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A Review on Major Challenges of Mobile Adhoc Networks

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ABSTRACT: MANET is a decentralized type of wireless network where mobile devices communicate with each other without relying on a fixed infrastructure, such as base stations or access points. MANETs are often used in situations where a fixed network infrastructure is unavailable, impractical, or costly to implement, such as in emergency or military operations, vehicular networks, or sensor networks. In MANETs, devices dynamically form temporary networks and communicate with each other directly or through intermediate devices, making them highly adaptable to changing network conditions. This paper elaborates on the various challenges over MANET including routing issues, congestion control, frequent path breakage due to induced mobility, reliability, compromised security, multicasting, power efficiency, IP addressing, QoS and scalability.

KEYWORDS: Adhoc, Challenges, MANET, Mobile, Network, QoS, Routing, Security

I. INTRODUCTION

Wireless networks refer to any type of computer network that uses wireless data connections for communication between network nodes. These networks are commonly used in various settings, including homes, businesses, public spaces, and industrial environments. Wireless networks have revolutionized the way people and devices communicate and collaborate, offering flexibility, mobility, and connectivity in diverse environments. Continued advancements in wireless technology and standards are driving further innovations and expanding the capabilities of wireless networks. The Wireless network types are as follows:-

- Infrastructure Wireless Network
- Infrastructure-less Wireless Network

Figure 1: Wireless Networks

In case of Infrastructure wireless networks [1,2], medium is required to create and supports infrastructure to establish networks. In these networks, the communication takes place between wireless nodes through base station that is fixed. Cellular phone can be considered as an example to understand the concept of infrastructure network that needs towers for its functionality. In this type of network, access points can be added easily to enhance the range. This network is suitable for permanent network and also used to connect with other types of network such as wired network. There is no fixed base station in this type of network [1,2], mobile nodes are free to move while establishing communication path. Here, all nodes can participate to become a router. Routes are established dynamically and network is formed as and when required. Figure 2 depicts Infrastructure & Infrastructure-less Wireless Networks.

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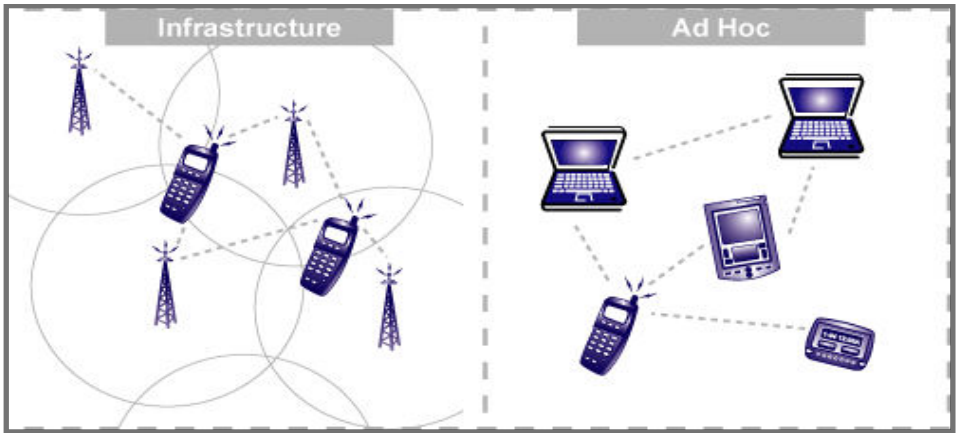

Figure 2: Infrastructure& Infrastructure-less Wireless Networks

II. MOBILE ADHOC NETWORK

A Mobile Ad hoc Network is a type of wireless network where mobile devices communicate with each other without the need for a fixed infrastructure or centralized administration. In MANETs, nodes can move freely, and the network topology may change frequently due to node mobility, adding or removing nodes, and environmental factors. Some of the key characteristics of MANETs include decentralization, node mobility, dynamic topology, ad hoc connectivity, multi-hop communication, limited resources, security challenges and battery constraints.

