Implementation of WiFiRe PHY Sectorization in OPNET

A dissertation submitted in partial fulfillment of
the requirements for the degree of

Master of Technology

by

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Dissertation Approval Sheet

This is to certify that the dissertation entitled

Implementaion of WiFiRe PHY Sectorization in OPNET

by

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is approved for the degree of **Master of Technology**.

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CERTIFICATE OF COURSE WORK

This is to certify that **Mr. P Sreedhar Reddy** was admitted to the candidacy of the M.Tech. Degree and has successfully completed all the courses required for the M.Tech. Programme. The details of the course work done are given below.

Sr.No.	Course No.	Course Name	Credits
		Semester 1 (Jul – Nov 2006)	
1.	HS699	Communication and Presentation Skills (P/NP)	4
2.	CS601	Algorithms and Complexity	6
3.	CS615	Formal Specification and Verification of Programs	6
4.	CS631	Implementation Techniques for Relational Database Systems	6
5.	CS683	Advanced Computer Architecture	6
6.	CS699	Software Lab	4
7.	CS694	Seminar	4
		Semester 2 (Jan – Apr 2007)	
8.	CS616	Parallelizing Compilers	6
9.	CS638	Program Analysis	6
10.	CS640	Natural Computing	6
11.	IT610	Quality of Service in Networks	6
12.	IT628	Information Technology Project Management	6
		Semester 3 (Jul – Nov 2007)	
13.	CS641	Advanced Computer Networks	6
14.	CS683	Mobile Computing	6
		M.Tech. Project	
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Abstract

WiFiRe - WiFi Rural extension, is an extension of the existing WiFi protocol for providing long range broadband access for rural areas in cost effective way. As 802.11 MAC is not suitable for long range communications, WiFiRe replaces the MAC of existing 802.11b with MAC of 802.16 while retaining 802.11b PHY layer to extend the range. WiFiRe uses star topolgy and divides the region in to sectors, with each sector having one base station with sectorized antenna and one or more subscriber terminal with directional antenna. WiFiRe system has single MAC for all sectors, which helps to co-ordinate the medium access using multisector TDM.

In this thesis, we discuss the WiFiRe model design in OPNET. The PHY part of WiFiRe is implemented with OPNET using pipeline stages which describes the physical behaviour of wireless medium. The directional antennas in a six sectored system are modelled using OPNET antenna pattern editor. Some experiments are performed for range of sectorization and number of VoIP calls supported by ST in six sectored system to validate the model. Results shows the model is working as expected.

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Abbreviations and Notations

S :	WiFiRe System
BS :	Base Station
ST :	Subscriber Station
TDD :	Time Division Duplex
TDD-MSTDM :	Time Division Duplex, multi sector TDM
CID :	Connection Identifier
DL MAP :	Downlink MAP
UL MAP :	Uplink MAP
BW Req :	Bandwidth request
PHY :	Physical Layer
KP :	Kernel Procedures
UGS :	Unsolicited Grant Service
rtPS :	Real Time Polling Service
nrtPS :	non-real Time Polling Service
DCF :	Distributed Coordination Function
PCF :	Point Coordination Function
DSA Req :	Dynamic Service Addition
DSD Req :	Dynamic Service Deletion
DL-MAP :	Down Link Slot Allocation Map
VoIP :	Voice over IP
WiFi :	Wireless Fidelity
WiFiRe :	Wireless Fidelity for Rural Extension
WiMAX :	Worldwide Interoperability for Microwave Access

Chapter 1

Introduction and Motivation

1.1 Background

More than seventy percent of the population in India is living in the villages. There is a need for Broadband Internet access in villages for applications such as distance learning, e-governance, market information access, Voice over IP and email etc. Inorder to bridge the gap between the urban and rural areas, there is need for rural connectivity. With today available technologies deploying wired networks or cellular networks in rural areas in India is not a feasible solution because high cost of deployment [2]. The last mile from town to village has to be wireless.

The needs of present Indian rural telecom, and the economics of currently available broadband access technologies motivate a new system for rural broadband access, which we call WiFiRe (WiFi Rural Extension) [5]. As with the structure of Indian rural area, where most of the land is farmland and typically houses are in two or three clusters, the option that WiFiRe proposes is the 802.11 family of wireless technologies.

1.2 IEEE 802.11 Family

IEEE 802.11b MAC layer [4] is not suitable for long-range outdoor communication network, especially for voice traffic as the DCF (Distributed Coordination Function) mechanism in 802.11b MAC layer does not provide any delay guarantees and the PCF(Point Coordination Function) mechanism becomes inefficient with increase in number of stations and distance.

Due to widespread of technology, inter-operable standard and competitive mass production, the equipment and chip sets are inexpensive. The WiFIRe system takes advantage from widely available and cost-reduced WiFi chipsets. From these chipsets only the PHY is retained and employs a new MAC similar to IEEE 802.16 MAC.

1.3 WiFiRe Approach

The main design goal of WiFiRe system [2] is development of low cost hardware and network operations for rural connectivity, this is possible because

- WiFiRe system avoids frequency licensing costs by operating in the unlicensed 2.4 GHz frequency band
- WiFiRe uses the IEEE 802.11b PHY for its physical layer, due to the low cost and easy availability of IEEE 802.11b PHY chipsets.

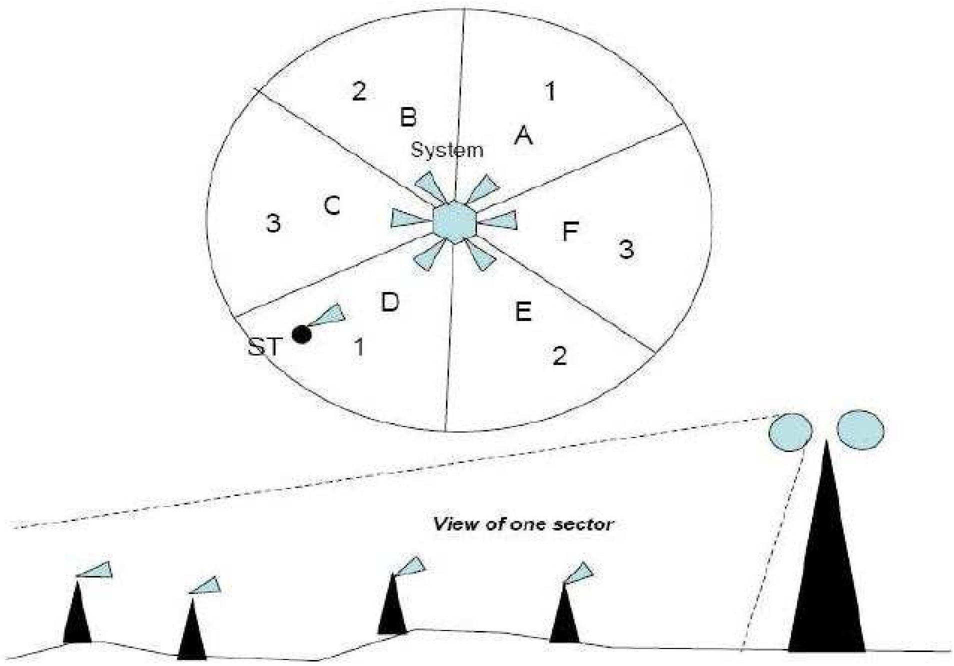


Figure 1.1: WiFiRe Network Topology [2]

WiFiRe replaces 802.11b MAC [4] mechanism (DCF/PCF) with more suitable one for long range communication, while continuing to use 802.11b PHY. WiFiRe adopts a star network topology using directional antennas, a WiFiRe system S consists of a set of base stations (BSs), each with a sectorized antenna, mounted on a transmission tower at a height of 40 meters for enabling line-of-sight communication. The WiFiRe cell is sectored and each sector will be covered by one BS. Subscriber Terminals in the surrounding villages are fixed with directional antenna, mounted at a height of around 10 meters, which minimizes co-channel interference to neighboring cells.

WiFiRe extends the transmission range to cover a cell with a radius between 15-20 Kilometres, by using

- A deployment strategy based on sectorized/directional antennas placed at BS and ST.
- Replace the 802.11b MAC mechanisms with WiMAX MAC layer while continuing to use the 802.11b PHY support.

1.4 Problem Definition

The WiFiRe model in OPNET was started with implementing with some functionalities of WiMAX MAC model by modifying for WiFiRe [9] [1]. The model is to be implemented by replacing 802.11b MAC with WiMAX like MAC while retaining 802.11b PHY.

The main problem focuses on

- Understanding the function of WiFiRe protocol.
- Setting up directional antennas for wireless transmission in a sector for proper transmission in a sector.
- Modelling some pipeline stages in OPNET to simulate wireless behaviour.
- Setting up the simulation model and perform some experiments.

The WiFiRe model with physical layer characteristics are now modelled with MAC part of WiFiRe. The wireless network scenario are modelled with pipeline stages with directional antennas in a six sectored WiFiRe system. Some experiments are performed to validate the model in OPNET.

1.5 Thesis Outline

The remainder of thesis is organized as follows. The second chapter discusses how to design a new model in OPNET. Chapter 3 describes the WiFiRe protocol details. Chapter 4 presents work done earlier on WiFiRe model, explains how to model physical layer characteristics and setup of antenna pattern with WiFiRe model. Chapter 5 focusses on simulation setup and experiment results of the WiFiRe model. Chapter 6 concludes the thesis.

Chapter 2

New Model Design In OPNET

2.1 OPNET Overview

OPNET Modeler [8] is one of the leading network and modeling simulation programs allowing users to model both wired and wireless communication systems. OPNET provides a comprehensive development environment for modeling and performance evaluation of communication networks and distributed systems [3]. The package consists of a number of tools, each one focusing on particular aspects of the modeling task. These tools fall into three major categories that correspond to the three phases of modeling and simulation projects: Specification, Data Collection and Simulation, and Analysis.

OPNET Models [7] are structured hierarchically. Specialized editors address issues at different levels of the hierarchy. This provides an intuitive modeling environment and also permits re-use of lower level models.

2.1.1 Modeling Domains

The Network, Node, and Process modeling environments are sometimes referred to as the modeling domains of OPNET, as they span all the hierarchical levels of a model.

Network Domain:

The Network Domain role is to define the topology of a communication network. The communicating entities are called nodes and the specific capabilities of each node are defined by

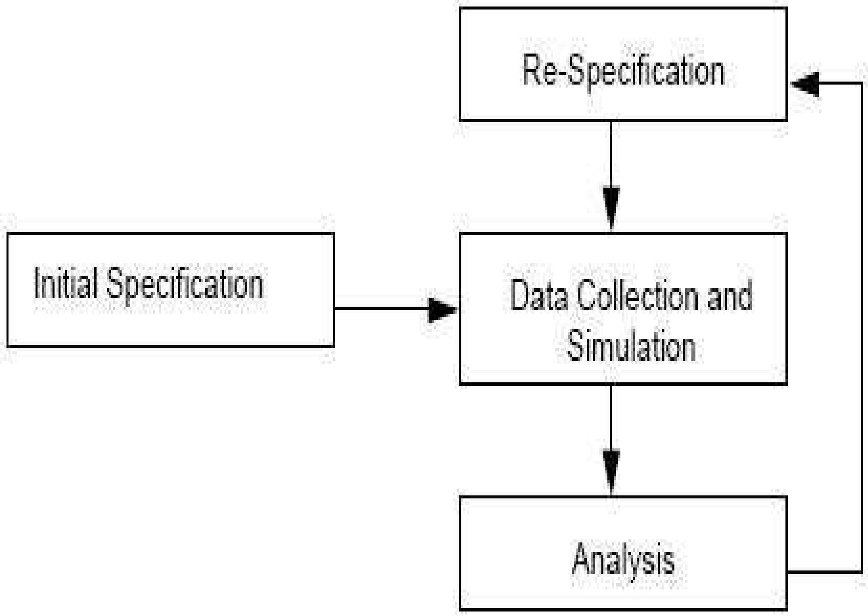


Figure 2.1: Simulation Project Cycle

designating their model. Nodes are instances of node models, developed using the Node Editor. Network models consist of nodes and links which can be deployed within a geographical context. OPNET provides fixed nodes, point-to-point and bus links. The Radio version in addition provides mobile and satellite nodes.

