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In-band Full-duplex MAC Protocol for Ad Hoc Networks

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ABSTRACT

Ad hoc networks are becoming more popular as wireless communication technologies improve a new method called in-band full-duplex (IBFD) wireless communication can potentially double the network's data transfer speed (throughput). While many protocols for managing network communication called Medium Access Control or MAC protocols have been developed for standard Wi-Fi networks using IBFD, very few exist specifically for ad hoc networks. This project introduces a new MAC protocol called ad hoc-FDMAC, designed for ad hoc networks using IBFD. It builds on and modifies existing Wi-Fi communication rules based on the IEEE 802.11 standard. The protocol ensures efficient data transfer and routing between devices in an ad hoc network. Throughput improvement that ad hoc - FDMAC achieves higher data transfer speeds than traditional MAC protocols, with 51 Mbps for 5 devices and 41 Mbps for 50 devices. Faster routing is it reduces the time needed for routing data compared to traditional AODV routing protocols. Efficiency over distances that data takes 33.33% less time to travel three hops in the network compared to AODV routing.

1-INTRODUCTION

This project investigates how Wireless ad hoc networks rely on efficient Medium Access Control (MAC) protocols for Ad hoc network to manage communication between devices without centralized coordination. Traditional MAC protocols operate in half- duplex mode, meaning a node can either transmit or receive at a given time, leading to underutilization of network resources and increased latency. In-band full-duplex (IBFD) communication presents a revolutionary approach by allowing simultaneous transmission and reception on the same frequency channel, effectively doubling the network capacity. However, implementing IBFD in ad hoc networks introduces several challenges, such as self-interference cancellation, fairness, and collision avoidance. This project explores an In-Band Full-Duplex MAC Protocol for Ad hoc networks specifically designed for ad hoc networks, addressing key design considerations, performance improvements, and potential trade-offs.

MAC protocol is important for a successful packet delivery in a network. The current trends in the approaches to the design of MAC protocols for WCNs are based on half- duplex communications. These protocols are based on Orthogonal access schemes such as Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA) and Space Division Multiple Access (SDMA) and involve the division of resources (time, frequency, code and space) into sub-resources to enable collision-free channel access for the network nodes. Contention-free schemes have good potential for WCNs, because of the likelihood of low collision.

2-LITERATURE SURVEY

A literature survey for an IBFD MAC protocol for Ad hoc networks involves reviewing existing studies, technologies, and methodologies related to in-band full-duplex communication and its implementation in medium access control protocols. Below is a structured survey summarizing key contributions and insights from the existing body of research.

Bharadia et al. (2013) presented practical implementations of full-duplex radios, achieving significant improvements in spectrum efficiency by canceling interference up to 100 dB at the transceiver hardware level. The development of self-interference cancellation (SIC) techniques has enabled simultaneous bidirectional communication on the same frequency channel.

Sabharwal et al. (2014) provided a comprehensive survey on full-duplex wireless systems, discussing SIC techniques and their hardware and software integration. Self- interference was a major hurdle to achieving full-duplex communication. Hybrid SIC approaches combining analog and digital cancellation methods were proposed to mitigate this interference.

Zhou et al. (2016) introduced a TDMA-based full-duplex protocol that dynamically pairs nodes for bidirectional communication while maintaining fairness in the network. Protocols that adaptively switch between full-duplex and half-duplex modes based on network conditions have been proposed to ensure robustness.

Park et al. (2021) examined the impact of residual interference on full-duplex MAC performance, emphasizing the need for robust SIC mechanisms. The performance of IBFD MAC protocols is highly sensitive to the effectiveness of SIC techniques. Residual interference can significantly degrade communication quality.

Huang et al. (2023) proposed a hybrid MAC protocol combining CSMA and TDMA for full-duplex multi-hop communication, achieving significant gains in network efficiency. Designing scalable MAC protocols for multi-hop, multi-node networks remains a challenge, requiring advanced scheduling and coordination mechanisms.

There has been considerable research effort devoted to developing more reliable, efficient, and effective wireless communications operations using Wireless communications Sensor Network (WCN) systems in order to explore the marine environment for economic and social purposes. This chapter provides an overview/review of the technologies involved, focusing on recent advancements in MAC protocol design for WCN and full-duplex communication from the following perspectives: fundamental concepts and back- ground to Wireless communications and full-duplex communication, application areas, and acoustic channel characteristics as they relate to data packet communication wireless communications. Similarly, MAC protocols for WCNs are discussed, as well as their performance.

