

**END TO END SIMULATION OF TCP/IP MODEL FOR AD-HOC NETWORKS USING MATLAB**

#### A MINOR PROJECT REPORT 18TE64

**Submitted by**

|  |  |
| --- | --- |
| **Girija S Sajjanar** | **1RV18TE012** |
| **Sai Nagendra D M** | **1RV18TE041** |

#### Under the guidance of Miss Usha Padma

Assistant Professor

Department of Electronics and Telecommunication Engineering RV College of Engineering

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#### Telecommunication Engineering 2020-2021

##### (Autonomous Institution Affiliated to VTU, Belagavi)

**DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION ENGINEERING**



#### CERTIFICATE

Certified that the minorproject work titled ***“End to End Simulation of TCP/IP Model for Ad-Hoc Networks using MATLAB”*** is carried out by **Girija S Sajjanar (1RV18TE012)** and **Sai Nagendra D M (1RV18TE041)** who are bonafide students of RV College of Engineering, Bengaluru, inpartialfulfillment for the Sixth semester Examination of **Bachelor of Engineering**in**TelecommunicationEngineering**of the Visvesvaraya Technological University, Belagavi during the year 2020-2021. It is certified that all corrections/suggestions indicated for the Internal Assessment have been incorporated in the minor project report deposited in the departmental library. The minor project report has been approved as it satisfies the academic requirements in respect of minor project work prescribed by the institution for the said degree.

##### Signature of Guide Signature of Head of the Department Miss Usha Padma Dr. K. Sreelakshmi

**Assistant Professor Professor and Head,**

##### Dept. of ETE, RVCE Dept. of ETE, RVCE

**External Viva**

##### Name of Examiners Signature with Date

**(Autonomous Institution Affiliated to VTU, Belagavi)**

**DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION ENGINEERING**

### DECLARATION

We,**Girija S Sajjanarand Sai Nagendra D M** students of sixth semester B.E., Department of Electronics and Telecommunication Engineering, RV College of Engineering, Bengaluru, hereby declare that the minor project titled ***“*End to End Simulation of TCP/IP Model for Ad-Hoc Networks using MATLAB*”***has been carried out by us and submitted in partial fulfilment for the Sixth semester Examination of **Bachelor of Engineering** in **Telecommunication Engineering**during the year 2020-2021.

Further we declare that the content of the dissertation has not been submitted previously by anybody for the award of any degree or diploma to any other university.

We also declare that any Intellectual Property Rights generated out of this project carried out at RVCE will be the property of RV College of Engineering, Bengaluru and we will be one of the authors of the same.

Place: Bengaluru Date:

##### Names Signature

1. **Girija S Sajjanar** (1RV18TE012)
2. **Sai Nagendra D M** (1RV18TE041)

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**ABSTRACT**

The end-to-end argument or principle states that it's proper to implement the function in the end systems. The architecture and growth of the Internet was shaped by the end-to end principle. It allowed keeping the Internet simple and adding features quickly to end systems.End-to-end acknowledgment and retransmission isthe responsibility of the connection-oriented Transmission Control Protocol (TCP) which sits on top of IP. The LANs used in the implementation is wireless ad hoc network which is one that is spontaneously formed when devices connect and communicate with each other. Ad hoc networks are mostly wireless local area networks (LANs) without infrastructure.

A multi-node WLAN network with 802.11a Physical (PHY) and MAC is simulated using discrete event simulation in MATLAB. The IEEE® 802.11™ is a set of MAC and PHY specifications for WLAN implementation. A typical WLAN network will have multiple devices (nodes) sharing the same channel resources. Each node can have different types of applications transmitting or receiving packets from other nodes. As the nodes share the channel, their transmissions may collide or interfere with each other. Modeling a WLAN network with multiple nodes typically involves modeling the MAC layer, PHY, shared communication channel, data traffic pattern, and interference.

The simulation of this model generates a run-time plot depicting the time spent on channel contention, transmission, and reception for each node.Metrics for each node such as – number of transmitted, received, and dropped packets at PHY and MAC layers are measured. A mat file statistics with detailed statistics is obtained at each layer for each node.

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### List of Acronyms

Advanced Encryption Standard Additive White Gaussian Noise Clear Channel Assessment Carrier Sense Multiple Access Clear To Send

|  |  |
| --- | --- |
| AES | - |
| AWGN | - |
| CCA | - |
| CSMA | - |
| CTS | - |
| DCF | - |
| DFS | - |
| ED | - |
| EIFS | - |
| IP | - |
| IFS | - |
| LAN | - |
| MAC | - |
| NPA | - |
| RTS | - |
| SINR | - |
| TCP | - |
| TPS | - |
| WLAN | - |

Distributed Co-ordination Function Dynamic Frequency Selection Energy Detection

Extended Inter Frame Spacing Internet Protocol

Inter Frame Spacing Local Area Network Media Access Control Node Position Allocator Request To Send

Signal To Interference plus noise Ratio Transmission Control Protocol Transmit Power Control

Wireless Local Area Network

# CHAPTER 1

## INTRODUCTION

#### Introduction

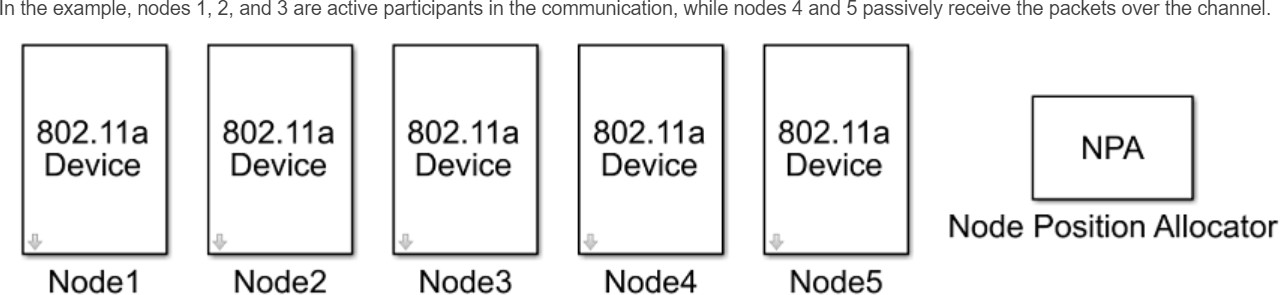
Internet Protocol (IP) is a connectionless datagram service with no delivery guarantees. When a function has to be supported in a networked system, the designer often asks if it should be implemented at the end systems; or should it be implemented within the communication subsystem that interconnects all the end systems. The end-to-end argument or principle states that it's proper to implement the function in the end systems. The communication system itself may provide a partial implementation but only as a performance enhancement.

The architecture and growth of the Internet was shaped by the end-to-end principle. It allows keeping Internet simple and adding features quickly to end systems.On the internet, IP is used for nearly all communications. End-to-end acknowledgment and retransmission is the responsibility of the connection-oriented Transmission Control Protocol (TCP) which sits on top of IP. The functional split between IP and TCP exemplifies the proper application of the end-to-end principle to transport protocol design.

WLAN Toolbox™ in the MATLAB Simulink provides functions that led to the model of end-to-end communication links.The nodes implement carrier-sense multiple access with collision avoidance (CSMA/CA) with physical carrier sensing and virtual carrier sensing. The physical carrier sensing uses the clear channel assessment (CCA) mechanism to determine whether the medium is busy before transmitting. Whereas,the virtual carrier sensing uses the RTS/CTS handshake to prevent the hidden node problem. The IEEE 802.11™ is a set of MAC and PHY specifications for WLAN implementation. A typical WLAN network will have multiple devices (nodes) sharing the same channel resources. Each node can have different types of applications transmitting or receiving packets from other nodes. As the nodes share the channel, their transmissions may collide or interfere with each other.

Modeling a WLAN network with multiple nodes typically involves modeling the MAC layer, PHY, shared communication channel, data traffic pattern, and interference. The figure 1.1 shows how to model a multi-node WLAN network with 802.11a PHY and MAC using discrete event simulation.The model in the figure 1.1 outputs various statistics such as the number of transmitted, received, and dropped packets at PHY and MAC layers, and plots that help in analyzing/estimating the node-level and network-level performance.

The modeling includes:

* + 1. Multiple nodes, where each node contains an application, a MAC layer, and a PHY.
    2. Packets transmitted over the channel, which is shared across multiple nodes.
    3. A shared channel is simulated with these channel impairment options: free-space path-loss, range propagation loss and multi-path fading.
    4. A node position allocator, which is used to configure the position of nodes in the network.

**Figure 1.1 WLAN Model[4]**

Fig 1.1 represents the WLAN Model with the 5 nodes that are considered. The LANs used in the implementation is wireless ad hoc network which is one that is spontaneously formed when devices connect and communicate with each other. Ad hoc networks are mostly wireless local area networks (LANs) without infrastructure. The devices communicate with each other directly instead of relying on a base station or access points as in wireless LANs for data transfer co-ordination. Each device participates in routing activity, by determining the route using the routing algorithm and forwarding data to other devices via this route. The concept of a wired isolated LAN also differs from that of a wireless isolated LAN. A wired isolated LAN is a set of hosts connected via a link-layer switch (in the recent generation of Ethernet). A wireless isolated LAN, called an ad hoc network in wireless LAN terminology, is a set of hosts that communicate freely with each other. The concept of a link-layer switch does not exist in wireless LANs. Figure 1.2 and

1.3 shows two isolated LANs, one wired and oneAd-hoc Network.

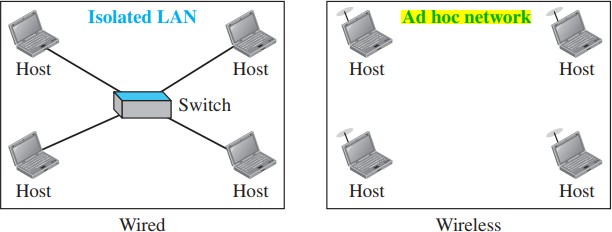


Figure 1.2 Wired LAN[2] Figure 1.3 Ad-hoc Network[2]

#### Literature Review

The term ‘end-to-end’ has become a familiar characterization of the architecture of the Internet, not only in engineering discourse, but in contexts as varied as political manifestos, commercial promotions, and legal arguments. Its ubiquity and opacity cloak the complexity of the technology it describes, and stand in for a richer controversy about the details of network design. This considers the appearance of the term ‘end-to-end’ in computer science discourse and the term became a point of contention within disputes about how to build a packet-switched network[4].

End-to-end communication can be classified into synchronous and asynchronous services. In synchronous communication services, information is delivered as a bit stream with a fixed delay and a given error rate. Dynamic information such as audio and video can be transmitted as bit streams. In asynchronous communication services the bit stream to be transferred is divided into packets. Packets are received by the destination with varying delays, and a fraction of them may not be received correctly. Asynchronous services are thus evaluated by their quality of service, such as the packet error rate, delay, and throughput. Static information such as data and image is organized in bit files, usually transmitted in packets, and is more error sensitive and delay insensitive relative to dynamic information[3].

The design principle that helps inthe placement of functions among themodules of a distributed computer system was presented in [5]. The principle, called the end-to-end

argument,suggests that functions placed at low levels of a system may be redundant or of little value when compared with the cost of providing them at that low level.Bit error recovery, security using encryption, duplicatemessage suppression, recovery from system crashes, and delivery acknowledgement are discussed in [5]. Low level mechanisms to support these functions are justified only as performanceenhancements [5].

The draft IEEE 802.11 wireless local area network (WLAN) specification is approaching completion. The IEEE 802.11 protocol was explained, with particular emphasis on the medium access control sub-layer. Performance results are provided for packetized data and a combination of packetized data and voice over the WLAN. Performance investigation reveals that an IEEE 802.11 network may be able to carry traffic with time- bounded requirements using the point coordination function. It was mentioned that the packetized voice traffic must be handled in conjunction with an echo canceller [9].

