802.11n Performance Validation Experiments with ns3-dev and ns-3.30

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Abstract

This document discusses the experiments conducted and results obtained for comparison of Dr. Westall's netsim application with similar simulations run using an ns-3 script in ns3.30 and ns3-dev environments.

1 Experiments

The following experiments, from Dr. Westall's report [1], will be conducted to validate the 802.11n network performance results obtained using netsim network models. A modified version of the ns-3 example script, wifi-simple-adhoc-grid, will be used for validation. Details of this script and experiment parameters used are discussed in 2.

1. Two node maximum distance - We will create a two node linear network using 802.11n WiFi. The purpose of this test is to identify the maximum distance at which the two nodes can communicate without loss. We will additionally identify the distance at which latency and loss are first observed for transmitted packets. Results will be compared against those from Table 3 in [1]. Experiment parameters include:

   - APDU size - 1472 bytes
   - Total simulation time - 30 seconds
   - Sending rate - 1 packet/second
   - Inter-node distance - Increase in increments of 1 distance units till the distance measures of interest are identified
   - MCS - 0,1,2
   - OLSR routing protocol not enabled

   Metrics to be reported are:

   - Minimum and average latency observed for each MCS rate

2. Two node maximum achievable throughput - Using the two node linear grid, we will increment the sending rate till maximum achievable throughput is reached. Maximum achievable throughput is the highest rate at which no packet loss is observed. Results will be compared against those from Table 6 in [1]. Experiment parameters include:

   - APDU size - 1472 bytes
   - Sending rate - Increase in increments of 0.1 Mbps till max. achievable throughput identified
   - Inter-node distance - 4 distance units
   - MCS - 0,1,2
   - OLSR routing protocol enabled

   Metrics to be reported are:

   - Observed max APDU throughput

3. Linear model performance - We will simulate a 7x1 linear node grid model in ns-3. The inter-node distance will be the max. distance identified from the experiment 1 to ensure that a packet traverses all nodes. Packets will be sent from node 0 to node 6 and latency will be measured. Results will be compared against those from Table 9 in [1]. Experiment parameters include:

   - APDU size - 1472 bytes
   - Sending rate - 200, 300, 400 (Kbps)
   - Total simulation time - 40 seconds (from 20 - 60s in the simulation)
   - Inter-node distance - Max. distance from Experiment 1
   - MCS - 0
   - OLSR routing protocol enabled

   Metrics to be reported are:

   - One way latency
   - Tx Rate, Rx Rate

2 ns-3 script parameters

The following parameters will be used in the modified ns-3 script, wifi-simple-adhoc-grid, to re-create testing conditions similar to [1].

1. WiFi Phy mode - Data rates corresponding to the MCS being tested for.
2. WiFi Settings - YansWifiPhyHelper::Default.

3. Channel Settings - YansWifiChannelHelper::Default. From [2], default means a channel model with propagation delay equal to a constant, the speed of light, and a propagation loss based on a log distance model with a reference loss of 46.6777 dB at reference distance of 1m.

4. WiFi Standard - WIFI_PHY_STANDARD_80211n_5GHZ with 20 MHz channel width and short guard interval.

5. Mobility Model - ns3::ConstantPositionMobilityModel; the script uses ns3::GridPositionAllocator to set up the nodes as per experiment specifications.

6. Application Layer - UDP unicast sending through a traffic generation function defined in the script.

7. Traces and logs -

   (a) Per node level packet captures

   (b) All routing tables every 2 seconds

   (c) OLSR neighbor cache every 2 seconds

   (d) ASCII trace file of all exchanged packets in the grid

2.1 ns3 script notes

1. Setting the MCS data rates - While OfdmRate[X]Mpbs is used for setting data rates for 802.11a, data rates for 802.11n are set using HtMcs[X]. For 802.11a, X refers to the data rates in Mbps and takes values of 6,9,12,18,24,36,48, and 54. For 802.11n, X refers to the the MCS index and takes values from 0 to 7.

