# 10 Study how throughput and error of a Wireless LAN network changes as the distance between the Access Point and the wireless nodes is varied

## 10.1 Introduction

In this experiment we will study the physical layer standard for IEEE 802.11b WiFi. A physical layer standard (abbreviated as PHY standard) defines the mechanism by which logical information bits are transmitted over the wireless channel that has been allotted to the WiFi system. WiFi systems are confined to working in an approximately 80MHz bandwidth in the 2.4GHz ISM band. Within this bandwidth, any particular WiFi Access Point (AP) must choose to work in one of 13 channels, each of nominal bandwidth 22MHz. In this experiment, we aim to study how the packet error performance of an IEEE 802.11b AP-STA connection varies as the distance between the AP and the STA varies.

## 10.2 Background

The IEEE 802.11b standard defines 4 digital modulation schemes for such channels. All are based on Direct Sequence Spread Spectrum (DSSS) with a chipping rate of 11 million chips per second (11 Mcps). An 11 chip Barker code yields 1 million symbols per second (1 Msps). These symbols are Differential Phase Shift Keying modulated to get 1 bit per symbol, thereby yielding 1 Mbps, and Quarternary Differential Phased Keying modulated to get 2 bits per symbol, thereby yielding 2 Mbps. In order to get 5.5 Mbps and 11 Mbps, each symbol is made from 8 chips, so that the symbol rate is 1.375 Msps. A technique called Complementary Code Keying (CCK) then provides 4 bits per symbol, yielding 5.5 Mbps, and 8 bits per symbol, which yields 11 Mbps.

A simple qualitative fact is that, for a given signal to noise ratio at the receiver, as the modulation scheme attempts to send more bits per second, the bit error probability increases. This happens because, as the bit rate increases, the bit sequences that the receiver needs to distinguish between become closely packed, so that bit errors become harder to resolve. The signal to noise ratio (SNR) at the receiver depends on the transmission power, the attenuation of power from the transmitter to the receiver, and noise power.

$$SNR = \frac{P_{received}}{N_0 W}$$

Where $N_0$ is the noise power spectral density (W/Hz) and $W$ is the system bandwidth (nominally 22 MHz)? The noise power works out to approximately $-100$ dBm. The received power $(P_{received})$ is obtained by subtracting the *path-loss,* between the transmitter and the receiver, from the transmitted power (e.g., $P_{transmit} = 0$ dBm, would arise from a transmit power of 1 mW). A simple expression for path-loss is given by

$$P_{received} = P_{transmit} - c_0 - 10\,\eta\, log_{10}\, d$$

where $c_0$ is the path loss at the "reference" distance of 1m, $\eta$ is the path-loss exponent and $d$ is the distance between the transmitter and the receiver It may be noted that this deterministic expression ignores random phenomena such as "shadowing" and "fading."

As $d$ increases, the received power decreases, e.g., doubling the distance reduced the received power by approximately $3\eta$, since $\log_{10} 2 \approx 0.3$. Typical values of $\eta$, indoors, could be 3 to 5, resulting in 9 dB to 15 dB additional path loss for doubling the value of $d$.

## 10.3 Network Setup

Open NetSim and click **Examples > Experiments > Impact-of-distance-on-Wifi-throughput-and-error > Sample-1** as shown below **Figure 10-1**.