Two independent network protocols that have risen to the top of the list of contenders for the title of 'the' standard are described and compared. They are the transmission control protocol/internet protocol (TCP/IP), which was developed as a research project conducted by the US Department of Defense, and the open systems interconnection reference model developed by the (ISO). A brief discussion of the various types of physical networks was given as background. The basic structure of the two protocols and the way they go about achieving their respective ends are examined. It is concluded that the OSI model is better structured than TCP/IP. However, TCP/IP is the older of the two protocols and has had time to develop a substantial user base, especially in the Unix community it has already become an unspoken standard and clearly dominates the market[11].

Ad hoc networks are a key factor in the evolution of wireless communications. Selforganized ad hoc networks of PDAs or laptops are used in disaster relief, conference, and battlefield environments.These networks inherit the traditional problems of wireless and mobile communications, such as bandwidth optimization, power control, and transmission-quality enhancement. In addition, their multi-hop nature and the possible lack of a fixed infrastructure introduced new research problems such as network configuration, device discovery, and topology maintenance, as well as ad hoc addressing and self-routing [8].

A simple, fast and accurate analytical model of TCP was presented in [13]. This model

presented Internet performance metrics, assuming that only basic network parameters such as the network topology, the number of users, link capacity, distance between network nodes and router buffer sizes are known. The TCP performance model derives performance metrics which express the network quality of service. To obtain the performance metrics, TCP and network sub-models wereused [13].

A novel flow control method using PI controller for motion control system over network waspresented in [14]. UDP/IP protocol is known to be effective for motion control systems over network such as bilateral control system. UDP does not have a mechanism of congestion avoidance. The congestion, which causes large communication delay, jitter and packet loss, significantly deteriorates performance and stability of motion control systems. To avoid this congestion, a novel congestion control method, which adjusts a packet- sending period in real time, was proposed in [14]. The experimental results were validated through simulation for the model proposed in [14].

Technical corrections and clarifications to IEEE Standard 802.11 for wireless local area networks (WLANs) as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions were specified. The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area [15].

TCP is an end to end transmission control protocol was originally tuned for wired network. As the random packet loss due to bit error is not negligible in wireless network, it causes a sever performance degradation of TCP under wireless environment. A heterogeneous network was considered in which Challenges of TCP were well emphazised. Different versions of TCP have been explained and compared on the basis of simulation results [16].

#### INFERENCE:

Understanding previous models on TCP/IP layer communication through research papers and references gave the confidence to work into it and progress into the project. It also helped to understand the different types of functions it performs and the ways of implementing it. MATLAB software is used to work on this model. It also strengthened the knowledge on Deep-learning concepts and gave the perspective on which software

will be suitedforthe model and which features are important to make the model of use to the public.

#### MOTIVATION:

Complexity impedes scaling due to higher Operating Expenses and Capital Expenses.Thus, the end-to-end principle leads to the simplicity principle. At the network layer IP is the dominant protocol. Though the end-to-end simulation has been worked in different software, here the concept is to try with help of MATLAB which is new at higher levels. At higher layers, it has many protocols for supporting diverse applications. At lower layers, it has many protocols suited to different physical networks. IP can be said to "hide the detailed differences among these various technologies, and present a uniform service interface to the applications above".IP itself is simple and general. It's supported by all routers within the network. Application-level functions are kept at endpoints. Application developers could therefore innovate without any special support from the network, with some calling it the generative Internet. The principle has been credited with making Internet a success.

#### Problem Statement

Study and simulation of end-to-end system for TCP/IP model using MATLAB and Simulink.

#### Objectives

* + - Study of fundamental concepts of TCP/IP protocol suite and its different layers.
    - Simulation and analyzing the application layer which has to transmit the packets.
    - Simulation and analyzing the physical layer which communicates the information in the form of bits.
    - Implementation of the end-to-end principle using MATLAB Simulink and measure parameters such as packet rate , packet sizes , drop in Physical layer packets , packets dropped in Mac Layer and throughput.

#### Proposed Methodology

##### Block Diagram:

To show how the layers in the TCP/IP protocol suite are involved in communication between two hosts, assume thattheTCP/IP protocol suite is used in a small internet made up of three LANs (links), each with a link-layer switch. Also assume that the links are connected by one router. Fig 1.4 represents the layers of TCP/IP Model.

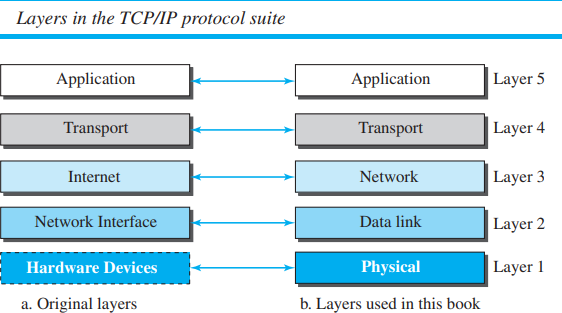


Figure1.4Layers in TCP/IP Model [2]

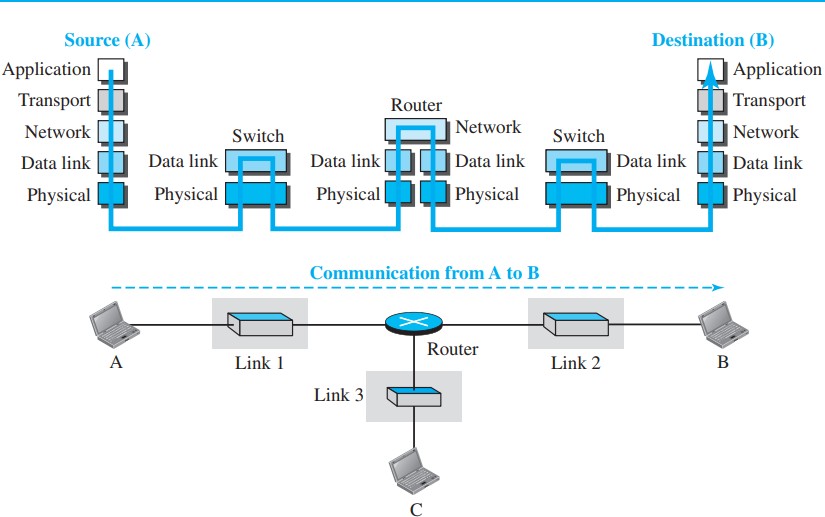


Figure 1.5Communication through an internet[2]

Assume that computer A communicates with computer B. As the figure 1.5 shows, there arefive communicating devices in this communication: source host (computer A), the link-layer switch in link 1, the router, the link-layer switch in link 2, and the destination host (computer B). Each device is involved with a set of layers depending on the role of the device in the internet. The two hosts are involved in all five layers; the source host needs to create a message in the application layer and send it down the layers so that it is physically sent to the destination host. The destination host needs to receive the communication at the physical layer and then deliver it through the other layers to the application layer.

The router is involved in only three layers; there is no transport or application layer in a router as long as the router is used only for routing. Although a router is always involved in one network layer, it is involved in n combinations of link and physical layers in which n is the number of links the router is connected to. The reason is that each link may use its own data-link or physical protocol. For example, in the fig 1.5, the router is involved in three links, but the message sent from source A to destination B is involved in two links. Each link may be using different link-layer and physical-layer protocols; the router needs to receive a packet from link 1 based on one pair of protocols and deliver it to link 2 based on another pair of protocols.

A link-layer switch in a link is involved only in two layers, data-link and physical. Although each switch in the fig 1.5 has two different connections, the connections are in the same link, which uses only one set of protocols. This means that, unlike a router, a link-layer switch is involved only in one data-link and one physical layer.

The model has a WLAN network with five nodes. These nodes implement carrier-sense multiple access with collision avoidance (CSMA/CA) with physical carrier sense and virtual carrier sense. The physical carrier sensing uses the clear channel assessment (CCA) mechanism to determine whether the medium is busy before transmitting. Whereas, the virtual carrier sensing uses RTS/CTS handshake to prevent the ‘hidden node problem’.Fig 1.6 represents the Flow chart of Multi-Node 802.11a Network Model.

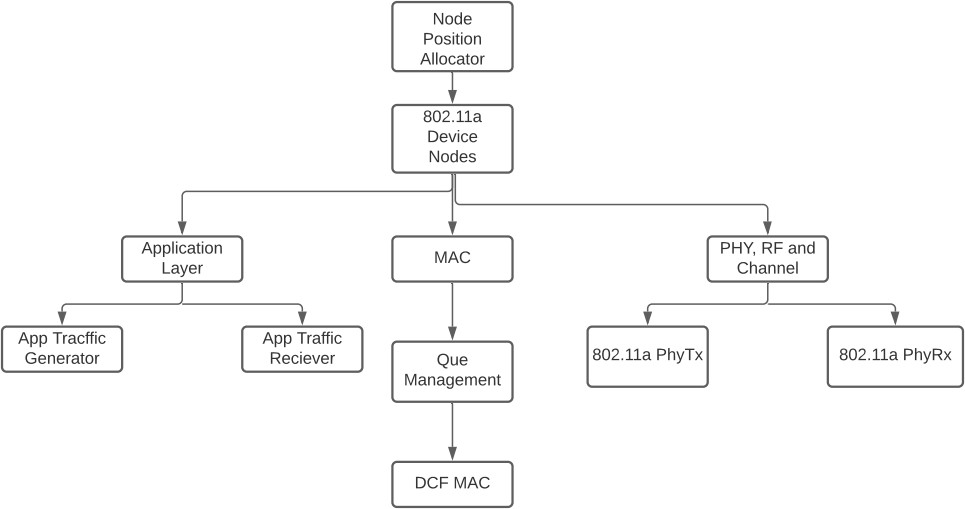


Figure1.6Flow chart of Multi-Node 802.11a Network Model

The modeling includes:

* Multiple nodes, where each node contains an application, a MAC layer, and a PHY.
* Packets transmitted over the channel are broadcasted to multiple nodes.
* A shared channelis simulated with these channel impairment options: free-space path-loss, range propagation loss and multi-path fading (using Rayleigh channel model).
* A node position allocator is used to configure the position of nodes in the network.

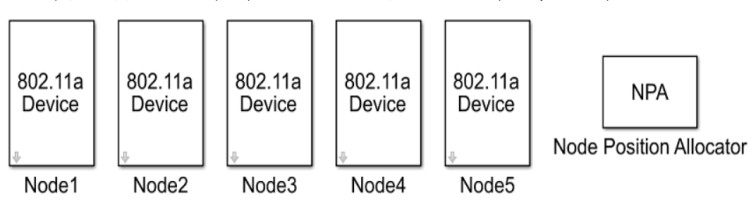
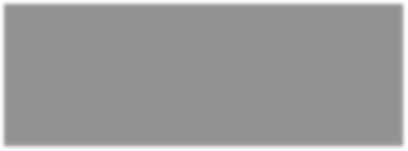


Figure 1.7 WLAN network with five nodes

Fig 1.7 represents the WLAN network with five nodes. Nodes 1, 2, and 3 are active participants in the communication, while nodes 4 and 5 passively receive the packets over the channel in figure 1.7.

#### Software and Hardware requirements:

* + - 1. MATLAB R2020b for simulation of MATLAB inbuilt codes of the model.
      2. MATLAB Simulink for designing of the model and to make further explorations and changes.
      3. Laptop with i5 7th Gen. Processor for fast and speedy processing.

#### Organization of the report

This report is organized as follows:

* Chapter 1 deals with introduction to the project, Literature review, Motivation, Problem Definition, Objectives and Methodology.
* Chapter 2 contains Design Theory,flowcharts, algorithms and software used for performing thesimulation.
* Chapter 3 explains in detail about the Implementation of the work carried out.
* Chapter 4 presents the Results, Discussions and Inferences.
* Chapter 5 contains conclusion and Future Scope of this Project.

