Optimization of data rates in channel varying mobile ad-hoc networks

PROJECT REPORT

Submitted in the fulfilment of the requirements for

the award of the degree of

Bachelor of Technology
in
Electronics and Communication Engineering

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
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VIGNAN'S FOUNDATION FOR SCIENCE, TECHNOLOGY AND RESEARCH
(Deemed to be University)

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CERTIFICATE

This is to certify that the project report entitled **"Optimization of data rates in channel varying mobile ad-hoc networks"** that is being submitted by Gayathri Gopisetty[201FA05014], Challa Guru Pavan[211LA05029], Gangula Venkata Sushma[211LA05031], in fulfilment for the award of B. Tech degree in Electronics and Communication Engineering to VFSTR (Deemed to be University), is a record of bonafide work carried out by them under the supervision of **Dr. B. Seetharamanjaneyulu**, Professor Department of ECE.

23/5/24

Signature of the guide	**Signature of Head of the Department**
Dr. B. Seetharamanjaneyulu	**Dr. T. Pitchaiah, M.E, Ph.D, MIEEE**
Professor	**Professor**

DECLARATION

We here by declare that the project entitled **"Optimization of data rates in channel varying mobile ad-hoc networks"** is being submitted to Vignan's Foundation for Science, Technology and Research (Deemed to be University) in fulfilment for the award of B. Tech degree in Electronics and Communication Engineering. The work originally designed and executed by us under the guidance of **Dr. B. Seetharamanjaneyulu** at Department of Electronics and Communication Engineering, VFSTR (Deemed to be University) and was not duplication of work done by someone else. We hold the responsibility of originality of the work incorporated into this report.

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Finally, we would like to thank our parents and friends for the moral support throughout the project work.

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LIST OF ACRONYMS ABBREVIATION

BPSK: Binary Phase Shift Keying

BGP: Border Gateway Protocol

CSMA: Carrier Sense Multiple Access

DSSS: Direct Sequence Spread Spectrum

GUI: Graphic User Interface

IDE: Integrated Development Environment

IMANET: Internet based Mobile Adhoc Network

LDP: Label Distribution Protocol

MAC: Medium Access control

MIMO: Multiple- Input Multiple -Output

MANET: Mobile Adhoc Network

NED: Network Description

OFDM: Orthogonal Frequency Division Multiplexing

Omnet: Objective Modular Network Testbed

OSPF: Open Shortest Path First

PER: Packet Error Rate

QPSK: Quadrature Phase Shift Keying

QAM: Quadrature Amplitude Modulation

SPAN: Smart Ad-hoc Network

RTS: Real Time System

SNIR: Signal to Interference plus Noise Ratio

TCP: Transmission Control Protocol

VANET: Vehicular Ad-hoc Network

UDP: User Datagram Protocol

LIST OF FIGURES

ABSTRACT

Because of the dynamic nature of the maritime environment and the features of mobile ad hoc networks (MANETs), maritime mesh networks present unique problems for data rate optimization. In this study, we consider data rate optimization in channel-varying maritime mesh networks. Utilizing the IEEE 802.11 standard, in particular IEEE 802.11g, which enables devices to adapt to changing channel conditions and dynamically select the best bitrate for data transmission. IEEE 802.11g supports multiple data rates through adaptive modulation and coding (AMC) and rate control, two important features of the standard. This lowers the probability of mistakes and retransmissions while raising the network's throughput, both of which contribute to better network performance overall. Our suggested method dynamically modifies data rates according to current channel circumstances. To improve throughput and maintain reliable communication, we combine dynamic routing algorithms designed for maritime conditions with adaptive modulation and coding approaches. We assess the performance of our optimization approach by comprehensive simulations with different channel conditions. When compared to traditional approaches, our results show how effective the suggested methodology is at increasing network performance, decreasing packet loss, and improving overall reliability. Our approach provides a potential alternative for attaining dependable and efficient communication in maritime mesh networks by addressing the communication constraints of marine environments through dynamic data rate optimization.

Major Design (Final Year Project Work) Experience Information

Student Group	Gayathri Gopisetty (201FA05014)	Challa Guru Pavan (211LA05029)	Gangula Venkata Sushma (211LA05031)
Project Title	Optimization of data rates in channel varying mobile ad-hoc networks		
Program Concentration Area	Wireless Ad-hoc communication Networks, IoT		
Constraints - Examples			
Economic	Fixed Budget		
Environmental	Friendly		
Sustainability	NA		
Manufacturability	No		
Ethical	Followed the standard professional ethics		
Health and Safety	NA		
Social	Improved wireless devices communication reliability		
Political	None		
Other	Used for mobile communication environment		
Standards			
1. IEEE 802.11 Wi-Fi	This standard is used to implement wireless Ad-hoc networks.		
2. IEEE 802.11g	It offers Rate control feature of the IEEE 802.11 wireless networking standard. It allows devices to adapt to changing channel conditions and dynamically select the optimal bit rate for transmitting data.		
Previous Course Required for the Major Design Experience	Wireless Communication networks		

Supervisor **Project Co-Ordinator** **Head of the department ECE** 23/5/24.

CHAPTER 1

1.1 INTRODUCTION TO WIRELESS AD-HOC NETWORK

A wireless ad hoc network (WANET) is a type of local area network (LAN) that is built spontaneously to enable two or more wireless devices to be connected to each other without requiring typical network infrastructure equipment, such as a wireless router or access point.

In most cases, a PC, laptop or smartphone Wi-Fi interface is used to build an ad hoc network. In other situations, devices such as wireless sensors are designed to work primarily in an ad hoc mode. Because the devices in the ad hoc network can access each other's resources directly through basic peer-to-peer (P2P) or point-to-multipoint modes, central servers are unnecessary for functions such as file sharing or printing. In a WANET, a collection of devices, or nodes -- such as a wireless-capable PC or smartphone is responsible for network operations, such as routing, security, addressing and key management.

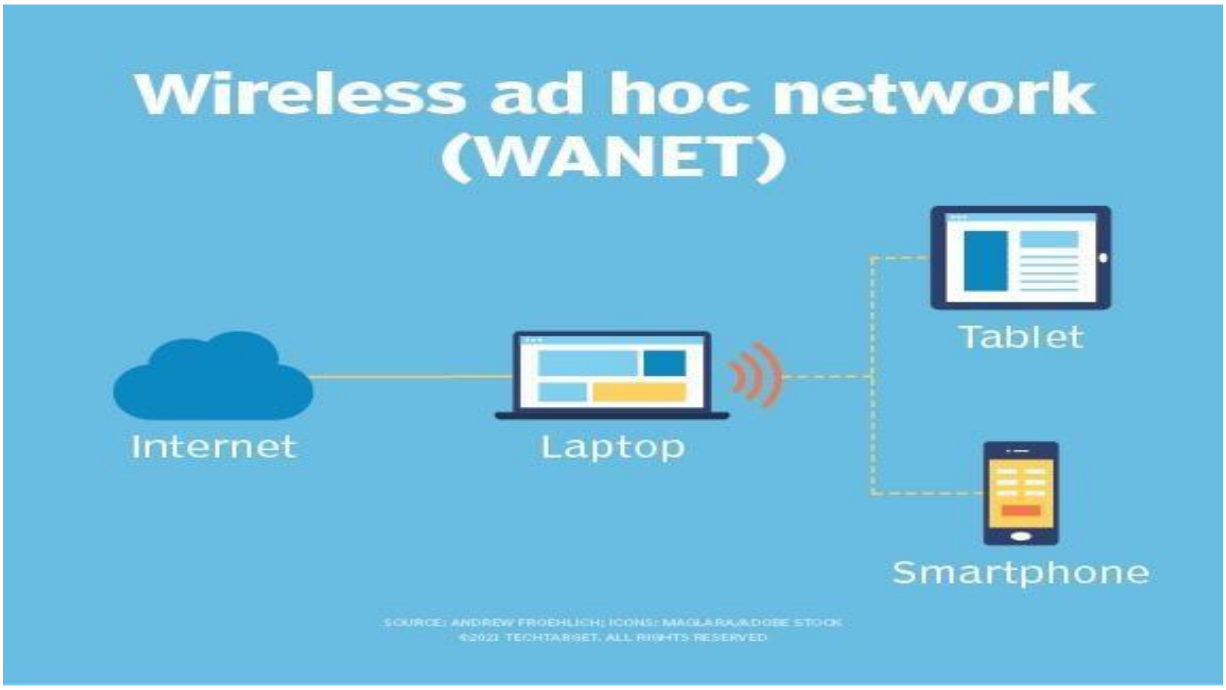

Fig 1: Wireless Ad-hoc network

1.2 TYPES OF WIRELESS AD-HOC NETWORKS

Types of WANETs vary by application need and use. Choosing a wireless ad hoc network type depends on the wireless equipment capabilities, physical environment and purpose of the communication.

MANET:

A mobile ad hoc network involves mobile devices communicating directly with one another. A MANET is a network of wireless mobile devices without an infrastructure that are self-organizing and self-configuring. A MANET is sometimes referred to as an "on-the-fly" or "spontaneous network." Examples of MANETs include smart home lighting, ad hoc streetlight networks, ad hoc networks of robots, disaster rescue ad hoc networks and hospital ad hoc networks. In many cases, these networks use proprietary or non-TCP/IP networking standards for communication.

IMANET:

Internet-based mobile ad hoc networks support internet protocols, such as TCP/IP (Transmission Control Protocol/Internet Protocol) and User Datagram Protocol (UDP). The IMANET employs a TCP/IP network-layer routing protocol on each connected device to link mobile nodes and set up distributed routes automatically. IMANETs may also be used in the collection of sensor data for data mining for a variety of use cases, such as air pollution monitoring.

SPAN:

Smartphone ad hoc networks employ existing hardware, such as Wi-Fi and Bluetooth, and software protocols built into a smartphone operating system (OS) to create P2P networks without relying on cellular carrier networks, wireless access points or other traditional network infrastructure equipment. Different from traditional hub-and-spoke networks, such as Wi-Fi Direct, SPANs support multi-hop relays. Multi-hop relay is the process of sending traffic from device A to device C using intermediary device B. Therefore, device A and C do not need to have a direct P2P connection established for traffic to reach its destination. Because SPANs are fully dynamic in nature, there is no group leader in this type of application and, thus, peers can join or leave without harming the network.

Vehicular ad hoc network:

This network type involves devices in vehicles that are used for communicating between them and roadside equipment. An example is the in-vehicle safety and security system OnStar.

WMN:

Wireless mesh networks are comprised of radio networks set up in a mesh topology and frequently consist of mesh clients, mesh routers and gateways. In mesh networking, the devices -- or nodes -- are connected so at least some, if not all, have many paths to other nodes. This creates many routes for information between pairs of users, increasing the resilience of the network if a node or connection fails. WMNs are useful in situations where a temporary wireless network is required or in more permanent scenarios where network cabling cannot be run to create an infrastructure-based wireless network.

1.3 APPLICATIONS OF WIRELESS AD-HOC NETWORK

With the large number of small size gadgets also as advancement in remote communication, the ad hoc networking is picking up exertion with the large number of far-reaching applications. Ad hoc networking can be utilized whenever, any place with restricted or then again, no correspondence framework. The first framework is extravagant or irritating to utilize. The ad hoc network architecture can be utilized continuous business applications, corporate organizations to expand the efficiency and benefit.

The ad hoc networks can be arranged by their application as:

Mobile Ad hoc Network (MANET) which is a self-organizing infrastructure less system of cell phones communicated through remote connection.
Vehicular Ad hoc Network (VANET) utilizes vehicles as nodes in a network to make a mobile network.
Wireless Sensor Network (WSN) comprises of independent sensors to control the ecological activities.

Usages of Ad-Hoc network:

Military – An ad hoc networking will give access to the army to maintain a network among all the soldiers, vehicles and headquarters.
Personal area network (PAN) – It is a short range, local network where each node is usually related with a given range.
Crisis Condition – Because it is fairly easy to create it can be used in time of crisis to send emergency signals.
Medical Application – It can use to monitor patient.
Environmental Application – It can be used to check weather condition, forest fire, tsunami etc.

1.4 INTRODUCTION AND CHARACTERISTICS OF MANET

MANET stands for Mobile Ad hoc Network also called a wireless Ad hoc network or Ad hoc wireless network that usually has a routable networking environment on top of a Link Layer ad hoc network. They consist of a set of mobile nodes connected wirelessly in a self-configured, self-healing network without having a fixed infrastructure. MANET nodes are free to move randomly as the network topology changes frequently. Each node behaves as a router as they forward traffic to other specified nodes in the network.

MANET may operate a standalone fashion or they can be part of larger internet. They form a highly dynamic autonomous topology with the presence of one or multiple different transceivers between nodes. The main challenge for the MANET is to equip each device to continuously maintain the information required to properly route traffic. MANETs consist of a peer-to-peer, self-forming, self-healing network MANET's circa 2000-2015 typically communicate at radio frequencies (30MHz-5GHz). This can be used in road safety, ranging from sensors for the environment, home, health, disaster rescue operations, air/land/navy defense, weapons, robots, etc.

Characteristics of MANET:

Dynamic Topologies:

Network topology which is typically multi hop may change randomly and rapidly with time, it can form unidirectional or bi-directional links.

Bandwidth constrained, variable capacity links:

Wireless links usually have lower reliability, efficiency, stability, and capacity as compared to a wired network

Autonomous Behavior:

Each node can act as a host and router, which shows its autonomous behavior.

Energy Constrained Operation:

As some or all the nodes rely on batteries or other exhaustible means for their energy. Mobile nodes are characterized by less memory, power, and lightweight features.

Limited Security:

Wireless networks are more prone to security threats. A centralized firewall is absent due to the distributed nature of the operation for security, routing, and host configuration.

CHAPTER 2

2.1 IEEE 802.11 STANDARDS

IEEE 802.11 standards, commonly known as Wi-Fi standards, define the specifications for wireless local area networking (WLAN) technology. Here are some of the key IEEE 802.11 standards:

802.11a: Operates in the 5 GHz frequency band and provides data rates up to 54 Mbps. It uses orthogonal frequency-division multiplexing (OFDM) modulation.

802.11b: Operates in the 2.4 GHz frequency band and provides data rates up to 11 Mbps. It uses direct-sequence spread spectrum (DSSS) modulation.

802.11g: Operates in the 2.4 GHz frequency band and provides data rates up to 54 Mbps. It also uses OFDM modulation but maintains compatibility with 802.11b networks.

