PERFORMANCE ENHANCEMENT OF IEEE802.11ah BASED IoT NETWORK USING COOPERATIVE NOMA

A PROJECT REPORT

Submitted by

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ABSTRACT

The proliferation of Internet of Things (IoT) devices has led to significant challenges in wireless network performance, particularly in the realms of throughput, energy consumption, and latency. The IEEE 802.11ah standard, also known as Wi-Fi HaLow, is specifically tailored for IoT applications due to its extended range and penetration capabilities. However, the standard's performance in dense IoT environments is often hampered by these challenges. To address this, our project introduces a novel application of Cooperative Non-Orthogonal Multiple Access within IEEE 802.11ah networks, aiming to substantially enhance network efficiency and capacity. This study focuses on implementing COOP-NOMA techniques to improve the throughput and reduce the energy consumption and latency compared to the conventional orthogonal methods typically used in such networks. By allowing multiple IoT devices to transmit data simultaneously over the same frequency bands without requiring orthogonal resource allocation, COOP-NOMA promises to improve spectral efficiency and reduce transmission delays key factors in enhancing IoT network performances. Using MATLAB simulations, we rigorously evaluate and analyze the performance of IEEE 802.11ah networks incorporating Cooperative NOMA. These results are intended to provide a solid foundation for the adoption of Coop-NOMA in future IoT networks, potentially setting a new standard for network design in high-density environments.

Keywords: IEEE 802.11ah, Wi-Fi HaLow, Internet of Things (IoT), Cooperative Non-Orthogonal Multiple Access (COOP-NOMA).

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LIST OF ABBREVIATIONS

SYMBOLS	ABBREVIATIONS
ALOHA	Areal Locations of Hazardous Atmospheres
ACK	Acknowledgement
CDMA	Code Division Multiple Access
CD NOMA	Code Domain NOMA
COOPMAC	Cooperative Medium Access Control Protocol
CSMA	Carrier Sense Multiple-Access
CSMA/CA	Carrier Sense Multiple Access/Collision-Detection
CSMA/CD	Carrier Sense Multiple Access/Collision-Avoidance
CTS	Clear-to-Send
DAMA	Demand Assigned Multiple Access
DCF	Distributed Coordination Function
DIFS	Distributed inter frame spacing
DPC	Dynamic Power Control
FDMA	Frequency Division Multiple Access
GSM	Global System for Mobile Communication
HTS	Helper Ready to Send

IEEE	Institute of Electrical and Electronics Engineers
IOT	Internet of Things
LoRa WAN	Long range wide area network
LTE	Long-Term Evolution
M2M	Machine to Machine
MAC	Medium Access Control
MATLAB	Matrix Laboratory
NOMA	Non-Orthogonal Multiple Access Techniques
NOMA-CA	Non-Orthogonal Multiple Access-Collision Avoidance
OEC-MAC	Novel OFDMA Based Efficient Cooperative MAC Protocol
OFDMA	Orthogonal frequency division Multiple Access
OMA	Orthogonal Multiple Access
OSI	Open System Intercommunication
PD NOMA	Power Domain NOMA
PHY	Physical Layer
QoS	Quality of Service
RAW	Resource Allocation Window
RTS	Request-to-Send

SDMA	Spatial Division Multiple Access
SDR	Software defined ratio
SIC	Successive Interference Cancellation
SIFS	Short Interframe Space
SINR	Signal-to-interference-plus-noise ratio
SMS	Short Message Service
SNR	Signal-to-Noise
SWIPT	Simultaneous Wireless Information and Power Transfer
TDMA	Time Division Multiple Access
TXOP	Turning Based Channel Access scheme
VANET	Vehicular ad hoc networks
WIFI	Wireless Fidelity
WiMAX	Worldwide Inter-operability for Microwave Access
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network

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LIST OF SYMBOLS

SYMBOLS	DEFINITION
τ	Time slot that the station transmits
ρ	Condition collision probability
σ	Random exponential backoff"
S_s	Source station
S_h	Helper station
S_d	Destination station
P_s	Success probability
P_c	Collision probability
P_{tr}	At least one station transmits during particular period
E[B]	Average amount of back-off slots
E_T	The average energy required during packet transmission in the j^{th} RAW slot
E_b	energy required during the back-off procedure

E_f	Energy used when a gadget stalls its back-off timer
E_s	Energy used for gearbox
E_c	Energy used for collision
n_j	Energy Consumption per bit
Δ_{ACK}	Time taken to transmit the data packet
Δ_{DATA}	Time taken to transmit the data acknowledgement
P_{idle}	Idle state probability
P_{Tx}	Transmission probability
P_{Rx}	Receiving probability
δ_s	SIFS duration
δ_d	DIFS duration
N_t	Average number of transmission attempts before a successful transmission
N_o	Average number of transmission overhead

CHAPTER 1

INTRODUCTION

In the current landscape of wireless communication, the burgeoning demands for higher throughput, increased reliability, and greater energy efficiency have driven the development of innovative technologies. Among these, Non-Orthogonal Multiple Access (NOMA) and Cooperative Medium Access Control (Cooperative MAC) stand out as two pivotal advancements aimed at optimizing the performance of congested and spectrum-limited wireless networks. NOMA distinguishes itself by allowing multiple users to share the same frequency bands simultaneously, a significant deviation from the traditional Orthogonal Multiple Access (OMA) methods, which strictly partition network resources among users. This is primarily achieved through superposition coding—a technique where signals at different power levels are transmitted simultaneously, but are decoded sequentially using successive interference cancellation (SIC). This method notably improves spectral efficiency and lowers latency, making NOMA ideal for environments with diverse user requirements and dense user populations. Additionally, it offers a fairer distribution of network resources among users with varying channel conditions, thus balancing quality of service across a broad spectrum of network conditions. On the other hand, Cooperative MAC protocols leverage the cooperative behaviour among devices to enhance network performance. This involves devices assisting each other in transmitting data, particularly beneficial in scenarios where some devices suffer from poor connectivity or high interference. By using relaying techniques, where devices with strong signals relay information for those with weaker signals, Cooperative MAC not only extends network coverage but also enhances the reliability and overall energy efficiency of the communication system. Such protocols take advantage of spatial diversity and collaborative efforts among multiple nodes, which can significantly mitigate the effects of fading and improve the resilience of the network against interruptions. Both NOMA and Cooperative MAC represent robust solutions to the pressing challenges faced by modern wireless networks, characterized by overcrowded spectra and escalating demands for data-intensive applications. By intelligently managing spectrum usage and fostering cooperative interactions among devices, these technologies not only enhance throughput and reliability but also contribute to a more sustainable and efficient use of wireless network resources. Their deployment is crucial for meeting the evolving needs of an increasingly connected world, paving the way for more resilient, efficient, and high- capacity wireless communication. As the world becomes increasingly connected, the deployment of advanced technologies such as NOMA and Cooperative MAC will be crucial in meeting the evolving demands of a wide array of internet-enabled devices and services. From smart city applications and industrial IoT to high-definition video streaming and virtual reality, the efficient and intelligent use of spectrum resources will play a pivotal role in shaping the future of wireless communications.

1.1 NEED OF THE PROJECT

- To Increase Network Capacity: Address the challenge of handling an exponentially growing number of IoT devices by enhancing network capacity through the efficient sharing of spectrum resources using Cooperative NOMA.

- To Improve Throughput: Ensure higher data transfer rates for a large number of connected devices, crucial for efficient operation in IoT applications, by improving the overall throughput of the network.
- To Reduce Latency: Lower transmission delays to enhance the responsiveness of real-time IoT applications, such as health monitoring and industrial automation, through efficient resource allocation techniques inherent in Cooperative NOMA.
- To Enhance Energy Efficiency: Optimize power usage in transmissions to reduce the energy consumption of IoT devices, extending their operational life and conserving battery resources.
- To Address Spectrum Scarcity: Utilize the available spectrum more efficiently than traditional methods, allowing for better management of limited resources amidst increasing device connectivity.
- To Improve Reliability: Increase the reliability of data transmissions in dense network environments by utilizing multiple paths for data transfer, thus reducing signal interference and packet loss.
- To Reduce Network Congestion: Alleviate congestion issues by allowing simultaneous transmissions over the same channel, thus managing data traffic more efficiently among numerous IoT devices.
- To Enable Scalability: Make the network infrastructure more adaptable to scaling with the number of IoT devices without significant modifications, supporting scalable growth through Cooperative NOMA.
- To Facilitate Better Resource Management: Enhance the dynamic allocation of network resources to ensure that all connected devices receive adequate bandwidth and service quality according to their requirements.