Domain	Editor	Modeling Focus
Network	Project	Network topology described in terms of subnetworks, nodes, links, and geographical context.
Node	Node	Node internal architecture described in terms of functional elements and data flow between them.
Process	Process	Behavior of processes (protocols, algorithms, applications), specified using finite state machines and extended high-level language..

Table 2.1: OPNET Modelling Domains

Node Domain:

The Node Domain provides for the modeling of communication devices that can be deployed and interconnected at the network level. Node models are developed in the Node Editor and are expressed in terms of smaller building blocks called modules. Node modules consist of modules and connections. Modules are information sources, sinks, and processors. Some modules have predefined behavior. Processor and queue modules are programmable via their process model. Connections such as packet streams and statistic wires allow information to flow between modules.

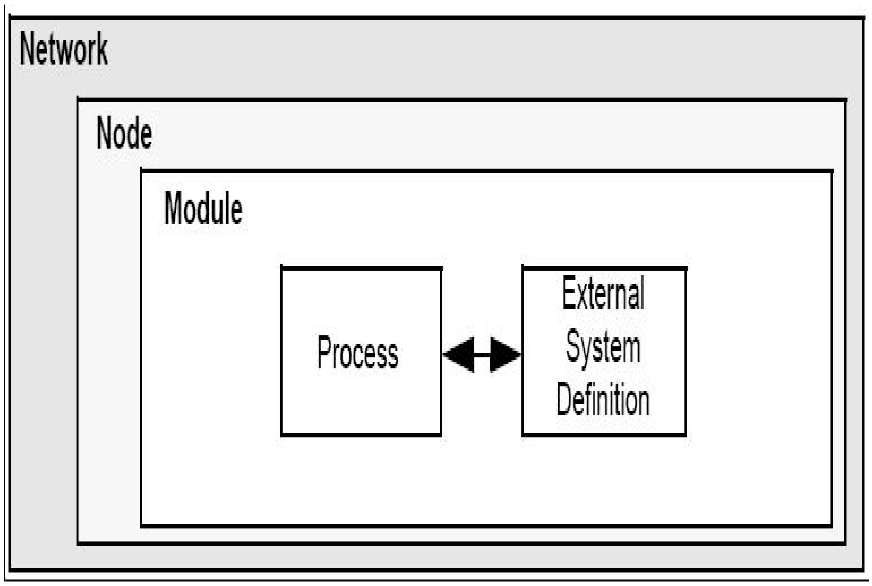


Figure 2.2: Hierarchial levels in OPNET Models [7]

Process Domain:

Process models define behavior for programmable modules. Processes in OPNET are based on process models that are defined in the Process Editor. A process is an instance of a process model and operates within one module. Initially, each programmable module contains only one process. processes can create additional child processes dynamically. These can in turn create additional processes themselves. This paradigm is well-suited to modeling systems with dynamically instantiated contexts. Processes respond to interrupts, which indicate that events of interest have occurred such as the arrival of a message or the expiration of a timer. When a process is interrupted, it takes actions in response and then blocks, awaiting a new interrupt.

It may also invoke another process and its execution is suspended until the invoked process blocks.

Process models are expressed in Proto-C, a language combining graphical state-transition-diagrams, embedded C/C++ language data items and statements, and a library of Kernel Procedures that provide commonly needed functionality for modeling communications and information processing systems.

OPNET Models

OPNET objects have behavior and structure that is specified by a model. Models also specify part or all of an objects interfaces. Some objects have implicit models that cannot be changed, others can be assigned models via their model attribute, allowing extensive customization.

2.2 Antenna pattern in OPNET

Radio receiver and Radio trasmitter objects are entry and exit points of packets through wireless environment via antenna object.

- Radio receiver object act as the entry points in a node for packets received on radio communication links. Radio receivers are considered as data sources from the perspective of other modules within the node. The receiver is connected to an antenna module via an input stream.

- Radio transmitter object act as the exit points of a node for packets transmitted on radio links. Radio transmitter objects are the interface between a node and the radio transmission medium.

Antennas are only used for modeling radio transmission, and affect the simulation through their association with radio transmitters and receivers. Packet streams are used to couple antennas to receivers and transmitters. A packet stream exists from a radio transmitter to an antenna, or from an antenna to a radio receiver.

OPNET antenna pattern editor [7] has been utilised, to define the antenna patterns. The antenna pattern can be associated with a radio transmitter and/or receiver to provide the gain defined by the pattern using an antenna module in the node editor.

2.3 OPNET Transceiver Pipeline

The transceiver pipeline stages [7], are a series of software blocks that perform all the wireless physical layer operations. A wireless link is not statically represented by physical object, as point to point. A wireless link can exist between any radio transmitter and radio receiver object and is dynamically established during simulation.The transceiver pipeline stages, implements physical layer characteristics and determines if a packet can be received by receiver. Stages 1 to 5 are the transmitter pipeline stages associated with radio transmitter and stages 6-13 are the receiver pipeline stages associated with radio receiver. The stages in the pipeline are executed on per receiver basis when a transmission occurs.

2.3.1 Pipeline Stages

1. **Receiver group:** Each transmitter maintains its own list of receiver group which are possible candidates of receiving transmission from the object. The purpose is to create an initial receiver group for each transmitter channel. Next stages in the pipeline are evaluated for only those receivers which are in receiver group of the transmitter.

2. **Transmission delay:** The purpose is to compute the time required for the radio transmitter of interest to completely process and transmit the packet. It calculates total time taken to transmit a packet. Result from this stage is also used with result from propagation stage in order to schedule reception of a packet at the receiver.

3. **Closure:** It determine if the transmitted signal can physically attain the candidate receiver channel and affect it in any way. This stage is invoked once for each receiver channel in the receiver group. This stage applies to interfering transmissions as well as desired ones. The computations performed by this stage are based mostly on physical considerations such as occlusion by obstacles and the surface of the earth. It returns boolean value, TRUE if signal can be established between transmitter and receiver, FALSE when

signal contact between the transmitter and receiver is not possible and no further stage is evaluated.

4. **Channel match:** It determines the compatibility between a radio transmitter channel and a radio receiver channel, purpose of this stage is to classify the current transmission with respect to receiver channel as three categories.

   - Valid transmission, in which the receiver is capable of processing, the packet may be accepted and forwarded to next modules for further processing.
   - Noise, in this class the data cannot be received at the receiver but the transmission can generate the interference at the receiver.
   - Ignore, transmission in this class doesn't affect the receiver channel in any way and hence can be ignored, further pipeline stages are suspended for the current transmission.

5. **Transmitter antenna gain:** Transmitter antenna gain is calculated for all receivers that are classified noise and valid by the channel match stage. It is used to compute gain provided by the transmitter's associated antenna, using the vector between the transmitter and receiver.

6. **Propagation delay:** It is time taken by packet signal to travel from source to destination. It depends on distance between the transmitter and receiver.

7. **Receiver antenna gain:** This is first stage at receiver. Calculated at each receiver depending on the direction leading from receiver to transmitter.

8. **Received power:** The computation of received power occurs independently for each packet that is able to reach and affect the radio receiver channel. It Calculate the received power of arriving packet's signal. For packets classified as valid, the receiver power is an indication of how accurately receiver can capture the information in the packet. Executed also for packets classified as noise (usefull in calculating relative strength of valid packets to noise). Computation of received power depends on many factors like transmission power, distance separating transmitter and receiver, transmission frequency, transmitter and receiver antenna gain. It Enables the remaining stages to compute signal to noise ratio and then derive bit error rate. It computes the average power in watts of the signal

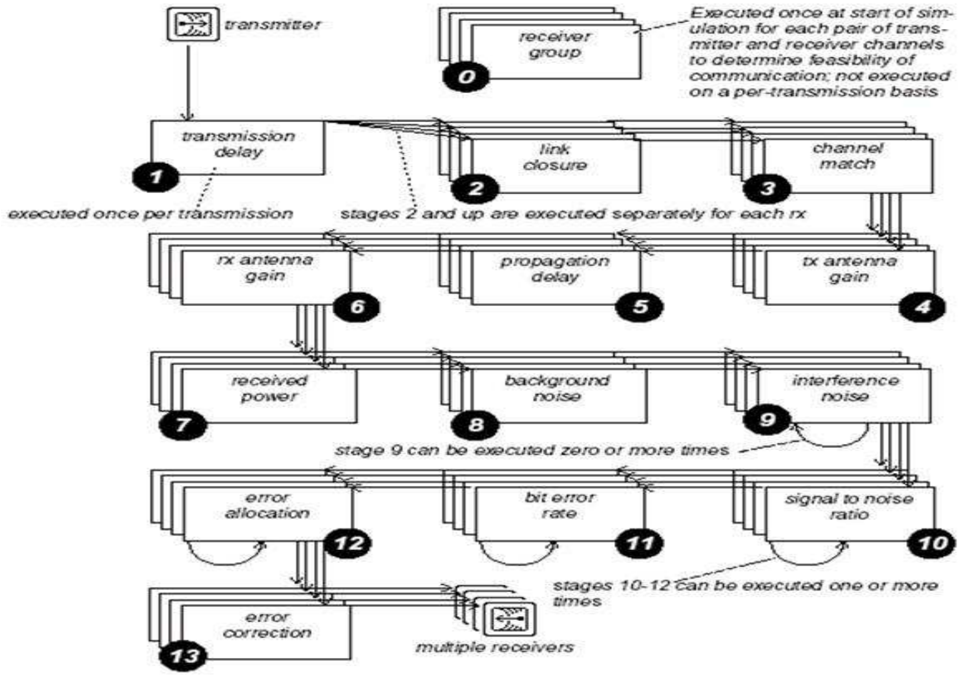


Figure 2.3: Radio Transceiver Pipeline Execution Sequence [7]

associated with a transmitted packet.The fundamental performance measure computed by the default Radio Transceiver Pipeline is the average power level of signals received by radio receiver channels

9. **Interference noise:** The purpose of this stage is to account for the transmissions that arrive at the receiver concurrently. The actual effect of interference depends on the properties of the transmitting and receiving devices and the timing of the transmissions. The computation of interference noise occurs only when two packets are simultaneously present at the same radio receiver.

10. **Background noise:**Represent the effect of all noise sources except for other concurrently arriving transmissions (these are accounted by the interference noise stage). The expected result is sum of the power (in watts) of other noise sources, measured at the receivers location and in the receiver channel's band. Typical background noise sources include thermal and galactic noise, emissions from neighbouring electronics and otherwise unmoduled radio transmissions.

