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# Study of Impact of Mobile Ad – Hoc Networking and its Future Applications

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**Abstract -** *Today, many people carry numerous portable devices, such as laptops, mobile phones, PDAs and mp3 players, for use in their professional and private lives. For the most part, these devices are used separately-that is, their applications do not interact. Imagine, however, if they could interact directly: participants at a meeting could share documents or presentations; all communication could automatically be routed through the wireless corporate campus network. These examples of spontaneous, ad hoc wireless communication between devices might be loosely defined as a scheme, often referred to as ad hoc networking, which allows devices to establish communication, anytime and anywhere without the aid of a central infrastructure.*

*This paper describes the concept of mobile ad hoc networking (MANET) and points out some of its applications that can be envisioned for future. Also, the paper presents two of the technical challenges MANET poses, which include Geocasting and QoS.*

**Index Terms -** *Ad hoc networking, MANET, MIPMANET, Personal Area Network (PAN), Bluetooth technology, QoS, Geocasting.*

## 1. INTRODUCTION

A Mobile Ad-hoc NETwork (MANET), also known as Mobile Packet Radio Networking, is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing infrastructure or centralized administration. Since the nodes in a network of this kind can serve as routers and hosts, they can forward packets on behalf of other nodes and run user applications.

MANETs are networks in which mobile routers are connected via wireless links forming dynamic topologies. An important function of network management in a MANET is to observe network conditions: at the node level, this may mean keeping track of the traffic load; at the network level, the system must monitor active routes and changes in the network topology. [1]

MANETs have their own advantages such as high robustness and ease to set up despite the resource constraints like limited bandwidth and power. Typical applications of MANETs are in tactical networking and disaster recovery operations. Recently, the rising popularity of multimedia applications among end users in various networks and the potential usage of MANETs in civilian life have led to research interest in providing QoS support in MANETs. It is a huge challenge to provide QoS in MANETs. A network's ability to provide a specified quality of service between a set of endpoints depends upon the inherent properties such as delay, throughput, loss rate, error rates of links and nodes, etc.

Many mobile phones and other electronic devices already are or will soon be Bluetooth-enabled. Consequently, the ground for building more complex ad hoc networks is being laid. In terms of market acceptance, the realization of a critical mass is certainly positive. But perhaps even more positive- as relates to the end-user- is that consumers of Bluetooth-enabled devices obtain a lot of as-yet unraveled ad hoc functionality at virtually no cost.

The purpose of this paper is to propose technological requirements for the successful working of MANETs. The main features of the proposal are (1) to show efficient routing algorithms as a necessity to develop MANETs and (2) to provide excellent quality of service (QoS).

The remainder of the paper is structured as follows in the form of five sections. First Section reviews the background of ad hoc networking. Second Section describes the MANET technology. Third Section elaborates on Mobile IP for mobile ad hoc networks (MIPMANET). Fourth Section focuses on some of the significant applications of MANETs. Fifth Section provides the technological requirements for the development of an ad hoc network and proposes the importance of QoS and Geocasting in MANETs.

## 2. HISTORY OF AD-HOC NETWORKING

The roots of ad hoc networking can be traced back as far as 1968, when work on the ALOHA network was initiated (the objective of this network was to connect educational facilities in Hawaii). Although fixed stations were employed, the ALOHA protocol lent itself to distributed channel-access management and hence provided a basis for the subsequent development of distributed channel-access schemes that were suitable for ad hoc networking. The ALOHA protocol itself was a single-hop protocol, that is, it did not inherently support routing. Instead every node had to be within reach of all other participating nodes.

Mobile Ad Hoc Network is a name currently being given to a technology under development for the past 20 or so years, principally through research funding sponsored by the U.S. Government. Its initial sponsors included the Defense Advanced Research Projects Agency (DARPA), the U.S. Army and the Office of Naval Research (ONR). [8]

Inspired by the ALOHA network and the early development of fixed network packet switching, Defense Advanced Research

