time, plus a slot time.

$$T_{frame} = \sum_{i=1}^{\infty} P[n=i] \cdot \sum_{j=0}^{i-1} \Big[aSIFSTime + T_{ack}^{m} + aSlotTime + \overline{T}_{bkoff}(j) + T_{data}^{m}(L) \Big] + T_{data}^{m}(L) + aSIFSTime + T_{ack}^{m}. \qquad (6)$$

and P[n=i] is the probability of successful transmission after *"i"* transmission attempts[6] given by

$$P[n=i] = \left[1 - P_{success}^{m}(L)\right]^{i-1} \cdot P_{success}^{m}(L). \qquad (10)$$

Finally, to compute the throughput *"G"* we need to consider the interval between two successful frame transmissions, which will be given by *aDIFSTime*+ $\overline{T}_{bkoff}(0)$ [7] as one can deduce from Section II:

$$G = \frac{8 \cdot L}{T_{frame} + aDIFSTime + \overline{T}_{bkoff}(0)}. \qquad (11)$$

C. *Throughput Results*

Using the IEEE 802.11b PHY layer values shown in TABLE I in the equations derived above and the frame size of L = 1500 bytes, we obtain a throughput as a function of the SNR, for every PHY mode, as shown in Figure 4. One can imagine that this ideal performance can be achieved only if the SNR at the receiver is known to the transmitting STA in advance. We later compare the performance of our proposed algorithm with this ideal case.

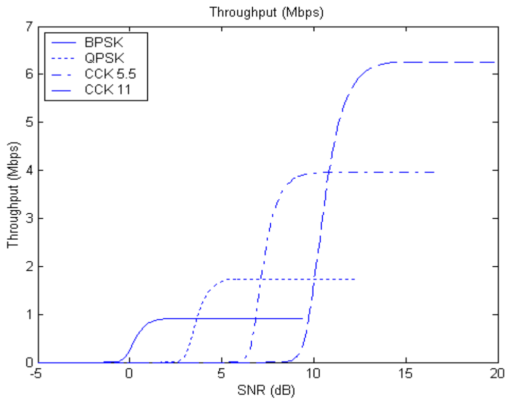

Figure 4. IEEE 802.11b throughput vs. SNR

IV. LINK ADAPTATION ALGORITHM

In wireless systems, the propagation and interference environments vary over time and space due to such factors as STA mobility, time-varying interference, location-dependent errors, and so on. As a result, there is no single modulation that can be optimal under all scenarios. A Link Adaptation (LA) algorithm is a major solution to handle this problem. Its principle is to improve the efficiency of a system by adapting the modulation scheme to the current link condition.

The IEEE 802.11b standard provides 1, 2, 5.5 and 11 Mbps raw PHY transmission rates. The PHY rate to be used for a particular transmission is solely determined by the transmitting STA. In general, the higher transmission rate, the higher Signal-to-Noise Ratio (SNR) is required to maintain the same communication quality. In order to determine the best transmission rate at a given time, the transmitting STA needs to know two things in advance ideally: (1) SNR or Signal-to-Interference Ratio (SIR) at the receiving STA, and (2) the frame error rate vs. SNR/SIR at the receiving STA for different transmission rates. In reality, neither of the above can be known to the transmitting STA, and both of them are time-varying factors.

In this section, we present a novel link adaptation algorithm developed for a non-AP IEEE 802.11b STA operating in an infrastructure mode. IEEE Std. 802.11-1999 defines two modes of operation, namely, infrastructure and ad-hoc modes. Here, we mainly focus on the infrastructure mode, in which the STAs are associated with an AP. Note that according to IEEE 802.11-1999, an STA relays every frame through the AP, even if it is destined to another station in the same Basic Service Set (BSS). However, our algorithm can be easily extended for the ad-hoc mode as well as the AP transmissions in the infrastructure mode.

A. *Available Information*

For the design of the algorithm, we assume that the AP cannot send any information regarding the link condition to the STA, which is true according to the standard specification [1]. Therefore, as discussed above, the information needed for the ideal link adaptation is not available to the transmitting STA, and hence we need to estimate the conditions of the receiving STA, i.e., AP. One important fact is that irrespective of the receiver performance and channel behavior, the frame error probability depends on the received frame length and its transmission rate. Note that the frame length is determined and known by the transmitting STA obviously.

The second fact is that the transmitting STA can estimate the path loss and channel behavior relatively by keeping track of the Received Signal Strength (RSS) measured from the frames sent by the AP. As long as the AP uses a fixed transmission power level for all its transmissions, the changes in the RSS should be indicative of the changes in the path loss and channel behavior. Note that the transmission power control is rarely used for the 802.11 devices today.