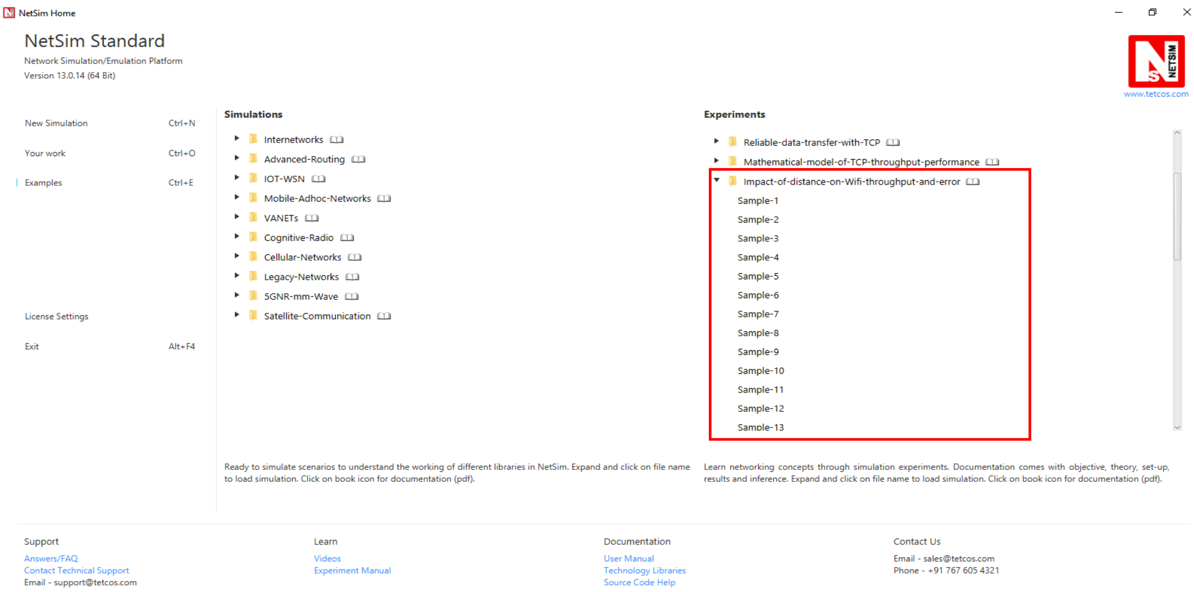


Figure 10-1: Experiments List

NetSim UI displays the configuration file corresponding to this experiment as shown below **Figure 10-2**.

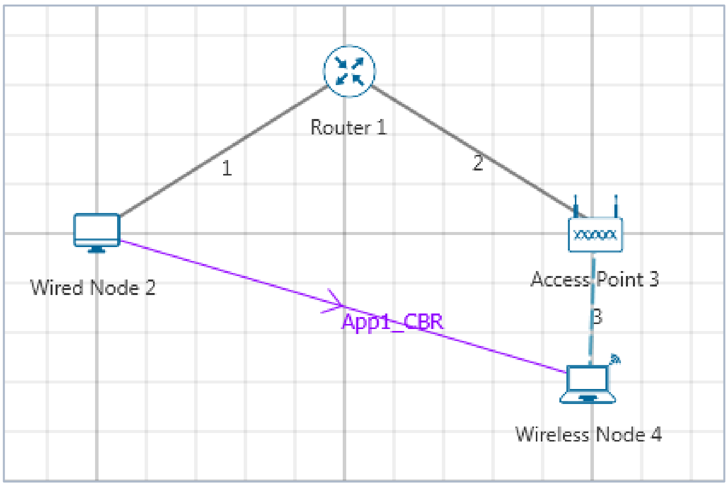

Figure 10-2: WiFi Network Scenario

## 10.4 Procedure

The following set of procedures were done to generate this sample.

**Step 1:** A network scenario is created in NetSim GUI comprising of 1 Wired Node, 1 Router, 1 Access Point and 1 Wireless Node in the **"Internetworks"** Network Library.

**Step 2:** In the Destination Node, i.e. Wireless Node 4, the Interface 1 (WIRELESS) > Physical Layer, Protocol Standard is set to IEEE802.11b and in the Interface 1 (WIRELESS) > Datalink Layer, Rate Adaptation is set to False.

