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Performance Comparison of Peer-Peer vs Client-Server 802.11ac WLAN using 80Mhz Channel Size

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Abstract: In this paper, the performance of IEEE 802.11ac wireless LAN using IPv4, IPv6, TCP, UDP, peer-peer, and client-server networks is investigated while implementing WPA2 security. The latest operating systems are used in the study, Windows 10 for workstations and Server 2016 for the server. Packet sizes used range from 128 to 1408 Bytes. Parameters measured were bandwidth, Round Trip Time (RTT), and CPU utilisation. For TCP, client-server WLAN with IPv4 has the highest throughput for all packets, having 105 Mbps for packet size of 128 Bytes and 620 Mbps for packet size of 1408 Bytes while peer-peer with IPv6 had the lowest throughput ranging from 79Mbps for 128 Bytes packet and 335 Mbps for 1408 Bytes packet. For UDP, the highest throughput is achieved again by client-server with IPv4. The bandwidth ranged from 88 Mbps at packet size of 128 Bytes to 808 Mbps for 1408 Bytes and the lowest throughput is that of peer-peer with IPv6, with the lowest of 77 Mbps at packet size of 128Bytes and 403 Mbps for packet size of 1408 Bytes.

Keywords: Wireless LAN, IEEE 802.11ac, 80Mhz Channel, Client Server, Peer-Peer

1. INTRODUCTION

In the modern communication era, almost everyone has used some sort of wireless electronics device allowing users to connect to the world wide web assisting in the day to day tasks and communications. From devices such as laptops, mobile phones, and video game consoles, wireless technology allows users to communicate with each other and share resources, have entertainment, shop, and get education, all with the freedom to move around without being restricted by wires. Wireless LAN (WLAN, WiFi) is commonly used to access the internet from anywhere, any time. The newest version of the WLAN standard is IEEE802.11ac, that is gradually replacing the 802.11n standard [1]. IEEE802.11ac is a "supercharged" upgrade over IEEE802.11n, many of the features introduced in IEEE802.11n are carried over and improved, along with new features exclusive to IEEE802.11ac.

One of the features of IEEE802.11ac is enhanced MIMO (multiple input, multiple output) technology. IEEE802.11n was the first standard to introduce MIMO system so that signal strength is boosted, and connections between a client and wireless access point become stronger, leading to better performance [2]. MIMO increases throughput and performance, by using multiple transmitter and receiver pairs, instead of one. Before the development of MIMO in IEEE802.11n, a single transmitter and receiver was used to transmit signals between devices in a wireless network, known as a radio chain or SISO (single in, single out) systems. MIMO allows multiple channels to be aggregated into a single stream, for example allowing two channels of 20MHz to be aggregated into a single 40MHz channel, theoretically doubling throughput, using spatial streaming of 4x4 in IEEE802.11n [3]. IEEE802.11ac doubles this to 8x8 (8 spatial streams) channels to be multiplexed into a single stream. To achieve this, the inclusion of SDMA (space division multiple access) was developed into the standard, meaning that streams are not separated by frequency, but instead resolved spatially [3]. IEEE802.11ac can channel aggregate of up to 8x8 20Mhz for up to 160MHz bandwidth, with 256 QAM (quadrature amplitude modulation). Also, IEEE802.11ac devices introduce MUMIMO (multi user multiple input output) which will allow the device to send multiple frames to multiple receiver devices at the same time, allowing for higher quality antennas [3].

Another technology implementation new to WLAN was beamforming that uses directional antennas. Prior to 802.11ac, the antennae used in WLAN standards were omnidirectional. The signal was scatters in 360 degrees covering all areas around the access point. As result of this is reduced security, if anyone is in within the range,

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the signals will reach them. The radio channels also are busy in all the possible directions [4]. An alternative is Beamforming that sends the signal in the direction of client-access point path using directional antennas. Beamforming enhances the wireless performance by increasing the Signal-to-Noise Ratio (SNR). Using higher channel sizes of up to 160Mhz, enhanced MIMO and beamforming, IEEE 802.11ac theoretically can provide up to 1.3 Gbps [5]. This is the first wireless standard to take throughput up to gigabit speeds. When compared to IEEE802.11n that uses both 2.4Ghz and 5Ghz and can have channel size of up to 40Mhz, IEEE802.11ac only operates at the 5Ghz band and can use 20, 40, 80 and 160 MHz bandwidth channels [2].