# CHAPTER 2

## DESIGN THEORY

#### DESIGN THEORY

IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data-link layers. It is sometimes called wireless Ethernet. In some countries, including the United States, the public uses the term Wi-Fi (short for wireless fidelity) as a synonym for wireless LAN. Wi-Fi is a wireless LAN that is certified by the Wi-Fi Alliance, a global, nonprofit industry association of more than 300 member companies devoted to promoting the growth of wireless LANs.

#### Architecture

The standard defines two kinds of services: the basic service set (BSS) and the extended service set (ESS).

##### Basic Service Set

IEEE 802.11 defines the Basic service set (BSS)as the building blocks of a wireless LAN. A basic service set is made of stationary or mobile wireless stations and an optional central base station, known as the access point (AP). The BSS without an AP is a stand- alone network and cannot send data to other BSSs. It is called an ad hoc architecture. In this architecture, stations can form a network without the need of an AP. They can locate one another and agree to be part of a BSS. A BSS with an AP is sometimes referred to as an infrastructure BSS.

##### Extended Service Set

An Extended service set (ESS)is made up of two or more BSSs with APs. In this case, the BSSs are connected through a distribution system, which is a wired or a wireless network. The distribution system connects the APs in the BSSs. IEEE. 802.11 do not restrict the distribution system.It can be any IEEE LAN such as an Ethernet. The extended service set uses two types of stations: mobile and stationary. The mobile stations are normal stations inside a BSS. The stationary stations are AP stations that are part of a wired LAN. Figure 2.1 shows an ESS.

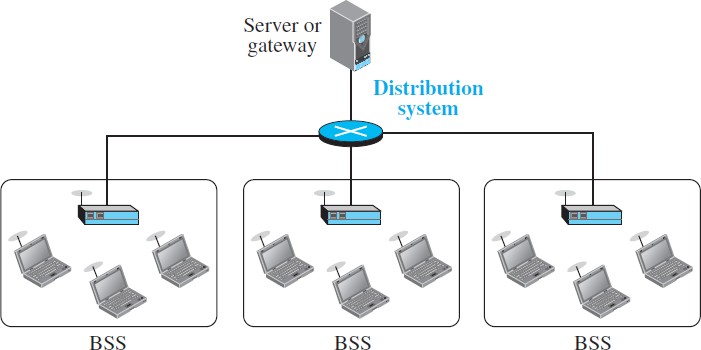


Figure 2.1 Extended service set (ESS) [14]

When BSSs are connected, the stations within reach of one another can communicate without the use of an AP. Communication between a station in a BSS and outside BSS occurs via the AP.

##### Station Types

IEEE 802.11 defines three types of stations based on their mobility in a wireless LAN: no-transition, BSS-transition, and ESS-transition mobility. A station with no- transitionmobilityis either stationary (not moving) or moving only inside a BSS. A station withBSS-transitionmobilitycan move from one BSS to another, but the movement is confined inside one ESS. A station with ESS-transition mobilitycan move from one ESS to another. IEEE 802.11 does not guarantee that communication is continuous during the move.

#### MAC Sub-layer

IEEE 802.11 defines two MAC sublayers: the distributed coordination function

(DCF) and point coordination function (PCF). Figure 2.2 shows the relationship between the two MAC sublayers, the LLC sublayer, and the physical layer.

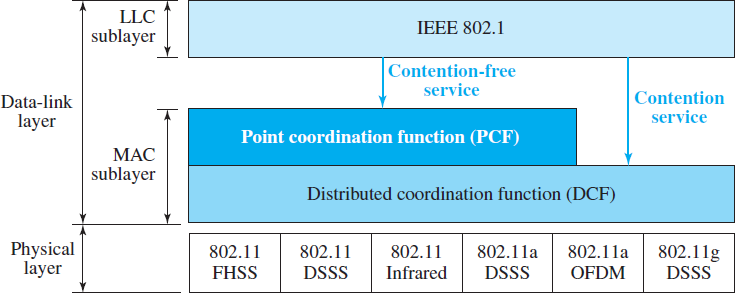


Figure 2.2 MAC layers in IEEE 802.11 standard [14]

##### Distributed Coordination Function

One of the two protocols defined by IEEE at the MAC sublayer is called the distributed coordination function (DCF). DCF uses CSMA/CA as the access method.

##### Frame Exchange Time Line

Figure 2.3 shows the exchange of data and control frames in time.

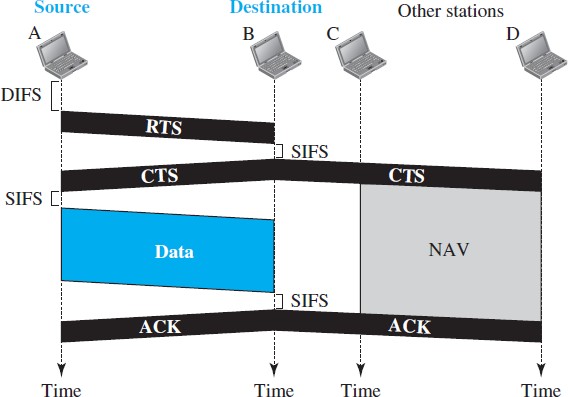


Figure 2.3 CSMA/CA and NAV [14]

* Before sending a frame, the source station senses the medium by checking the energy level at the carrier frequency.
* The channel uses a persistence strategy with back-off until the channel is idle.
* After the station is found to be idle, the station waits for a period of time called the distributed interframe space (DIFS);then the station sends a control frame called the request to send (RTS).
* After receiving the RTS and waiting a period of time called the short interframe space(SIFS), the destination station sends a control frame, called the clear tosend

(CTS), to the source station. This control frame indicates that the destinationstation is ready to receive data.

* The source station sends data after waiting an amount of time equal to SIFS.
* The destination station, after waiting an amount of time equal to SIFS, sends an acknowledgment to show that the frame has been received. Acknowledgment is needed in this protocol because the station does not have any means to check for the successful arrival of its data at the destination. On the other hand, the lack of collision in CSMA/CD is a kind of indication to the source that data have arrived.

##### Network Allocation Vector

When a station sends an RTS frame, it includes the duration of time that it needs to occupy the channel. The stations that are affected by this transmission create a timer called a network allocation vector (NAV)that shows how much time must pass before these stations are allowed to check the channel for idleness. Each time a station accesses the system and sends an RTS frame, other stations start their NAV. In other words, each station, before sensing the physical medium to see if it is idle, first checks its NAV to see if it has expired. Figure 2.3 shows the idea of NAV.

##### Collision during Handshaking

If there is a collision during the time when RTS or CTS control frames are in transition, often called the handshaking period- Two or more stations may try to send RTS frames at the same time. These control frames may collide. Because there is no mechanism for collision detection, the sender assumes there has been a collision if it has not received a CTS frame from the receiver. The back-off strategy is employed, and the sender tries again.

##### Hidden-Station Problem

The solution to the hidden station problem is the use of the handshake frames (RTS andCTS). Figure 2.3 also shows that the RTS message from B reaches A, but not C. Since both B and C are within the range of A, the CTS message, which contains the duration of data transmission from B to A, reaches C. Station C knows that some hidden station is using the channel and refrains from transmitting until that duration is over.

##### Point Coordination Function (PCF)

The point coordination function (PCF)is an optional access method that can be implemented in an infrastructure network (not in an ad hoc network). It is implemented on top of the DCF and is used mostly for time-sensitive transmission.PCF has a centralized, contention-free polling access method. The AP performs polling for stations that are capable of being polled.

The stations are polled one after another, sending any data they have to the AP.

To give priority to PCF over DCF, another interframe space, PIFS, has been defined. PIFS (PCF IFS) is shorter than DIFS. This means that if, at the same time, a station wants to use only DCF and an AP wants to use PCF, the AP has priority.

##### Fragmentation

The wireless environment is very noisy, so frames are often corrupted. A corrupt frame has to be retransmitted. The protocol, therefore, recommends fragmentation—the division of a large frame into smaller ones. It is more efficient to resend a small frame than a large one.

##### Frame Format

The MAC layer frame consists of nine fields, as shown in Figure 2.4.

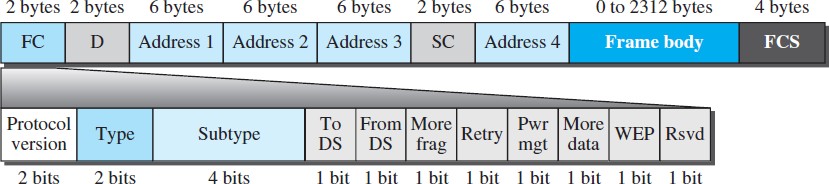


Figure 2.4Frame formats [14]

**Frame control (FC).** The FC field is 2 bytes long and defines the type of frame and some control information.

* **D.**This field defines the duration of the transmission that is used to set the value of NAV. In one control frame, it defines the ID of the frame.
* **Addresses.** There are four address fields, each 6 bytes long. The meaning of each address field depends on the value of the To DS and From DS subfields and will be discussed later.
* **Sequence control.** This field, often called the SC field, defines a 16-bit value. The first four bits define the fragment number; the last 12 bits define the sequence number, which is the same in all fragments.
* **Frame body.** This field, which can be between 0 and 2312 bytes, contains informationbased on the type and the subtype defined in the FC field.
* **FCS.** The FCS field is 4 bytes long and contains a CRC-32 error-detection sequence.

##### Frame Types

A wireless LAN defined by IEEE 802.11 has three categories of frames: management frames, control frames, and data frames.

##### Management Frames

Management frames are used for the initial communication between stations and access points.

##### Control Frames

Control frames are used for accessing the channel and acknowledging frames. Figure

2.5 shows the control frame format.



Figure 2.5Control frames [14]

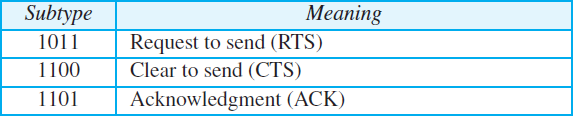
For control frames the value of the type field is 01.The values of the subtype fields for frames are shown in fig 2.6.

Figure 2.6Values of subtype fields in control frames [14]

##### Data Frames

Data frames are used for carrying data and control information.

#### 2.3 Addressing Mechanism

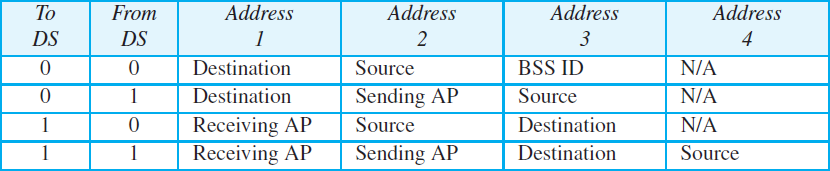
The IEEE 802.11 addressing mechanism specifies four cases, defined by the value of the two flags in the FC field, To DS and From DS.

Figure 2.7 Addresses [14]

Each flag can be either 0 or 1, resulting in four different situations. The interpretation of the four addresses (address 1 to address 4) in the MAC frame depends on the value of these flags, as shown in fig 2.7.

#### Summary

IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data-link layers. Addressing Mechanism, MAC Sublayer, Frame controls and Architecture are discussed in this chapter.

# CHAPTER 3

## DESIGN IMPLEMENTATION

#### Simulation of Multi-Node 802.11a Network Model

Simulation of Multi Nodes 802.11a of the considered Network Model with 5 nodes is carried out.

