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Overview of Ad Hoc Networks: Applications, Challenges and Solutions

Naveen Rai

B.Tech ECE, VIT Univeristy, Vellore, Tamil Nadu

***Abstract*: Ad hoc networks are a new wireless networking paradigm for mobile hosts. Unlike traditional mobile wireless networks, ad hoc networks do not rely on any fixed infrastructure. Instead, hosts rely on each other to keep the network connected. The military tactical and other security-sensitive operations are still the main applications of ad hoc networks, although there is a trend to adopt ad hoc networks for commercial uses due to their unique properties. One main challenge in design of these networks is their vulnerability to security attacks. In this paper, we study the threats an ad hoc network faces and the security goals to be achieved. We identify the new challenges and opportunities posed by this new networking environment and explore new approaches to secure its communication. In particular, we take advantage of the inherent redundancy in ad hoc networks — multiple routes between nodes to defend routing against denial of service attacks. We also use replication and new cryptographic schemes, such as threshold cryptography, to build a highly secure and highly available key management service, which forms the core of our security framework.**

***Keywords*: Wireless Sensor Networks, Routing, Topolog, MANET, PDA.**

I. INTRODUCTION

Numerous factors associated with technology, business, regulation and social behaviour naturally and logically speak in favor of wireless ad hoc networking. Mobile wireless data communication, which is advancing both in terms of technology and usage/penetration, is a driving force, thanks to the Internet and the success of second-generation cellular systems. As we look to the horizon,we can finally glimpse a view of truly ubiquitous computing and communication. In the near future, the role and capabilities of short-range data transaction are expected to grow, serving as a complement to traditional large-scale communication: most man- machine communication as well as oral communication between human beings occurs at distances of less than 10 meters; also, as a result of this communication, the two communicating parties often have a need to exchange data.As an enabling factor, license-exempted frequency bands invite the use of developing radio technologies (such as Bluetooth) that admit effortless and inexpensive deployment of wireless communication. In terms of price, portability and usability and in the context of an ad hoc network, many computing and communication devices, such as PDAs and mobile phones, already possess the attributes that are desirable. As advances in technology continue, these attributes will be enhanced even further.

Finally, we note that 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 unravelled ad hoc functionality at virtually no cost.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. Today, our vision of ad hoc networking includes scenarios such as those depicted in Figure 1, where people carry devices that can network on an ad hoc basis. A user's devices can both interconnect with one another and connect to local information points—for example, to retrieve updates on flight departures, gate changes, and so on. The ad hoc devices can also relay traffic between devices that are out of range. The airport scenario thus contains a mixture of single and multiple radio hops.

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 1 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.

Ad hoc networks are a new paradigm of wireless communication for mobile hosts (which we call nodes). In an ad hoc network, there is no fixed infrastructure such as base stations or mobile switching centers. Mobile nodes that are within each other's radio range communicate directly via wireless links, while those that are far apart rely on other nodes to relay messages as routers. Node mobility in an ad hoc network causes frequent changes of the network topology. Figure 2 shows such an example: initially, nodes A and C have a link between them via node B. When B moves out of A's radio range, the link is broken. However, the network is still connected, be A can reach C through G, E, and D .