- To Enhance Quality of Service (QoS): Prioritize network traffic effectively based on the urgency and importance of the data, improving the QoS for critical IoT applications.

These points articulate the critical needs and benefits of implementing Cooperative NOMA in IEEE 802.11ah based IoT networks, underlining the project's potential to significantly enhance network performance.

1.2 OBJECTIVE OF THE PROJECT

- To Calculate the throughput for Determining how much data can be successfully transmitted from one point to another within a certain time period under Cooperative NOMA. This involves setting up scenarios with varying network loads and measuring the data rates achieved.
- Analyse the Delay by Assessing the time taken for data to travel from the source to the destination across the network. This analysis helps in understanding the latency involved in Cooperative NOMA implementations, which is crucial for time-sensitive IoT applications.
- Quantifying the energy used by devices when Cooperative NOMA is implemented. This is especially important in IoT contexts where devices often rely on battery power. Measuring energy consumption involves monitoring the power usage of network devices during data transmission processes and comparing it with idle states.
- By Conducting side-by-side comparisons of throughput, delay, and energy consumption between Cooperative NOMA and conventional methods. This will involve simulating both environments under identical conditions to obtain accurate comparative data.

- By Utilizing statistical methods to analyse the data collected during the tests to determine the significance of the differences observed. This analysis will help validate whether improvements using Cooperative NOMA are statistically significant.

1.3 INTRODUCTION TO WIRELESS PROTOCOLS

Wireless communication protocols are crucial for the seamless operation of modern technology, enabling devices to transmit and receive signals without physical connections. These protocols determine the speed, reliability, and security of data transmission across various network systems.

The evolution of wireless protocols began with the first generation (1G) of cellular networks in the 1980s, using analog signals for voice calls. This evolved into the digital systems of the second generation (2G) in the 1990s, such as the Global System for Mobile Communications (GSM), which introduced services like SMS and basic data communications. The advent of third-generation (3G) networks brought broadband speeds and internet services, while fourth-generation (4G) technologies, particularly Long-Term Evolution (LTE), dramatically enhanced internet-based communications with high data rates.

Presently, fifth-generation (5G) networks are being deployed globally, supporting higher speeds, ultra-low latency, and massive connectivity, essential for technologies like the Internet of Things (IoT) and autonomous vehicles. 5G utilizes advanced protocols like Non-Orthogonal Multiple Access (NOMA), which increases network efficiency by allowing multiple devices to share the same resources.

Wi-Fi and Bluetooth also play significant roles in everyday wireless communications, with Wi-Fi connecting devices to the internet within limited ranges, and Bluetooth facilitating short-range connections between devices. For IoT applications, protocols like Zigbee and LoRaWAN provide low-power, long-range communication suitable for sensor networks in applications such as smart cities. The future of wireless protocols, including 6G, involves exploring higher frequency bands to meet the growing demand for bandwidth and supporting data rates up to several terabits per second. Research continues into more efficient spectral usage, enhanced security features, and the integration of artificial intelligence to optimize network operations.

In conclusion, as the digital landscape evolves, so too must wireless protocols to meet the complex demands of an increasingly interconnected world. The development of these protocols is pivotal not only in advancing technical capabilities but also in enhancing security and user experience across a myriad of devices and applications.

1.3.1 IEEE 802.11ah

IEEE 802.11ah, commonly known as Wi-Fi HaLow, stands as a pioneering wireless networking standard meticulously designed to cater to the unique demands of the burgeoning Internet of Things (IoT) landscape. As in Figure 1.3.1, Operating within the Sub-1 GHz license-exempt bands, it represents a significant evolution from traditional Wi-Fi standards, offering a myriad of benefits tailored specifically for IoT and Machine-to-Machine (M2M) communication. One of its standout features is its ability to penetrate obstacles with remarkable efficacy and provide extended coverage ranges, surpassing those achievable by conventional Wi-Fi standards. This attribute is particularly advantageous for IoT deployments spanning vast areas or dense urban environments, where obstacles such as walls and buildings might impede wireless communication. Moreover, IEEE 802.11ah boasts support for data rates of up to 347 Mbps, ensuring ample bandwidth to accommodate the diverse array of data generated and transmitted by IoT devices. Its utilization of narrow channels and sophisticated scheduling mechanisms allows for the efficient coexistence of numerous devices within a network, minimizing interference and optimizing spectrum utilization. Furthermore, Wi-Fi HaLow incorporates power-saving functionalities and synchronization protocols, crucial for prolonging the battery life of IoT devices. These features make it an ideal choice for various IoT applications, including smart homes, agricultural monitoring, industrial automation, and environmental sensing. In essence, IEEE 802.11ah emerges as a cornerstone in the advancement of wireless networking technologies, playing a pivotal role in facilitating the seamless integration and proliferation of IoT devices across diverse environments and industries.

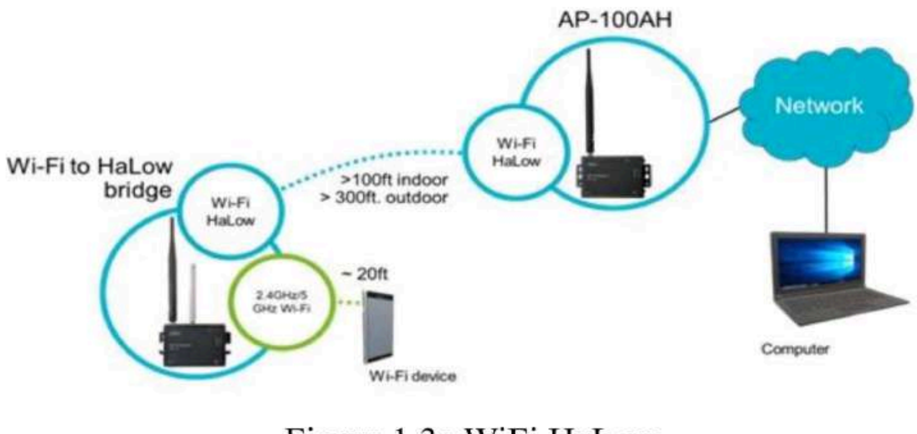

Figure 1.3a WiFi HaLow

1.3.2 MAC

The Medium Access Control (MAC) protocol plays a pivotal role in network communications by regulating how devices access and transmit data over shared media, especially within the data link layer of the OSI model. Its importance is underscored in wireless networks where issues such as interference and dynamic topologies are prevalent. MAC protocols can be broadly classified into fixed assignment, random access, demand assignment, and token passing protocols.

Fixed assignment protocols like Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) structure data transmission by allocating specific time slots or channels to each user, thereby reducing collision and interference risks. Random access protocols, including ALOHA and Carrier Sense Multiple Access (CSMA) methodologies like CSMA/CA (Collision Avoidance) and CSMA/CD (Collision Detection), allow for spontaneous data transmissions, checking channel availability and managing collisions dynamically. Demand Assigned Multiple Access (DAMA) optimizes bandwidth utilization by dynamically allocating resources based on current demand.

In wireless contexts, MAC protocols address additional challenges such as high error rates and the hidden node problem. For instance, Wi-Fi networks utilize CSMA/CA under the 802.11 WLAN standards to manage access and avoid collisions efficiently. Bluetooth technology under the 802.15 standard employs a mix of TDMA and master-slave mechanisms to control communications, while 802.16 WiMAX uses a combination of fixed and dynamic TDMA for efficient broadband wireless access.

With the expansion of IoT and the need for efficient real-time data handling, newer MAC protocols have emerged. Cooperative MAC protocols improve throughput by enabling nodes to share channel state information and make collective transmission decisions. Cognitive Radio MAC protocols enhance spectrum utilization by adapting channel access methods based on real-time environmental sensing. These advancements underscore the ongoing evolution of MAC protocols, integrating more sophisticated features to tackle the complexities of modern network communication environments efficiently and reliably.

