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Opportunistic Random Media Access in WLANs

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OPPORTUNISTIC RANDOM MEDIA ACCESS IN WLANs

by

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ABSTRACT

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This thesis proposes a new medium access protocol for IEEE 802.11 wireless local area networks, which is called opportunistic medium access. The protocol changes the media access opportunities of nodes by adjusting the contention window dynamically according to the different bit rates. Thereby, the protocol can reduce collision and improve throughput significantly. The traditional IEEE 802.11 standards access channel with binary exponential back-off algorithm and all nodes choose the back-off interval from the same initial range. The new protocol in this thesis divides nodes as well as contention windows in proportion to data rate. It offers three methods to group nodes and contention window with different lower boundary or upper boundary. So, nodes can choose their back-off intervals distinguished based on their channel conditions. As a consequence, the nodes with better channel condition will get smaller back-off values, that enables these nodes win the contention with a larger probability. Besides, the protocol takes a *data rate normalized average history throughput* into the computation of contention window to achieve temporal fairness. The protocol has been implemented based on ath9k wireless driver and the experimental results show that the new protocol gets 20% more throughput compare to the original IEEE 802.11n protocol. Besides, in order to verify the performance in a large network, some simulations conducted in NS-3 which shows proposed protocol have good performance as well.

ACKNOWLEDGMENTS

This thesis presents not only my work at media access, but also a milestone in two years of work at the University of Southern Mississippi and especially within Wireless Communications and Networking Group. My experience at USM is nothing but amazing. I have felt at home at USM since I came here on August 27th, 2010. I have been given so many opportunities to conduct research, and this thesis is one of the fruits of that work. There are some remarkable individuals that helped me with some work whom I wish to acknowledge.

First and foremost I want to thank my advisor, Dr. Shaoen Wu, the director and founder of Wireless Communications and Networking Group. He has been supportive since the days I began working in the group. Ever since, Dr. Wu has supported me not only by providing a research assistantship over two years, but also academically and emotionally through the tough work to finish this thesis. I had the opportunity to design the algorithms in my thesis and test it on the test bed. He helped me come up with the thesis idea and guided me through almost one year of development. When I was in the most difficult times, he gave me very helpful advice and the freedom to continue.

I also want to thank my thesis committee which guided me in these days. Thanks to Zhaoxian Zhou and Nan Wang for being my thesis committee members. They both gave me expert advice to my thesis work, and those advice made my thesis more convincing and comprehensive.

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CHAPTER I

INTRODUCTION

In wireless local area networks, channel conditions are varying time to time due to fading, mobility and shadowing. As a result, wireless users often experience different channel conditions. A link may be good enough to transmit data at the highest rate at a moment, or may be too poor to transmit any data even at the lowest rate at the next moment. In response to the channel variation, IEEE 802.11 standards allow the physical layer to provide multiple rates ability by adapting different modulation scheme. When the channel condition is good enough, the transmitter will adopt higher data rate to transmit data, vice verse. As a media access protocol, one of the essential features is to adopt the transmission bit rate to accommodate the channel conditions according to some physical hints like signal-to-noise ratio (SNR), bit error rate (BER), received signal strength indicator (RSSI) and so forth. By adopting different data rates, although the nodes with better channel condition can transmit data at a shorter time, the opportunity to access the channel of every node has not changed, and the temporal fairness has not been achieved. Because of this, the traditional wireless communication approaches consider this channel randomness as detrimental, but most recent *opportunistic* approaches attempt to exploit the inherent randomness property to serve the wireless communication better. Most of them focus on opportunistic rate adaptation [8], transmission [3], scheduling [24, 23] and routing [5, 14, 11], and they improved the performance of wireless network effectively. In this thesis, a new protocol is proposed to utilize the randomness property, it takes data rate into the computation of the contention window to change the opportunities of the accessing channel between nodes. Since contention window controls the medium access, we call the proposed algorithm as opportunistic medium access.

There are two basic network architectures: centralized and distributed. A centralized network has a base station to coordinate all nodes in this network. If a node has packets need to transmit, it must get the allowance from the base station. A centralized network is uncomplicated and quite effective since there is no collision exist. However, the base station must be very complex, especially when the base station is a mobile node due to the power problem. Moreover, if the base station down, the entire network cannot work any more. In a distributed network, nodes are typically constructed as an end-system, and there is no central node exists. In coordinated multiple access, such as in cellular systems, opportunistic access matured into parts of standards such as IS-856 [1, 18]. Despite the noteworthy achievement of opportunism in these areas, little effort has been dedicated to opportunistic *random* multiple access that still faces challenges to design distributed fair and efficient algorithm for channel access.