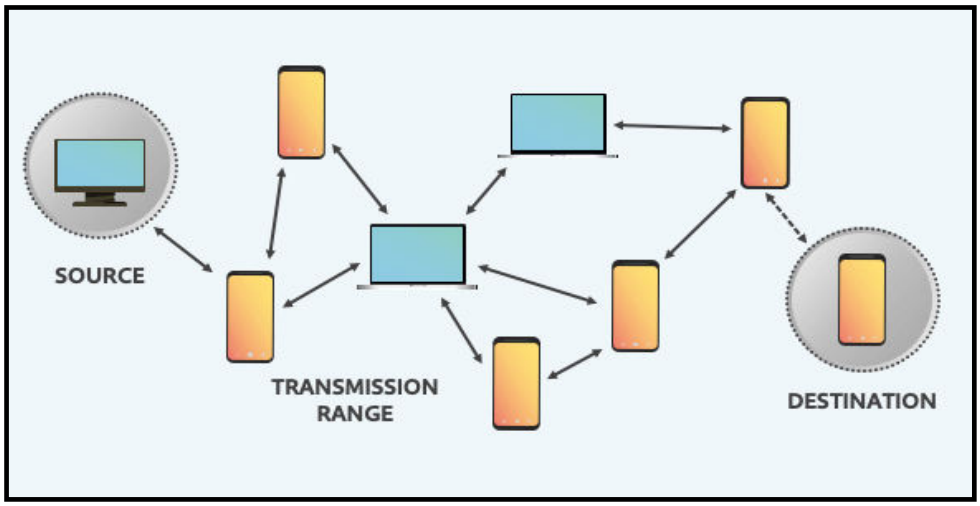

Figure 3: Working of MANET

MANETs have applications in various domains, including military operations, disaster recovery, emergency response, smart transportation systems, and Internet of Things deployments. Designing efficient routing protocols, resource management algorithms and security mechanisms is crucial for realizing the full potential of MANETs in these applications. Figure 3 depicts the working of MANET.

III. MANET CHALLENGES

Mobile adhoc networks have numerous benefits in comparison to traditional wireless networks, such as quick deployment and reduced dependability on a fixed infrastructure but there are also some challenges in implementation too. In nutshell, the salient features of MANET introduce many technological opportunities together but there are few major issues and challenges that can't be ignored. Some of the key challenges [3,4] for MANET are given below:-

- How to handle the limited bandwidth of wireless networks
- How to handle the dynamic network topology

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- How to achieve the stable and efficient routing
- How to tackle the network overhead
- How to handle the issue of scalability
- How to achieve QoS parameters
- How to handle the security threats and implement secure routing
- How to handle the power/battery constraints and achieve energy efficient routing
- Lack of centralized management will make it difficult to control node trust and how to deal with it.

