PA1.docs

Q1-1 How many packets did the client send in total?

* **The client sent 4 packets in total. The first packet was sent at 2 seconds, and the last packet was sent at 8 seconds. Each packet is sent at an interval of 2 seconds, and no packet was sent at t = 10 seconds because the client application was stopped at that time.**

Q1-2 Open the PCAP files using Wireshark. From the timestamps of packets at the client, what is the round trip time (RTT) as seen by the client? What is the relationship between the RTT and the P2P link delay?

* **The RTT is 36ms. The RTT is equal to twice the P2P link delay (10ms \* 2 = 20ms) plus the processing time at the server and client. This matches the console output, which shows the RTT for each packet as 36ms.**

Q1-3 What is the data (content) in the payload of each packet? This can be found in the Data field in Wireshark for any UDP packet. How many bytes did each layer (UDP, IP, PPP) add to the payload?

* **The Wireshark capture shows a total length of 1054 bytes for each UDP packet. This is made up of 1024 bytes of the application data, 8 bytes of UDP header, 20 bytes of IP header, and 2 bytes of PPP header.**

Q1-4 Can you adjust the channel delay in a manner that will lead to a packet collision (between the packet sent by the client and the echo packet from server)? If yes, give an example of such a channel delay. If not, then why not?

* **You cannot create package collision by adjusting channel delay. This is because PPP is full duplex, which means it provides separate channels for each direction. There are also only two nodes on the link.**

Q2-1 What is the configured application data rate at the client? What is the final (total) average throughput (printed as Average throughput after every simulation) achieved? Is there a difference? If yes, why?

**The configure application data rate at the client is 100Mbps. The final (total) average throughout achieved is 32.4017 Mbit/s. There is a significant difference of about 67.6 Mbps which is ~67.6% loss.** **This is because of some of the following reasons:**

* **WiFi has a lot of overhead (MAC layer, PHY layer) which reduces the effective throughput.**
* **TCP has its own overhead (ACKs, congestion control, etc.) which reduces the effective throughput.**
* **The distance between the AP and the STA is 10 meters, which is not ideal for WiFi communication. The signal strength decreases with distance, leading to lower throughput.**
* **The physical layer rate is set to HtMcs7, which is not the highest possible rate. Higher rates can be achieved with better channel conditions and shorter distances.**

Q2-2 When does the throughput drop to zero? We will use this distance in the next question. Position the STA and AP to be within 5 meters of each other. Enable PCAP tracing for this simulation (variable pcapTracing)

* **The throughput drops to zero at approximately 165 meters where the average throughput is zero.**

Q2-3 Enable packet capture (variable pcapTracing). From the PCAP, observe just the first second of simulation. What is the configured beacon interval?

* **The configured beacon interval is 102.4ms which is the standard 802.11 default interval**

Q2-4 What is the first frame from the STA? What triggers this frame?

* **The first frame from STA is frame 3 at t = 113.9ms and it is an Association request (Association Request, SN=0, FN=0, Flags=.......C, SSID="network”).**
* **It is triggered by the receiving beacon at t = 102.4ms. The STA receives beacon frames from the AP advertising SSID "network"**

A screenshot of a computer

Description automatically generated

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Q3-1 Set enableRts to false. Run the simulation with and without enableLargeAmpdu. What is the throughput observed? Elaborate on the reason for the difference observed.

* **With enableLargeAmpddu set as True**
  + **Average throughput STA1: 23.8864 Mbit/s**
  + **Average throughput STA2: 24.6731 Mbit/s**
  + **Average total throughput: 48.5595 Mbit/s**
  + **Average throughput STA1:** 0.0011776 **Mbit/s (Hidden Node)**
  + **Average throughput STA2:** 0.0341504 **Mbit/s (Hidden Node)**
  + **Average total throughput:** 0.035328 **Mbit/s (Hidden Node)**
* **With enableLargeAmpddu set as False**
  + **Average throughput STA1: 15.6833 Mbit/s**
  + **Average throughput STA2: 15.8646 Mbit/s**
  + **Average total throughput: 31.5479 Mbit/s**
  + **Average throughput STA1:** 0.005888 **Mbit/s (Hidden Node)**
  + **Average throughput STA2:** 0.0306176 **Mbit/s (Hidden Node)**
  + **Average total throughput:** 0.0365056 **Mbit/s (Hidden Node)**
* **With enableLargeAmpddu set as True there is 53.9% throughput improvement because more time is spent transmitting actual data instead of protocol overhead. It reduces MAC layer overhead by combining multiple packets into larger frames, sharing headers and inter-frame spacing across multiple data units.**

Q3-2 Based on the range that you found out in Q2-2, if the STAs are positioned at [−x0,0,0] and [x0,0,0], at what value of x0 approximately does this scenario create hidden terminals? Position the STAs in a manner that there are hidden nodes (STAs should always be in range of the AP). Save this ns-3 source file as “q3.cc”.

* **At approximately x0 = 165 meters, the hidden terminal problem was confirmed. This proves that at 330m STA-to-STA separation, continuous collisions occur at the AP.**

Q3-3 With enableLargeAmpdu set to false, run the simulation with and without RTS/CTS. How do the throughputs compare? Is there a difference? Give reason.

* **With enableRts set as True**
  + **Average throughput STA1: 13.7002 Mbit/s**
  + **Average throughput STA2: 13.4176 Mbit/s**
  + **Average total throughput: 27.1178 Mbit/s**
  + **Average throughput STA1:** 0.011776 **Mbit/s (Hidden Node)**
  + **Average throughput STA2:** 0.0270848 **Mbit/s (Hidden Node)**
  + **Average total throughput:** 0.0388608 **Mbit/s (Hidden Node)**
* **With enableRts set as False**
  + **Average throughput STA1: 15.6833 Mbit/s**
  + **Average throughput STA2: 15.8646 Mbit/s**
  + **Average total throughput: 31.5479 Mbit/s**
  + **Average throughput STA1:** 0.005888 **Mbit/s (Hidden Node)**
  + **Average throughput STA2:** 0.0306176 **Mbit/s (Hidden Node)**
  + **Average total throughput:** 0.0365056 **Mbit/s (Hidden Node)**

Q3-4 Briefly explain the frame exchange sequence with RTS/CTS enabled. How does it mitigate the problems caused by hidden nodes?

Instead of each STA being in constant communication with the AP, they both constantly send CTS/RTS Packets to verify that they wont collide and mangle packets with STA that are outside of their range. This mitigates the hidden node by having the AP let each STA know that it’s communicating with either STA.

Q3-5 With enableLargeAmpdu set to true, run the simulation with and without RTS/CTS. How is the throughput affected by RTS/CTS? Compare the effect of RTS/CTS from Q3-4 and Q3-3. When is it more reasonable to use RTS/CTS?

With A-MPDU enabled the effects of RTC/CTS on throughput aren’t as drastic. It seems like it more reasonable to use RTS/CTS while A-MPDU is also enabled.