ISSN No. 0976-5697

Volume 6, No. 7, September-October 2015

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

A Study of Ad-Hoc Networks

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Abstract: Mobile Ad-hoc networks have been widely researched for many years. Mobile Ad-hoc Networks are a collection of two or more devices equipped with wireless communications and networking capability. These devices can communication with other nodes that immediately within their radio range or one that is outside their radio range. The Wireless Ad-hoc Networks do not have gateway, every node can act as the gateway .Mobile ad hoc networks have many advantages over traditional networks, such as scalability, mobility and robust city. The network can be formed easily. It is gained more and more attention in recent years for the using in urgent and abrupt occasion, for example communication in military battlefield, salvage, temporary assembly and open country construction, etc.
This paper focuses on the study of Ad-Hoc Network and its protocols.The concept of dynamic mobility is also introduced because nodes are moving from one place to another place, within this network any node can join the network and can leave the network at any time. This paper mainly focused upon the architecture, operating principle of Ad-Hoc networks. The various types of Routing Protocols are also discussed in this Paper; and finally applications, advantages and limitations of Ad-Hoc Networks are also discussed.

Keywords: Ad-Hoc Networks, Wireless Sensor Networks, Routing Protocols, MANET

1. INTRODUCTION

One Way to understand Ad-Hoc networks is by comparing them with infrastructure based wireless networks, such as cellular network and WLAN. In the infrastructure based wireless networks a node can only send a packet to a destination node only via access point (in cellular network like GSM, it is called base station). The access point establishes a network area and only the nodes in this area can use access point's services.

There are some unknown events, which cause access point's malfunction. The nodes lose their network and they are quasi not working. It is the biggest infrastructure's disadvantage. There are also some reasons to sacrifice or not to use access point's services. These can be cost factor, impossibility to install access point in short time, etc. In this case the nodes have to build their own network. This network is called wireless Ad-Hoc network[1].

The wireless Ad-Hoc networks[2] only consist of nodes equipped with transceiver. The network is created to be independent from an infrastructure. Therefore, the nodes must be able to arrange their own networks. Keep in mind that a node can now communicate only with other nodes in its transmission range.

It seems like, that the Ad-Hoc networks[3] are not powerful enough. Each node has its own transmission range, if these small transmission areas are combined, they will form a much bigger transmission area. The nodes transmit their data with single or multiple hopping techniques. Now a suitable routing algorithm must be implemented, so the process of transmitting data will be more effective. The figure 1 shows, how the nodes form a transmission cloud.

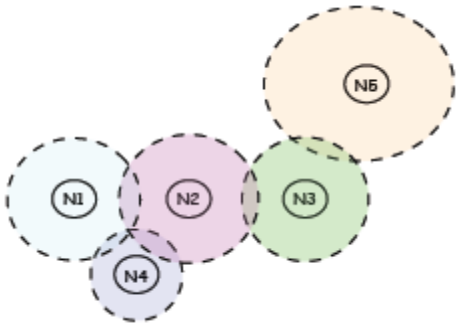


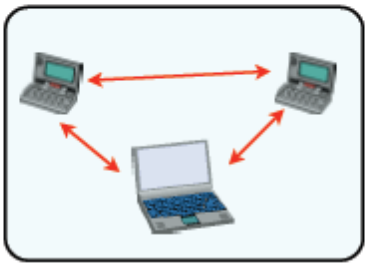
Fig.1 Transmission area in Ad-Hoc

II. ARCHITECTURE

The wireless networks can be categorized based on their system architecture[4] into two basically versions. The one is Infrastructure (Figure a) and second is Ad-Hoc network (Figure b). The biggest different of them is infrastructure networks consist of access point and nodes[5], meanwhile the Ad-Hoc networks are independent from access point.

In the infrastructure version, a terminal can't communicate directly with other terminals in the same cell and other cell. An access point here performs control messages. Messages are sent to the access point and then the access point distributes the messages to the desired terminal. If a terminal wants to communicate with a terminal, which is located in other cell, the access point will relay the message to other access point, which has control over desired cell. The access points are normally wired connected. The problem in infrastructure is if the access point defects, all terminals in this cell can't perform any communication.