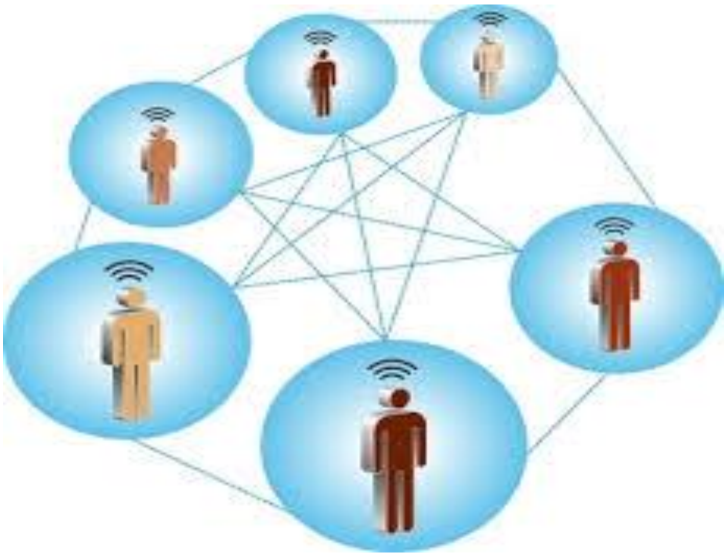

Fig.1 An Ad- Hoc Network of people inter connected via their devices.

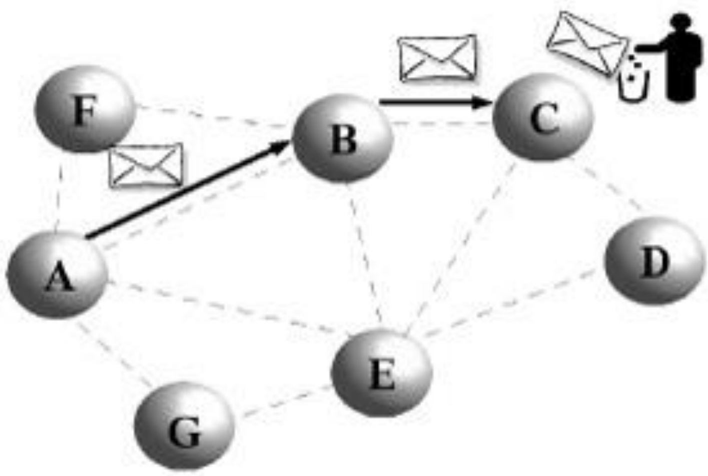

Fig.2 A dynamic topolgy for Ad-Hoc Networks.

2. CHARACTERISTICS

In contrast to traditional wireline or wireless networks, an ad hoc network could be expected to operate in a network environment in which some or all the nodes are mobile. In this dynamic environment, the network functions must run in a distributed fashion, since nodes might suddenly disappear from, or show up in, the network. In general, however, the same basic user requirements for connectivity and traffic delivery that apply to traditional networks will apply to ad hoc networks.Below, we discuss some typical operational characteristics and how they affect the requirements for related networking functions. To limit the scope of the discussion, we will examine the case of a PAN-oriented ad hoc network that involves a mix of notebook computers, cellular phones, and PDAs.

• Distributed operation: a node in an ad hoc network cannot rely on a network in the background to support security and routing functions. Instead these functions must be designed so that they can operate efficiently under distributed conditions.

• Dynamic network topology: in general, the nodes will be mobile, which sooner or later will result in a varying network topology. Nonetheless, connectivity in the network should be maintained to allow applications and services to operate undisrupted. In particular, this will influence the design of routing protocols. Moreover, a user in the ad hoc network will also require access to a fixed network (such as the Internet) even if nodes are moving around. This calls for mobility-management functions that allow network access for devices located several radio hops away from a network access point.

• Fluctuating link capacity: The effects of high bit-error rates might be more profound in a multihop ad hoc network, since the aggregate of all link errors is what affects a multihop path. In addition, more than one end-to-end path can use a given link, which if the link were to break, could disrupt several sessions during periods of high bit-error transmission rates. Here, too, the routing function is affected, but efficient functions for link layer protection (such as forward error correction, FEC, and automatic repeat request, ARQ) can substantially improve the link quality.

• Low-power devices: In many cases, the network nodes will be battery-driven, which will make the power budget tight for all the power-consuming components in a device. This will affect, for instance, CPU processing, memory size/usage, signal processing, and transceiver output/input power. The communication-related functions (basically the entire protocol stack below the applications) directly burden the application and services running in the device. Thus, the algorithms and mechanisms that implement the networking functions should be optimized for lean power consumption, so as to save capacity for the applications while still providing good communication performance. Besides achieving reasonable network connectivity, the introduction of multiple radio hops might also improve overall performance, given a constrained power budget. Today, however, this can only be realized at the price of more complex routing.

