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A Survey on Taxonomy of Wireless Ad hoc Networks

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Abstract: Wireless Ad hoc Networks contains different characteristics and is therefore classified into mobile ad hoc networks, wireless mesh networks and wireless sensor networks. In this paper, we have analyzed each of the above categories of wireless ad hoc networks. Their salient characteristics and applications are gathered and summarized. Further, this paper briefly addresses the scalability issues of wireless mesh networks. This paper will help the reader to understand the various issues related to the wireless networks and to propose efficient schemes to improve their performance.

Keywords: Wireless Mesh Networks, Mobile Ad Hoc Net Works, Wireless Sensor Networks and Scalability.

I. INTRODUCTION

Computer networks play an increasingly important role in our lives. ‘‘Computer network" to mean a collection of autonomous computers interconnected by a single technology. Computer networks [1] classified into wired networks and wireless networks. In figure1 shows Taxonomy of Computer Networks. We will now examine each of these in turn.

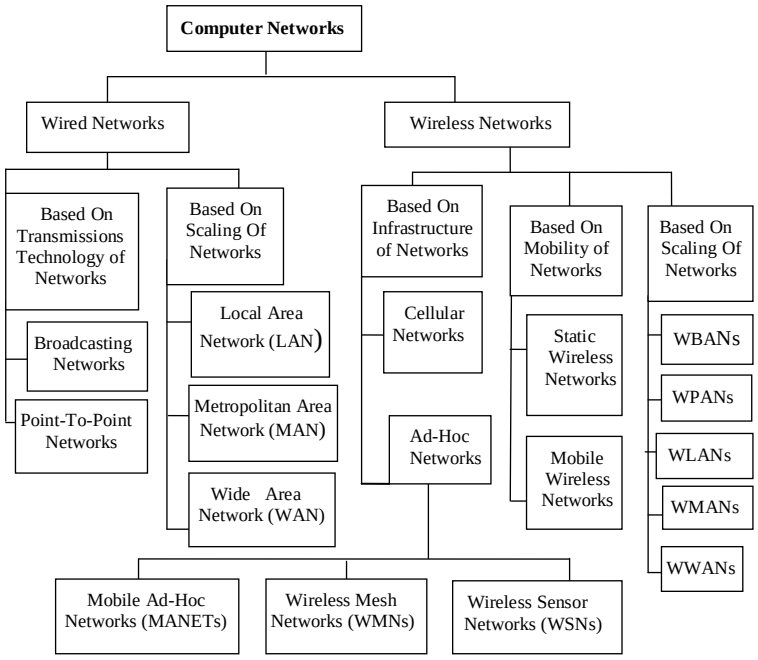

Figure 1. Taxonomy of Computer Networks

II. TAXONOMY OF WIRED NETWORKS

Taxonomy of wired networks into which all computer networks fit, but two dimensions stand out as important: transmission technology and scale. We will now examine each of these in turn.

[1] Based on the Transmission Technology of the Network:

There are two types of technology transmission that are in widespread use. They are as follows:

a) Broadcast links
b) Point-to-point links.

***a. Broadcast links*:** Broadcast networks have a single communication channel that is shared by all the machines on the network. Short messages, called packets in certain contexts, sent by any machine are received by all the others.

b. Point-to-point links: In contrast, point-to-point networks consist of many connections between individual pairs of machines. To go from the source to the destination, a packet on this type of network may have to first visit one or more intermediate. machines. Often multiple routes, of different lengths, are possible, so finding good ones is important in point-to-point networks. As a general rule (although there are many exceptions), smaller, geographically localized networks tend to use broadcasting, whereas larger networks usually are point-to-point. Point-to-point transmission with one sender and one receiver is sometimes called unicasting.

[2] Based on the Geographical Area or Scaling of the Network:

An alternative criterion for classifying networks is their scale. In fig1 we classify multiple processor systems by their physical size. At the top are the personal area networks, networks that are meant for one person. For example, a wireless network connecting a computer with its mouse, keyboard, and printer is a personal area network. Also, a PDA that controls the user's hearing aid or pacemaker fits in this category. Beyond the personal area networks come longer-range networks. These can be divided into local, metropolitan, and wide area networks. Finally, the connection of two or more networks is called an internetwork. The worldwide Internet is a well-known example of an internetwork. Distance is important

as a classification metric because different techniques are used at different scales are illustrated in figure 2.

