# Performance Analysis of Destination Multiplexing for Wireless LANs

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## Abstract

This paper describes the performance of the IEEE 802.11 Medium Access Control (MAC) Protocol [1] with and without destination multiplexing. IEEE 802.11 MAC protocol, the most widely used standard for wireless Local Area Networks (LANs), allows the wireless channel to be effectively shared by portable computers or wireless stations.

In this paper we consider the most common WLAN structure, one where wireless stations connect to a "backbone" wired LAN through a fixed base station or access point (AP). We consider traffic from APs to wireless stations since typically most of the data flows in this direction. We also take into account fading since it is unavoidable in real wireless channels.

An AP using First In First Out (FIFO) packet scheduling transmits or retransmits a data packet until it is successfully received. Fading that lasts for several retransmissions will degrade the performance of the system. A channel state dependent scheduling approach [2][3][4], destination multiplexing (DM), selects a different destination after a failed transmission. Because of the statistical independence of the fading between the AP and different wireless stations, a transmission to another destination is more likely to be successful.

We performed a computer simulation study of throughput and average delay for the overall system. The following factors are considered in our simulations: multiple APs, different traffic models, and effect of packet length. Our results show that under some conditions destination multiplexing can improve the throughput by up to 20% and decrease the average delay.

## 1. IEEE 802.11 WLAN Architecture and MAC Layer

In this section, we will briefly describe the IEEE 802.11 WLAN architecture and its MAC layer. There are two major architectures of the WLANs, Ad-Hoc and infrastructure networks. Our research focuses on the latter. The basic structure for this type is a few wireless stations and a fixed base station or access point (AP) which is connected to the backbone LAN by wire. The wireless stations are able to access the LAN through the AP. The packets are transmitted between the wireless stations and the wired LAN via the AP.

- **MAC Layer**

The IEEE 802.11 WLAN MAC layer coordinates the use of a shared medium. The MAC protocol specified in IEEE 802.11 is distributed coordination function (DCF) known as carrier sense multiple access with collision avoidance (CSMA/CA). CSMA/CA, which is implemented in all wireless stations and APs, is designed to reduce the collision probability when multiple stations access a medium. When using the CSMA/CA mechanism, if a station has a packet to be transmitted, it may transmit if the medium is free for greater than or equal to a DCF inter frame space (DIFS) time. If the medium is busy, it follows the backoff procedure to set a random backoff timer. The timer will decrease by one only when the medium is clear for a slot time period and will be frozen during the busy period. When the backoff timer reaches zero, the station transmits the packet. Since the probability that two stations choose the same backoff timer is very small, packet collisions are minimized. Carrier sensing (CS) can be achieved both through physical and virtual mechanisms. The realization of physical CS mechanism is through the physical layer and is described in the IEEE 802.11 standard. We will not touch on it here. The realization of virtual CS mechanism is through the exchange of special small request-to-send (RTS) and clear-to-send (CTS) packets before the actual data packet. Usually the data transmission procedure is as follows: the source station sends RTS after DIFS or backoff procedure. After short inter frame space (SIFS), the destination station sends CTS back if it received the RTS. Both RTS and CTS contain a Network Allocation Vector (NAV) which indicates the time duration that is reserved for transmitting the actual data packet. This information is transmitted to all other stations which will stop transmission during this period to avoid collision and solve the hidden station problem. Then, after SIFS, the source station sends the data packet if it received the CTS. When the packet is received successfully, as determined by the cyclic redundancy check (CRC), the destination station transmits an acknowledgment (ACK) packet to the source station after SIFS. The whole transmission mechanism is shown in Figure 1-1. Retransmissions happen when the source station doesn't receive CTS or ACK. The short retry limit or long retry limit is the maximum number of retransmissions of a data packet due to failure of receiving CTS or ACK.

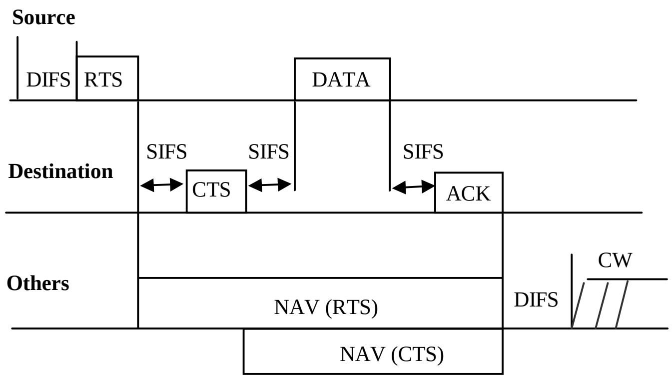


**Figure 1-1**

- **Backoff Time**

When a station receives a packet to be transmitted, it listens to the medium to ensure that there is no other node transmitting. If the medium is free, then it starts to exchange RTS/CTS and transmit the packet. Otherwise, the backoff procedure will be followed. In IEEE 802.11, random backoff timer is set as follows:

*Backoff Timer = Random() * Slot time*

Where Random() is the pseudo random integer drawn from a uniform distribution between 0 and CW. CW, which stands for Contention Window, is an integer between $CW_{min}$ and $CW_{max}$. For the current packet's first transmission CW is set to be $CW_{min}$. After each collision (indicated by not receiving CTS or ACK), CW for the current packet is doubled until it reaches $CW_{max}$ according to CA mechanism.

## 2. Fading Channel and Destination Multiplexing

Since there exists multi-path propagation and shadowing between the wireless stations and the AP, wireless channels are bursty and time varying. The wireless link is usually shared when the wireless stations communicate with the AP. If the AP tries to transmit the packets to the wireless stations, the First In First Out (FIFO) packet scheduling in the AP degrades throughput and causes unfair allocation of wireless bandwidth. This is because the AP must repeat the transmission of the head of line (HOL) packet due to the channel burst errors and the packets destined for the other wireless stations are blocked [5]. These packets may have been successfully transmitted during the repeated transmission period because of the statistical independence of wireless links. The destination multiplexing scheduling appears to be the solution to this problem. The destination multiplexing selects the "best" destination when the AP has packets queued for more than one destination. According to this method, in the AP there are many queues, each of which corresponds to a wireless station. In each queue, the packets are transmitted based on the FIFO principle. The AP continues sending from a queue only while RTS packet and data packet transmissions are acknowledged. We did the computer simulation to compare the results from destination multiplexing and non-destination multiplexing (based on the IEEE 802.11 MAC). We shall discuss the simulation and results in more detail below.

## 3. Simulations and Results

We use Omnet++[6] to conduct the simulation. We perform the simulation under both destination and non-destination multiplexing conditions. The Gilbert model [7] is used to simulate the fading channel. The basic structure is shown in Figure 3-1. The simulations are done as follows. First, we consider the one AP and four nodes model (Figure 3-2 and Figure 3-3). Then, the two APs and four nodes model is studied (Figure 3-4 and Figure 3-5). There are two traffic models employed in the simulation, one is Poisson packet arrival, the other is FTP where there are a fixed number of packets in each queue (Figure 3-6). Finally, we study the effect of packet length (Figure 3-7 and Figure 3-8). The throughput and the overall average delay are two statistical results that we obtain and analyze. For the FTP traffic situation, we calculate the throughput of one AP and one-to-nine nodes scenario. We assume that each node has a 2M byte file to be sent. Table 3-1 shows the default values used in the simulation. Based on the parameters in the table, we can deduce that the mean channel good and bad time is 90% and 10% respectively and the fading rate is 10Hz.

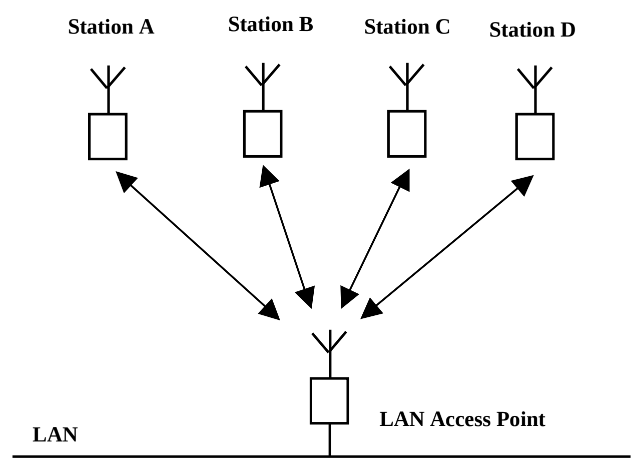


**Figure 3-1**

| **Parameter** | **Description** | **Default** |
|---|---|---|
| SIFS | Short inter frame space | 28 µs |
| DIFS | Distributed Coordination Function inter frame space | 128µs |
| Slot Time | | 50µs |
| RTS | Ready to send packet length | 160 bits |

| | | |
|---|---|---|
| CTS | Clear to send packet length | 112 bits |
| ACK | Acknowledgment packet length | 112 bits |
| DATA | Data packet length | 8000 bits |
| Bit Rate | Data rate | 1 Mbit/sec |
| CTS_Time out | The maximum waiting time for the CTS frame | 300µs |
| ACK_Time out | The maximum waiting time for the ACK frame | 300µs |
| Contention Window | Maximum and minimum size of Contention Window ($CW_{min}$, $CW_{max}$) | (15, 1023) |
| Short Retry Limit | Maximum number of retransmission of a packet because of no receipt of the CTS | 7 |
| Long Retry Limit | Maximum number of retransmission of a packet because of no receipt of the ACK | 4 |
| Probability of good state to bad state | This value must be defined when Gilbert model is used | 0.09 |
| Probability of bad state to good state | This value must be defined when Gilbert model is used | 0.01 |
| Update rate for Gilbert channel | Channel state change rate for the Gilbert channel | 10Hz |