(a) Infrastructure



(b) Ad-Hoc

Fig.2 Architecture

Unlike the infrastructure[6], the Ad-Hoc networks have a different method to distribute messages. The nodes are equipped with wireless transceiver. They don'tneed any additional infrastructure, such as base station orwired access point, etc. Therefore, each node doesn't onlyplays the role of an end system, but also acts as a router, thatsends packets to desired nodes.

III. OPERATING PRINCIPLE

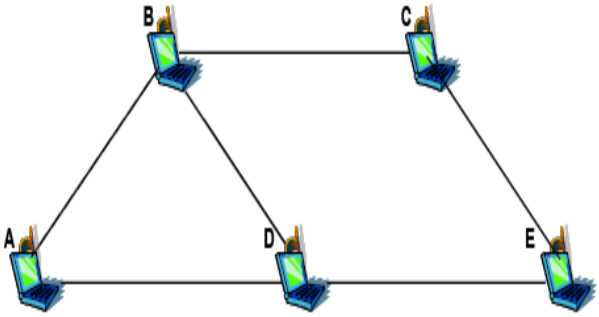


Fig. 3 Peer-to-Peer multi-hop Ad-Hoc network

Mobile node A communicates directly with B (single hop) when a channel is available. If Channel is not available, then multi-hop communication is necessary e.g. A->D->B. For multi-hop communication to work, the intermediate nodes should route the packet i.e. they should act as a router. Example: For communication between A-C, B, or D & E, should act as routers

A. Bringing up an Ad-Hoc Network

Ad-Hoc network begins[7] with at least two nodes broadcasting their presence (beaconing) with their respective address information. They may also include their location info if GPS equipped. Beaconing messages are control messages. If node A is able to establish a direct communication with node B verified by appropriate control messages between them, they both update their routing tables. Third node C joins the network with its beacon signal. Two scenarios are possible:

i. A & B both try to determine if single hop communication is feasible
ii. Only one of the nodes e.g. B tries to determine if single hop communication is feasible and establishes a connection

The distinct topology updates[8] consisting of both address and the route updates are made in three nodes immediately. In first scenario, all routes are direct i.e. A->B, B->C, and A->C (Let's assume bi-directional links). In the second scenario, the routes are updated:

i. First between B & C,
ii. then between B & A,
iii. Then between B & C again confirming that A and C both can reach each other via B

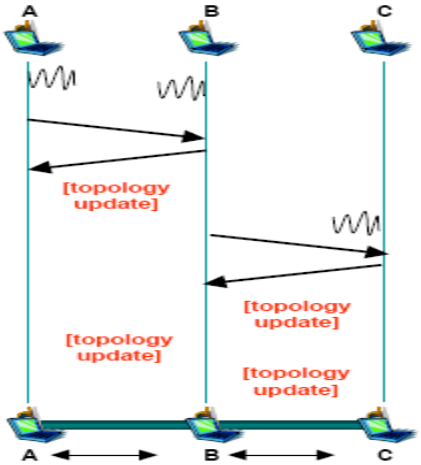


Fig. 4 Topology update when new node joins the Ad-Hoc network

B. Topology Update Due to a Link Failure

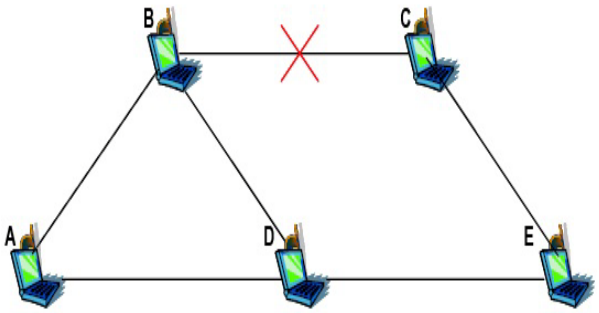


Fig. 5 Topology Update due to a link failure

Mobility of nodes may cause link breakage requiring route updates. Assume link between B & C breaks because of some reason. Nodes A & C are still reachable via D and E, So old route between A &C was A->B->C is to be replaced by A->D->E->C

All five nodes are required to incorporate this change in their routing table. This change will happen first in nodes B & C, then A & E and then D