Both the peer-peer and client-server WLANs network with was set up using latest operating systems Microsoft Windows 10 and Microsoft Windows Server 2016 operating systems. WPA-2 security is implemented in all test scenarios, for both peer-peer and client-server test beds, scenarios which are used in home and business environments.

Previous work indicated that operating systems has impact on performance of the wireless LAN standards [6]. It is therefore important to evaluate latest WLAN standard using latest windows operating systems, Windows 10 for client and Server 2016 for server. These operating systems have the most user-friendly GUI (graphical user interface) in the series and bring new networking capabilities such as voice searching with Cortana, network connection with the Microsoft Xbox game console, screen sharing with mobile devices, and better multitasking [7]. These operating systems utilize both IPv6 (Internet Protocol version 6) and IPv4 (Internet Protocol version 4). The results were provided for both IPv4 and IPv6. IPv6 is the latest version, and is expected to overtake IPv4, as it provides built-in IPsec encryption, better QoS provisioning, more efficient routing, more addressing space, and does not need to incorporate a DHCP server or NAT (network address translation). We evaluated both IPv4 and IPv6.

This paper aims to provide real life network set up and data comparison of IEEE802.11ac using 80Mhz channel size, for both peer-peer and client-server networks with latest Windows operating systems, using IPv4, IPv6, TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). The parameters investigated were throughput, round trip time, and CPU usage.

Some of the related works regarding performance of IEEE802.11ac are as follows. In 2017, Kolahi and Almatrook [8] investigated the impact of WPA2 security on bandwidth and latency in a client-server wireless network using the IEEE802.11ac standard. In 2015, Siddiqui et al. [9] investigated the parameters that restrict IEEE 802.11ac from achieving the maximum bandwidth beyond 1Gbps. Then Y. Zeng, et al. [10] studied the effect of some parameters including distance, power consumption, and interference on 802.11ac throughput in an indoor environment. In 2014, Dianu, et al. [11] studied the impact of distance, propagation environments, and Wi-Fi interference on 802.11ac WLANs performance. Demir et al. [12] did an examination of IEEE 802.11ac WLANs with regards to the power consumption of the access point during transfer data. In 2011, M. Park, et al. [13] carried out a simulation experiment to study the effect of using the primary and secondary channel bandwidths between 20, 40, and 80MHz for the first wave of 802.11ac (draft version).

To the authors knowledge, there is no research to date in the literature on comparing peer-peer and client-server using IEEE802.11ac and the latest windows operating systems as operating system affects the WiFi perfromance [6]. The motivation behind this study therefore is to evaluate TCP and UDP, IPv6 and IPv4, for IEEE 802.11ac for the above and produce new results.

This paper is organized as follows. This section covered introduction, related works, and motivation. In the next section, the network set up and hardware specification are discussed. Section three covers the traffic measurement and data generating tools. Section four is practical results and discussion. Section five covers the conclusions followed by future works.

2. NETWORK SETUP

To measure the performance of IEEE802.11ac for both peer-peer and client server, two networks were set up in a laboratory environment, a peer-peer and client server network with identical hardware in both scenarios. For the client-server network, a Windows Server 2016 operated machine was installed on the server connected to a Ubiquiti UniFI AC-HD business wireless access point via a Cat 6 crossover cable. The Windows 10 Client machine connected wirelessly to the server through the access point. The distance between the access point and the client machine was well within meters, to maintain the maximum signal strength. The channel bandwidth of the Ubiquiti UniFi AC-HD access point was configured for using 80MHz bandwidth channel size. The hardware specifications for both client and server machines consist of an Intel Core i7 Duo 6300 2.87 GHz, a Western Digital Caviar 160 GB hard drive, 16.00 GB of RAM. The client machine was installed with an Asus AC-68 802.11ac wireless network interface card. The test bed setup remained consistent for all testing conducted in the client-server section. The test bed diagram is shown in Figure 1.

Figure 1. Client-Server Testbed.

The setup of the peer-peer network is the same as the one for client-server, except using two client machines, without any servers, connected to each other through the access point. Both client machines were installed with Windows 10 and a home group was created between them through the Ubiquiti UniFi AC-HD business access point. The hardware specifications for both client machines were same as the client-server environment. The test bed remained identical during the duration of testing. The test bed diagram is shown in Figure 2.

Figure 2. Peer-Peer Test-Bed.