11. **Signal to noise ratio:** Executed for valid packets for following three conditions that the packet arrives at its destination channel. The packet is already being received and another

packet (valid or invalid) arrives. The packet is already being received and another packet (valid or invalid) completes eception. Purpose is to compute the current average power SNR for the arriving packet.

12. **Bit error rate:** Executed for all valid packets for which SNR stage is executed. Purpose is derive probability of bit errors during the past interval of constant SNR. This is not empirical rate of bit errors, but the expected rate usually based on SNR. In general BER provided by this stage is also a function of the type of modulation used for the transmitted signal.

13. **Error Allocation:** The purpose of the stage is to estimate the number of bit errors in a packet segment where the bit error probability has been calculated and is constant. This segment might be entire packet, if no changes in bit error probability occur over the course of packet's reception. Bit error count estimation is usually based on the bit error probability obtained from stage 11 and the length of affected segment.

14. **Error correction stage:** This Stage is to determine whether the arriving packet can be accepted or not. This is usually dependent upon whether the packet has expereinced collisions or not. By comparing error correction threshold of the receiver with the number of errors in the packet the acceptability of a given packet at receiver is determined.

Chapter 3

WiFiRe Overview

3.1 WiFiRe Introduction

The WiFiRe system [2] consists of set of base stations, typical number of BS are six each with directional antennas mounted a top of tower. The area covered by a single system is called cell, which used to cover a radius of 15-20km. A Cell is divided in to sectors, for each sector there is a base station with a sectorized antenna and subscriber terminals with directional antennas in surrounding villages.

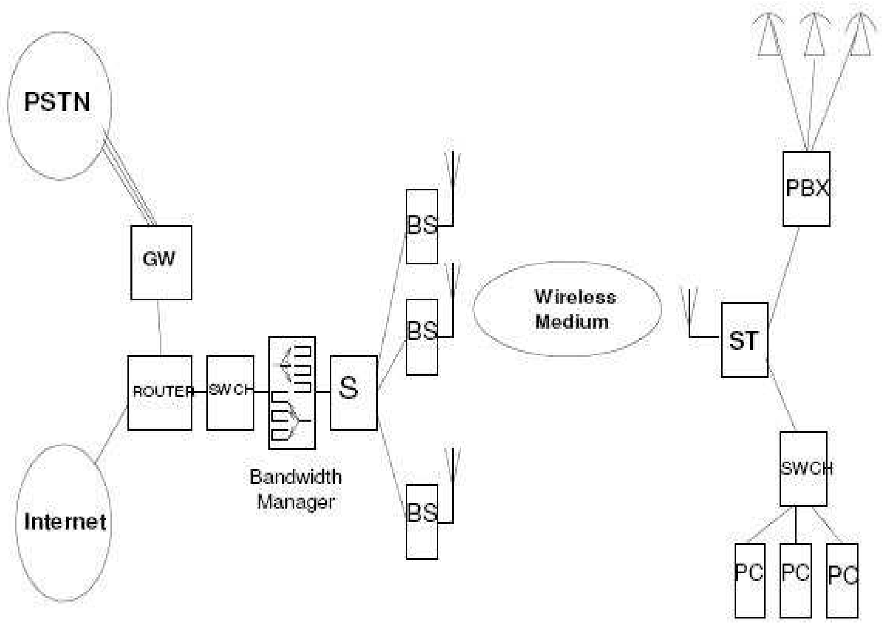


Figure 3.1: WiFiRe System Architecture

To coordinate medium access among all the sectors WiFiRe has one common medium access controller [1], WiFiRe TDD-MSTDM mechanism. In this mechanism time is divided in to frames, which is further divided in to a downlink and uplink subframes as shown in the figure. Multiple BS antennas can transmit in DL simultaneously, provided that they operate in non interfering manner and with Multiple STs in UL can transmit to a BS provided that they transmit in non interfering manner.

The DL segment starts with each BS in the system transmitting a beacon packet which contains information regarding time synchronization of the STs, DL and ULMAPs(DL and UL slot allocations) for next frame and other control information. In the WiFiRe system all the Base stations use same WiFi channel for communication with their STs, Proper sectorization of a cell while using the same frequency channel for all sectors is a key feature in WiFiRe.

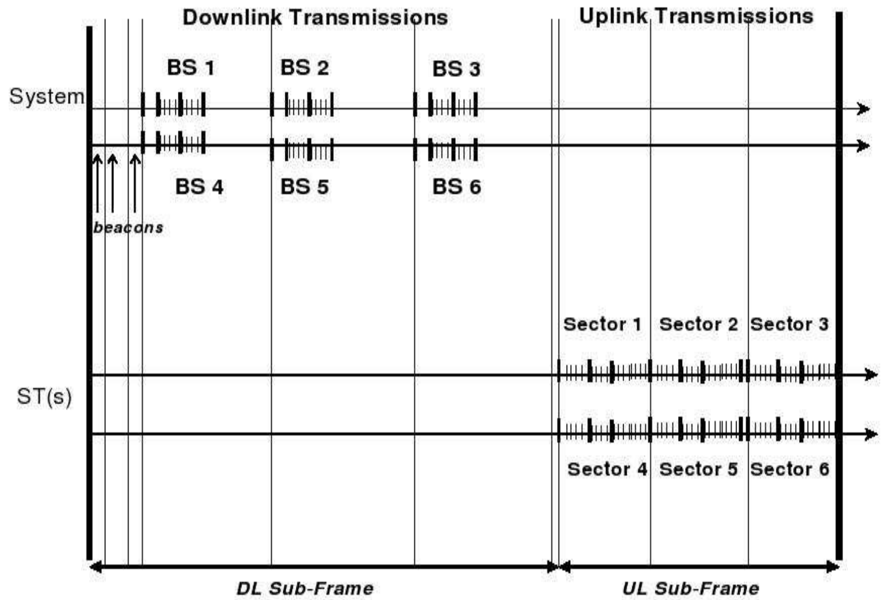


Figure 3.2: Parallel transmission in a six sector system [2]

3.2 WiFiRe Design

For enhancing the 802.11b PHY for long range communication the WiFiRe MAC layer is designed with directional antennas. The radiation patterns of directional antennas for a transmitter gives sectorized coverage area. WiFiRe uses multiple sectorized antennas for longer reachability and for complete coverage around transmitting point. The MAC layer is a multi-sector MAC which has a functionality that can control all antennas simultaneously.

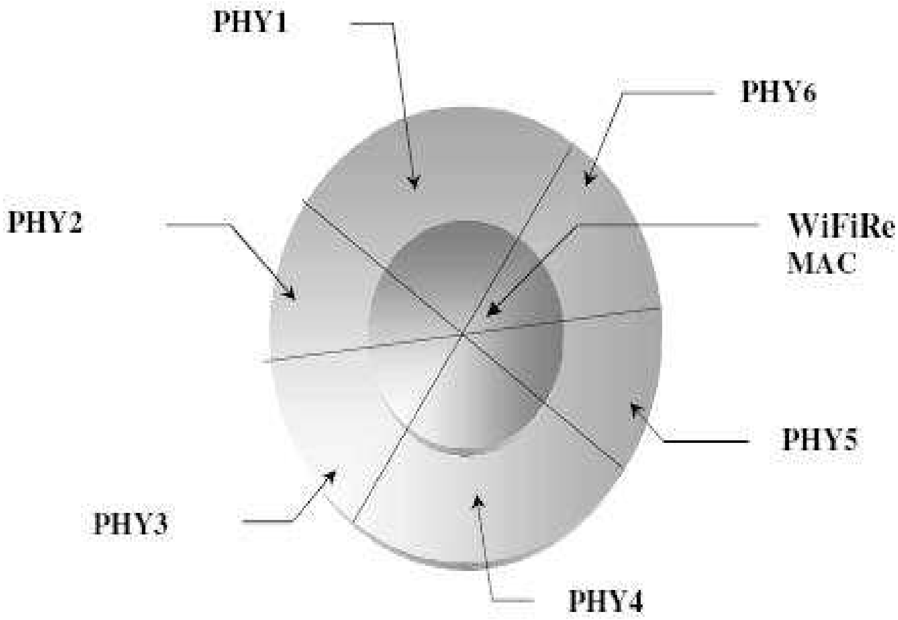


Figure 3.3: Single WiFiRe MAC controlling six WiFi PHYs [2]

As all the sectors in a multiple antenna configuration uses the same frequency channel, transmission by one antenna will interfere with an adjacent sector. Opposite sectors may be completely free from interference, based up on antenna models and transmission power level. The MAC layer needs to coordinate the transmission between the antennas in order to avoid interference.

In WiFiRe multi-sector system, each antenna controlled by an 802.11b PHY. The MAC layer at WiFiRe system is on top of all of these 802.11b PHY(s) as shown in figure 3.3. From the perspective of the MAC, each PHY is addressable and identifiable. Thus a single MAC controls more than one PHY and is responsible for scheduling MAC messages appropriately, while resolving possible transmission conflict from the perspective of receivers.

3.3 WiFiRe PHY

WiFiRe uses IEEE 802.11b which operates in license free nature of the WiFi spectrum in 2.4GHz band. With WiFiRe, it can support about 25 Mbps (uplink + downlink) per cell, using a single WiFi carrier at 11 Mbps service. WiFiRe physical layer directly employs the low cost WiFi PHY(802.11b). WiFiRe extends the transmission range of the WiFi PHY, by using sectorized, directional antennas and line of sight communication.

3.4 WiFiRe MAC operation details

The WiFiRe MAC protocol can be divided into two major phases:

- **Network Entry and Initialization:** An Subscriber station, upon powering up, listens for beacons for the operator ID and system ID. Up on receiving the beacons, ST forms a Ranging Request message and sends in the ranging block of UL sub frame for each BS that ST hears. Thereafter ST waits and monitors the DL-MAP in all beacons of subsequent frames for a Ranging Response. If no response is received within a timeout period, ST sends ranging request again after random backoff period. System S receives the ranging request message and selects an appropriate BS, then it constructs the ranging response and puts it in the transmit queue of the corresponding BS and it invokes the scheduler. After successful Ranging, ST will register with its BS by sending Registration Request

- **Connection Management and Data Transport:** Connection management and data transport session enables the ST to create, maintain and terminate a connection with desired QoS parameters. When higher layer at ST initiates a connection to send data, then ST sends Dynamic Service Addition request message to BS. System S assigns data CID and responds with Dynamic Servie response message. To terminate connection ST sends Dynamic Service Deletion message to BS

3.5 MAC services:

The WiFiRe MAC defines various scheduling service classes. Subscriber terminal can establish connections using the scheduling service class. Each ST request the service agreements with the BS during connection setup. The BS uses these scheduling classes while allocating uplink bandwidth for the STs. The scheduling service classes are Unsolicited Grant Service (UGS), Real-Time Polling Service (rtPS), Non-Real-Time Polling Service (nrtPS), and Best Effort (BE) Service.

- **UGS:** UGS pre-allocates periodic transmission opportunities to the STs, which eliminates the overhead involved in the bandwidth request-grant process. so it is designed to support fixed size data packets on a periodic basis, such as VoIP.