802.11n: Supports multiple-input multiple-output (MIMO) technology and operates in both the 2.4 GHz and 5 GHz frequency bands. It can provide data rates up to 600 Mbps.

802.11ac: Also known as Wi-Fi 5, it operates in the 5 GHz frequency band and supports wider channels and higher data rates compared to 802.11n. It can provide data rates up to several gigabits per second.

802.11ax: Also known as Wi-Fi 6, it operates in both the 2.4 GHz and 5 GHz frequency bands and introduces several enhancements such as orthogonal frequency-division multiple access (OFDMA), target wake time (TWT), and uplink and downlink multi-user MIMO (MU-MIMO). It offers improved efficiency and performance in dense deployment scenarios and can provide higher data rates than previous standards.

802.11ay: Operates in the 60 GHz frequency band and aims to provide very high throughput wireless links, potentially reaching data rates in the multi-gigabit per second range. It is designed for short-range, high-speed communication.

IEEE 802.11 Standards									
802.11 Standard	Date	Frequency	Channel Bandwidth	Non-Overlapping Channels	Max Data Transfer	Antenna Configuration	Range	Spectrum	Notes
802.11b	1999	2.4GHz	20MHz	1, 6, and 11	11Mbps	1x1 SISO	~300ft	DSSS	First to receive Wi-Fi Seal of Approval and least expensive standard
802.11a	1999	5.0GHz	20MHz	See Notes	54Mbps	1x1 SISO	~150ft	DSSS and OFDM	*1; fast, expensive, and limited range.
802.11g	2003	2.4GHz	20MHz	1, 6, and 11	54Mbps	1x1 SISO	~300ft	DSSS and OFDM	Operates in "native mode" and "mixed mode."
802.11n	2009	2.4GHz and 5.0 GHz	20MHz and 40MHz	See Notes	100-600Mbps	Up to 4x4 MIMO	~300ft	OFDM	*2 *3 *4
802.11ac	2013	5.0GHz	20, 60, 80, and 160 MHz	See Notes	1Gbps	Up to 3x3 MU-MIMO	~300ft	OFDM	*5

***1**: For 802.11a, in the 5.0GHz band, there are 24 non-overlapping 20MHz channels and only 12 non-overlapping 40MHz channels.

***2**: For 802.11n, in the 2.4GHz band, there are 3 non-overlapping 20MHz channels (1, 6, and 11) and only 1 40MHz channel (3). In the 5.0GHz band, there are 24 non-overlapping 20MHz channels and only 12 non-overlapping 40MHz channels.

***3**: For 802.11n, dual-band 802.11n devices can operate in both the 2.4GHz and 5.0GHz band. Therefore, an 802.11n WAP can support 802.11b/g and 802.11a devices. This was not a part of the standard, but was included by manufacturers

***4**: For 802.11n, there are three modes: "legacy mode (non-HT)," "Greenfield mode (HT)," and "mixed mode."

***5**: For 802.11ac, in the 5.0GHz band, there are 24 non-overlapping 20MHz channels, 12 non-overlapping 40MHz channels, 6 non-overlapping 80MHz channels, and 2 non-overlapping 160MHz channels

Fig 2: Table of IEEE 802.11 standards

2.2 FEATURES OF IEEE 802.11g

IEEE 802.11g is a wireless networking standard that operates in the 2.4 GHz frequency band, offering higher data rates compared to its predecessors like 802.11b. Here are some key features of IEEE 802.11g:

Data Rates: IEEE 802.11g supports data rates of up to 54 Mbps, which was a significant improvement over the maximum 11 Mbps provided by the 802.11b standard.

Backward Compatibility: One of the notable features of 802.11g is its backward compatibility with 802.11b devices. This means that 802.11g access points and routers can communicate with 802.11b devices at their lower data rates.

OFDM Modulation: Similar to 802.11a, 802.11g uses Orthogonal Frequency Division Multiplexing (OFDM) modulation, which helps in mitigating the effects of multipath interference and improves overall signal reliability and robustness.

Interference Mitigation: IEEE 802.11g employs techniques such as Clear Channel Assessment (CCA) and Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) to mitigate interference from other devices operating in the same frequency band.

Security: 802.11g supports various security mechanisms such as Wired Equivalent Privacy (WEP), Wi-Fi Protected Access (WPA), and later versions of WPA like WPA2, providing options for securing wireless communications.

Range: The range of IEEE 802.11g networks can vary depending on environmental factors and the presence of obstacles, but it generally offers a range comparable to other standards operating in the 2.4 GHz band.

Compatibility: IEEE 802.11g devices are widely compatible with existing infrastructure, making it easier for users to upgrade their networks without having to replace all existing equipment.

CHAPTER 3

LITERATURE REVIEW

S.NO	TITLE	AUTHOR	YEAR
1.	Analysis of IEEE 802.11g standard for communication in a traffic light distributed control system	Danilo S. Miguel, Guilherme B. Castro, André R. Hirakawa	2015
2.	Simulative Comparison of Parallel Redundant Wireless Systems with OMNet++	Hassan H. Halawa, Ramez M. Daoud, Hassanein H. Amer	2014
3.	Performance Analysis of IEEE 802.11g Multi-Rate Support for Industrial Applications	Federico Tramarin and Stefano Vitturi	2013
4.	Adaptive Rate Control for Broadcasting Multimedia Streams in IEEE 802.11 Networks	Guan-Hsiung Liaw, Ke-Han Tsai , Sun-Yuan Wang , Tain-Lieng Kao , Lain-Chyr Hwang	2013
5.	High-Performance Industrial Wireless: Achieving Reliable and Deterministic Connectivity Over IEEE 802.11 WLANs	ADNAN AIJAZ	2019

6.	Wider-Bandwidth Operation of IEEE 802.11 for Extremely High Throughput: Challenges and Solutions for Flexible Puncturing	SANGHYUN KIM, AND JI-HOON YUN	2020

7.	CFFD-MAC: A Hybrid MAC for Collision Free Full-Duplex Communication in Wireless Ad-Hoc Networks	RUKAIYA RUKAIYA , MUHAMMAD UMAR FAROOQ , SHOAB A. KHAN, FARHAN HUSSAIN, AND ADNAN AKHUNZADA	2021
8.	An Efficient Backoff Procedure for IEEE 802.11ax Uplink OFDMA-Based Random Access	KATARZYNA KOSEK-SZOTT AND KRZYSZTOF DOMINO	2021

In [1], They analyze the wireless communication behavior, using the IEEE 802.11g standard as a basis and aiming at proposing a reliable communication model to a distributed control system of traffic lights. Moreover, analyzes were carried out, by simulations and experiments. Parameters such as distance, power and transmission rate were considered in the analysis and the validation of the results was performed by comparing the delay obtained in the experiments with the theoretical delay obtained in equations which consider the specifications of the IEEE 802.11 physical layer.

In [2], Parallel redundant point-to-point transmission utilizing a dual-radio wireless infrastructure has been identified as a powerful approach to improve the performance of wireless communication. This method can be applied for every existing wireless standard, but has not been deeply researched so far. To fill this gap, an OMNet++ simulation model for IEEE 802.11g (Wi-Fi) and IEEE 802.15.4 (ZigBee) is developed and some simulation scenarios performed to get a better understanding of the comparative performance characteristics of parallel redundant operation for these wireless standards.

In [3], They focus on the performance of two alternative RA techniques, namely Static retransmission rate ARF (SARF) and Fast rate reduction ARF (FARF), specifically conceived for the industrial communication scenario. In particular, we take into consideration a prototype network, typical of low levels of factory automation systems, and evaluate the behavior of these techniques by means of meaningful performance indicators obtained through numerical simulations. They also propose a comparison with results obtained, for the same network, when fixed transmission rates are used.

In [4], a novel adaptive rate control mechanism with packet loss rate tracing is proposed for broadcasting multimedia streams such that the subscribers will eventually get almost the same level of packet loss in short interval. The proposed mechanism is implemented on an access point (ADI Pronghorn Metro platform) with Atheros 802.11g interface card. Several experiments are performed and the results show the effectiveness of the proposed mechanism.

In [5], proposes a novel solution for providing reliable and deterministic communication, through Wi-Fi, in industrial environments. The proposed solution, termed as HAR2D-Fi (Hybrid channel Access with Redundancy for Reliable and Deterministic Wi-Fi), adopts hybrid channel access mechanisms for achieving deterministic communication. It also provides temporal redundancy for enhanced reliability. HAR2D-Fi implements different medium access control (MAC) designs that build on the standard physical (PHY) layer.

In [6], describes about the wideband operation of conventional IEEE 802.11 systems and the low-efficiency problem related to their contiguous channel-bonding limitations. Next, they describe how the puncturing of IEEE 802.11ax supports noncontiguous channel bonding. After that, we discuss the challenges of the limited bandwidth patterns of puncturing as a tradeoff problem between signaling overhead and transmission bandwidth. To reduce this signaling overhead, splitting and delivering the information over multiple channels can be considered, but with the increased difficulty to find all of these channels available at the same time.

In [7], proposes a novel hybrid MAC protocol for full-duplex ad-hoc networks. The proposed MAC combines time division multiple access (TDMA) and IEEE 802.11 distributed coordination function (DCF) strengths in chains of time-slotted contention-based control frames and collision-free data frames. The aim is to fully utilize FD transmission opportunities to increase network throughput. The proposed protocol modifies request-to-send (RTS) and clear-to-send (CTS) frames in IEEE 802.11 DCF MAC to form FD-RTS/CTS frames.

In [8], this paper, they address this problem by modifying the UORA backoff selection method. The proposed solution allows an access point to adjust the OFDMA random access backoff (OBO) countdown rate to decrease the probability of uplink transmission failures. The implemented changes considerably improve UORA performance. They show through extensive simulations, that the proposed efficient OFDMA random access backoff (E-OBO) ensures throughput, efficiency, and collision probability close to optimal and outperforms state-of-the-art solutions.

CHAPTER 4

BACKGROUND OF THIS WORK

In mobile Ad-hoc network, wireless nodes are moving with different speeds and changing their positions continuously. Due to this link breakages will happen thereby many retransmissions and packet error rates are occurred. This effect leads to reduction of throughput performance and increase in latency happened. So, we have to dynamically control the data rates to get maximum throughput.

Mobile Ad Hoc Networks (MANETs) are self-configuring networks of mobile devices connected by wireless links. In these networks, nodes can move freely and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Due to this dynamic nature, the network faces significant challenges in maintaining optimal data rates, which are crucial for efficient communication.

The performance of MANETs is influenced by various factors, including node mobility, varying channel conditions, interference, and limited bandwidth. Channel variations, in particular, pose a significant challenge as they can lead to fluctuations in link quality and affect the overall network throughput and latency.

The primary objective is to develop an optimization framework to maximize data rates in channel-varying Mobile Ad Hoc Networks. This involves designing algorithms and protocols that adapt to changing network conditions and ensure efficient utilization of available resources.

The optimization framework must be scalable to handle large numbers of nodes and varying network sizes without significant degradation in performance.

- Interference from other devices and networks can degrade signal quality, necessitating robust interference management techniques.
- Limited bandwidth, power, and computational resources necessitate efficient resource management strategies.
- High mobility can lead to frequent topology changes, making it challenging to maintain stable connections and optimal routing paths.

CHAPTER 5

5.1 IEEE 802.11 RATE CONTROL

Rate control is a key feature of the IEEE 802.11 wireless networking standard that allows devices to adapt to changing channel conditions and dynamically select the optimal bitrate for transmitting data. This helps to improve the overall performance of the network by reducing the likelihood of errors and retransmissions, and increasing the throughput of the network. In INET, several different variants of the 802.11 rate control mechanism are implemented, allowing users to choose the most appropriate one for their specific needs.

The physical layers of IEEE 802.11 devices are capable of transmitting at several different rates. The different rates can use different channel access methods, like orthogonal frequency division multiplexing (OFDM) or directs sequence spread spectrum (DSSS), and different modulation schemes like binary phase shift keying (BPSK) or types of quadrature amplitude modulation (QAM). Each of these has different tolerances of effects like fading, attenuation, and interference from other radio sources. In varying channel conditions, using the fastest rate might not be optimal for performance. Rate control algorithms adapt the transmission rate dynamically to the changing channel conditions, so the performance of the radio link can be maximized.

For example, in certain channel conditions, if hosts transmitted with 54 Mbps, the transmissions would not be received correctly, and the throughput would drop to zero. However, transmissions with 6 Mbps would be correctly receivable due to the simpler modulation (BPSK instead of 64QAM). It is not obvious which rate works the best with what channel conditions. The goal of rate control algorithms is to find the best rate and maximize throughput.

