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MANETs: Challenges and Future Research Scope

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Abstract*: *MANET (Mobile Ad hoc Network) is an ad hoc network that may be constructed on demand. Due to its dynamic nature, it allows nodes in the network to communicate with each other without the use of any infrastructure. When compared to conventional wireless networks, MANET's on-demand setup makes it more popular. Conventional wireless networks require a central authority for overall system operations, while MANET is an infrastructure-less and self-organized network that is generally a wise choice when it comes to certain application areas like military operations, communication in natural disasters, man-made emergencies, rescue procedures, and vehicular ad hoc network (VANET) for sharing information among vehicles as well as providing traffic conditions and warnings. This new network, however, faces several challenges and difficulties, including compromised security, routing issues, cooperation, multicasting, power efficiency, IP addressing, QoS etc., that must be properly taken care of before it can be deployed in real-time. The current paper provides a full analysis of MANET, including its problems, concerns, and possible research topics, which will be very useful for academics who want to begin their work on this subject.

Keywords*: *Ad-hoc Networks, Challenges in MANET, MANET, Mobility, Routing, Security, Wireless Communication

I. INTRODUCTION

MANETs are a sort of wireless network that operates without any infrastructure. Because there is no central authority in MANETs, all nodes act as both transmitters and receivers for communication purposes. When the endpoint is inside the source's transmission range (the destination is directly approachable from the source) both can interact without the need for any third party; otherwise, the possibility of communication relies on the nearest neighbours. This implies that in MANETs, each node serves as a router [1]. MANETS' connections are all bidirectional. The ability of wireless networks to let nodes communicate with each other while being mobile is their most important characteristic. Because MANETs do not need any fixed infrastructure, nodes are free to move to any location. Because a MANETS node's broadcast range is restricted, direct interaction between source-destination pairs is unlikely when they are not in each other's transmission ranges. hence, intermediary nodes participate in the communication. This mechanism can be categorized into "single-hop communication" and "multiple-hop communication." Nodes in the transmission range of each other engage immediately in the former, whereas the destination is communicated by using multiple steps or hops in the latter.

These systems can function alone, or they can link to a larger system, such as the Internet. These networks feature a collection of wireless links that multi-hops utilize to communicate with one another without the usage of any other communication assistance. These are sometimes referred to as multi-hop wireless networks or mobile radio networks. When two or more multi-hops are within range of one other, one mobile node may receive the transmission from another mobile node.

Wireless communication has grown in popularity in recent decades, and it continues to pique the curiosity of a large group of experts and academics. MANET is a self-contained system which has network elements (smartwatches, mobile phones, PDAs, laptops etc.) that are linked by a wireless connection but lack a standardized wireless link architecture and any sort of permanent or fixed infrastructure. MANET is a self-configurable infrastructure-less network, which implies that each node is free to go in any direction in the network and form any network configuration [2].

Because there is no defined infrastructure, the nodes follow a peer-to-peer mode of communication. The point to be noted here is that there are numerous wireless network restrictions, such as a high rate of failure, power limitations, bandwidth limitations, and so on, yet these cannot halt the development of wireless communication. MANET is a particular topic of interest for corporates and scholars worldwide. Especially because this technology comes in a variety of forms, and it is easy to apply in uncompromising implementation areas such as disaster management [3].

II. CURRENT ISSUES AND CHALLENGES

Despite the many features and interesting applications of MANET, several difficulties and problems need to be thoroughly examined before widespread commercial implementation can be carried out.

These issues are problems with unanswered questions, which have enormous potential from the research point of view. Over the past several years, MANETs have gained popularity as a subject of study. Nearly every aspect of the network has been investigated in some form at various levels. Below are listed MANET's top difficulties and present research trends.[4], [5], [6], [7]:

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A. Demand-based vs. proactive operation

The operation should be reactive rather than demand-based to decrease network control overhead and prevent wasting resources (bandwidth, power, processing memory, etc.). Hence the protocol must only function when necessary and not send control information regularly.

B. Support for unidirectional links

The radio environment may lead to the development of unidirectional connections. In addition to being bidirectional, these connections also improve the efficiency of the routing algorithm. Routing protocols must be bidirectional with an option of unidirectionality as per required.