B. *Proposed Algorithm*

The basic idea of our LA algorithm is that the transmitting STA adapts the transmission rate depending on the RSS measured from the frames it receives from its AP. Without considering rapid fluctuations of the SNR/SIR, we can assume that the RSS has a linear relationship in average with the SNR. Changes in the RSS indicate that the conditions in the wireless link between the STA and the AP are changing, and it might be necessary to adapt the transmission rate accordingly.

The PHY rate adaptation can be made when the average RSS measured from the received frames passes some *thresholds.* As explained below, every STA will store and update its own 12 thresholds. The initial value of every threshold will be 0, and they will be updated dynamically as the

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[6] We assume that there is no retransmission limit to simplify the analysis.

[7] CW value is reset after a successful retransmission.

STA starts its operation. These thresholds indicate the minimum RSS values required for a particular transmission PHY rate. For example, if a STA, that is monitoring the RSS from beacons and other frames sent by the AP, detects that the RSS is becoming lower than one of the thresholds (e.g., due to an increasing distance between the AP and the STA), the next transmission attempt may be at a lower rate to ensure the correct reception of the frame.

The algorithm is presented in Figure 5. As explained above, upon reception of any frame addressed to itself or broadcast/multicast addressed frame from its AP, the STA will *update* the averaged *RSS_avg* using the RSS measured from the received frame. On the other hand, upon transmission of a frame, the *thresholds* are updated if necessary depending on whether the transmission was successful. For example, if a frame transmission at a particular rate is unsuccessful, the threshold for that rate should be subsequently raised using the RSS value that is currently stored in the STA. Accordingly, the subsequent transmission attempts for that RSS value may be at a lower PHY rate. Note that the thresholds value will vary depending on the receiver characteristics of the AP as well as the local interference in the AP. For the *rate selection*, a STA will consider the values of *RSS_avg*, thresholds, frame size and number of retransmission attempts. The algorithm will automatically decrease the PHY rate when the number of retransmission attempts exceeds the retransmission limit *Y*. After every retransmission attempt, the thresholds are adjusted.

In this algorithm, we consider three intervals for the frame length, which were chosen according to two different facts: (1) the known traffic statistics from the Internet[8], and (2) the frame error rate must differ significantly from one interval of frame length to another, for a given SNR/SIR. We choose to classify the frames within three intervals: 0–100 bytes, 100–1000 bytes, and 1000–2400 bytes.

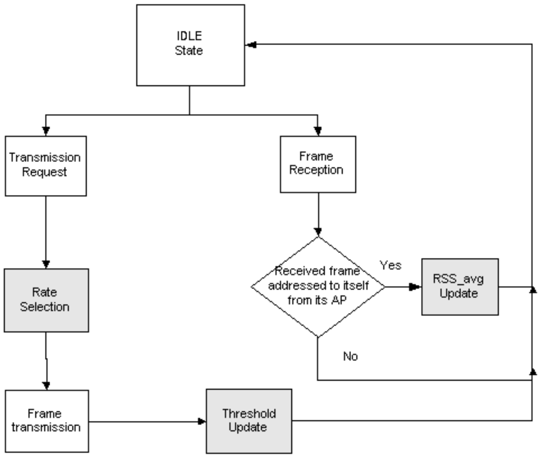

Figure 5. Link adaptation algorithm

We define Threshold *Th*[*i,j*] as the minimum *RSS_avg* value to transmit a frame within length interval *j* (from 1 to 3) at PHY mode *i* (from 1 to 4 for 802.11b). *Th*[*i,j*] is the boundary between PHY modes *i* and *i-1* for frames of length in interval *j*. For example, *Th*[*3,3*] is the "estimated" minimum *RSS_avg* value to ensure correct transmission of a frame of length between 1000 and 2400 bytes at PHY mode 3 (i.e., 5.5 Mbps).

To update Thresholds *Th*[*i,j*] and *RSS_avg*, we define the following algorithms:

$$Th[i,j] := a_1 \cdot Th[i,j] + a_2 \cdot RSS \qquad \begin{array}{l} a_1 + a_2 = 1, \\ a_1 \geq 0, \\ a_2 \geq 0, \end{array} \tag{12}$$

$$RSS\_avg := a_3 \cdot RSS\_avg + a_4 \cdot RSS \qquad \begin{array}{l} a_3 + a_4 = 1, \\ a_3 \geq 0, \\ a_4 \geq 0, \end{array} \tag{13}$$

where *RSS* is the received signal strength measured from the latest frame received. The values a_1, a_2, a_3 and a_4, determine the speed of the adaptation in this exponential moving average algorithm.