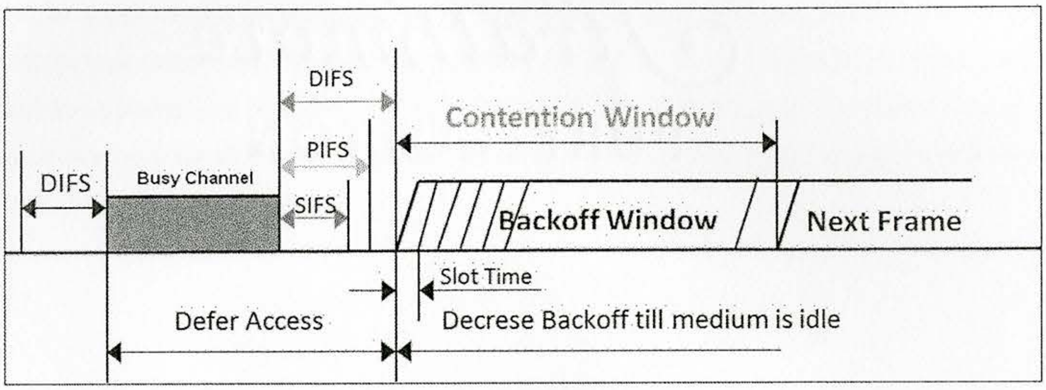

Figure I.1: Contention Window

In previous paragraphs, we have discussed how nodes accessing media in a multiple access network. As we can see, whatever the channel condition is, all nodes have the same opportunities of accessing media regardless of channel condition, since they select the back-off value from the same range (same contention window). Namely, a node A with poorer channel condition may beat another node B experiencing better channel condition. However, in common sense, it is reasonable to let the node with the best channel condition transmit packets first since the link pair condition change incessantly, no matter between static nodes or mobile nodes in practical situations. If A beat B, there are two issues will arise. First, node B would have used the wireless channel more efficiently; Second, Node B with presently better channel conditions may not keep these good channel conditions when it wins the channel later because of the highly dynamic and random variations of the wireless channel. However, node A needs a longer time than B to transmit data packets with the same length, this will reduce the whole network's efficiency.

In order to avoid wasting the channel, and to improve throughput of the network as a whole, a node with better channel conditions should be favored to win the contention for the channel. Besides, if a link is better than others, letting the nodes within this link win the contention is beneficial to any single node and the whole network as well. Since the node transmits data at a better channel condition, it will transmit at a higher rate and will finish the transmission quickly, of course, a higher throughput it will get. If a node with worse channel wins the contention, a relatively longer time needed to send the packets with the same length, which is harmful to the throughput.

In this thesis, a new protocol is proposed to utilize the randomness characterize of wireless communication. This protocol includes three algorithms to get higher throughput. The major work of this thesis includes but not limit in: (1) a fully opportunistic media access algorithm was proposed, (2) a half-deterministic media access algorithm is proposed, (3) normalizes contention window to differentiate the probabilities of accessing the channel between nodes with different channel conditions, (4) a testbed prototype based on ath9k wireless driver was developed.

CHAPTER II

MOTIVATION

This thesis based on some previous works. This chapter will discuss them and the motivation to conduct this thesis.

II.1 Opportunistic Transmission and Opportunistic Access

There are several researches have been conducted to exploit the dynamic characteristic of wireless channels, such as OAR[3] and MOAR [20]. OAR is a protocol based on other rate adaptation protocols, like RBAR[7] and ARF. Its main idea is to exploit channel conditions first with RBAR, after getting the accurate current data rate as much as possible, it transmits multiple packets in proportion to the ratio of current data rate over the basic rate. For example, if the current bit rate is 11 Mbps and the basic rate is 2 Mbps, then the ratio should be $\lfloor 11/2 \rfloor = 5$, so OAR will transmits five packets instead one. Besides, the paper demonstrated that the coherence time in IEEE 802.11b is long enough to support the transmission of five packets over 11 Mbps. OAR can work because even the poorest channel can support the propagation of one packet over the basic rate even if the packet is fully loaded. Otherwise, the entire wireless communication cannot work. Moreover, OAR takes the same ratio to maintain temporal fairness between nodes. For example, the transmission term of five packets over 11 Mbps and one packet over 2 Mbps are almost identical. OAR works based on RBAR[7], so the transmission time can easily be notified to other nodes by setting the transmission time in RSH (Reservation Sub Header). Any other nodes hear the RSH message will adjust their NAV values to the new one implied in RSH. From the above discussion, we can see that OAR focuses on the data transmission phase after the transmitter wins the contention of the channel. Its main purpose is to determine how many packets should be transmitted opportunistically and how to keep fairness in this procedure, but not the way of nodes access to channel. We classify the protocols that focus on transmission stage like OAR as *Opportunistic Transmission* (OT) protocol, since they focus on how to transmit packets opportunistically. The protocol proposed in this thesis is much different with OTs, since it focuses on contention stage. It is designed to determine how to access the channel opportunistically. This thesis will category it as *Opportunistic Access*(OA) protocol.