According to studies on the design of MAC protocols for Wireless communication network, MAC protocols for WCNs face numerous challenges that necessitate the use of alternative and more suit- able solutions to ensure good Quality of Service (QoS) and energy efficiency. Due to the fact that the majority of radio frequency (RF) based MAC protocols do not account for long propagation delays, low data rates, and high- power consumption they cannot be directly applied to WCNs. Additionally, while a few full-duplex MAC protocols have been developed for terrestrial WSN systems, additional research is needed to extend these protocols for wireless communication in order to fully exploit in-band full-duplex communication wireless communication.

3-WIRELESS COMMUNICATION PARADIGMS

The wireless communication system of interest is composed of numerous sensors that are deployed wireless communication and are capable of communicating via acoustic links. The type of wireless communication system of interest system is made up of many sensors deployed wireless communication with capability to communicate via acoustic links. Converged wireless communication operations based on WCN paradigm is depicted in Figure

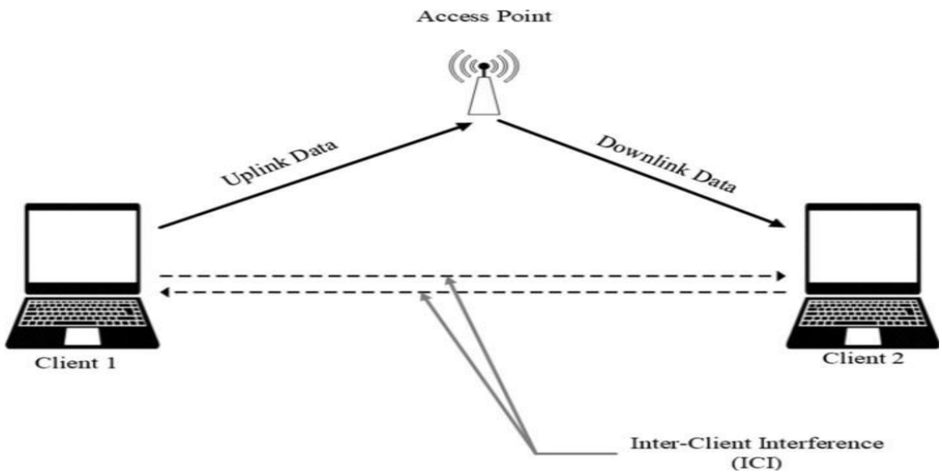


Fig 3.1 wireless communication operationsConventional wireless communication operations have largely depended on cabled big machines such as Remotely Operated Vehicles (ROVs). Also, traditional monitoring approaches involve deploying wireless communications sensors to the ocean-bottom to record data of interests and the sensors are recovered at a later time to analyze the

recorded data. A combination of both active and passive solutions can reduce the burden of higher signal processing at the clients as well as increase the performance metrics of the wireless network. In-band full duplex radio can be utilized to various application domains, such as cellular networks where base station and clients can transmit and receive simultaneously in the same frequency band, thereby increasing the number users within a cellular tower. Self-interference cancellation in a base station (of the cellular network) is a major concern because the base station transmits with a high power to ensure long distance coverage. In-band FD radio technologies can be very useful for Internet of Things (IoT) devices which require limited transmission power and cover short distances. Reduction of power consumption by in- band FD tiny wireless devices is a future research scope because the uses of hand-held devices are increasing exponentially and those tiny devices possess low powered batteries. These traditional approaches have the following limitations. Additionally, traditional monitoring approaches involve the deployment of wireless communications sensors to the ocean bottom to collect data of interest and then recovering the sensors to analyze the collected data. These established methods have the following drawbacks.

No real-time monitoring: Because the deployed instruments must be recovered before the data can be retrieved, there is no real-time monitoring. This may require several months to accomplish [14]. This impairs the reliability and effectiveness of wireless communications real-time operations.

No online reconfiguration of the system:

Additionally, once the systems are deployed, configuration commands cannot be sent from onshore stations to the systems, such as ROVs. As a result, system tuning and reconfiguration become more difficult.

Longer result period: Moreover, conventional wireless communications operations may take longer to accomplish due to the time required for deployment, data gathering, and recovery. For instance, seismic imaging operation for oil exploration may take many years to complete.