1.3.3 COOPMAC

COOPMAC, or Cooperative MAC, is a type of Medium Access Control protocol COOPMAC, or Cooperative MAC, represents an innovative advancement in wireless networking protocols, specifically designed to optimize network performance through cooperation among nodes. This protocol is particularly beneficial in environments where direct communication between nodes is compromised by factors such as distance, interference, or physical obstructions. COOPMAC enhances communication reliability and efficiency by enabling nodes within the network to assist each other in the transmission of data.

One of the cornerstone features of COOPMAC is its reliance on relay-based communication. In this setup, selected nodes within the network function as relays. These relays receive data from a source node and then forward this data to the intended destination. This not only extends the effective range of communication but also helps in overcoming barriers and improving the signal quality through better handling of fading and interference.

COOPMAC also introduces the concept of spatial diversity, where multiple relay nodes provide several potential communication paths from the source to the destination. Each relay experiences different channel conditions, which can be leveraged to enhance the overall transmission reliability and quality. This diversity is particularly useful in wireless environments characterized by variable and unpredictable conditions.

Additionally, the protocol supports increased spectral efficiency. By allowing multiple transmissions over the same channel without requiring orthogonal channel separation, COOPMAC can significantly increase the network's capacity. This is achieved through sophisticated coordination and timing mechanisms that manage the transmission schedules of the nodes to minimize collision and maximize throughput.

Another critical aspect of COOPMAC is its impact on energy consumption. By using relay nodes strategically, the energy required for transmission can be reduced, as signals can be sent over shorter distances or through less congested paths, thereby conserving battery life in mobile or remote nodes.

In summary, COOPMAC is a dynamic MAC protocol that enhances wireless network throughput, extends communication range, improves signal reliability, increases spectral efficiency, and reduces energy consumption through cooperative strategies among network nodes. Its application is particularly suited to challenging wireless environments, making it a valuable tool for modern network communications.

1.4 MULTIPLE ACCESS SCHEME

Multiple access schemes are essential methodologies in telecommunications that enable numerous users to simultaneously share the same communication channels without interfering with one another. These techniques are crucial in environments such as mobile networks, satellite communications, and other wireless communication systems where bandwidth is a scarce and valuable resource. Effective multiple access methods optimize the use of bandwidth, maximizing network capacity and user data throughput. Frequency Division Multiple Access (FDMA) is one of the oldest forms of these schemes, segmenting the available bandwidth into distinct frequency bands assigned to different users, thereby avoiding interference by keeping each channel in separate frequency spaces. Time Division Multiple Access (TDMA) allocates the channel in time slots, allowing users to share the same frequency by transmitting in sequential times, which minimizes interference by ensuring only one user transmits at any moment. Code Division Multiple Access (CDMA) permits all users to use the same frequency space simultaneously but distinguishes them using unique orthogonal codes, enabling the receiver to isolate each user's signal from a composite signal. Orthogonal Frequency-Division Multiple Access (OFDMA) refines FDMA by dividing each channel into smaller frequency slots known as subcarriers that are orthogonally spaced to reduce interference, effectively handling high data rates in technologies like LTE and Wi-Fi. Spatial Division Multiple Access (SDMA) leverages the physical separation between users with directional antennas to direct focused beams towards individual users, thus enhancing frequency reuse and network capacity. Non-Orthogonal Multiple Access (NOMA) allows multiple users to share the same time and frequency resources at different power levels, using advanced interference cancellation techniques to distinguish the signals, which enhances spectral efficiency and is viewed as a promising approach for future 5G networks. Each of these multiple access schemes plays a critical role in the evolution and performance optimization of modern telecommunications infrastructure, tailored to meet varying network conditions and requirements.

1.4.1 OMA

Orthogonal Multiple Access (OMA) represents a fundamental technique in wireless communication, where distinct resources such as frequency, time, or code are allocated to different users to avoid interference during transmissions. This segregation ensures that transmissions are orthogonal, meaning they do not overlap and are perfectly separable when using the same communication medium. One of the earliest and simplest forms of OMA, Frequency Division Multiple Access (FDMA), divides the available bandwidth into distinct frequency bands, with each user assigned a unique band, thus preventing users from interfering with each other as they operate in separate frequency spectrums. Time Division Multiple Access (TDMA) extends this concept to time, allocating the channel to users in different time slots, ensuring that only one user transmits on the channel at any given time. This method eliminates cross-user interference by partitioning transmission times. Another sophisticated variant, Code Division Multiple Access (CDMA), allows all users to transmit simultaneously over the same frequency bandwidth but assigns a unique spreading code to each user. These codes, which are orthogonal to each other, enable the receiver to separate overlapping signals that exist simultaneously in time and frequency. The advantages of OMA include its relative simplicity in implementation compared to non-orthogonal methods, robustness due to reduced interference, and predictability in resource allocation, which simplifies network planning and management. Traditionally employed in many wireless systems, FDMA was typical in early analog cellular systems, TDMA was utilized in 2G GSM networks, and CDMA dominated 3G networks. Despite the advent of more advanced, spectrum-efficient methods like NOMA, OMA remains widely used due to its effectiveness in ensuring reliable, interference-free communication, particularly in scenarios where minimizing system complexity and power consumption is crucial.

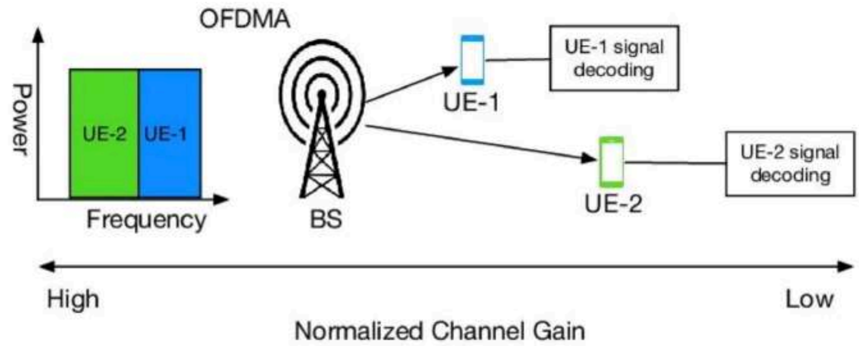

Figure 1.4a Orthogonal Multiple Access (OMA)

1.4.1 NOMA

The fundamental concept of NOMA facilitates in supporting multiple users in the same resource block. In contrast to the traditional multiple access techniques, NOMA performs multiplexing within one of the classic time/frequency domains using a new dimension. In traditional orthogonal multiple access techniques, the total transmission signal power in a particular orthogonal resource slot is allocated to the single user or node as shown in Figure. 1.4 a. Differently, NOMA serves multiple nodes concurrently in a single resource block (either in time or frequency domain) by exploiting the new dimension of power domain as shown in Figure. 1.4 b. To achieve interference-free data transmission, this scheme superimposes data packets from far node (far away from the source node) and near node (near distant from the source node) by allocating different transmission power levels to each node. The near node employs SIC technique to get the required signals from those multiplexed signals. The far node decodes its corresponding data packet by treating the near node data packet as noise signal. Again, due to the fact that it exploits a new dimension, namely the power domain, NOMA can be used as an add-on technique for any of the existing OMA technique, such as TDMA, FDMA, CDMA, OFDMA. Given the mature status of superposition coding and SIC techniques both in theory and practice, NOMA may be amalgamated with the existing multiple access techniques.

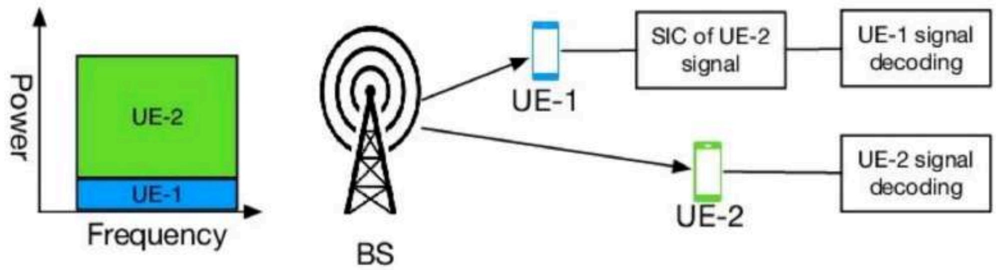

Figure 1.4 b Non-Orthogonal Multiple Access (NOMA)

Classification of NOMA

NOMA is basically classified into two types:

- Power Domain Non-Orthogonal Multiple Access (PDNOMA)
- Code Domain Multiple Access (CDNOMA)

Power Domain Non-Orthogonal Multiple Access

Power-Domain Non-Orthogonal Multiple Access (Power-Domain NOMA) is an advanced communication technique used to enhance the spectral efficiency of wireless networks. It allows multiple users to share the same frequency resources (such as time slots and bandwidth) by superposing their signals at different power levels. This approach significantly differs from traditional orthogonal multiple access (OMA) techniques, where users are separated using different frequency bands, time slots, or spreading codes.