3. DATA GENERATION & TRAFFIC MEASUREMENT TOOLS

D-ITG 2.8.1 (Distributed Internet Traffic Generator) [14, 15] tool which that is available both in command line and graphical user interface was selected as the primary data generation and traffic measurement tool to evaluate the performance of the networks. D-ITG is a freeware tool which us capable of producing traffic at packet level, accurately replicating appropriate stochastic processes for both IDT (Inter Departure Time) and PS (Packet/Payload Size). This tool supports packet generation of both IPv4 and IPv6 and can generate traffic at TCP, and UDP. It supports Linux, and Windows operating systems. With this powerful tool, traffic can be generated and then throughput, RTT delay, and packet loss can be measured.

4. PRACTICAL RESULTS

This section presents data on the throughput, RTT (Round Trip Time) and CPU utilization of TCP and UDP for both IPv4 and IPv6 on an IEEE802.11ac peer-peer and client server networks with WPA2 security. Note the bandwidth for systems without WPA2 security is higher than data reported here as WPA2 reduces the bandwidth of a wireless link [16]. For each packet size, several test runs are carried out, and the results averaged out with the standard deviation calculated. As the results of runs are different, the runs are continued until average results with 95% confidence internal is achieved. This usually occurred after average of 15 to 20 runs.

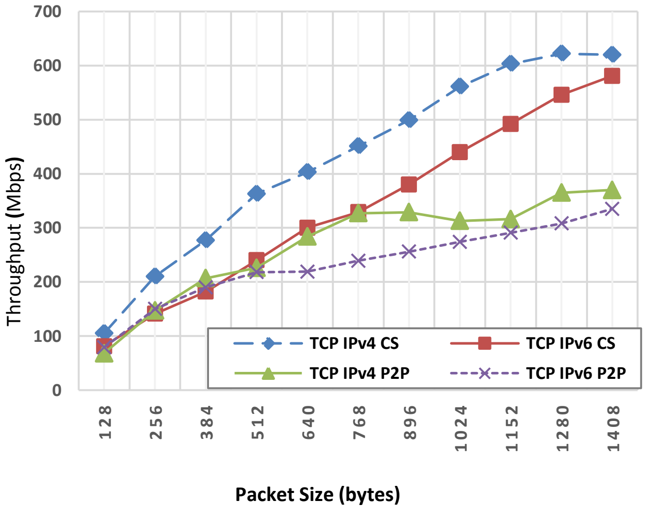

Figure 3. TCP Throughput of 802.11ac Client-Server (CS) vs. Peer-Peer (P2P), Channel Width 80MHz.

Figure 3 presents throughput of the TCP protocol for peer-peer and client-server networks using IPv4 and IPv6. All testing is performed on two Windows 10 machines for peer-peer and a Windows Server 2016 and Windows 10 client for client-server. Packet sizes used range from 128 to 1408 Bytes, and through observation, as packet size increases, so does the throughput. Client-server WLAN with IPv4 has the highest throughput for all packets, having 105 Mbps for packet size of 128 Bytes and 620 Mbps for packet size of 1408 Bytes. Peer-peer with IPv6 had the lowest throughput ranging from 79Mbps for 128Byte packets and 335 Mbps for 1408 Bytes packet.

As can be seen in the diagram, overall, IPv4 generally outperforms IPv6, and client server generally outperforms peer-peer. However, at low packet sizes, the difference was not much. Some of our run results at low packet sizes had high variance, partly because a very large number of packets involved.

The reason for some of these results discussed at the end.

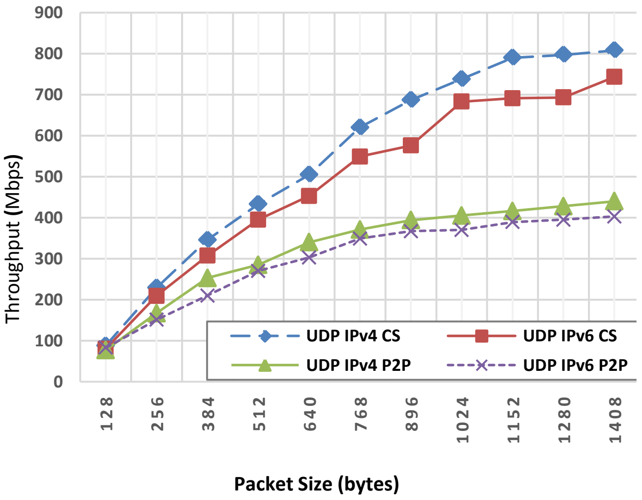

Figure 4. UDP Throughput of 802.11ac Client-Server (CS) vs. Peer-Peer (P2P), Channel Width 80MHz.