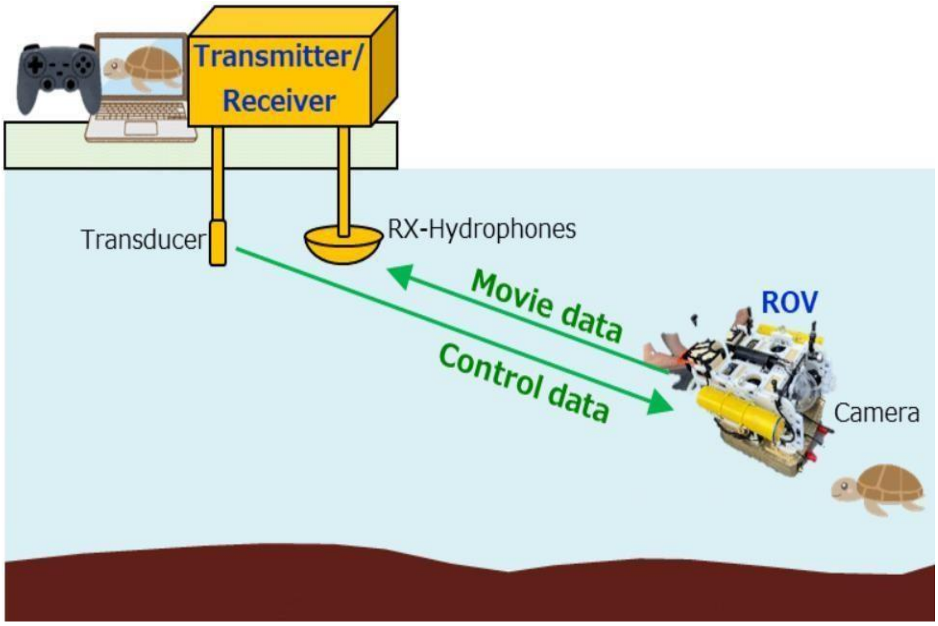


Figure 3.2 ROV in Wireless communications operation

Not impervious to failure: Similarly, system failure is a frequent occurrence in wireless communications operations due to the environment's nature. Given the lack of onshore station-to-target system interactions with the traditional approaches, it will be im- possible to detect instrument failure until they are recovered. As a result, this can have an effect on the outcome of the entire wireless communications operation.

On the other hand, WCN systems deployed in the sea, ocean, or shallow waters may be more efficient, and cost effective, as they support onshore-to-system interaction and configuration in real time, and are well suited for large-scale deployment.

4-IN-BAND FULL-DUPLEX COMMUNICATION

In-Band Full-Duplex (IBFD) communication refers to a phenomenon whereby network nodes can transmit and receive data packets simultaneously within the same band (In- band). It is theoretically expected that FD communication can double the channel capacity (spectral efficiency) achieved by half-duplex communication given the same resources. Because of the low data rate associated with wireless communications, it may be possible to investigate the use of IBFD technology to efficiently double the theoretical bandwidth and consequently, potentially double the transmission data rate. The efficiency of links, the user experience, and the usage of available resources could all be significantly improved as a result. As a result, the monitoring efficiency (a measure of the effectiveness of the monitored data with respect to the rate of data retrieval) with respect to wireless communications pipeline can be improved. However, half-duplex transmission has lower network performance and in turn lower monitoring efficiency because, it cannot simultaneously transmit and receive in band, thus, less effectively reuse spectrum as compared to full-duplex.

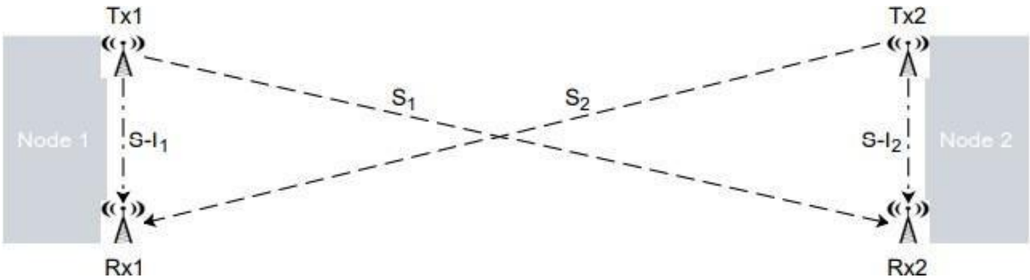


Figure 4.1 In band Full-Duplex Transmission scenario

Basically, full-duplex communication can be achieved using two basic forms of links, the unidirectional and bidirectional links.

Bidirectional Communication

On the contrary, bidirectional communication mode involves all full duplex nodes

On the other hand, bidirectional full-duplex communication represents a more advanced form of IBFD operation, in which all participating nodes are equipped with full-duplex capabilities. In this setup, every node can transmit and receive data concurrently on the same frequency band, resulting in true two-way communication. This approach is especially useful in point-to-point or peer-to-peer communication models, where two nodes frequently exchange data in real time. Applications such as video conferencing, autonomous vehicle communication, and real-time control systems benefit immensely from bidirectional communication because it minimizes latency and maximizes data throughput.