**Table 3-1**

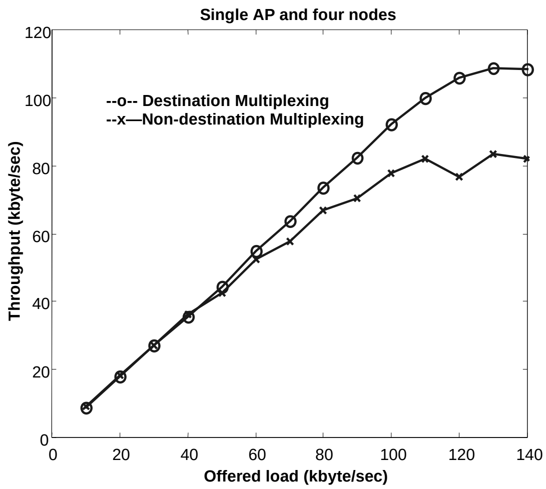


**Figure 3-2**

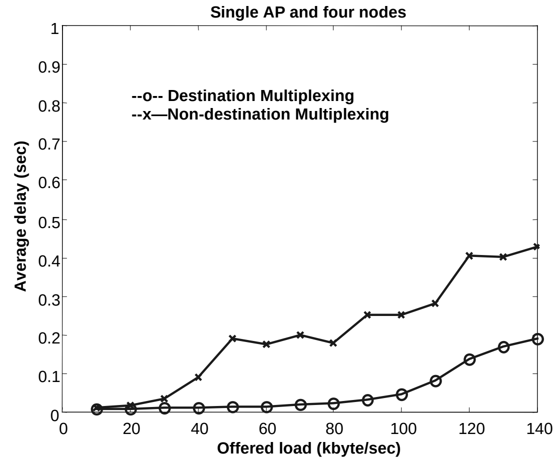


**Figure 3-3**

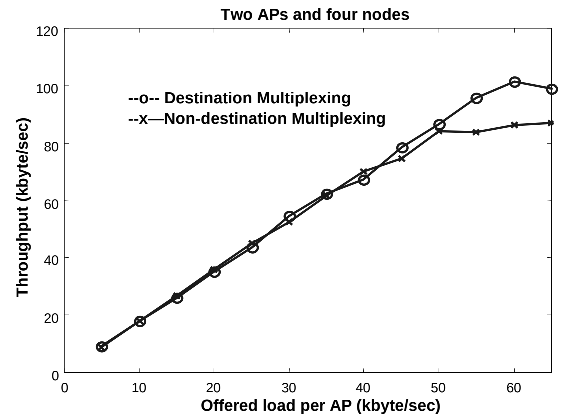


**Figure 3-4**

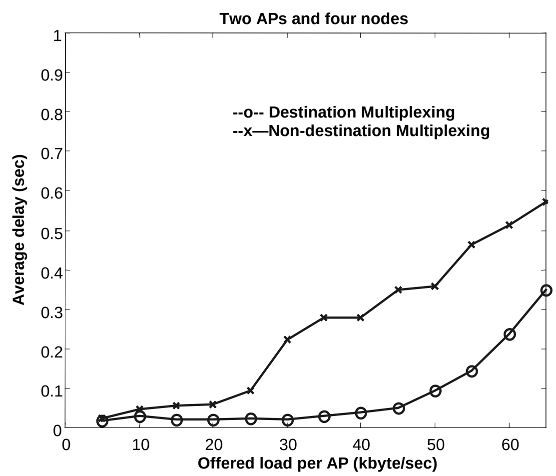


**Figure 3-5**

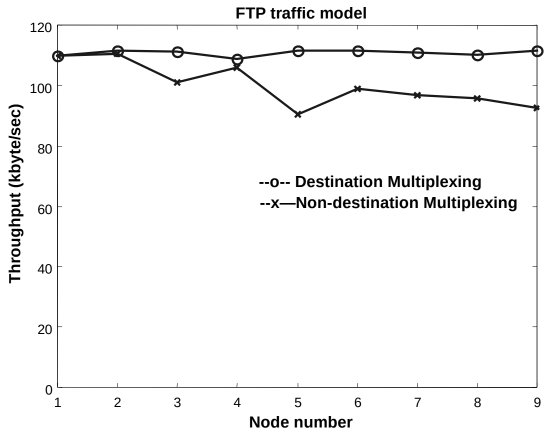


**Figure 3-6**

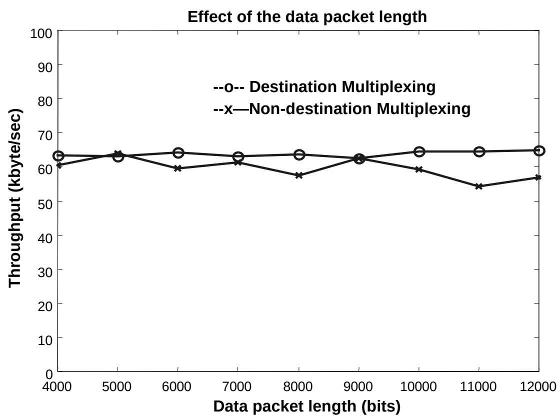


**Figure 3-7**

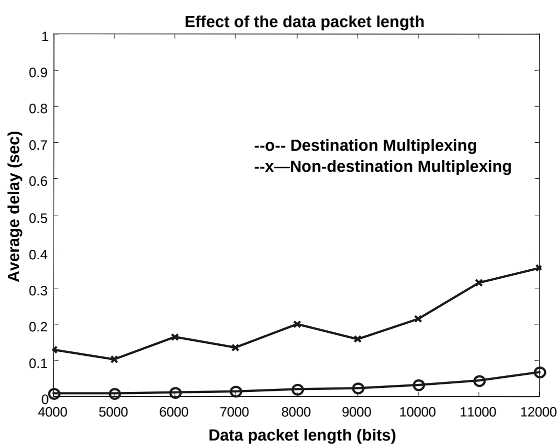


**Figure 3-8**

## 4. Results Discussion

Figure 3-2 and Figure 3-3 show the throughput and average delay when one AP is communicating with four nodes. We can see much improvement from using destination multiplexing. The throughput is increased by more than 20%. The average delay is also decreased. In Figure 3-4 and Figure 3-5, we investigate the effect of collision. Since there are two APs involved in the simulation, collision is unavoidable. Therefore, the throughput is a little bit less than that of one AP. However, the throughput of destination multiplexing is still 15% more than that of non-destination multiplexing. We also find the average delay performance of destination multiplexing is definitely better. From Figure 3-6, we can see that destination multiplexing performs much better when more nodes are added. In Figure 3-7 and Figure 3-8, we want to investigate the effect of data packet length on overall system performance. Average delay increases with increasing packet length. This is because it is more likely for the wireless link to fade during the transmission of a longer data packet. The destination multiplexing scheduling still has better performance.