In Figure 4, the results gathered from the same networks as Figure 3, but instead of TCP, UDP protocol is used. All other specifications and settings remaining identical. The highest throughput is achieved again by client-server with IPv4. The bandwidth ranged from 88 Mbps at packet size of 128 Bytes to 808 Mbps for 1408 Bytes. The lowest throughput is that of Peer-Peer with IPv6, with the lowest of 77 Mbps at packet size of 128 Bytes and 403 Mbps for packet size of 1408 Bytes.

Similar to TCP, IPv4 had higher bandwidth than IPv6 and client server had higher bandwidth than peer-peer. At low packet sizes, overall, the graph shows that from packet 128 to 512 Bytes, throughput performance differences are not that great between peer-peer and client-server, but slowly the gap is increased as packet sizes increased. Generally low packet sizes data had high variance, due to large number of packers involved.

Figures 3 and 4 also show that overall UDP had higher bandwidth than TCP for all scenarios. The highest TCP bandwidth was 620 Mbps (Figure 3) while the highest UDP bandwidth was 808Mbps (Figure 4).

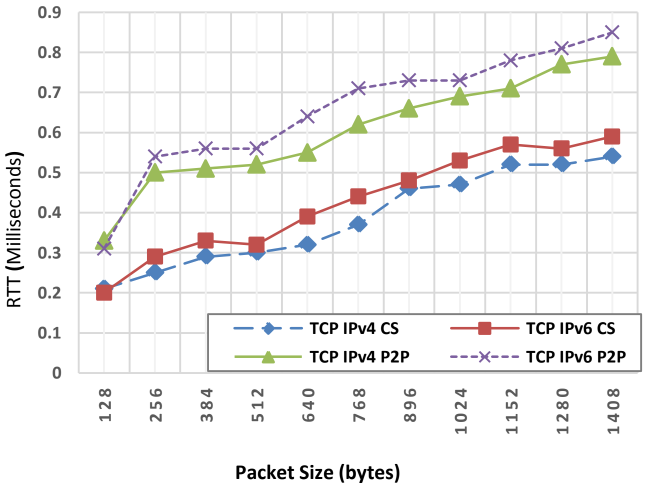

Figure 5. TCP RTT of 802.11ac Client-Server (CS) vs. Peer-Peer (P2P), Channel Width 80MHz.

Figure 5 shows the TCP RTT for both client-server and peer-peer networks using IPv4 and IPv6. The settings and configurations of the network are the same as those used for Figures 3 and 4, so that results are consistent. The graph shows that TCP IPv4 client-server has the lowest latency and outperforms other protocols (UDP/IPv6) displayed, having 0.21 milliseconds for packet size of 128 Bytes, and 0.54 milliseconds for packet size of 1408 Bytes. TCP IPv6 peer-peer had the most latency for all packets, having 0.31 milliseconds for packet size of 128 Bytes and 0.85 milliseconds for packet size of 1408 Bytes.

As can be seen in Figure 5, client server had lower delay than peer-peer and IPv4 outperforms IPv6. For packet size of 128 Bytes, IPv4 and IPv6 had similar latency, but this could be because the runs for 128 Bytes had high variations from one run to next. Similar results were obtained in other studies at 128 Byte packet size [17].

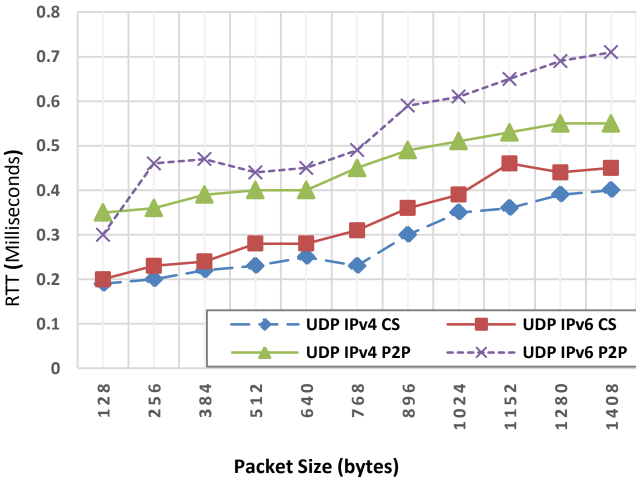

Figure 6. UDP RTT of 802.11ac Client-Server (CS) vs. Peer-Peer (P2P), Channel Width 80MHz.