- **rtps:** Real-Time Polling Service ensures that STs get periodic bandwidth request opportunities. The STs can then request bandwidth from the BS. It is designed to support variable size data packets on periodic basis such as streaming video.

- **nrtps:** Non-Real-Time Polling Service is designed for applications that need high bandwidth connections and are not delay sensitive, for example, bulk file transfers.

- **Best Effort:** Best Effort service targets best effort traffic where no throughput or delay guarantees are necessary.

All important modules in WiFiRe are simulated including PHY layer. The sectorization in six sectored WiFiRe system is designed using directional antennas. The wireless behaviour of pipeline stages are implemented using pipeline stages.

Chapter 4

WiFiRe Model in OPNET

4.1 Work Done Earlier

Implementation of WiFiRe model was started with the WiMAX patch available in OPNET [8]. As WiFiRe MAC is similar to WiMAX in several respects, the patch is modelled to the needs of WiFiRe.

4.1.1 Overview

The block diagram of WiFiRe model [9] in OPNET with one ST and BS is shown in the Figure 4.1. The WiFiRe OPNET model has common MAC process model, Base Station(BS) node model, Subscriber Terminal(ST) node model, BS child control process model and ST Child control process model. The WiFiRe common MAC process model runs at both BS and ST for implementing common modules like constructing MAC frames, segmentation and reassembly and beacon processing etc. This module calls ST and BS child processes depending upon the packet type. For example it calls ST control child process model when DSA request invoked and BS control child process model when Bandwidth request is made. Base Station node model has Admission control, slot scheduler and MAP generator specific tasks. DSA request, BW Req generator, etc are ST specific taks. The figure shows how all modules work together to build the WiFiRe model.

When simulation starts, ST will send the DSA request to BS, which contains the service flow parameters for requesting connection and source MAC address. BS calls Admission control module up on receipt of DSA request message, processes it and sends DSA response to

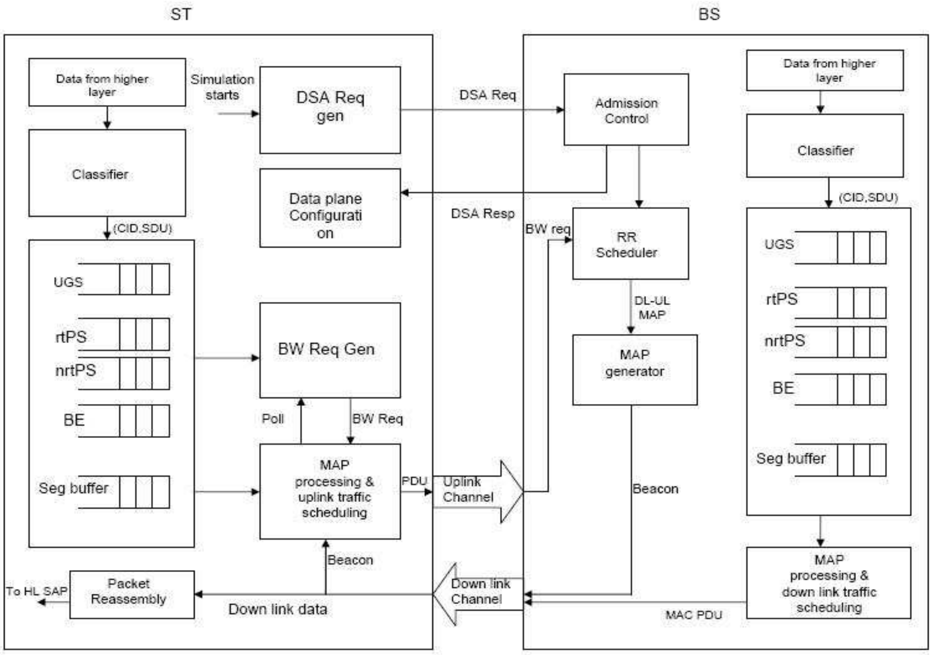


Figure 4.1: WiFiRe Model design block diagram

requested ST. DSA response contains acceptance status and accepted service flow parameters. ST up on receipt of DSA response message with accepted state of connection it will configure datastructures like classifier, data queue, segmentation buffer.

As MAC receives a packet from higher layer, it gives the packet to the classifier module. The classifier classfies the packet into the connection it belongs to and gives connection ID (CID). After classification, the higher layer SDU is enqueued into the queue corresponding to that CID. ST receives a beacon from BS which contain slot scheduling information for downlink and uplink, and extracts the Uplink MAP and schedules the traffic in corresponding slots. ST sends a BW request, if it polled. The scheduler calls the segmentation module, if next packet size in the queue is greater than allocated slots of that connection. It then segments the packet and schedules for transmission and at reassembly module reconstructs the segmented packets and sends to upper layer.

Initial contributions by [1]

The initial part of this work started by setting up simulation model of WiFiRe, the contributions of the work are

- Performed initial setup of the WiFiRe MAC model from WiMAX patch, released by OPNET to refer for implementation.
- From WiFiRe MAC model, implemented the common process between the Subscriber station and Base station like process data paket, process map, enqueue and process control packet. Base station specific functionalities like DSA request, Send map, process BW request and Subsciber specific functionalities like DSA request send, process DSA response.
- Implemented greedy heurisic scheduler at Base Station, with optimization parameter as UGS grant size of subscriber station. The subscriber stations are scheduled with greater UGS grant always gets preference.
- Studied innterference pattern for six sectored partitioned cell. Performed preliminary experiments on throughput and delay with setup of BS and some STs with each ST registered UGS an BE uplink and downlink flows at BS.

Initial contributions by [9]

The Implementation was mainly to model the MAC functionalities of WiFiRe by modifying WiMAX MAC model. The contributions of the work are

- Round robin scheduler is implemented to schedule accepted flows in which scheduler first allocates polling slots to rtPS and nrtPS flows, allocates admitted number of slots for UGS flows and allocates requested number of slots for rtPS and nrtPS if required number of slots are less than admitted number of slots and remaining slots to BE flows.
- Beacon processing and traffic schedulling has implemented which works at both Subscriber terminal and Base station, in which downlink transmission is followed by uplink transmission by Subscriber Stations.
- Polling and Bandwidth request mechanism are implemented in WiFiRe model to simulate rtPS and nrtPS service flows.

- Experiments performed to analyze queuing delay, end to end delay MAC delay, throught-put and best slot length for UGS, rtps service flows with different slots lengths.

4.2 WiFiRe model status

The modelling of WiFiRe system in OPNET has started with inital setup containing some MAC functionalities like greedy heuristic scheduler, WiFiRe MAC process models to simulate the traffic between ST and BS. Later the main functionalities like round robin schedulling, beacon processing, packet segmentation and reassembly, polling and bandwidth are modelled by modifying WiMAX MAC excluding PHY layer functionalities.

The WiFiRe model with physical layer characteristics are now modelled with MAC part of WiFiRe. Using pipeline stages the wireless network scenario of WiFiRe are modelled with directional antennas. OPNET antenna pattern editor had been utilized to define the antenna patterns. The antenna pattern can be asscociated with a radio transmitter and receiver to provide gain defined by pattern using an antenna module. Some experiments like range of sectorization, effect of directional antennas on wireless medium, and queuing delay are performed to show the correctness of model. The following table shows the status of work in detail.

Anirudh [1]	Venkat [9]	Present work
1. Intially started with QualNET for WiFiRe setup and due to lack of sufficient resources available in Qualnet, latter shifted to OPNET. 2. Implemented Base station specific functionalities, Subscriber station specific functoinalities and common process which implements common functionalities between the ST and BS. 3. Greedy heuristic scheduler at BS was implemented with optimisation parameter 'UGS grant size' of Subscriber station. 4. Performed preliminary experiment on throughput and delay with setup of BS and some STs with each ST registered with UGS and BE uplink and downlink flows at BS. 5. physical layer functionalities and some MAC fuctionalities like segmentation, polling and Bandwidth request etc, are not modelled.	1. Implemented mainly WiMAX MAC model modifying for WiFiRe [9]. 2. Implemented Round robin scheduler to schedule various accepted service flows. 3. Common fuctionalities of both ST and BS like Beacon processing and traffic schedulling are implemented. 4. Polling and Bandwidth request mechanisms are implemented in WiFiRe model to simulate rtPS and nrtPS service flows. 5. Experiments performed to analyze queuing delay, end to end delay and MAC delay and throughtput and best slot length for UGS, rtps service flows with different slots lengths. 6. Physical layer functionalities are not modelled.	1. Wireless network scenario with six sectored setup using directional antennas are modelled. 2. Implemented some pipeline stages to simulate the physical layer characteristics. • *Transmission delay:* Computes the time required for the transmission of packet from length of packet and transmission data rate. • *Channel match:* It is Modelled to determine the compatibility between transmitter and receiver channel. • *Antenna gain:* Using vectors between tx and rx gain is calculated. • Other stages like *snr*, *prop delay*, *received power* are modelled to needs of system. 3. Modifying of MAC part of WiFiRe to support PHY. 4. Support of Muliple sectors. 5. Performed Experiments for range of sectorization, effect of directional antennas on wireless medium, better snr values through directional antennas and experiments to perform end to end, queuing dealy for different configurations.

4.3 Components in WiFiRe model:

The components are backbone to build the WiFiRe system. The ST and BS are main components in the system with each of them has connection between the MAC module to the antenna through transmitter and receiver.

1. Subscriber Terminal: Each ST is having directional antenna pointed towards system S. Each ST having common MAC process with respect to BS. This MAC process is responsible for defining service flows, activating service flows, mapping incoming packets to corresponding connection, queuing, processing beacon and serving packets from queue. Each ST having one control process, it is responsible for processing control packets such as DSA-Req, DSA-Resp and Bandwidth Request packets.Figure 4.2 will show typical ST node model.

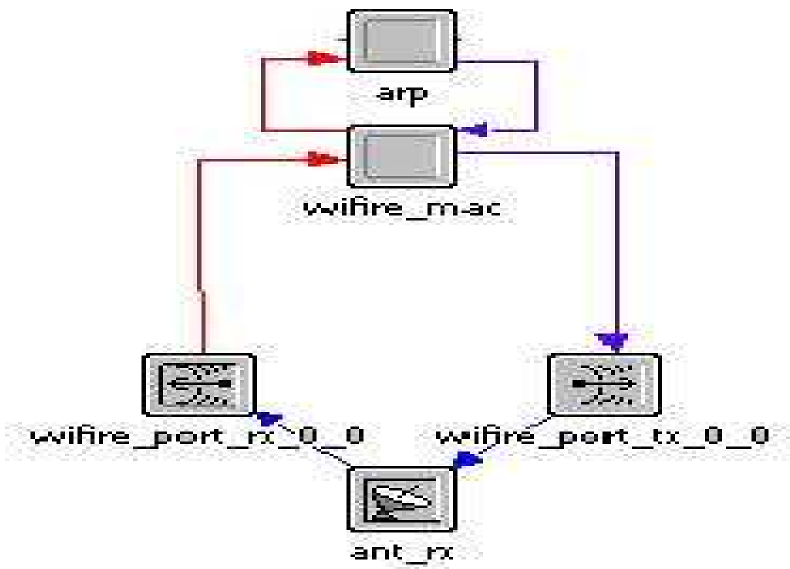


Figure 4.2: WiFiRe ST Node Model

Each ST has Radio receiver, Radio transmitter as entry points and exit points respectively at node for packets received from radio links. The receiver and transmitter module is connected to an antenna module through an input stream and output stream.