The primary advantage of bidirectional communication is its superior spectral efficiency. Since both directions of communication occur simultaneously and on the same frequency, the available bandwidth is used more effectively than in any other traditional or hybrid system. Furthermore, the reduction in communication delay— since acknowledgments, feedback, or responses can be sent without waiting—improves the responsiveness of time-sensitive applications. Bidirectional communication also simplifies the MAC protocol in homogeneous networks where all nodes are full-duplex enabled. However, the implementation of bidirectional IBFD is not without its own set of challenges. The most prominent issue is self-interference, where a node's transmitted signal can overwhelm its receiver. Although modern self-interference cancellation (SIC) techniques have made tremendous progress—some achieving cancellation levels up to 100 dB—residual interference can still degrade performance, especially in high- data-rate applications or dense network environments. Additionally, equipping every node with full-duplex capability increases system cost, energy consumption, and hardware complexity, making this mode less practical for large-scale, resource- constrained networks.

When comparing unidirectional and bidirectional communication modes, the choice largely depends on the specific requirements and constraints of the network. Unidirectional mode is more appropriate in hierarchical networks, such as sensor networks or disaster recovery systems, where a central node or relay can be upgraded to full-duplex capabilities while leaf nodes remain half-duplex. In contrast, bidirectional mode is ideal for mesh networks, real-time applications, and homogeneous systems where all nodes can afford the hardware and energy requirements of full-duplex operation. Hybrid networks that support both modes dynamically based on context and traffic conditions are also being explored as a flexible and scalable solution for future wireless communication systems.

In conclusion, unidirectional and bidirectional communication modes serve distinct purposes in the deployment and operation of IBFD ad hoc networks. While unidirectional communication provides a practical and economical path to gradually introduce full-duplex capabilities into existing networks, bidirectional communication offers the highest level of performance in environments where full hardware support and low-latency communication are critical. The continued advancement of SIC technologies and energy-efficient full-duplex transceivers will play a key role in determining how widely and effectively these communication modes can be deployed in the wireless networks of the future.

5-SOFTWARE AND HARDWARE REQUIREMENTS

MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB stands for matrix laboratory, and was written originally to provide easy access to matrix software developed by LINPACK (linear system package) and EISPACK (Eigen system package) projects. MATLAB is therefore built on a foundation of sophisticated matrix software in which the basic element is array that does not require pre dimensioning which to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of time. MATLAB features a family of applications specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow learning and applying specialized technology. These are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control system, neural networks, fuzzy logic, wavelets, simulation and many others. Typical uses of MATLAB include: Math and computation, Algorithm development, Data acquisition, Modeling, simulation, prototyping, Data analysis, exploration, visualization, Scientific and engineering graphics, Application development, including graphical user interface building.

Basic Building Blocks of MATLAB

The basic building block of MATLAB is MATRIX. The fundamental data type is the array. Vectors, scalars, real matrices and complex matrix are handled as specific class of this basic data type. The built in functions are optimized for vector operations.

No dimension statements are required for vectors or arrays.

MATLAB Window

The MATLAB works based on five windows: Command window, Workspace window, Current directory window, Command history window, Editor Window, Graphics Window and Online-help window.

Command Window

The command window is where the user types MATLAB commands and expressions at the prompt (>>) and where the output of those commands is displayed. It is opened when the application program is launched. All commands including user written programs are typed in this window at MATLAB prompt for execution.

Work Space Window

MATLAB defines the workspace as the set of variables that the user creates in a work session. The workspace browser shows these variables and some information about them. Double clicking on a variable in the workspace browser launches the Array Editor, which can be used to obtain information.

Current Directory Window

The current Directory tab shows the contents of the current directory, whose path is shown in the current directory window. For example, in the windows operating system the path might be as follows: C:\MATLAB\Work, indicating that directory "work" is a subdirectory of the main directory "MATLAB"; which is installed in drive C. Clicking on the arrow in the current directory window shows a list of recently used paths. MATLAB uses a search path to find M-files and other MATLAB related files. Any file run in MATLAB must reside in the current directory or in a directory that is on search path.

Command History Window

The Command History Window contains a record of the commands a user has entered in the command window, including both current and previous MATLAB sessions. Previously entered MATLAB commands can be selected and re-executed from the command history window by right clicking on a command or sequence of commands. This is useful to select various options in addition to executing and is useful feature when experimenting with various commands in a work session. The sink node receives data packets from nodes farther down the Ad Hoc and forwards them to the sea surface communication platform. The last transmitting node in the Ad Hoc does not relay packets; instead, it transmits only its own data packets to the next transmitting node in the Ad Hoc.

Hardware specifications:

System : i3 or above.

Ram: 4 GB.

Hard Disk : 40 GB

Software specifications:

Operating system : Windows8 or Above. Software : MATLAB 2013 or above Coding Language : MATLAB C

6-ALGORITHMS

Three algorithms used in the simulation are GEA, DGCA, and GRA and how they address the IBFD resource allocation and scheduling problem.

GEA (Genetic Evolutionary Algorithm)

GEA applies principles of genetic algorithms to search for optimal configurations. In this context, it finds the best setting for the proportion of small base stations (SBSs) operating in IBFD mode and the corresponding capacity performance.

