MOBILE AD HOC NETWORKS

A GENERAL PERSPECTIVE

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ABSTRACT

An ad hoc network is a collection of wireless mobile hosts forming a dynamic, network without the aid of any centralized administration or fixed network infrastructure. In such an environment, mobile hosts cooperate to perform as hosts as well as routers, and forward packets to each other in order to communicate. Such networks have fluid, rapidly changing and multi-hop topologies composed of bandwidth-constrained wireless links. Hosts enter and leave the ad hoc network as they desire, according to their transmission capabilities. The ad hoc network hence continuously adapts and modifies its configuration over time. Such ad hoc networks have tremendous potential in commercial, military and domestic applications. They can enable connectivity between mobile nodes when there is little or no infrastructure available, or it is inconvenient to use. When integrated with the Internet, they can provide roaming net connectivity to mobile nodes.

This paper provides an introduction into the fast developing area of ad hoc networks and the inspiration behind it. It presents a general overview of the technologies and methodologies relating to ad hoc networks, and compares it to related mobile technologies like Mobile IP. Characteristic features and design considerations in ad hoc networks are elucidated. The paper also covers the interesting area of routing in ad hoc networks. In this regard, the various routing algorithms developed for ad hoc networks are described and compared. The range of constraints imposed on performance such networks due to low power limitations, and capability of current day transmission media are also considered. As a glimpse into future, it ventures upon the possible applications of ad hoc networks and provides a brief overview of the challenges facing the implementation of ad hoc networks.

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MOBILE AD HOC NETWORKS

1 INTRODUCTION

Ubiquitous access to information, anywhere, anyplace, and anytime, will characterize whole new kinds of information systems in the 21st Century. These are being enabled by rapidly emerging wireless communications systems. These systems are based on radio and infrared transmission mechanisms, and utilize cellular telephony, wireless devices, and mobile ad hoc networks. They have the potential to dramatically change society as workers become untethered from their information sources and communications mechanisms.

A mobile ad hoc network, also known as a MANET, is a collection of wireless nodes with no pre-established infrastructure, forming a dynamic network. Each of the nodes has a wireless interface and communicate with each other over radio or infrared transmission technologies.

Such an ad hoc network does not have any centralized administration. This ensures that the network remains functional when one or more mobile nodes move out of the transmission range of the other nodes. Nodes thus can enter and leave the network as they wish. In areas in which there is little or no communication infrastructure available, wireless mobile users may still be able to communicate through the formation of an ad hoc network. In such a network, each mobile node operates not only as a host but also as a router, forwarding packets for other mobile nodes in the network that may not be within direct wireless transmission range of each other. Each node participates in an ad hoc routing protocol that allows it to discover multi-hop paths through the network to any other node.

The idea of ad hoc networking is sometimes also called infrastructure-less networking, since the mobile nodes in the network dynamically establish routing among themselves to form their own network on the fly. These mobile nodes are equipped with wireless transmitters and receivers using antennas that may be either omni directional or highly directional. This ad hoc topology may change dynamically with time as the nodes move or adjust their transmission and reception parameters. The wireless hardware implemented in MANETs can use Bluetooth, WAP or similar forms of wireless connectivity.

1.1 APPLICATIONS OF AD HOC NETWORKS

Some of the applications of ad hoc networks are listed below.

- Industrial and commercial applications.
- Cooperative mobile data exchange.
- Robust, inexpensive alternatives to cellular networks.
- Military networking.
- Wearable computing and communications.
- Remote communications using satellite-based information delivery.
- Ubiquitous Computing applications.
- Multimedia computing and collaborative networking applications.

2 AN OVERVIEW

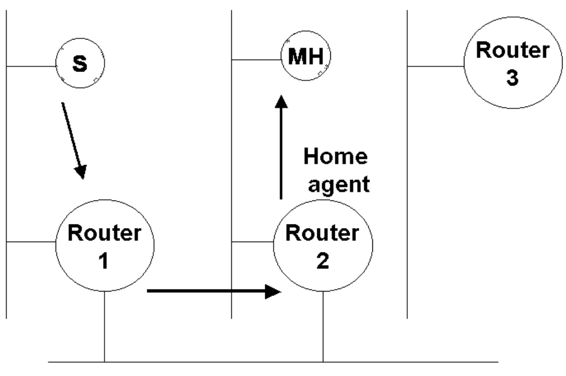
The vision of mobile ad hoc networking is to support robust and efficient operation in mobile wireless networks by incorporating routing functionality into mobile nodes. Such networks are envisioned to have dynamic, random rapidly changing and multi-hop topologies that are composed of bandwidth-constrained wireless links.