2. Base Station: Each BS node model consists of six WiFiRe interfaces, each WiFiRe interface represents a sector. The BS component also uses the common MAC process for common MAC functions, like classification, packet transmission scheduling etc. Each

Base Station will have one control child process, which is responsible for sending beacon periodically, processing DSA-Req and sending DSA-Resp, scheduling downlink traffic, etc.

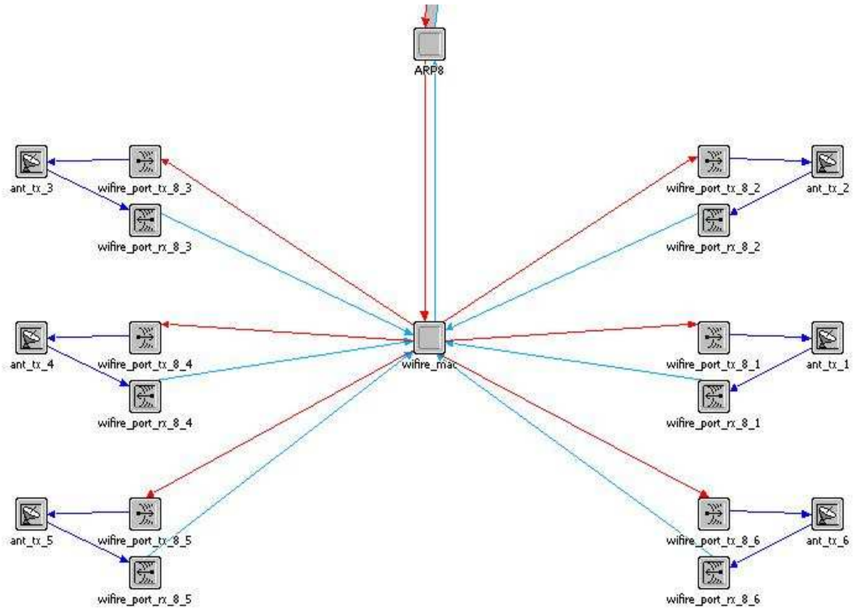


Figure 4.3: WiFiRe BS Node Model

3. WiFiRe Configuration Node: WiFiRe config node is used to define new service classes and its parameters. This is also used to define MAC parameters such as data rate, Frame duration (num of slots), slot duration, number of contention slots and number of ranging slots etc.

4.4 Antenna Pattern

The wireless model have been added in recent years, which does not incorporate the 802.11 based MAC layer. We can customize the wireless model for the specific purpose by setting numerous attributes such as the modulation scheme, data rate, bandwidth, center frequency as well as antenna patterns.

The primary purpose of the antenna object is to allow modeling of directional gain at radio receivers and transmitters. Each antenna is assigned a gain pattern which species the gain relative to isotropic radiated power as a function of horizontal plane angles, phi and theta.

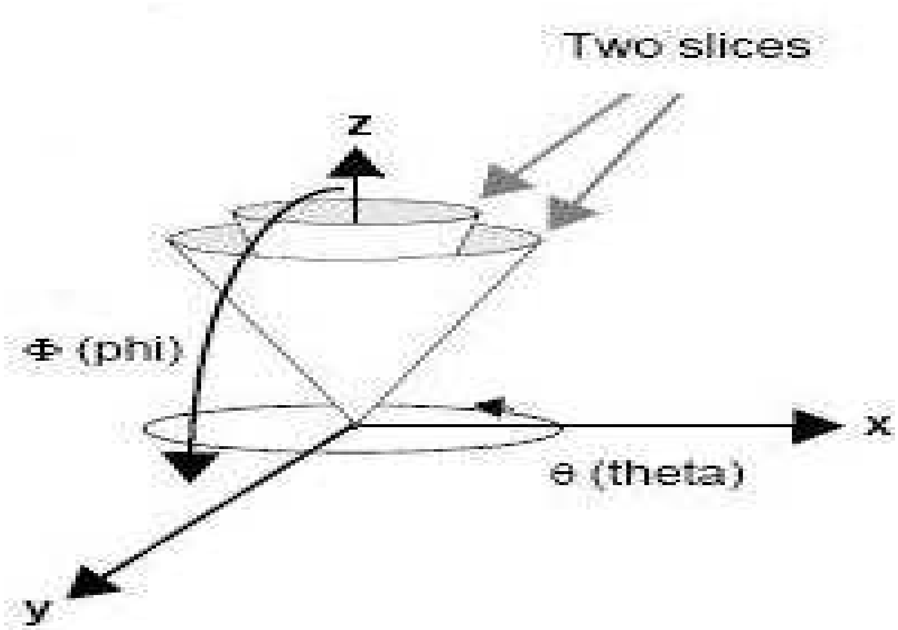


Figure 4.4: Antenna pattern using spherical angles phi and theta

The processor module for antenna calculates the information that the antenna needs to point at a target. This pointing processor makes this calculation by using a Kernel Procedure that converts a nodes position in a subnet. Information is transferred from a stationary transmitter object to a stationary receiver object, these objects are connected by a radio link. The radio link depends on many different physical characteristics of the components involved, including frequency band, modulation type, transmitter power, distance, and antenna direction.

The antenna pointing processor calculates the position of the transmitter module and sets the antenna modules targeting attributes. The process model determines the identities of the objects of interest, and then retrieves and modifies the object's attribute values. Kernel Procedures [7] in the Identification and Topology Packages (prefixed with op_id and op_topo) will find position of the transmitter module. A Kernel Procedure from the Ima Package (with the prefix op_ima) does antenna module's targeting attributes.

Algorithm 1 Antenna pointing process

```
Assign processor parent object id to receiver node object.
rxnode_id ← parent objid(processor)
Get object id of the subnet object from receiver node object
subnet_id ← KP( objid(rxnode_id))
Get object id of transmitter node from transmitter node, subnet_id
txnode_id ← KP(transmitter node, subnet_id)
Assign object id of the antenna module with in the receiver node to receiver antenna object
rxant_id ← KP(rxnode_id, antenna module)
Calculate the antenna value attributes with values retreived from transmitter node
```

4.5 Transceiver Pipeline models

4.5.1 Modification of pipeline stages

The physical layer of the System is modeled with pipeline stages which are used to calculate the step by step total effect of the physical transmission medium. For this we examined OPNETs 802.11 radio wireless node models. We choose to base our model on the 802.11b PHY model, and modified the MAC layer and many of the pipeline stages to better meet our needs. Each pipeline stage is a model made with OPNET flavored C or C++. The used pipeline stage models can be defined by transmitter and receiver attributes. Each stage is simply a piece of software that can be substituted or modified as desired which perform all the wireless physical layer operations. Stages 1-5 are the transmitter pipeline stages and stages 6-13 are the receiver pipeline stages. Figure 4.5 shows the transmission of packet over different stages from transmitter through receiver.

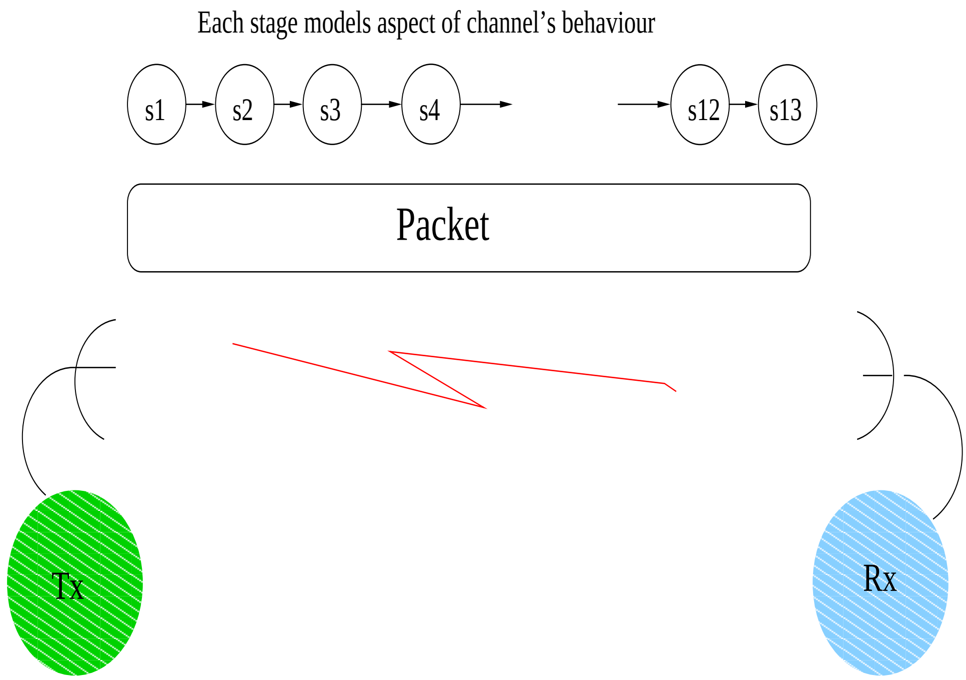


Figure 4.5: Transmission of packet in pipeline stages

The OPNET Simulation Kernel has Transmission data attributes(TDA) to provide pipeline stages with access to a minimum standard set of values to support communication between pipeline stages and each other. The underlying implementation of link can be thought of as a sequentially executed set of pipelines. The pipeline stage sequence of a link is executed once for each packet transmission that is submitted at the source of the link when a packet is sent to a transmitter. The opnet simulation kernel proceeds to call appropriate pipeline stages to process the packet. Certain pipeline stages are executed when the packet is transmitted and others are executed later due to delay associated with the traversal of the link and transmission of the packet. If some of the pipeline stages are not important to the goals of the simulation, we can skip these stages. To skip a pipeline stage, assign "NONE" to the pipeline stage attribute in a radio transmitter or radio receiver module. Figure 4.6 represent transmitter pipeline stages where packets are transmitted from transmitter to different stages.