##### Node

Each node is modeled as a subsystem with a network stack, which includes

* Application layer
* MAC
* Physical layer

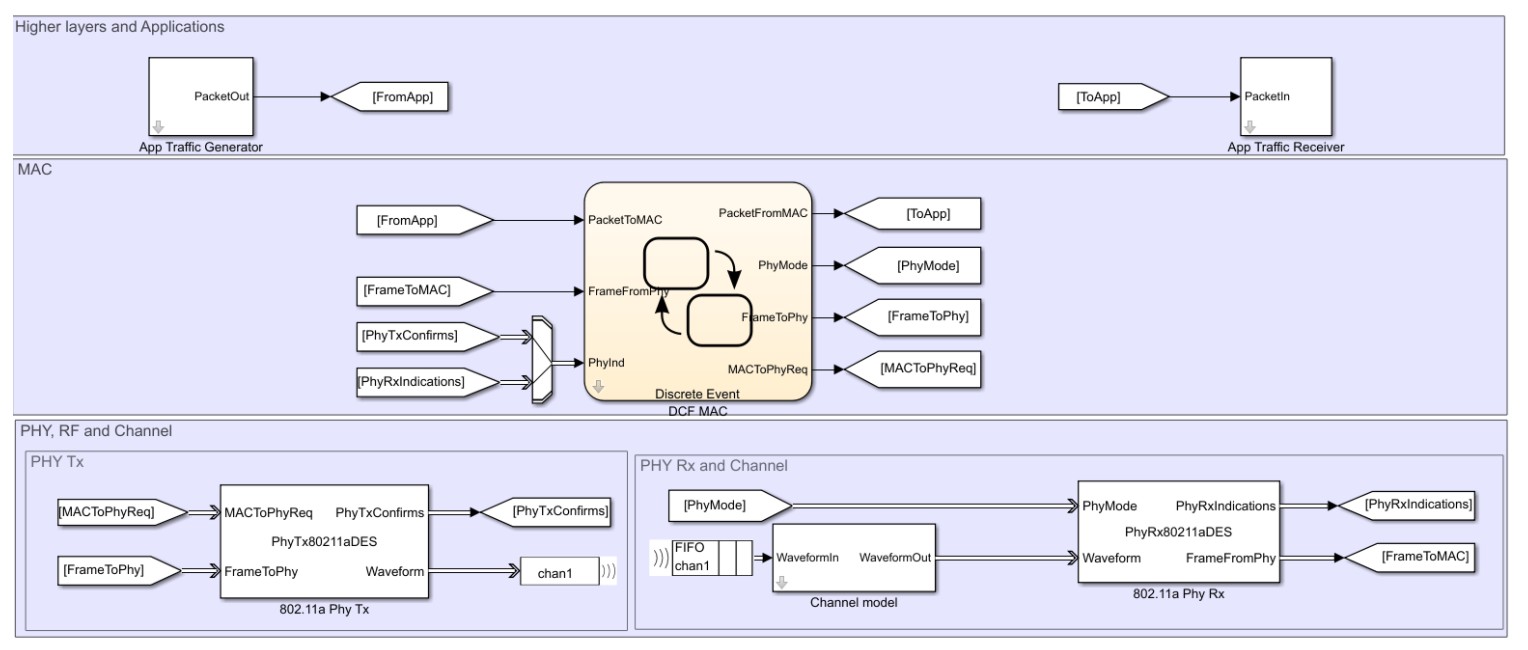
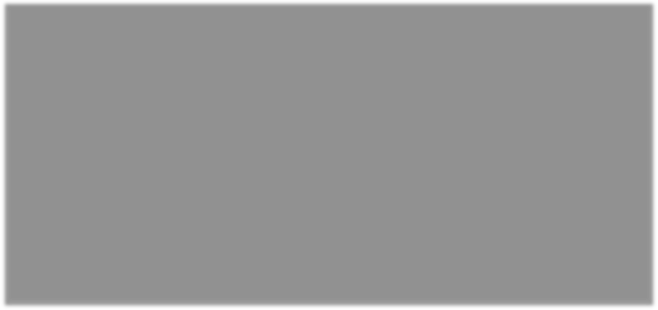


Figure 3.1 PHY RF & Channel, MAC and Application layer in a node

Fig 2.1 represents the PHY, RF and Channel, MAC and Application Layer in a node

* The application layer generates packets using SimEvents Entity Generator (SimEvents) block.
* The DCF(Distributed coordination function)in MAC is modeled as a Discrete Event Chart.
* The PHY is modeled using SimEvents Discrete Event System block.
* The shared channel is modeled inside each node in the receive path.

#### Application Layer

The application layer is implemented to generate and receive application traffic. It is divided into two sub-blocks:

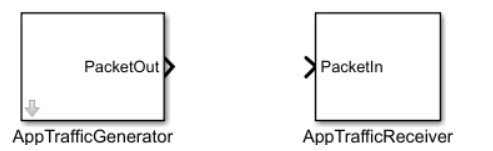
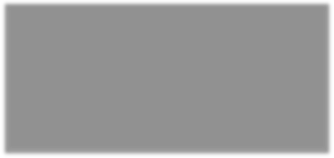


Figure 3.2 Application layer

* + - AppTrafficGenerator uses SimEvents Entity Generator (SimEvents) block to generate data packets with configured packet size, inter-packet interval, and destination node. These data packets are passed to the MAC layer.
    - AppTrafficReceiver uses SimEvents Entity Terminator (SimEvents) block to receive the data packets from MAC layer.
    - Fig 2.2 represents the AppTrafficGenerator and AppTrafficReceiver.

#### MAC Layer

The MAC layer implements the DCF algorithm. The basic medium access protocol is a DCF that allows for automatic medium sharing between compatiblePHYs through the use of CSMA/CA and a random back-off time following a busy medium condition. Inaddition, all individually addressed traffic uses immediate positive acknowledgment (Ack frame), in whichretransmission is scheduled by the sender if no Ack frame is received.

Before transmitting a packet, the MAC layer senses the shared channel to determine the state of the channel. If the channel is idle, packet transmission is initiated. If the channel is busy, packet transmission is deferred. The packets waiting for transmission are queued. In the model, the MAC layer has two components: queue management and contention algorithm.

##### Queue Management

Packets received from the application layer are queued until the channel is available. Packets are dequeued for transmission once the channel becomes available. The size of the queue is configurable. The default queue size is 10.Fig 2.3 represents Enqueing and Dequeing mechanism in MAC.

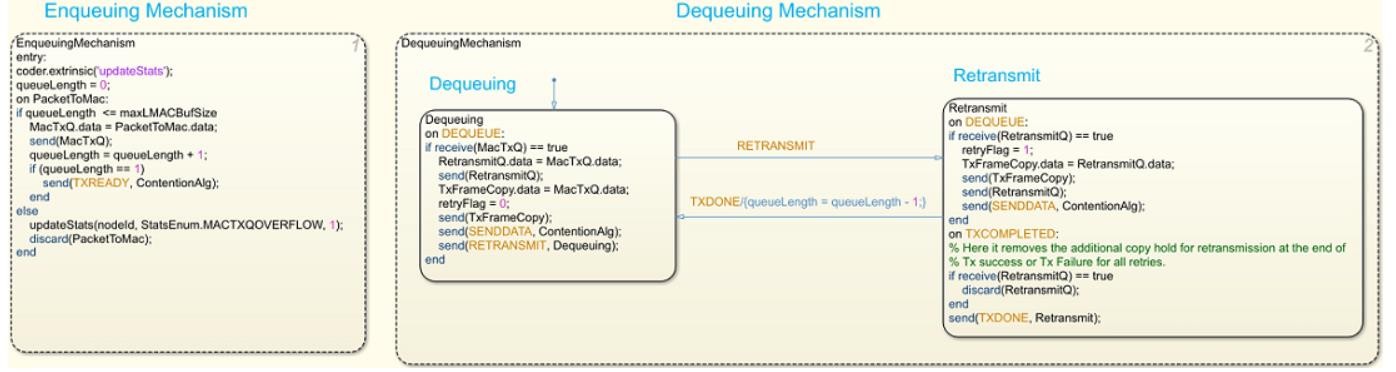
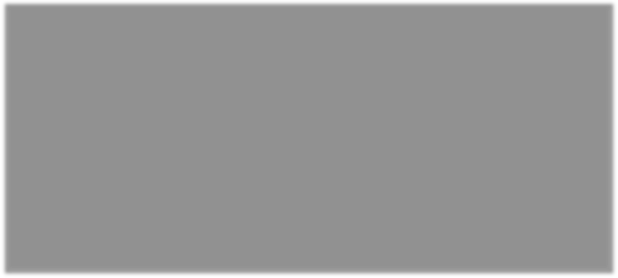


Figure 3.3Enqueing and Dequeing mechanism in MAC

##### Contention Algorithm

The contention algorithm implemented in the MAC layer is the DCF functionality as specified. It is implemented as a finite state machine with these six different states:

* Idle: No active operations
* Contend: Contends for the channel
* Rx: Receives and processes the frame
* WaitForRx: Waits for a response frame
* SendingData: Transmits a frame
* Eifs: Defers transmission for error recovery

Fig 2.4represents theState Level Processing in the MAC Layer.

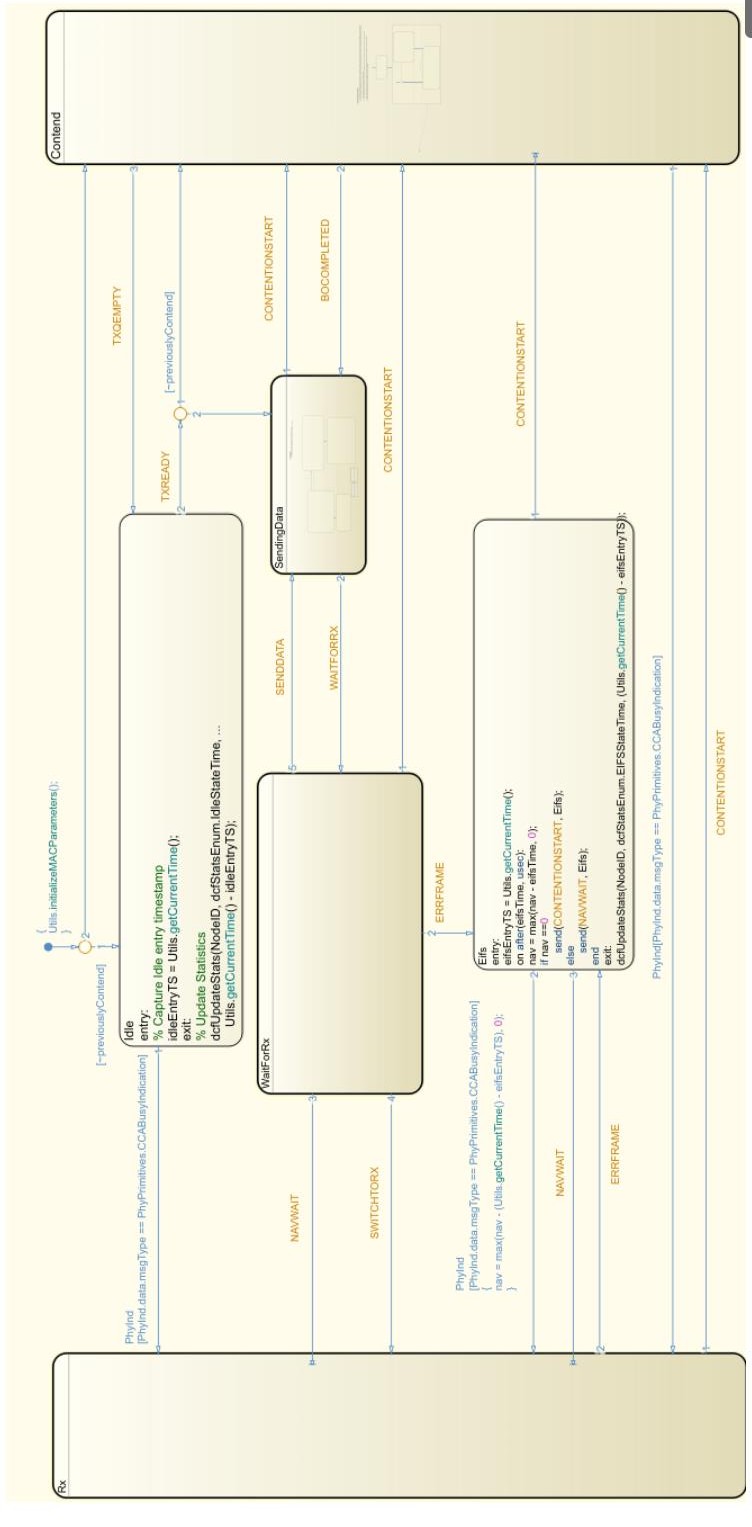
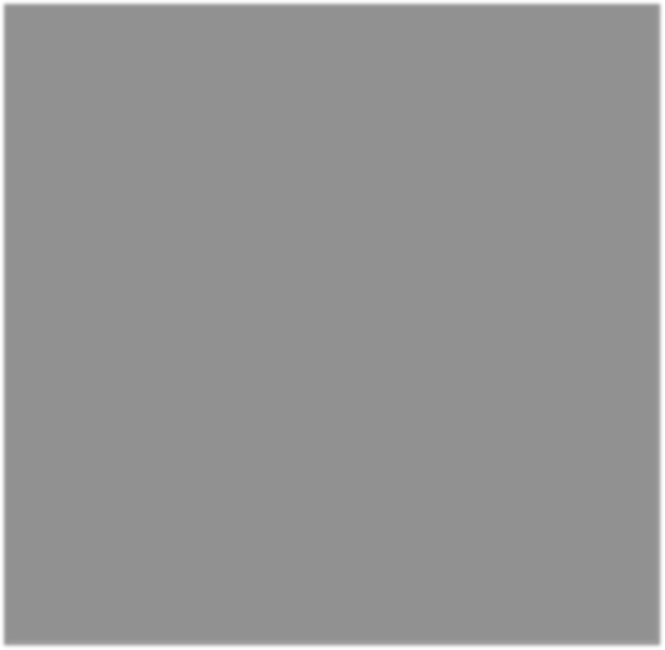