V. PERFORMANCE EVALUATION

Computer simulation is used to evaluate the performance of the proposed algorithm. In this section, we present the simulation results obtained with the Link Adaptation algorithm implemented in OPNET 8.0.B.

A. *Simulation Scenario*

For the simulation, we create a scenario composed of an infrastructure BSS, with a fixed AP and one mobile station. The BSS is working under the DCF mode. The mobile station follows a pre-defined trajectory of 45 meters (see Figure 6). We simulate 120 seconds during which the mobile station moves farther from the AP, arrives at the end of the trajectory, then comes back. The speed of the mobile simulates an average person walking while using a WLAN device. The STA generates a single stream of 1500 bytes long data frames at a high data rate such that the WLAN is overloaded. The AP sends a beacon every 100 ms and no downlink traffic is generated. According to the MAC specification, the ACK frame from the AP is transmitted at the rate equal to or lower than the data frame rate. Therefore, in our scenario, the LA algorithm in the mobile node only uses beacon and ACK frames from the AP to calculate the optimal transmission rate.

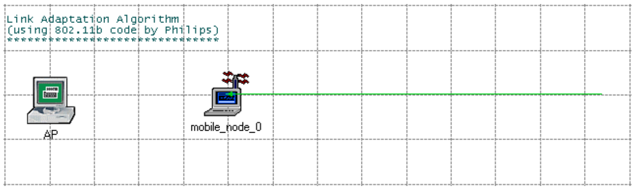

Figure 6. The OPNET Simulation Scenario

In this scenario, we assume that there is no interference; therefore, the errors are only due to the background noise. The propagation delays are also negligible. For the calculation of the BER, the modulation curves shown in Figure 2 were implemented in the simulation model. We use the curves to determine the BER of the frame transmission using a modulation table look-up based on the estimated SNR.

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[8] At Hot Chips '01, Agere presented a new Internet traffic mix: 64 bytes frames represent the 55% of the number of total frames of the Internet traffic, 72 bytes frames the 5%, 596 bytes frames the 17% and 1520 bytes frames the 23%.

B. Simulation Results

Figure 7 shows the throughput obtained, (1) with a fixed PHY rate of 11 Mbps and (2) with the Link Adaptation algorithm and different retransmission limits *Y*. In the simulations, we use 0.5 for each of a_1, a_2, a_3 and a_4 values. These results closely follow the expected outcome, the PHY rate clearly drops level by level as the STA moves farther away from the AP. The PHY rate subsequently increases again as the STA moves back toward the AP, eventually regaining the maximum PHY rate. On the other hand, when the fixed PHY rate at 11 Mbps is used in the STA, the period of link failure is clearly visible when the STA moves beyond the maximum range of the 11 Mbps rate.

The retransmission limit selection is observed to be an important factor when designing the algorithm. A retransmission limit of Y=1 is too low and the PHY rate is changed too fast. One may conclude that to maximize the system throughput one should allow 10-20% of retransmissions. For example, an error-free transmission at 5.5 Mbps will result in a lower throughput than allowing 10-20% of retransmissions at 11 Mbps apparently. This is exactly what we observe in Figure 7. A retransmission limit of Y=4 seems to achieve the best results in terms of throughput. On the other hand, a retransmission limit of Y=5 is too aggressive, avoiding a fast enough adaptation and resulting in a lower throughput during transient periods.

Figure 8 compares the simulation results obtained for Y=4, with the theoretical bound calculated in Section III. We have exported the throughput values from the second half of Figure 7 for *Y*=4 and plug them into Figure 8. We observe that our LA algorithm achieves the maximum throughput based on the analysis in most cases.

VI. CONCLUSION

The IEEE 802.11 WLAN supports multiple PHY rates, and a transmitting station selects which rate to use for each particular frame transmission. In this paper, we have proposed a novel link adaptation algorithm for the IEEE 802.11 WLAN, which selects the best rate for a particular frame transmission based on the Received Signal Strength measurements. The algorithm has been then evaluated via simulation and compared with the analytical results. The algorithm has been presented for an 802.11b STA in the infrastructure mode, but one may extend it easily for 802.11a PHY and for an AP or an STA in ad-hoc mode.