Wireless communication has some inherent matters, like fading, interference and inadequate wireless channel resource. To improve the utilization of scarce wireless resources, opportunistic access is proposed in this thesis to grant the channel can be assigned to the node which is most likely to generate the largest instantaneous network throughput. Meanwhile, the node with the best channel conditions deserves the chance to use the channel because its channel may degrade later. This aggressive exploitation of user diversity is significantly beneficial to the performance of the overall network and individual nodes. Opportunistic access has been exhaustively exploited in coordinated multiple access networks like cellular systems [18]. The coordinators (base station) have the global information of the channel conditions to each user through pilot channels or slots. Then, the coordinators opportunistically schedule transmissions for users. However, the benefits of opportunism in random multiple access have not yet been fully exploited.

Opportunistic *transmission* [3] based on rate adaptation protocols has been demonstrated with significant improvements to performance in IEEE 802.11 random access networks where a node opportunistic transmits multiple frames if its bit rate is high, instead of traditional only one frame. Opportunistic transmission occurs after the channel contention, but it is still conducted with traditional non-opportunistic approach: equal long-term opportunities accessing. Namely, it exploits the local diversity at a node, but not the user diversity in a network. Because channel conditions vary temporally, the node with the best channel condition may not have the same conditions at a later moment. Regularly, equal probability accessing without opportunistic will degrade the entire network performance if the node with the best channel condition loses the contention. Therefore, opportunistic access is necessary and beneficial in a random multiple access network. They will be used to exploit the congregate opportunism in a network, i.e. user diversity.

In order to achieve the objective that the nodes with better channel condition have a larger probability to access channel, the initial minimum contention window will be computed in proportion to data rate since the data rate reflects the channel condition in multi-rate WLANs. From the discussion about CSMS/CA in the last chapter, we know that the sender should pick up a back-off value from range [0, CW_{min}]. If the CW_{min} of the node with the best channel condition is the smallest one comparing to all other nodes, the back-off value selected from it will have a great probability to be smaller than those choose from larger contention window. Certainly, the back-off value of a node with the highest data rate will reach zero first, so it can get channel first. Opportunistic media access also confronted with fairness, delay, and starvation issues [18].

II.2 Throughput Fairness and Temporal Fairness

CSMA/CA is based on a kind of anomaly that the node with lower bit rate will harm the throughput of the nodes with higher bit rate as well as the throughput of the whole network [13]. Since every node selects a back-off value from the same initial range([0, CW_{min}]) uniformly, all of them have the same probability to win the channel contention. When the node with lowest bit rate wins the contention, it will transmit data at the lowest rate. The channel will be occupied by this node a long time. The author in [13] has proved that even only one node transmits data at a lower rate will remarkable decrease the overall throughput of the whole network. However, the circumstance is much different if a node with a higher bit rate got the channel. If so, the transmission will finish in a relatively short time interval; a higher throughput can be achieved. In traditional CSMA/CA media access methods, the protocol actually leads to a situation that every node gets the same *throughput* due to it grants every node has the equal long-term probability to access channel, namely, equal transmission opportunities. This is so called *Throughput Fairness* protocol. When a sender finishing transmission, it will enter the channel contention again. From common sense, we know the nodes with better channel condition deserve higher throughput, which will benefit not only the throughput of the node itself, but the performance of the overall network. For this reason, many previous researchers, like TBR[17], proposed *Temporal Fairness* protocols for multi-rate WLANs. Experiments also show the temporal fairness protocol can lead to distinct improvement in aggregate performance while avoiding starvation. The new protocol proposed in this thesis will keep *time fairness* since it grants every node has the almost same occupancy time to transmit data. TBR [17] discussed the temporal fairness in detail, and [3] also keep temporal fairness in their work. This work inherited the merits in previous works in the aspect of fairness. Although it achieves long-term temporal fairness, it may starve nodes with low bit rates in a short term because they are less likely to be granted the use of the channel. Meanwhile, some applications such as real time multimedia have strict requirements on latency in practice. These problems have been extensively investigated in opportunistic coordinated access with many proportional fair scheduling algorithms proposed [12, 16, 9, 2]. It is also necessary to design opportunistic random access algorithms with the capability to address these issues.