Broadly speaking, there are two distinct approaches for enabling wireless communication between hosts. The first approach is to let existing cellular network infrastructure carry data as well as voice. This method is limited by the problem that such networks are limited to places where there exists such a cellular network infrastructure. A second approach is to form an ad hoc network among all users wanting to communicate with each other. This means that all users participating in the network must be willing to forward packets to make sure that the packets are delivered from sources to destination. Some of the advantages of this system include on demand setup, fault tolerance and unconstrained connectivity.

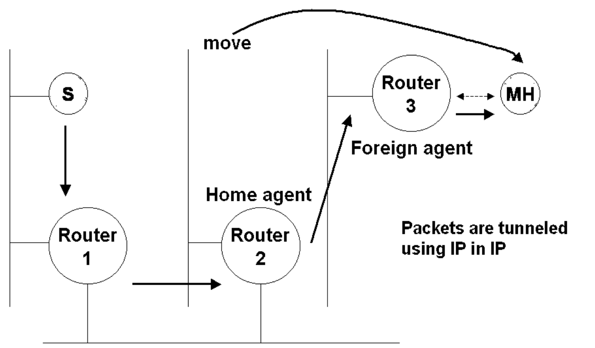
Currently, the transmission capabilities of the individual nodes limit the range ad hoc networks. Standards for routing protocols, performance, security and Quality of Service are primary research areas. This paper ventures a general overview of current trends in mobile ad hoc networks, and a glimpse into the future issues which need to be addressed, in order to truly harness the potential of ad hoc networks.

2.1 COMPARISON OF AD HOC NETWORKS AND MOBILE IP

Within the Internet community, routing support for mobile hosts is presently being formulated as Mobile IP technology. This is a technology to support nomadic host roaming. A mobile node has a home network associated with it. When it moves into a foreign network, suitable arrangements are made to forward packets to the foreign network from the home network. This is known as tunneling. As is obvious, this technology still depends on the availability to fixed networks, either at home or at a foreign location, for the mobile node to receive packets from. The above technology is illustrated in the figures below. The changes that occur when a mobile node moves to a foreign network are also shown.

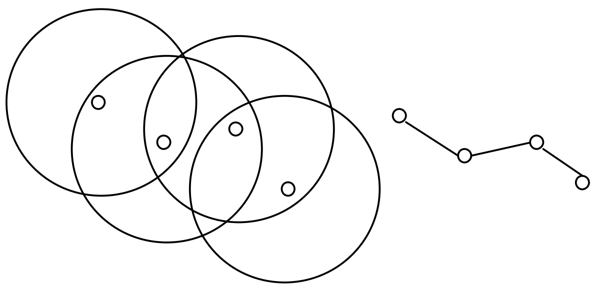


The **Mobile Host** (MH) is attached to its Home Network. Packets from a Source Node (S) are addressed to the **Home Agent**. The home agent forwards these packets to the Mobile Host.

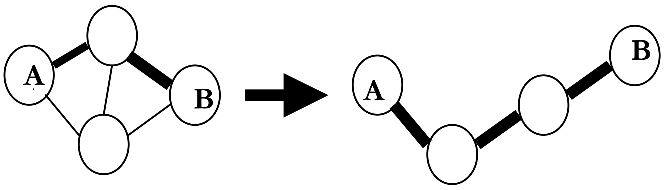


The Mobile Host (MH) moves to a foreign network. The Home agent **tunnels** packets from the source (S) to the **Foreign Agent**. The Foreign Agent then forwards these packets to the MH.

Thus, in Mobile IP technology, the number of wireless hops to the destination node is **exactly one**, in both cases illustrated above. Contrasted below, is a typical wireless ad hoc network topology.



As can be seen from the diagram, wireless transmission ranges of the MANET nodes overlap with one another. Packets transmitted between remote hosts need to travel over **multiple wireless hops** to reach destination. These packets are transmitted via intermediate wireless hosts in the MANET in a store-and-forward fashion.



In the diagram above, mobile nodes in a typical MANET change their relative position as the ad hoc network topology changes over time. The network route between the nodes A and B changes as a result. This implies that intermediate nodes on the path must update their routing tables to reflect the change, so that packet routing and forwarding between A and B can continue uninterrupted.

3 MANET CHARACTERISTICS

3.1 DYNAMIC TOPOLOGIES

Nodes are free to move arbitrarily; thus the network topology that is typically multihop, may change randomly and rapidly at unpredictable times, and may consist of both bidirectional and unidirectional links.

