ET4394 Wireless Networking

NS3 Project Report

by

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Introduction

IEEE 802.11ac is a wireless networking standard in the 802.11 family (which is marketed under the brand name Wi-Fi), developed in the IEEE Standards Association process,[1] providing high-throughput wireless local area networks (WLANs) on the 5 GHz band.[1]

This specification has expected multi-station WLAN throughput of at least 1 gigabit per second and a single link throughput of at least 500 megabits per second (500 Mbit/s). This is accomplished by extending the air interface concepts embraced by 802.11n: wider RF bandwidth (up to 160 MHz), more MIMO spatial streams (up to eight), downlink multi-user MIMO (up to four clients), and high-density modulation (up to 256-QAM).

Unlike IEEE 802.11a and IEEE 802.11b which usually performs to be acceptable for area range within 30m, 802.11ac shows the probability to deploy outdoor WLAN for a larger range. ns-3 is a discrete-event network simulator for Internet systems,

targeted primarily for research and educational use. ns-3 is free software, licensed under the GNU GPLv2 license, and is publicly available for research, development, and use.[2] ns-3 provides models for 802.11a, 802.11b, 802.11g, 802.11n (both 2.4 and 5 GHz bands) and 802.11ac physical layers. Hence, it is used in this project to simulate the performance of different networks.

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Project Description

2.1. Objective

In this project, the performance of 802.11ac Wifi network and the performance of 802.11b Wifi network will be compared in the scenario with long distance between the access point and the station. The maximum transmission range will be measured at different transmission powers under these two protocals. Finally, due to the differences within their physical layers, the performance of these two networks, especially the range, will be compared.

2.2. Hypothesis

When the distance between the access point and station is larger than 50m, the 802.11ac network will have a better performance than the 802.11b network. The working range of Wifi network is affected by the signal frequency, the transmission power and the environment. Higher bands are faster but lower bands travel further. Hence, since 802.11ac uses higher bands, the cover range of 802.11ac network will be less than that of 802.11b when the nodes mobility, transmission power and propagation model are the same. But within the working range, 802.11ac network will have a better performance.

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Results and Analysis

Figure 3.1 shows the simulation result under different protocals. In this project, only one access point and station are created each time.

3.1. Scenario

Table 1 shows the scenario of two networks:

	802.11b	802.11ac
Channel Width	22 MHz	80 MHz
Channel Frequency	2.407GHz	5.000 GHz
Data Rate	11 Mbps	260.0 Mbps
VHT Mode	N	Y
Payload Size	1472 Bytes	
Propagation Delay	Constan tSpeed Propagation Delay Model	
Propagation Loss	Friis Propagation Loss Model	
Flow	1 STA -> 1 Ap	

Table 1. Simulation Scenario

3.2. Distance vs. Throughput

Figure 3.1 shows the relation between nodes distance and average throughput. The attenna gain is set to be 0, hence the permitted maximum transmit power for 802.11 standard will be 100 mW [1]. Therefore, three transmit powers are tested for each kind of network: 16.0206 dBm (40 mW), 18.4510 dBm (70 mW), 20 dBm (100 mW).

It shows that for both protocols, higher transmit powers will give larger working area. Within the working area, the average throughput keeps at the same value. But once the station left this area, the average throughput will drop significantly for all kinds of protocols with various transmit powers.

Within the working range, the 802.11ac network has a much better performance with an stable average throughput of 5859.15 Mbps while that of the 802.11b network is around 3510 Mbps. This is because of the high data rate of 802.11ac network.

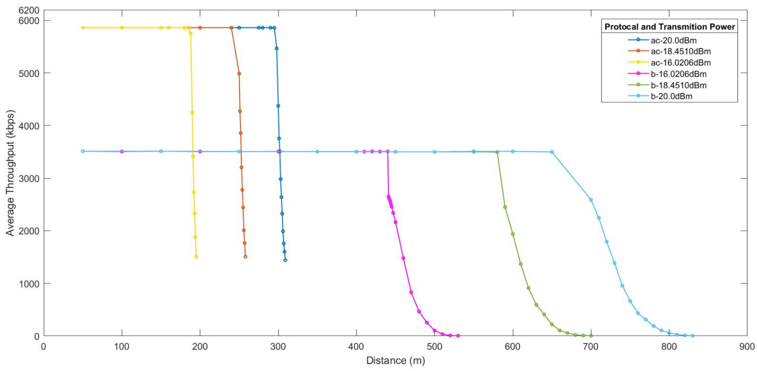

Figure 3.1: Average throughput vs. distance between access point and station

However, the maximum working distance for 802.11ac is not larger than that of 802.11b. The range is affected by the transit power, antenna ability, ED and Cca thresholds and the environment. In this project, the transit power, antenna gain, thresholds and the power propagation and loss model are all the same. The problem lays in the `Friis Propagation Loss Model`.[3] In this model, the received power is calculated by:

$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 L}$

With:

P_r: reception power (W)

P_t: transmission power (W)

G_t: transmission gain (unit-less)

G_r: reception gain (unit-less)

λ: wavelength (m)

d: distance (m)

L: system loss (unit-less)

Since the 802.11ac network has the frequency of 5GHz, the wavelength of the signal becomes smallter than the wavelength of 802.11b network. Hence, the reception power decreases much faster. Once it drops under the detection threshold, the reception antenna will not recognize these signals.