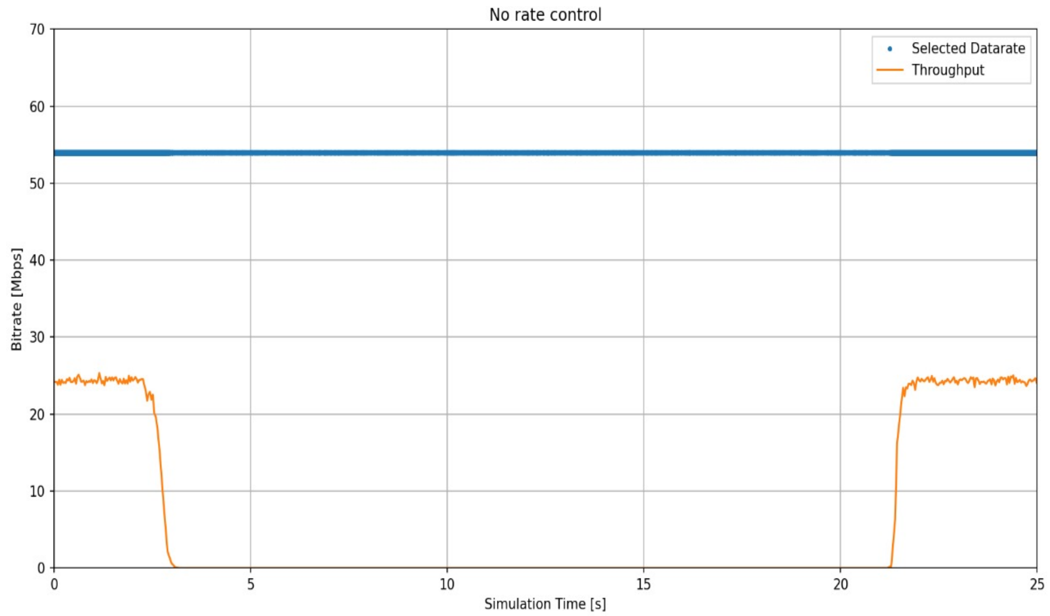

Fig 3: No Rate control mechanism

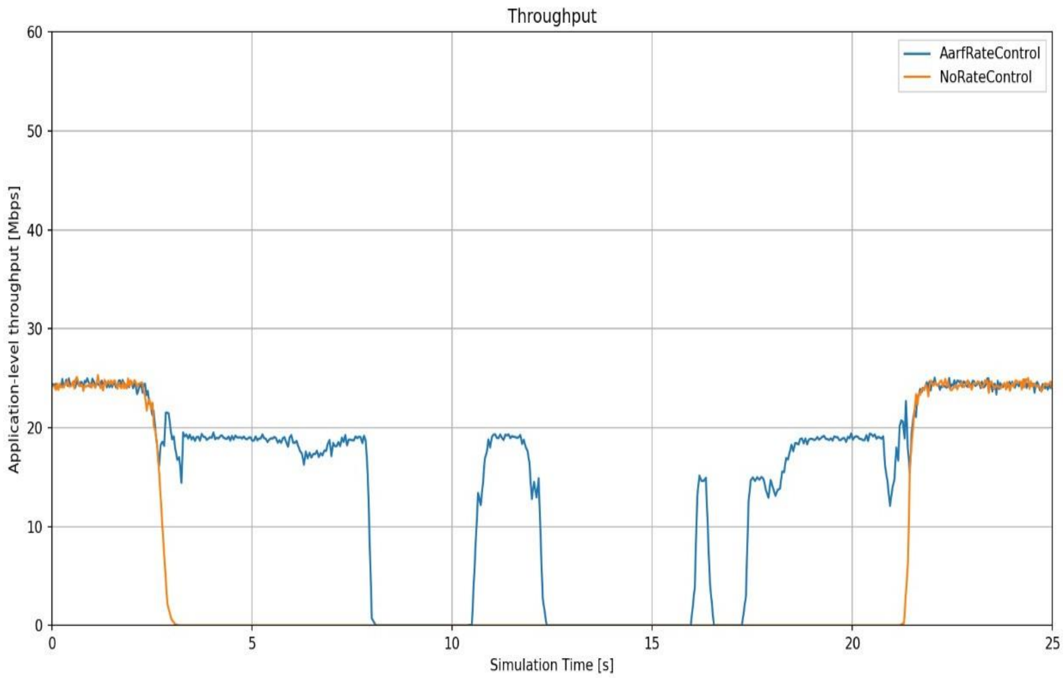

Fig 4: Throughput graph

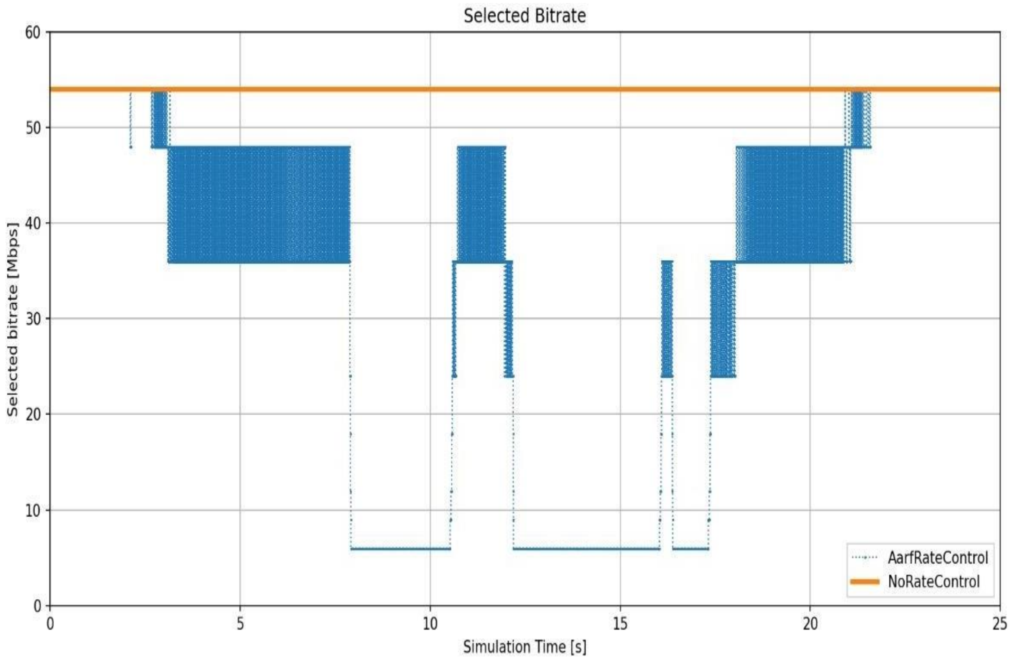

Fig 5: Selected bit rate

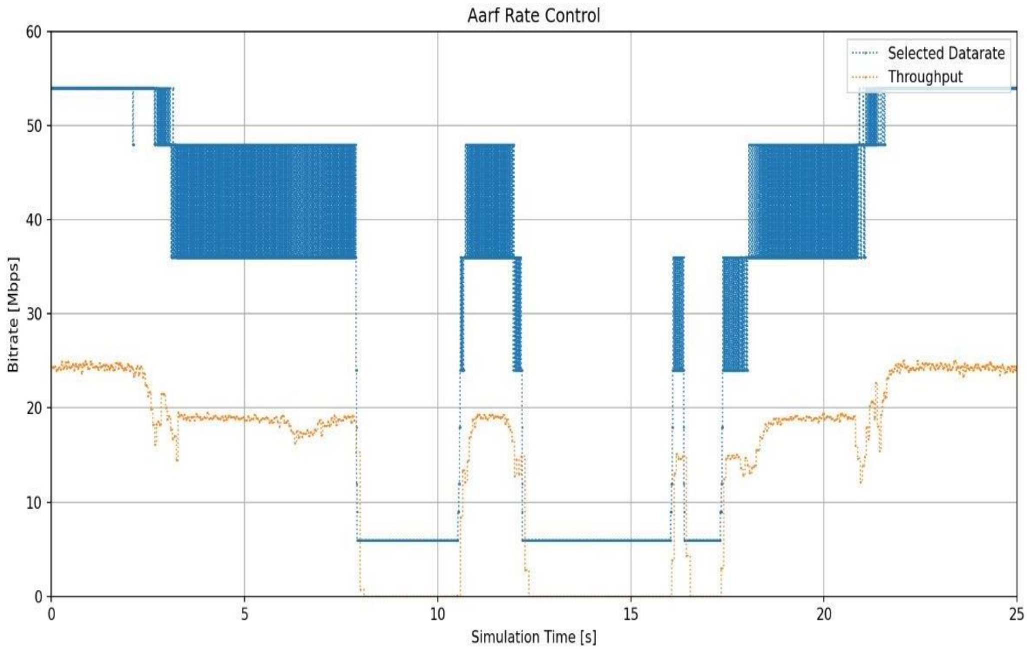

Fig 6: Aarf Rate control mechanism

5.2 PACKET LOSS VS DISTANCE USING VARIOUS BIT RATES

The packet error rate is measured at various Wi-Fi bitrates, providing insights into the impact of different bitrates on the quality of communication over different distances. The distance will run between 10 and 550 meters, in 2-meter steps. The bitrate will take the ERP modes in 802.11g: 6, 9, 12, 18, 24, 36, 48 and 54 Mbps. This results in about 2100 simulation run.

The two-ray ground reflection path loss model requires a ground model, which is configured in the physical Environment module to be Flat Ground. The heights of the hosts above the ground are set to 1.5 meters.

In each simulation run, the source host will send a single UDP packet (56 bytes of UDP data, resulting in a 120-byte frame) to the destination host as a probe. At packet reception, the error model will compute bit error rate (BER) from the signal-to-noise-plus-interference-ratio (SNIR). Packet error rate (PER) will be computed from BER. The simulation records SNIR, BER, and PER. Note that in this simulation model, the physical layer simulation is entirely deterministic, hence there is no need for Monte Carlo.

SNIR, BER, and PER are recorded from the simulation runs. SNIR is measured at the receiver and depends on the power of the noise and the power of the signal. The signal power decreases with distance, so SNIR does as well. SNIR is independent of modulations and coding schemes, so it is the same for all bitrates. This can be seen on the following plot, which displays SNIR against distance. we examine how packet error rate changes as a function of distance in an 802.11g wireless network. The packet error rate is measured at various Wi-Fi bitrates, providing insights into the impact of different bitrates on the quality of communication over different distances.

Packet error rate increases quickly as the distance approaches the critical point. Slower bitrates are less sensitive to increasing distance because they use simpler modulation. Faster bitrate modes are advantageous in short distances because of the increased throughput, but slower modes work better at longer distances. Furthermore, using rate adaptation, a host can use fast modes for short distances and slower modes for larger ones. When the number of lost packets increases and throughput drops, it becomes more viable to change to a slower bitrate mode.

The next plot shows how packet error rate decreases with SNIR. Slower bitrates use simpler modulation like binary phase shift keying, which is more tolerant to noise than more complex modulations used by faster bitrates, hence the difference on the graph between the different bitrates. The various modulations and coding rates of 802.11g ERP modes are the following:

6 and 9 Mbit/s modes use BPSK, coding rates 1/2 and 3/4

12 and 18 Mbit/s modes use QPSK, coding rates 1/2 and 3/4

24 and 36 Mbit/s modes use 16-QAM, coding rates 1/2 and 3/4

48 and 54 Mbit/s modes use 64-QAM, coding rates 1/2 and 3/4

Note that the completely flat and completely vertical lines on the plot are due to the signal power decreasing below the sensitivity of the receiver.

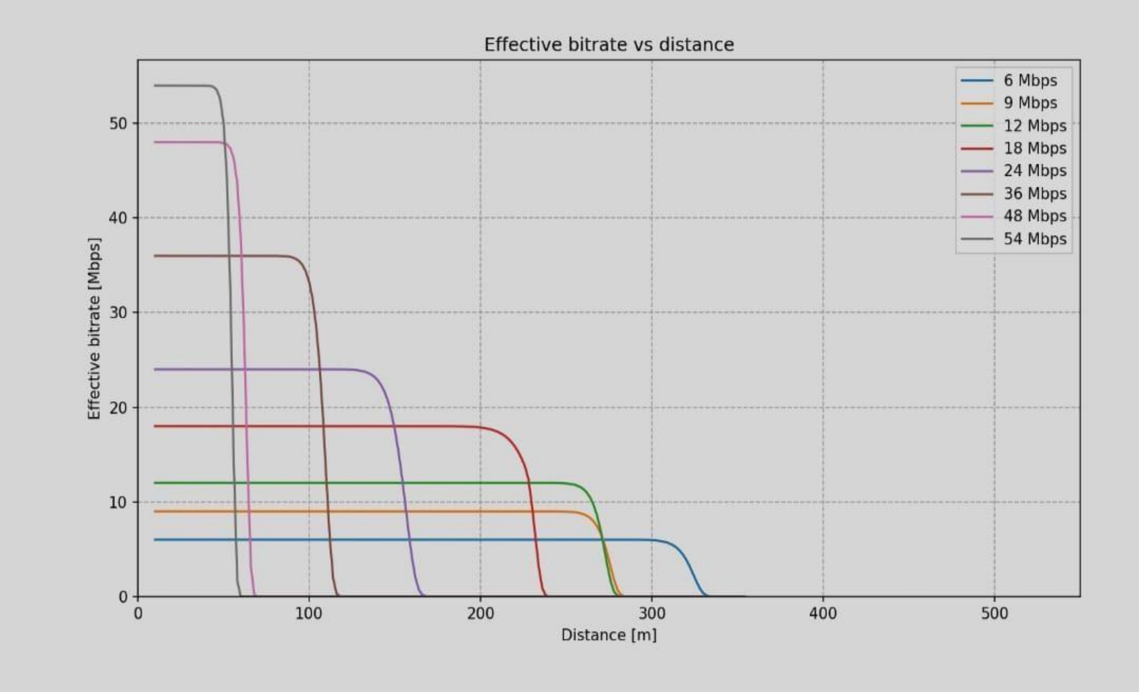

Fig 7: SNIR Vs Distance

The following plot shows the packet error rate vs distance. Again, slower bitrates show fewer packet errors as the distance increases because of the simpler modulation.

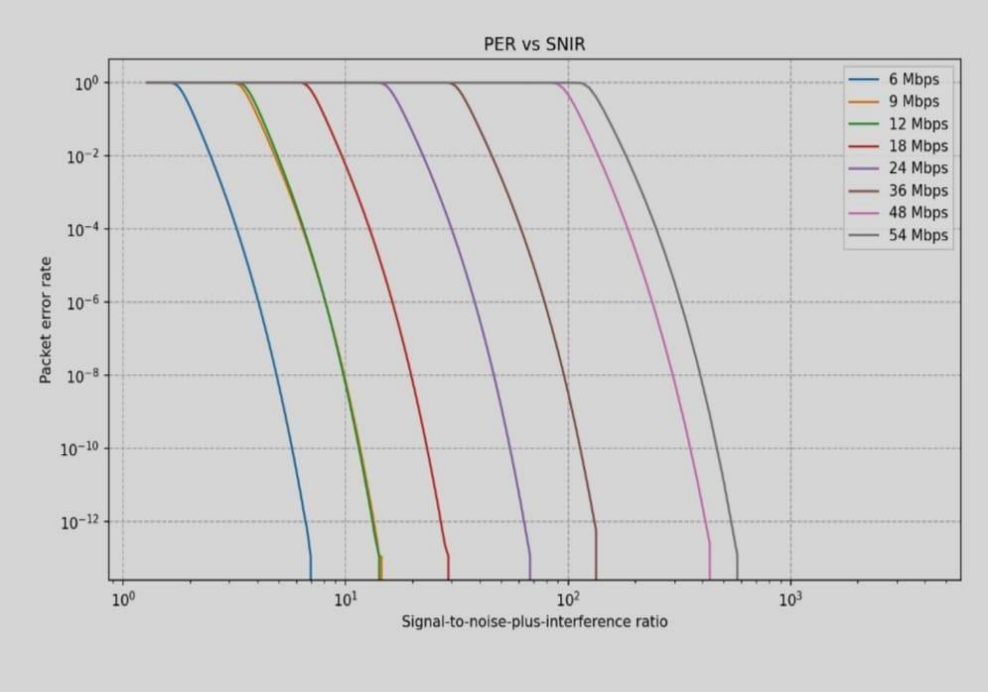

Fig 8: PER Vs SNIR

Effective bitrate vs distance is shown on the next plot. Higher bitrates are more sensitive to increases in distance, as the effective bitrate drops rapidly after a critical distance. This critical distance is farther for slower bitrates, and the decrease is not as rapid.