Code-Domain Non-Orthogonal Multiple Access

Code-Domain Non-Orthogonal Multiple Access (Code-Domain NOMA) is a type of NOMA technology that allows multiple users to share the same frequency and time resources by differentiating the users through the use of different codebooks or spreading sequences. Unlike Power-Domain NOMA, which differentiates users based on power levels and uses successive interference cancellation to decode the signals, Code-Domain NOMA uses distinctive code patterns that enable simultaneous multi-user transmission within the same spectral resources.

Uplink NOMA

The generic system model for up-link NOMA, consisting of one base station (BS) and two nodes (U1 and U2) as depicted in Fig. 1.4c. Both nodes can use the same transmit power to send their messages within the orthogonal resource block. The received powers of the two nodes at the node BS differ due to differences in path loss. Accordingly, the SIC decoding is performed at the node BS to retrieve the messages of U1 and U2 from the superimposed signal in the up-link NOMA. In particular, the node BS first decodes the message of node U1 and then subtracts U1's message from the superimposed signal. Then, the node BS can decode the message of U2.

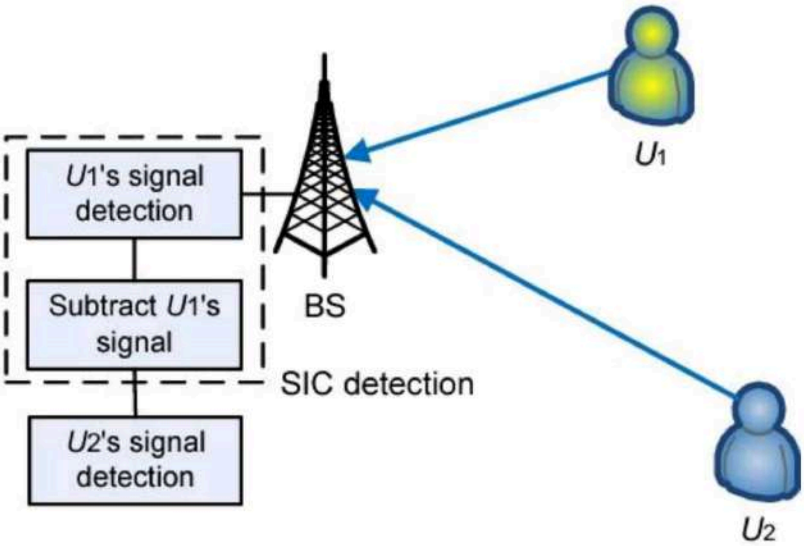

Figure 1.4 c Uplink NOMA

Downlink NOMA

The generic system model for down-link NOMA, consisting of one base station node (BS) and two receiving nodes (U1 and U2), is shown in Fig. 1.4 d The node BS transmits the superimposed signals of both U1 and U2 nodes with different transmit power levels in a particular orthogonal resource block. In down-link NOMA systems, the SIC decoding is implemented at the near node (U1). It means that near node U1 first decodes far node U2's message signal by considering the signal intended for U1 as noise signal. Subsequently, U1 subtracts message signal intended for U2 from the composite signal before decoding its own message signal. On the other hand, node U2 does not require to perform interference cancellation and directly decodes its own message signal by considering the interference from signal intended to node U1 as noise signal.

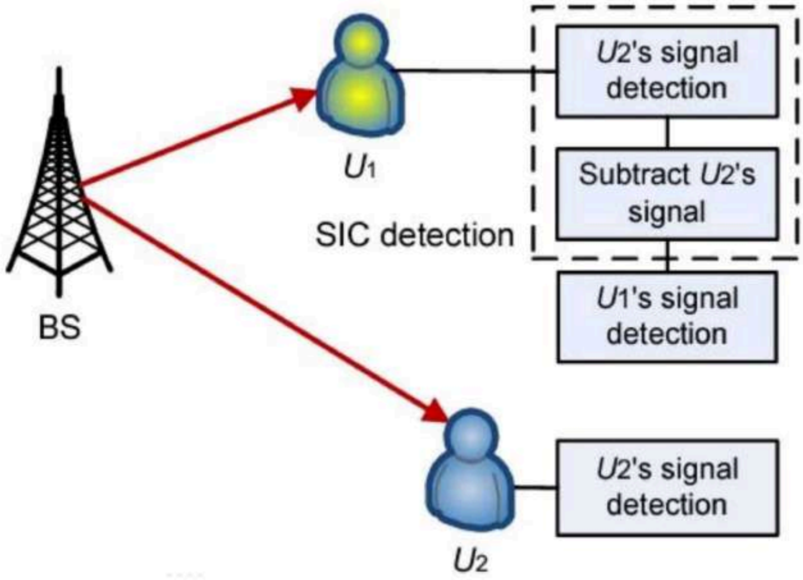

Figure 1.4 d Downlink NOMA

1.5 ORGANISATION OF PROJECT

CHAPTER 1: Includes the introduction and overview of COOPERATIVE and NOMA Also, literature Survey objective of the project and organization of the report are presented.

CHAPTER 2: Reviews relevant literature on IEEE 802.11ah and NOMA technologies.

CHAPTER 3: Provides an in-depth discussion of IEEE 802.11ah, including its operation and applications.

CHAPTER 4: Describes NOMA fundamentals, operations, and specific benefits for IoT networks.

CHAPTER 5: Elaborates on the proposed COOP-NOMA scheme, including its design and expected advantages.

CHAPTER 6: Details the performance analysis methodology and discusses the results.

CHAPTER 7: Provides the Conclusion of the project.

CHAPTER 2

LITERATURE SURVEY

In the following literature survey, the paper [3] [9] [1] [7] are based on NOMA. The research paper [8] [2] [4] [10] are based on Cooperative MAC protocol. The article [5] [6] are based on the concept of wireless LAN.

- BadarlaSri et al.(2023) proposes improve the performance of IEEE 802.11ah multi-rate Non-Orthogonal Multiple Access (NOMA)-Internet of Things networks, the paper uses unique approach called the "TXOP Tuning-based Channel Access Scheme". Essentially, it tackles the difficulty of effectively handling channel access in Iot networks, where numerous devices with different data speeds coexist. This strategy prioritises the transmission of high-rate NOMA users by optimising the Transmission Opportunity (TXOP) duration based on dynamic adjustments, which enhances network performance as a whole. Through careful adjustment of the TXOP duration based on user demands and channel conditions, the suggested system seeks to improve user fairness, increase throughput, and decrease latency.
- S.Zhou et al.(2018) addresses NOMA/CA, which refers to "NOMA-based Random Access with Pattern Detection and Collision Avoidance." It's a technique used in wireless communication systems to enhance random access protocols by employing Non-Orthogonal Multiple Access (NOMA) along with pattern detection and collision avoidance mechanisms. NOMA allows multiple users to share the same resources by allocating them different power levels or codes, improving spectral efficiency. The addition of pattern detection and

collision avoidance helps to further optimize the system's performance by reducing collisions and improving overall throughput.