Interprocessor distance	Processors localed in same	Example
1 m	Square meter	Personel area network
10 m	Room	Local area network
100 m	Building	
1 Km	Campus	
10 km	City	Metropolitan area network
100 Km	Country	Wide area network
1000 Km	Continent	
10,000Km	Planet	The Internet

Figure 2. Classification of interconnected processors by scale

a. Local Area Networks (LAN):

Local area networks, generally called LANs, are privately-owned networks within a single building or campus of up to a few kilometers in size. They are widely used to connect personal computers and workstations in company offices and factories to share resources (e.g., printers) and exchange information. LANs are distinguished from other kinds of networks by three characteristics:

a) their size
b) their transmission technology
c) their topology

LANs are restricted in size, which means that the worst-case transmission time is bounded and known in advance. Knowing this bound makes it possible to use certain kinds of designs that would not otherwise be possible. It also simplifies network management. LANs may use a transmission technology consisting of a cable to which all the machines are attached, like the telephone company party lines once used in rural areas. Traditional LANs run at speeds of 10 Mbps to 100 Mbps, have low delay (microseconds or nanoseconds), and make very few errors. Newer LANs operate at up to 10 Gbps.

b. Metropolitan Area Networks(MAN):

A metropolitan area network, or MAN, covers a city. The best-known example of a MAN is the cable television network available in many cities. This system grew from earlier community antenna systems used in areas with poor over-the-air television reception. In these early systems, a large antenna was placed on top of a nearby hill and signal was then piped to the subscribers' houses.

c. Wide Area Networks(WAN):

A wide area network, or WAN, spans a large geographical area, often a country or continent. It contains a collection of machines intended for running user (i.e., application) programs. We will follow traditional usage and call these machines hosts. The hosts are connected by a communication subnet, or just subnet for short. The hosts are owned by the customers (e.g., people's personal computers), whereas the communication subnet is typically owned and operated by a telephone company or Internet service provider. The job of the subnet is to carry messages from host to host, just as the telephone system carries words from speaker to listener. Separation of the pure communication aspects of the network (the subnet) from the application aspects (the hosts), greatly simplifies the complete network design.

III. TAXONOMY OF WIRELESS NETWORKS

In contrast to wired networks, wireless networks are available in a great diversity. In fact, the liberty in result to the absence of wires has provided the opportunity of multidimensional progress in wireless networks; therefore, the application of wireless networks is more diversified and multiplex, and there are several ways to classify wireless networks. Since the classification of wireless networks is out of the scope of this thesis, a brief review of the different classification approaches and categories of the wireless networks is provided in this section for a basic understanding of the area. Further details on the classification of wireless networks can be viewed in references [6], [7], [8], [9], [10], [11], [12], [13] and [14].

[3] Based on the Geographical Area or Size of the Network:

This classification approach is similar to the traditional LAN/MAN/WAN classification in wired networks. Wireless networks have more divisions than wired networks due to their greater multiformity, notwithstanding the inter-division boundaries are obscure as in wired networks. Following are the common divisions of wireless networks according to this classification approach.

a. Wireless Body Area Networks (WBAN):

Simply body area networks are networks of wireless sensor nodes placed in an extremely limited area, usually on the human body, for the monitoring of body parameters. Such networks are mainly used for health monitoring and other similar purposes.

b. Wireless Personal Area Networks (WPAN):

WPAN[9] are small scale personal or private purpose networks of wireless enabled devices established by individuals usually at home. The usual reach of such networks is the space around a person within the distance to which his/her voice reaches. Home networking is one typical use of such networks.

c. Wireless Local Area Networks (WLAN) :

WLAN can be considered as the wireless equivalent of wired LANs. The typical range of such networks is few hundred meters. The most widely available WLANs are networks based on the IEEE 802.11 standards [8]. Such networks are usually established at airports, train stations, restaurants, offices, or conferences to provide internet access or similar services to the temporary or mobile users.

d. Wireless Metropolitan Area Networks (WMAN):

WMAN are usually community networks where wireless technologies are used for the intercommunication purpose.

Like WLANs, the main purpose of these networks is also to provide internet related services but in a larger geographical area such as a university campus or a housing facility or remote areas where wired infrastructure is either not available or is costly to provide.

e. Wireless Wide Area Networks (WWAN):

WWAN mainly include cellular networks and satellite networks. These networks are established to provide public mobile service over a large geographical area. The most commonly available form is the mobile phone network.