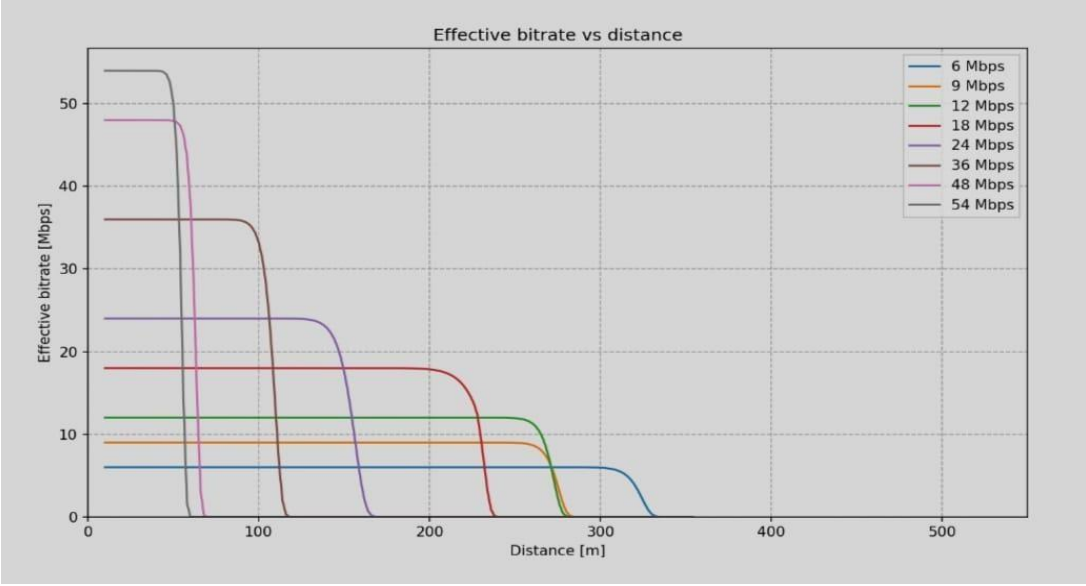

Fig 9: Effective bit rate vs distance

CHAPTER 6

6.1 INTRODUCTION TO OMNET++

OMNeT++ is an extensible, modular, component-based C++ simulation library and framework, primarily for building network simulators. "Network" is meant in a broader sense that includes wired and wireless communication networks, on-chip networks, queueing networks, and so on. Domain-specific functionality such as support for sensor networks, wireless ad-hoc networks, Internet protocols, performance modelling, photonic networks, etc., is provided by model frameworks, developed as independent projects. OMNeT++ offers an Eclipse-based IDE, a graphical runtime environment, and a host of other tools. There are extensions for real-time simulation, network emulation, database integration, Systems integration, and several other functions. OMNeT++ is distributed under the Academic public license.

Although OMNeT++ is not a network simulator itself, it has gained widespread popularity as a network simulation platform in the scientific community as well as in industrial settings, and building up a large user community.

OMNeT++ provides a component architecture for models. Components *(modules)* are programmed in C++, then assembled into larger components and models using a high-level language *(NED)*. Reusability of models comes for free. OMNeT++ has extensive GUI support, and due to its modular architecture, the simulation kernel (and models) can be embedded easily into your applications.

6.2 Components

The main ingredients of OMNeT++ are:

- Simulation kernel library (C++)
- The NED topology description language
- Simulation IDE based on the Eclipse platform
- Interactive simulation runtime GUI (Qtenv)
- Command-line interface for simulation execution (Cmdenv)
- Utilities (make filé creation tool, etc.)

6.3 Simulation IDE

The Simulation IDE is a powerful, feature-rich environment for developing, running, and evaluating simulation models. Please note that using the IDE is entirely optional; model development and execution are also possible and fully supported through the command line or alternative editors/IDEs.

6.4 INET FRAMEWORK

INET Framework is an open-source model library for the OMNeT++ simulation environment. It provides protocols, agents and other models for researchers and students working with communication networks. INET is especially useful when designing and validating new protocols, or exploring new or exotic scenarios.

INET contains models for the Internet stack (TCP, UDP, IPv4, IPv6, OSPF, BGP, etc.), wired and wireless link layer protocols (Ethernet, PPP, IEEE 802.11, etc.), support for mobility, MANET protocols, Diff Serv, MPLS with LDP and RSVP-TE signaling, several application models, and many other protocols and components.

Several other simulation frameworks take INET as a base, and extend it into specific directions, such as vehicular networks, overlay/peer-to-peer networks, or LTE.
[INET is a prominent open-source model library for the OMNeT++ simulation framework, widely used for research in communication networks. It provides a comprehensive suite of modules that simulate various network protocols, devices, and utilities.
INET is a powerful tool for network simulation, providing detailed models and utilities that are essential for both academic research and practical network design.

6.5 NED FILE

The network description is denoted as the NED and it is considered as the topology description language of OMNeT++. Ned includes the simple process to define the regular topologies and structures such as.

Tree

Hypercube

Mesh

Ring

Chain

NED (Network Description) files are a fundamental part of OMNeT++ (Objective Modular Network Testbed in C++), a discrete event simulation environment used for simulating computer networks, wireless ad-hoc networks, queuing networks, and other distributed systems.

NED files use a specific syntax that is somewhat similar to a simplified programming language.

This syntax is used to define modules (both simple and compound), their parameters, gates, and connections.

These consist of multiple simple or compound modules and define how these modules are interconnected.

CHAPTER 7

7.1 Adhoc network scenario

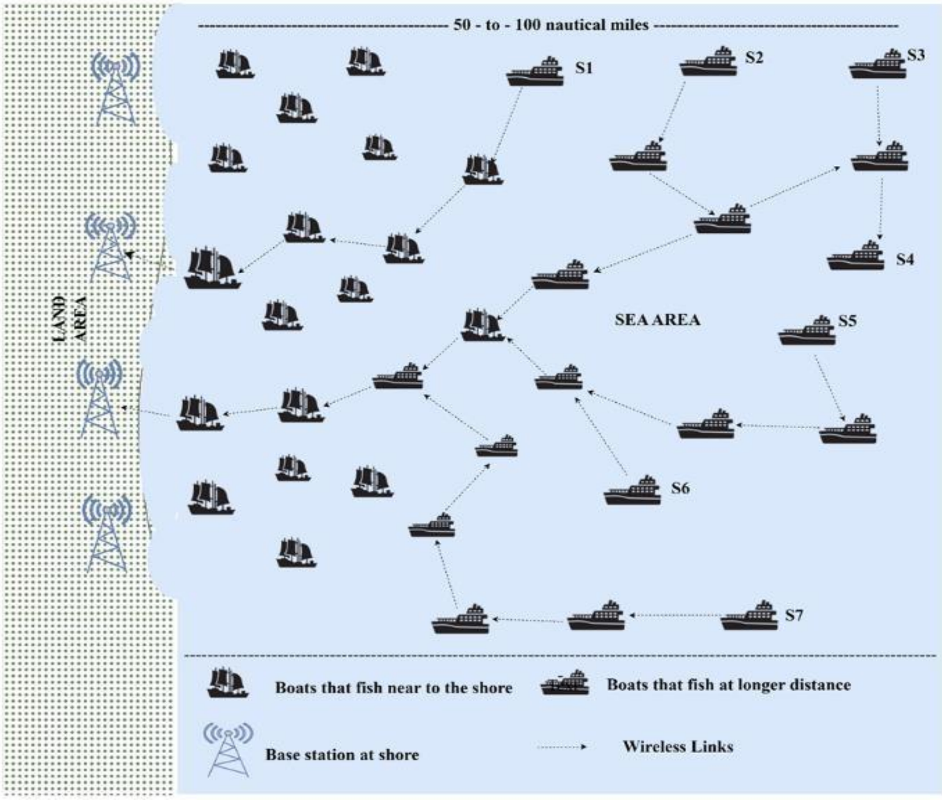

Fig 10: Typical Ad-hoc network scenario on the seas

For this, one-to-one communication is considered between the nodes. A scenario where one node is stationary while the other node is in movement is created for this purpose. Simulation is performed for sufficient enough time until the moving node goes out of coverage of the stationery node. This experiment is conducted for different power levels. Absolute throughput values achieved at the receiver are recorded.

As can be observed, sharp fall of throughput takes place at various distances for different power levels. Having this cutoff distance information readily available helps in deciding the power levels with which the ad-hoc grid network can be experimented. In addition to finding the throughput values, packet error rates are also recorded for each of the above cases of one-to-one communication.

IEEE 802.11g uses Orthogonal Frequency Division Multiplexing (OFDM) for modulation. The data rates supported by IEEE 802.11g include 6, 9, 12, 18, 24, 36, 48, and 54 Mbps. These data rates allow for efficient communication in various scenarios, including ad-hoc networks.

IEEE 802.11g uses Orthogonal Frequency Division Multiplexing (OFDM) for modulation. The data rates supported by IEEE 802.11g include 6, 9, 12, 18, 24, 36, 48, and 54 Mbps. These data rates allow for efficient communication in various scenarios, including ad-hoc networks.

7.2 SCENARIO 1:

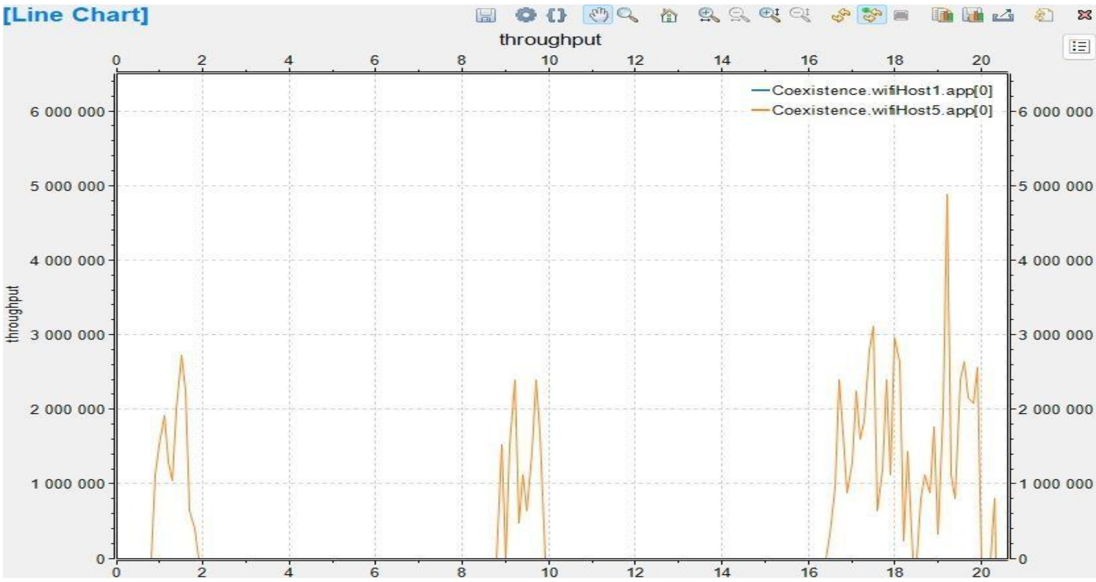

Fig 11:40mw No Rate Control - 0mps

In this above figure, nodes are constant and there is no mobility (0mps) speed with 40MW power There are large fluctuations in throughput.

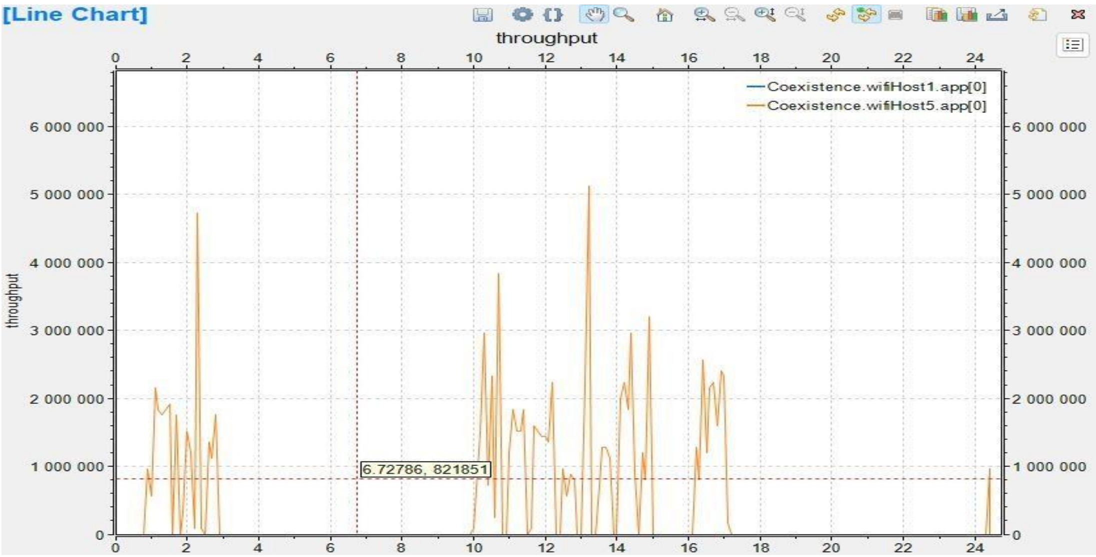

Fig 12:40mw Aarf Rate control - 0mps

In this above figure, we are using Aarf rate control mechanism Nodes are constant and travels with 0mps speed and with 40MW power. Minimum number of fluctuations are obtained and maximum throughput.