**Step 3:** The position of the Wireless Node and the Access Point in the grid environment is set according to the values given in the below table see **Table 10-1**.

| Device Positions | | |
|---|---|---|
| | Wireless Node 4 | Access Point |
| X/Lon | 200 | 200 |
| Y/Lat | 130 | 100 |

Table 10-1: Device Positions

**Step 4:** Right click on **Wirelessnode** and **AccessPoint,** select Properties and select DCF as the Medium Access Protocol in the DATALINK_LAYER of INTERFACE_1

**Step 5:** Right-click the link ID (of a wired/wireless link) and select Properties to access the link's properties. The parameters are set according to the values given in the below table **Table 10-2**/**Table 10-3**.

| Wired Link Properties | |
|---|---|
| Max Uplink Speed (Mbps) | 100 |
| Max Downlink Speed (Mbps) | 100 |
| Uplink BER | 0.0000001 |
| Downlink BER | 0.0000001 |
| Uplink Propagation Delay (µs) | 5 |
| Downlink Propagation Delay (µs) | 5 |

Table 10-2: Wired link Properties

| Wireless Link Properties | |
|---|---|
| Channel Characteristics | Path Loss Only |
| Path Loss Model | Log Distance |
| Path Loss Exponent | 3 |

Table 10-3: Wireless Link Properties

**Step 6:** Right click on **App1 CBR** and select Properties or click on the Application icon present in the top ribbon/toolbar.

A CBR Application is generated from Wired Node 2 i.e., Source to Wireless Node 4 i.e., Destination with Packet Size set to 1450 Bytes and Inter Arrival Time set to 770 µs. It is set such that, the **Generation Rate** equals to 15 Mbps.

Transport Protocol is set to **UDP** instead of TCP.

**Step 7:** Packet Trace is enabled in NetSim GUI. At the end of the simulation, a very large .csv file is containing all the packet information is available for the users to perform packet level analysis.

**Step 8:** Plots are enabled in NetSim GUI. Run simulation for 10 sec.

Similarly do the other samples by varying the distance between Access Point and Wireless Node as 60, 85, 90, 100, 110, 115, 180, 260, 360, 400, 420, 440, 460, 480, up to 500 m.

## 10.5 Output

Note down the values of Data rate and Throughput for all the samples and compare them with IEEE standards.

Phy rate can be calculated from packet trace by using the formula given below:

$$Phy\ rate\ (802.11b)\ =\ Phy\_layer\_payload * 8/(phy\ end\ time - phy\ arrival\ time - 192)$$

192 microseconds is the approximate preamble time for 802.11b

Calculate PHY rate for all the data packets coming from Access Point to Wireless node. For doing this please refer section 8.5.1 How to set filters to NetSim Packet Trace file from NetSim’s User Manual. Filter Packet Type to CBR, Transmitter to Access Point and Receiver to Wireless node.

Since $\boldsymbol{PER} = \mathbf{1} - (\mathbf{1} - \boldsymbol{BER})^{\boldsymbol{PL}}$ where PER is packet error rate, PL is packet length in bits and BER is bit error rate, we get $\boldsymbol{BER} = \mathbf{1} - \boldsymbol{e}^{\frac{\log(1-PER)}{PL}}$

$$Packet\ error\ probability = Packets\ Errored / Packets\ Transmitted$$

On tabulating the results, you would see **Table 10-4.**

| Distance (m) | 802.11b | | | | |
|---|---|---|---|---|---|
| | **PHY rate in Mbps (Channel capacity)** | **Application Throughput (Mbps)** | **Packets Transmitted** | **Packets Errored** | **Packet error probability** |
| **30** | 11 | 5.93 | 5110 | 0 | 0 |
| **60** | 11 | 5.93 | 5110 | 0 | 0 |
| **85** | 11 | 5.83 | 5099 | 70 | 0.0137 |
| **90** | 11 | 5.55 | 5058 | 276 | 0.0545 |
| **100** | 5.5 | 3.79 | 3266 | 0 | 0 |
| **110** | 5.5 | 3.79 | 3266 | 0 | 0 |
| **115** | 5.5 | 3.64 | 3253 | 117 | 0.036 |
| **180** | 2 | 1.68 | 1445 | 0 | 0 |
| **260** | 2 | 1.68 | 1445 | 0 | 0 |
| **360** | 2 | 1.67 | 1445 | 7 | 0.004 |
| **400** | 2 | 1.48 | 1436 | 163 | 0.113 |
| **420** | 1 | 0.89 | 769 | 0 | 0 |
| **440** | 1 | 0.89 | 769 | 0 | 0 |
| **460** | 1 | 0.89 | 769 | 0 | 0 |
| **480** | 1 | 0.89 | 769 | 0 | 0 |
| **500** | 0 | 0 | 0 | 0 | 0 |