3.2 BANDWIDTH-CONSTRAINED, VARIABLE CAPACITY LINKS

Wireless links will continue to have significantly lower capacity than their hardwired counterparts. In addition, the realized throughput of wireless communications is much less than a radio's maximum transmission rate. Congestion is a common occurrence in such networks.

3.3 TRANSMISSION ERRORS

Due to the higher error probability inherent in wireless links, higher bit error rates are inevitable.

3.4 ENERGY-CONSTRAINED OPERATION

Some or all of the nodes in a MANET may rely on batteries or other exhaustible means for their energy. For these nodes, the most important system design criteria for optimization may be energy conservation.

3.5 LIMITED PHYSICAL SECURITY

Mobile wireless networks are generally more prone to physical security threats than wired networks. The increased possibility of eavesdropping, spoofing, and denial-of-service attacks increase their vulnerability. On the positive side, the decentralized nature of network control in MANETs provides additional robustness against the single points of failure.

3.6 DECENTRALIZED MODE OF OPERATION

In a mobile architecture of the like employed in ad hoc networks, availability of central locations for control are impossible. Hence, the network management responsibilities in MANETs are essentially distributed among the currently active set of nodes. This feature affects the routing protocols employed in MANETs.

4 INTEGRATION WITH THE INTERNET

An important achievement in ad hoc network technology would be its successful integration with the existing wired Internet infrastructure. This implies that a mobile IP protocol needs to be developed, which can be deployed in the unique scenario of ad hoc networks. Such an improved mobile routing capability at the IP layer can provide a benefit similar to the intention of the original Internet, which was to provide an interoperable internetworking capability over a heterogeneous networking infrastructure. In case of MANETs, the infrastructure is wireless, rather than hardwired, consisting of multiple wireless technologies, channel access protocols, etc.

In other words, IP routing in a MANET must be developed to provide consistency for multihop networks composed of nodes using a mixture of physical-layer media. With the development of these technologies, along with availability of user applications, mobility support, and a rich range of handheld and portable computing devices, mobile internetworking will become truly ubiquitous.

4.1 INTERACTION WITH STANDARD IP ROUTING

In the near term, it is currently envisioned that MANETs will function as stub networks, meaning that all traffic carried by MANET nodes will either be sourced or sinked within the MANET. Because of bandwidth and possibly power constraints, MANETs are not presently envisioned to function as transit networks carrying traffic that enters and then leaves the MANET. Subsequent technology advances may remove this restriction. This substantially reduces the amount of route advertisement required for interoperation with the existing fixed Internet. For stub operation, routing interoperability in the near term may be achieved using some combination of mechanisms such as MANET-based anycasting and mobile IP.

Future interoperability may be achieved using mechanisms other than mobile IP. Interaction with Standard IP Routing will be greatly facilitated by usage of a common MANET addressing approach by all MANET routing protocols. Development of such an approach is underway which permits routing through a multi-technology fabric, permits multiple hosts per router and ensures long-term interoperability through adherence to the IP addressing architecture.

5 MANET ROUTING

Many different routing protocols have been developed for MANETs. Some of them have been adapted from traditional wired networks, while others have been specifically developed for MANETs. Before delving to the protocols themselves, some of the desirable properties and performance metrics of routing protocols are articulated below. These metrics should be independent of any given routing protocol.

5.1 QUALITATIVE METRICS

- Distributed operation
- Loop freedom
- Demand based operation
- Proactive operation
- Security
- Sleep period operation
- Unidirectional link support

5.2 QUANTITATIVE METRICS

- End-to-end data throughput and delay
- Route Acquisition Time
- Percentage Out-of-Order Delivery
- Efficiency

5.3 INTERNAL METRICS FOR EFFICIENCY

- Average number of data bits transmitted per data bit delivered
- Average number of control bits transmitted per data bit delivered
- Average number of control and data packets transmitted per data packet delivered

5.4 NETWORK PARAMETERS

- Network Size
- Average Connectivity of a Network Node
- Rate of change of Network Topology
- Effective Link Capacity
- Presence of Unidirectional Links
- Traffic Patterns

- Mobility
- Fraction and frequency of sleeping nodes

6 MANET ROUTING PROTOCOLS

6.1 PROACTIVE PROTOCOLS

Pro-active algorithms try to maintain consistent, up-to-date routing information for all nodes in the network. They require each node to maintain tables of routing information, and respond to changes in network topology by propagating updates throughout the network in order to maintain a consistent network view.