Figure 3.4State Level Processing in the MAC Layer

##### State Level Processing in the MAC Layer

* Initially the MAC layer is in *Idle* state. On receiving a packet from the application layer, the MAC layer moves to the *Contend* state.
* In the *Contend* state, if the channel is sensed as idle for a period of DCF inter frame space (DIFS) time followed by a random back-off time, the MAC layer moves to the *SendingData* state.
* In the *SendingData* state, a frame is transmitted, and the MAC layer moves to the *WaitForRx* state.
* In the *WaitForRx* state, the MAC layer waits for a period of ACK/CTS timeout. On receiving a response frame, MAC initiates next frame transmission. If a response frame is not received within the timeout period, the frame is re-transmitted.
* On receiving a clear channel assessment (CCA) as busy from the PHY layer, the MAC layer moves to the *Rx* state. Frames are received and processed in the *Rx* state. If an errored frame is received in the *Rx* state, the MAC layer waits for extended inter frame space (EIFS) time in the *Eifs* state. If the frame is intended for other node, network allocation vector (NAV) is updated and transmission is deferred until NAV becomes zero. If the frame is intended to this node, a response frame is sent if needed.

MAC parameters such as RTS threshold, retry limit and data rates are configurable for each node.

#### PHY and Channel

The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11PHYs:

* Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with PHY transceivers are known to be unable to receive network frames.
* Are unprotected from other signals that are sharing the medium.
* Communicate over a medium significantly less reliable than wired PHYs.
* Have dynamic topologies.
* Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs might be “hidden” from each other).
* Have time-varying and asymmetric propagation properties.
* Might experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas.

##### Transmit Chain:

The MAC layer initiates the transmission by sending a transmission start request containing Tx vector information. On receiving the start request, the PhyTx80211aDES block configures the PHY transmission parameters with the given Tx vector, and sends the transmission start confirm to the MAC layer. The PHY parameters are configured in a non-HT format configuration object of type [wlanNonHTConfig](https://in.mathworks.com/help/wlan/ref/wlannonhtconfig.html). On receiving the start confirm, the MAC layer sends the frame to the PhyTx80211aDES block.

The PhyTx80211aDES block generates a waveform for the MAC frame using [wlanWaveformGenerator](https://in.mathworks.com/help/wlan/ref/wlanwaveformgenerator.html) function. It also scales the samples of waveform with the configured Tx gain. The generated waveform is transmitted through the shared channel.

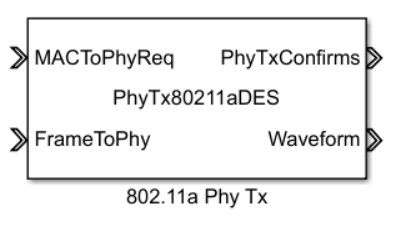
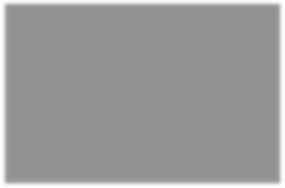


Figure 3.5PhyTx80211aDES block

The mask properties of Tx power (dBm) and the Tx gain (dB) for the PhyTx80211aDES block can be configured.

##### Channel Impairments Modeling:

Channel impairments determined by free-space path-loss model and Rayleigh multipath fading are added to the transmitted PHY waveform. These impairment models can be enabled or disabled. In addition to the impairment models, the signal reception range can also be limited by an optional range propagation loss model. To model any of these losses, the channel model must contain both the sender and receiver positions along with the transmitted signal strength. The channel is modeled inside each receiving node, before passing the waveform to the PhyRx80211aDES block.

##### Receiver Chain:

When the PhyRx80211aDES block receives a waveform, it scales the waveform with the configured Rx gain. The PhyRx80211aDES block then applies thermal noise and interference to the received waveform. This is done by calculating the expected signal to interference-plus-noise Ratio (SINR) at the end of preamble, header, and payload. The calculated SINR is added to the preamble, header, and payload of the received waveform as an Additive White Gaussian Noise (AWGN). The PhyRx80211aDES block then compares the waveform power with the energy detection (ED) threshold. If the waveform power is greater than the ED threshold, the PHY sends a CCA busy indication to the MAC layer and starts decoding the waveform. Otherwise, the PHY considers the waveform as noise and adds it as interference to the upcoming waveforms for the duration of the current waveform. If an error is found while decoding, the PHY stops further processing of the waveform and sends an error indication to the MAC layer. If the preamble and header are decoded successfully, the PhyRx80211aDES block sends a start indication to the MAC layer. If the payload is also decoded successfully, the payload is passed to the MAC layer along with a success indication.

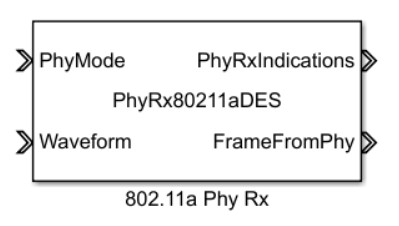
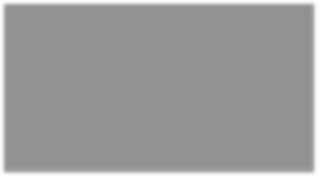


Figure 3.6PhyRx80211aDES block

Fig 3.6 represents the reception block.The Rx gain (dB) and the noise figure (dB) can be configured for the PhyRx80211aDES block.

#### Node Position Allocator

Node position allocator is used to assign initial position of nodes. It supports linear and list position allocation strategies.

**Linear Position Allocation Strategy** – Places nodes uniformly in a straight line, on a 2D grid.

**List Position Allocation Strategy** – Assigns node positions from a list [[x1 y1 z1] [x2 y2 z2] ... [xnynzn]] such that (xk, yk, zk) is the position of the kth node for all k in (1, 2, ..., n).

#### Summary:

Each node in the model is studied and various layers in each node such as Application layer, MAC layer and PHY layer functions are analyzed and understood. The transmitter chain and receiver chain functions are analyzed. Queue Management and contention algorithm is implemented in the MAC layer so that proper transfer of the packets is performed. Node position allocator which is used to assign initial position of nodes is implemented to place the nodes.

# CHAPTER 4

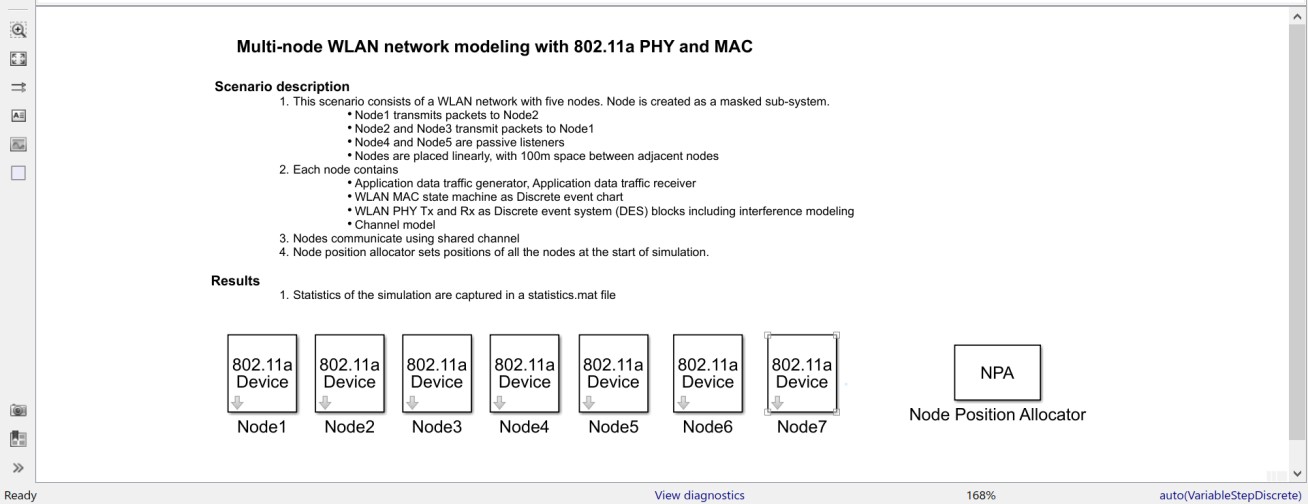
## RESULTS AND DISCUSSION

#### Results and Discussion

Variation in Nodes and Sub-systems of Nodes of the considered Network Model were carried out, such as Incrementing the number of nodes, Variation in The MAC parameters, variation in the Application parameters. NPA is enabled to analyze the state- flow of the considered Network.

##### Variation of Nodes in the Network

Additional nodes are created in the model to analyze the change in the results.Node 6 and Node 7 are the new nodes created in the multi-node network modeling.The nodes in this type of network are not stationary, they are mobile and the connectivity is also dynamic and arbitrary. The wireless nodes in this type of network can act as a router and host at the same time and can also take an active part in the creation and maintenance of routes in the network. Incrementing the nodes will make additional nodes taking part in the transmission,receptionand thus slightly decreases the node timeline but more number of nodes may decrease the performance of TCP/IP model here.