Given the operating conditions listed above, what can the user expect from an ad hoc network? The support of multimedia services will most likely be required within and throughout the ad hoc network. As an example, the following four quality-of-service (QoS) classes would facilitate the use of multimedia applications including :-

• conversational (voice)

• streaming (video/audio)

• interactive (Web)

• background (FTP, etc.).

2.1. Multi Hoppi Ng In Ad-Hoc Networks:

In dealing with an unreliable wireless broadcast medium, special “radio” considerations should be addressed in the communication system of an ad hoc network, to ensure reliable and efficient operation. One way of doing this is to employ multihopping, which facilitates the reuse of resources in both the spatial and temporal domains, provided that the nodes which participate in the network are reasonably well distributed in space.In contrast, single- hop networks mainly share the channel resources in the temporal domain. Figure 3 shows a schematic depiction of the spatial interference in multihopping and single hopping scenarios. Each case considers an identical situation with respect to node distribution, sources, and destinations. In the multihopping scenario, packets are routed over intermediate relays. However, the single-hop network sends the data directly from the source to destination. The circles in the figure indicate a power-controlled range of the transmitting nodes.

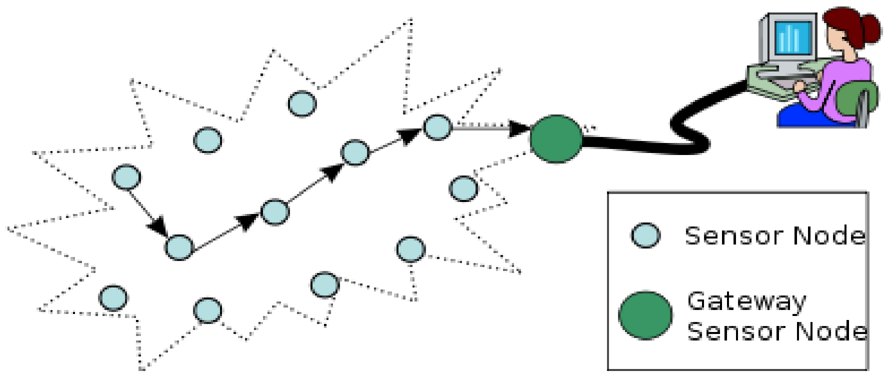

Fig.3 Multi hopping in Ad- Hoc Networks.

2.2. Multi Hopping Over Single Hopping:

Whether multi-hopping is necessary, suitable or even possible depends on factors such as the number and distribution of terminals in the network, relative traffic density, radio channel characteristics, practical communication limitations, and reasons for optimizing certain parameters. Under some circumstances, a multihop network might actually degenerate into a single-hop network.One obvious reason for employing multi-hopping is to provide connectivity, since some terminals might be out of range of each other, and cannot therefore form a single-hop network.

3. APPLICATIONS

Mobile ad hoc networks have been the focus of many recent research and development efforts. So far, 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 commercial sector, equipment for wireless, mobile computing has not been available at a price attractive to large markets. However, as the capacity of mobile computers increases steadily, the need for unlimited networking is also expected to rise. Commercial ad hoc networks could be used in situations where no infrastructure (fixed or cellular) is available. Examples include rescue operations in remote areas, or when local coverage must be deployed quickly at a remote construction site. Ad hoc networking could also serve as wireless public access in urban areas, providing quick deployment and extended coverage. The access points in networks of this kind could serve as stationary radio relay stations that per-form ad hoc routing among themselves and between user nodes. Some of the access points would also provide gateways via which users might connect to a fixed back- bone network.