[4] Based on the Topology or Mobility of the Network :

Wireless devices have the luxury to move around. Due to this feature, wireless networks will either be with static topology or dynamic topology. Mobility in itself is a versatile phenomenon. The simplest form is the relative mobility of the nodes in a network that are able to communicate with each other.

a. Static Wireless Networks:

Static wireless networks are wireless networks of the nodes with fixed position or location. Certainly, this definition predominantly depends on the type of mobility. For example, a WBAN is a static network as all the nodes implanted on the body of a human do not change their positions in relation to each other. However, usually these sensors have to transmit the collected data to a central monitoring node. If the person carrying this WBAN is allowed to move in relation to that central node, the whole WBAN is changing its position. WPANs can also be static if all the participating nodes have fixed locations. Wireless metropolitan area networks established in remote areas to provide last mile connectivity to the households are other examples of static wireless networks.

b. Mobile Wireless Networks:

Mobile wireless networks are wireless networks with nodes being able to change their position or location. Cell phone networks and WLANs [15] are the two main examples from this category. In fact, Mobile Ad hoc Networks (MANET), the most popular version of wireless ad hoc networks these days, is by definition a sub-category of mobile wireless networks as well as wireless ad hoc networks.

A more concrete approach to distinguish between the static and mobile wireless networks is, whether the mobility of the participating nodes during the time when network is functional will effect the operation of the network. de. If the person carrying

[5] Based on the Infrastructure of the Network:

Wireless networks can also be categorized as infrastructure-based wireless networks and infrastructure-less wireless networks.

a. Infrastructure-Based Wireless Network :

Infrastructure-based wireless network are wireless networks with the concept of central or base station and a specific topological structure. Cellular networks and WLANs are two typical examples from this category. In such networks, every node is directly connected to a special purpose central or base node (Access Point in case of WLANs) and intercommunication between individual nodes as well as the delivery of network services is performed through this base node.

***b. Infrastructure-Less Wireless Networks or Wireless Ad Hoc Networks*:**

Wireless ad hoc networks are those wireless networks where individual nodes can directly communicate with each other to form a network. The WBANs, WPANs, and WLANs discussed earlier usually exist in both infrastructure-based and infrastructure-less mode. A Mobile ad hoc network is a group of wireless mobile computers (or nodes); in which nodes collaborate by forwarding packets for each other to allow them to communicate outside range of direct wireless transmission. Ad hoc networks require no centralized administration or fixed network infrastructure such as base stations or access points, and can be quickly and inexpensively set up as needed [4].Wireless ad hoc networks classified into several types. We will now examine each of these in turn.

a) Mobile Ad-hoc Networks (MANETs):

A MANET is an autonomous group of mobile users that communicate over reasonably slow wireless links. The network topology may vary rapidly and unpredictably over time, because the nodes are mobile. The network is decentralized, where all network activity, including discovering the topology and delivering messages must be executed by the nodes themselves. Hence routing functionality will have to be incorporated into the mobile nodes. MANET[6] is a kind of wireless ad-hoc network and it is a self-configuring network of mobile routers (and associated hosts) connected by wireless links – the union of which forms an arbitrary topology. The routers, the participating nodes act as router, are free to move randomly and manage 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.

i. Characteristics of MANETs:

Mobile ad hoc network nodes are furnished with wireless transmitters and receivers using antennas, which may be highly directional (point-to-point), Omni-directional (broadcast), probably steerable, or some combination thereof [6]. At a given point in time, depending on positions of nodes, their transmitter and receiver coverage patterns, communication power levels and co-channel interference levels, a wireless connectivity in the form of a random, multihop graph or "ad hoc" network exists among the nodes.

This ad hoc topology may modify with time as the nodes move or adjust their transmission and reception parameters.
The characteristics of these networks are summarized as follows:

(i) Communication via wireless means.
(ii) Nodes can perform the roles of both hosts and routers.
(iii) Bandwidth-constrained, variable capacity links.
(iv) Energy-constrained Operation.
(v) Limited Physical Security.
(vi) Dynamic network topology.

(vii) Frequent routing updates.

ii. Applications of MANETs:

Some of the applications of MANETs[3] are as follows:

(i) Tactical Networks
  (a) Military communications
  (b) Automated battlefields

(ii) Emergency Services
  (a) Search and rescue operations, as well as disaster recovery, Replacement of fixed infrastructure in case of earthquakes, hurricanes, war etc.

(iii) Home and Enterprise Networking
  (a) Home/Office wireless networking
  (b) Personal Area Networks (PANs)

(iv) Educational Applications
  (a) Setup virtual classrooms or conference rooms
  (b) Setup ad hoc communication during conferences, meetings or lectures.

b) Wireless Mesh Networks (WMNs):

As various wireless networks evolve into the next generation to provide better services, a key technology, wireless mesh networks (WMNs), has emerged recently. In WMNs, nodes are comprised of mesh routers and mesh clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. A WMN is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves (creating, in effect, an ad hoc network). This feature brings many advantages to WMNs such as low up-front cost, easy network maintenance, robustness, and reliable service coverage.

i. The characteristics [2] of WMNs:

(i) WMNs support ad hoc networking, and have the capability of self-forming, self-healing, and self-organization.