C. Security

Because the network architecture is not as well defined and the very nature of the transmission medium, the MANET is susceptible to a variety of attacks. They are more prone to security breaches such as repeated transmissions and spoofing attacks than other wired networks. Flooding happens frequently. Due to the frequent addition and removal of numerous nodes, a rogue node may easily penetrate a network. That node will find it easy to monitor network activity, divert traffic, and overwhelm the whole network as a result. Security is crucial to preventing any kind of network disruption.

D. Power conservation

Due to their small batteries and tendency to enter a sleep mode to conserve power, laptops and constrained clients like PDAs can function as nodes in the MANETs network. Thus, these sleep settings must be supported by the routing protocol.

E. Multiple routes

The use of multiple routes may minimize the number of responses to network topology changes and traffic congestion. If one path is no longer an option, it may still be possible to use a previously cached route, saving the routing protocol from having to repeat the route discovery process. This may look attractive at first, but maintenance of multiple paths can be a very complex task.

F. Support for Quality of Service

Group communication systems often allow real-time multimedia applications (e.g. decentralized gaming, videoconferencing, and streaming services). To send the very same stream of data to a predefined collection of recipients, these applications require a multicast routing protocol that is the quality of service (QoS) aware. QoS must be included in some form in routing.

G. Scalability

MANET routing protocols must have the ability to adapt their size to suit the requirements of the network. Scalability is a network's ability to deliver a sufficient level of service even when there are many nodes. As a network grows, each node sends more packets, which depletes the network's finite battery power and reduces its lifespan, making scalability a key challenge.

H. Consumption and management of energy

Each MANET node functions as both a host and a router. It is also expected to send data to other network nodes. The routing protocol must reduce overhead and congestion caused by these control packets. Energy plays a crucial role in route selection, especially during the stages of route discovery and route repair. Proper management and maintenance of power is a big issue in MANET.

I. The unpredictable nature of the environment

No specific wireless medium defines or restricts the wireless environment. The majority of the time, wireless signals are blocked and have difficulty passing through solid objects, it might encompass everything from hills to houses to single walls to persons. When there is an impediment between the end terminals, communication efficiency never is optimal in a Line of Sight (LOS) operation. The possibility of signal strength being compromised increases as the number of obstructions between the transmitter and the receiver grows. Although the LOS functioning of terminals is impractical in the real world, its effects can be reduced by employing particular spectrum frequencies.

J. Reliability issues of Wireless Communication

Because of excessive interference in the shared common channel, wireless media is more error-prone. Interferences induced by neighbouring frequencies significantly reduce wireless network performance.

K. Reliability and Robustness

A network's performance can be negatively impacted by nodes that misbehave and links that are not trustworthy. These sorts of misbehaviours cannot be discovered and isolated fast due to a lack of centralised monitoring. The intricacy of the design is therefore dramatically increased.

L. Issues in transmission

The wireless medium might lead to some transmission errors. The signal received at the receiver end may contain some errors if a portion of the signal is impacted by environmental conditions. The basic networking layers have to provide appropriate error detection and correction capabilities.

M. Limited Bandwidth

Compared to infrastructure networks, wireless communications continue to have a far lesser capacity. Furthermore, after taking into account the effects of multiple access, distortion, interference, fading etc., the actual throughput of wireless communication is typically significantly lower than the maximum transmission rate of a radio.

N. Routing

Routing is a prominent topic of discussion among academics because routing protocols are a crucial problem in this area due to frequent changes in network architecture. To deal with extremely dynamic and fluid network conditions, a routing protocol must be effective and clever.

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O. Time-Varying Nature of Wireless Link

Transmission barriers including route loss, fading, obstruction, and interference increase the susceptibility of wireless channels. Numerous reasons work against wireless transmission efficiency.

P. Inter-Networking

Along with communication in an ad hoc network, inter-networking among IP-based static networks and MANET is extremely important. The operational management of mobility is complicated further by the use of routing protocols in such a dynamic environment.

Q. TCP/ UDP

The two most common protocols used on the Internet are TCP and UDP. TCP and UDP transport layer protocols are essential for MANET applications including HTTP and real-time sound / visual.

R. Asymmetric link

In the majority of wired networks, symmetric links—which are always fixed—are utilised. However, MANET is unique since the nodes may move throughout the network and do so often.

S. Routing Overhead

Due to the topology's mobility and frequent changes, nodes in MANETs networks usually shift to a new location inside the network. Because of this, the routing table creates some outdated routes, adding to the routing overhead.