## 5. Conclusions

In this paper, the performance (throughput and average delay) of wireless LANs with/without destination multiplexing using the IEEE 802.11 MAC protocol was studied by computer simulation. We consider the effects of collisions, data packet length, and two different traffic models. We found the performance of the overall system using destination multiplexing is significantly better. We found throughput increases up to 20% and even more significant reductions in average delay.

## References

[1] IEEE, Piscataway, NJ, IEEE 802.11 – Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, May. 9, 1997. P802.11D6.1

[2] M. Inoue, “Channel state dependent resource scheduling for wireless message transport with framed ALOHA-reservation access protocol”, IEICE Transaction on Fundamentals of Electronics, Communications and Computer Sciences, pp 1338-1346, July 2000

[3] C. Fragouli, *et al*, “Controlled multimedia wireless link sharing via enhanced class-based queuing with channel state dependent packet scheduling”, Proceedings of IEEE INFOCOM 98, pp 572-580

[4] Pravin Bhagwat, *et al*, “Using channel state dependent packet scheduling to improve TCP throughput over wireless LANs” Wireless Networks, pp 91-102, 1997

[5] Pravin Bhagwat, *et al*, “Enhancing throughput over wireless LANs using channel state dependent packet scheduling”, Proceedings of IEEE INFOCOM 96, pp. 1133-1140

[6] Andras Varga, OMNeT++ discreet event simulation system, http://www.hit.bme.hu/phd/vargaa/omnetpp.htm

[7] E. N. Gilbert, “Capacity of a Burst-Noise Channel”, The Bell System Technical Journal, September 1960, pp.1253-1265