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Projects Agency (DARPA) began work, in 1973, on the PRnet (packet radio network)-a multihop network. In this context, multihopping means that nodes cooperated to relay traffic on behalf of one another to reach distant stations that would otherwise have been out of range. PRnet provided mechanisms for managing operation centrally as well as on a distributed basis. As an additional benefit, it was realized that multihopping techniques increased network capacity, since the spatial domain could be reused for concurrent but physically separate multihop sessions. Although many experimental packet radio networks were later developed, these wireless systems did not ever really take off
in the consumer segment. When developing IEEE 802.11-a standard for wireless local area networks (WLAN)- the Institute of Electrical and Electronic Engineering (IEEE) replaced the term packet-radio network with *ad hoc* network. Packet-radio networks had come to be associated with the multihop networks of large-scale military or rescue operations and by adopting a new name, the IEEE hoped to indicate an entirely new deployment scenario. The *ad hoc* devices can also relay traffic between devices that are out of range.
Mobile ad hoc wireless networks differ fundamentally both in functionality and capability from their static wireline network counterparts due to a variety of reasons, including random node mobility, unpredictable network dynamics, fluctuating link quality, limited processing capabilities, power constraints, etc. All of these characteristics give rise to a need for dynamic changes both in the functioning and management of the underlying network.

## 3. MANET-THE TECHNOLOGY

A Mobile Ad hoc NETwork (MANET) consists of mobile platforms (each platform logically consisting of a router, possibly with multiple hosts and wireless communications devices), herein simply referred to as "nodes"--which are free to move about arbitrarily. A MANET is an autonomous system of mobile nodes. The nodes may consist of separate, networked devices, or may be integrated into a single device such as a laptop computer. The nodes may be located in or on airplanes, ships, trucks, cars, perhaps even on people, and there may be multiple hosts per router. The nodes are equipped with wireless transmitters and receivers using antennas which may be omnidirectional (broadcast) highly-directional (point-to-point) or some combination thereof. At a given point in time, depending on the nodes' positions and their transmitter and receiver coverage patterns, transmission power levels and co-channel interference levels, a wireless connectivity in the form of a random, multihop graph or "ad hoc" network exists between the nodes. This is in contrast with the topology of the existing Internet, where the router topology is essentially static (barring network reconfiguration or router failures). In a MANET, the routers are *mobile* and inter-router connectivity may change frequently during normal operation. Unlike conventional wireless networks, ad hoc networks have no fixed network infrastructure or administrative support. The topology of the network changes dynamically as mobile nodes join or depart the network or radio links between nodes become unusable. [4] A MANET may operate either in isolation, or may be connected to the greater Internet via gateway routers.
MANETs have several salient characteristics:

1. **Dynamic topologies:** Nodes are free to move arbitrarily; thus, the network topology--which is typically multihop--may change randomly and rapidly at unpredictable times. Adjustment of transmission and reception parameters such as power may also impact the topology.
2. **Bandwidth-constrained, variable capacity links:** Wireless links will continue to have significantly lower capacity than their hardwired counterparts. One effect of the relatively low to moderate link capacities is that *congestion* is typically the norm rather than the exception, i.e. aggregate application demand will likely approach or exceed network capacity frequently.
3. **Power-constrained operation:** Some or all of the nodes in a MANET may rely on batteries for their energy. For these nodes, the most important system design criteria for optimization may be that of power conservation.
4. **Limited physical security:** Mobile wireless networks are generally more prone to physical security threats than are fixed, hardwired nets. Existing link security techniques are often applied within wireless networks to reduce security threats.

### 3.1 MIPMANET

Mobile IP for mobile ad hoc networks (MIPMANET) is designed to give nodes in ad hoc networks

1. Access to the Internet; and
2. The services of mobile IP.

The solution uses mobile IP foreign agents as access points to the Internet to keep track of the ad hoc network in which any given node is located and to direct packets to the edge of that ad hoc network.

The ad hoc routing protocol is used to deliver packets between the foreign agent and the visiting node. A layered approach that employs tunneling is applied to the outward data flow, to separate the mobile IP functionality from the ad hoc routing protocol. This makes it possible for MIPMANET to provide Internet access by enabling nodes to select multiple access points and to perform seamless switching between them. In short, MIPMANET works as follows:

1. Nodes in an ad hoc network that want Internet access use their home IP addresses for all communication, and register with a foreign agent.
2. To send a packet to a host on the Internet, the node in the ad hoc network tunnels the packet to the foreign agent.
3. To receive packets from hosts on the Internet, packets are routed to the foreign agent by ordinary mobile IP mechanisms. The foreign agent then delivers the packets to the node in the ad hoc network.
4. Nodes that do not require Internet access interact with the ad hoc network as though it were a stand-alone network

that is, they do not require data regarding routes to destinations outside the ad hoc network.

5. If a node cannot determine from the IP address whether or not the destination is located within the ad hoc network, it will first search for the visiting node within the ad hoc network before tunneling the packet.