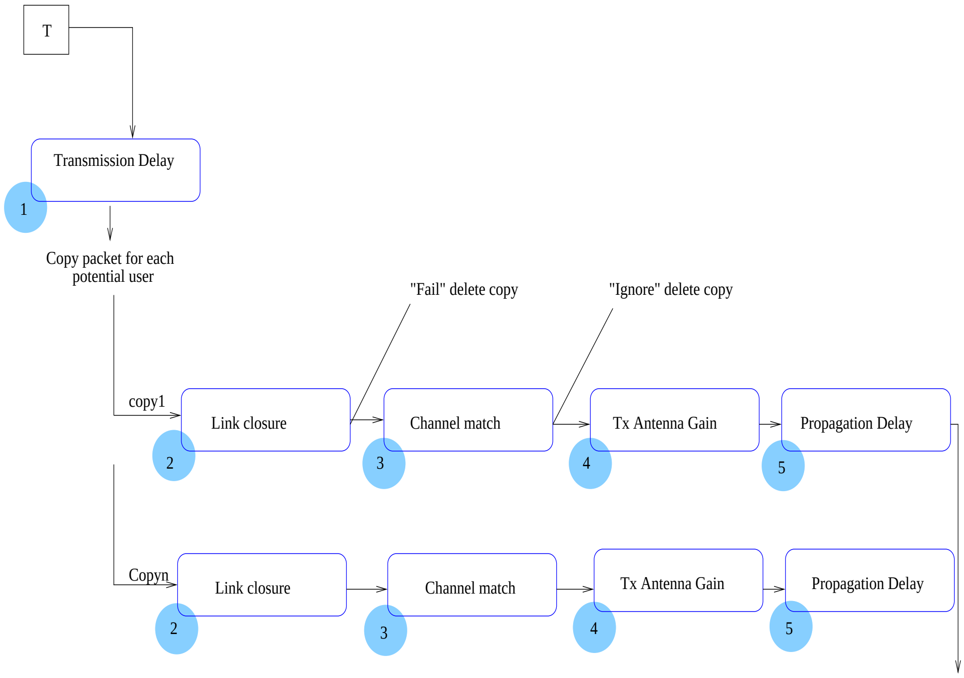


Figure 4.6: Transmitter pipeline stages

- **Transmission delay:** This module computes the time required to complete transmission of packet from the length of packet and the transmission rate of the channel, and it retrieves the transmission data rate from the packet. It is invoked upon the start of a packet transmission. Executed once for every transmission. It calculates total time taken to transmit a packet and executed only once irrespective of number of receivers in the receiver group. Result of this stage is used to schedule end of transmission event at the transmitter module. When this event is generated the transmitter schedules transmission of remaining packet else the transmitter becomes idle. The result of transmission delay in the packet is placed in reserved transmission data attribute OPC_TDA_RA_TX_DELAY.

Algorithm 2 Transmission delay

{Compute the transmission delay associated with the transmission of a packet}
Obtain the transmission rate(tx drate) of the channel from packet using KP
Get length of packet(pk len) using kernal procedure
tx delay ← pk len / tx drate
Place transmission delay(tx delay) in packet transmission attribute for use of latter stages

- **Channel Match:** This Stage is used to determine the compatibility between transmitter and receiver channels. By comparing the transmitting channel attributes and receiving channel attributes like transmitting frequency, bandwidth, datarate and modulation, it classifies the packets as noise, ignored and valid

Algorithm 3 Channel match stage

Get transmitting channel attributes.
Get receiving channel attributes
{For nonoverlapping, packet has no effect}
if (tx_freq > rx_freq + rx_bw) || (tx_freq + tx_bw < rx_freq) **then**
    Set match status to ignore.
else if (tx_freq ! = rx_freq) || (tx_bw ! = rx_bw) || (tx_drate ! = rx_drate) || (tx_mod ! = rx_mod) **then**
    Set match status to noise.
else
    Set match status to valid.
end if

- **Transmitter/Receiver antenna gain:** In receiver and transmitter antenna gain radio pipeline stages, the pointing direction of the antenna is needed. The changes in the receiver and transmitter pipeline stages are identical as the pointing direction of antenna are same with both transmitter and receiver.

This module first calculates difference vetor which is from transmitter to receiver between the transmitter and receiver vectors. This calculation depends upon geocentric coordinate system which is obtained by a call to function in geocentric_model available in OPNET. The angles phi and theta pointing directions for antenna are computed based on the target point of the antenna module and position of the transmitter.

If transmiter and receiver are the same then calculation are unnecessary we set gain to zero else the gain is obtained from the kernel procedure op_tbl_pat_gain which provide particular antenna direction to gain value corresponding to that direction. The resulting gain values are stored in packet for use by power model.

Algorithm 4 Antenna gain

```
{ Compute the gain associated with the transmitter's antenna.}
{ Compute the vector from the transmitter to the receiver.}
if (Transmitter and Receiver are Same) then
    gain ← zero
else
    gain ← obtain from kernal procedure which converts antenna direction into gain value
    corresponding to direction.
end if
Set the tx antenna gain in the packet's transmission data attribute.
```

- **Propagation delay:**This stage computes Propagation delay separating the transmitter and ther receiver. It is calculated for every receiver that is classified noise or valid by the channel match stage. For calculation of propagation delay the distance between transmitter and receiver is provided by the transmission data attributes simulation kernel procedure

- **Received Power:** The computation of received power occurs independently for each packet that is able to reach and affect the radio receiver channel. In this model the busy or idle state information of the radio receiver channel obtain from signal lock field is used to prevent the simultaneous correct reception of multiple packets.

Algorithm 5 Propagation delay

```
Get the distance between transmitter and receiver from kernel procedure
prop distance ← OPC_TDA_RA_START_DIST;
Compute propagation delay to start of reception.
prop delay ← prop distance / prop velocity
Place both propagation delays in packet prop delay transmission data attributes.
OPC_TDA_RA_START_PROPDEL ← prop delay;
```

This model is used to implement verification of the channels status, as this stage is invoked at the time of packet reception. The valid packets arrive at an idle receiver channel causes the channel busy. For invalid packets, the value of signal lock is only relevant to the power calculation because their noise contribution might affect the correct reception of other packets.

The object ID which is obtained from the kernel procedureis used to access the channels state information to check the signal lock value. If signal lock is non zero, indicates the receiver is already busy for receiving a valid packet, the status of the newly arriving packet is considered as invalid packet by using kernel procedure. This prevents the packet from later being correctly received and processed within the destination node.

Pathloss describes the loss in power as the radio signal propagates through in space. In general wireless communication the power of the signal decays as the square of the distance [6]. The mean power of a signal decays as nth power of the distance i.e $L = cd^n$ where c is a constant and exponent n varies from 2 to 5. The loss in power is a factor that limits the coverage of transmitter. The value of exponet n is fixed to 2 in opnet which specifies normal simulating scenario that creates the problem for simulating environments where the exponent is not 2. The result of the Received Power Model for each packet, represents the received power level for the packet placed in the packets OPC_TDA_RA_RCVD_POWER transmission data attribute for use of latter stages. Figure 4.7 shows the receiver pipeline stages.

Algorithm 6 Receiverd Power

```
/** Compute the average power of signal associated with transmitted packet **/
if Incoming packet is valid then
    Channel match set to noise, receiver node is disabled
else
    The receiving node is enabled
    Get the objid of receiver channel
end if
{Access channel state information}
if Channel is already locked then
    Packet is considered as noise
else
    Receiver channel will become locked until the packet reception ends
end if
{Compute the path loss}
if Prop distance > 0 then
    if (exponet> 2.0) and (exponet <= 5.0) then
        Get distance d
        path loss ← (lambda * lambda) / (SIXTEEN_PI_SQ × d ×d);
    else
        path loss ← (lambda * lambda) / (SIXTEEN_PI_SQ × prop_distance × prop_distance);
    end if
else
    path loss ← 1.0
end if
Get power allocated to transmitter channel {Calculate received power level.}
Received power ← tx power * tx ant gain * path loss * rx ant gain;
```

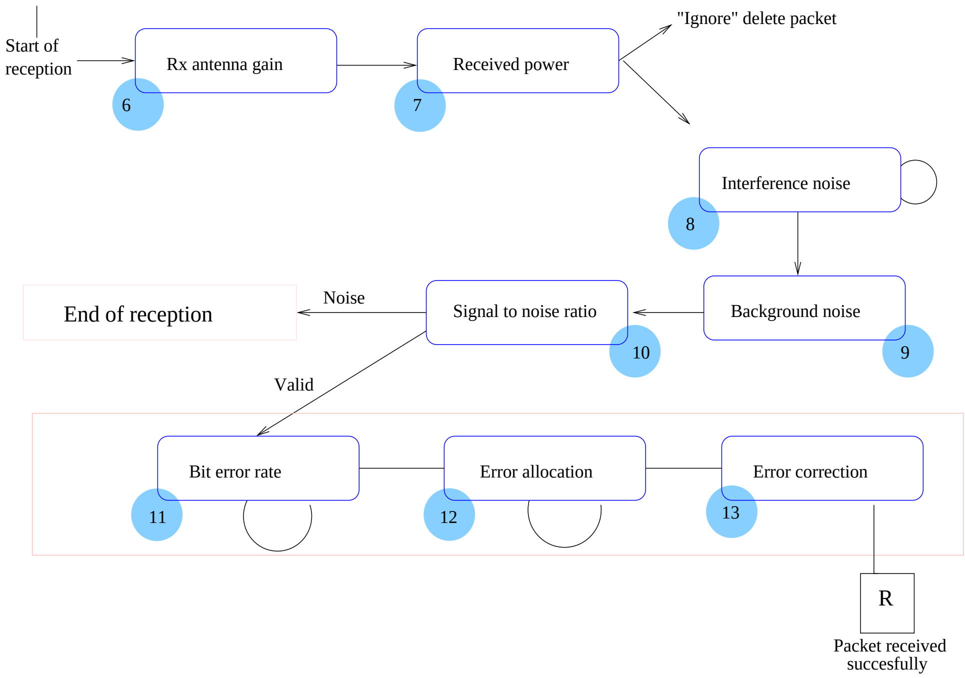


Figure 4.7: Receiver pipeline stages

- **Interference noise:** This stage Executed in two circumstances
  - The packet is valid and arrives at destination while another packet is being received.
  - The packet is being received while another (valid/noise) arrives.

This stage will not necessarily be invoked during execution of the Radio Transceiver Pipeline if a packet experiences no collisions. This stage is called several times if the packet should collide with another packet.

If a collision occurs, it increments the number of collisions for each packet and determines if the packets are interference packets or valid packets, and retrieves the received power levels of both packets. Computations of noise contribution are only necessary for affected valid packets, because invalid packets are not considered for reception. For valid packets, noise contributions from other packets are based on the interfering packets power level.

Algorithm 7 Interference ratio

```
{prev pkt, the pkt currently received}
if Previous packet ends when new one arrives then
    Not a collision
end if
{D}etermine arriving packet is valid or noise
if Arriving packet is valid then
    Determine interference of previous packet on arriving packet
end if
```

- **Signal to noise ratio:** This stage computes the snr for the given packet. The calculation of this stage is usually based on values obtained from earlier stages.

Algorithm 8 Signal to noise ratio

```
{Compute the signal-to-noise ratio for the given packet }
Get the packet power level.
Get the interference noise
Snr ← received power / noise
```

- **Bit error rate:** Bit error rate is typically a function of signal-to-noise ratio (SNR). Bit error rate is evaluated at the time where a packet segment ends, because it is not usually possible to predict the timing of SNR changes. Bit error rate is measured for the last segment of each packet at the time where it completes reception. The bit error rate is derived from the effective SNR based on a modulation curve assigned to the receiver.

Algorithm 9 Bit error rate

```
Get snr value of snr from previous stage
Determine address of modulation table using kernel procedure
Place the BER in packet transmission attribute
```

Chapter 5

Experiments

The main goal is to build WiFiRe model in OPNET. The Experiments performed on WiFiRe model based on various parameters. Following experiments performed to show the model is working as expected.

- Setup a sector using directional antennas for range of sectorization.
- The number of VoIP calls that each ST support with given parameters.
- The setup of STs in six sectored system with VoIP configuraton with two different scenarios.
- Setting up of VoIP and Video scenario with round robin scheduler.

5.1 Experiments

The Table 5.1 and 5.2 shows the WiFiRe setup parameters and PHY profile set up parameters for all the simulations. Experiments are performed with BPSK modulation technique and coding rate of 1/2 are used according to 802.11b.