CHAPTER III
PROTOCOL DESIGN

In the previous section, we have described the main idea to achieve the opportunistic multiple media access with temporal fairness, that is changing the contention window. In this section, we will elaborately discuss how to design the protocol. This protocol includes three parts and all of them will be elaborated in this section. The first two parts are two algorithms to compute the contention window in proportion to the current channel condition dynamically. The third algorithm not only compute the contention window just like the first one, but also change the selection method of back-off value from the uniform distribution to the normal distribution. The first two effectively differentiate the probability to make the nodes with higher data rate to win the channel contention. The protocol is expected can get higher throughput while keep temporal fairness than others. In this protocol, a node's current data rate is taken as the reference of channel condition. The three algorithms will be discussed in the following section one by one.

III.1 Fully Opportunistic

The first fully opportunistic method computes nonequal initial minimum contention window size as Formula (1) below whenever it is ready to contend channel for a new transmission. In the formula, contention window will be calculated in proportion to the ratio of current data rate over the basic data rate.

$$CW = \rho \times \frac{R_b}{R_i} \times CW_{base} \tag{III.1}$$

where R_i refers to the current bit rate of a particular node, R_b denotes the basic rate in a rate set. In the experiments, the basic rate is 13 Mbps when there are two streams over 20 MHz bandwidth with the short SGI disabled in IEEE 802.11n. CW_base is a constant basic value and α is introduced to make sure that computed window for the highest bit rate is larger than very small values to maintain the randomness in access. From this formula, intuitively, a higher bit rate leads to a smaller CW and thereby a larger probability to win the channel contention. Then, the computed CW can be utilized to provide opportunistic access.

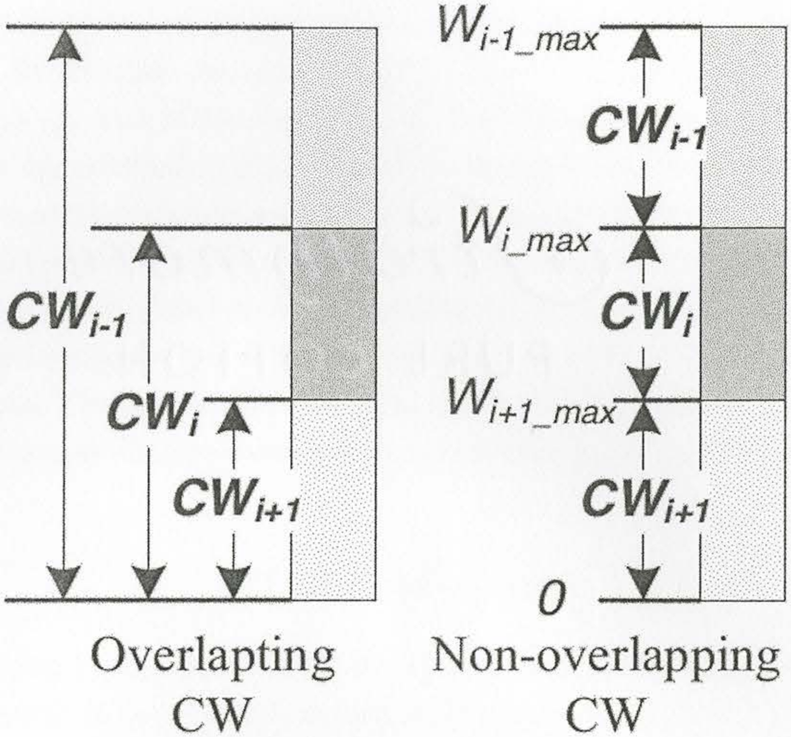

Figure III.1: Proposed Contention Window

However, since the back-off value is still selected from the contention window in *uniform distribution*, the nodes with lower bit rate still have the probability to get the smallest back-off interval because the contention windows of all nodes overlap with the same lower boundary. This overlapping contention window concept is illustrated on the left of Figure III.1. The second approach is introduced to guarantee the node with the highest bit rate win the channel contention.