3 Results from ns-3-dev

3.1 Experiment 1

Lat(Min) and Lat(Avg) are the minimum and average latency observed at the *No Loss* distance. *No Loss* distance is the distance at which all packets transmitted by Node 0 are received by Node 1. *Max Dist* is the distance at which at least 1 packet transmitted by Node 0 is received by Node 1. Latency values are in μs.

Fig. 1 compares the results obtained from experiment 1 (Table 1) with corresponding results in Table 3 of [1].

3.2 Experiment 3

Packet loss and re-transmissions were being observed when using the *No Loss* distance from Table 1 as the inter-node distance. Lowering the inter-node separation to 80 curbed both these issues while ensuring that each packet traversed all nodes in the grid. The simulation trace file shows that each packet sent from node n is received by nodes $(n-1)$ and $(n+1)$,

MCS	Lat(Min)	Lat(Avg)	No Loss	Max Dist
0	1948	4145.4	97	103
1	992	2682.9	77	81
2	676	1684.73	62	66
3	516	1083.97	46	49
4	356	1150.2	37	39
5	276	671.7	25	27
6	252	718.5	23	25
7	228	615.7	21	22

Table 1: Max distance supported with each 802.11n MCS index in ns-3-dev

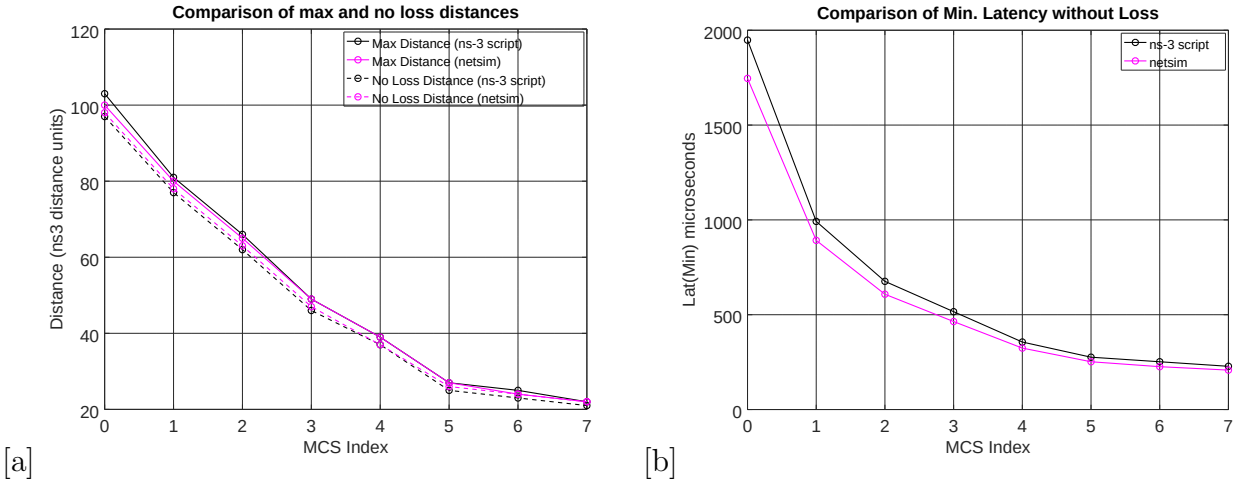

Figure 1: (a) Comparison of operational distances (b) Comparison of minimum latency without loss

and forwarded by node $(n+1)$ till the sink is reached. Packet loss of 1-2 packets was observed as the sending data rate exceeded 400 kbps.

