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Unlocking the Potential of 5G in Mobile Ad-Hoc Networks: Key Challenges and Emerging Opportunities

Dr.S.Sangeetha¹, V. Priyanka², Dr.A.Kalaivani³

Assistant Professor and Head, Department of PG Computer Science, Sri Vasavi College (Self Finance Wing),
Erode, Tamil Nadu, India¹

Assistant Professor, Department of Computer Science, Sri Vasavi College (Self Finance Wing), Erode,
Tamil Nadu, India²

Assistant Professor and Head, Department of Computer Applications, Nehru Arts and Science College,
Coimbatore, Tamil Nadu, India³

ABSTRACT: The emergence of 5G networks and the increasing demand for mobile ad hoc networks (MANETs) have led to the development of a new architecture that combines the benefits of both technologies. In this paper, we propose a 5G-based MANET architecture that enables mobile devices to communicate with each other directly, without relying on a fixed infrastructure. The proposed architecture utilizes 5G New Radio (NR) technology to provide high-speed, low-latency communication between devices.

KEYWORDS: 5G, Mobile Ad-Hoc Networks, MANETs, Opportunistic Networks, Mobile Communications, 5G Applications

I. INTRODUCTION

The rapid growth of wireless communication technologies has led to an increasing demand for mobile ad hoc networks (MANETs). MANETs are self-organizing networks that enable mobile devices to communicate with each other directly, without relying on a fixed infrastructure. However, traditional MANETs face several challenges, including limited bandwidth, high latency, and poor reliability.

II. RELATED WORK

Several research studies have investigated the integration of 5G networks and MANETs. In [1], the authors proposed a 5G-based MANET architecture that utilizes network slicing and edge computing to provide high-speed, low-latency communication between devices. In [2], the authors developed a simulation-based framework to evaluate the performance of 5G-based MANETs.

An Optimized Fuzzy Based Ant Colony Algorithm for 5G-MANET: This study proposes a security-aware, fuzzy improved ant colony routing optimization protocol for MANETs in 5G networks. The goal is to develop a MANET routing protocol that can provide stable packet transmission, low overhead connectivity, and low end-to-end latency.

Scalability Analysis of MANET in 5G Environment: This research analyzes the scalability of MANETs in 5G environments, considering factors such as density, mobility, and data rate.
Structure of MANETS used for 5G Communication

Networks: This study presents a structure for MANETs used in 5G communication networks, highlighting the importance of updating network topology information as nodes move.

Scalability Analysis of MANET in 5G Environment

A study analyzed the scalability of MANETs in 5G environments, considering factors such as density, mobility, and data rate. The researchers evaluated the performance of MANETs using metrics like Packet Delivery Ratio, Average residual energy of node, and Network lifetime.

Connection-Aware Digital Twin for Mobile Adhoc Networks in the 5G Era

Another study proposed a connection-aware digital twin for 5G-based MANETs, enabling agile and versatile communication infrastructures for deploying contextual applications.

Performance Analysis of Routing Protocols for Mobile Ad Hoc Networks in 5G

Researchers conducted a performance analysis of routing protocols for MANETs in 5G, evaluating their performance, scalability, and suitability for various MANET scenarios.

Performance Analysis of MANET Protocols: A Comparative Study

A comparative study analyzed the performance of MANET protocols, considering key performance metrics like packet delivery ratio, average throughput, and average delay.

Validating 5G Technology Performance

A research study validated 5G technology performance, assessing 5G architecture and application scenarios, including performance evaluation in heterogeneous infrastructure.⁵

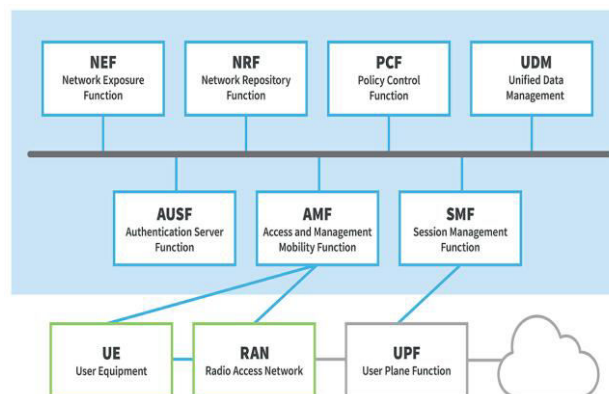
These studies demonstrate ongoing efforts to explore the potential of integrating 5G networks and MANETs, addressing challenges and opportunities in areas like routing protocols, scalability, and network architecture

III. OVERVIEW OF 5G TECHNOLOGY

High-level introduction to 5G, its evolution from previous generations (4G, 3G, etc.), and its unique capabilities such as high data rates, ultra-low latency, massive connectivity, and reliability. Fifth-generation (5G) wireless technology promises to revolutionize the way we communicate, with faster data rates, lower latency, and greater connectivity. The advent of 5G technology marks a significant milestone in the evolution of wireless communication. 5G promises to deliver faster data rates, lower latency, and greater connectivity, enabling a wide range of applications and use cases.