T. Interference

As transmission factors cause connections to establish and break, transmitted data may interfere with the other. Furthermore, a malicious node may eavesdrop on a conversation between nodes, corrupting the entire communication.

U. Dynamic topology

Because of dynamic network topology, mobile nodes may move. As a result of which the communication properties may also change. To take into account these topological changes, MANETs networks must update their routing tables and algorithms. For instance, in a fixed network, the routing table is refreshed every 30 seconds. For MANETs networks, this update frequency could be relatively low. Also, for optimal route selection, and identification of newly joined nodes to the network, there is a need for a dynamic update at the node level.

V. Distributed operation

There is no centralised router structure, thus the participating nodes must distribute routing.

W. Loop-freeness

The aim is to avoid route maintenance and discovery operations that loop indefinitely between nodes.

X. Route Changes Caused by Mobility

An ongoing session experiences numerous path interruptions in an ad hoc wireless network caused by extremely dynamic network topology caused by the mobility of nodes. Frequently changing routes result from this circumstance.

Y. IP Addressing

The list of IP addresses given to ad-hoc networks is one of the foremost crucial problems. In MANETs, IP addressing and address autoconfiguration have received a lot of attention.

Z. Fault Tolerance Mechanism

Due to the mobility of the nodes, it is obvious that they will randomly move and join the network at random, resulting in path failures and the formation of new connections as well. Fault-tolerance mechanisms are implemented for route maintenance. detection and correction are two primary functions of fault-tolerant mechanism and is crucial at times of network failure. This mechanism may not work as efficiently as one would like.

AA. Multiple Accesses

The countermeasure of inefficient utilization of bandwidth is to provide effective medium access protocols that enhance aggregate channel usage in MANETs by optimizing spectral reuse. This has its own set of complications.

BB. Radio Interface

Mobile nodes use their antennas or radio interface to communicate. It is useful to consider packet forwarding or reception in MANETs employing radio interfaces or antenna approaches. Like every interface, the radio interface may give rise to standardisation and protocol issues.

CC. Frequent Network Partitions

Partitioning of the network is frequently caused by the random movement of nodes. The intermediate nodes are most impacted by this.

DD. Packet Drop Due to Communication Errors

MANET incur a significantly greater packet loss because of variables like increased collisions due to hidden terminals, unidirectional links, interference, and regular route breakdowns caused by the mobility of nodes.

EE. Hidden Terminal Problem

It refers to the simultaneous and parallel transmission by node/s that are not in the sender's direct transmission range but are in the receiver's transmission range, resulting in network congestion on the receiver side.

FF. Resource-Constrained Nodes

Wireless networks enable simultaneous communication between several users and a network source. New nodes instantly become part of the network, therefore some nodes that are interacting at the same time will use some of the available bandwidth. The battery, communication bandwidth, computing power, computational memory, and any extra storage are the resources that are limited in the nodes. Resource constraint at the node level forms the bigger problem of bandwidth constraint network.

GG. Node Failures

The issue of ongoing data transfer arises if a node fails to owe to a lack of battery power.

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One significant research question that is being looked at is the failure of intermediary nodes during data transmission. In the worst-case scenario, these failures can be managed by utilising recovery methods. These failures can be prevented through efficient prediction algorithms and proper energy management.

HH. Over-congested Links or Competing Nodes

MANET only has a finite bandwidth that all active nodes must use. As a result, the nodes are constrained by their bandwidth usage. Since wireless nodes require the same medium for communication, they naturally compete for access to the bandwidth's available links. When several nodes in a region communicate simultaneously, the connections get congested.

II. Geo-casting and Multicasting

Multicast services enable users to communicate with other group members. Users who use broadcast services can communicate with every network member.

JJ. Clustering

Clustering's major feature is that it divides the network into many subgroups known as clusters and provides a suitable foundation for routing, cooperation, resource management, and network support. This may give rise to non-cooperation among nodes and network subgroups.

KK. Heterogeneity

Major components of the Internet of Things (IoT), which will be a constant in upcoming research and applications, are heterogeneous ad hoc networks (HANETs). It is used in various industries in recent years, particularly in environmental monitoring, weaponry management, automation in transportation, inventory management, smart cities, and other sectors [8].