- **Population-Based Search:** A set of candidate solutions (each representing a potential configuration) is maintained.
- **Genetic Operators:** The algorithm uses selection, crossover, and mutation operations to evolve the population. These operations allow the algorithm to explore the search space, combining good solutions and introducing diversity.
- **Fitness Evaluation:** Each candidate is evaluated based on a fitness function (e.g., downlink throughput or a combined metric including the proportion of IBFD SBSs). The candidates with higher fitness are more likely to be selected for the next generation.

  Iterative Improvement: Over multiple generations, the algorithm converges toward an optimal or near-optimal solution.DGCA(Distributed Graph Coloring Algorithm)

  DGCA leverages graph coloring techniques for resource allocation. In wireless networks, interference can be modelled as a graph where nodes (SBSs) are vertices and potential interference links are edges.
- **Graph Representation:** Each SBS is represented as a node in a graph. An edge between two nodes indicates that the corresponding SBSs could interfere with each other if operating in IBFD mode simultaneously.
- **Color Assignment:** The algorithm assigns "colors" (which can represent time slots, channels, or operational modes) to the nodes. The goal is to ensure that adjacent nodes (those that can interfere) do not share the same colour.
- **Distributed Operation:** Since decisions are made based on local information,

  DGCA is well-suited for decentralized network environments. Each node can make its own decision while considering the colors of its neighbors.
- **Optimization Goal:** The algorithm seeks to maximize network capacity while ensuring interference is minimized, allowing more SBSs to operate in IBFD mode without causing harmful interference.

GRA (Greedy Agorithm)

The Greedy Algorithm (GRA) is a heuristic approach that makes local, instantaneous decisions to optimize network performance. It aims to quickly assign operational modes (IBFD vs. HD) to SBSs based on immediate benefits.

- **Iterative Decision-Making:** At each step, the algorithm chooses the option that appears best at that moment—such as selecting the SBS that, if switched to IBFD, would yield the highest immediate increase in capacity.
- **Local Optimality:** It focuses on locally optimal choices without considering the overall global impact. For example, it might prioritize SBSs with the best channel conditions.
- **Simplicity and Speed:** Due to its straightforward nature, the greedy approach is computationally efficient and easy to implement.
- **Outcome:** Although it might not always achieve the global optimum, GRA provides a practical solution with lower complexity, which is valuable in scenarios with limited computational resources or where fast decisions are needed.

7-APPLICATION

The In-Band Full-Duplex (IBFD) Medium Access Control (MAC) protocol is a transformative innovation in wireless communication that enables simultaneous transmission and reception of data over the same frequency channel. This capability significantly improves spectral efficiency, reduces latency, and enhances the overall performance of wireless systems. Below are detailed applications of IBFD MAC protocols across various domains:

Faster and More Reliable Internet Connections

Wi-Fi Networks

- **Home and Office Wi-Fi:** IBFD protocols allow simultaneous uploading and downloading on the same channel, resulting in faster internet speeds and smoother video streaming, online gaming, and cloud-based tasks. Reduces congestion in crowded networks, ensuring a better user experience in shared environments like coffee shops, offices, or public places. Example is Streaming Netflix while simultaneously uploading videos to YouTube.

Mobile Hotspots

- **Enhanced Performance:** Portable Wi-Fi devices can handle multiple connected devices more efficiently, improving overall speed and stability.

Improved Mobile Communication (5G and Beyond)

- **Seamless Voice and Video Calls:** BFD protocols enhance call quality by enabling uninterrupted two-way communication, reducing call dropouts and delays.
- **Better Data Speeds:** Faster downloads and uploads improve the experience of sending photos, videos, or large files in real time.

Smart Homes

- **IoT Device Interactions:** Devices like smart speakers, security cameras, and thermostats benefit from IBFD, enabling them to send data (e.g., live video feed) and receive updates (e.g., firmware upgrades) simultaneously.
- **Example in Daily Life:** A smart security system sending live footage to your phone while receiving commands to adjust settings.

Autonomous Vehicles

- **Enhanced Safety and Efficiency:** Vehicles equipped with IBFD communication systems can simultaneously exchange data with other vehicles (V2V) and infrastructure (V2I) for collision avoidance and traffic management.
- **Example in Daily Life:** A self-driving car detecting a sudden stop by a vehicle ahead and simultaneously informing nearby vehicles to avoid pile-ups.

Public Wi-Fi in Urban Spaces

- **Smart Cities:** Public Wi-Fi networks in parks, transport hubs, and shopping malls leverage IBFD to provide seamless connectivity to multiple users simultaneously.
- **Example in Daily Life:** Browsing the internet at a bus stop while the system handles real-time traffic data for public transport management.