The 5G architecture consists of the following components:

- Radio Access Network (RAN)
- Core Network (CN)
- Transport Network (TN)



User Equipment (UE) like 5G smartphones or 5G cellular devices connect over the 5G New Radio Access Network to the 5G core and further to Data Networks (DN), like the Internet.

The Access and Mobility Management Function (AMF) acts as a single-entry point for the UE connection.

Based on the service requested by the UE, the AMF selects the respective Session Management Function (SMF) for managing the user session.

The User Plane Function (UPF) transports the IP data traffic (user plane) between the User Equipment (UE) and the external networks.

The Authentication Server Function (AUSF) allows the AMF to authenticate the UE and access services of the 5G core. Other functions like the Session Management Function (SMF), the Policy Control Function (PCF), the Application Function (AF) and the Unified Data Management (UDM) function provide the policy control framework, applying policy decisions and accessing subscription information, to govern the network behavior.

IV. IMPORTANCE OF COMBINING 5G AND MANETS

The integration of 5G and Mobile Ad-hoc Networks (MANETs) is a crucial step towards achieving ubiquitous connectivity. The advent of 5G networks promises to revolutionize the way we communicate, with faster data rates, lower latency, and greater connectivity. However, 5G networks have limitations, particularly in areas with limited infrastructure. MANETs, on the other hand, offer a flexible and resilient solution for communication in dynamic environments. Combining 5G and MANET can unlock the full potential of both technologies.

The integration of 5G and MANET enables the extension of network coverage to areas with limited infrastructure. MANETs can provide connectivity in remote or disaster-stricken areas, while 5G networks can provide high-speed data transfer. Combining 5G and MANET provides improved reliability, as MANETs can self-heal and adapt to changes in the network topology. This ensures that communication remains uninterrupted, even in the event of network failures. The integration of 5G and MANET supports IoT and mission-critical applications, such as smart cities, industrial automation, and public safety. MANETs can provide low-latency communication, while 5G networks can provide high-speed data transfer. Combining 5G and MANET provides enhanced security features, such as encryption and authentication, to protect against cyber threats. MANETs can provide secure communication channels, even in areas with limited infrastructure.

V. PROPOSED ARCHITECTURE

The proposed 5G-based MANET architecture consists of the following layers:

Device Layer

Mobile devices, such as smartphones, tablets, and laptops, are the primary components of the device layer. These devices are equipped with 5G-enabled interfaces, enabling seamless communication with other devices. D2D communication is a critical feature of 5G-based MANETs, enabling direct communication between devices without the need for infrastructure. D2D communication is facilitated by the device layer, which manages device discovery, connection establishment, and data transmission. Device management is a critical function of the device layer, ensuring that devices are properly configured, monitored, and maintained. Device management includes functions such as device registration, authentication, and authorization.

Device discovery is the process of identifying and locating devices within the network. The device layer manages device discovery, enabling devices to discover and establishing a connection between devices. The device layer manages connection establishment, ensuring that devices can communicate with each other seamlessly. It manages data transmission, ensuring that data is transmitted efficiently and reliably.

MANET Layer

The MANET Layer is a critical component of the 5G-based MANET architecture. It enables devices to discover and communicate with each other in a dynamic and autonomous manner.

The MANET Layer performs the following key functions:

1. Neighbor Discovery: Devices in the MANET discover their neighbors and establish connections with them.
2. Routing: Devices use routing protocols to determine the best path for forwarding data packets to their destinations.
3. Topology Management: Devices manage the network topology by updating their routing tables and neighbor lists in response to changes in the network.
4. Data Forwarding: Devices forward data packets to their destinations using the routing information.

Routing Protocols

The MANET Layer uses various routing protocols to enable devices to communicate with each other.

1. Ad Hoc On-Demand Distance Vector (AODV) Routing: AODV is a reactive routing protocol that establishes routes on demand.
2. Dynamic Source Routing (DSR) Protocol: DSR is a reactive routing protocol that uses source routing to forward data packets.
3. Optimized Link State Routing (OLSR) Protocol: OLSR is a proactive routing protocol that uses link state routing to maintain a topology map of the network.

The 5G New Radio (NR) layer

The 5G NR layer is a critical component of 5G-based MANET architecture, enabling efficient and reliable communication between devices. The 5G NR layer provides several functionalities, including data transmission, resource allocation, error detection and correction, and security. However, the 5G NR layer also faces several challenges, including interference management, resource allocation, security, and scalability.