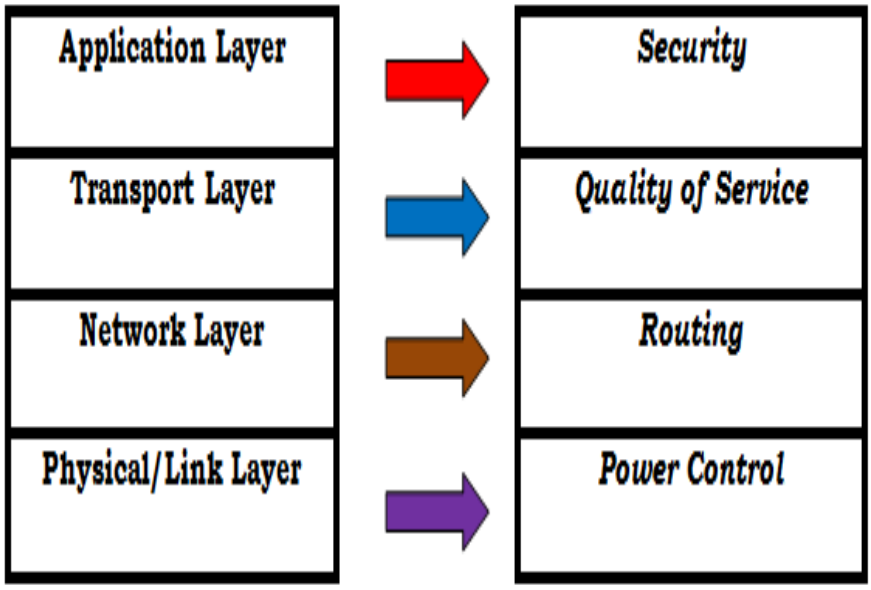

Figure 4: Challenges at Different Layers of MANET

The layered structure depicting different layers and corresponding MANET challenge is showing figure 4. In nut shell, the prominent challenges that affect implementation of mobile adhoc networks are as follows:

a) Network Routing
b) Dynamic Topology
c) Mobility
d) Frequent Path Breakage
e) Link Stability
f) Reliability
g) Scalability
h) Security
i) Congestion Control
j) Power Management
k) Quality of Service (QoS)

The challenges faced are explained one by one as follows:-

3.1 Routing

Due to high data rate needs and severe latency constraints, maintaining real-time traffics like audio and video in the context of dynamic network topology is extremely difficult. MANET wireless medium entirely validate the need for better routing techniques as opposed to those created for wired networks. One of the main issues in MANET is reliable packet routing. From small adhoc groups to larger mobile multi-hop networks, routing protocols are expected to function well in a wide range of networking framework. To address these issues and satisfy a variety of application needs, several routing protocols for MANETs have been anticipated. Traditional proactive routing protocols, for instance, removed the initial route discovery time but were ineffective under certain adhoc situations. The underlying cause is the routing technique, which wastes the limited system to discover routes that are not required. In contrast, reactive routing has the main benefit that route discovery only takes place when there is a request for communication between two network nodes. Routing paths become unsuitable in MANET due to constant topological changes. The

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performance of the network is also impacted adversely by frequent path failures. An assuring technique for handling this problem is to use various redundant paths between the initial mobile node and the target mobile node but alternate route selection has to be quick enough to handle link failures effectively.

3.2 Dynamic Topology

The network topology has a tendency to change rapidly and arbitrarily in MANET. The nodes in the network are mobile in nature and dynamically set up routing of their own as they keep on moving and forming their own network with time. Mobile nodes forming adhoc network join and leave the network arbitrarily without any preceding information that causes regular changes in network topologies. This temporary behaviour of MANET topology causes serious risk to efficiency of computing in such unreceptive environment. Computing efficiency is fatally challenged by this characteristic of MANET and traffic patterns in this networking environment.

3.3 Mobility

Mobility refers to the capability of nodes to move freely without any fixed infrastructure. The performance of MANET can be significantly impacted by the nodes' mobility. When a node moves, the topology changes repeatedly, which affects routing of packets. Therefore, it is essential to consider the mobility of nodes when designing routing protocols for MANET. Mobility in MANET can be characterized by various parameters such as speed, direction, and acceleration. The movement of nodes inside the network is modelled using these parameters which help to predict their future positions. Several techniques can be used to improve the performance of MANET in the presence of node mobility, such as adaptive routing, location-based routing, and energy-efficient routing . The choice of routing protocol will depend on the specific characteristics of the network, including nodes mobility, network size and the application requirements.

3.4 Frequent Path Breakage due to Induced Mobility

Frequent path breakage due to induced mobility can be a significant issue that affects the network's performance. Induced mobility refers to the movement of nodes caused by external factors, such as environmental changes or interference from other wireless devices. When nodes in a MANET move frequently, the network's topology can change rapidly, leading to frequent path breakage. This can result in significant delay and packet loss, which can affect the network's overall performance. Several techniques can be used to mitigate the impact of frequent path breakage due to induced mobility in MANET. One approach is to use proactive routing protocols that establish routes in advance and update them periodically. This can help to reduce the delay caused by route discovery and path re-establishment. Another approach is to use reactive routing protocols that establish routes on-demand. This approach can be more efficient in situations where nodes are highly mobile, as it reduces the overhead of route discovery. A hybrid approach that combines proactive & reactive routing protocols can also be used to balance the trade-offs between overhead and delay. Additionally, techniques such as link quality estimation and link stability analysis can be used to identify the most reliable routes in the network and reduce the impact of frequent path breakage.