Online Gaming

- **Low Latency Gaming:** IBFD protocols reduce delays by enabling instant two- way communication between gaming servers and devices, improving response times.
- **Example in Daily Life:** Playing multiplayer games without experiencing lag during intense gameplay.

Augmented and Virtual Reality (AR/VR)

- **Enhanced Immersive Experiences:** Real-time bidirectional communication reduces latency in AR/VR applications, providing smoother interactions.
- **Example in Daily Life:** Using AR glasses for navigation or VR headsets for gaming and virtual meetings.

8-RESULT

Our results demonstrate the effectiveness of IBFD MAC protocols in achieving high- throughput, low-latency communication. We highlight the benefits, performance metrics, and challenges associated with IBFD MAC protocols, providing insights into their potential applications and future research directions.The figure describes a MATLAB-generated line graph that illustrates the downlink throughput (in bits/s/Hz) as a function of the number of antennas, comparing the performance of four different methods: GEA (red), DGCA (green), GRA (blue with triangles), and LB (blue with circles). The x-axis represents the number of antennas, ranging from 50 to 300, while the y-axis indicates the downlink throughput.

From the graph, it is evident that GEA, DGCA, and GRA deliver very similar and high throughput performance, all clustering around the 230 to 270 bits/s/Hz range, with minor fluctuations as the number of antennas changes. These three methods show consistent efficiency across all antenna configurations. On the other hand, the LB method consistently underperforms compared to the others, with throughput values significantly lower—ranging roughly from 160 to 215 bits/s/Hz. This clearly demonstrates the superior effectiveness of GEA, DGCA, and GRA in maximizing throughput, while LB lags behind in performancehe figure describes is a MATLAB-generated line graph that displays the proportion of small base stations (SBSs) operating in BFD (Bidirectional Full Duplex) mode versus the number of antennas. The graph compares three different schemes or algorithms: GEA (red line), DGA (green line), and GRA (blue line). Each line indicates how effectively each algorithm enables SBSs to operate in BFD mode across a range of antenna counts, from 50 to 300.

From the graph, it is evident that the GRA algorithm consistently outperforms the others, achieving the highest proportion of BFD-operating SBSs, often above 90%. The DGA algorithm performs moderately well with values hovering around 75–80%, while GEA shows the lowest performance with more fluctuations and values typically ranging between 55% and 75%. This visual comparison highlights the efficiency and reliability of the GRA method in maintaining high BFD operation rates as the antenna count increases.

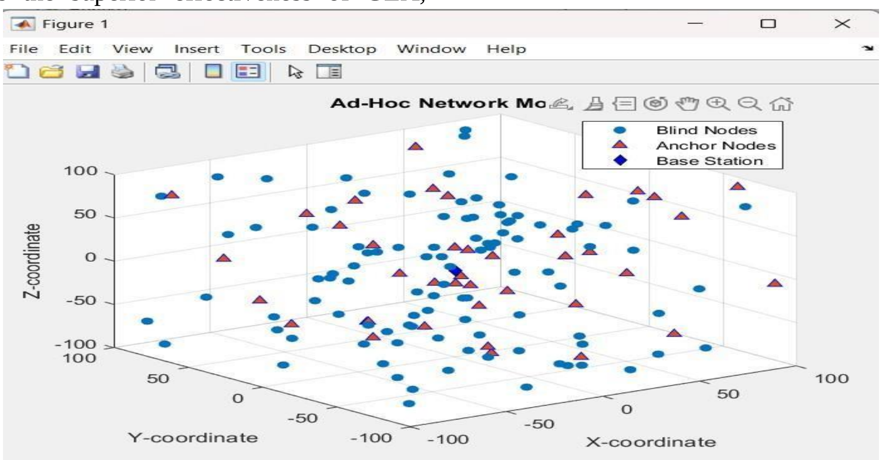


Fig: 1 creation of nodes

The figure represents a 3D simulation of an Ad-Hoc Network Model, likely created using MATLAB. It visualizes the spatial distribution of three types of nodes within a defined 3D area. Blind nodes, shown as blue circles, are scattered throughout the space and do not know their positions. Anchor nodes, marked as red triangles, are fewer in number and serve the purpose of helping blind nodes determine their location by acting as reference points. At the centre of the network is a base station, represented by an orange diamond, which serves as a centralized point for data collection or communication coordination. The X, Y, and Z axes indicate the spatial dimensions, and the placement of nodes illustrates how a wireless ad hoc network might be organized for tasks such as localization, communication, and data transmission in a distributed system.