6.1.1 DESTINATION SEQUENCED DISTANCE VECTOR ROUTING (DSDV)

DSDV is based on the distance vector protocol commonly used in wired networks. It makes some modifications to adapt it for routing in MANETs. In DSDV, packets are routed between nodes of an ad hoc network using routing tables stored at each node. Each node contains a routing table with an entry for every node in the network, containing the next hop node to reach that node. Broken links cause cascading changes in routing tables in the MANET, as and when they are discovered.

6.1.2 CLUSTERHEAD GATEWAY SWITCH ROUTING (CGSR)

This is based on the DSDV algorithm. It is hierarchical in nature in an attempt to improve scalability. It is different in that it divides the nodes in the network into clusters and each cluster elects a node as a clusterhead. A node that is in range of two clusterheads is called a gateway. Routing takes place from clusterhead to gateway to clusterhead till the message reaches the cluster of the destination. Each node maintains a table of all nodes in the network and their clusterheads. These clusterhead tables are propagated regularly through the network as in DSDV.

6.2 REACTIVE ALGORITHMS

The reactive approach to routing in MANETs is characterized by routes being created only when required by some node. When a node requires a route to a destination, it initiates a route discovery process within the network. Once a route is established, some form of route maintenance maintains it, till the route is either invalid or unnecessary.

6.2.1 DYNAMIC SOURCE ROUTING (DSR)

DSR is designed to allow nodes to dynamically discover a source route across multiple network hops to any destination in the ad hoc network. When using source routing, each packet to be routed carries in its header the complete, ordered list of nodes through which the packet must pass. Thus intermediate hops do not need to maintain routing information. DSR does not require the periodic transmission of router advertisements or link status packets, reducing messaging overhead when mobility is low. DSR has also been designed to compute correct routes in the presence of unidirectional links.

6.2.2 AD HOC ON-DEMAND DISTANCE VECTOR ROUTING (AODV)

AODV Routing tries to improve DSDV by minimizing the number of broadcasts by creating routes on an on-demand basis. Route discovery is initiated by the sending of a Route Request (RREQ) packet to its neighbours, which in turn forward the packet to their neighbours till a fresh enough route is found. Destination sequence numbers are used to keep routes loop free and fresh. On reaching a node with a fresh route, the node sends a route reply (RREP) packet. Route maintenance is similar to the policy followed in DSR.

6.2.3 TEMPORALLY ORDERED ROUTING ALGORITHM (TORA)

TORA is based on the concept of link reversal. TORA is designed to work in a highly dynamic MANET. It also provides multiple routes to any desired destination. This protocol has three phases. In the first and second, route creation and maintenance, nodes use a height metric to establish a Directed Acyclic Graph (DAG). Thereafter, links are assigned a direction, upstream or downstream based on the relative height of neighbouring nodes. When a link is broken, a node generates a new height, which propagates and causes the direction of links to change. The third phase is an erase phase where invalid routes are erased.

6.2.4 ASSOCIATIVITY BASED ROUTING (ABR)

ABR defines an interesting metric for routes in MANETS, degree of association stability. In ABR, a route is selected based on the degree of association stability of nodes. Each node generates regular beacons on which neighbouring nodes update a count. The count increases proportional to the association stability between nodes. A high value of this metric generally indicates low mobility. The fundamental objective of ABR is to derive longer-lived routes in a MANET.

6.2.5 SIGNAL STABILITY ROUTING (SSR)

SSR is similar to ABR, but uses the metric of signal stability between nodes. This algorithm, therefore, tends to generate routes that have strong signal strength.

6.3 HYBRID PROTOCOLS

Pro-active schemes provide valid routes instantly. But, they result in more messaging overhead and computation for route maintenance. They are useful in real-time applications. In the case of reactive protocols, preventing constant maintenance of routes saves power and bandwidth, but there is latency involved in finding a route. Pro-active protocols can prove even more expensive when the degree of mobility involved is high. There also exists a hybrid combination of the two in the Zone Routing Protocol.

6.3.1 ZONE ROUTING PROTOCOL

This routing algorithm tries to combine the pro-active and reactive approaches. For every node, a zone is maintained that contains all nodes within zone radius hops from the node. Two routing protocols are employed, the Intrazone Routing Protocol (IARP) and the Interzone Routing Protocol (IERP). The IARP is pro- active and the IERP is reactive. The zone radius can be varied according to the needs of the application.

6.4 LOCATION BASED ALGORITHMS

Location based algorithms store and utilize information about the MANET topology obtained from external sources. These sources provide the nodes with geographical information about node positions.

This information can be used to design more efficient routing algorithms that minimize the routing overheads in the system. At the same time, these algorithms require additional complexity at the nodes and the need to maintain periodically updated location information.