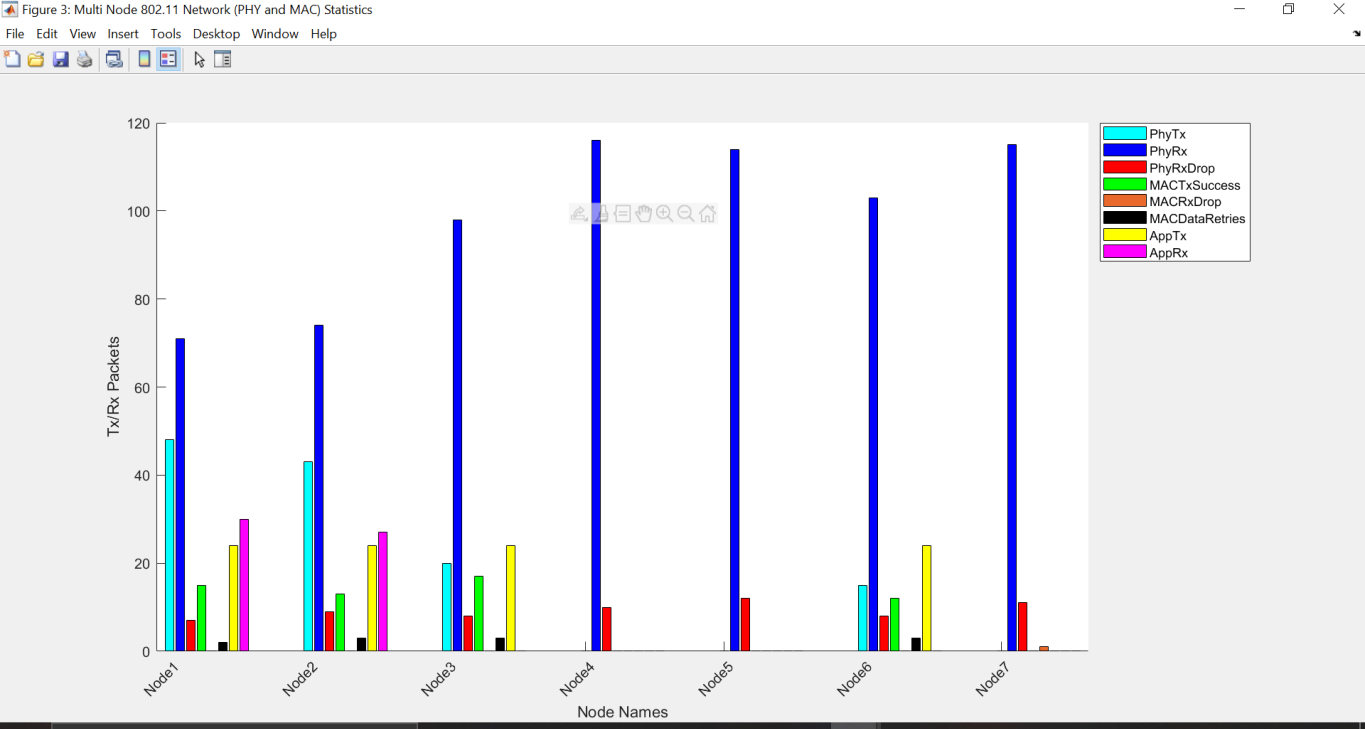
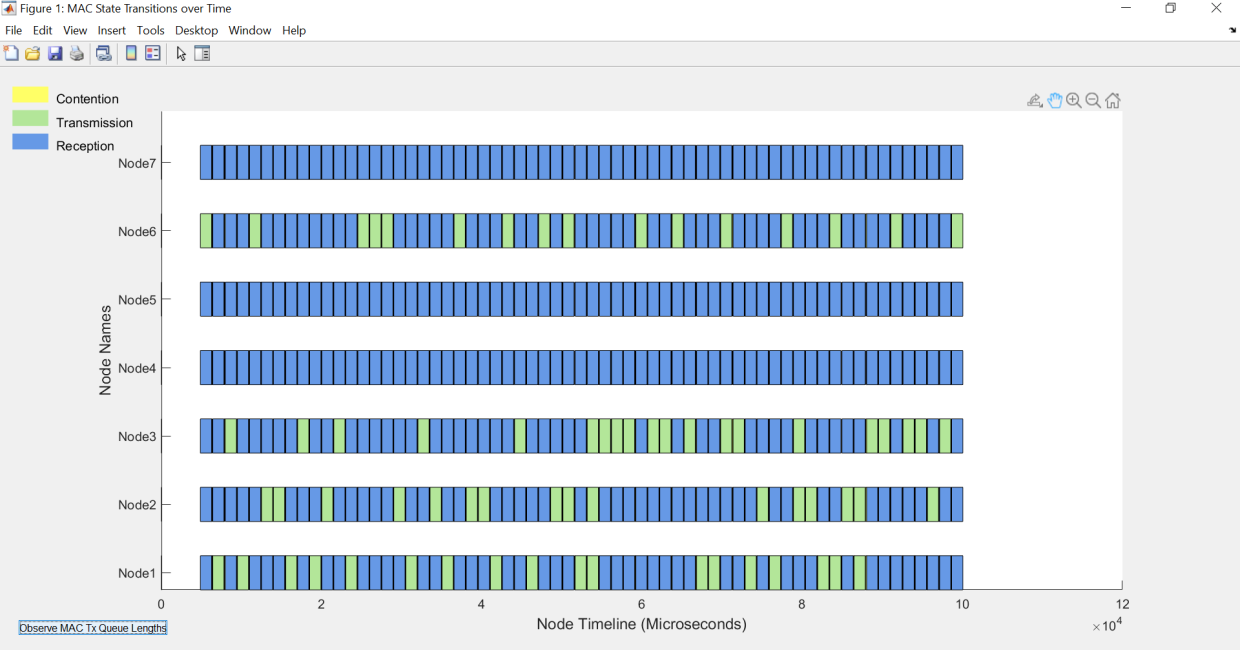


Figure 4.1aIncrementing Nodes in the Network



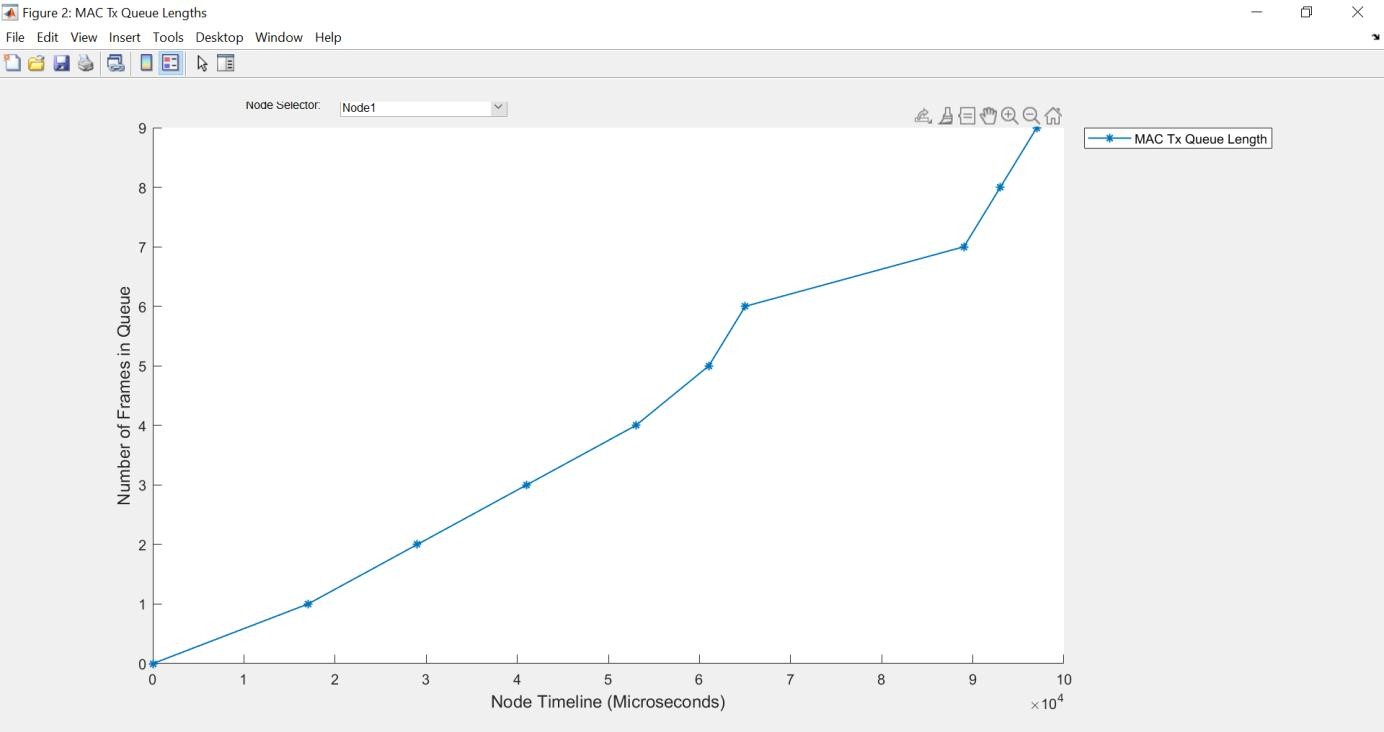
Figure 4.1b Incrementing Nodes in the Network

Figure 4.1 Incrementing Nodes in the Network

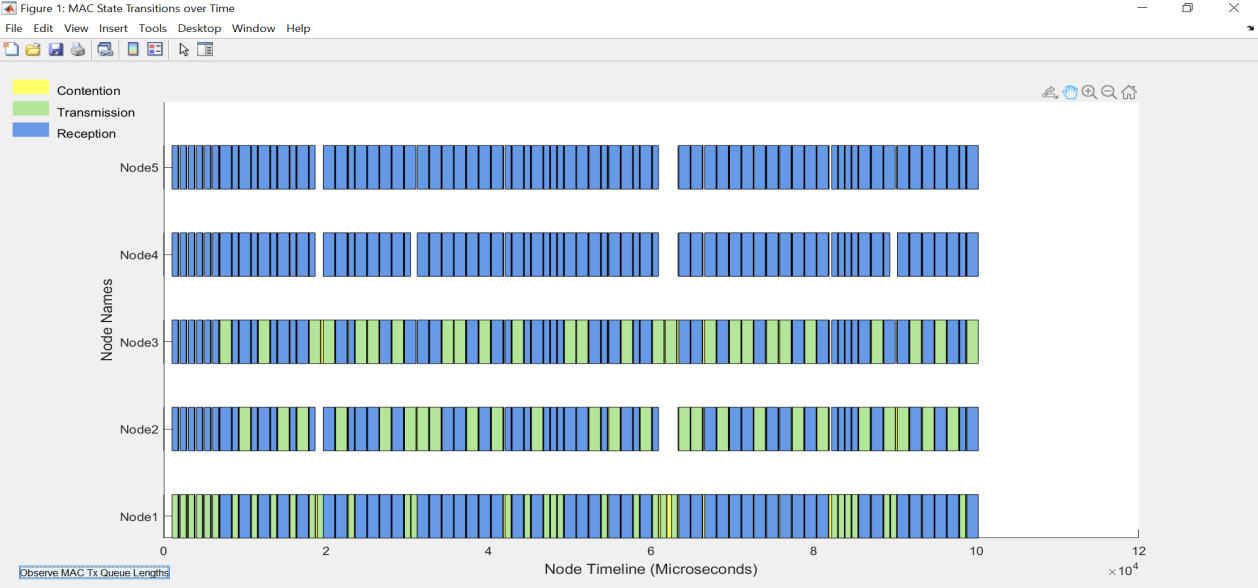
Figure 4.1a, 4.1b and 4.1represents the results of change in number of nodes.

#### Variation of Application Parameters

Varying the application parameters: packet size and packet interval.

**For** Packet size=500 and Packet interval=0.001 : When both the packet size and packet interval aredecreasedthe throughput increases, the Tx/Rx value will increase as seen from the fig 4.2 graph. Lesser the packet size more the number of packets need to be

transmitted and the packets are narrower in the state transition graph compared to original.