III.2 Half-deterministic

The main idea of the second approach is to *separate* the contention window for nodes with different bit rates as the right of Figure III.1. It computes the contention window just like the first approach. However, in contrast to the first approach, the second one changes every group's lower boundary. In the first approach, the lower boundary is always zero, but in second one, the lower boundary is not zero any more but the value of one plus computed minimum contention window of the nodes with just higher data rate. On the right of Figure III.1, W_{i_max} and W_{i+1_max} denote the computed contention window of bit rate R_i and R_{i+1} respectively just like the first approach. Then, the upper boundary of contention window CW_i associated with bit rate R_i is assigned as the lower boundary of $W_{i+1\_max} + 1$. For example, the window is $[W_{i+1\_max} + 1, W_{i\_max}]$ to make sure the lower boundary ($W_{i+1\_max} + 1$) of the contention window CW_i of the lower rate R_i is certainly larger than the upper boundary (W_{i+1_max}) of the contention window CW_{i+1} of the higher rate R_{i+1}. This approach is "semi-deterministic" in that (1) the access of nodes with the same bit rate is random since they have the same initial window size to generate a back-off interval randomly, but (2) the access of nodes at different rates is deterministically prioritized because the lower rate nodes can never get a smaller back-off interval than the higher rate nodes. This approach provides tight opportunism by grouping nodes with similar channel conditions into the same random access team at the cost of randomness across teams.

III.3 Normal Distribution

The third approach is proposed to change the algorithm in selecting back-off value from the contention window. In this approach, the initial contention window is still constructed as in the first approach: different initial minimum contention window(the upper boundary) on bit rates but with the same lower bound 0 as on the left of Figure III.1. However, the method that nodes select back-off value from the contention window following a normal distribution other than uniform distribution. With the expectation of the normal distribution set to a proper value within the contention window and a proper standard deviation, the node with higher bit rate has significantly larger probability of obtaining the smallest back-off interval.

III.4 Temporal Fairness Avoiding Starvation

Temporal fairness is motivated and proposed in this thesis. It is used to maintain each node has approximately equal time in using the channel. In this situation, the nodes with high bit rate will generate high throughput that they deserve, and the nodes with low bit rate will not be detrimental to the throughput of the whole network.

To achieve temporal fairness while forwards large delays and starvation in opportunistic random access wireless networks, we propose to use a *bit rate normalized average throughput* as a metric in computing initial contention window size. Each node tracks the average throughput T updated in an exponentially weighted window t_w. Suppose Node K is the transmitter at a certain moment, T is updated at each node k that has packets ready for transmission in each time slot with low-pass filter as:

$$T_k[m+1] = \begin{cases} (1-\frac{1}{t_w}) \times T_k[m] + \frac{1}{t_w} \times R_k[m] & \text{if } k = K \\ (1-\frac{1}{t_w}) \times T_k[m] & \text{if } k \neq K \end{cases} \quad \text{(III.2)}$$

The *bit rate normalized average throughput* for node k with bit rate R_k in the m-th window is defined as: $T_{normalized}[k,m] = T_k[m]/R_k$. This is used to compute the initial contention window and Formula 2 is accordingly updated as:

$$CW = \alpha \times T_{normolizd}[k,m] \times CW_{base} \quad \text{(III.3)}$$

The contention with Formula 3 maintains two important features: temporal fairness and opportunism. The temporal fairness is provided, because the bit rate normalized average throughput can actually be explained as the *temporal quota* of a node in transmission period. This is clear if we rewrite the definition of $T_{normalized}[k,m]$ as $(t_c \times T_k[m]/R_k)/t_c$ in a period of length t_c: $t_c \times T_k[m]$ is the average transmitted payload in bits and thereby $t_c \times T_k[m]/R_k$ is the transmission time. The opportunism is provided by the bit rate in the definition. If a node has a higher bit rate, its $T_{normalized}[k,m]$ tends to be small. Therefore, it has a small contention window CW to win the channel. If it uses the channel for too long, it will have a large average throughput $T_k[m]$ that enlarges its contention window and decreases its chance to win the channel.