IV. INTERNET CONNECTIVITY FOR AD-HOC NETWORKS

Initially, nodes belonging to an Ad-Hoc network[9] can only communicate among themselves, using multi-hop wireless transmission. In this case, each node has a unique address which is 'meaningless' outside the Ad-Hoc network, since there is no external connectivity. However, there are some solutions which extend this architecture providing Internet access for Ad-Hoc nodes[10]. This means that one (or more) of the nodes has at least two network interfaces, one making it

part of the Ad-Hoc network, and another connecting to the Internet. This node becomes a gateway and provides Internet access for the wireless-only nodes. The gateway is managing a certain address space, and each Ad-Hoc node needs to acquire the address which it will use to communicate through the gateway. This is required to enforce that data packet from the Internet to the Ad-Hoc node travel via the gateway.

There are two general approaches for providing Internet connectivity[11]: *with and without tunneling*. In both approaches, a mobile node needs to know the gateway address and have a route to it. Mobile nodes also need to know their network prefix and compare it with the destination address.

When using the tunnel, if the destination lies outside the mobile network, mobile nodes encapsulate the packets directed to the Internet and put the gateway address as a destination. When such a packet is received by the gateway, it de-capsulate its contents and forwards the packet to the desired destination. Because of this encapsulation, we can say that the packets are tunneled between the mobile node and the gateway.

In another approach, if the destination lies outside the mobile network, mobile nodes send the packet with the 'real' destination address and direct the packet to the next hop for the gateway. Each of the nodes needs to keep a default route, as in standard Internet connectivity. The next hop for such route is the next hop to the gateway.

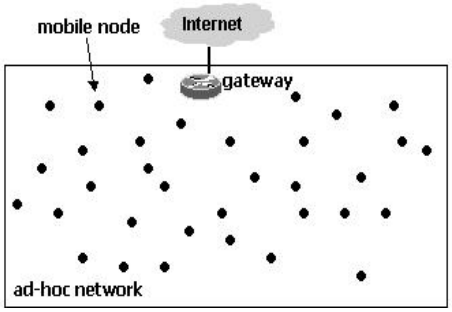


Fig. 6 Internet Connectivity for Ad-Hoc Networks

V. AD-HOC MOBILE ROUTING PROTOCOLS

Routing protocols[12] between any pair of nodes within an Ad-Hoc network can be difficult because the nodes can move randomly and can also join or leave the network. This means that an optimal route at a certain time may not work seconds later.

A. Types of Routing Protocols

Discussed below are three categories that existing Ad-Hoc network routing protocols fall into:

1) Table Driven Protocols
2) On Demand Protocols
3) Hybrid Protocols

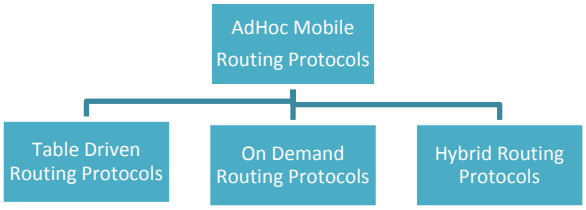


Fig. 7Types of Routing Protocols

1) Table Driven Routing Protocols

These are also known as Proactive Protocols[13]; work out routes in the background independent of traffic demands. Each node uses routing information to store the location information of other nodes in the network and this information is then used to move data among different nodes in the network.

This type of protocol is slow to converge and may be prone to routing loops. These protocols keep a constant overview of the network and this can be a disadvantage as they may react to change in the network topology even if no traffic is affected by the topology modification which could create unnecessary overhead. Even in a network with little data traffic, Table Driven Protocols will use limited resources such as power and link bandwidth therefore they might not be considered an effective routing solution for Ad-Hoc Networks.

2) On Demand Routing Protocols[14]

These are also known as Reactive Protocols, establish routes between nodes only when they are required to route data packets. There is no updating of every possible route in the network instead it focuses on routes that are being used or being set up. When a route is required by a source node to a destination for which it does not have route information, it starts a route discovery process which goes from one node to the other until it arrives at the destination or a node in-between has a route to the destination.