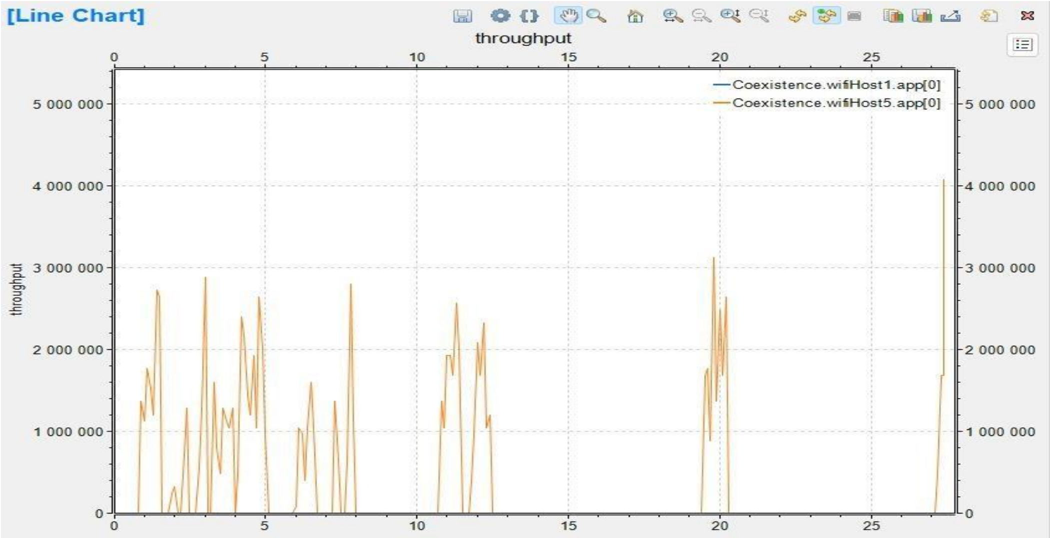

Fig 13:50mw No Rate control- 0 mps

In this above figure, we are using No rate control mechanism Nodes are constant and travels with 0mps speed and with 50MW power. We increased power. Throughput is constant from 1 to 8 seconds simulation time and later throughput remains zero and again it starts increasing.

Bit rate is about 2500000 mps.

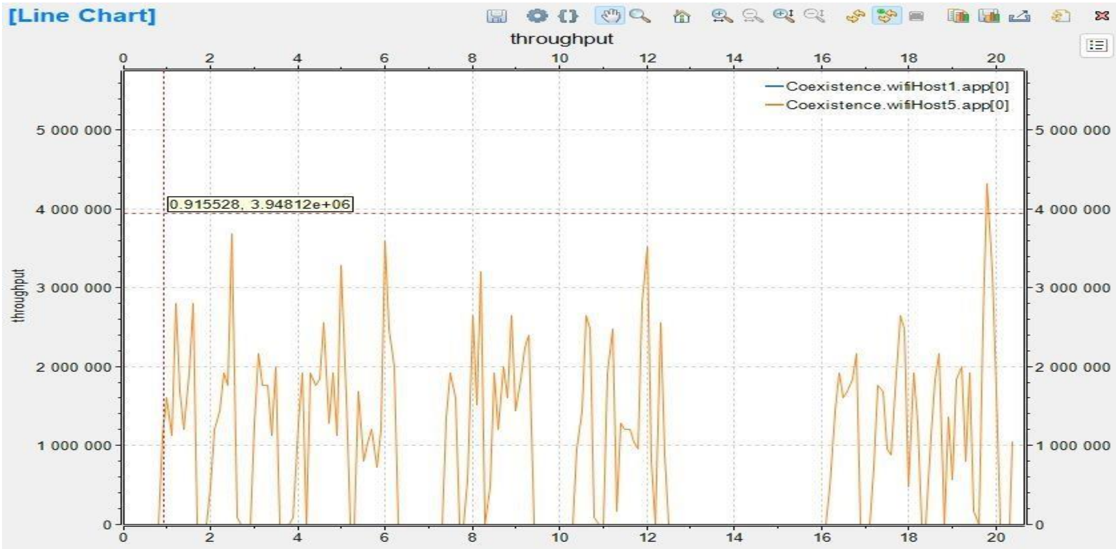

Fig 14:50mw Aarf Rate control- 0 mps

In this above figure, we are using Aarf rate control mechanism. Nodes are constant and travels with 0mps speed and with 50MW power. We increased power. Throughput is almost obtained except at 12 to 16 seconds simulation time. Bit rate increases about 3600000 mps.

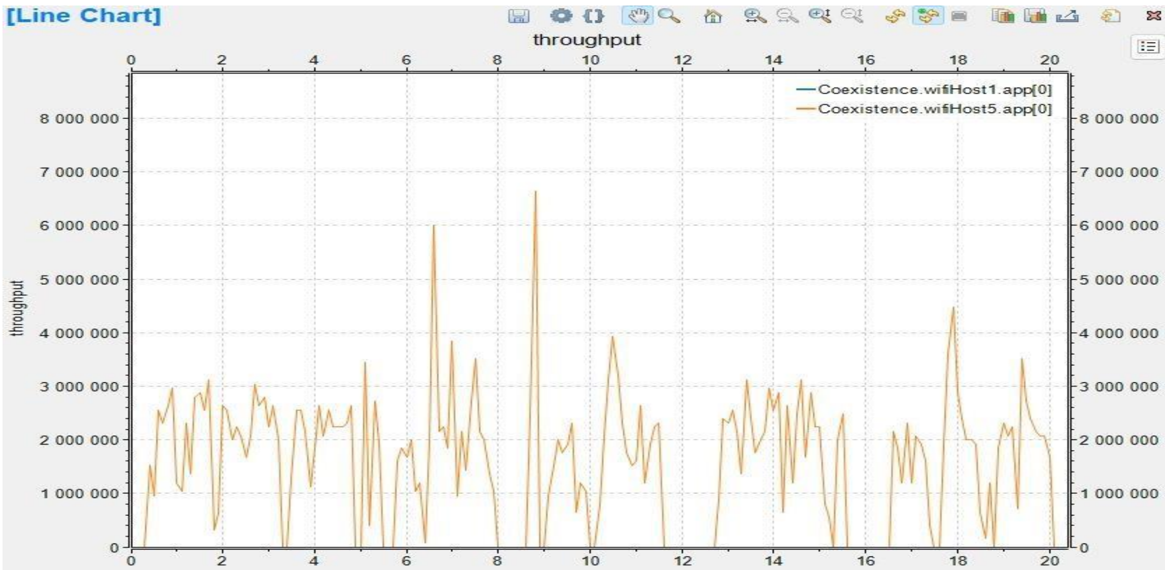

Fig 15:100MW No Rate control- 0mps

In this above figure, we are using No rate control mechanism. Nodes are constant and travels with 0mps speed and with 100MW power. As we increased the power maximum number of packets are transmitted and throughput is constant and it does not fluctuate except at 12 and 16 seconds simulation time. Throughput increases.

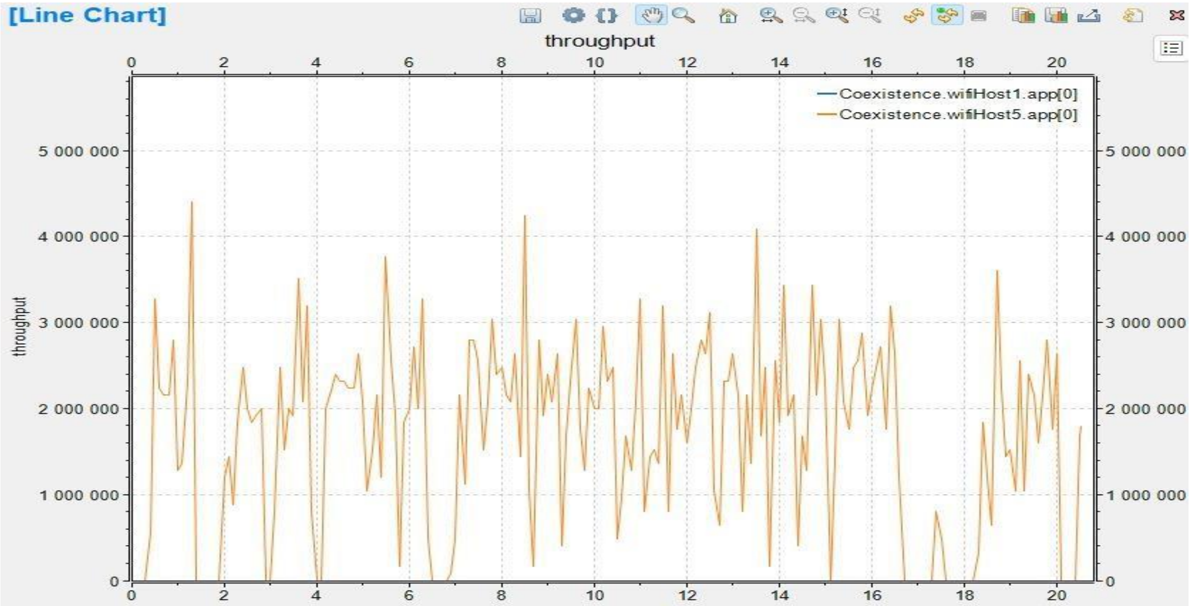

Fig 16:100MW Aarf Rate control- 0mps

In this above figure, we are using Aarf rate control mechanism. Nodes are constant and travels with 0mps speed and with 100MW power. As we increased the power maximum number of packets are transmitted and throughput is constant and it obtained at every simulation time. There are no fluctuations with maximum throughput.

7.2 Scenario 2: Nodes with less mobility

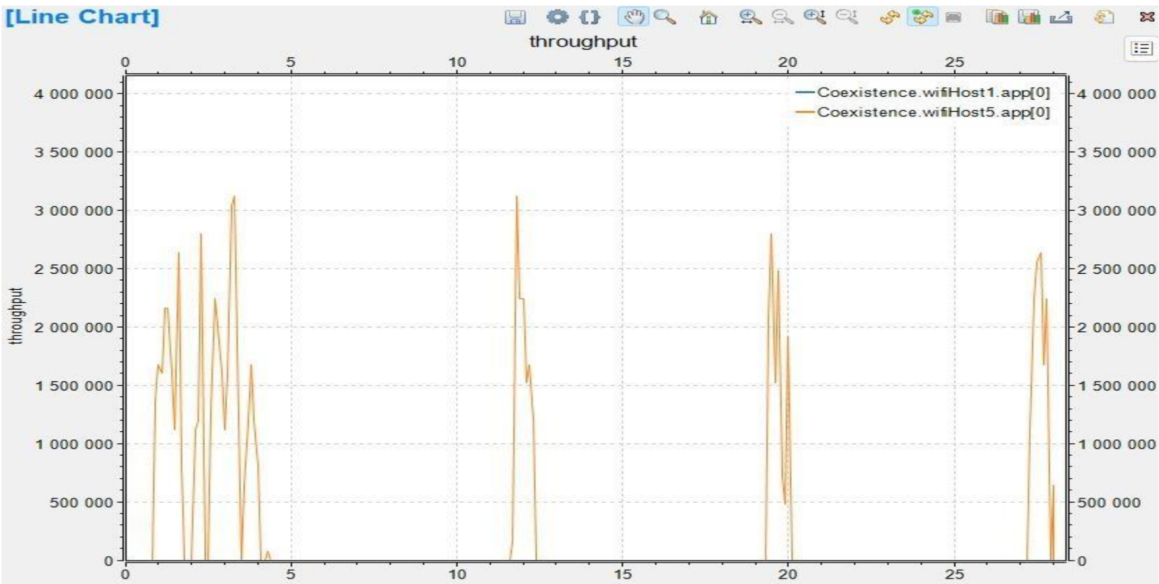

Fig 17: 40MW No Rate control-5mps

In this above figure, nodes are moving with less mobility of around 5mps speed with 40MW power. There are large fluctuations in throughput. It is not obtained at every simulation time.

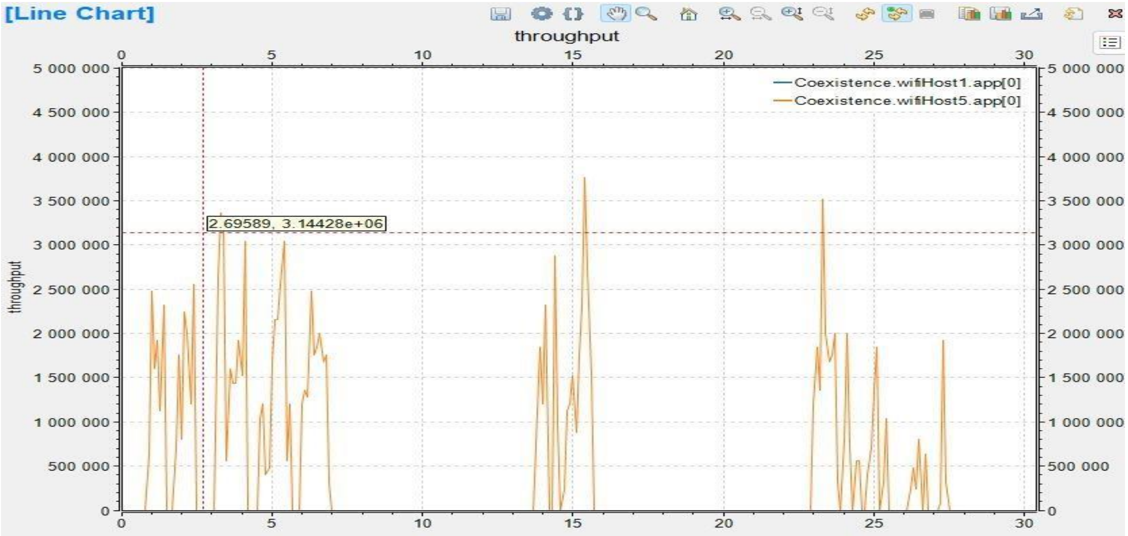

Fig 18:40MW Aarf Rate control-5mps

In this above figure, we are using Aarf rate control mechanism. Nodes are moving with less mobility of around 5mps speed and with 40MW power. Minimum number of fluctuations are obtained and maximum throughput.