S.No	Parameter	Value
1	Data Rate	11 Mbps
2	Control packet data rate	2 Mbps
3	Frame Duration	10 ms
4	Slot duration	32μsec
5	DL-UL ratio	2:1
6	Scheduling algorithm	round robin
7	Service class	UGS

Table 5.1: System setup parameters

S.No	Parameter	Value
1	Frequency Channel	2.4 GHz
2	Bandwidth	22 MHz
3.	Duplexing technique	TDD
4.	PHY overhead	96μsec
5.	Number of symbols/frame	220000
6.	Symbol duration	0.045μsec
7.	Voice codec	G729

Table 5.2: PHY profile setup parameters

5.1.1 Experiment for range of Sectorization

The main goal of the experiment is to setup a 60 degrees sectorized antenna at base station. The information that the antenna needs to point at a target is through processor module which calculates through kernel procedure that converts a node's position in a subnet into the global coordinates that the antenna requires.

The following figure 5.1 and 5.2 consits of two scenarios one with a base station and three subscriber stations designed in a sector , in another scenario one base station with five subscriber stations with a unit of 5km in each scenario. Each Subscriber station is configured with service flows [9]. Using opnet antenna editor, a sector with sectorized antenna about 60 degrees at base station and directional at the subscriber station is modelled. In first scenario 3 STs are in the range of sectorization.

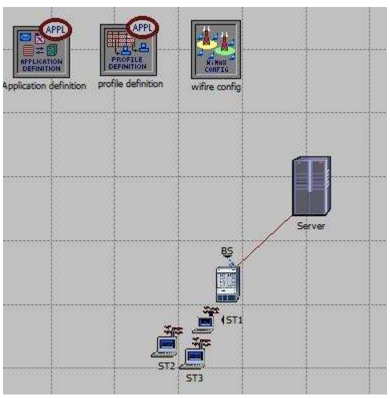


Figure 5.1: Scenario with a BS and 3 STs

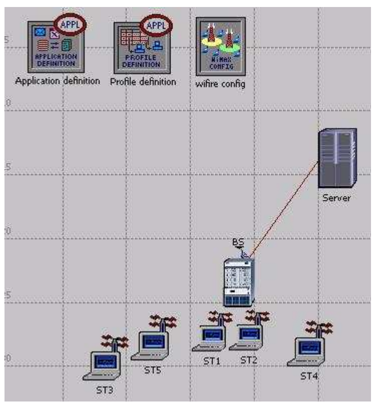


Figure 5.2: Scenario with a BS and 5 STs

Each ST is requested with 20Kbps, the total load offered with first scenario is 60Kbps. Figure 5.3 depicts total load offered in sector with respect to first scenario. Throughput in figure 5.4 for first scenario with 3 STs is same as load. This is due to proper sectorization of BS with respect to directionalility of ST. The load offered for scenario 2 is 100Kbps. In figure 5.5 for second scenario with 5 STs the throughput is less compared with load as some STs in this scenario are out of range in the sector. The performance evaluation was under no channel error conditions and no interference.

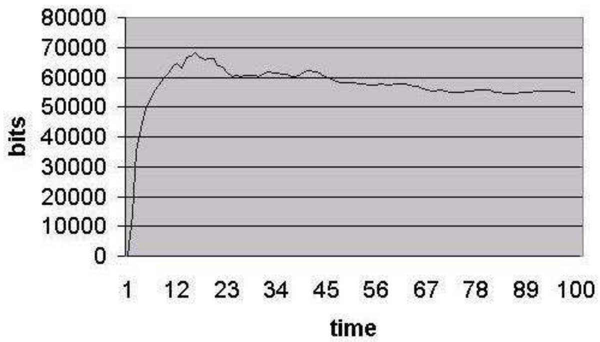


Figure 5.3: Load for first scenario

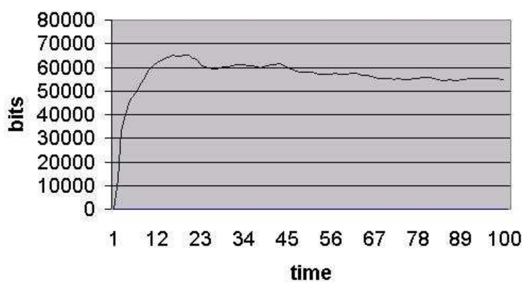


Figure 5.4: Throughput for scenario 1

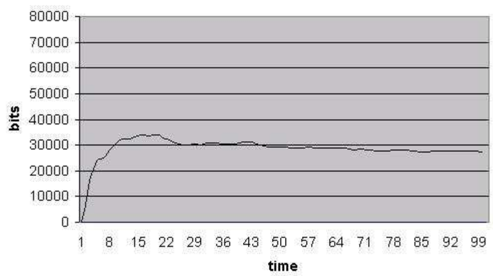
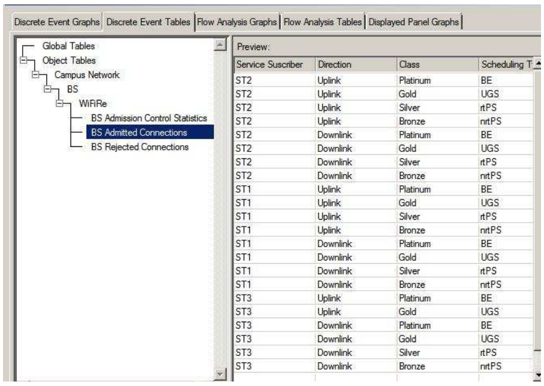


Figure 5.5: Throughput for scenario 2

Figure 5.6 and 5.7 represents admitted and rejected connections for the two scenarios. For the first scenario almost all connections are admitted. In second some connections are rejected for the ST that are out of range in a sector.

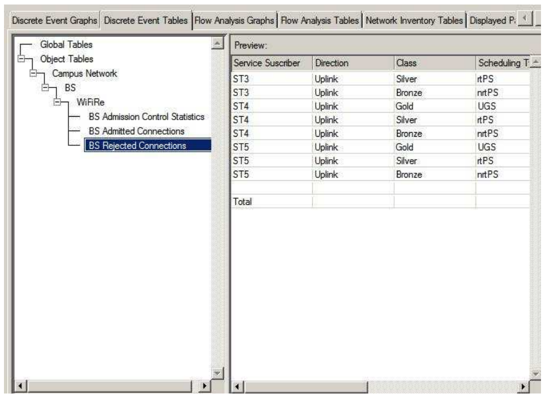
5.1.2 Calculation of VoIP calls in six sectored system

The main aim of the experiment is setup STs in six sector system, to simulate the number of VoIP calls that each ST support with ST requesting BW of 120Kbps with two different



Service Suscriber	Direction	Class	Scheduling T
ST2	Uplink	Platinum	BE
ST2	Uplink	Gold	UGS
ST2	Uplink	Silver	rtPS
ST2	Uplink	Bronze	nrtPS
ST2	Downlink	Platinum	BE
ST2	Downlink	Gold	UGS
ST2	Downlink	Silver	rtPS
ST2	Downlink	Bronze	nrtPS
ST1	Uplink	Platinum	BE
ST1	Uplink	Gold	UGS
ST1	Uplink	Silver	rtPS
ST1	Uplink	Bronze	nrtPS
ST1	Downlink	Platinum	BE
ST1	Downlink	Gold	UGS
ST1	Downlink	Silver	rtPS
ST1	Downlink	Bronze	nrtPS
ST3	Uplink	Platinum	BE
ST3	Uplink	Gold	UGS
ST3	Downlink	Platinum	BE
ST3	Downlink	Gold	UGS
ST3	Downlink	Silver	rtPS
ST3	Downlink	Bronze	nrtPS

Figure 5.6: Admitted connections for scenario 1



Service Suscriber	Direction	Class	Scheduling T
ST3	Uplink	Silver	rtPS
ST3	Uplink	Bronze	nrtPS
ST4	Uplink	Gold	UGS
ST4	Uplink	Silver	rtPS
ST4	Uplink	Bronze	nrtPS
ST5	Uplink	Gold	UGS
ST5	Uplink	Silver	rtPS
ST5	Uplink	Bronze	nrtPS
Total			

Figure 5.7: Rejected connections for sceanrio 2

scenarios, one with 40 STs and other of 120 STs

From the following calculations with mentioned parameters from table 5.1, the total number of slots, with each ST requesting 120Kbps and WiFiRe overhead is 6, out of which 3 slots are for WiFiRe PHY overhead and remaining are data slots. For this configuration atmost 3 VoIP calls can be possible per ST depending up on total number of STs available in the System S.

Calculation of total number of slots with requested bandwidth

Original Bandwidth request from ST = 120Kbps

Requested rate with MAC overhead = $rate \times (\frac{avgpktsize + Wifireheaer}{avgpktsize})$

$$= (120 \times 10^3) \times (\frac{60+5}{60}) = 130Kbps$$

Requested rate in symbols per second = $rate\_mac \times (\frac{1}{numberofbitspersymbol \times codingrate})$

$$= (130 \times 10^3) \times (\frac{1}{1 \times \frac{1}{2}}) = 260 \times 10^3$$

Number of symbols required per frame = (req rate in sps)$\times$ (frame duration)

symbols per frame = $260 \times 10^3 \times 10 \times 0.001$ =2600 symbols

symbols per slot = $\frac{32}{0.045} = 711$ symbols

WiFiRe PHY overhead = 96 micro sec

Number of symbols with WiFiRe PHY overhead = $\frac{PHY overheadduration}{Symbolduration} = 2133 symbols.$

Total number of symbols required is sum of PHY overhead and requested rate

= PHY overhead + Number of symbols requested

= 2133+2600=4733 symbols

Total number of slots = $\frac{Totalnumberofslots}{symbolsforslot}$

= $\frac{4733}{711} = 6$

The VoIP scenario is simulated with each ST requesting 120Kbps and number of STs are varied in two different scenarios. As DL and UL bandwidth is 2:1 in ratio, downlink bandwidth is 66 percentage of total bandwidth of 11 Mbps, through this each ST gets 7260Kbps if a VoIP packet is served in two frames. With 40 STs each ST has 323 Kbps and with 120 each ST has 119 Kbps.

Down link bandwidth = $\frac{66}{100} \times 11 * 10^6 = 7.26 \times 10^6$

With 40 ST's ratio each ST has 323 Kbps if voice packet server in two frames

= $\frac{7260Kbps}{40} \times$ 2=323Kbps

similarly with 120 STs it is around 119 Kbps which is close to requested bandwith

5.1.3 Experiment to simulate VoIP calls

Figure 5.8 and 5.9 shows the two scenario of simulation setup with a scale of 5Km, first scenario with 40 STs and second scenario with 120 STs. Each ST has registered with UGS flow service at BS. The experiment was simulated under no channel error conditions and no interference.