CHAPTER IV

DISCUSSION

The size of the weighted window, t_{win}, requires more investigation. It should be associated with the latency requirement of applications. If it is large, it allows the node of the optimal channel condition to use the channel for long duration, but may hurt other nodes having applications requiring low latency. If it is small, the channel is switched frequently among nodes of different bit rates and the overall performance may be degraded. Another concern is the support of QoS. If multiple classes of applications are involved, each class has different requirements, especially on latency. Then, a weight parameter ϕ_c for each class of application is necessary in updating the average throughput in Formula 2 as: $T_k[m+1] = (1-\frac{1}{t_w}) \times T_k[m] + \frac{1}{t_w} \times \phi \times R_k[m]$.

CHAPTER V

IMPLEMENTATION

This section will discuss the implementation and experiments result. The algorithms have been implemented based on ath9k wireless adaptor driver. I will describe the base of implementation and experimental data gathering in detail. In order to evaluate the performance in a large network, we also use NS-3 as the simulation tool to do the simulation. We will discuss the in the next section. In this section, we present the implementation platform and architecture, hardware and experimental environment, the methodology and the results.

V.1 Implementation Platform and Architecture

The testbed is configured with Wifi adaptors of Atheros R9xxx chipset because of some outstanding features: (1) Atheros R9xxx chipset support IEEE 802.11n mode, which already became a mainstream protocol in wireless communication nowadays. (2) Atheros R9xxx chipsets are fully supported by open source driver ath9k[19] for Linux based systems. Ath9k is a wireless driver which has been merged into Linux kernel since version 2.26.27-rc3. (3) The ath9k driver has its own rate control algorithm implemented, so the information we need, such as current rate, can get from inside of ath9k. (4)Ath9k supports lots of working modes, like AP, Mesh, Master. It is easy to test the proposed protocol in many circumstances. (5) The last one, ath9k enable us to control transmission frame by frame. So we can compute the contention window every frame to make it apportion to the transmission rate. The Linux wireless modules and the relationship between them have been presented and analyzed in [22]. At last, the implementation is based on Linux kernel version 3.3.1.

V.2 Experimental Environment

The experiments are conducted in the building with floor plan shown in Figure V.1. The building consists of offices and classrooms. We conduct all the experiments at night. The objective is to minimize the externally surrounding interference, since all classes dismissed and people got off work at night. The testbed consists of several experiment boxes with

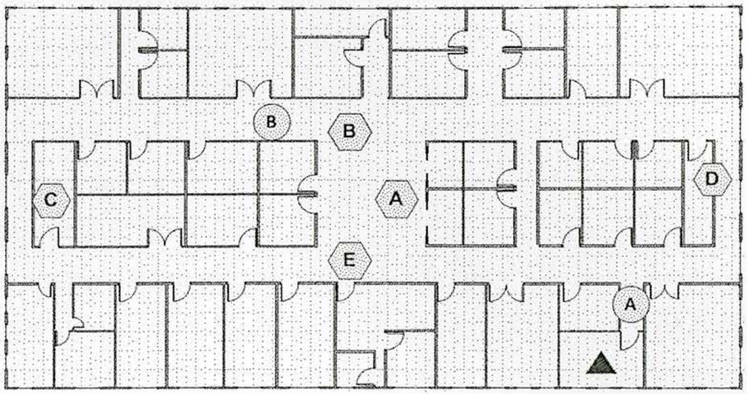

Figure V.1: Floor Plan

AMD G CPU, RAM 400M, hard driver 8G and Wifi adaptor with chip Atheros R9xxx. There are three non-overlapping channels(1, 6, 11) available in IEEE 802.11. We chose channel 1 since channel 6 and channel 11 have been heavily used by surrounding networks. As for the software, we use iperf to generate traffic from clients to the access point. We configure iperf to generate UDP traffic. The reason we do not choose TCP traffic is that UDP traffic is unidirectional, no acknowledge packet is required. This enables us to focus on transmission only. The access point is configured to work in IEEE 802.11n mode, use two transmission streams and 20MHz band width. Correspond to the configuration, the data rate set in Mbps will be: 13, 26, 39, 52, 78, 104, 117, 130.

V.3 Verification of Computed CW

The implementation has been evaluated by revealing the computed contention window and its relationship with bit rate. Figure V.2 shows the variation of contention window along with the variation of data rate.