3.3. Distance vs. Delay

When the distance is within the working range, 802.11ac network shows a relatively good performance with almost no delay for these packets. Unlike the 802.11b network, whose delay increases gradually when the station leaves the working range,

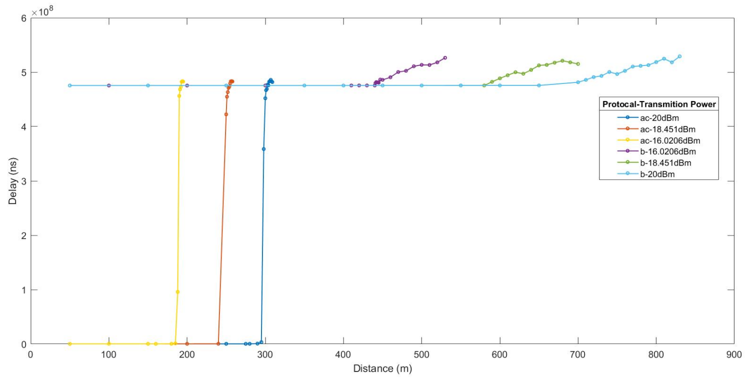

Figure 3.2: Packet delay vs. distance between access point and station

the delay of 802.11ac network grows significantly. But on overall, the delay of 802.11ac network is still much less than that of 802.11b network.
Network delays include processing delay, queuing delay, transmission delay and propogation delay. Since both networks are using `Constant Speed Propagation Delay Model`[4] during simulation, we can conclude the propagation delays are the same and the differences are related to other kinds of delays.

3.4. Distance vs. Packet Loss

The packet loss is defined as the percentage of packets lost with respect to packets sent.[5] Packet loss is typically caused by network congestion. When content arrives for a sustained period at a given router or network segment at a rate greater than it is possible to send through, then there is no other option than to drop packets.[5]
Figure 3.3 shows that the packet loss of 802.11b network is more than 40%, which is not acceptable in practice. Packet loss is typically caused by network congestion. However, for the 802.11ac network, 5 GHz band is used with 13 channels, providing more channels to use and hence less congestion. Therefore, the packet loss of 802.11ac network represents a value close to 0.

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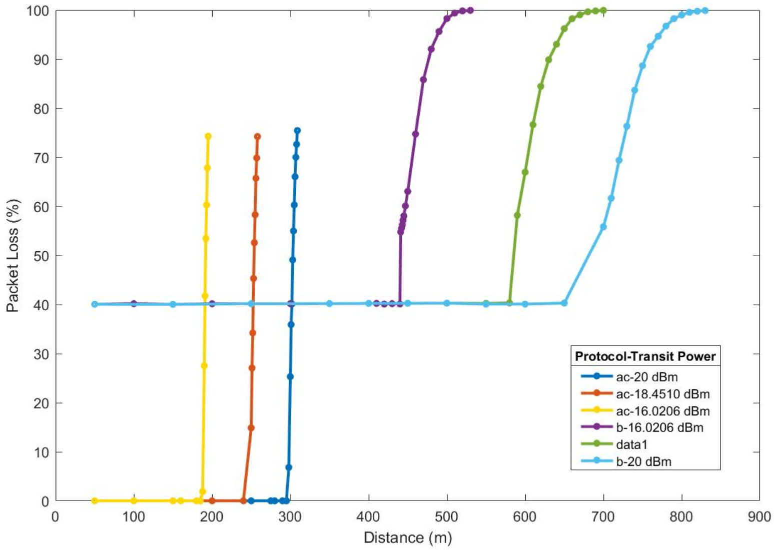

Figure 3.3: Packet Loss vs. distance between access point and station

Conclusion

Based on all the simulation results, the performance of the 802.11b and 802.11b networks are shown in Table 2. The "Range" is defined as the maximum distance that the network can keep its normal throughput. All other values in this table are measured within this range.

	802.11b			802.11ac		
	16.0206 dBm (40 mW)	18.4510 dBm (70 mW)	20 dBm (100 mW)	16.0206 dBm (40 mW)	18.4510 dBm (70 mW)	20 dBm (100 mW)
Range (m)	440	580	650	180	240	295
Average Throughput (Mbps)	3500 ~ 3510			5859.15		
Delay (ns)	475400000 ~ 475650000			468000 ~ 486000		
Packet Loss (%)	40.067 ~ 40.283			0.017		

Table 2. Simulation Result

It can be concluded that:

- Compared to 802.11b, 802.11ac network has a better performance in the aspects of delay, average throughput and packet loss.
- Under the same protocol, higher transmit power will give further Wi-Fi range.
- The performance of 802.11 networks changes significantly once the distance between access point and station exceed the working range due to the thresholds.
- The transmit power of 802.11ac network decreases with the distance quickly due to the large frequency.
- Within the working range, the average throughput, delay and packet loss do not based on the transmit power.

The original proposed scenario is to simulate the Long-range Wi-Fi outdoor Wi-Fi [6] under 802.11ac and compare it with the normal indoor Wi-Fi under 802.11b protocol. But due to the time and knowledge limitation, I could not figure out the entire structure of 802.11ac which has many new technologies such as MU-MIMO, Very High Throughput frame and Beamforming technology. Moreover, currently there is no NS3 example for 802.11ac network online which increases for implementation.
Due to these reasons, there are some work can be done to improve this project:

- There are only one access point and one station node, which could not represent the advantage of 802.11ac network to support multi-user cases.
- All nodes are static now. Other mobilities can be introduced to enrich the result.
- `Friis Propagation Loss Model` and `Constant Speed Propagation Delay Model` are used in this project. However, for long-distance, outdoor networks, other propagation model in NS3 like `Okumura Hata Propagation Loss Model` may be more suitable.

References

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4. https://en.wikipedia.org/wiki/Network_delay
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6. https://en.wikipedia.org/wiki/Long-range_Wi-Fi