3.5 Stable Routing

One of the challenges that MANET faces is to choose the stable and best route between any two nodes. To find reliable multi-hop routes for communication between two nodes is complex due to dynamic topology that results from mobile node mobility. A technique that advances routing efficiency is to choose the most stable path so as to reduce overhead and the latency time that occurs due to route reformation. The topology in a MANET may alter randomly and frequently at irregular intervals since the nodes might relocate unpredictably. To find and keep an ideal path is challenging as a result of this nature. Topological changes must get prompt response from the routing algorithm. Whenever there is link failure, maximum existing protocols keep record of single route and rediscover for new route. When transferring information, the widely used adhoc routing protocol typically chooses the shortest or least number of hops. These routes contain long haul links; due to this routes fail recurrently and tough to rely upon. The most critical factor in packet transfer is stable routing, which makes the protocol reliable and ready to use.

3.6 Reliability

Network reliability [5] is a crucial parameter and is of major concern in MANET as its topology keeps on changing dynamically and randomly. Frequent link failure is a major challenge to estimate reliability as nodes are mobile in nature. Ease of access, stability and realization are the major factors to assess performance of MANET and its reliability. Nodes are mobile in nature and hence, unpredictable that leads to low performance of the routing protocols. The performance relies on the interval of interconnections between any two nodes which are mobile and tends to transfer data. Data transmission errors, packet loss due to mobility of nodes, limited range of wireless transmission are among the major causes of network reliability issues to be addressed.

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3.7 Scalability

Scalability is a crucial factor in MANET on account of dynamic network topology. The scalability of a MANET refers to the capability of network to maintain its performance on account of increase in nodes. In a MANET, the scalability can be impacted by various factors viz. routing overhead, network congestion, and the capacity of wireless links. As nodes increase, the routing overhead also increases, which lead to higher delays and reduced throughput. Additionally, congestion can occur when there are too many nodes trying to communicate simultaneously, leading to packet loss and reduced network performance. Several techniques can be used to improve the scalability of MANETs. One approach is to use distributed routing protocols that allow each node to make routing decisions independently. This can reduce the routing overhead and improve the network's scalability. Another approach is to use hierarchical routing protocols that divide the network into smaller clusters and use different routing mechanisms within each cluster. This can reduce the routing overhead and improve the network's scalability. Furthermore, the use of efficient power management techniques, such as sleep mode and duty cycling, can reduce energy consumption and improve the scalability of MANETs. These techniques allow nodes to conserve energy when they are not actively participating in the network, reducing the number of active nodes and improving the network's scalability.