Figure V.2: Relationship between CW and Bit rate

V.4 Infrastructure

This experiment is designed to reveal the performance of the protocol in infrastructure network. The main characteristic is that there is an access point exists in a network at least. Any node has to send data to the access point first, then the access point will forward to the destination node. It is necessary to test the uplink stream(the link from client to the access point) throughput in an infrastructure network. The Figure V.3 showed the specific topology. For software, we use iperf as the test tool. Iperf is widely used for networking load testing. It can generate both TCP and UDP data streams and measure the throughput of a network that is carrying them. Iperf allows users to set various parameters that can be used to control the iperf working mode and output. There are two parts in iperf: client and server. Functionally, iperf can measure the throughput between the two ends, either unidirectionally or bidirectionally. UDP traffic is chosen in the test since it is unidirectional, no acknowledgment is required. This feature enables us to focus only on the uplink transmission flow.

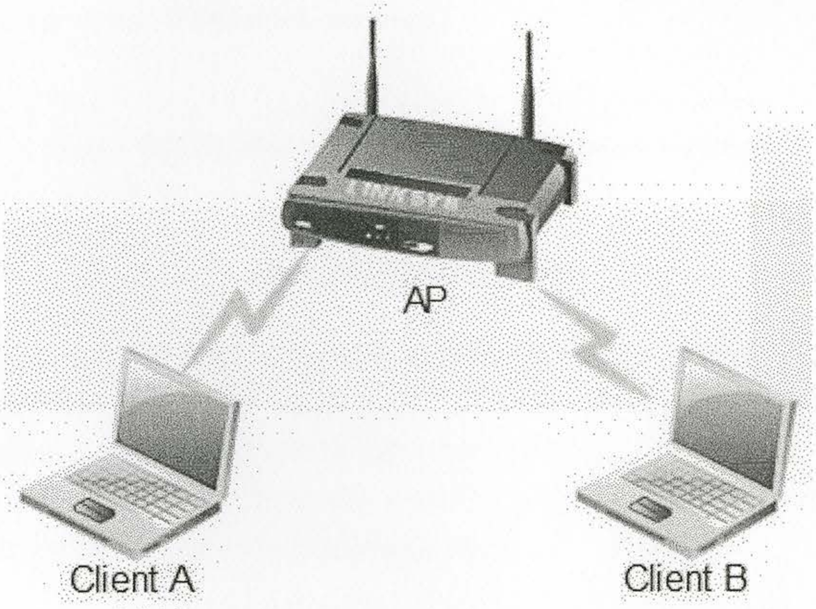

Figure V.3: Infrastructure Topology

In this experiment, the access point is configured to run an iperf server to discard the UDP traffic from clients. It starts UDP tests with the -u argument, which makes iperf will give invaluable information about the jitter and the packet loss. In this experiment, we record the jitter and throughput of UDP packets that reported by iperf server. The jitter is the latency variation and does not depend on the latency. We may have high response times but a low jitter. The jitter value is particularly important on network links supporting voice over IP (VoIP) because a high jitter can break a call. Iperf server also starts with parameter "-l 1" to report the transmission details every second, that is the shortest time interval iperf can provide.

In the first situation, the access point(AP in the figure) runs the original driver follow the IEEE 802.11n standard, client A and B run the driver with the proposed algorithm to reveal the network's throughput. In the second one, the access point still runs the original driver, but the two clients run original driver too. The purpose of this configuration is to make a comparison between the media access algorithm of original default IEEE 802.11n and the proposed algorithm. We run iperf client for one minute to transmit UDP stream to server. From the iperf manual, 10 seconds are enough to reveal the network throughput. In order to eliminate the variation at startup and completion of the experiment, we will trim the beginning 5 seconds and end 5 seconds. The recorded data include the delay jitter of UDP packets and the throughput of every client. We run the experiment twice and the final data will be the average value of these two runnings.

Figure V.4: Experiment results of Infrastructure Topology

V.5 Ad-hoc topology

Ad hoc topology is another wireless network architecture that is widely used. The protocol's performance in ad hoc network is significant as that in an infrastructure network. The most noticeable feature of ad hoc network is that no access point exists in it. A node may be a transmitter at a moment and forwarder even the destination at another moment. The Figure V.5 reveals the topology the experiments used.