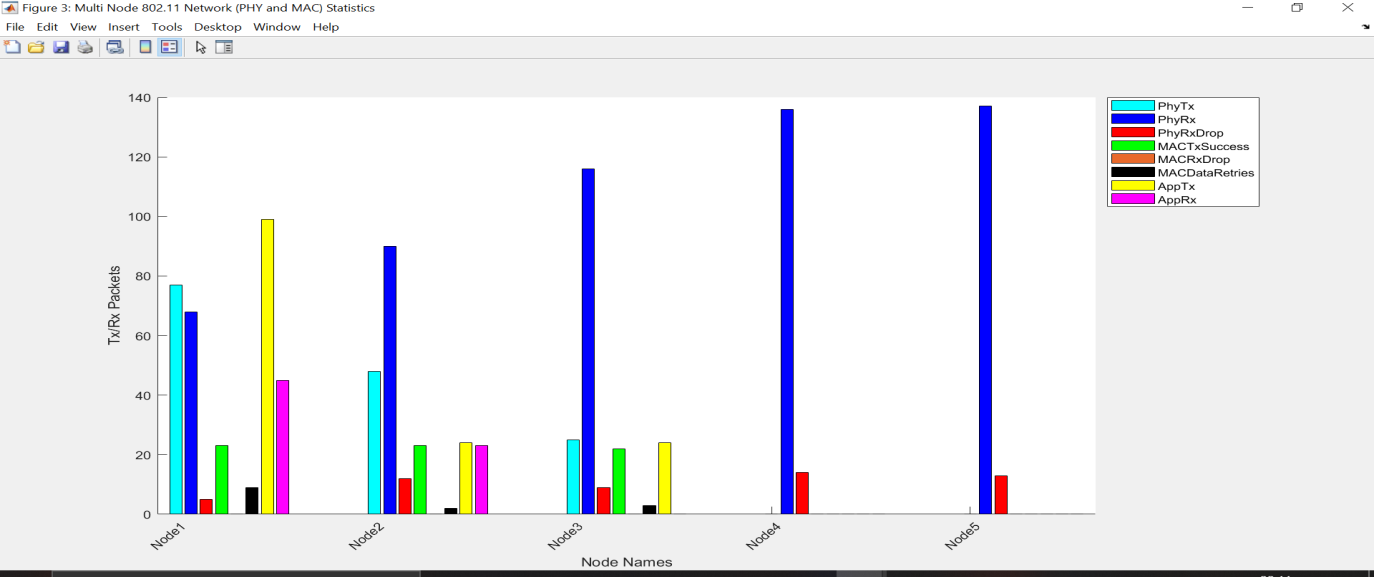
Figure 4.2aDecrease in application parameters

Figure 4.2b Decrease in application parameters

Figure 4.2a and 4.2b represents the results of decrease in application parameters.

For Packet size=1500 and Packet interval=0.007 : When both the packet size and packet interval For is increased the throughput decreases, the Tx/Rx value will decrease as seen from the below graph. More the packet size lesser the number of packets needs to be transmitted and the packets are broader in the state transition graph compared to original. Figure 4.3a and 4.3b represents the results of increase in application parameters.

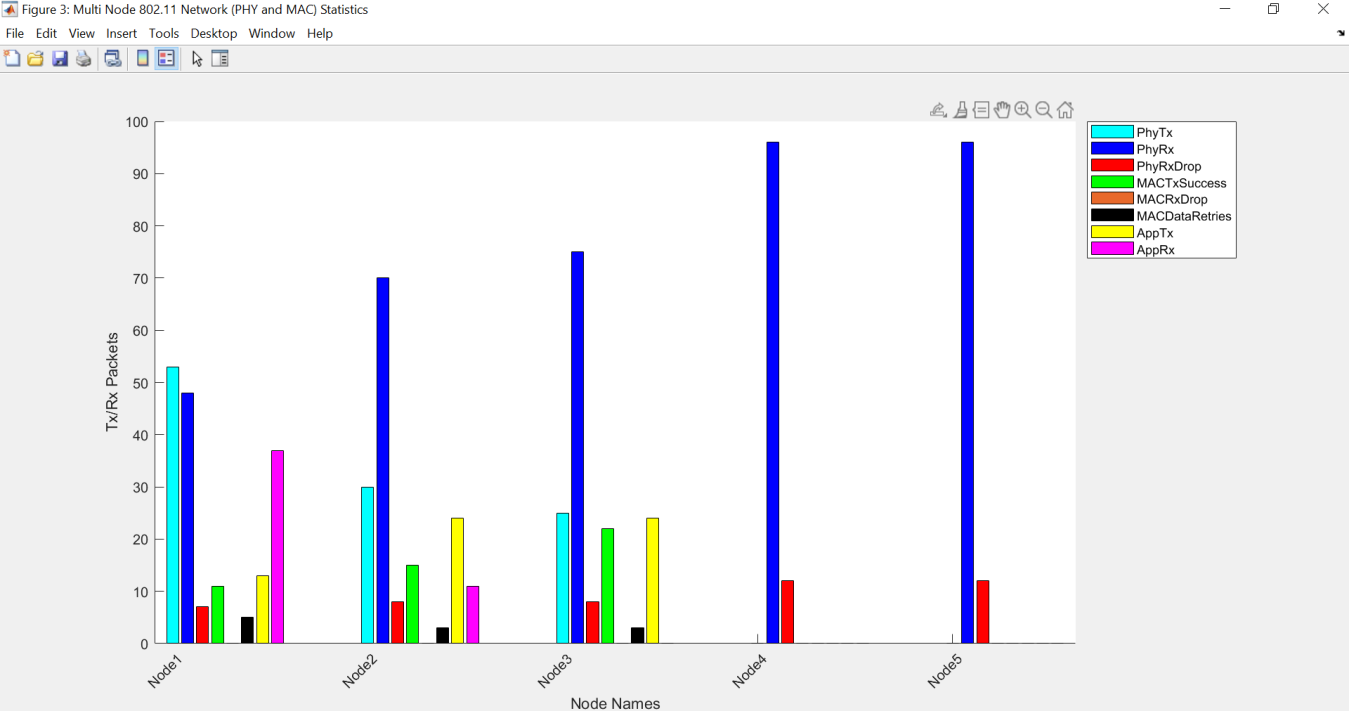


Figure 4.3a Increase in Application Parameters



Figure 4.3b Increase in Application Parameters

#### Sequence viewer

Sequence Viewer visualizes message flow, function calls, and state transitions.Sequence Viewer is used to see the interchange of messages, events, function calls in Simulinkmodels. Simulink behavior models in System Composer and between Stateflowcharts in Simulink models are also visualized.

In the Sequence Viewer window, event data related to Stateflow chart execution and the exchange of messages between Stateflow charts can be viewed. The Sequence Viewer

window shows messages as they are created, sent, forwarded, received, and destroyed at different times during model execution. The Sequence Viewer window also displays state activity, transitions, and function calls to State flow graphical functions, Simulink functions, and MATLAB functions. The Sequence Viewer is enabled to visualize message flow, function calls, and state transitions after implementing in the MATLAB.

Fig 4.4a and 4.4b represent the Sequence viewer which visualizes message flow, function calls, and state transitions.

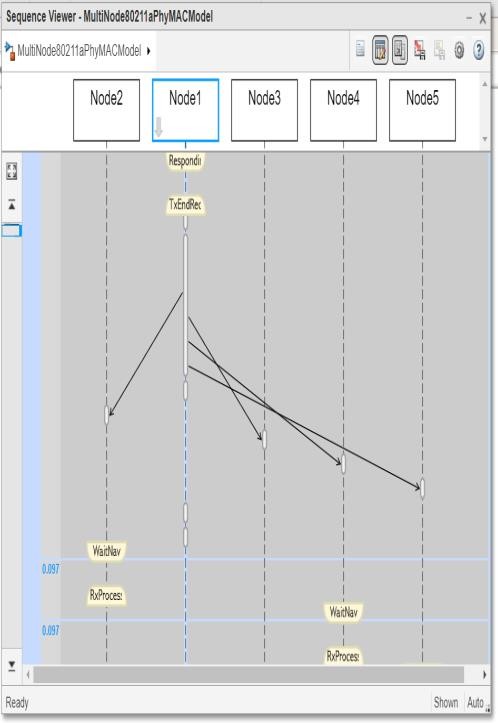
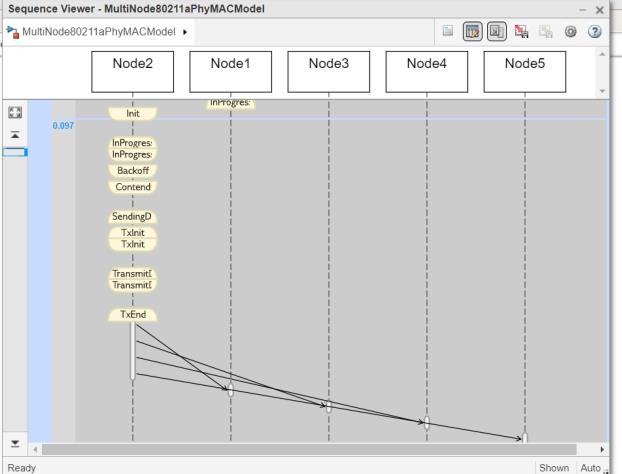


Figure 4.4aSequence Viewer Figure 4.4 bSequence Viewer

#### Node Position Allocation using NPA

Node position allocator is used to assign initial position of nodes. It supports linear and list position allocation strategies. The gap between 2 nodes(delta) is 100. There are 2 allocation strategies in Node position allocator for the allocation of the nodes in the WLAN.

**Linear Position Allocation Strategy** – Places nodes uniformly in a straight line, on a 2D grid. X and Y Directions are available along with the respective initializations for the node position allocations. Fig 4.5 represents the Block parameters of NPA in Linear Position Allocation strategy.

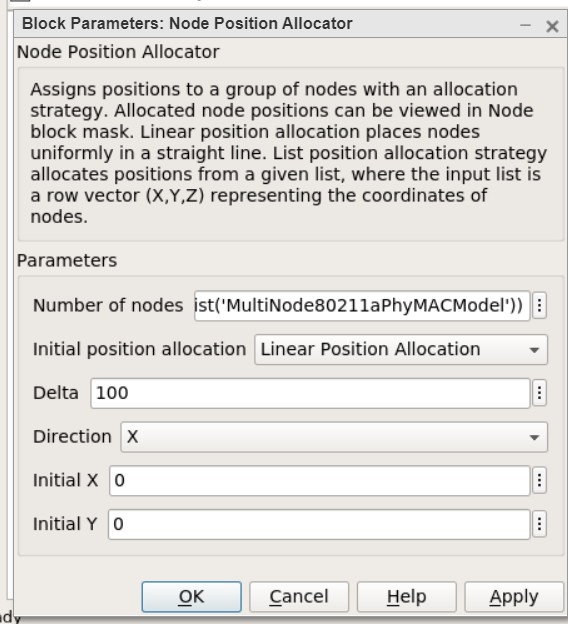
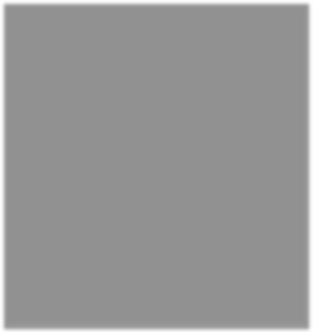


Figure 4.5Block Parameters of NPA (Linear Position Allocator)

**List Position Allocation Strategy** – Assigns node positions from a list [[x1 y1 z1] [x2 y2 z2] ... [xnynzn]] such that (xk, yk, zk) is the position of the kth node for all k in (1, 2, ..., n). Fig 4.6 represents the Block parameters of NPA in List Position Allocation strategy.