As the future work, we will compare the proposed scheme with some other existing algorithms, e.g., proposed in [4][5][6][7]. We will also investigate the effect of some time-varying local interference, such as Bluetooth interferences, and analyze the effect of multipath or fast Doppler channels. The algorithm may need to be adjusted to adapt the PHY rate correctly in such situations.

REFERENCES

[1] IEEE Std. 802.11-1999, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications, Reference number ISO/IEC 8802-11:1999(E), IEEE Std. 802.11, 1999 edition, 1999.

[2] IEEE Std. 802.11b, Supplement to Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-speed Physical Layer Extension in the 2.4 GHz Band, IEEE Std. 802.11b-1999, 1999.

[3] Daji Qiao and Sunghyun Choi, “Goodput Enhancement of IEEE 802.11a Wireless LAN via Link Adaptation,” in *Proc. IEEE ICC ’01*, June 2001, pp. 1995-2000.

[4] Daji Qiao, Sunghyun Choi, and Kang G. Shin, "Goodput Analysis and Link Adaptation for IEEE 802.11a Wireless LANs," *IEEE Trans. on Mobile Computing*, vol. 1, no. 4, pp. 278-292, October-December 2002.

[5] Jean-Lien C. Wu, Hunh-Huan Liu and Yi-Jen Lung, “An Adaptive Multirate IEEE 802.11 Wireless LAN,” in *Proc. 15th International Conference on Information Networking*, 2001, pp. 411-418.

[6] Gavin Holland, Nitin Vaidya and Paramvir Bahl, “A Rate-Adaptive MAC Protocol for Multi-Hop Wireless Networks,” in *Proc. ACM SIGMOBILE’01*, July 2001, pp. 236-251.

[7] Ad Kamerman and Leo Monteban, “WaveLAN-II: A High-Performance Wireless LAN for the Unlicensed Band,” *Bell Labs Technical Journal*, pp. 118–133, Summer 1997.

[8] Olav Queseth, Fredrik Gessler, and Magnus Frodigh, “Algorithms for Link Adaptation in GPRS,” in *Proc. IEEE VTC’99*, 1999, pp. 943–947.

[9] Zihuai Lin, Goran Malmgren, and Johan Torsner, “System Performance Analysis of Link Adaptation in HiperLAN Type 2,” in *Proc. IEEE VTC’00*, 2000, pp. 1719–1725.

[10] C. Andren and M. Webster, "CCK Modulation Delivers 11Mbps for High Rate 802.11 Extension," in Wireless Symposium/Portable By Design Conference Proceedings, Spring 1999.

[11] Intersil, “HFA3861B; Direct Sequence Spread Spectrum Baseband Processor,” January 2000.

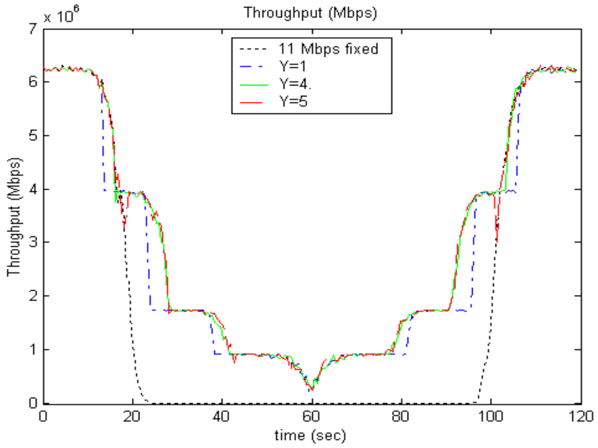

Figure 7. Throughput for different retransmission limits (*Y*)

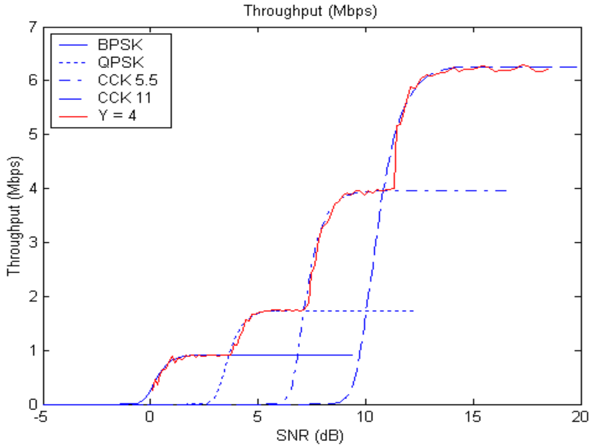

Figure 8. Link adaptation algorithm simulation results