In order to eliminate the influence from other facts like routing protocols. All nodes use the default routing protocol that implemented in MAC 80211 in the experiment. MAC 80211 is the wireless management layer in Linux kernel. Let us suppose the client C and D is a pair, B and E is a pair in this topology. However, client C and D cannot hear each other, client B and E cannot hear each other too. Any one of them wants to transmit data to the other side, it has to transmit the data to A first, and then A will forward the data to the other side. There are two hops in each communication link, which is the minimum

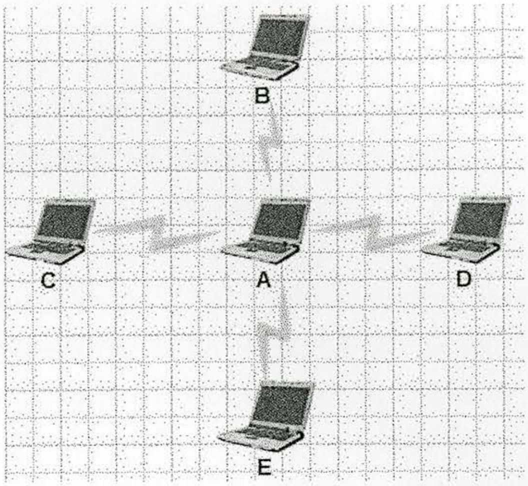

Figure V.5: Two Hops Topology

number of hops in ad hoc network(one hop situation is equivalent to infrastructure network). In this experiment, iperf sever run on node D and E, node B and C will be the client. We start B and C at the same time to transmit UDP traffic frame to D and E respectively. Just like the experiment in infrastructure topology, the recoded data also include delay jitter and throughput. We treat the raw data as same as we did in infrastructure mode: trim the beginning and ending to eliminate unstable intervals, get the average value. Figure V.6 show the experimental result.

Figure V.6: Experiment Results in Ad Hoc Topology

The left part of figure V.6 is the result of B running proposed algorithm. We can see that since the link of B to E has a better channel condition, the throughput produced by B is much higher than that produced by C. Meanwhile, since C has a lower bit rate, the jitter of C is larger than B. C has a smaller probability than B, so it may get the channel after multiple packets have been transmitted by B. The right part of figure V.6 is the result of node B and C running original algorithm. We can see that the throughput of B and C is almost the same, although the jitter has a little bit different. Besides, the aggregate throughput of revised algorithm is higher than the original algorithm.

V.6 Influence of t_w

In this section, we will discuss the influence of t_w value. In equation (2), t_w value determined the degree of opportunism. Theoretically, the computation of contention window will process once in t_w milliseconds. Therefore, the opportunism degree will be large when t_w increase, vice verse. When the opportunism degree is larger, the corresponding aggregate throughput will be larger, and the jitter of the node with lower bit rate will be larger. Because when the opportunism degree is larger, the node with higher bit rate has more opportunities to transmit its data, the aggregate throughput will be higher. Nevertheless, since the node with lower bit rate has low opportunities, its jitter will be larger, and starvation may happen.

Figure V.7: t_w's Influence to Throughput

Figure V.8: t_w's Influence to Jitter

The test is processed in infrastructure topology and corresponding throughput and jitter are recorded. In this test, the value 50ms, 80ms and 100ms are chosen. The result of throughput is shown in Figure V.7 and test result of jitter is shown in Figure V.8.

CHAPTER VI

RELATED WORKS

To my best knowledge, a few researches focused on opportunistic random access. However, there are many researches have been conducted to exploit the opportunistic feature of wireless channels and some protocols have been designed based on this feature. Through thoughtful design and careful implementation and simulation, they have very good performance contrast to those previous protocols.

OAR[3] is an opportunistic random media access protocol. It allows nodes to transmit data packets in proportion to the ratio of the current bit rate over the basic one. That means, nodes with the higher-than-basic bit rate are allowed to transmit multiple data packets but not only one.

OSAR[10] is proposed by researchers from the University of Florida. It first exploits channel variation, then try to increase the throughput of the overall system. OSAR not only matching the channel condition for a node pair in communications, but also adaptation rate according to the multi-user diversity.

There are other protocols utilize the variation of the wireless channel. Just as I said, the protocol proposed in this thesis is the first one to focus on opportunistic media access. This protocol inherent some merits from those previous protocols, including theory and experiment parts.

CHAPTER VII

CONCLUSION

A new media access protocol is proposed in this thesis, named OMA. Unlike the other media access protocols, OMA changes the opportunities of channel access of all nodes in a WLAN by changing the contention window in proportion to the bit rate, since the bit rate denotes the channel condition in multiple bit rate WLAN. OMA includes three algorithms to change the contention window with temporal fairness. Another significant contribution is that a stereotype has been implemented based on the existed wireless driver. The experiment shows that proposed protocol has a better throughput than default protocol no matter in an infrastructure network or Ad hoc network.

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