A. Physical Layer (PHY)

The PHY layer is responsible for transmitting and receiving data between devices. The 5G NR PHY layer uses Orthogonal Frequency Division Multiple Access (OFDMA) and Multiple Input Multiple Output (MIMO) techniques to achieve high data rates and reliability.

B. Medium Access Control (MAC) Layer

The MAC layer is responsible for managing access to the shared wireless medium. The 5G NR MAC layer uses a grant-based approach to manage access, ensuring efficient and reliable communication.

C. Radio Link Control (RLC) Layer

The RLC layer is responsible for managing the transmission of data between devices. The 5G NR RLC layer uses a combination of Automatic Repeat Request (ARQ) and Hybrid ARQ (HARQ) techniques to ensure reliable transmission.

D. Packet Data Convergence Protocol (PDCP) Layer

The PDCP layer is responsible for managing the transmission of packet data between devices. The 5G NR PDCP layer uses a combination of header compression and encryption techniques to ensure efficient and secure transmission.

Network Slicing Layer

The Network Slicing layer is a key component of 5G-based MANET architecture, enabling the creation of multiple independent networks on top of a shared physical infrastructure. The Network Slicing layer provides several functionalities, including network slice creation, management, resource allocation, and security. However, the Network Slicing layer also faces several challenges, including scalability, complexity, security, and interoperability.

A Network Slice Instance (NSI) is a logical network that provides a specific set of network services to a particular application or use case. A Network Slice Template (NST) is a pre-defined template that defines the characteristics of a network slice, such as bandwidth, latency, and security. A Network Slice Orchestrator (NSO) is responsible for managing the lifecycle of network slices, including creation, modification, and deletion. Network Function Virtualization (NFV) is a key technology that enables the creation of virtual network functions, such as firewalls and routers. The Network Slicing layer enables the creation of network slices, each providing a specific set of network services including modification and deletion.

The Edge Computing layer

The Edge Computing layer is a key component of 5G-based MANET architecture, enabling the processing of data at the edge of the network. The Edge Computing layer provides several functionalities, including data processing, resource allocation, network optimization, and security. However, the Edge Computing layer also faces several challenges, including scalability, complexity, security, and interoperability.

Edge Nodes are the primary components of the Edge Computing layer, providing computing resources and storage for data processing. Edge Servers are specialized servers that provide additional computing resources and storage for data processing. Edge Routers are responsible for routing data between Edge Nodes and Edge Servers. The Edge Orchestrator is responsible for managing the Edge Computing layer, including resource allocation and data processing.

VI. USE CASES AND APPLICATIONS**Public Safety Networks**

5G-based MANETs can be used to establish public safety networks for emergency responders, such as police, firefighters, and ambulance services. These networks can provide reliable and secure communication services, including voice, video, and data, in emergency situations.

Smart Cities

5G-based MANETs can be used to establish smart city networks, enabling the connection of various smart city devices, such as sensors, cameras, and traffic lights. These networks can provide real-time data analytics, enabling city officials to make informed decisions about traffic management, public safety, and waste management.

Industrial Automation

5G-based MANETs can be used to establish industrial automation networks, enabling the connection of various industrial devices, such as sensors, machines, and robots. These networks can provide real-time data analytics, enabling industrial operators to optimize production processes, improve product quality, and reduce costs.

Vehicular Networks

5G-based MANETs can be used to establish vehicular networks, enabling the connection of vehicles, roadside infrastructure, and pedestrians. These networks can provide real-time data analytics, enabling improved road safety, traffic management, and autonomous driving.

Military Communications

5G-based MANETs can be used to establish military communication networks, enabling the connection of various military devices, such as radios, sensors, and drones. These networks can provide secure and reliable communication services, including voice, video, and data, in tactical environments.

IoT Applications

5G-based MANETs can be used to establish IoT networks, enabling the connection of various IoT devices, such as sensors, actuators, and wearables. These networks can provide real-time data analytics, enabling improved smart home automation, industrial automation, and healthcare services.

Disaster Response and Recovery

5G-based MANETs can be used to establish disaster response and recovery networks, enabling the connection of various devices, such as emergency responders' radios, sensors, and drones. These networks can provide secure and reliable communication services, including voice, video, and data, in disaster scenarios.

Smart Grids

5G-based MANETs can be used to establish smart grid networks, enabling the connection of various smart grid devices, such as smart meters, sensors, and grid management systems. These networks can provide real-time data analytics, enabling improved grid management, energy efficiency, and renewable energy integration.

Healthcare Services

5G-based MANETs can be used to establish healthcare networks, enabling the connection of various healthcare devices, such as medical sensors, wearables, and telemedicine systems. These networks can provide real-time data analytics, enabling improved patient care, remote health monitoring, and telemedicine services.