At the local level, ad hoc networks that link notebook or palmtop computers could be used to spread and share information among participants at a conference. They might also be appropriate for application in home networks where devices can communicate directly to exchange information, such as audio/video, alarms, and configuration updates. Perhaps the most far-reaching applications in this context are more or less autonomous networks of interconnected home robots that clean, do dishes, mow the

lawn, perform security surveillance, and so on. Some people have even proposed ad hoc multihop networks (denoted sensor networks)—for example, for environmental monitoring, where the networks could be used to forecast water pollution or to provide early warning of an approaching tsunami. 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.

4. CHALLENGES

In general, mobile ad hoc networks are formed dynamically by an autonomous system of mobile nodes that are connected via wireless links without using the existing network infrastructure or centralized administration. The nodes are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. Mobile ad

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hoc networks are infrastructure-less networks since they do not require any fixed infrastructure, such as a base station, for their operation. In general, routes between nodes in an ad hoc network may include multiple hops, and hence it is apropriate to call such networks as 'multi-hop wireless ad hoc networks. Each node will be able to communicate directly with any other node that resides within its transmission range. For communicating with nodes that reside beyond this range, the node needs to use intermediate nodes to relay the messages hop by hop.

One of the major problem associated with ad hoc networks and major wireless commuication techniques is the ease of eavesdropping. In the case of ad hoc network, their functionality is established through the cooperation of it's nodes amongst them and the mobile ad hoc networks are inernally susceptible to various security attacks. There are basically two types of possible attacks that can happen in an ad hoc network, active and passive. In the case of passive attacks, the broker tries to gather useful information from the system by just listening to the channel. Since no traffic is produced in the system therefore most of the times it is very difficult to detect such type of an attack. On the other hand, in the case of an active attack the attacker actively participates in the accessing of the information from the system and disrupts the functioning of the network. The ad hoc networks flexibility and convenience do come at a price. Ad hoc wireless networks inherit the traditional problems of wireless commnications and wireless networking :-

- Hidden-terminal and exposed-terminal phenomena may occur.
- The channel has time-varying and asymmetric propagation properties.
- The channel is unprotected from outside signals.
- The wireless medium is significantly less reliable than wired media.

To these problems and complexities, the multi-hop nature, and the lack of fixed infrastructure add a number of characteristics, complexities, and design constraints that are specific to ad hoc networking. In addition to all of the above the various challenges that occurs in a Ad Hoc networks are:-

1) Host is no longer an end system - can also be an acting intermediate system.
2) Limited wireless bandwidth.
3) Changing the network topology over time.
4) Potentially frequent network partitions.
5) Every node can be mobile.

Mobile devices rely on batteries for energy.Battery power is finite, and represents one of the greatest constraints in designing algorithms for mobile devices. Projections on progress in battery technology show that only small improvements in the battery capacity are expected in next future. Under these conditions, it is vital that power utilization be managed efficiently by identifying ways to use less power, preferably with no impact on the applications. Limitation on battery life, and the additional energy requirements for supporting network operations (e.g.,routing) inside each node, make the energy conservation one of the main concern in ad hoc net-working . The importance of this problem has produced a great deal of research on energy saving in wireless networks in general , and ad hoc networks in particular . Strategies for power saving have been investigated at several levels of a mobile device including the physical-layer transmissions, the operating system, and the applications points out battery properties that impact on the design of battery powered devices.

5. SOLUTIONS

1) Security: Protecting data transformation in mobile ad hoc networks is an important aspect to be seen. Parties within the network want their communication to be secure. At present MANET do not have any stick security policy. This could possibly lead active attackers to easily exploit or possibly disable mobile ad-hoc network. Mobile ad-hoc networks are highly dynamic i.e. topology changes and link breakage happen quite frequently. We need a security solution which is dynamic too. Any malicious or misbehaving nodes can create hostile attacks. These types of attack can seriously damage basic aspects of security.

