An Overview of MANETs: Applications, Characteristics, Challenges and Recent Issues

Diaa Eldein Mustafa Ahmed, Othman O. Khalifa

Abstract: ***In recent years, due to emerging technologies in the field of wireless networks, ad hoc networks have attracted much attention from the research community and industry since has important technical advances have arisen as a consequence. Mobile ad-hoc Networks (MANETs) is a group of self-organized and self-configured wireless mobile nodes (MNs) such as mobile devices, laptops ,and PDAs , able to communicate with each other without the need of any neither fixed network infrastructure nor centralized administrative support. MANET is a network that exchanges information among the entities that are potentially mobile without any pre-defined infrastructure based communication support. These networks are of practical importance in applications like environmental monitoring, health care, military, location tracking, disaster recovery and many more. This paper provides a comprehensive study of MANETs applications scenarios, main features and characteristics, challenges facing the deployment of MANET, current issues and latest research issues.***

Keywords: MANET applications, Characteristics, Challenges, recent issues

I. INTRODUCTION

Last decades wireless communication has grown and still it is an area of interest to large number of scientist and researchers. Mobile ad hoc network (MANET) is an autonomous system consisting of a collection of mobile nodes such as (laptop, cell phones, PDA, etc...) connected by wireless link, but has no any fixed infrastructure and predefined topology of wireless links. MANET is a type of infrastructure less network which is self configurable in nature i.e. each node is able to move in random direction and can make an arbitrary Network topology[1, 2]. The absence of fixed infrastructure means that the nodes communicate directly with one another in a peer-to-peer fashion. There are different limitations techniques of wireless network such as high error rate, power restrictions, bandwidth constraints, etc. but these could not limit the rise of wireless technology. Mobile Ad-hoc Network MANET is a special point of focus for industry and academic researchers from all around the globe. This technology has come with its own flavors it is easy to deploy in disaster areas and for emergency operations [3].

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This paper is organized as follows. Section 2 gives an overview of the recent applications scenarios of MANET. Section3 presents MANET characteristics. Section4 explain MANET recent research trends and challenges. Section 5 includes the scope for future research. The last section concludes and presents some future works.

II. MANETS APPLICATIONS AND RECENT ADVANCES

Although initially mobile ad-hoc networks were conceived as a general-purpose network, in terms of real-world deployment and industrial adoption [4] , MANET applications are emerged as specialized networks that are managed by a single authority and tailored to solve specific problems in different areas , for example in military networks, vehicular networks or sensor networks. Additionally, MANETs are expected to become a key component in the 4G architecture, and use most of the important functionality of overall next-generation wireless network technologies. In this section, typical applications scenarios and some of the most illustrative use cases nowadays are described in table(1) which contains different applications of MANETs through military, civilian and commercialized applications, so the rest of the table including the recent and advancement in the MANET applications :

Table (1): Typical Application of MANETs

Application	Possible Scenarios
Tactical networks	-Support communication and coordination needs between soldiers, military vehicles and information headquarters.
Extended network connectivity	-Provide communication between devices or with the Internet in areas with limited infrastructure or intermittent access.
Emergency Services	-Used in disaster situations after disasters or catastrophes, such as flood, earthquake or fire.
Commercial and civilian Environment	-Used in the E-commerce such as electronic payments anytime and anywhere environments[5]. -Used as road or accident guidance and it is used in transmission of road and weather conditions, taxi cab network, and inter-vehicle networks. - Used in sports stadiums, trade fairs, and shopping malls. It service as networks of visitors at airports.

Vehicular Networks (VANETs)	- Vehicles are equipped with wireless interfaces that enable them to communicate with each other (V2V) or with road-side fixed infrastructure (V2 I). - V2V communications allow vehicles to participate in vehicle coordination platforms as well as the routing of other communications - V2 I connectivity allow vehicles to obtain information about road conditions, traffic congestion or accident warnings - IEEE 1609 standards define architecture and a complementary, standardized set of services and interfaces that collectively enable secure V2V and V2I wireless communications.
In VANETs	- Main goal of planning InVANETs is to avoid vehicle crash so that can keep passengers as safe as possible. -Vehicles form MANET for communication using WiMax IEEE802.16 and WiFi 802.11
Wireless Personal Area Networks (PANs)	-Allows the proximal electronic devices with specific purposes, such as cameras, storage devices, televisions, mobile phones, or laptops, to dynamically share information through an autonomous home networks.
Body Area Networks (BANs)	-System of wireless medical sensors can be located in or around a human body operating as a health monitoring system. -BANs formed by medical sensors used in telemedicine systems
Wireless Sensor Networks (WSNs)	- Used to interconnect a set of low-cost and low-power sensor devices deployed in the environment or, alternatively, carried by animals. -These devices usually are embedded, for instance, in buildings, bridges, streets, on animals, or mountains and they are used to environmental or industrial monitoring and, more generally, to monitor events and phenomena
Smart Cities	-New scenario of the modern wireless communication where all the devices communicate via a common platform and thus can easily be controlled remotely
Mobile Conferencing	-Enable mobile conferencing for business users who need to collaborate outside their office where no network infrastructure is available -The users need to share documents, upload and download files, and exchange ideas
Internet of Things (IoT)	-Objects of everyday life will be equipped with micro-controllers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with one another and with the users becoming an integral part of the Internet easy access and interaction with a wide variety of devices such as, for instance, home appliances, surveillance cameras, monitoring sensors, actuators, displays, vehicles, and so on
Education	- Universities and campus settings - Virtual class rooms - Ad hoc communications during meetings or lectures
Entertain-ment	- Multi-user games - Wireless P2P networking - Outdoor internet access - Robotic pets - Theme parks
I MANETs	- Internet based mobile ad hoc networks - Are ad hoc networks that link mobile nodes and fixed Internet gateway nodes. For example, multiple sub
FANET	- Flying, mobile ad hoc network, mobile base stations is to mount them on flying vehicles like helicopters, hot air balloons or drones - In this approach, a subset of the base stations can be equipped with the necessary infrastructure to communicate with the ground base or satellite while the other base stations can simply transfer their data through this subset to the underlying network.

III. MANET CHARACTERISTICS

The study and development of infrastructure-less wireless networks have been very popular in recent years. MANETs may be constructed by any kind of wireless device equipped with radio transmitter and receiver, such as nodes maintain compatible radio interfaces (IEEE 802.11 Wi-Fi, IEEE 802.15 Bluetooth, IEEE 802.15.4 ZigBee, IEEE 802.16 WiMAX, etc.). Since these nodes are wireless devices and may be using battery power, they are completely autonomous. Therefore, they might move anywhere while still communicating each other. Both node mobility and heterogeneity are common characteristics of MANETs. In this kind of network, every node must be able to forward and route packets that belong to other transmissions. This decentralized routing is the key for the proper operation of the network. Figure (1) depicts the usual appearance of an self-configured or infrastructure-less MANETs ,where Figure (2) show the infrastructure based MANETs [6].

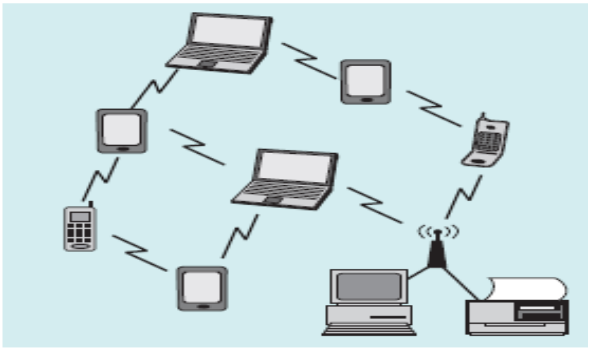

Fig (1): Infrastructure-less Network (Mobile Ad-Hoc Networks (MANETs)

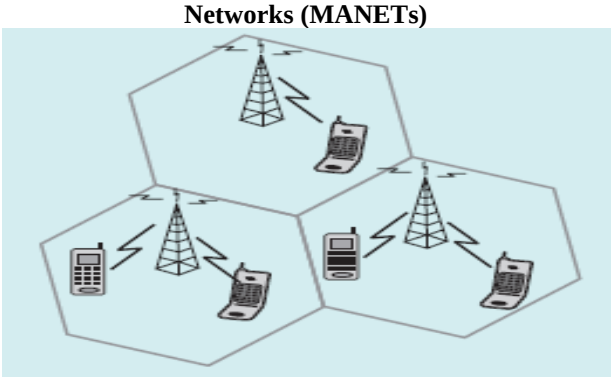

Fig (2): Infrastructure Network (Cell phone Network)

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As consequence we can mention most of the characteristics of MANETs as follows:

1. Infrastructure-less Nature:

MANET is formed based on the collaboration between independent peer-to-peer nodes to communicate with other nodes for a particular purpose[7]. No prior base station or organization is defined and all devices have the same role in the network. In addition, there are no pre-set roles such as routers or gateways as the nodes participating in the network are provided, each device can work as a node and router at the same time. That is, it is autonomous in behavior and nodal connectivity is intermittent.

2. Dynamic Topology

MANET nodes are free to move around; thus they could be in and out of the network, constantly changing their links and topology. In addition, the links between nodes could be bi-directional or unidirectional. This feature however causes high user density and large level of user mobility.

3. Bandwidth Constraints and Variable Link Capacity:

Wireless links that connect the MANET nodes have much smaller bandwidth than those with wires[7]. Due to the effects of multiple accesses, multipath fading, noise, congestion, fluctuation and signal interference,
the capacity of a wireless link can be degraded over time and the effective throughput may be less than the radio's maximum transmission capacity.

4. Multi-Hop Communications:

Due to signal propagation characteristics of wireless transceivers, MANETs require the support of multi hop communications[8]; that is, when a source node and destination node for a message is out of the radio range, the MANETs is capable of multi-hop routing for mobile nodes that cannot reach the destination node. A message from source node to destination node goes through multiple nodes because of limited transmission radius. Every node acts as a router and forwards packets from other nodes to facilitate multi-hop routing[9].

5. Constrained Resources (Light-Weight Terminals)

Most of the MANET devices are small hand-held devices ranging from laptops, smart phones and personal digital assistants (PDA) to cell phones. These devices have limited power (battery operated) processing capabilities and storage capacities.

6. Fluctuating Link Capacity

The nature of high bit-error rates of wireless connection might be more profound in a MANET. One end-to-end path can be shared by several sessions. The channel over which the terminals communicate is subjected to noise, fading, and interference, and has less bandwidth than a wired network. In some scenarios, the path between any pair of users can traverse multiple wireless links and the link themselves can be heterogeneous.

7. Limited Device Security

MANET devices are usually small and portable and are not restricted by location. As a result, these devices can be easily lost, damaged or stolen.

8. Limited Physical Security

Wireless links made MANET more susceptible to physical layer attackers, such as eavesdropping, jamming, spoofing and Denial of Service attack (DoS). However, the decentralized nature of MANET makes them better protected against single failure points. But in other side mobile wireless networks are more prone to threats than infra-structured networks. As in MANETs, all the networking functions like routing, packet forwarding are performed by the nodes itself, because of this reason securing a mobile wireless network is very challenging. The increased possibility of eavesdropping, spoofing and minimization of denial of-service type attacks should be carefully into consideration[10]. The distributed nature of operation of security, routing and host configuration cause to the absent of centralized firewall here.

9. Limited Device Security

MANET devices are usually small and portable and are not restricted by location. As a result, these devices can be easily lost, damaged or stolen.

10. Short Range Connectivity

MANET depends on radio frequency (RF) or infrared (IR) technology for connectivity, both of which are generally used for short range communications. Therefore, the nodes that wish to communicate directly need to be in close proximity to each other. To overcome this limitation, multi-hop routing techniques are used through intermediate nodes that act as routers to connect distant nodes. Since MANETs can be deployed rapidly without the support of a fixed infrastructure, they can be used in situations where temporary network connectivity is needed.

11. Distributed Operation:

There's no background network for the central control of the network operations, the control of the network is distributed on the list of nodes. The nodes involved in a MANET should cooperate with one another and communicate among themselves and each node acts as an exchange as needed, to implement specific functions such as routing and security[11].

12. Heterogeneity in Node and Link Capabilities:

Every node in the network may have one or more different radio interfaces which have varying transmitting and receiving capabilities, which operates on different frequency bands. This variation in the node radio capabilities leads to asymmetric links. Each node may also have different processing capabilities because of heterogeneity in software/hardware configuration. For such heterogeneous network, the design of protocols and algorithms is complicated, requiring dynamic adaptation to the changing conditions[10].

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IV. MANET CHALLENGES AND CURRENT ISSUES

Regardless of the attractive applications and different characteristics of MANET, we can introduce several challenges and issues that must be studied carefully before a wide commercial deployment can be expected. MANET environment has to overcome these issues and challenges. These challenges represent the open issues and unresolved problems. MANETs have been popular field of study during the last few years. Almost every aspect of the network has been explored in one way or another at different level of problem. The most important challenges and recent research trends of the MANET are mentioned bellow [5, 12-15]:

1. Limited Bandwidth

Wireless link continue to have significantly lower capacity than infrastructure networks. In addition, the realized throughput of wireless communication after accounting for the effect of multiple access, fading, noise, and interference conditions, etc., is often much less than a radio's maximum transmission rate.

2. Routing:

Routing is a significant point of view with researchers since routing protocols is essential issue in this field, because changes in network topology occur frequently. An efficient and intelligent routing protocol is required to cope with highly dynamic and fluid network conditions.

3. Routing Overhead

In MANETs, nodes often change their location and topology within network due to the dynamic nature of MANET. So, some stale routes are generated in the routing table which leads to unnecessary\`y routing overhead.

4. The Wireless Link Characteristics Are Time-Varying In Nature

There are transmission impediments like fading, path loss, blockage and interference that add to the susceptible behavior of wireless channels. The reliability of wireless transmission is resisted by different factors.

5. TCP/ UDP

TCP and UDP are the standard protocols used in the Internet. Applications running over MANET, such as http and real time audio/video need transport layer protocols like TCP and UDP to send packets over the links.

6. Route Changes Due To Mobility

The network topology in an ad hoc wireless network is highly dynamic due to the movement of nodes; hence an on-going session suffers frequent path breaks. This situation often leads to frequent route changes.

7. Dynamic Topology

Dynamic topology membership may disturb the trust relationship among nodes. The trust may also be disturbed if some nodes are detected as compromised.

8. IP Addressing

One of the most important issues is the set of IP addresses that are assigned to the ad-hoc network. IP addressing and address auto configuration have attracted much attention in MANETs.

9. Multiple Accesses

A major issue is to develop efficient medium access protocols that optimize spectral reuse, and hence, maximize aggregate channel utilization in MANETs.

10. Battery Constraints

Devices used in these networks have restrictions on the power source in order to maintain portability, size and weight of the device.

11. Radio Interface

Mobile nodes rely on the radio interface or antenna to transmit packets. Packet forwarding or receiving via radio interface or antenna techniques in MANETs are useful investigations.

12. Power Management

A power management approach would help reducing power consumption and hence prolonging the battery life of mobile nodes. Because most devices operate on batteries, power management becomes an important issue.

13. Frequent Network Partitions

The random movement of nodes often leads to partition of the network. This mostly affects the intermediate nodes.

14. Packet Losses Due to Transmission Errors

The Ad hoc wireless networks experiences a much higher packet loss due to factors such as increased collisions due to the presence of hidden terminals, presence of interference, uni-directional links, and frequent path breaks due to mobility of nodes.

15. Hidden Terminal Problem

The hidden terminal problem refers to the collision of packets at a receiving node due to the simultaneous transmission of those nodes that are not within the direct transmission range of the sender, but are within the transmission range of the receiver.

16. Security Threats

The wireless mobile ad hoc nature of MANETs brings new security challenges to the network design. As the wireless medium is vulnerable to eavesdropping and ad hoc network functionality is established through node cooperation, mobile ad hoc networks are intrinsically exposed to numerous security attacks.

17. Multicasting and Geo-Casting

Multicast service supports users communicating with other members in a multicast group. Broadcast service supports users communicating with all members on a network.

18. Location Service:

Location information uses the Global Positioning System (GPS) or the network based geo-location technique to obtain the physical position of a destination.

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19. Clustering:

Clustering is a method to partition the hosts into several clusters and provide a convenient framework for resource management, routing and virtual circuit support.

20. QoS/ Multimedia

Quality of Service (QoS) and Multimedia require high bandwidth, low delay, and high reliability.

21. Fault Tolerance

This issue involves detecting and correcting faults when network failures occur. Fault-tolerance techniques are brought in for maintenance when a failure occurs during node movement, joining, or leaving the network.

22. Diffusion Hole Problem:

The nodes located on boundaries of holes may suffer from excessive energy consumption since the geographic routing tends to delivers data packets along the whole boundaries by perimeter routing if it needs to bypass the hole. This can enlarge the hole because of excessive energy consumption of the node boundaries nodes.

23. Device Discovery:

Identifying relevant newly moved in nodes and informing about their existence need dynamic update to facilitate automatic optimal route selection.

24. Inter-Networking:

In addition to the communication within an ad hoc network, inter-networking between MANET and fixed networks (mainly IP based) is often expected in many cases. The coexistence of routing protocols in such a mobile device is a challenge for the harmonious mobility management.

25. Topology Maintenance:

Updating information of dynamic links among nodes in MANETs is major challenging issue.

26. Robustness and Reliability:

Misbehaving nodes and unreliable links can have a severe impact on overall network performance. Due to the lack of centralized monitoring and management mechanisms, these types of misbehaviors cannot be detected and isolated quickly and easily. This increases the design complexity significantly.

27. Heterogeneity

The Heterogeneous Ad Hoc Networks (HANETs) are Important components of the Internet of things (IoT), which become an inevitable trend in the future researches and applications. In recent years, the ad hoc networks have been widely employed in many fields, especially in environment monitoring, weapon control, intelligent transportation, smart city and other domains[16].

V. SCOPE FOR FUTURE RESEARCH

The successful deployment and exploitation of MANET in practice are becoming quite a formidable task. However, the design and analysis of a reliable MANET introduces a formidable challenge since the required knowledge encompasses a whole range of topics viz., network complexity, routing optimization issues, QoS, scalability, heterogeneity, clustering, security ,reliability ,bandwidth management, mobility management etc[17]. In this context we are try to demonstrate some of the research directions in the future run related to some unresolved problems that we are expected that the coming in research efforts will overcome these topics.

1. Secure Routing Protocols With Qos–Aware:

More and more efficient routing protocols for MANET might come in front in the coming future, which might take security and QoS (Quality of Service) as the major concerns. So far, the routing protocols mainly focused on the methods of routing, but in future a secured but QoS-aware routing protocol could be worked on. Ensuring both of these parameters at the same time might be difficult. A very secure routing protocol surely incurs more overhead for routing, which might degrade the QoS level. So an optimal trade-off between these two parameters could be searched[18].

2. Multicast Routing with QoS-Aware:

In the recent years some multicast routing protocols have been proposed. The reason for the growing importance of multicast is that this strategy could be used as a means to reduce bandwidth utilization for mass distribution of data. As there is a pressing need to conserve scarce bandwidth over wireless media, it is natural that multicast routing should receive some attention for MANETs. So it is, in most of the cases, advantageous to use multicast rather than multiple unicast, especially in MANET environment where bandwidth comes at a premium. MANETs find applications in civilian operations (collaborative and distributed computing) emergency search and-rescue, law enforcement, and warfare situations, where setting up and maintaining a communication infrastructure is very difficult. In all these applications, communication and coordination among a given set of nodes are necessary. Considering all these, in future the routing protocols might especially emphasize the support for multicasting in the network.

3. HANET:

A network formed by connecting devices with different capabilities (like mobile phones, mobile electronic devices) must be able to exchange messages with one another in a consistent and unified way. This way of connecting different devices with some dedicated potential roles is heterogeneity. Device specifications like memory, storage space, and processor speed vary significantly among them which make it difficult to implement a uniform programming interface on all nodes[17]. HANETs have become a critical research field, which consists of Wireless Sensor Networks (WSN), wireless fidelity networks (Wi-Fi) or (Wi-MAX), telecommunication networks and other smart ad hoc networks. Researchers devote themselves to improve the performance of HANETs in recent years. With large-scale deployment of smart devices, HANETs are applied to various scenarios.

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However to improve the communication performance among smart terminals is an important research topic, such as self-organizing protocols, energy saving and security mechanisms in HANETs.

4. Geo-Protocols:

With the growing popularity of positioning devices, geographic routing protocols are one of the choices for use in MANETs. Periodic broadcasting of packets that contain the geographic location coordinates of the nodes is a popular method used by most Geographic routing (GEO) protocols to maintain neighbor positions. Ultimate aim is to reduce the energy consumption and receive more packets at minimum end to end delay with adaptive position updates. In addition, Enhance Adaptive Position Update (E-PU) scheme dynamically gives better solution for node movements. Mean while we can list some of the hot areas of open research that will overcome MANET inherent features such as the high mobility, dynamic topology, scalability, location services and to some extend the heterogeneity as follows:

a) Energy Based Geographic Routing in MANETs.
b) Clustering with Energy Efficient routing protocols.
c) QoS support video streaming applications, and operating in an energy-efficient way.
d) Multicasting and cross-layer Design to support real-time video transmissions.

VI. CONCLUSION AND FUTURE WORKS

This paper presents a comprehensive survey and overview of the recent application scenarios.
Of MANET. In addition we focus on the most important characteristics and challenges facing the deployment of MANETs. Also this review paper provides the recent direction of research works related to MANETs that will help to invent and produce new products of applications that has an impact in different areas such as military, education, video streaming, real-time video games , health care and monitoring and IoT applications.

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