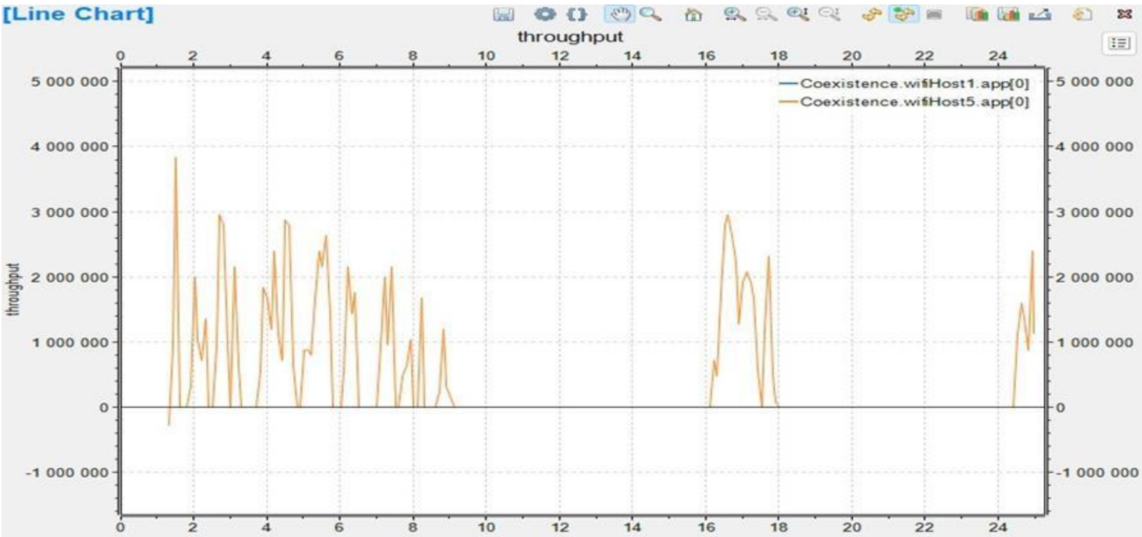

Fig 19: 50MW No Rate control- 5mps

In this above figure, we are using No rate control mechanism. Nodes are moving with less mobility of around 5mps speed and with 50MW power. As node mobility is less throughput decreases and PER increases. Throughput is constant from 1 to 9 seconds simulation time and later throughput fluctuates, it remains zero and again it starts increasing. Bit rate is about 2800000 mps.

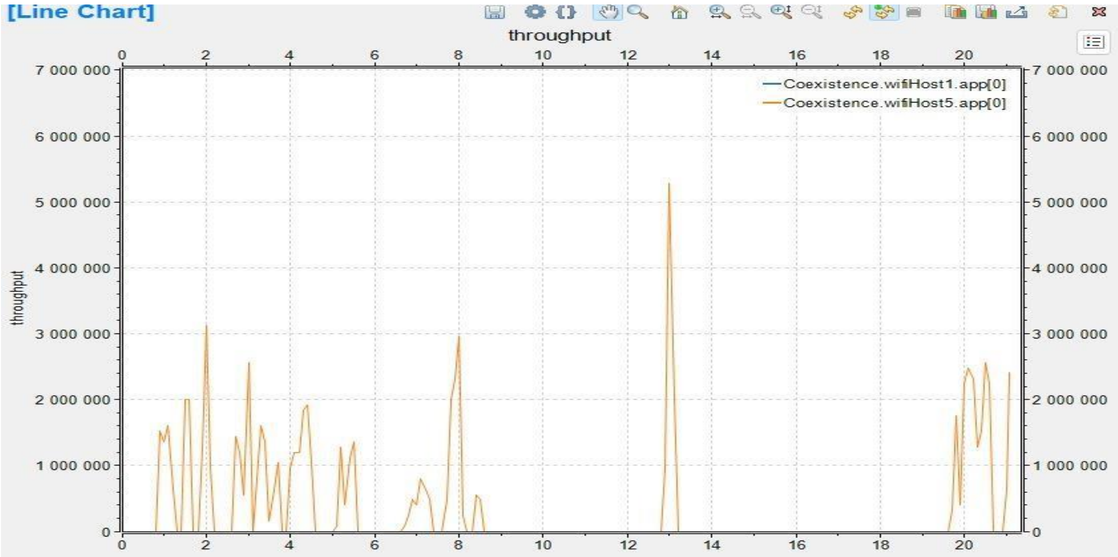

Fig 20: 50MW Aarf Rate control- 5mps

In this above figure, we are using Aarf rate control mechanism .Nodes are moving with less mobility constant of around 5mps speed and with 50MW power.We increased power.Throughput is almost obtained except at some simulation time.At 13 seconds simulation time
Throughput is about 5000000 mps.

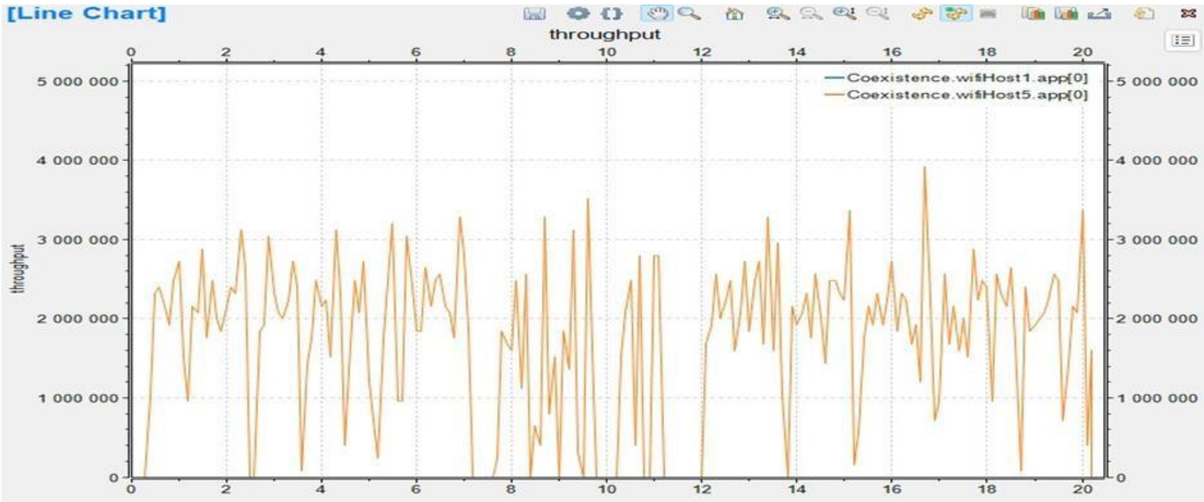

Fig 21: 100MW No Rate control- 5mps

In this above figure, we are using No rate control mechanism. Nodes are moving with less m of around 5mps speed and with 100MW power. As we increased the power maximum number of packets are transmitted and throughput is constant and it does not fluctuate. Throughput is about 3000000mps.

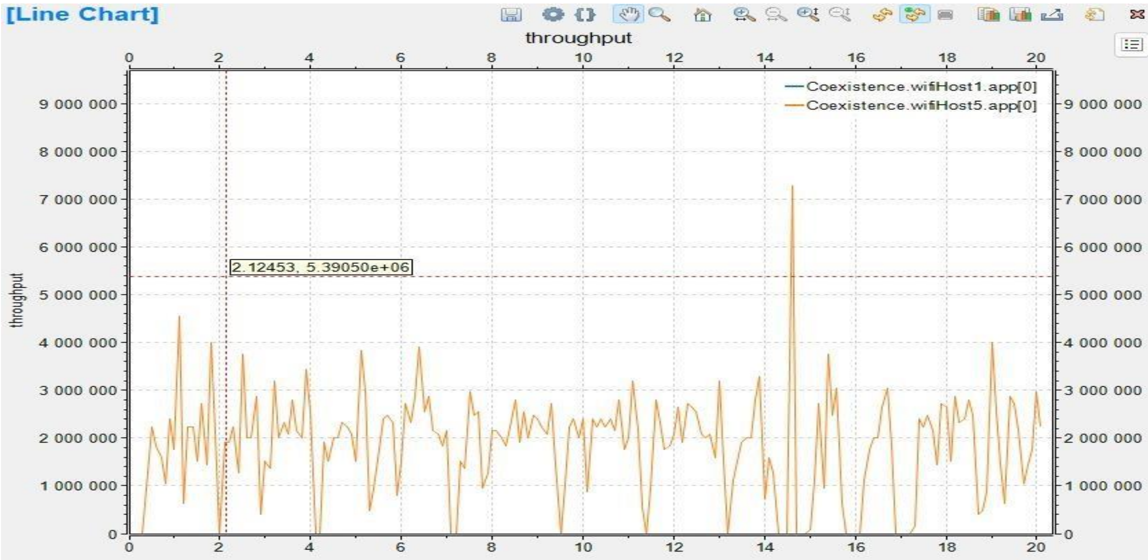

Fig 22: 100MW Aarf Rate control

In this above figure, we are using Aarf rate control mechanism. Nodes are moving with less mobility of around 5mps speed and with 100MW power. Maximum throughput is obtained.

7.3 Scenario 3: Nodes moving with high mobility

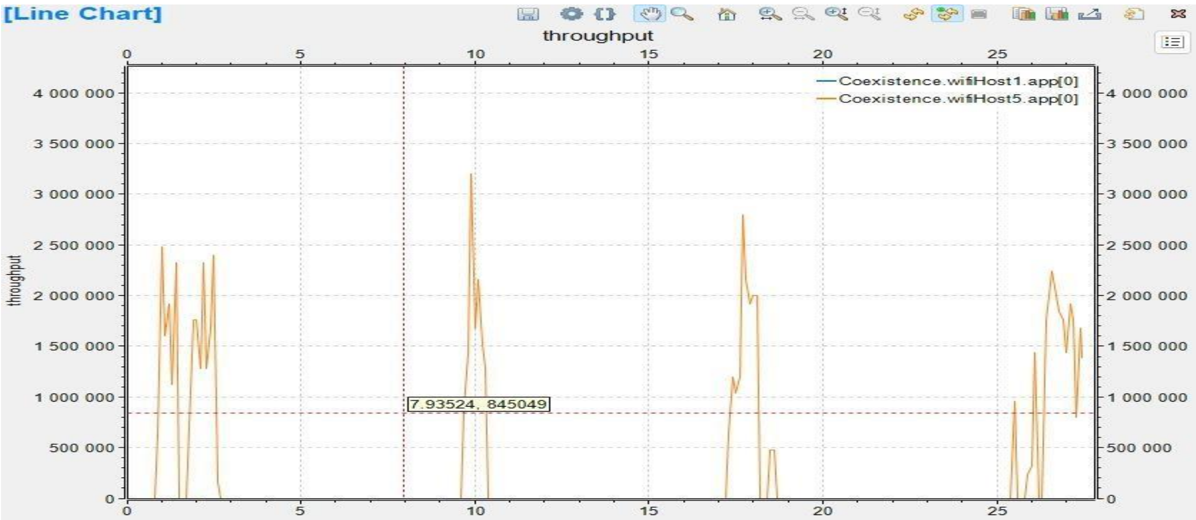

Fig 23: 40MW No Rate control--10mps

In this above figure, nodes are moving with highmobility of around 10mps speed with 40MWpower . Throughput obtained is very less.

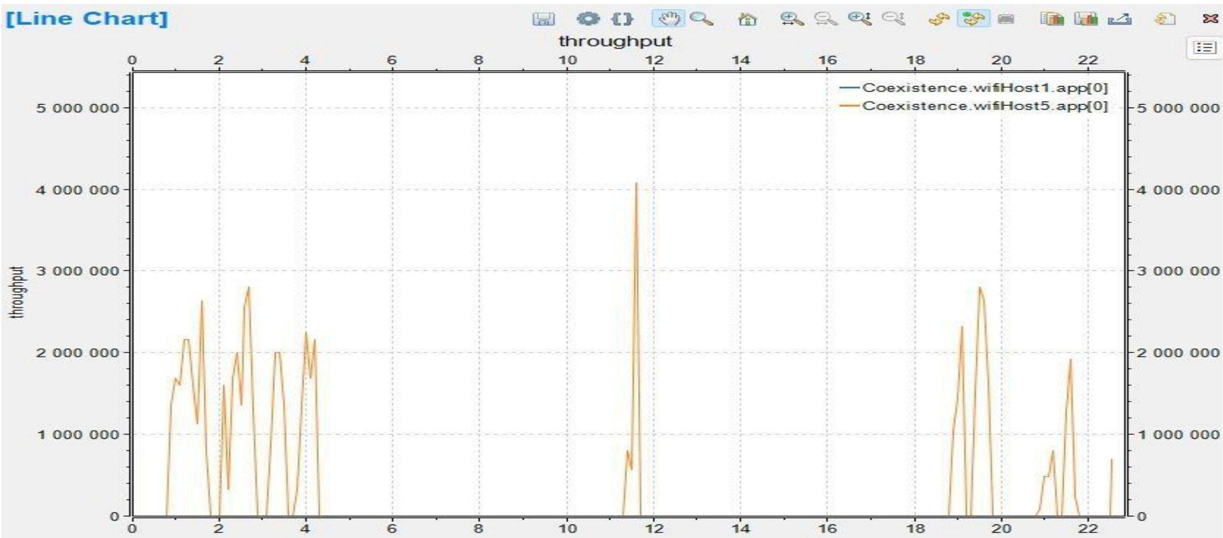

Fig 24: 40MW Aarf Rate control--10mps

In this above figure, we are using Aarf rate control mechanism .Nodes are moving with high mobility of around 10 mps speed and with 40MW power.Throughput is slightly increased.

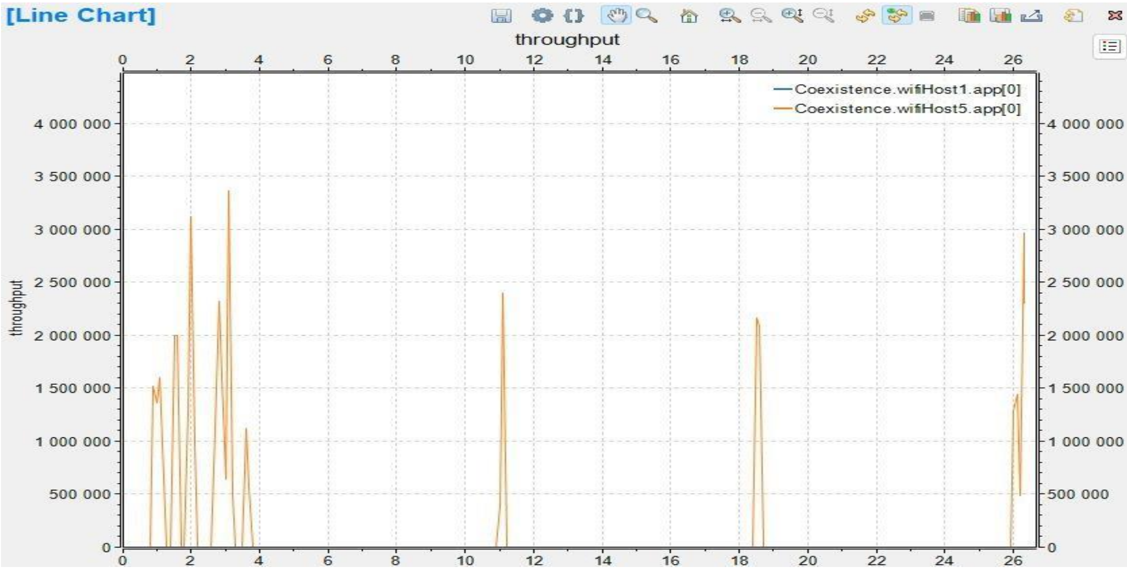

Fig 25: 50MW No Rate control--10mps

In this above figure, we are using No rate control mechanism. Nodes are moving with high mobility of around 10mps speed and with 50MW power. As node mobility is high frequent topology changes and route disruptions occur. Throughput gradually decreases and PER increases.

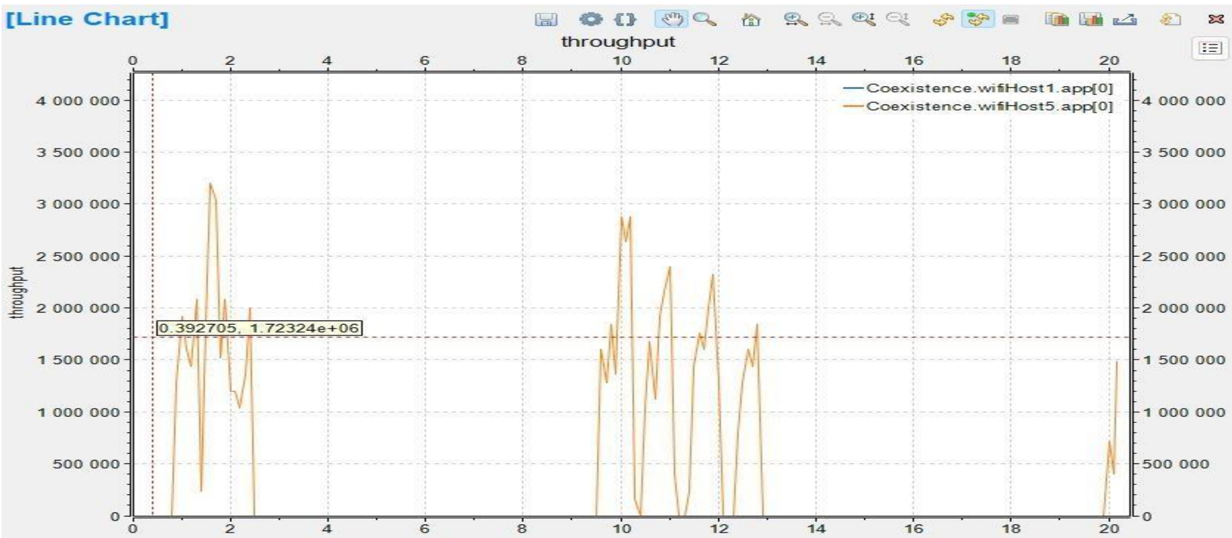

Fig 26: 50MW Aarf Rate control--10mps

In this above figure, we are using Aarf rate control mechanism. Nodes are moving with high mobility of around 10mps speed and with 50MW power. As node mobility is high frequent topology changes and route disruptions occur. Throughput occurs at 1 to 2.5 seconds and at 9.5 to 13 seconds simulation time. Bitrate is about 3000000mps.

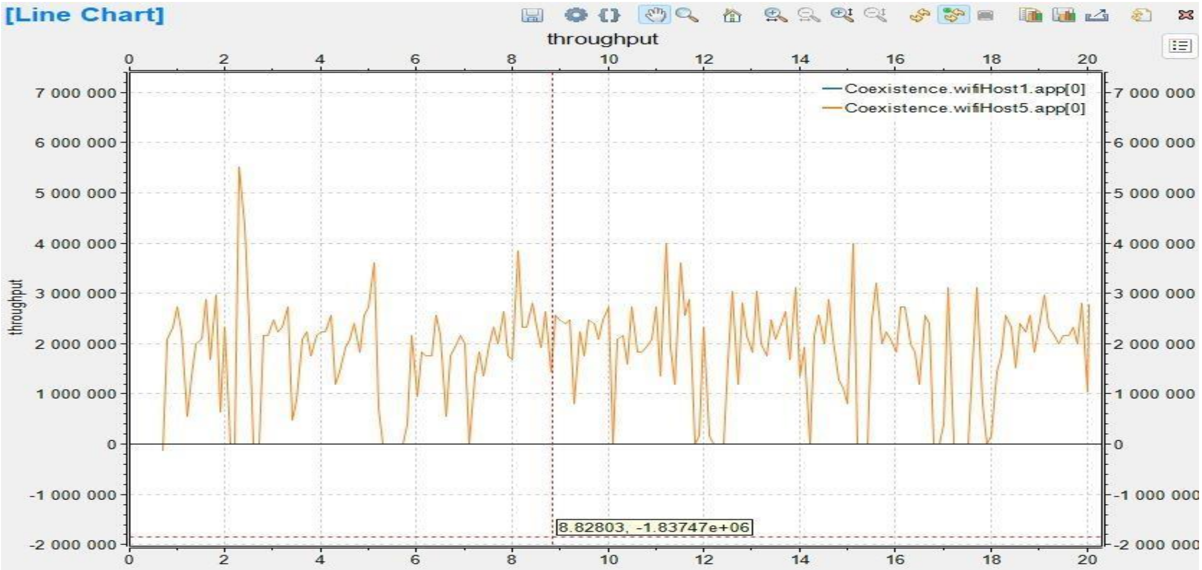

Fig 27: 100MW No Rate control--10mps

In this above figure, we are using No rate control mechanism. Nodes are moving with high mobility of around 10mps speed and with 100MW power. As we increased power though put is constant at every simulation time.

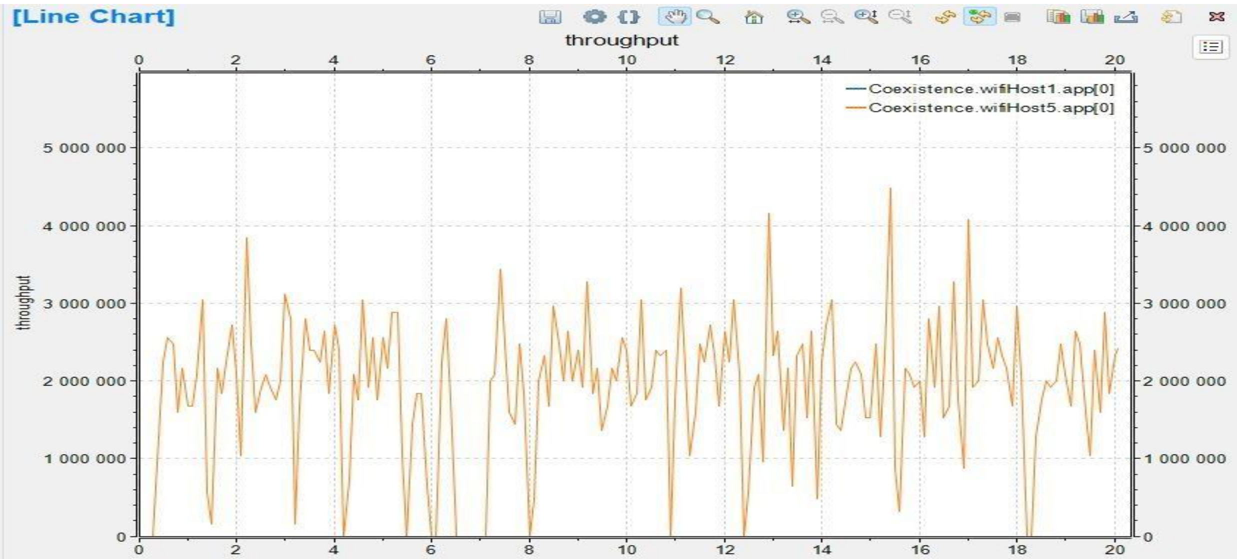

Fig 28: 100MW Aarf Rate control--10mps

In this above figure, we are using Aarf rate control mechanism. Nodes are moving with high mobility of around 10mps speed and with 100MW power. As we increased power though put is constant at every simulation time . Throughput increases with maximum bit rate.

7.4 Scenario 4: Two sources with two destinations

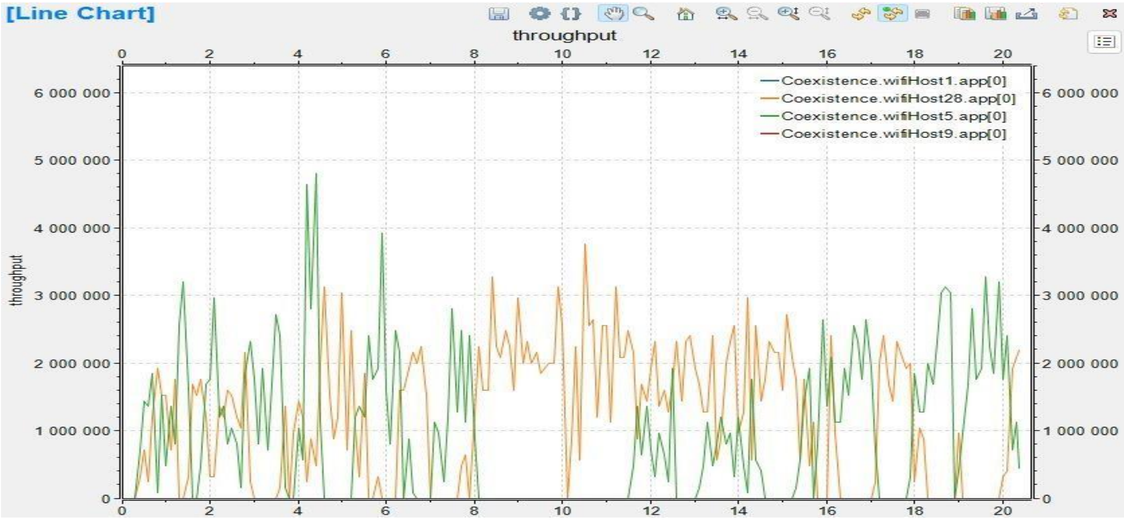

Fig 29: 100MW No Rate control--2mps

In this above figure we are using no rate control mechanism with two sources and two destinations. Nodes are moving with less mobility of around 2 mps speed and 100MW power. Maximum throughput is obtained.

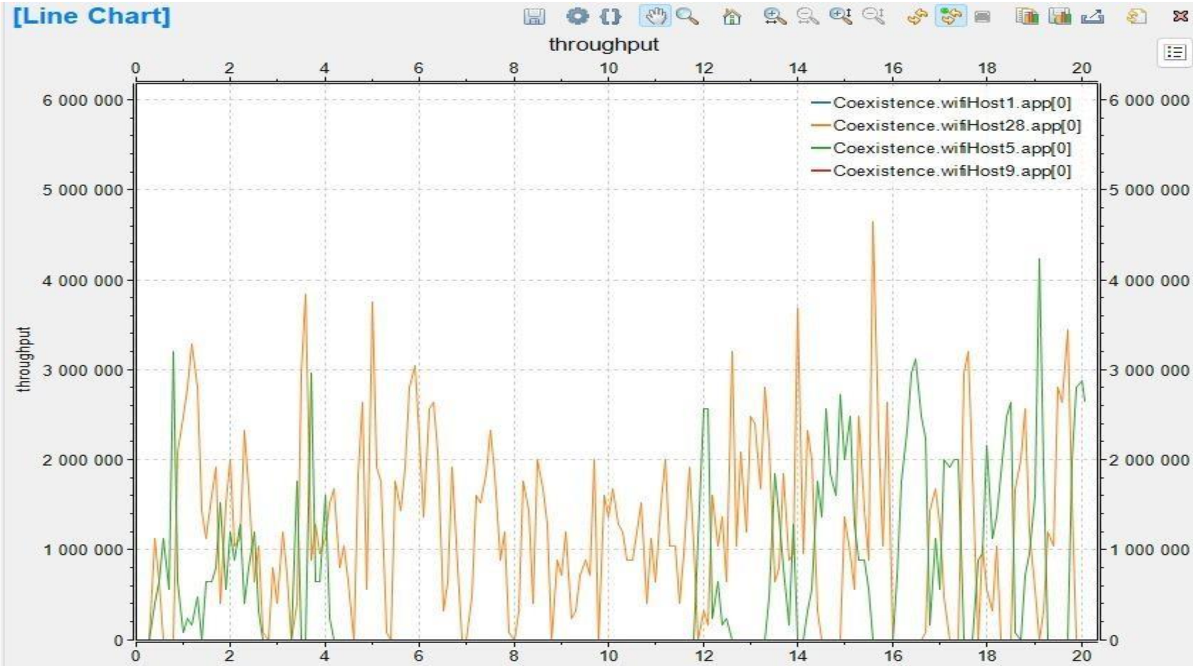

Fig 30: 100MW Aarf Rate control--2mps

In this above figure we are using Aarf rate control mechanism with two sources and two destinations. Nodes are moving with less mobility of around 2 mps speed and 100MW power. Maximum throughput is obtained.

CHAPTER 8

CONCLUSION

In conclusion, optimizing data rates in channel-varying mobile ad hoc networks (MANETs) involves a comprehensive approach that addresses both the dynamic nature of network topologies and fluctuating channel conditions. Key strategies include implementing adaptive modulation and coding (AMC) for dynamic adjustment based on channel state, employing cross-layer design for enhanced inter-layer coordination, and utilizing adaptive routing protocols that consider link quality and mobility. Additionally, power control mechanisms can mitigate interference, and network coding can improve throughput efficiency. Incorporating machine learning techniques to predict and adapt to channel variations and mobility patterns further enhances network performance. By integrating these strategies, MANETs can achieve optimal data rates, ensuring robust and efficient communication in varying environments.

CHAPTER 9

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An Efficient Backoff Procedure for IEEE 802.11ax Uplink OFDMA-Based Random Access

CHAPTER 10

APPENDIX

10.1 NED FILE CODE

```
import inet.networklayer.configurator.ipv4.Ipv4NetworkConfigurator;
import inet.node.inet.AdhocHost;
import inet.node.inet.ManetRouter; //from #bmj-showcases-routing-manets
import inet.node.wireless.Probe;
import inet.node.wireless.AccessPoint;
import inet.visualizer.canvas.integrated.IntegratedCanvasVisualizer;
import inet.node.inet.WirelessHost;
import inet.environment.common.PhysicalEnvironment;
import inet.physicallayer.wireless.ieee80211.packetlevel.Ieee80211ScalarRadioMedium;
//import inet.visualizer.integrated.IntegratedMultiVisualizer;//from #bmj-showcases-routing-
manets
network Coexistence{
    @statistic[bitErrorRate](title="Bit error rate"; source=bitErrorRate(packetSentToUpper);
record=vector);
    @statistic[packetErrorRate](title="Packet error rate";
source=packetErrorRate(packetSentToUpper); record=vector);
    @display("bgb=50000,50000");
    submodules:
        visualizer: IntegratedCanvasVisualizer
 @display("p=8773.319,391.5568");
        }
        configurator: Ipv4NetworkConfigurator {
            @display("p=7194.856,391.5568"); }
        //radioMedium: Ieee80211ScalarRadioMedium {  //from #bmj-showcases-routing-manets
```

```
   // @display("p=100,100"); // }
//visualizer: IntegratedMultiVisualizer { //from #bmj-showcases-routing-manets
 //   @display("p=100,200"); // }
radioMedium: Ieee80211ScalarRadioMedium {
    @display("p=5959.005,379.32065");
}
physicalEnvironment: PhysicalEnvironment {
    @display("p=4967.877,391.5568") }
wifiHost1: ManetRouter {
    @display("p=10,400"); //bmj done for 50m in b/w zigbee
    //@display("p=0,50;i=device/laptop");   //bmj doing for 40m to both wifi hosts in b/w zigbee
    //@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee  }
wifiHost2: ManetRouter {
    @display("p=1010,400"); //bmj done for 50m in b/w zigbee
    //@display("p=0,50;i=device/laptop");   //bmj doing for 40m to both wifi hosts in b/w zigbee
    //@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee  }
wifiHost3: ManetRouter {
    @display("p=2010,400"); //bmj done for 50m in b/w zigbee
    //@display("p=0,50;i=device/laptop");   //bmj doing for 40m to both wifi hosts in b/w zigbee
    //@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee   }
wifiHost4: ManetRouter {
    @display("p=3010,400"); //bmj done for 50m in b/w zigbee
    //@display("p=0,50;i=device/laptop");   //bmj doing for 40m to both wifi hosts in b/w zigbee
```

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost9: ManetRouter {

@display("p=10,1400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost10: ManetRouter {

@display("p=1010,1400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost11: ManetRouter {

@display("p=2010,1400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost12: ManetRouter {

@display("p=3010,1400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost17: ManetRouter {

@display("p=10,2400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost18: ManetRouter {

@display("p=1010,2400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost19: ManetRouter {

@display("p=2010,2400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost20: ManetRouter {

@display("p=3010,2400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost25: ManetRouter {

@display("p=10,3400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost26: ManetRouter {

@display("p=1010,3400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost27: ManetRouter {

@display("p=2010,3400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost28: ManetRouter {

@display("p=3010,3400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee }

wifiHost5: ManetRouter {

@display("p=4010,1400"); //bmj done for 50m in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 40m to both wifi hosts in b/w zigbee

//@display("p=0,50;i=device/laptop"); //bmj doing for 20m to both wifi hosts in b/w zigbee

}

10.2 INI FILE CODE

[Config Coexistence]

network = Coexistence

sim-time-limit = 100 s # for every 2km 1 wpan

radio medium settings

*.radioMedium.analogModel.typename = "DimensionalAnalogModel"

*.radioMedium.backgroundNoise.typename = "IsotropicDimensionalBackgroundNoise"

```
#*.radioMedium.backgroundNoise.powerSpectralDensity = -113dBmWpMHz
*.radioMedium.pathLoss.typename = "FreeSpacePathLoss"   #bmj added line for tworaygroundreflection pathloss
**.radio.transmitter.power
${power=4,5,9.96,9.97,9.98,9.99,10,10.001,10.0001,10.01,10.02,10.03,10.04,10.05,10.06,10.07,10.09,10.1,10.2,10.3,10.4,11,15,16,17,18,19,19.01,19.02,19.06,19.07,19.08,19.09,19.1,19.2,19.3,19.4,19.5,19.6,19.7,19.8,19.9,20,20.01,20.02,20.03,20.04,20.05,20.06,20.07,20.08,20.09,21,30,33,35,40,45,46,47,48,49,49.99,49.98,50,50.01,50.02,50.03,50.04,51,99.99,99.98,100,100.01,100.4,101,102,103,103.1,104,105,106,107,200,210,220,230,240,250,260,270,280,290,300,350,400,450,500,550,600,650,700,750,800,850,900,950,1000,1100,1200,1300,1400,1500,1600,1700,1800,1900,2000,2500}mW # for every 2km
# routing protocol parameters
..routingApp.typename = "Aodv" #bmj-showcases-routing-manets
..routingApp.activeRouteTimeout = 1s
..routingApp.deletePeriod = 0.5s #bmj-showcases-routing-manets
# radio settings
# 2452MHz/20MHz bw
.wifiHost.wlan[*].radio.typename = "Ieee80211DimensionalRadio"
#.wifiHost.wlan[*].radio.channelNumber = 1
#receivers
.wifiHost1.wlan[*].radio.channelNumber = 1
.wifiHost2.wlan[].radio.channelNumber = 1
.wifiHost3.wlan[].radio.channelNumber = 1
.wifiHost4.wlan[].radio.channelNumber = 1
.wifiHost5.wlan[].radio.channelNumber = 1
.wifiHost9.wlan[].radio.channelNumber = 1
.wifiHost10.wlan[].radio.channelNumber = 1
.wifiHost11.wlan[].radio.channelNumber = 1
.wifiHost12.wlan[].radio.channelNumber = 1
.wifiHost17.wlan[].radio.channelNumber = 1
```

.wifiHost18.wlan[].radio.channelNumber = 1

.wifiHost19.wlan[].radio.channelNumber = 1

.wifiHost20.wlan[].radio.channelNumber = 1

.wifiHost25.wlan[].radio.channelNumber = 1

.wifiHost26.wlan[].radio.channelNumber = 1

.wifiHost27.wlan[].radio.channelNumber = 1

.wifiHost28.wlan[].radio.channelNumber = 1

.wifiHost.wlan[*].radio.transmitter.frequencyGains = "left c-b*1.5 -40dB linear c-b -28dB linear c-b*0.5-1MHz -20dB linear c-b*0.5+1MHz 0dB linear c+b*0.5-1MHz 0dB linear c+b*0.5+1MHz -20dB linear c+b -28dB linear c+b*1.5 -40dB right"

#.Host.wlan[0].radio.antenna.typename = "ConstantGainAntenna"

#.Host.wlan[0].radio.antenna.gain = 20dB

.*Host.wlan[*].radio.receiver.snirThresholdMode = "mean"

.*Host.wlan[*].radio.receiver.errorModel.snirMode = "mean"

#.*Host.wlan[*].radio.transmitter.communicationRange = "500m"

#*.wifiHost21.numApps = 1

#*.wifiHost21.app[0].typename = "PingApp"

#*.wifiHost21.app[0].destAddr = "wifiHost4"

#*.wifiHost21.app[0].printPing = true

wifi hosts app settings using udp basic app

*.wifiHost1.numApps = 1

*.wifiHost1.app[0].typename = "UdpBasicApp"

#*.wifiHost21.routingApp.typename = "AodvRouter" #bmj added line to use AODV-RP 4m Tutorials Wireless Tutorial Step 10. Configuring ad-hoc routing (AODV)

#.wifiHost21..routingApp.activeRouteTimeout = 1s #bmj-showcases-routing-manets

#.wifiHost21..routingApp.deletePeriod = 0.5s #bmj-showcases-routing-manets

*.wifiHost1.app[0].destAddresses = "wifiHost5"

*.wifiHost1.app[0].messageLength = 1000 byte

*.wifiHost1.app[0].packetName = "From 1 to 5"

```
*.wifiHost1.app[0].startTime =0s
*.wifiHost1.app[0].sendInterval = 4 ms
*.wifiHost1.app[0].destPort = 5000
*.wifiHost5.numApps = 1
*.wifiHost5.app[0].typename = "UdpSink"
*.wifiHost5.app[0].localPort = 5000
**.constraintAreaMinX = 0m     #bmj line for mobility
**.constraintAreaMaxX = 50000m  #bmj line for mobility for every 2 km
**.constraintAreaMinY = 0m            #bmj line for mobility
**.constraintAreaMaxY = 50000m    #bmj line for mobility for every 2 km
**.constraintAreaMinZ = 0m            #bmj line for mobility
**.constraintAreaMaxZ = 0m            #bmj line for mobility
.wifiHost.mobility.typename = "LinearMobility"
**.mobility.speed = 0 mps
.wifiHost.mobility.initialMovementHeading = uniform (0deg,0deg)
.wifiHost.mobility.updateInterval = 1s
#*.wifiHost.mobility.initialMovementHeading = 270deg
#*.wifiHost21.mobility.updateInterval = 1s
# visualizer settings
.visualizer..mobilityVisualizer.displayMobility = true # master switch
.visualizer..mobilityVisualizer.displayPositions = true
.visualizer..mobilityVisualizer.displayOrientations = true
.visualizer..mobilityVisualizer.displayVelocities = true
.visualizer..mobilityVisualizer.displayMovementTrails = true
*.visualizer.physicalLinkVisualizer.displayLinks = true
*.visualizer.dataLinkVisualizer.displayLinks = true
*.visualizer.mediumVisualizer.displaySignals =  true
*.visualizer.mediumVisualizer.displayTransmissions =  true
*.visualizer.mediumVisualizer.displayReceptions =  true
```

*.visualizer.mediumVisualizer.displaySpectrums = false

.visualizer.dataLinkVisualizer.packetFilter = "AODV" #Wireless Tutorial Step 10. Configuring ad-hoc routing (AODV)

.visualizer..routingTableVisualizer.destinationFilter = "wifiHost5" #bmj-showcases-routing-manets

#.visualizer..dataLinkVisualizer.packetFilter = "aodv::Rreq" #bmj-showcases-routing-manets

*.visualizer.mediumVisualizer.signalRingSize = 5m

*.visualizer.mediumVisualizer.signalWaveLength = 5m

.visualizer.infoVisualizer.modules = ".wifiHost*.wlan[*].mac.dcf.channelAccess.contention"

*.visualizer.infoVisualizer.format = "%t"

*.visualizer.infoVisualizer.placementHint = "topCenter"

*.visualizer.infoVisualizer.placementPriority = -10

*.visualizer.routingTableVisualizer.displayRoutingTables = false

*.visualizer.packetDropVisualizer.displayPacketDrops = true

*.visualizer.packetDropVisualizer.labelFormat = "%r"

data link visualizer ########## #bmj-showcases-routing-manets

#.visualizer..numDataLinkVisualizers = 5

#.visualizer..dataLinkVisualizer[*].activityLevel = "peer"

#.visualizer..dataLinkVisualizer[*].displayLinks = true

#.visualizer..dataLinkVisualizer[0].packetFilter = "aodv::Rreq"

#.visualizer..dataLinkVisualizer[1].packetFilter = "ping* or UDP*"

#.visualizer..dataLinkVisualizer[1].*Color = "blue"

#.visualizer..dataLinkVisualizer[2].packetFilter = "aodv::Rrep"

#.visualizer..dataLinkVisualizer[2].*Color = "darkslategray"

#.visualizer..dataLinkVisualizer[3].packetFilter = "aodv::Rerr"

#.visualizer..dataLinkVisualizer[3].*Color = "red"

#.visualizer..dataLinkVisualizer[4].packetFilter = "Hello"

#.visualizer..dataLinkVisualizer[4].*Color = "green"

nic settings

```
.*wifiHost.wlan[].opMode = "g(erp)"
#.*host.wlan[].radio.transmitter.power = ${power=1,4,5,9.96,9.97,9.98,9.99,10,10.001,10.0001,10.01,10.02,10.03,10.04,10.05,10.06,10.07,10.09,10.1,10.2,10.3,10.4,11,15,16,17,18,19,19.01,19.02,19.06,19.07,19.08,19.09,19.1,19.2 19.3,19.4,19.5,19.6,19.7,19.8,19.9,20,20.01,20.02,20.03,20.04,20.05,20.06,20.07,20.08,20.09,21,25,26,27,30,33,35,40,45,46,47,48,49,49.99,49.98,50,50.01,50.02,50.03,50.04,51,99.99,60,70,80,90,99.98,100,100.01,100.4,101,102,103,103.1,104,105,106,107,110,120,130,140,150,160,170,180,190,200,250,300,350,400,450,500,550,600,650,700,750,800,850,900,950,1000,1100,1200,1300,1400,1500,1600,1700,1800,1900,2000,2500}W # for every 2km
.*wifiHost.wlan[].mgmt.typename = "Ieee80211MgmtAdhoc"
.*wifiHost.wlan[].agent.typename = ""
.*wifiHost.wlan[].mac.*.rateControl.typename = ${rateControl="", "AarfRateControl"}
.*wifiHost.wlan[].mac.*.rateControl.initialRate = 54Mbps
.*wifiHost.wlan[].mac.dataBitrate = (${rateControl} == "" ? 54Mbps : -1bps)       # use 54Mbps rate when not using rate control, and let ratecontrol set the rate when using
.*wifiHost.wlan[].mac.*.rateSelection.dataFrameBitrate = (${rateControl} == "" ? 54Mbps : -1bps)  # use 54Mbps rate when not using rate control, and let ratecontrol set the rate when using
.*wifiHost.wlan[].mac.dcf.rateControl.increaseThreshold = 20
.*wifiHost.wlan[].mac.dcf.rateControl.decreaseThreshold = 5
.*wifiHost.wlan[].mac.dcf.rateControl.interval = 1s
# arp type
*.wlan[].bitrate = 24 Mbps
*.configurator.addStaticRoutes = false
**.netmaskRoutes = ""
.*Host.ipv4.arp.typename = "GlobalArp"  #####for AODV it is working
```