Some of the main security requirements of MANET are:-
1) Certain Discovery- Route should always be found if it exits between two nodes.
2) Isolation Misbehaving- Nodes misbehaving nodes should always be identified and isolated from routing.
3) Location Privacy- Protection of information about node location and network structure .

2) Bandwidth: The motivation for bandwidth allocation is to ensure each user receives appropriate quality of service. Achieving this in wireless ad hoc networks requires the network and MAC layers to cooperate; the network layer determines (at least implicitly if not explicitly) an appropriate band-width allocation entitlement for each flow. Based on this determination, the MAC layer coordinates transmissions so that each flow receives its entitled bandwidth allocation. Factors to look for when comparing bandwidth allocation schemes are:-

1) How the network and MAC layers interact?
2) How much extra information is passed around the network to support the algorithm?
3) The time it takes for the flow rates to reach steady state (convergence rate).
4) The interference model used.
5) The computational and implementation complexity of the scheme.

3) Energy Efficient Routing: A mobile ad-hoc network (MANET) faces various challenges including limited energy, limited communication bandwidth, computation constraint and cost. Therefore, clustering of sensor nodes is adopted which involves selection of cluster-heads for each cluster. This enhances system performance by enabling bandwidth reuse, better resource allocation and improved power control. Energy optimization in wireless sensor networks is a field of research in itself with various proposed algorithms to enhance the system lifetime.The well known algorithms proposed are LEACH(Low Energy Adaptive Clustering Hierarchy), PEAGSIS(Power Efficient Gathering In Sensor Information System) which is an improvised and an effective counterpart of the LEACH and many more.The main objective of proposing these algorithms is to reduce the energy consumption of the nodes and the devices such that they can operate for a longer period of time and cicrculate the information in the system.If the nodes die out then this will result in the overall failure of the system and the essential information may not reach the destination which can be fatal in time critical applications.

6. CONCLUSION

In this article we have tried to survey ad hoc networking mainly from a technical point of view. We have also made an attempt to clarify what an ad hoc network actually is and found that the definitions vary. However, by proceeding from familiar wireless network architectures, we have allowed the level of independent operation of the network nodes to define the notion of ad hoc networking. Typically, these networks operate with distributed functions and allow traffic to pass over multiple radio hops between source and destination.

Furthermore, we have discussed some of the typical properties of ad hoc networks, such as routing algorithms and the implications of radio layers. The inherent unpredictability in a network whose nodes move poses a challenge to routing and mobility functions if they are to deliver data consistently between the network nodes. Nonetheless, multihop radio systems also make it possible to save battery capacity while retaining, or even improving, performance. In any case, the most attractive property of an ad hoc networking model is perhaps its independence from centralized control and, thus, the increased freedom and flexibility it gives the user.

7. FUTURE SCOPE

Ad hoc networks, the most talked about term in wireless technologies, approach to be the emperor of future airs provided the vision of “anytime, anywhere” communications. At present, the general trend is toward mesh architecture and large scale. New applications call for both bandwidth and capacity, which implies the need for a higher frequency and better spatial spectral reuse. Propagation, spectral reuse, and energy issues support a shift away from a single long wireless link (as in cellular) to a mesh of short links (as in MANET).

Research on “multi-hop” architecture showed it a promising solution to the implementation of ad hoc networks. As the evolvement goes on, especially the need of dense deployment such as battlefield and sensor networks, the nodes in MANET will be smaller, cheaper and capable. From a technical perception, the realisation of this vision still requires a large number of challenges to be solved related to the devices, protocols, applications and the services provided. The concise discussion in this paper shows that, despite the large efforts of the MANET research community and the rapid progress made during the last years, a lot of challenging technical issues still needs to be solved efficiently. Mobile ad hoc networks that are a new paradigm of networking and technology have also opened up new business opportunities for the telecom operators and the service providers. To sum it up, appropriate business scenarios, the applications and their economical models needs to be identified, along with the technological advances, thus making a transition of the ad hoc networks to the commercial world feasible.

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