- Aritz et al.(2022) says that the wireless-NOMA (Non-Orthogonal Multiple Access) is gaining traction in Industry 4.0 for its ability to enhance spectral efficiency and accommodate massive connectivity. It enables multiple users to share the same frequency resources simultaneously, which is crucial for IoT devices in industrial settings. With NOMA, different devices can transmit data at the same time and frequency, improving overall network capacity and efficiency. This is particularly beneficial in environments where a large number of devices need to communicate concurrently, such as in smart factories or industrial automation systems. Implementing High Efficiency Wireless-NOMA solutions in Industry 4.0 can lead to improved communication reliability, reduced latency, and increased productivity.
- Mahesh et al.(2022) proposes NOMA-based Resource Allocation Window (RAW) mechanisms to enhance performance in dense IEEE 802.11ah IoT networks. Traditional access methods can lead to congestion in such scenarios. NOMA-based RAW allows multiple devices to transmit simultaneously within the same window, leveraging the power domain for multiplexing. This improves spectrum utilization, throughput, and reduces latency, meeting the needs of dense IoT deployments. By dynamically adjusting resource allocation based on channel conditions and traffic, NOMA-based RAW adapts to network changes, further boosting performance in IEEE 802.11ah networks.
- Muhammet et al. (2020) introduces OEC-MAC, a novel protocol for enhancing communication efficiency in Vehicular Ad-Hoc Networks (VANETs). OEC-MAC utilizes Orthogonal Frequency Division Multiple Access (OFDMA) to optimize spectrum utilization, enabling

simultaneous data transmission from multiple vehicles. It fosters cooperative communication among vehicles, extending communication range and improving reliability. OEC-MAC incorporates efficient Medium Access Control (MAC) mechanisms tailored to VANET characteristics, minimizing contention and collisions. The protocol dynamically adjusts transmission parameters based on real-time network conditions, enhancing performance and scalability. OEC-MAC offers a promising solution for addressing VANET communication challenges, with applications in safety, traffic management, and infotainment services.

- Ahsan et al.(2021) introduces Cooperative NOMA, which combines NOMA with cooperative transmission techniques to enhance network performance. It advocates for prototyping and experimental evaluation using Software Defined Radio (SDR) platforms to assess feasibility and effectiveness. Implementing Cooperative NOMA algorithms on SDR hardware enables real-world experiments, validating theoretical findings and optimizing system parameters. This approach supports rapid prototyping and iterative refinement of Cooperative NOMA techniques, facilitating deployment in Industry 4.0 ecosystems.
- Jiazhen et al.(2021) likely explores optimizing user pairing strategies in cooperative NOMA networks. Cooperative NOMA enhances network performance by allowing users to collaborate and decode each other's signals. The study investigates different pairing schemes to maximize throughput, minimize interference, and improve efficiency. Analyzing the impact of pairing strategies on metrics like throughput and latency, it aims to design efficient cooperative NOMA systems for diverse deployment scenarios and user needs.
- Zhiqiang et al.(2017) explores a novel cooperative non-orthogonal multiple access (NOMA) scheme that operates in both the downlink

and uplink directions, termed as a Hybrid Downlink-Uplink Cooperative NOMA Scheme. In this scheme, users collaboratively assist each other in transmitting and receiving signals, enhancing spectral efficiency and reliability. Through cooperative NOMA, users with stronger channel conditions help weaker users in decoding their signals, exploiting power domain multiplexing. This approach optimizes resource utilization and mitigates interference, contributing to improved system performance in wireless communication networks.

- Kyung-scop et al.(2017) focuses on optimizing scheduling and power allocation in WLAN systems using Non-Orthogonal Multiple Access (NOMA) and directional beam-based communication. NOMA enables multiple users to share the same frequency resource simultaneously by exploiting the power domain for user separation. Directional beams in WLAN systems enhance spectral efficiency by concentrating energy toward intended receivers. The paper likely proposes algorithms or methodologies to jointly optimize scheduling and power allocation to maximize system performance, considering the directional characteristics of communication beams. By integrating NOMA and directional beamforming, the goal is to enhance WLAN capacity and efficiency, meeting the growing demands for high data rates and reliable connectivity in wireless networks.
- Khorov et al.(2018) optimizes downlink transmission in Wi-Fi networks using NOMA, improving spectral efficiency by allowing multiple users to share the same frequency. It develops scheduling algorithms for NOMA-enabled Wi-Fi, maximizing throughput and fairness while tackling challenges like intra-cell interference and power allocation. By proposing efficient scheduling mechanisms, it advances NOMA implementation in Wi-Fi, potentially enhancing network capacity and user experience.

CHAPTER 3

PROPOSED SCHEME

3.1 SYSTEM MODEL

The CoopMAC protocol relies on the Distributed Coordination Function (DCF) of IEEE 802.11ah. The assumption is that all stations' transmission powers are fixed. RTS and CTS packets can be overheard by stations other than the transmitter and intended recipient in figure.3.1a. Transmitting stations select the optimal modulation technique based on the received signal-to-noise ratio. Uplink and downlink traffic use the same frequency, resulting in symmetric channels. The CoopMAC protocol allows nodes to choose between director relayed transmission and data rate based on real-time network measurements. When a source node S transmits a data packet, it sends an RTS (Ready-To-Send) frame to the destination node D. When D gets an RTS frame, it determines the transmission technique (direct or relayed) based on the SNR (Signal to Interference and Noise Ratio) value. D compares the SNR value to a predetermined threshold, denoted as SNRcoop. If the SNR value exceeds SNRcoop, direct transmission is used; else, rely upon transmission is employed.

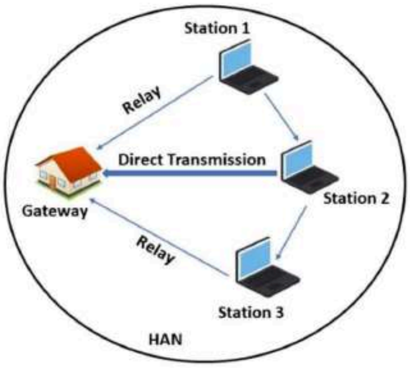

Figure 3.1 a Cooperative Transmission

Source station (S_s):

Every time a packet is buffered in the queue, S_s ought to look through the CooperTable for a potential helper. If a helper entry has been successfully discovered, Ss sends a CoopRTS message with the helper ID in the Address 1 field to indicate the helper that has been selected. Additionally, the predicted data rates between S_s and respectively, should be indicated by R_{sh} and R_{hd} in the relevant fields of CoopRTS. In the event that a CTS is lost before the helper's send HTS (Helper Ready to Send), neither an HTS from nor a CTS from S_d is heard, S_s should randomly backoff as through it had collided. In the event that S_s hears a CTS from S_d but does not get any HTS messages from S_h, it should respond to destination S_d and transmit the data using a direction transmission. When a SIFS time has passed and the HTS message is still not received, S_s should increase the number of failures in order to update the CoopTable. When the number of Number of failures exceeds the predetermined threshold of 3, S_s should remove the entry from CoopTable.upon receiving the RTS and CTS messages, S_s sets the ACK timeout and transfers the data to S_h at the rate of R_{sh}. After an acknowledgment (ACK) timeout, S_s

shall randomly backoff, in accordance with the legacy 802.11ah protocol, if ACK is not received. If not, after a successful completion S_s, should move on to the next packet in the queue.

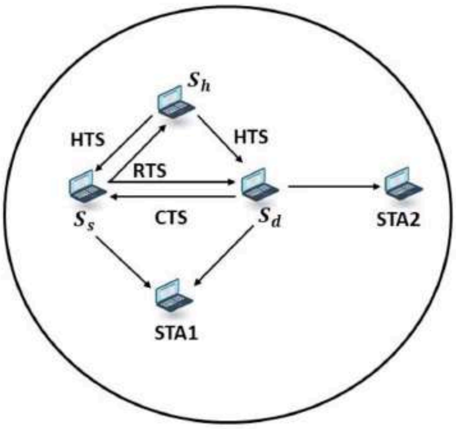

Figure 3.1 b Exchange of Control Frame In COOPMAC

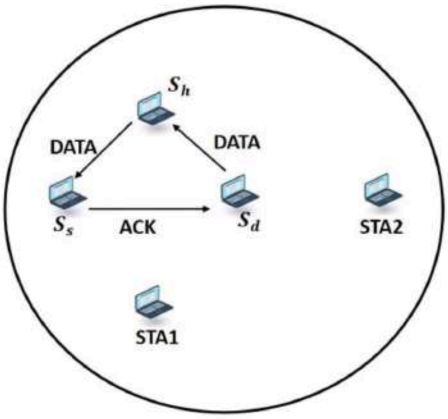

Figure 3.1 c Exchange of Data Frame In COOPMAC

Helper station (S_h):

In the event that S_h gets a CoopRTS message with its MAC address included in the Address 1 field, S_h should confirm the sustainability of the suggested rates R_{hd} and R_{sh} between S_d and S_s in the CoopRTS message. If so, after a SIFS interval, it returns an HTS message to S_s as shown in figure.3.1c. S_h should run a timer with a value of T_{SIFS}+T_{CTS} after sending the HTS to S_s and wait for a CTS from S_d. Should S_h receive a CTS of that kind, it ought to bide its time until the data packet from S_s arrives SIFS time following the CTS message.S_h should presume that the data communication was stopped and return to the starting state if the data packet or the CTS message is not received by it as predicted as in figure.3.1b. Following the completion of the reception, S_h should transfer the data packet to S_d at the rate R_{hd}, as soon as it arrives. When S_h is unable to sustain rates R_{hd} and S_h, S_h just returns to the original condition.