(ii) WMNs are multi-hop wireless networks, but with a wireless infrastructure/backbone provided by mesh routers.

(iii) Mesh routers have minimal mobility and perform dedicated routing and configuration, which significantly decreases the load of mesh clients and other end nodes.

(iv) Mobility of end nodes is supported easily through the wireless infrastructure.

(v) Mesh routers integrate heterogeneous networks, including both wired and wireless. Thus, multiple types of network access exist in WMNs. Power-consumption constraints are different for mesh routers and mesh clients. WMNs are not stand-alone and need to be compatible and interoperable with other wireless networks. Therefore, WMNs diversify the capabilities of ad-hoc networks instead of simply being another type of ad hoc network. These additional capabilities necessitate new algorithms and design principles for the realization of WMNs.

ii. The applications [5] which motivate the research and development of WMNs are:

(i) Cellular Backhaul
(ii) Campuses
(iii) Municipalities, including downtown cores and parks
(iv) VoIP Interoperability
(v) Broadband Residential Networking
(vi) Real-Time Multicast Video
(vii) GPS Resource Tracking
(viii) Multimedia Instant Messaging
(ix) Military operations, disaster recovery and temporary installations
(x) Intelligent Transportation Systems and Logistics
  (a) Large warehouses, shipping yards, construction sites and Commuter rail lines.
  (b) Airport terminals and hangers.
  (c) Video Surveillance and traffic monitoring cameras.
  (d) Traffic and environmental sensor monitoring.
  (e) Fixed and portable variable message signs.
  (f) Adaptive traffic signals.
  (g) Automatic Vehicle Location (AVL).
  (h) Remote reporting and database access.
(i) Fleet management and communications.
(i) Community and Neighbourhood networking
(ii) Law Enforcement Agencies
  (a) Instant incident communications
  (b) Mobile data, video and voice services
  (c) Real time video surveillance feeds
  (d) Interdepartmental communications
  (e) High bandwidth data connectivity for officers on the street
(i) Enterprise networking
(ii) Metropolitan area networks
(iii) Sensor Networks
  (a) Chemical, bio, nuclear detection and monitoring
  (b) Traffic observation, detection and management
  (c) Industrial Control Systems
  (d) Portable and mobile site monitors
  (e) Security and Video monitoring systems
(i) Health and medical systems

Scalability is the most critical question in WMNs. Hierarchical routing protocols can only partially solve this problem due to their complexity and difficulty of management. Geographic routing relies on the existence of GPS or similar positioning technologies, which increases cost and complexity of WMNs. Moreover, the inquiry of destination position produces additional traffic load. Thus, new scalable routing protocols need to be developed. Existing performance metrics incorporated into routing protocols need to be expanded. Moreover, how to integrate multiple performance metrics into a routing protocol so that the optimal overall performance is achieved is a challenging issue.

To overcome the scalable issue in WMNs with my proposal is A Cross Layer Waypoint Routing called MCDOA (Multi-metric Cross Layer DSR over AODV) Routing is

simulated using GloMoSim, a network simulator. DOA [3] is a waypoint routing approach where the whole path from source to destination is divided into segments, and routing occurs at intersegment and intrasegment levels. In DOA, DSR is used for Intersegment routing and AODV for intrasegment routing (hence the name DOA). The new protocol is more scalable as it reduces control overhead to greater extent. As it maintains routes at segment level, the overhead due to link failure is also less. Initially the segment size is fixed to some constant value in DOA routing, which is some randomly selected value. MCDOA shows a new approach where the path is divided into segments based on link and physical layer parameters (hence the suffix Cross Layer). Using Link layer and radio layer parameters the path is divided into segments. As segment size is radio and link aware, the time to repair segments on failure is also comparatively low. Thus, the proposed MCDOA routing protocol is more scalable, cross layer and thus more suitable for wireless mesh networks.

c) Wireless Sensor Networks (WSNs):

In the last few years wireless sensor networks (WSNs) have drawn the attention of the research community, driven by a wealth of theoretical and practical challenges [6]. This progressive research in WSNs explored various new applications enabled by larger scale networks of sensor nodes capable of sensing information from the environment, process the sensed data and transmits it to the remote location [6]. WSNs are mostly used in, low bandwidth and delay tolerant, applications ranging from civil and military to environmental and healthcare monitoring.

i. The characteristic of WSNs:

(a) Fault tolerant: the system should be robust against node failure (running out of energy, physical destruction, H/W, S/W issues etc). