Study of Ad hoc Wireless Network: An Overview

Vikrant B. Joshi
Research Scholar
Raisoni Centre of research and Innovation
G H Raisoni University, Amravati.
vikrant.joshi@rediffmail.com

Dr. Prabhat Chandra Shrivastava
Professor
Raisoni Centre of research and Innovation
G H Raisoni University, Amravati
prabhatphd@gmail.com

Dr. Sanjeev Kumar Srivastava
Associate Professor
Pillai College of engineering, Panvel.
sanjeevkumar.srivastava1@gmail.com

***Abstract*—An ad hoc wireless network is an infrastructure less network (without access points and base station) consisting of a group of wireless terminals, which uses a wireless communication channel to communicate with each other. The ad hoc wireless network establishment takes place in a decentralized manner with the help of distributed nodes. The nodes acts as the main pillar of network as they themself perform routing and security functions. Therefore, the main driving force of the ad hoc wireless networks is the nodes itself. Mobile ad hoc network (MANET) is a type of ad hoc wireless network in which the mobile nodes are arbitrarily and dynamically located in such a manner that their position keeps on changing with respect to each other. This kind of network deployment has challenges corresponding to routing, security, quality of service (QoS) similarly it also offers opportunities for research in the areas related to mobility, security, routing, coordination and scalability. In this paper, we have surveyed the latest research work in Ad-hoc networks and presented the challenges and future directions. In addition, we have identified a key area to improve the overall performance of the network. We believe our work will be useful to all researchers and engineers working in this domain.**

***Index Terms*—MANET, DOD, PRNET, SURAN, GlOMO, NTDR, FHSS, DSSS, SAP, DSDV, AODV, DSR.**

I. Introduction

The word ad hoc represents "for this (only)" in Latin so in terms of networks, the ad hoc wireless networks mean instant networks not having any infrastructure. In an infrastructure based wireless networks data exchange between the nodes or devices takes place through access point (which is known as base station in GSM). Thus the access point serves as a central connection point. The access point only serves a dedicated network area and only those nodes which fall under this area are allowed to use access point's services. The biggest disadvantage in such a network is that the failure of access point makes the nodes connected in the network purposeless as it is impossible to install a new access point in a short time. The other factor associated with infrastructure based wireless networks is their high cost factor. Thus it is necessary to make the nodes independent of access point so that the nodes can build their own temporary network. This network is known as ad hoc wireless network. In ad hoc wireless network the nodes itself acts as transceiver as they must be in a position to arrange their own network as the network is infrastructure less network. Ad hoc wireless networks are not powerful networks as a node can only communicate with the nodes which falls in its own transmission range(each node has its own transmission range). In the infrastructure based wireless network, the nodes can have communication with other node, which is outside its network area. In an ad hoc wireless networks a proper routing scheme is necessary for data transmission as nodes transmit their data with a single or multiple hopping technique. This paper is going to contribute to the existing literature on ad hoc wireless networks especially MANET, by providing information on MANET related to their structure, routing, mobility, scalability, security and applications.

The paper is structured as follows Section I Introduction to ad hoc wireless network which is already presented above, Section II Introduces to related work in ad hoc networks, Section III Describes about architecture of ad hoc wireless network, Section IV. Application of ad hoc wireless network, Section V. Describes about ad hoc wireless network components, Section VI. and Section VII. Speaks about the merits and demerits of ad hoc wireless networks, Section VIII. Conclusion of the paper.

II. Related Work

The journey of ad hoc wireless networks started in the year 1972 when the defense department (DOD) of USA financed Packet Radio Network (PRNET) project which came to be known later as Survivable Adaptive Radio Networks(SURAN)[1]. The primary objective of this project was to established a communication link in the form of infrastructure less networks based on packet switching framework for deployment in sensitive and hostile zones. For establishment of such networks having proper packet switching coordination is essential which is accomplished by having control over medium access. For medium access the PRNET uses combination of ALOHA and CSMA methods and is a type of vector routing which takes into consideration the distance of communication. Due to the use of high scalability link state routing protocols survivable adaptive radio networks significantly proved to be better on the radios (smaller in size, low cost, power frugal), due to expandability of algorithms, and its pliability to electronic attacks.

In 1990s there was significant enhancement in ad hoc networking because of new developments, such as communication devices based on infrared and RF , Notebook computers.

The concept of an Ad hoc wireless network was suggested in two conference papers [2,3], and the term "ad hoc networks"

was accepted by IEEE 802.11 subcommittee. Few other commercial applications of ad hoc networking were introduced.

During same period, the DOD continued, funding programs such as the near term Digital Radio (NTDR), the Global Mobile Information Systems (GlOMO), the objective of GlOMO was to provide multimedia connectivity in transportable units.

Channel access propositions were now in the TDMA and CSMA/CA molds, and many new routing and topology control plans were developed. The NTDR based on clustering and link state routing, and self-organized into a two tier ad hoc network. NTDR is the only "real" (non-prototypical) ad hoc network used by US army.

During halfway to late 90s, the increased curiosity in ad hoc networks, encouraged to evolved a number of standards activities and commercial standards. To systematized routing protocols for ad hoc wireless networks ,the MANET team was form ,within IETF. The routing protocols were classified as proactive (routes ready-to-use) and reactive (routes on demand) [4].

The medium access protocol was also standardized by 802.11 Subcommittee considering tolerable hidden nodes and collision avoidance , making it suitable for developing mobile ad hoc network prototypes using notebooks and 802.11 PCMCIA cards.

Few other standards which benefited and addressed ad hoc networking were HIPERLAN and Bluetooth .

Table1: Dissimilarities between Infrastructure and Infrastructure less networks.

Infrastructure networks	Infrastructure less Networks
Stable, pre-determined cell location and access points	No access point, quick deployment
Static backbone network topology	most dynamic network topologies with multi-hop
Comparatively natured environment and, firm connectivity	Hostile environment (losses, noise) and sporadic connectivity.
Detailed planning required before base stations installation.	Ad hoc network automatically forms and adapts to changes.
Large scalability	Limited scalability
No network resource constraint	Network resource constraint

III. ARCHITECTURE

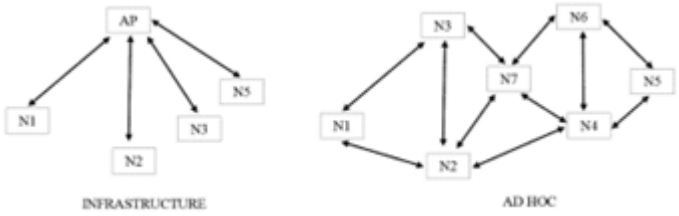

Fig.1. Infrastructure Vs Ad Hoc wireless network

Based on their system architecture wireless networks are classified into two types [5]. First type is infrastructure networks and other is ad hoc wireless network as seen in Figure 1. The major difference between these two types is that infrastructure networks always have an access point alongwith terminals or nodes, However infrastructure less or ad hoc wireless networks are without access point.

Direct communication between the nodes within the cell or other cell is not possible in the infrastructure network. Thus an access point needs to be established which plays an important role. Data is first forwarded to the base station (or access point) and then to the destination node via base station (or access point).

If a node terminal wants to initiate the process of communication with an another node terminal, that lie outside its transmission range (cell), then the base station (AP) of that cell will forward the data to base station (AP) of other cell, having control over identified cell. These base station (AP) are normally cable connected. The main drawback of infrastructure network is that if the base station (AP) fails, all nodes in that cell loses the connectivity and can't communicate. Where as there are different ways to forward the data in ad hoc wireless networks.

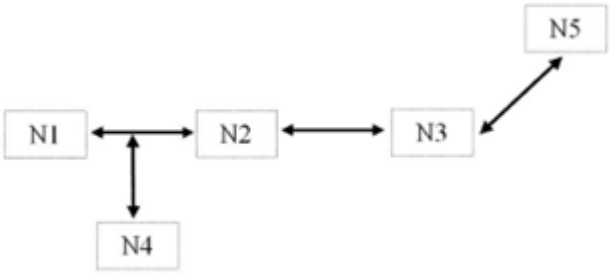

Fig.2. Communication in adhoc wireless network.

Consider a network as shown in Figure 2 if N1 desire to send some information to N5 and if N5 is situated outside transmission range of N1, then N1 must hop the message to N4 to N2 toN3 to N5 or N2 to N3 to N5. Normally routing algorithm decides the best route to perform communication or data transfer. Now even if N4 leaves the network there will not be any problem, as N1 still has an alternate route to communicate with N5. That is why ad hoc networks are considered robust than infrastructure networks.

1) Use of IEEE 802.11 standard: The IEEE Standard 802.11 (IEEE, 1999) narrates regular family of wireless LANs [5]. It explains medium access control (MAC) and physical layer (PHY) of wireless transmission. Its purpose was to define the specification for simple and strong license free wireless LAN communication by supporting energy saving with taking into consideration the mobility of the terminal along with its hidden node.

I. physical layer: The 802.11 standards supports three types of physical layer. One of them is infrared, and other two are based on radio data transmission at 2 and 4 GHz. These are Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS) which uses Clear Assessment (CCA) signal to inform medium status. It also came up with Service Access Point (SAP) supporting digital information rate of 1 - 2 Mbit/s. The infrared communication works in the wavelength ranging from 850-950 nm with in a distance of approximately 10m . Thus they are suitable for smaller room, as they can be blocked easily with the help of a thin paper they can not be used outside the room.In FHSS technique total bandwidth is divided into smaller bandwidths. The Tx and Rx switches to other narrow channel periodically. FHSS uses both FDM and TDM and It is further classified as slow hopping and fast hopping.

If sender uses one frequency for one or more bits time duration then it is called as slow hopping and when the transmitter changes frequencies while sending a single bit it is called as fast hopping.

A DSSS method straight away acts on the data by X-ORing it with the chip-sequence. The DSSS [6] resemble coincidental noise based on the method used for the generation of the Chipping sequence, hence occasionally called pseudo noise sequence. The bandwith resultant signal depends on spreading factor (s = tb/tc). If signal bandwidth is w, then the range of spread signal is given by s.w.

II. MAC Layer: MAC layer is accountable for control the media access. It also helps for power management, and roaming. Its basic services are optional time-bounded service and asynchronous data service. The 802.11 Standard defined for ad hoc network supports only asynchronous data service. The IEEE Standard 802.11explains three access methods which are [5].

A) CSMA/CA with DFWMAC:

- This .is mandatory for every IEEE-802.11 execution
- Process based on Randomized “back-off” model for Collision avoidance.
- Least distance between succeeding packets.
- Use of acknowledgements (ACK) packet (for non broadcasts use).

B) Use of RTS/CTS along with DFWMAC:

- Not complusory.
- Distributed Foundation Wireless MAC (DFWMAC).
- Address the issue of hidden node.

C) DFWMAC with polling:

- Not mandatory.
- Access point polls nodes as per the list.

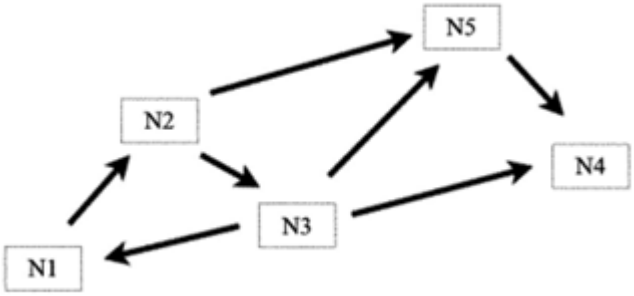

Fig.3. Asymmetric Link.

2) Role of Routing protocols in infrastructureless Networks: Routing algorithm plays a vital role in in a ad hoc wireless network. The cellular network and WLAN are also wireless networks which are supported with infrastructure. Such networks fare with a cell set up where each terminal in the cell can be access by infrastructure. Hence terminal in the cell can communicate with another terminal in cell through infrastructure and without single- or multi-hop.

When the terminal is located in other cell, the infrastructure can pass on to another station, where the destination terminal is situated. On contrary the ad hoc wireless network works independently. A destination terminal can be situated beyond transmission range. In this situation networks requires a routing, to estimate a path from a Transmitter to a receiver. The Figure 3 shows asymmetric ad hoc wireless network topology. The node N1 wish to send a data to node N5, the route is N1 to N2 to N5. Now N5 needs to send an acknowledge when it receives the data. Now N5 has information, about path used by N1. But as shown in fig 3 ,there is no possible path for N1. Such situation frequently happens in ad hoc wireless networks. The above example shows the basic difference in Infrastructure and infrastructure less network. Some of the other routing issues related to ad hoc wireless networks are,

1) **Asymmetric link**: When a terminal A can hear a signal from terminal B ,that does not mean, that terminal B can also hear a signal from A. This might be because of weak signal from A , hence B can’t hear signal from A. So A can not send a packet directly to B, So A has to find out some path to communicate with B. Such a communication pattern is known as asymmetric connection framework. A large number of routing algorithms are based on such asymmetric connection framework.
2) **Redundant connection:** communication links in wireless ad hoc networks must have provision for back-up paths to retrieve the network from communication link failures. Networks with large number of back-up paths is look forward to perform strong even in the case of communication link failures. A balance needs to be achieved between back-up paths and link failures as it adds to network delay since the routing protocol has to deal with the process of periodically updating the routing information database.

3) **Interference:** As wireless networks are not using any cable for data communication, thus data transmission with wave is at risk due to interference caused by different external factors (i.e. scattering, shadowing, weather etc.). Also when two wireless terminals, are in closed vicinity with each other, they end up disturbing themselves.
4) **Dynamic topology:** Since in ad hoc wireless network terminals are allowed to move freely ,they can make or break with the network easily. This requires terminals to update their routing table.

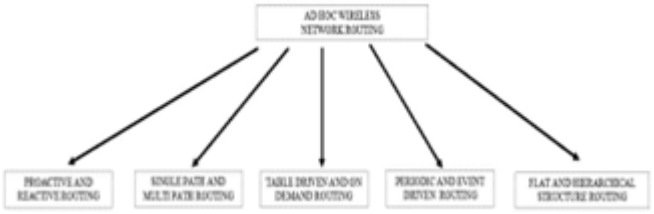

Fig.4. Types of routing in ad hoc wireless networks.

Hence there are various conditions (ie like how paths are computed and how routing information is exchanged etc) for categorizing and designing the routing protocols to be used for ad hoc wireless networks. [7]

As described in the Figure 4 types of routing in ad hoc wireless networks are as follows :

- Reactive and Proactive Routing: In case of Proactive routing method paths to different terminals are calculated. So whenever terminal need to communicate it can use the desire path.
  Example: Destination Sequenced Distance Vector (DSDV).
  In case of reactive routing the path is discovered as an when need arises when terminal wants to communicate with other terminal. Hence reactive routing method has less routing overheads
  Example: Dynamic Source Routing (DSR), Ad Hoc on Demand Distance Vector (AODV)
- Single path and Multi path : The ad hoc wireless network can have redundant connection, as they can recover link failures. Data throughput is better with redundant connections but leads to more overhead and multipath than single path routing.
- Table driven and on demand routing :In case of table driven protocol route information from each terminal to every other terminal is updated. Change in topology is also updated. Whereas in On demand routing the terminal is not updated with route information, as terminal calculate the routing when they wants to communicate with other terminal.
- Periodic and Event Driven:In Periodical update protocol routing information is disperse intermittently. These updates are utilize to maintain network consistency. These periodic update results in overhead.
- Flat and Hierarchical Structure :When each terminals in the networks is at same level having same routing configuration then it is referred as Flat structure. Such a structure is suitable for smaller network because when network expands it takes more time for routing information to reach at the destination terminal. Whereas when terminals are assembled in smaller group known as clusters and these clusters are arranged again in larger groups known as super clusters and so on.

IV. APPLICATION

Ad hoc wireless network has wide range of application. It is more useful when it not possible to develop infrastructure network or impossible to build it. These networks are more popular now a days as it supports mobility and freedom . Thus without using access point, portable memory or cables data can be now exchanged. Many manufactures of mobile phone and computers now a days provides ad hoc technology. Few applications are discussed below

1) Military Application: The ad hoc wireless network was initially developed for military use only[8],because in the battlefield where large number soldiers are present it impossible to have an infrastructure or provide cable connected transmitters to individual soldier. So the only option is to provide each soldier with wireless transmitter to communicate with each other. Such arrangement is not suitable for military application, because only one node can use only one channel for communication and enemy can intercept it. So in such situations ad hoc wireless network are very much useful, as every soldier is now provided with transmitter having smaller coverage area to communicate with few other soldiers. However each of these transmitter is now capable of relaying messages in single or multiple hop fashion. This type of ad hoc wireless network are tough to intercept, robust and are useful for military applications.
2) Emergency and mission deliverance :Consider a post-earthquake scenario ,where communication infrastructure is completely collapsed. Now establishing a communication network is on top priority. such network should be easy to deploy, maintain and capable to adapt dynamic topology in term of number of particpants [9] . Ad hoc wireless network is useful in such situations, as it is easy to set up and does not require any infrastructure component and it is easy to be removed once the infrastructure setup is ready.

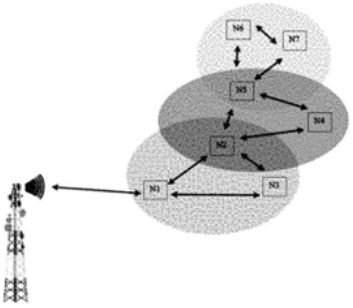

Fig.4. Piconet network.

3) PAN and Bluetooth: The concept of personal area network(PAN) is to provide a local network of various network terminal belonging to one person [10]. Such a wireless network is built up with Bluetooth technology,having small area coverage (10m -100m) also known as Piconet. These operates in unlicensed 2.4 GHz spectrum[11].This piconet network works with principle of one master node and many active slave nodes. Piconet can work on large scale as shown in fig 2 but master can not work as master of two or more piconet.[5]
4) Wireless sensor networks: Wireless sensor network (WSN) is convergence of three technologies :sensing, Networking and wirelessly communicating [8]. It consists of many sensor terminals ,each having a wireless transceiver. The two important role of transceiver are, one to work as a sensor to measure and/or sense various parameters and second to work as network to relay collected information to data sinks.
5) Wireless mesh networks(WMN): It has two terminal mesh routers and mesh clients[8]. mesh routers generally can not move as they are provided with power supply, their role is to perform single hop or multi hop routing. Mesh clients are linked with users , and can be mobile or stationary.it is similar to mobile phones used in GSM . if Mesh a clients wants to communicate with other mesh client ,then said communication takes place via mesh routers .Example are Metropolitan Area Networks (MANs) and Local Area Networks (LANs)

V. NETWORK COMPONENTS

As discussed above the ad hoc wireless networks are used in difficult situations where infrastructure network is not existing or can't be build. So adhoc wireless networks must be simple and easy to be deployed, this requires proper planning and coordination as the end terminals used in ad hoc wireless network are more complicated as compare to infrastructure network. Following section describes components of ad hoc wireless network.

1) Hardware: As ad hoc wireless networks are infrastructure less, only they are amalgamated with different network's type. Since it only needs end terminals to establish itself ,each terminal must have transceiver to receive and transmit a signal and should be IEEE802.11 standard compatible. Generally Personal Digital Assistant (PDA), laptops and smart phone are accomplished with IEEE 802.11 standards so they can be a part of infrastructure or ad hoc wireless networks.
2) Software: The software component i.e. Routing algorithms plays a vital role in ad hoc wireless networks. Commonly used routing algorithms are
   - Destination-Sequenced Distance-Vector (DSDV)
   - Dynamic Source Routing (DSR)
   - Ad Hoc on-Demand Distance-Vector (AODV)

   a) Destination-Sequenced Distance-Vector (DSDV): Extended version of Distance Vector Routing is DSDV, which based on table-driven routing algorithm used for ad hoc wireless mobile networks[12]. It uses distance vector method which works on principle of Distributed Bellman-Ford algorithm. Performance of this algorithm with dynamic topology is not good, since it has count-to-infinity problem. In order to update with actual topology , terminals have to swap their routing table constantly.