Destination station S_d:

When S_d receive a CoopRTS, it set the RA field to S_d's MAC address, S_d ought to await S_d's equivalent HTS message. After a SIFS interval, suppose S_h sends S_d an HTS message, it sends back CTS message to S_s. Then data timer is started, and it measures the anticipated time a data packet will arrive. If the data frame does not arrive before this timeout expires, it considers that the data transmission was halted and goes back to the starting state. S_d uses the conventional 802.11ah method and transmits the CTS message subsequent to another SIFS period if it does not get the HTS message after that time.

CoopMAC -data transmisson:

It should be possible for each CoopMAC station to distinguish between a packet intended for oneself and one that will be sent to a different station. This will be possible for each station in an RTS/CTS secured data stream. Nevertheless, CoopMAC permits a data frame to be sent by the nodes straight to a possible helper node in 802.11 MAC's base mode operation, bypassing the RTS/CTS process. Consequently, we require a distinct CoopMAC data frame.

3.2 Saturated Throughput Analysis

Assume that there are an equal number of mobile stations in the coverage zone and that the highest transmit ranges for 11 Mbps, 5.5 Mbps, 2 Mbps, and 1 Mbps are, respectively, R_{11}, $R_{5.5}$, R_2, and R_1 meters. If the helper is situated within Rx meters of the source station and Ry meters of the destination station, it can aid the communication in a two-hop manner utilizing rates of x and y Mbps. Given that the distance between the centers of the two circles is L and their respective radii are R_1 and R_2, the region of overlap between the 2 circles is,

$$T_{11} = T_{OH} + \frac{L}{R_{11}} \quad (1)$$

$$T_{5.5} = T_{OH} + \frac{L}{R_{5.5}} \quad (2)$$

$$T_2 = T_{OH} + \frac{L}{R_2} \quad (3)$$

Where, T_{OH} is the transmission overhead time.

$$T_{OH} = T_{DIFS} + T_{RTS} + T_{CTS} + 3T_{SIFS} + T_{ACK} \quad (4)$$

Where, DIFS stands for distributed inter-frame space, which is the time interval that wireless stations wait before sending after sensing that the channel is clear. SIFS - Short Interframe Space is a small delay in time between receiving a frame and transmitting an acknowledgment frame in IEEE 802.11 networks.

$$T_1 = T_{COOPOH} + \frac{2}{R_{5.5}} \tag{5}$$

Where,

$$T_{COOPOH} = T_{DIFS} + T_{RTS} + 2T_{CTS} + 5T_{SIFS} + T_{ACK} \tag{6}$$

The coopMAC overhead transmission is called by the sum of durations of DIFS, RTS, CTS, SIFS, ACK.

$$\tau = \frac{2(1-2P_c)(1-P_c)^{m+1}}{W_0(1-2P_c)(1-P_c)+(1-2P_c)(1-P_c)^{l+1}+2^m W_0(P_c)^{m+1}(1-(P_c)^{l-m}} \tag{7}$$

Where the randomly selected slot time that the station transmits is represented by probability τ. The conditional collision probability ρ determines τ.

$$P_c = 1 - (1-\tau)^{n-1} \tag{8}$$

The success probability is given by,

$$P_s = \frac{n * \tau(1-\tau)^{(n-1)}}{P_{tr}} \tag{9}$$

Where,

$$P_{tr} = 1 - (1 - \tau)n \tag{10}$$

Where, Ptr is when at least one station transmits during a particular period, the channel is more likely to be busy. Finally, the overall throughput of the conventional IEEE 802.11ah WLAN is provided by,

$$S_s = \frac{P_{tr} P_s E[P]}{E[slot]} \tag{11}$$

3.3 ENERGY CONSUMPTION ANALYSIS

Energy consumption is an average quantity of energy required for effective packet delivery. The DCF mechanism allows devices to be in three states: back-off, freezing, or transmission. Every device uses energy through four components. E_b is the energy used throughout the back-off process; E_f is the energy consumed when a device freezes its back-off counter; and E_s and E_c are the energies consumed during a successful gearbox and collision. The average energy spent throughout the back-off procedure can be calculated as,

$$E_b = E[B]\sigma P_{idle} \tag{12}$$

E[B] is the average number of back-off slots, which is provided by,

$$E[B] = \sum_{i=0}^{R} P_{b,j}^{i} (1 - P_{b,j}) \sum_{j=0}^{i} \frac{W_{j-1}}{2} \tag{13}$$

The energy spent by the device due to overhearing various nodes during the back-off procedure is marked as,

$$E_f = N_0[P_{s,j}\varepsilon' + (1 - P_{s,j})(\varepsilon - \Delta_{ACK})]P_{idle} \tag{14}$$

The average energy consumed for successful gearbox and collision is as follows:

$$E_s = P_{Tx}\Delta_{DATA} + P_{Rx}\Delta_{ACK} + P_{idle}(\delta_s + \delta_d) \tag{15}$$

$$E_c = N_t[P_{Tx}\Delta_{DATA} + P_{idle}(\delta_s + \delta_d)] \tag{16}$$

The average energy required during packet transmission in the j^{th} RAW slot can be computed as follows:

$$E_T = E_b + E_f + E_s + E_c \tag{17}$$

Finally, the energy consumption per bit is given by,

$$n_j = \frac{E_T}{E[Payload]} \tag{18}$$

3.4 DELAY ANALYSIS

The amount of time it takes for a signal to travel from source to receiver across the physical medium. This relies on the distance between the source and destination and the speed with which the signal propagates across the medium of communication. The delay equation is given by,

$$\text{Delay} = \frac{T_{received\ packet\ at\ destination} - T_{packet\ sent\ from\ source}}{Packet\ Received} \qquad (19\ )$$

The delay experienced by packets in the network is calculated as the Difference between when the packet is received at the destination (Treceived packet at destination) and the time it was transmitted from the source (Tpacket sent from source). This difference represents the time it takes for a packet to travel across the network from its source to its destination.

CHAPTER 4

RESULTS AND DISCUSSIONS

Throughput Analysis:

The result indicates the successful implementation of performance enhancement of IEEE802.11ah-based IoT networks using cooperative NOMA protocol. The above Table 4.1 shows the parameters used for comparing the number of users and aggregate throughput as shown in the Figure 4.1. It compares the saturation throughput of different WLAN configuration

Parameters used in the calculation of saturated throughput are,

Table 4.1 Simulation Parameter for throughput analysis

Packet Payload	8184 bits
MAC Header	272 bits
PHY Header	128 bits
ACK	240 bits
RTS	288 bits
CTS	240 bits
Channel Bit Rate	1 Mbit/s
Propagation Delay	1 μs
Slot Time	50 μs
SIFS	28 μs
DIFS	128 μs
ACK_Timeout	300 μs
CTS_Timeout	300 μs