In MIPMANET, only registered visiting nodes are given Internet access, thus the only traffic that will enter the ad hoc network from the Internet is traffic that is tunneled to the foreign agent from a registered nodes home agent. Likewise, traffic that leaves the *ad hoc* network is tunneled to the foreign agent from a registered node. This results in a separation between, and thereby the capacity to control, traffic that is local in the *ad hoc* network and traffic that enters the *ad hoc* network.

## 4. APPLICATIONS OF AD-HOC NETWORKING

Characterized by their flexibility to be deployed and functional in on-demand situations, combined with their capability to transport a wide spectrum of applications, mobile ad hoc networks (MANETs) are gaining rapid momentum both in the commercial and military arenas. To turn mobile ad hoc networks into a commodity, we should move to more pragmatic "opportunistic ad hoc networking" in which multihop ad hoc networks are not isolated self-configured networks, but rather emerge as a flexible and low-cost extension of wired infrastructure networks coexisting with them. [7]

### 4.1 Military Sector

The ad hoc packet-radio networks have mainly been considered for military applications, where a decentralized network configuration is an operative advantage or even a necessity. In the military sector, MANETs are becoming the basis for the future network-centric warfare (NCW) paradigm as exemplified by the Future Combat Systems (FCS) and Warfighter Information Network-Tactical (WIN-T) programs.

The success of MANETs is however critically tied to their capability of transporting a wide spectrum of applications with varying quality of service (QoS) requirements or service level agreements (SLAs), and providing continued/un-interrupted service (i.e., seamless recovery) despite failures in the underlying network.

Today, MANETs enable war fighters to benefit from a sophisticated Internet protocol (IP)-based communications network that can be set up even in difficult terrain and in remote war zones. Furthermore, tactical network applications of MANETs also include realization of automated battlefields, wherein autonomous robots and autonomous ground vehicles are used to explore hostile battlegrounds and check for land mines. These significant strides have made ad hoc networking a very valuable option in modern tactical military communication networks and the industry is facing significant demand for MANET solutions from defense establishments worldwide.

### 4.2 Commercial Sector-Pan

Short-range ad hoc networks can simplify intercommunication between various mobile devices (such as a cellular phone and a PDA) by forming a PAN, and thereby eliminate the tedious need for cables. This could also extend the mobility provided by the fixed network (that is, mobile IP) to nodes further out in an ad hoc network domain. The Bluetooth system is perhaps the most promising technology in the context of personal area networking (PAN).

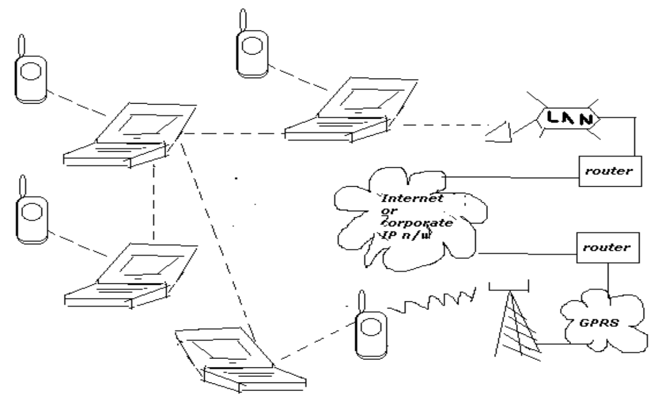


**Figure1. PAN scenario with four interconnected PANs, two of which have an Internet connection via a Bluetooth LAN access point and a GPRS/UMTS phone.**

A PAN can also encompass several different access technologies distributed among its member devices which exploit the ad hoc functionality in the PAN. For instance, a notebook computer could have a wireless LAN (WLAN) interface (such as IEEE 802.11) that provides network access when the computer is used indoors. Thus, the PAN would benefit from the total aggregate of all access technologies residing in the PAN devices.

Figure 1 shows a scenario in which four Bluetooth PANs are used. The PANs are interconnected via laptop computers with Bluetooth links. In addition, two of the PANs are connected to an IP backbone network, one via a LAN access point and the other via a single GPRS/UMTS phone.

In traditional 802.11 networks, clients dictate timing of communication, and APs do not coordinate with one another (client-controlled communication). Instead, the clients choose when to connect and which AP to connect with, and APs choose when to respond to each client. With an infrastructure-controlled approach, the WLAN can decide which AP or client transmits when and can guarantee packet delivery while dynamically reserving bandwidth over the air for VoIP communication.