Table 10-4: PHY rate, Application throughput and Packet Transmitted/Errored and packet error Probability vs. distance.

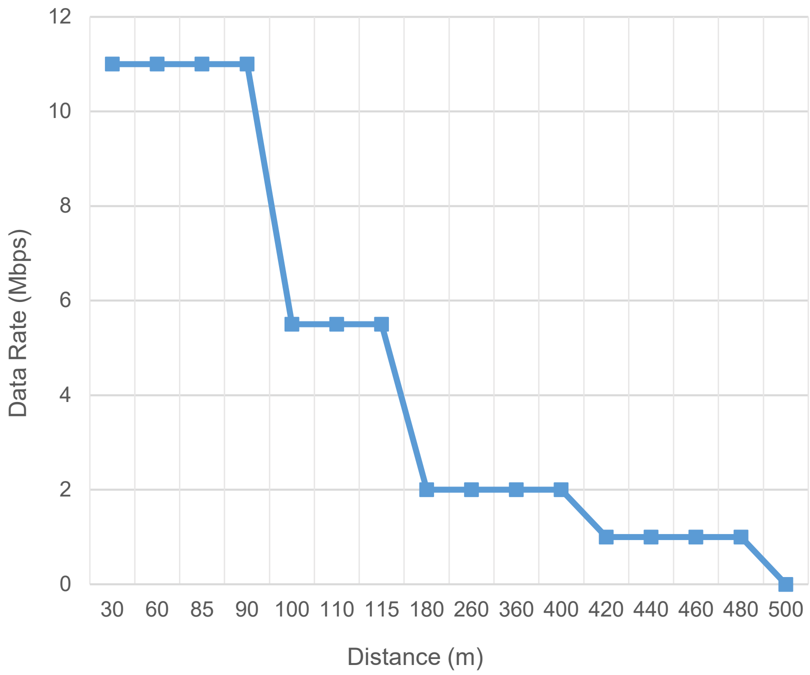


Figure 10-3: Data Rate vs. Distance

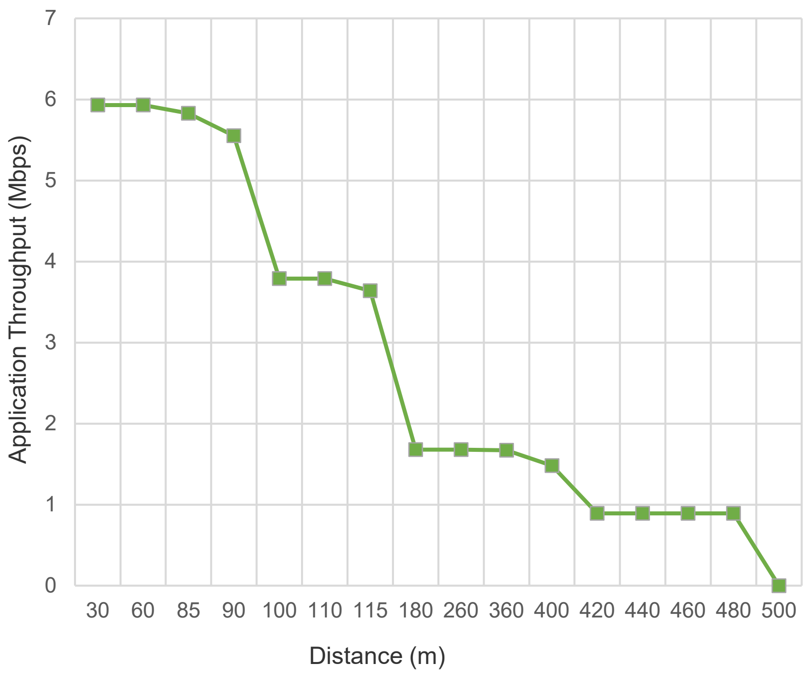


Figure 10-4: Application Throughput vs. Distance

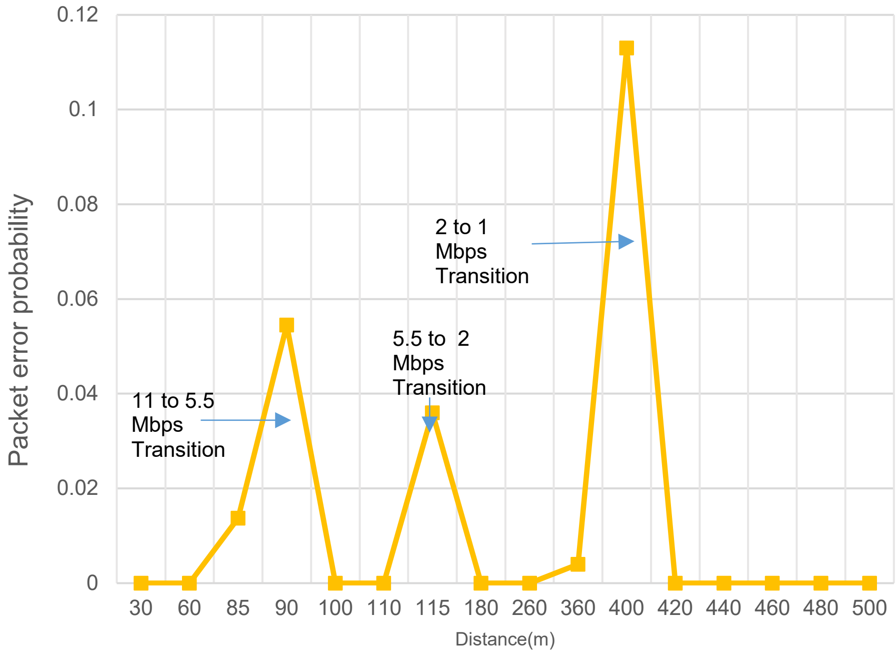


Figure 10-5: Packet Error Probability vs. Distance

***Note:*** *All the above plots highly depend upon the placement of nodes in the simulation environment. So, note that even if the placement is slightly different, the same set of values will not be got but one would notice a similar trend.*

## 10.6 Inference

We notice that as the distance increases, the 802.11b PHY rate (channel capacity decreases) decreases. This is because the underlying data rate depends on the received power at the receiver.

$$Received\ Power = Transmitted\ Power - RF\ losses$$

RF losses are directly proportional to distance to the power of path loss exponent. As RF propagation losses increase, the received power decreases.

We can see that the rate drops from 11 Mbps to 5.5 Mbps at around 95m, and then to 2 Mbps at 175 m and to 1 Mbps at 415 m (in this case the path loss exponent is set to 3.0). We also notice how the packet error rate increases with distance, then when the data rate changes (a lower modulation scheme is chosen), the error rate drops. This happens for all the transitions i.e., 11 to 5.5, 5.5 to 2 and from 2 to 1 Mbps. One must note that WLAN involves ACK packets after data transmission. These additional packet transmissions lead to a reduced Application throughput of 5.9 Mbps (at lower distances) even though the PHY layer data rate is 11 Mbps and the error rates is almost NIL. The application throughput is dependent on the PHY rate and the channel error rate, and one can notice it drops / rises accordingly.