Sending Rate (kbps)	Tx Rate	Rx Rate	One-Way Delay (ms)
200	199.90	200.04	12.59
300	302.25	302.49	12.58
400	406.47	406.98	12.59
500	539.93	540.38	12.57
600	659.85	660.55	12.58
700	742.29	743.04	12.58
800	841.14	842.09	12.58
900	981.33	982.41	12.58
1000	1071.26	1071.84	12.58

Table 2: One-way delay for 7x1 grid

The actual Tx and Rx rates seemed to be higher than the specified sending rate. This

could be because of the sleep interval was used to implement the sending rate. The packet sending interval was calculated as

$$(SendingRate(kbps) * 1000)/(8 * APDUsize(bytes))$$

.Additionally, the observed Rx rates were slightly higher that the Tx rates. The Tx and Rx rates were calculated as

$$(\#Packets * APDUsize(bytes) * 8)/(T * 1000)$$

where T is the difference in Tx or Rx times of the first and the last packet.

Fig. 2 compares the results obtained from experiment 3 (Table 2) with corresponding results in Table 9 of [1].

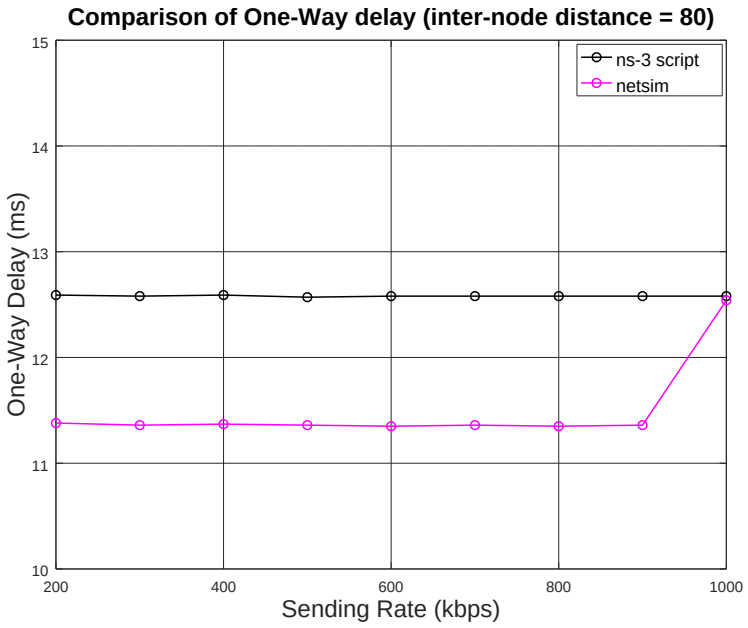

Figure 2: Comparison of obtained OWD at inter-node spacing of 80 distance units

4 Results from ns-3.30

4.1 Experiment 1

These results compare to Table 7 in [1]. Observed max and no loss distances are same as those in [1]. Latency observed is higher than that in [1].

4.2 Experiment 3

This experiment was conducted for MCS index 0 and the internode distance was set to max distance observed in Table 3, 51 distance units. Latency observed was consistent with results from ns-3-dev and packet loss was observed at sending rates of 300 kbps and higher.

MCS	Lat(Min)	No Loss	Max Dist
0	1948	51	51
1	992	51	51
2	676	51	51
3	516	48	50
4	356	38	39.4
5	276	26.1	27.4
6	252	24	25
7	228	21.9	22.5

Table 3: Max distance supported with each 802.11n MCS index in ns-3.30

Results from Tables 3 and 4 might indicate that while the max distance is a factor of the ns3 version used, observed latency is a factor of the message dissemination application used. These results compare to Table 14 in [1].

Sending Rate (kbps)	One-Way Delay (ms)
200	12.596
300	12.608
400	12.611
500	12.621
600	12.672
700	12.704
800	12.689
900	12.696
1000	18.001

Table 4: One-way delay for 7x1 grid in ns-3.30

References

[1] J. Westall, *Performance Analysis of ns3 Models of 802.11n Adhoc Grid Networks with Linear Traffic Flows*, Jun. 2020. [Online]. Available: https://people.cs.clemson.edu/ jmarty/projects/lowLatencyNetworking/ProjectMaterial/PerformanceA MW-5-26-2020.pdf

[2] Jun. 2020. [Online]. Available: https://www.nsnam.org/doxygen/classns3$_{11y}ans_wifi_channel_helper.htm$