III. EMERGING PROSPECTS OF RESEARCH

In reality, MANET installation and penetration are becoming more challenging. However, designing and analysing a dependable MANET presents a significant problem due to the expertise needed for a wide variety of topics such as topological complexities, difficulties with route optimization, QoS, scaling, heterogeneity, clustering, dependability, durability, capacity management, congestion control, and so on [9]. The current study may be expanded to provide new routing protocols that match the following other desirable characteristics:

A. Secure and QoS–Aware Routing Protocols

MANET routing protocols that prioritise security and quality of service may soon become better and more efficient. A safe yet QoS-aware routing protocol might be developed in the future. Up until now, routing protocols have mostly concentrated on routing methods. It could be challenging to guarantee both of these conditions at the same time. An extremely secure routing system undoubtedly adds to the routing overhead, which might lower the QoS level. Consequently, one might look for the best trade-off between these two factors [10].

B. QoS-Aware Multicast Routing

Several multicast routing techniques have come to light in recent years. Multicast is becoming more significant since it has the potential to lower the amount of bandwidth needed for data dissemination in bulk. Multicast routing for MANETs should receive considerable consideration given the compelling need to save limited wireless bandwidth. Therefore, using multicast instead of multiple unicast is typically desirable, specifically in a MANET setting when bandwidth is at a premium. When establishing and maintaining a communications system is challenging, MANETs are used in law and order, emergency search-and-rescue, social activities (cooperative and distributed), and military operations.

C. Attacks and Security

The privacy of ad-hoc networks is a crucial issue that demands attention. Applications that demand a high level of protection against adversaries and eavesdropping attackers (active and passive) include military and sensitive gatherings. A new protocol must have authenticated headers and the required authentication protocols to allocate credentials to users of ad-hoc networks. The development of a secure routing protocol utilising evolutionary algorithms is possible in the future.

D. Location-based Protocols

Given the increasing use of positioning devices, one possibility for implementation in MANETs is location-based routing algorithms. Most Geographic routing protocols employ the common technique of periodic dissemination of packets including the nodes' coordinates for their geographical location as a means of maintaining Neighbour location data. The ultimate goal is to use less energy while receiving more packets with adaptive location updates and as little end-to-end delay as possible. Additionally, the Enhanced Adaptive Position Update technique provides a better answer for node movement on a dynamic basis. In the meanwhile, the following list of hot areas of open research will help MANETs solve some of their inherent challenges, including expandability, topology changes, mobility, and to a certain extent heterogeneity:

- Geographic Routing for MANETs Based on Energy.
- Using energy-efficient routing techniques for clustering.
- QoS saves energy and allows video streaming applications.
- Real-time video broadcasts are supported through multicasting and cross-layer design.

E. HANET

Gadgets with varied capabilities (such as mobile phones and mobile electronic devices) are connected to create heterogeneous ad-hoc networks. These devices must be able to communicate with one another consistently and uniformly. It is diverse to link several devices in this manner with certain possible functions.

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It is challenging to establish a standard programming interface across all nodes due to the large differences in device characteristics, such as memory, storage capacity, and processing performance. HANETs, which include wireless sensor networks (WSN), wireless fidelity networks (Wi-Fi or Wi-MAX), telephony networks, and intelligent ad hoc networks, have emerged as a crucial study area. In recent years, researchers have focused on enhancing HANET performance. HANETs are used in a variety of scenarios with the vast deployment of smart devices. However, enhancing the performance of communication among smart terminals is a crucial study area, as are autonomous protocols, energy-aware techniques, and security measures in HANETs.

F. Different Network Scenario

A routing system must function in circumstances with high levels of mobility, numerous nodes, broad areas, and increased traffic.

G. Statistical Route Maintenance

To determine the likelihood of path failure before incidents of route failure, more study in the area of statistical route maintenance is necessary.

H. Routing Overhead

Ad-hoc network bandwidth will be largely used by routing messages; a new protocol must be developed to further minimise routing overhead compared to conventional routing protocols.

IV. CONCLUSION

This article provides a wide overview of MANET, including its problems and potential areas of future study. Despite all of MANET's benefits, the study mentioned above indicates that real-time MANET implementation is a very challenging undertaking. Anonymity, encryption, and other security goals are very challenging to accomplish. In MANET, node attributes are also quite challenging to manage. Therefore, it is determined that before real-time deployment, the issues and problems with MANET highlighted in this study must be treated with extreme caution by creating multiple protocols. Further research will be conducted in the areas of primarily security applications and disaster management, followed by others that are viewed as major future fields of study.

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