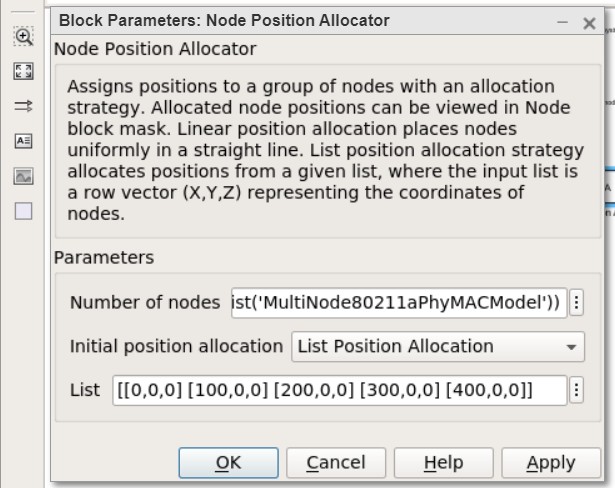
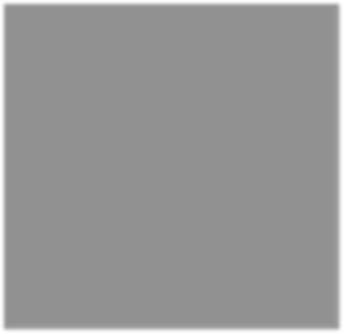


Figure 4.6 Block Parameters of NPA (List Position Allocator)

#### Variation of MAC parameters

Using RTS thresholds, RTS/CTS packets do not affect the throughput significantly. As the RTS threshold increases, the RTS/CTS packet exchange will significantly affect the performance. The MAC Transmission success rate is increased and also MAC Reception

drop rate is efficiently decreased or it is brought back effectively to null state. Even as seen from figure 4.7, The link layer has notification mechanisms in case of absence of the acknowledge packet or the clear to send (CTS) packet which permit the network protocols to research newer routes and update their routing table. The Tx/Rx value will increase as seen from the graph shown in fig 4.7.

* RTS Threshold - 5000
* Max Retries - 10
* Data Rate – 12 Mbps
* Max TX Queue size- 14

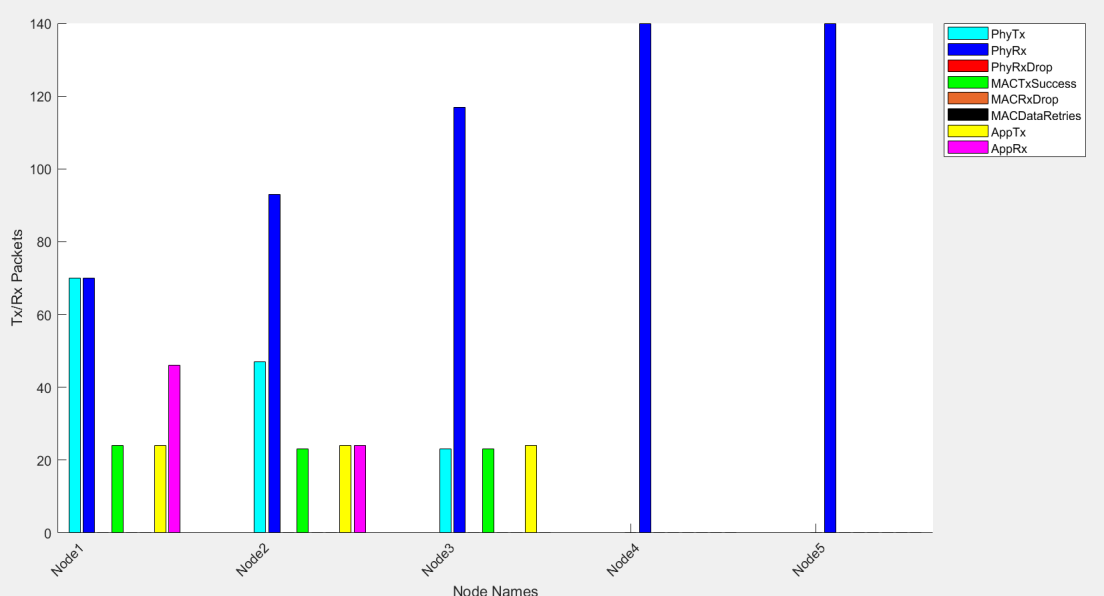


Figure 4.7 Figure showing Phy Rx drop almost zero when Mac parameters are increased

#### Variation of PHY parameters

* Rx Gain – 1.5 dB
* Rx Noise Figure – 3 dB

Noise figure (NF) and noise factor are measures of degradation of the signal-to-noise ratio (SNR), caused by components in a signal chain. It is a number by which the performance of a receiver that can be specified, with lower values indicating better performance.When the PhyRx80211aDES block receives a waveform, it scales the waveform with the configured Rx gain. The PhyRx80211aDES block then applies thermal noise and interference to the received waveform. This is carried out by calculating the expected signal to interference-plus-noise Ratio (SINR) at the end of

preamble, header, and payload. The calculated SINR is added to the preamble, header, and payload of the received waveform as an Additive White Gaussian Noise (AWGN). The PhyRx80211aDES block then compares the waveform power with the energy detection (ED) threshold. If the waveform power is greater than the ED threshold, the PHY sends a CCA busy indication to the MAC layer and starts decoding the waveform,and finally the Tx/Rx packet value will increase as seen from the graph in fig

4.8. The suppression of PHY Rx drop and MAC Rx drop results in a better performance.

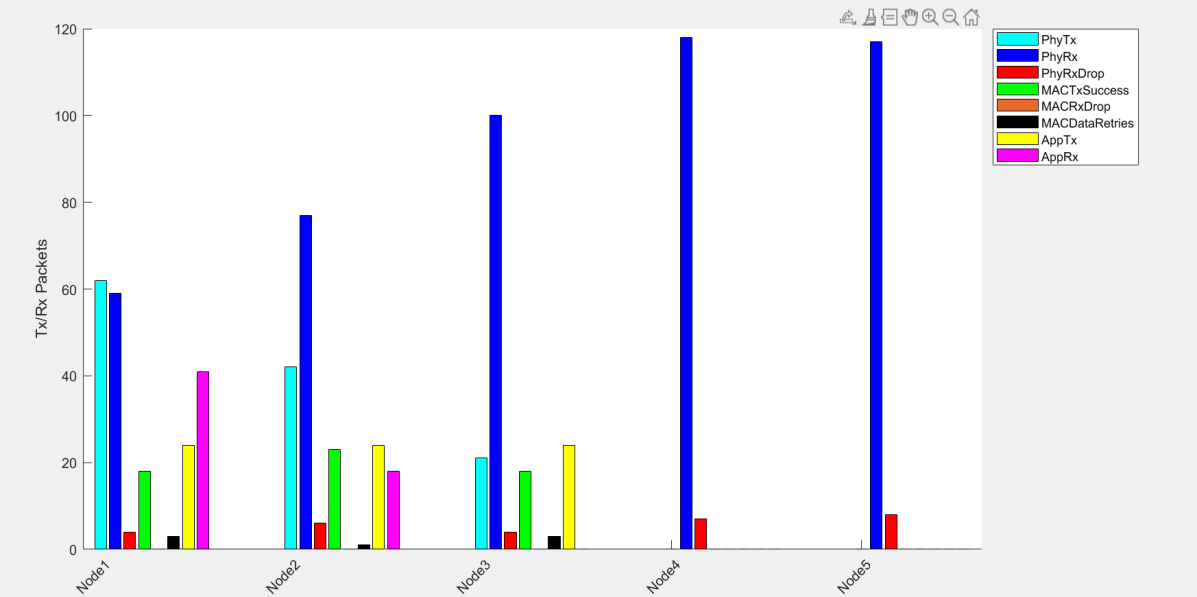


Figure 4.8 Figure showing PHY Rx drop and Mac Rx drop when Phy parameters are increased

#### Summary:

Communication between two ends is achieved using the MATLAB Simulink platforms. A file is taken as an input which will be chopped off into the several packets of the same size. In turn these packets of data are converted into the binary forms and this will in turn be converted into binary packets. The entire process will be tried to carry on with the MATLAB software. Further Explorations which were done by Varying Different Parameters on the Existing Network Model gave an insight about the Performance of the model. On the Internet, end-to-end principle is applied to provide reliable delivery, deduplication and in-order delivery of information.

The results and analysis obtained through the implementation are discussed in this chapter. Additional nodes are created in the model to analyze the changes. Incrementing the nodes will slightly decrease node timeline and also decrease the performance of TCP/IP model. Lesser the packet size, more number of packets to be transmitted and vice-versa. Sequence viewer visualizes the message flow, function calls and state transitions. Node position allocator supports linear and list position allocator strategies.

# CHAPTER 5

## CONCLUSION AND FUTURE SCOPE

#### Conclusions

IEEE 802.11™ standarddescribes the functions and services required by a device to operate within independent, personal, and infrastructure networks as well as the aspects of device mobility (transition) within those networks. Also it describes the functions and services that allow a device tocommunicate directly with another suchdevice outside of an independent or infrastructure network.The MAC procedures to support the MAC service data unit (MSDU) delivery services are also defined.

It Defines several PHY signaling techniques and interface functions that are controlled by the MAC. It Permits the operation of a device within a wireless local area network (WLAN) that coexists with multiple overlapping IEEE 802.11 WLANs. It also Describes the requirements and procedures to provide data confidentiality of user information and MAC management information being transferred over the wireless medium (WM) and authentication of devices. Mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in any band are also defined.

From Further Explorations the following conclusions were drawn:

* + 1. The wireless nodes in this type of network can act as a router and host at the same time.
    2. Node can also take an active part in the creation and maintenance of routes in the network. Incrementing the nodes will make additional nodes taking part in the transmission, reception but more number of nodes may decrease the performance of TCP/IP.
    3. When both Application parameters: packet size and packet interval are
       1. Decreased: the throughput increases, the Tx/Rx value also increase.
       2. Increased: the throughput decreases, the Tx/Rx value also decrease.
    4. NPA supports both linear and list position allocation strategies.
    5. MAC Parameters- Increase in RTS threshold: the RTS/CTS packet exchange will significantly affect the performance. The Mac Tx success rate is increased and also Mac Rx drop rate is efficiently decreased or it is brought back effectively to null state.
    6. The suppression of PHY Rx drop and MAC Rx drop results in a better performance.

#### Future Scope

802.11a operates in the 5 GHz band with a theoretical maximum net data rate of 54 Mbit/s. To practically achieve a data rate of 54Mbit/s Error correction code can be incorporated. It has seen widespread worldwide implementation, particularly within the corporate workspace.

In the present MATLAB 2020a, a basic 802.11a WLAN Model is available for simulation. The extensions of IEEE 802.11 which supports varied data rates, modulation techniques, applications, transmission range, channelization techniques,channel aggregation and channel coding techniques can be incorporated.

**Learning from the Project**

* WLAN Concepts studied in Computer Communication Networks was helpful for understanding and simulation of this project work.
* This Project helped to improve communication and presentation skills.
* Many aspects were explored on the existing WLAN Model.
* Helped in improving project report documentation.

#### Summary:

The conclusion and future scope of the project is discussed.Learning outcomes from the project are also discussed.

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**CO – PO Mapping**

Mapping of **‘End to End Simulation of TCP/IP Model for AD-HOC Networks using MATLAB’** to Program Outcomes (PO)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| End to End Simulation of TCP/IP Model for AD-HOC Networks using  MATLAB | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| M | H | M | H | H | L | M | H | M | H | - | M |

Mapping of **‘End to End Simulation of TCP/IP Model for AD-HOC Networks using MATLAB**’ to Course Outcomes (CO)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Project Title** | CO1 | CO2 | CO3 | CO4 |
| End to End Simulation of TCP/IP Model for AD-HOC Networks using MATLAB | H | H | H | M |

***Name Signature***

##### Girija S Sajjanar 1RV18TE012

* 1. **Sai Nagendra D M 1RV18TE041**

#### Signature of Guide