6.4.1 LOCATION AIDED ROUTING

LAR makes the use of geographic location of nodes in a MANET by using a Global Positioning System (GPS) receiver with each node. Based on this, every node defines a request zone and an expected zone where the destination is to be found. When a route request packet is sent, only those nodes that are in the expected zone forward the packet thus minimizing the area in which flooding is to be done. This brings about a saving in the number of messages required for finding a route.

7 CURRENT ISSUES IN MANETS

7.1 SECURITY

Mobile wireless networks are generally more prone to physical security threats than are fixed, hardwired networks. Existing link-level security techniques (e.g. encryption) are often applied within wireless networks to reduce these threats. Several levels of authentication policies are being explored.

7.1.1 RSA BASED SECURITY PROTOCOLS

RSA is one of the commonly used cryptosystems for ensuring security in networks today, and can be extended to mobile environments. Public Key – Secret Key pairs can be used to authenticate communication in the system, along with the use of shared certificates to further ensure that security of the hosts in the system is not compromised.

7.1.2 DESIGN ISSUES

Some of the design challenges in the security system design are explained below.

7.1.2.1 Security breach

Wireless transmissions are prone to security attacks, and it is very likely that adversaries will eventually break into a limited number of entities over time.

7.1.2.2 Mobility and service ubiquity

Mobile users incur dynamic topological changes. A mobile user may be able to perform effective and timely communication with its local neighbors but not with remote entities.

7.1.2.3 Network dynamics and scale

Channel errors, and node failures all incur dynamics into the network. Besides, an entity may join and leave the network over time. The number of networking devices can be large, thus a scalable solution is critical.

7.2 QUALITY OF SERVICE

Quality of Service guarantees provided by a particular network infrastructure specifies a level of performance that can be expected by applications with respect to transfer of information. Specifically QoS guarantees include reduction of error probabilities, minimal packet loss, out-of-sequence packets and transfer delays.

7.2.1 DESIGN ISSUES

The following requirements can be identified for a wireless network that offers QoS guarantees.

7.2.1.1 VC, bandwidth reservation

The wireless network must implement virtual circuits in order to support real time connections and allocate bandwidth to them at call setup time. VC bandwidth reservation in a mobile network is a major challenge, since the path changes dynamically.

7.2.1.2 QoS routing

To support QoS for real time traffic we need to know not only the minimum delay path to destination, but also the bandwidth available on it. Otherwise, it would disrupt the existing VCs.

7.2.1.3 Congestion control

Network congestion occurs due to the dynamics of mobility and of traffic patterns. Some of the concepts successfully used in other network infrastructures, i.e. selective packet dropping and input rate control, can be applied here.

7.2.2 DYNAMIC RSVP

dRSVP is a modification of the Reservation Protocol (RSVP), developed for ad hoc networks. It provides accommodations for the dynamic nature of MANETs. It provides for reservation of ranges of resource values, real-time variation of resource allocation and awareness of bottlenecks in the network.

8 CONCLUSION

This paper has aimed to provide a lucid coverage the area of mobile ad hoc networks. Mobile Ad Hoc Networks represent a paradigm shift in the way which networks are architected. MANETs shift the focus from the traditional client-server hierarchy to emphasize a system in which all the nodes in the system cooperate with each other to establish and maintain a collaborative networking environment. Such capabilities albeit require additional complexity at the network nodes in the MANET.

A considerable range of topics has been covered in the paper. The authors hope that this paper will provide a useful insight into the concepts and technologies being developed in ad hoc networks, and prove as a comprehensive introduction into this exciting new area of mobile computing.

9 GLOSSARY OF TERMS

Packet – The basic network level unit of data transfer.

Protocol – Set of rules devised for governing data transfer over a network.

Router – Hardware or software devices that direct packets in a network, from source to destination.

IP – The Internet Protocol, or the set of rules used to route packets over the Internet.

Virtual Circuit – Virtual path setup between two communicating nodes in a network.

Bluetooth – Standard used to enable communications between wireless devices.

Ubiquitous Computing – Computing technology in the interfaces are imbibed into the user's surrounding environment.

10 REFERENCES

[1] Andrew S. Tanenbaum, "Computer Networks", 3rd ed, Prentice Hall India, 1994

[2] E.M. Royer and C.K. Toh, A Review of Current Routing Protocols for Ad-Hoc Mobile Wireless Networks, IEEE Personal Communications Magazine, April 1999, pp. 46-55.

[3] Charles E. Perkins, Mobile IP: Design Principles and Practice, Addison-Wesley Longman, Reading, Mass., 1998.

[4] S. Corson & J. Macker, "Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations", IETF RFC 2501, January 1999