On Demand protocols are generally considered efficient when the route discovery is less frequent than the data transfer because the network traffic caused by the route discovery step is low compared to the total communication bandwidth. This makes On Demand Protocols more suited to large networks with light traffic and low mobility. An example of an On Demand Protocol is Dynamic Source Routing

3) Hybrid Routing Protocols

These Protocols[15]combine Table Based Routing Protocols with On Demand Routing Protocols. They use distance-vectors for more precise metrics to establish the best paths to destination networks, and report routing information only when there is a change in the topology of the network. Each node in the network has its own routing zone, the size of which is defined by a zone radius, which is defined by a metric such as the number of hops. Each node keeps a record of routing information for its own zone. Zone Routing Protocol (ZRP) is an example of a Hybrid routing protocols.

B. Routing's Problem in the Ad-Hoc Networks

The following are some of routing's problem[16] in the Ad-Hoc networks.

1) **Asymmetric link:** If a node X can hear signal from a node Y, it doesn't mean, that Y can hear signal from X too. This can happen, because X's signal is weaker, so Y can't hear signal from X. Obviously X can't direct send a packet to Y, so X must find a detour to Y. Many routing algorithms are based on symmetric connection.
2) **Redundant connection:** The connection in the Ad-Hoc networks shall be redundant to recover connection failures. A connection with high redundancy is expected to be robust though many node failures. The routing algorithm[17] can deal with high redundancy, but it cost very much time to update the routing table.

3) **Interference:** Unlike wired networks, Ad-Hoc networks don't use cable to transmit data. Transmitting data with wave is vulnerable to interferences such as, natural effect like weather, shadowing, scattering, etc. Moreover, as soon as two nodes, which are close, begin with a transmission, they can disturb themselves oppositely.
4) **Dynamic Topology:** The Ad-Hoc networks' nodes can move freely (MANET). The nodes can join or leave the networks anytime. This action cause the nodes to alter their routing table

VI. APPLICATIONS

Ad-Hoc networks are very well suited for many situations[18], in which an infrastructure's network can't be built or it is impossible to build an infrastructure. Data can be exchanged without cable, access point, or portable memory space. This section briefly explains some of applications[19] of Ad-Hoc networks:

A. Military use:

It is perhaps regrettable that, Ad-Hoc networks were first conceived for use in the military department. Imagine, a large number of soldiers spread out in a large battlefield and they have to communicate each other. Installing an infrastructure in the battlefield or equip each soldier with cable is out of the question.

An alternative would be to equip each soldier in the battlefield with a transmitter that can reach all other soldiers in the battlefield at all times. However, this method is not suited for military use. The enemy can intercept communication easily and there would be at most one person using the channel at any given time.

Ad-Hoc networks are very well suited for this case. Each soldier is equipped with transmitter. However the transmitter has smaller transmission area than the transmitter from the example above, so that each soldier can only reach a few other soldiers. However, the transmitter is designed, so that they can relay messages over a hop or multiple hops. These soldiers would form an Ad-Hoc network. This kind of network is obviously more robust, harder to intercept, and suitable to military scenario.

B. Rescue mission and emergency:

Imagine the situation after an earthquake when the communication infrastructure doesn't work anymore. A substitution of the infrastructure has to be installed as soon as possible to support rescue operation. It is obvious that the installed network has to be simple to configure, easy to set up and maintain, and it has to adapt to a dynamic topology in order to support changes in numbers and density of participants.

Ad-Hoc networks[21] especially MANETs can support this scenario. Ad-Hoc networks can be set up easily and quickly. They are designed so they are can install a network without fixed infrastructure. Ad-Hoc networks are temporal. As soon as a new infrastructure established in this area, the Ad-Hoc networks can be removed easily.

C. Personal area network and Bluetooth:

The Idea of a personal area network (PAN) is to create a localized network populated by some network nodes that are closely associated with a single person. The Bluetooth technology supports this scenario.

Bluetooth is a wireless local network, which has only small range area transmission (typically smaller than 10m or 100m and called piconet), operates in the unlicensed 2.4 GHz spectrum [7] and doesn't need infrastructure or cable to connect the end terminals. A piconet is an Ad-Hoc network that consists of one master device and several active slave devices. The piconets can also perform a bigger network, but a master device can't act as master of two or more piconets.