Autonomous Systems

5G-based MANETs can be used to establish autonomous system networks, enabling the connection of various autonomous devices, such as drones, self-driving cars, and robots. These networks can provide real-time data analytics, enabling improved autonomous system operation, navigation, and decision-making.

VII. OPPORTUNITIES IN UTILIZING 5G FOR MOBILE AD-HOC APPLICATIONS

With advanced 5G technologies like massive MIMO and beamforming, ad-hoc networks can maintain strong, reliable communication links even in challenging environments. Applications that require low-latency communication, such as autonomous vehicles, drones, and real-time emergency systems, benefit significantly from 5G. With faster data transfer, applications involving heavy data processing, such as augmented reality (AR) or virtual reality (VR) in ad-hoc settings, become more feasible. IoT devices in ad-hoc networks can leverage 5G's massive device support, enabling smart cities, environmental monitoring, and smart healthcare. 5G's flexibility in providing on-demand network resources can help optimize network performance in rapidly changing environments typical of mobile ad-hoc networks. The integration of security mechanisms in 5G can address challenges related to data protection and authentication in ad-hoc networks.

VIII. FUTURE DIRECTIONS

Future mobile ad-hoc networks can benefit from AI-driven network management, allowing for autonomous operation, fault detection, and optimization of 5G resources in dynamic environments. Future research could explore cooperative communication techniques to improve the reliability of ad-hoc networks in 5G environments, such as cooperative relays and distributed antennas. The role of edge computing in enhancing the performance of mobile ad-hoc applications by reducing latency and improving computational efficiency at the network edge.

Future research directions include:

1. Developing standardized protocols for 5G-MANET integration
2. Investigating novel architectures and algorithms for optimized performance
3. Exploring new applications and use cases for 5G-MANET integration

IX. CONCLUSION

In this paper, we proposed a 5G-based MANET architecture that enables mobile devices to communicate with each other directly, without relying on a fixed infrastructure. The proposed architecture utilizes 5G NR technology to provide high-speed, low-latency communication between devices. Emphasize the importance of overcoming challenges like energy consumption, interference, and deployment complexity. Suggest that with careful design, 5G can substantially improve mobile ad-hoc applications, enabling more dynamic, reliable, and high-performing networks in the future. Combining 5G and MANET is crucial for achieving ubiquitous connectivity. This integration offers numerous benefits, including enhanced network coverage, improved reliability, support for IoT and mission-critical applications, and enhanced security. Addressing the challenges and exploring future research directions will pave the way for widespread adoption of 5G-MANET integration. 5G is seen as a game-changer for enhancing mobile ad-hoc applications, especially in terms of supporting higher user density, high bandwidth, and improved network flexibility.

REFERENCES

- [1] 3GPP, "5G; NR; Overall description; Stage 2," 3GPP TS 38.300, 2020.
- [2] I. F. Akyildiz et al., "A survey on wireless multimedia sensor networks," *Computer Networks*, vol. 51, no. 4, pp. 921-960, 2007.
- [3] S. Singh et al., "A survey on 5G network architecture and emerging technologies," *IEEE Access*, vol. 7, pp. 46265-46284, 2019.
- [4] N. Bhushan et al., "Network densification: Challenges and opportunities," *IEEE Communications Magazine*, vol. 53, no. 11, pp. 102-109, 2015.
- [5] M. Condoluci et al., "5G network slicing: A survey," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 1693-1718, 2018.
- [6] A. Gupta et al., "5G for IoT: A survey," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 2, pp. 1134-1158, 2019.
- [7] H. Kim et al., "5G NR: A new air interface for 5G," *IEEE Communications Magazine*, vol. 56, no. 3, pp. 124-131, 2018.
- [8] J. Liu et al., "5G network architecture: A survey," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 1719-1743, 2018.
- [9] M. M. Matalgah et al., "5G network slicing: A survey of architectures and algorithms," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 2, pp. 1159-1184, 2019.
- [10] A. Osseiran et al., "The foundation of the 5G mobile network architecture," *IEEE Communications Magazine*, vol. 55, no. 9, pp. 124-131, 2017.
- [11] J. Sachs et al., "5G for industrial automation: A survey," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 2, pp. 1185-1206, 2019.
- [12] S. Singh et al., "5G network architecture: A survey of existing architectures and future research directions," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 1744-1763, 2018.
- [13] Y. Sun et al., "5G network slicing: A survey of security challenges and solutions," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 2, pp. 1207-1232, 2019.
- [14] W. Wang et al., "5G network architecture: A survey of existing architectures and future research directions," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 1764-1783, 2018.



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