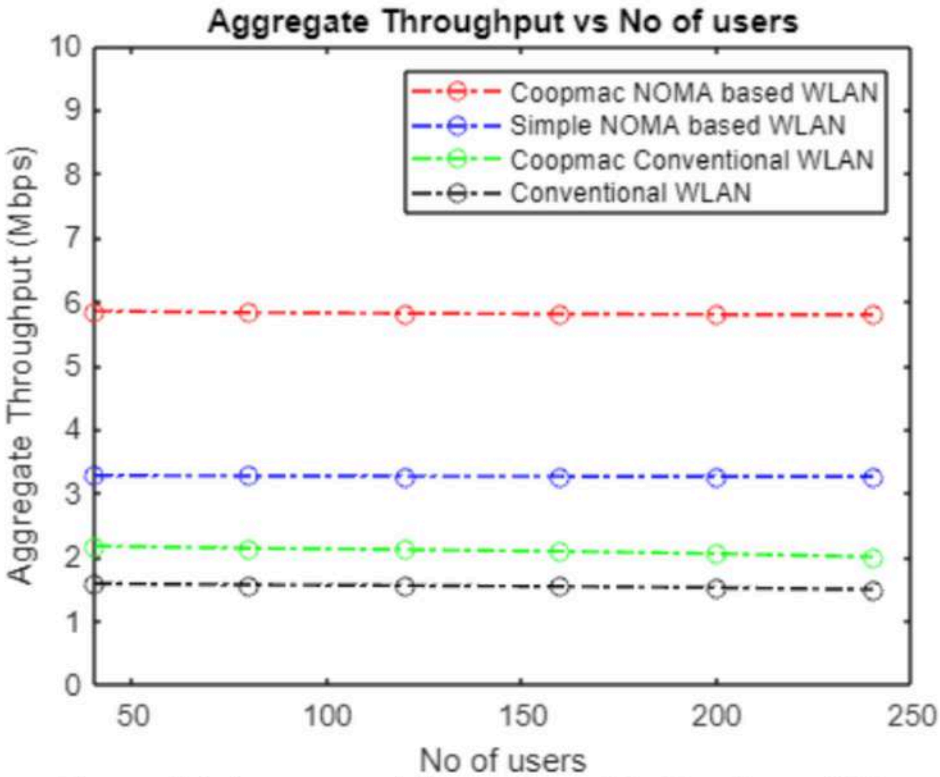

Figure 4.1 Aggregate Throughput Vs Number of Users

- The **X-axis** represents the range of users in the WLAN network.
- The **Y-axis** represents Average network throughput is the number of data packets that destination nodes in a network receive successfully per second.

- **CoopMAC NOMA (Blue Line with Circles):**

  This line represents the energy consumption per bit for a Cooperative MAC NOMA WLAN. Cooperative MAC NOMA integrates cooperative MAC protocols with NOMA techniques to improve network efficiency. As the number of users in the network increases, the energy consumption per bit decreases gradually. Cooperative MAC NOMA generally exhibits lower energy consumption per bit compared to other WLAN technologies, especially under higher user loads. This is due to its ability to efficiently allocate resources and mitigate interference using NOMA techniques and cooperative MAC protocols.

- **NOMA-based WLAN (Green Line with Stars):**

  This line represents the energy consumption per bit for a WLAN using NOMA without cooperative MAC. NOMA-based WLANs allocate resources non-orthogonally among users, allowing simultaneous transmissions. Similar to Cooperative MAC NOMA, the energy consumption per bit decreases as the number of users increases. However, NOMA-based WLANs may have slightly higher energy consumption per bit compared to Cooperative MAC NOMA, especially under higher user loads, as they lack the cooperative MAC mechanisms to optimize resource allocation and mitigate interference.

- **CoopMAC Conventional (Cyan Line with Triangles):**

  This line represents the energy consumption per bit for a Cooperative MAC conventional WLAN. Cooperative MAC Conventional utilizes cooperative MAC protocols but relies on conventional transmission techniques, likely including OFDMA or TDMA. The energy consumption per bit follows a similar decreasing trend with increasing users, albeit at a slightly higher rate compared to Cooperative MAC NOMA and NOMA-based WLANs. Cooperative MAC Conventional may exhibit higher energy consumption per bit compared to Cooperative MAC NOMA due to the absence of advanced resource allocation techniques like NOMA.

- **Conventional WLAN (Red Line with Squares):**

  This line represents the energy consumption per bit for a conventional WLAN without cooperative MAC or NOMA. Conventional WLANs typically use traditional MAC protocols like CSMA/CA. Similar to the other WLAN technologies, the energy consumption per bit decreases as the number of users increases. However, Conventional WLANs may have the highest energy consumption per bit among the compared scenarios, especially under higher user loads, due to the lack of cooperative MAC and NOMA techniques to optimize resource utilization and mitigate interference

Delay Analysis:

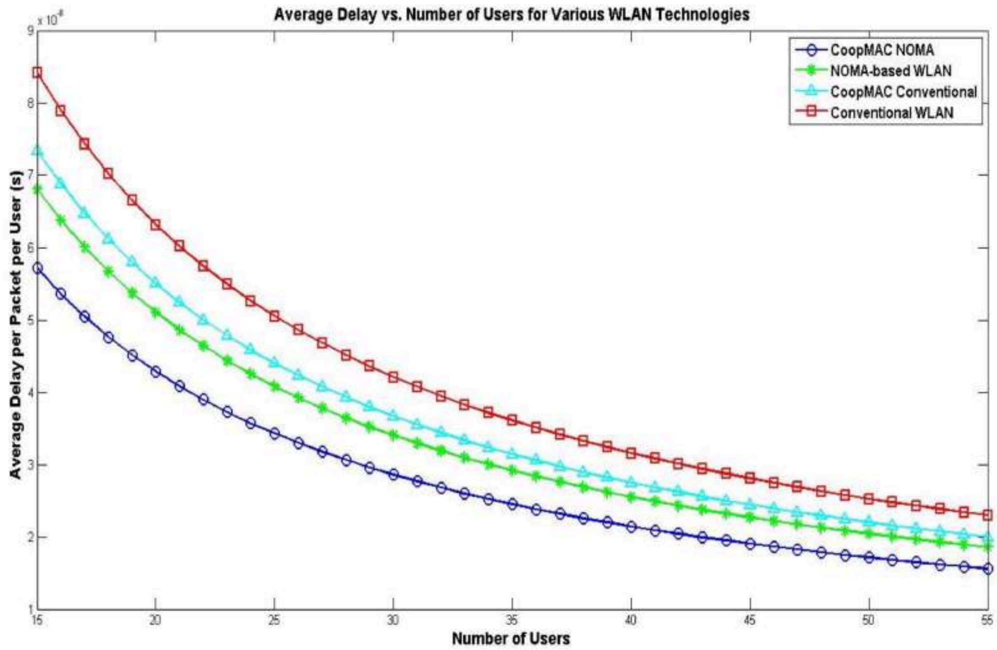

Figure 4.2 Average Delay Per User Vs Number of Users

Figure 4.2 indicates the successful implementation of performance enhancement of IEEE802.11ah-based IoT networks using cooperative NOMA protocol. It compares the average delay per packet per user of different WLAN configuration

- The **X-axis** represents the range of users in the WLAN network.
- The **Y-axis** represents the average delay experienced by each packet per user in seconds. It indicates the time it takes for a packet to be received after being sent.

- **CoopMAC NOMA (Blue Line with Circles):**

  This line represents the average delay per packet per user for a Cooperative MAC NOMA WLAN. Cooperative MAC NOMA integrates cooperative MAC protocols with NOMA techniques. As the number of users increases, the delay per packet per user generally increases. This increase in delay is likely due to increased contention and competition for channel access among users. However, the delay per packet per user for Cooperative MAC NOMA is expected to be lower compared to conventional WLANs, especially under moderate to high user loads, owing to the enhanced resource allocation strategies enabled by NOMA.

- **NOMA-based WLAN (Green Line with Stars):**

  This line represents the average delay per packet per user for a WLAN using NOMA without cooperative MAC. NOMA-based WLANs allocate resources non-orthogonally among users, allowing simultaneous transmissions. Similar to Cooperative MAC NOMA, the delay per packet per user generally increases with the number of users due to increased contention. However, NOMA-based WLANs may exhibit slightly higher delays compared to Cooperative MAC NOMA, especially under high user loads, as they lack the cooperative MAC mechanisms to coordinate transmissions among users.

- **CoopMAC Conventional (Cyan Line with Triangles):**

  This line represents the average delay per packet per user for a Cooperative MAC conventional WLAN. Cooperative MAC Conventional utilizes cooperative MAC protocols but relies on conventional transmission techniques, likely including OFDMA or TDMA. The delay per packet per user follows a similar trend to Cooperative MAC NOMA and NOMA-based WLANs, increasing with the number of users. However, Cooperative MAC Conventional may exhibit slightly higher delays compared to Cooperative MAC NOMA due to the absence of advanced resource allocation techniques like NOMA.