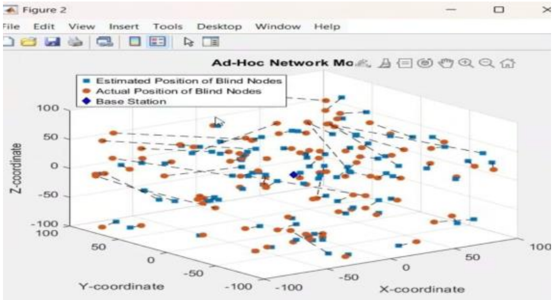


Fig:2 Calculating the position of nodes

This figure describes a 3D MATLAB plot titled "Actual vs Estimated Positions", which visually compares the real and calculated locations of nodes in a wireless ad-hoc network. The red circles represent the actual (true) positions of the nodes, while the blue squares indicate their estimated positions based on a localization algorithm. Dotted lines connect corresponding actual and estimated positions, showing the localization error or deviation. The X, Y, and Z axes represent the spatial dimensions, helping illustrate how close or far off the estimations are in three-dimensional space. This type of plot is commonly used to evaluate the accuracy and effectiveness of localization techniques, especially in scenarios involving sensor networks, GPS-free environments, or indoor tracking systems.

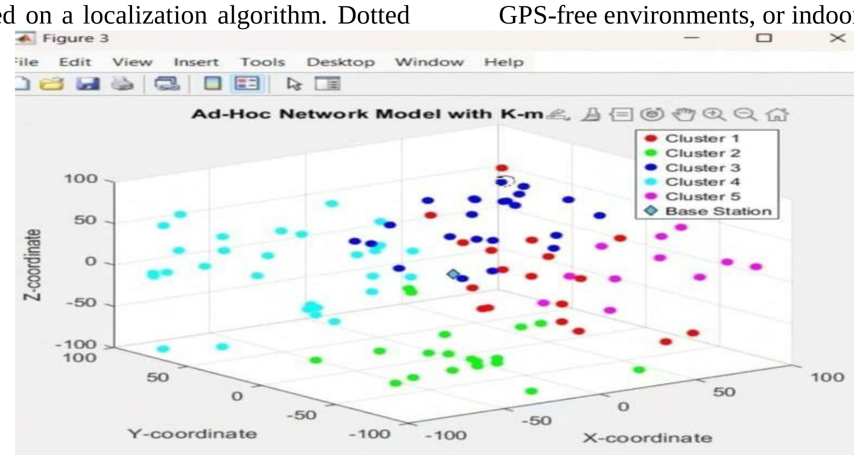


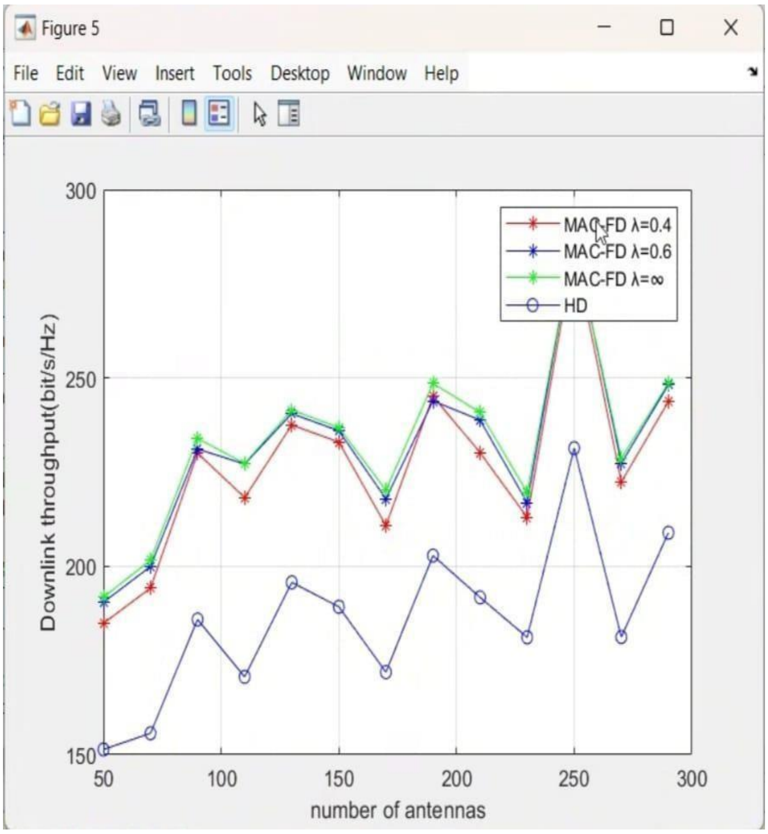
Fig:3 Creating clusters for channels

The figure describes a 3D MATLAB plot titled "Blind Node Clustering", which illustrates how

blind nodes in an ad-hoc network are grouped into clusters based on
their spatial positions. The nodes are categorized into five different clusters, each represented by a unique colour: blue, orange, yellow, green, and purple. These clusters likely result from a clustering algorithm such as K-means, used to enhance network efficiency by organizing nodes for better communication and management. A base station, shown as a cyan diamond, is located near the center of the clusters, suggesting it may serve as a central hub for coordinating or collecting data from these clusters. The X, Y, and Z axes define the 3D space in which the nodes are distributed, and the plot helps visualize how nodes are spatially grouped, which is important for tasks like routing, localization, and load balancing in wireless networks.