Figure 6 presents UDP RTT data with the same network setup and settings as that used in Figure 5, but we used UDP protocol instead of TCP. IPv4 client-server achieved the lowest RTT in all packet sizes, having 0.19 milliseconds at packet size of 128 Bytes and 0.4 milliseconds at packet size of 1408 Bytes. The highest latency is for peer-peer with IPv6 having 0.7 milliseconds at packet of 1408Bytes. Overall, IPv4 has lower RTT than IPv6. Client-server performs better (lower RTT) than peer-peer for both IPv4 and IPv6. When comparing the results of Figure 6 with Figure 5 (TCP RTT), UDP in all instance (peer-peer, client-server, IPv6, IPv4) performs better than TCP with a lower RTT. UDP IPv4 client-server peaks at 0.4 milliseconds while its TCP counterpart has 0.55 milliseconds. The results here are in line with throughput data (Figures 3 and 4) where UDP outperforms TCP. This means UDP has better throughput and lower RTT, however there UDP runs were not as stable as TCP.

We also measured CPU usage for both peer-peer and client server networks, using TCP, UDP, IPv4 and IPv6. For TCP, the results show that overall client-server network is utilizing more computers CPU than peer-peer. IPv4 UDP peer-peer has the least amount of CPU usage (11%). The highest CPU usage is by TCP IPv6 client server utilizing 20% of the computer’s CPU. Generally, IPv6 has more usage than IPv4, and TCP more than UDP.

For UDP, generally, client server has more CPU usage than peer to peer. The highest usage was for client server using IPv6 utilizing 17% of the CPU. Peer-peer with IPv4 have the least amount of CPU usage at 7%.

Generally, IPv4 had higher bandwidth than IPv6, less RTT, and less CPU usage, as we observed in the above data. This is due to higher overhead in IPv6 (40 Bytes) compared to IPv4 (20 Bytes) [18]. IPv6 used 128 bit for addressing while IPv4 has 32 bits. Higher overheads slow the network as it needs more processing.

Due to lower overheads in UDP datagram (8 Bytes) compared to TCP segment (20 Bytes) [19] that is more complex with more fields, UDP has higher bandwidth, less RTT, and less CPU utilization, as it needs to process less overheads. This is consistent with the results we obtained. The increase in bandwidth and RTT as the packet size increases is likely due to the amortization of overheads associated with larger packet sizes (larger payloads) [6]. For all cases, Client Server results had higher throughput and lower RTT than peer-peer results. This is due to having a server involved that makes the communication more stable and effective with better management capabilities. However, client server had higher CPU than peer to peer due to increased amount of processioning coming with more complexity of client server networks.

For the above reasons, UDP is the protocol of choice when reliability is not very important and user data is not involved. UDP is used in communications such as DNS (Domain Name Services), DHCP (Dynamic Host Configuration Protocol), SNMP (Simple Network Management Protocol), and VoIP (Voice over Internet Protocol). However, UDP is a connection less protocol, and has no error correction and considered un reliable.

5. CONCLUSION

In this paper, results show that IEEE802.11ac has much higher bandwidth performance and less latency when implemented in a client-server network model than that of a peer-peer network. The highest speed, with WPA2 implemented, was 808 Mbps (UDP IPv4 client-server) compared with 440 Mbps (UDP IPv4) that was the peak for peer-peer network. However, client server had higher CPU utilization. For both TCP and UDP, the results also show that IPv6 has lower bandwidth and higher latency than IPv4 due to higher overhead in IPv6 packet. IPv6 has high overhead of 40 Bytes compared to 20 Bytes overhead of IPv4 [18].

For TCP, Client-server WLAN with IPv4 has the highest throughput for all packets, having 105 Mbps for packet size of 128 Bytes and 620 Mbps for packet size of 1408 Bytes while Peer-peer with IPv6 had the lowest throughput ranging from 79Mbps for 128Byte packets and 335 Mbps for 1408 Bytes packet.

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UDP had higher bandwidth and lower RTT than TCP due to bigger overheads in TCP packet compared to UDP overheads. The reason for the overall higher throughput results for UDP is that UDP has a lower overhead of (8 Bytes) than TCP overhead of (20 Bytes) [19].

6. FUTURE WORKS

The future work includes testing more operating systems such as Linux, using multiple client machine for multi machine throughput testing, and open system testing, as results here were for a wireless LAN with WPA-2 security. The results can also be obtained for various channel sizes in 802.11ac and compare the results with 802.11n.

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