3.8 Security

Due to wireless connectivity of MANET and frequent changes in topology, MANET and its self-configuring mobile routers are mostly vulnerable [6]. There are many applications of MANET be it in medical field, military areas, tactical communications, wireless sensors, disaster network communication and many others. MANET is prone to cyber-attacks. To achieve security in MANET is very challenging because wireless links are vulnerable in nature. Many other hindrances to achieve security are inadequate physical security of mobile nodes, the irregular connectivity; dynamically change in topology, absence of a certification authority, and inappropriate centralized monitoring system. An adhoc network also faces security problems due to poor relay packets delivered to neighboring nodes. Other security issues are eavesdropping, infused of fake messages, poor system tracking for routing information, ink level security and privacy protection. Mobile nodes must cooperate for successful data transmission process in the self-governing environment of MANET where mobile nodes moves freely and depend on one another to establish communication. Each mobile node in the adhoc network must rely on one another to forward packets because there is no central controller, such as a router, to decide the communication paths in MANET. As a result, highly cooperative mobile nodes are necessary to ensure that the initiated data transmission process does not fail. Here, each mobile node has a certain amount of resources that must be protected, it is difficult to expect cooperation among them [7]. Because to their concern over resource degradation, such as depleted battery power and restricted processor power, Selfish Nodes (SNs) refuse to assist other nodes in forwarding packets. As a consequence, a system that may facilitate cooperation among mobile nodes without compromising their resources is required. MANET performance relies heavily on participation among its constituent nodes and the existence of SNs affect packet broadcast adversely. Even the best cryptographic mechanism may fail as the issue occurrence is due to internal modes. Hence, alternate solution is required that could encourage the assistance between mobile nodes as well as discourage selfish behaviour for energy conservation.

3.9 Congestion Control

Congestion is one of the major causes of packet delay or failure in MANET. In today's networks, the frequency of multimedia traffic is increasing speedily. User Datagram Protocol (UDP) flows are used to transmit these kinds of messages, however they lack in congestion handling. UDP traffic aggressively uses more bandwidth for extended time than Transmission Control Protocol (TCP) flows. For example, the Public Switched Telephone Network (PSTN) call is of two minutes duration, but Voice over Internet Protocol (VoIP) last for more time period. A trade-off is there between providing resources to delay-sensitive applications and protecting best connection-oriented traffic to ensure Quality of Service [8] for all existing users. Due to complexity of computing, MANET routing protocols have drawn a lot of attention in the literature.

The main classifications of protocols are are reactive protocols (e.g. Adhoc On-Demand Distance Vector (AODV) [9,10,11,12], and Dynamic Source Routing (DSR) [11,13,14]), proactive protocols (e.g. Destination Sequenced Distance Vector (DSDV) [9,190,11,12])and hybrid protocols (e.g. Zone Routing Protocol (ZRP) [11,15,16,17]). Due to outdated routes or a severe routing load, protocols experience excessive latency and packet loss. When the main route is congested, the shortest route algorithm used in conventional routing protocols does not yield optimal outcomes [18]. Network congestion significantly increases packet loss in MANET in addition to route failures caused by dynamic topology. Therefore, the routing protocol should not only focus on the mobility outline of the movable nodes but also consider traffic load of each path in order to minimize the end-to-end delay.

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3.10 Power Management

Power management is a critical issue in MANET due to limited battery life of the mobile nodes. Efficient power management is necessary to extend network lifetime. Power management in MANET involves reducing the energy consumption while maintaining network connectivity and performance. This can be achieved by various techniques such as sleep mode, duty cycling, and adaptive transmission power control. Sleep mode is a technique that involves putting the nodes into a low-power state when they are not actively participating in the network. In sleep mode, the node's radio is turned off, and the node consumes minimal power. This technique can considerably decrease energy consumption which leads to better network life. However, the downside of this technique is that it can introduce latency and reduce network connectivity. Duty cycling is a technique that involves turning the node's radio on and off periodically. In duty cycling, the node's radio is turned off for a specific period, and then it is turned on for a brief period to check for any incoming packets. This technique also reduces energy consumption. However, it can introduce latency and reduce the network's performance. Adaptive transmission power control is a method that involves adjusting the transmission power of nodes based on their distance from other nodes. This technique can reduce energy consumption by avoiding unnecessary high-power transmissions. It can also reduce interference and increase network capacity. However, it requires accurate location information, which can be challenging to obtain in a MANET. The choice of technique will depend on the specific characteristics of the network viz. mobility, size and the application requirements.