b) Dynamic Source Routing (DSR) : In the DSR protocol path discovery process begins when a transmitting terminal desires to connect with other terminal. DSR performs following steps to find the path [13]: – finding the path: A terminal tries to discover a path to its destination ,if at that instant no known path is available . – maintaining the path: The discovered path need to be maintained. If any terminal in the path has problem then sender must discover new path.

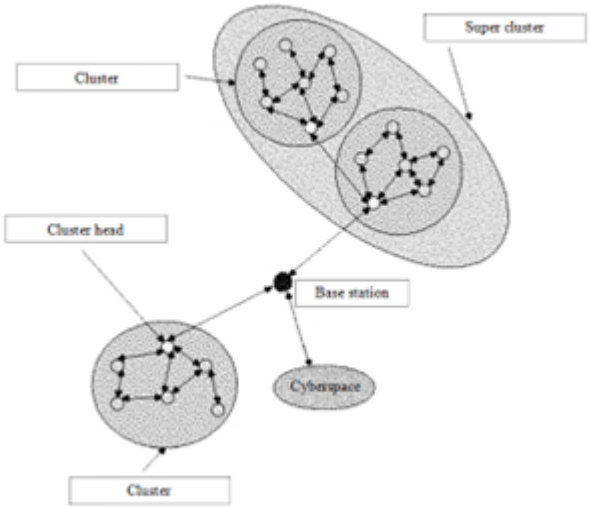

Fig.5. Clustering [15].

c) Ad Hoc On-Demand Distance-Vector (AODV): The AODV based routing method is somewhat identical to DSR based routing method in a sense that the process of route discovery is initiated whenever a transmitting terminal ask for it. Hence it is an on demand route discovery method. AODV based routing method make use of four different type of routing messages for ascertaining state of network terminals in order to instigate the process of route discovery. The primary objective of these messages is to implement path discovery and path maintenance functions in ad hoc wireless network routing. Route Request message (RREQ), Route Reply message (RREP), Route Reply Acknowledgment message (RREP-ACK) and Route Error message (RERR) are four different type of routing messages. Out of these Route Request mes-

sage (RREQ), Route Reply message (RREP) and Route Reply Acknowledgment message (RREP-ACK) are used to perform the route discovery operation were as Route Error message (RERR) is utilize for performing route maintenance operation [14].

d) Cluster Based Networks: All the three algorithm DSR,DSDV and AODV are used when number of terminals in networks are limited and also routing performance gets affected with high mobility of the terminals. For large number of terminals in the network ,smaller group of terminals can be formed as shown in fig 6.the main purpose of forming a set of terminal is to minimize the total updates due to dynamic topology.

VI. MERITS

Few important advantages of ad hoc wireless network are listed below:

1) infrastructure less and lower cost: In some situations, when the end user can not rely on infrastructure of communication systems[5]and also the use of infrastructure based communication becomes costly in such a scenario there is need of Ad hoc wireless network. A hilly area or desert region where it is difficult to establish an infrastructure based network and also if we analyze the service usability and data usage per day in such regions then the cost of infrastructure installation and repair, maintenance seems to be too expensive. Similarly in military application we can't establish infrastructure in battlefield. It will be too costly and also it can be easily destroyed by enemy so in such situation there is need of Ad hoc wireless network.
2) b. Mobility (MANET only): With advancement in wireless communication technology, in future there will be a need of quick roll out and self- reliant user network systems for emergency applications[16]. Some of these scenario include Disaster management, military application, emergency rescue operations, in these situations centralized communication system is not useful hence in such situations MANET can play an important role by providing communication till mobile destination device is accessible.
3) Distributed and robust: The main feature of adhoc wireless network is that they are robust[8]. Consider a situation that the access point in the network is not functioning then all the terminals using that access point will not have any connectivity with each other. An adhoc wireless network overcomes this difficulty , if any terminal leaves or not working then also source terminal can communicate with destination terminal through multi-hop, as long as communication path is available.
4) Simple to deploy and unstructured infrastructure: Breakdown of network infrastructure is sometime unavoidable and it is also difficult to restore or substitute infrastructure in small span of time. So use of ad hoc wireless network is better option. Participating terminals can act as adhoc nodes and hop the data.

VII. DEMERITS

There are few limitations of Ad hoc wireless network.

1) Higher error rate: Since wireless communication takes place using electromagnetic waves, their characteristic is concern. There is hardly any situation when electronic wave propagation takes place independently without any obstacle [5]. The obstacle results in, scattering, reflection, refraction, fading, diffraction of the wave. This results in higher error rate.
2) Lower data rate: Lower data rates is one of the key issue with ad hoc wireless network. In comparison with wired network ,the characteristics of wave used in wireless network communication restricts the higher data rates. The higher frequencies are more vulnerable to interference.
3) Dynamic topology and scalability: In wireless ad hoc network the terminals are mobile, so the routing data changes as terminal advances. The terminal has to send updated information to all the terminals in the network. Periodically Control messages are send in the network, this adds burden on bandwidth. So protocol for ad hoc wireless network are developed ,which also keeps updated information, with less number of control messages. Hence a good algorithm must be able to assess and balance scalability [10] of network with increased number of terminals and their mobility. Number of control messages used are also important since it affects the bandwidth.
4) Security: As ad hoc wireless network are infrastructure less, dynamically distributed and without any centralized observing unit, these are more vulnerable to different types of attacks[17]. Wireless channel used in ad hoc network is accessible to user and also to intruder, so they are more susceptible to active and passive attacks. Also due to power constraints and computation capabilities it is difficult to use heavy algorithm like public key. In active attack intruder can delete packet, modify packet and add packet, such type of attacks can be detected. In passive attack [18] intruder just listen the messages, these are difficult to detect. Different types of security issues of 802.11 are :
    a) Traffic analysis (passive): In this intruder observes transmission to know communication patterns.
    b) Masquerading (active): In this the intruder pretends to an permitted user and try to get access or to get additional facilities for which they are not entitled.
    c) Eavesdropping (passive), In this intruder is listening communication between two terminals.
    d) Replay (active), In this intruder spies communication and resends the message as the authentic operator.

e) Message alteration (active), In this the intruder modifies an initial message by adding to or by deleting.
f) Stoppage or Break in service (active), In this the intruder obstruct the regular use or controlling communication, the attacker stops or forbids the routine usage or management of communications provisions.

5) Power limitation (MANET only): In the MANET network there is no fixed infrastructure and the communicating nodes are mobile. So they are using battery power, that is why algorithm used must be energy-efficient and operating with minimum processing and memory resourses.[19]. Since terminals can not sacrify energy to operate at full link speed there is limitation on bandwidth usage. Some time receiving data from some node, on PDA, the battery gets exhausted, so retransmission of data is necessary after recharging. This makes clear that MANET can not be permanent Network.

VIII. CONCLUSION

The communication exchange in current infrastructure based wireless networks (cellular phone networks, wireless LANs,) takes place through an access point (wireless router). The dependency of the network on the access point makes the network centralized, this affects the network flexibility. Moreover defects in access point leads to failure of the network as nodes in the cell are not in the position to communicate again until a new access point is reestablished this add to the network cost. To overcome this infrastructure's drawback establishment of a temporary network becomes necessity. Thus we could make use of ad hoc wireless networks as they are flexible networks which are independent from infrastructure (access point). Mobility of the terminals in ad hoc wireless network affects its topology making the network asymmetric. This affects the network security, error rate, and throughput. As ad hoc wireless networks are likely to play a prominent role in the future there arises a need to developed an appropriate routing algorithms which can take into consideration node mobility and changes in topology.

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