Fig:4 Comparison of Half Duplex and Mac protocol Full duplex communication

The figure describes a MATLAB line graph that compares downlink throughput (bit/s/Hz) against the number of antennas for various communication strategies. The graph evaluates four configurations: MAC-FD with λ = 0.4, 0.6, and ∞, and HD (Half-Duplex). Each line represents the performance of a different approach, with MAC-FD schemes generally showing higher throughput than the HD scheme across all antenna counts. As the number of antennas increases, throughput improves significantly for all full-duplex methods, highlighting the advantage of full-duplex communication (especially MAC-FD with higher λ values) over half-duplex. This graph effectively illustrates how advanced antenna configurations and full-duplex techniques can greatly enhance communication performance in wireless systems.



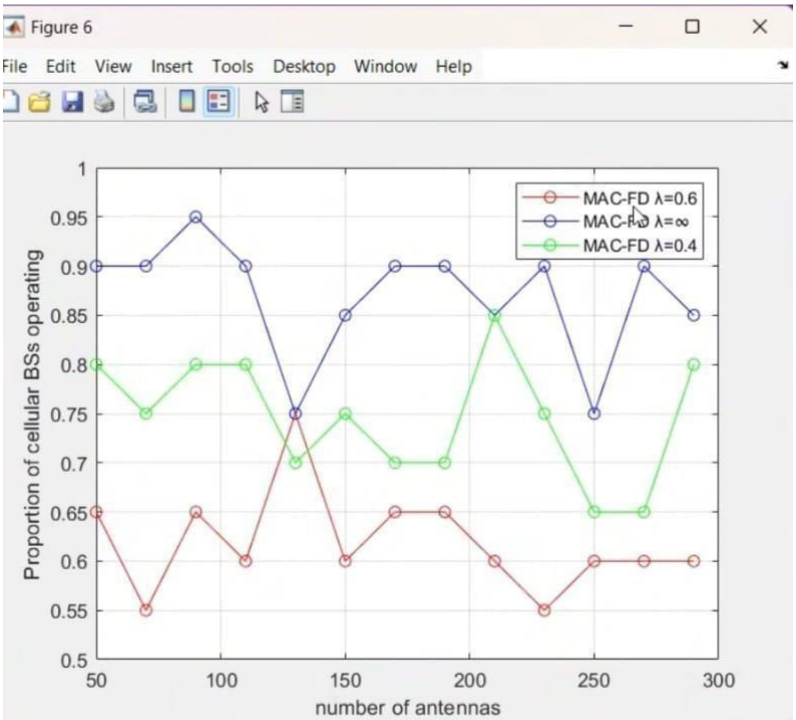


Fig:5 Comparison of MAC protocol for different wavelengths

The image displays a MATLAB line graph illustrating the relationship between the number of antennas and the proportion of cellular base stations (BSs) operating under different MAC-FD (Multiple Access Control Full-Duplex) configurations, characterized by λ values of 0.4, 0.6, and ∞.

Each colored line represents one of these configurations. As the number of antennas increases, the proportion of active base stations fluctuates for all three configurations, with MAC-FD λ=∞ consistently achieving the highest proportion, often nearing or exceeding 90%. This suggests that higher λ values enable more efficient use of base stations, leading to improved network resource utilization. The graph emphasizes how parameter tuning in full-duplex systems can significantly impact network performance and efficiency.

9-CONCLUSION

In conclusion, In-Band Full-Duplex MAC protocols for Ad hoc network represent a significant breakthrough in wireless communication technology. By enabling simultaneous transmission and reception of data on the same frequency band, IBFD MAC protocols for Ad hoc networks can potentially double the capacity of wireless networks, improving spectral efficiency and reducing latency. This technology has far- reaching implications for various applications, including wireless local area networks, cellular networks, ad Internet of Things (IoT) devices.

The benefits of IBFD MAC protocols for Ad hoc networks are numerous, including improved throughput, reduced latency, and enhanced overall network performance. However, implementing IBFD MAC protocols also poses significant technical challenges, including self-interference, hardware complexity, and interference management. To overcome these challenges, researchers and developers must continue to explore innovative solutions, such as advanced self-interference cancellation techniques, machine learning-based interference management, and hardware-software co-design approaches.

As the demand for high-speed and low-latency wireless communication continues to grow, IBFD MAC protocols for Ad hoc networks are likely to play an increasingly important role in shaping the future of wireless networks.