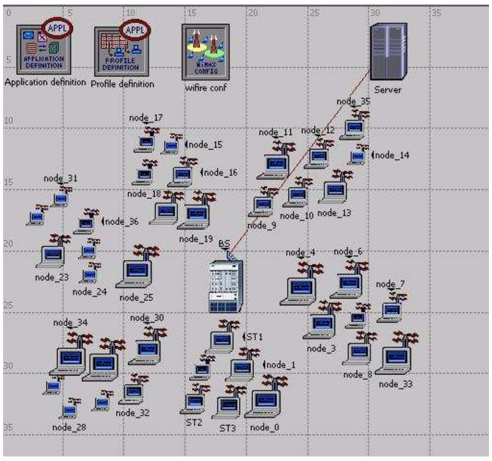


Figure 5.8: Scenario with 40 STs

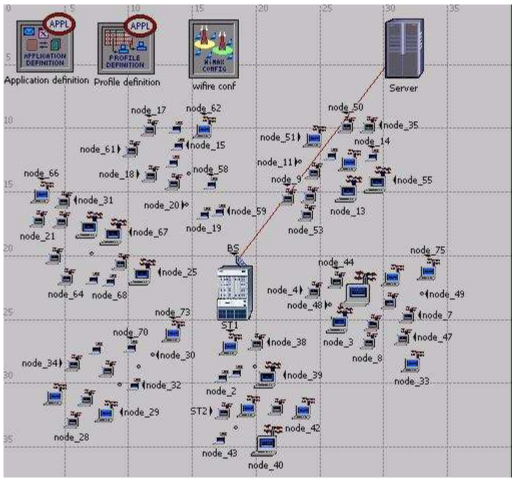


Figure 5.9: Scenario with 120 STs

Each ST is configured to request 120Kbps with VoIP scenario. The traffic sent with MAC overhead is 130 Kbps. Figure 5.10 and 5.11 depicts the original load and traffic sent in the WiFiRe system. Here the load of the system is same as the requesting bandwidth and the traffic sent is 130 Kbps.

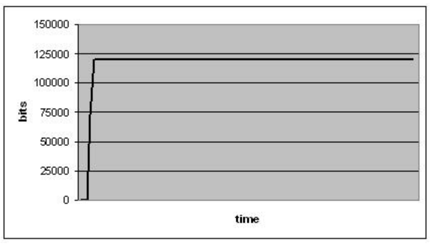


Figure 5.10: Actual load of the System

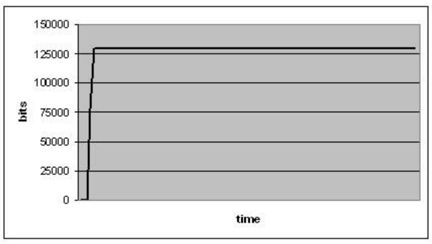


Figure 5.11: Actual traffic sent

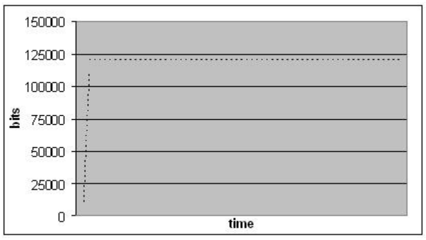


Figure 5.12: Traffic received for 40 STs

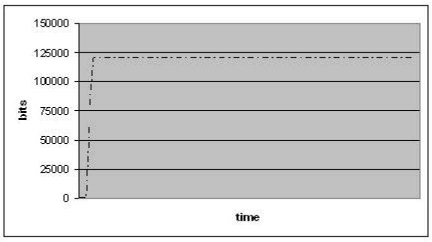


Figure 5.13: Throughput for 40 STs

Graph in the Figure 5.12 represents the traffic received and figure 5.13 represents throughput of System with 40 STs setup scenario. In this scenario, each ST has 323 Kbps with 3 data slots which can support 3 VoIP calls. Almost all 40 ST's are alloted with requested bandwidth. The throughput of this setup is equal to traffic sent. Figure 5.15 shows queuing delay is constant because arrival rate is equal to service rate and no traffic is dropped shown in Figure 5.14 as the all the STs has sufficient bandwidth.

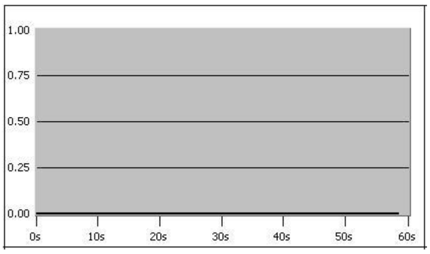


Figure 5.14: Data drop for 40 STs

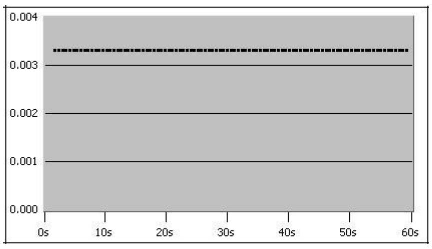


Figure 5.15: Queueing delay for 40 STs

With the second scenario setup of 120 STs each ST is congifured to request with 120 Kbps with VoIP scenario. The traffic sent with MAC overhead is 130 Kbps. The original load with MAC overhead and traffic sent in the WiFiRe system is shown in the Figure 5.10. The load of the system is same as the requesting bandwidth of 120 Kbps and the traffic sent with overhead is 130 Kbps.

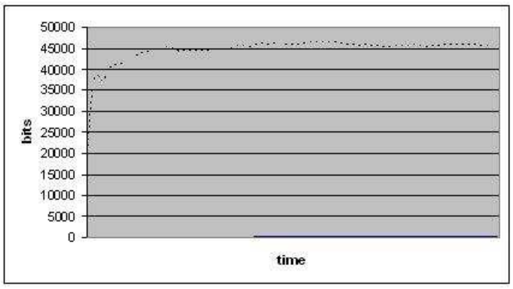


Figure 5.16: Throughtput for 120 STs

As the downlink bandwidth is 66 percentage of total bandwidth of 11 mbps, with the second scenario with 120 STs each ST will get bandwidth around 119Kbps which is not sufficient bandwidth for some STs and 3 voice calls are not feasible. The traffic recevied and throughput of system is less compared to compared to traffic sent. This will increase queuing. After some time queue will be filled and packets will be dropped after that.

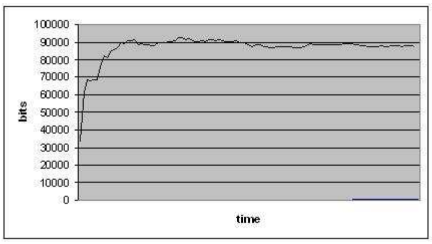


Figure 5.17: Data drop for 120 STs

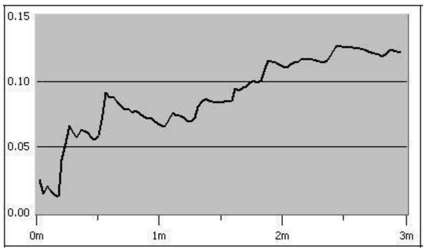


Figure 5.18: Queuing delay for 120 STs

5.1.4 Experiment to simulate VoIP and Video scenario

This experiment setup of WiFiRe model used to simulate VoIP and Video scenario with a Subscriber terminal and Base station. Figure 5.25 shows the scenario of simulation setup with unit of 5Km and no with no channel error and interference. The type of scheduling used is round robin scheduler that is modelled in WiFiRe [9], in which BS first allocates admitted number of slots for UGS flows. It then allocates requested number of slots for rtPS, if the requested number of slots are less than the admitted number of slots.

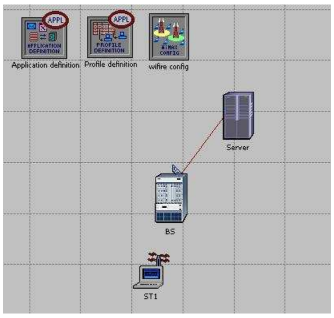


Figure 5.19: Senario with ST and unit distance of 5Km

Figure 5.26 and 5.27 shows the queing delay of UGS and rtPS connections. With UGS service flow ST is requesting with 120Kbps. The UGS service is serving smoothly because once UGS connection is accepted [9] BS allocates requested no of slots to UGS. BS allocates accepted number of slots in every frame until connection terminates. Queuing delay for this type of connections is almost constant.

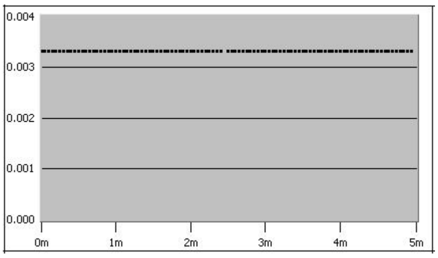


Figure 5.20: End to end delay of UGS

ST also requesting 120Kbps With rtPS connection. rtPS is allocated with requested number of slots. End to end delay first increases due to allocation of UGS flow then it reduces gradually reduces to constant till rtPS got it chance [9] earlier. Figure 5.28 depicts the throughput of UGS and rtPS which shows that UGS allocated with maximum sustained rate then rtPS.

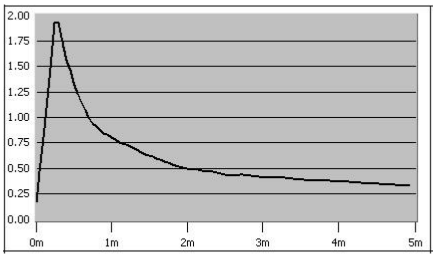


Figure 5.21: End to end delay of rtPS

Throughput of UGS connection is high intially compared to rtPS, as BS first allocates admitted number of slots to UGS. Throughput of rtPS reaches 120Kbps after some time with requested rate.

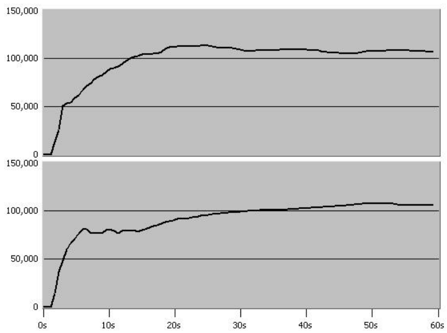


Figure 5.22: Throughput of UGS and rtPS

Chapter 6

Conclusion

We have implemented WiFiRe model in OPNET. In prior work WiFire model was started implementing with MAC functionalities with out PHY. In our work Directional antennas are modelled using OPNET antenna pattern editor which are used in communication with in a sector. Using this setup in WiFiRe system we are able to estblish communication links over long distance. The pipeline stages over the radio link are implemented to simulate physical behaviour of wireless link. Some Experiments are performed to support the validity of WiFiRe model implemented in OPNET. The results shown are with respect to multiple STs and sectorized deployment with help of directional antennas.

Experiments performed just support the validity of WiFiRe model implemented in OPNET. More experiments need to be performed in order to check performance of WiFiRe. Experiments are to be performd with different scenarios which categorized as voip only users, video conference users, Best effort users, voip and Best effort users. With each scenario has input parameter space and output measurements as shown in table Table 6.1.

Input parameters	Output measurements
Number of ST's active at same time	Max throughput per ST(bps)
VoIP/BE/Video connections allowed per ST	Max throughput per sector
Number of contention slots(10 to UL size)	Channel utilization(throughput/datarate)
Number of slots per DL/UL(208,100)	Average end to end delay between applications
Frame length	End to end Queing delay
Slot length(>32 micro seconds)	Number of packets dropped

Table 6.1: Input parameters and output measurements

Based up on the input parameters and output measurements the performance questions are to be answered are

- What is the maximum number of users per sector and throughput in the sector which depends up on maximum throughput that channel can achieve.
- What is packet delay in the sector.
- Number of packets dropped which depends on number of service flows and number of active users in the sector
- Why each slot length is 32 microseconds, why can't we allow different slots length for different services.
- Maximum number of allowed connections per ST.

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I. I. T. Bombay

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