D. Wireless sensor networks:

As the term implies, Wireless Sensor Networks[22] (WSNs) are on the intersection of three technologies: wireless communications, sensing, and networking. The WSNs consist of a large number of sensor nodes, each equipped with a wireless transceiver. The transceiver has two main roles: The sensors use it to measure and / or sense activities. And the network is used to relay the gathered information to data sinks. Therefore, the hop-count may be high. The applications of WSNs are like monitoring animal or very dangerous area.

VII. ADVANTAGESof AD-HOC NETWORKS

The following are the advantages of Ad-Hoc networks[23]:

A. No infrastructure and lower cost:

There are situations, with which a user of a communication system cannot rely on an infrastructure. Using a service from a infrastructure can be expensive for specific applications.

In an area with very low density, like desert, mountain, or isolated area it is not impossible to establish an Infrastructure. But if we compare how often the people there are using service of infrastructure and how many data per day transmitted with cost of installation, maintenance, and repair, it is may be too expensive.

Almost the same problem is with military network. It is obviously very useless to build an infrastructure in a battlefield.

Aside from cost of installation, the enemy can destroy the infrastructure in short time. An independent from infrastructure network is needed for both cases.

B. Mobility (MANET only):

In the next generation of wireless communication systems, there will be a need for the rapid deployment of independent mobile users. The most popular examples include military networks, emergency / rescue operations, and disaster effort. In these scenarios we can't rely on centralized connectivity. MANETs [24] support nodes' mobility. We can still communicate with our mobile devices as long as the destination is reachable.

C. Decentralized and robust:

Another advantage of Ad-Hoc networks is that they are inherently very robust. Imagine that for some reason one of the base stations is not working. In this case, all users of that base station will lose connectivity to other networks.

In the Ad-Hoc networks you can avoid such problem. If one node leaves the network or is not working, you can still have connectivity to other nodes and maybe you can use these nodes to multi-hop your message to the destination nodes, as long as there is at least one way to desired node.

VIII. DISADVANTAGES of AD-HOC NETWORKS

The following are thedisadvantages[25] of Ad-Hoc networks:

A. Higher error rate:

Unlike wired transmission, the wireless transmission may deal with problem the characteristic of the electronic wave. In a free room without obstacle the electronic wave propagate linear independently from its frequency. There is seldom such a situation. The obstacle causes shadowing, reflection, scattering, fading, refraction, diffraction of the wave. This propagation may lead to transmitted packets being garbled and thus received in error.

B. Lower data rate:

One of biggest Problem of Ad-Hoc networks[26] is reduced data rates. The characteristic of wave, which is used for wireless communication, prevents wireless communication to transmit data better than wired communication. A higher frequency can transmit more data, but then it is more vulnerable to interference and performs well in short range.

C. Security:

Due to dynamic distributed infrastructure-less nature and lack of centralized monitoring points, the Ad-Hoc networks are vulnerable to various kinds of attacks. Unlike wired channel, the wireless channel is accessible to both legitimate network users and malicious attacker. Therefore, the Ad-Hoc networks are susceptible to attacks ranging from passive attacks such as eavesdropping to active attack such as interfering.

Passive attack means, that the attacker does not send any message. The attacker just listens the channel; therefore, it is almost impossible to detect this attack. In contrast, the active attack modifies, deletes the packets, and injects packets to invalid destination. Active attack can be detected.

D. Energy limitation (MANET only):

A MANET network allows mobile nodes to communicate in the absence of a fixed infrastructure. Therefore, they operate with on battery power. Because of this limitation, they must have algorithms which are energy-efficient as well as operating with limited processing and memory resources.

IX. CONCLUSION AND FUTURE SCOPE

This paper discussed about Ad-Hoc networks, its different protocols, different types of network namely WSN, MANET and various features and advantage of these networks are also explained. After researching Ad-Hoc networks in depth, we believe that they will be the future of wireless networking. It is true that performance suffers as the number of devices grows and large ad-hoc networks become difficult to route and manage. However, much time is being devoted to achieving routing stability, and a few technical issues need to be solved before they become common place. The area of Ad-Hoc networks is a very fast growing area, and due to the vast research in them, we are seeing these problems disappear and they are coming into a world of their own. The future scope of this research paper is to concentrates on improving more accurate and effective communication of these different networks.

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