Adhoc networks have many benefits in various sectors, especially during natural disasters and calamities due to its temporal connectivity characteristics. Battery is one of the main sources to operate MANET that is exhaustible by nature. Due to this, developing such networks impose considerable challenge to maximize battery life mainly in situations where environmental constrains dominate. The most essential system for energy conservation for nodes is to design criteria for nodes that rely on battery [19]. Therefore, one of the important objectives is to maximize battery life. Batteries comprise the utmost weight of a mobile node that forms an adhoc network for communication. MANET is admired as it facilitates communication by establishing route on the fly but simultaneously it requires reduced component weight. Recharge of batteries frequently, carry standby batteries, less usage of mobile nodes are few ways to increase longevity of routes but doesn't ensure connections till the time it is required. Software for energy management can deactivate inactive components like pausing internal disk or turning off screen light. Power can be saved up to some extent by reducing communication, computation, memory usage and by lowering the execution of periodic operations so as to decrease overheads.

3.11 Quality of Service (QoS)

QoSis an essential factor in MANET to ensure reliable and efficient communication. MANETs are characterized by their dynamic topology, limited resources, and varying network conditions, which make providing QoS challenging. QoS in MANET is demarcated as the capability of network to provide reliable and predictable network services that meet specific application requirements. QoS in MANET can be achieved through various mechanisms such as traffic engineering, admission control, resource reservation, and priority-based scheduling. Traffic engineering involves optimizing the network traffic to meet specific QoS requirements. This can be achieved by using traffic classification, traffic shaping, and traffic policing. Admission control is a mechanism that controls the number of nodes that can join the network to ensure that the network resources are not overloaded. This mechanism can be used to prevent network congestion. Resource reservation is a mechanism that reserves network resources, such as bandwidth and buffer space, to ensure that the QoS requirements are met. This mechanism can be used to guarantee a certain level of service for specific traffic flows. Priority-based scheduling is a mechanism that prioritizes traffic based on its QoS requirements. This mechanism can be used to ensure that traffic with higher QoS requirements is given priority over other traffic. Furthermore, routing protocols that support QoS can be used to ensure that QoS requirements are met. The choice of mechanism will depend on the specific characteristics of the network and the QoS parameters.

Numerous works have been carried out in the area of MANET routing but QoS parameters still need more attention. QoS means a guarantee of some parameters like minimum bandwidth, minimum delay, jitter, services denial etc. Even though, MANET is used for various applications but the practical implementation requires pre-decided QoS. This requires adequate amount of network resources to perform well. MANETs make QoS even more challenging problem than ever before [20], despite some of reactive routing protocols [21] can be configured to generate paths that fulfil desired QoS parameters. With the change of resources requirement, intensity of QoS parameters also differs for all application. QoS is short termed due to the link quality variation in MANET [22]. Due to MANET performance limitations and transient network topology, many QoS routing techniques used in wired networks cannot be easily applied to MANETs. It's crucial that MANETs include QoS support for routing. The optimization of various QoS parameters such as stable routing, secure routing, power-aware routing [23], available bandwidth and the acceptable

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delay etc. is a big challenge in the present time. Finding a viable route between two nodes that has the required resources to satisfy QoS requirements is the key task of QoS routing. Exhaustive work has been carried out on QoS by experts from IETF. Most of the existing research on QoS demonstrates that table-driven QoS protocols are not best suited towards dynamic nature of MANET. Thus QoS is one of the critical and essential factor in MANET.

IV. CONCLUSION

Wireless networks have revolutionized the way people and devices communicate and collaborate, offering flexibility, mobility, and connectivity in diverse environments. Continued advancements in wireless technology and standards are driving further innovations and expanding the capabilities of wireless networks. MANETs possess several unique characteristics that distinguish them from traditional wired or infrastructure-based wireless networks. This paper presents key parameters of MANET along with various challenges. The prominent challenges include Dynamic Topology, Resource Constraints, Routing, Security, Quality of Service, Scalability, Interference and Signal Attenuation. Addressing these challenges requires the development of innovative algorithms, protocols, and techniques tailored to the specific requirements and constraints of MANETs. Collaboration between researchers and industry stakeholders is essential to advance the state-of-the-art in MANET technology and realize its full potential in various applications.

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