### 4.3 Commercial Sector-Bluetooth Networking

Worldwide, the industry has shown a tremendous interest in techniques that provide short-range wireless connectivity. In this context, Bluetooth technology is seen as the key component.[5] However, Bluetooth technology must be able to operate in ad hoc networks that can be stand-alone, or part of the IP-networked world, or a combination of the two.

Bluetooth devices can interact with one or more other devices in several different ways. The simplest scheme is when only two devices are involved, one of the devices acts as the master and the other as a slave. This ad-hoc network is called a piconet. A piconet can consist maximum of eight devices. The interconnection of piconets is called scatternet. The main purpose of Bluetooth is to replace cables between electronic devices, such as telephones, PDAs, laptop computers, digital cameras, printers, and fax machines, by using a low-cost radio chip. Short-range connectivity also fits nicely into the widearea context, in that it can extend IP networking into the personal-area network domain, as discussed earlier. Bluetooth must be able to carry IP efficiently in a PAN, since PANs will be connected to the Internet via UMTS or corporate LANs, and will contain IP-enabled hosts.[5] Generally speaking, a good capacity for carrying IP would give Bluetooth networks a wider and more open interface, which would most certainly boost the development of new applications for Bluetooth. In February 1998, the Bluetooth Special Interest Group (SIG) was founded to promote, develop and define the Bluetooth specification. The Bluetooth SIG aims at delivering a universal solution for connectivity among the heterogeneous devices. This is one of the first commercial realizations of ad-hoc wireless networking.

## 5. TECHNICAL CHALLENGES IMPOSED BY AD-HOC NETWORKING

This section outlines the technical requirements for mobile ad-hoc networks to achieve their potential because ad hoc wireless networks are self-creating, self-organizing, and self-administering. It outlines the need for QoS.

### 5.1 Geocasting

Geocasting is a variant of the conventional multicasting problem. For multicasting, conventional protocols define a multicast group as a collection of hosts which register to a multicast group address. However, for geocasting, the group consists of the set of all nodes within a specified geographical region. Hosts within the specified region at a given time form the geocast group at that time. [9]

When an application must send the same information to more than one destination, multicasting is often used, because it is much more advantageous than multiple unicasts in terms of the communication costs. Cost considerations are all the more important for a mobile ad hoc network (MANET) consisting of mobile hosts that communicate with each other over wireless links, in the absence of a fixed infrastructure. In MANET environments, the multicast problem is more complex because topology change of the network is extremely dynamic and relatively unpredictable. To do multicasting, some way is needed to define multicast groups. In conventional multicasting algorithms, a multicast group is considered as a collection of hosts which register to that group. It means that, if a host wants to receive a multicast message, it has to join a particular group first. In order to send a message to the multicast group, a host just needs to multicast the message to the address of that group. All the group members then receive the message. [6]

In Geocasting, the message (geocast message) is delivered to the set of nodes within a specified geographical area. Unlike the traditional multicast schemes, here, the multicast group (or geocast group) is implicitly defined as the set of nodes within a specified area. [9]

This section briefly explained the problem of *geocasting* – broadcasting to every node in a specified geographical area – in mobile ad hoc environments.

The basic routing philosophy on the Internet is “best-effort”; there are several requirements for it that are explored in the next section.

### 5.2 Ensuring QoS

This section addresses some of the quality of service issues for ad hoc networks which have recently started to receive increasing attention in the literature. The focus is on QoS routing. This is a complex and difficult issue because of the dynamic nature of the network topology and generally imprecise network state information. [2]

Quality of Service (QoS) refers to the ability of a network to provide better, more predictable service to selected network traffic over various underlying technologies, including IP-routed networks. QoS features are implemented in network routers by supporting dedicated bandwidth, improving loss characteristics, avoiding and managing network congestion, shaping network traffic, and setting traffic priorities across the network.

The notion of QoS is a guarantee by the network to satisfy a set of predetermined service performance constraints for the user in terms of the end-to-end delay statistics, available bandwidth, probability of packet loss, and so on. QoS guarantees can be attained only with appropriate resource reservation techniques. The most important element among them is *QoS routing*, that is, the process of choosing the routes to be used by the flow of packets of a logical connection in attaining the associated QoS guarantee. The cost of transport and total network throughput may be included as parameters. Obviously, enough network resources must be available during the service invocation to honor the guarantee. The first essential task is to find a suitable path through the network, or *route*, between the source and destination(s) that will have the necessary resources available to meet the QoS constraints for the desired service. The task of resource (request, identification, and) reservation is the other indispensable ingredient of QoS. By QoS routing, we mean both these tasks together. QoS routing offers serious challenges even for today's Internet. Different service types (e.g., voice, live video, and document transfer) have significantly different objectives for delay, bandwidth, and packet loss. [3]

Three distinct route-finding techniques are used for determining an optimal path satisfying the QoS constraints. These are *source routing*, *destination routing*, and *hierarchical routing*. In source routing, a feasible path is locally computed at the source node using the locally stored global state information, and then all other nodes along this feasible path are notified by the source of their adjacent preceding and successor nodes. In distributed or hop-by-hop routing, the source as well as other nodes is involved in path computation by identifying the adjacent router to which the source must forward the packet associated with the flow. Hierarchical routing, as the name suggests, uses the aggregated partial global state information to determine a feasible path using source routing where the intermediate nodes are actually logical nodes representing a cluster. *Flooding* is not an option for QoS routing, except for broadcasting control packets under appropriate circumstances (e.g., for beaconing, or at the start of a route discovery process).

This section briefly described the new but rapidly growing area of research on guaranteeing QoS in ad hoc mobile wireless networks.

## 6. WHERE DO WE GO FROM HERE: POSSIBLE SOLUTION TO THE CHALLENGES

The huge way in which research activity has been going on, in both academia and industry, on wireless mobile ad hoc networks, is a representation of their tremendous potential now being well recognized. More and more results are appearing on problems related to basic network limitations, new protocols and their performance evaluations, network architecture and design, new technologies, and so on.For increased network reliability and enhanced QoS, it is required to develop and implement efficient routing algorithms and protocols. The significant thing is that such an algorithm must be evolved which dynamically calculates the route to forward and transfer data reliably, within the ad-hoc network or to a node that wishes to communicate with the wider internet.Such an algorithm will achieve multicast efficiency by tracking the availability of resources for each node within its neighborhood. Computation of free bandwidth will be based on reservations made for ongoing sessions and the requirements reported by the neighbors. The algorithm will proactively choose the next node on the route and generate table spontaneously.An ad-hoc network is highly dynamic, and transmissions are susceptible to fades, interference, and collisions from hidden/exposed stations, therefore, the algorithm will provide routes that can most probably satisfy the bandwidth requirement of a route, as long as the route is established.

Also, the algorithm will dynamically re-establish routes for ongoing connections upon link failures and topology changes in the ad hoc network. This will make it easy to perform efficient resource utilization or to execute critical applications. Moreover, the algorithm must be optimized in order to minimize its computation complexity and hence achieve better results within the hardware constraints such as power limitations.The seamless integration of mobile ad hoc networks with other wireless networks and fixed infrastructures will be an essential part of the evolution towards future fourth generation communication networks. From a technological point of view, the realization of this vision still requires a large number of challenges to be solved related to devices, protocols, applications and services.

## 7. CONCLUSION

The objectives of this paper have been to examine the history of the ad hoc networking and various applications of MANETs esp. in commercial sector; to suggest the significance of the role of Geocasting in MANETs and to propose QoS as the new but rapidly growing area of research on guaranteeing QoS in ad hoc mobile wireless networks, and as a technical challenge and a necessary requirement to the growth of ad hoc networks.

MANETs have evolved a great deal over the two decades since its inception. Although the technology was confined to the military arena up until now, it is currently gaining traction in the commercial domain of late. The technology at present demands renewed attention owing to recent developments in radio communications and advancements in wireless networking. The proliferation of unmanned aerial systems (UAS) over the last decade is one of the most significant drivers for the increased deployment of MANETs in the battlefield.

## FUTURE SCOPE

Guaranteeing QoS in such a network may be impossible if the nodes are too mobile. The challenges increase even more for those ad hoc networks that, like their conventional wireless counterparts, support both best effort services and those with QoS guarantees, allow different classes of service, and are required to interwork with other wireless and wireline networks, both connection-oriented and connectionless. Algorithms, policies, and protocols for coordinated admission control, resource reservation, and routing for QoS under such models are only beginning to receive attention. QoS for ad hoc networks is a new area of research.

Much work remains to be done on cost-effective implementation issues to bring the promise of ad hoc networks within the reach of the public.

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***Continued from page no. 434***

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