- **Conventional WLAN (Red Line with Squares):**

  This line represents the average delay per packet per user for a conventional WLAN without cooperative MAC or NOMA. Conventional WLANs typically use traditional MAC protocols like CSMA/CA. The delay per packet per user also increases with the number of users, reflecting the increased contention and collisions in the network. Conventional WLANs may have the highest delays among the compared scenarios, especially under high user loads, due to the lack of cooperative MAC and NOMA techniques to mitigate contention and improve resource utilization. In summary, Cooperative MAC NOMA and NOMA-based WLANs generally exhibit lower delays per packet per user compared to Cooperative MAC Conventional and Conventional WLANs, especially under moderate to high user loads. However, Cooperative MAC NOMA tends to outperform NOMA-based WLANs due to the added benefit of cooperative MAC protocols.

Energy Analysis

Table 4.1 Parameter for Energy consumption analysis

E_Payload	512 bits
P_{Tx}	$255mW$
P_{Rx}	135mW
P_{idle}	1.3mW
N (no. of iteration)	1000
δ_s	$160\mu s$
δ_d	$264\mu s$

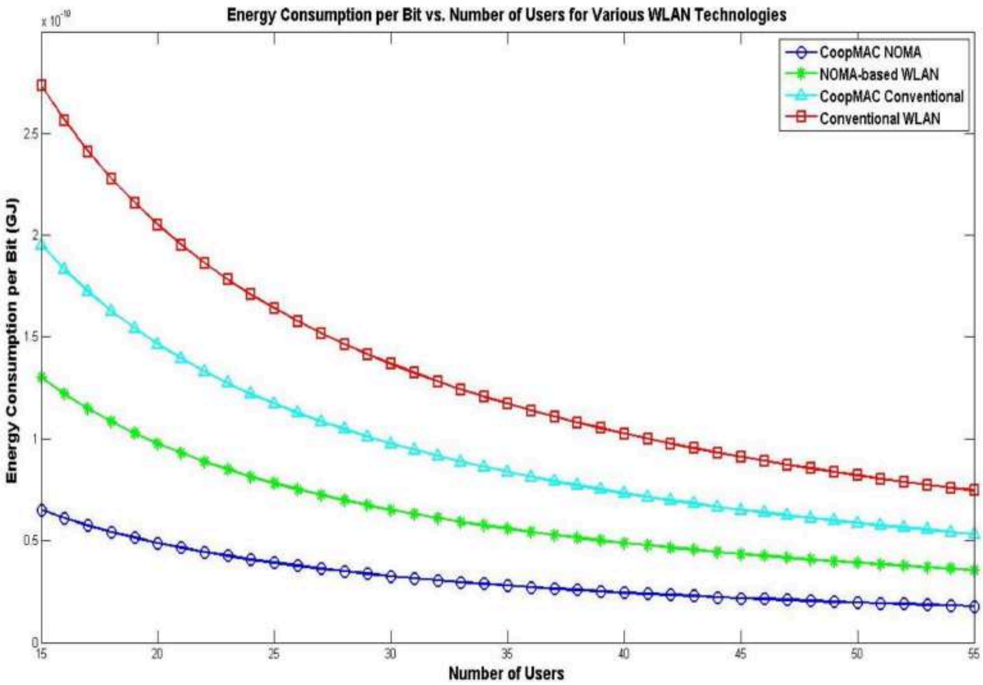

Figure 4.3 Energy Consumption Per Bit Vs Number of Users

- The X-axis represents the range of users in the WLAN network.
- The Y-axis represents the energy consumed per bit of data transmitted in gigajoules (GJ). It indicates the amount of energy required to transmit each bit of data

- **CoopMAC NOMA (Blue Line with Circles):**

  The CoopMAC NOMA line represents the energy consumption per bit for a Cooperative MAC NOMA WLAN. Cooperative MAC NOMA integrates cooperative MAC protocols with NOMA techniques to improve network efficiency. As the number of users in the network increases, the energy consumption per bit decreases gradually. Cooperative MAC NOMA generally exhibits lower energy consumption per bit compared to other WLAN technologies, especially under higher user loads. This is due to its ability to efficiently allocate resources and mitigate interference using NOMA techniques and cooperative MAC protocols.

- **NOMA-based WLAN (Green Line with Stars):**

  NOMA-based WLAN line represents the energy consumption per bit for a WLAN using NOMA without cooperative MAC. NOMA-based WLANs allocate resources non-orthogonally among users, allowing simultaneous transmissions. Similar to Cooperative MAC NOMA, the energy consumption per bit decreases as the number of users increases. However, NOMA-based WLANs may have slightly higher energy consumption per bit compared to Cooperative MAC NOMA, especially under higher user loads, as they lack the cooperative MAC mechanisms to optimize resource allocation and mitigate interference.

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  However, Conventional WLANs may have the highest energy consumption per bit among the compared scenarios, especially under higher user loads, due to the lack of cooperative MAC and NOMA techniques to optimize resource utilization and mitigate interference.

CHAPTER 5

CONCLUSION

5.1 SUMMARY OF THE THESIS

The integration of Cooperative Non-Orthogonal Multiple Access (NOMA) with IEEE 802.11ah protocols in IoT networks represents a forward-looking strategy that significantly enhances network performance. By adopting Cooperative NOMA, these networks benefit from increased spectral efficiency, which allows for more simultaneous transmissions within the same bandwidth. This is particularly advantageous in IoT environments characterized by a high density of devices. Furthermore, Cooperative NOMA helps in extending network coverage and reducing transmission latency, key factors that improve the reliability and responsiveness of IoT systems. This method also facilitates better device coexistence and communication efficiency, essential for the scalability of IoT operations. However, while the potential of Cooperative NOMA to transform IoT connectivity is immense, it introduces greater complexity in terms of interference management and device coordination. As such, the future of IoT networks using this technology hinges on effectively addressing these technical challenges and achieving a standardization that can accommodate the unique demands of diverse IoT applications. Addressing these issues is crucial for maximizing the transformative potential of Cooperative NOMA and ensuring it can meet the evolving needs of sophisticated IoT networks.

5.2 FUTURE WORK

The exponential increase in network users poses significant challenges for the future development of Wireless Sensor Networks (WSNs), demanding solutions to support massive connectivity and improve energy and spectral efficiency. This thesis has made strides in addressing these challenges by leveraging NOMA (Non-Orthogonal Multiple Access) based cooperative communications and optimizing power and frequency allocations. However, numerous research avenues remain unexplored. Future directions stemming from this work include exploring Cooperative Simultaneous Wireless Information and Power Transfer (SWIPT) within NOMA for WSNs, enabling energy harvesting and information processing simultaneously. These future research directions hold potential for advancing the performance of IEEE 802.11ah-based IoT networks using Cooperative NOMA, addressing the escalating demands of wireless sensor networks while ensuring efficient utilization of resources. The possible directions for further research include

- **Dynamic Power Control in Cooperative NOMA**

  In Cooperative NOMA, multiple devices share the same frequency resources by superposing their signals at different power levels. Dynamic Power Control (DPC) can be implemented to optimize power allocation among the devices dynamically based on real-time channel conditions and traffic demands. This approach can help in reducing interference and boosting the signal-to-interference-plus-noise ratio (SINR) for all users, particularly those at the cell edge, thus enhancing overall network performance.

- **AI-Driven User Clustering and Resource Allocation**

Leveraging artificial intelligence (AI), particularly machine learning algorithms, can revolutionize how resources are allocated in an IEEE 802.11ah network using Cooperative NOMA. By implementing AI-driven clustering algorithms, the network can dynamically group devices based on their channel conditions, QoS requirements, and data traffic patterns. Subsequently, resource blocks (power and bandwidth) can be allocated to these clusters more efficiently, taking into account the collective characteristics of each group.

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has presented at **4th International Conference on Artificial Intelligence, 5G Communications and Network Technologies (ICA5NT 2024)** organized by the **Department of Electronics and Communication Engineering & Department of Information Technology**, Velammal Institute of Technology, Chennai held on **21 & 22, March 2024.**

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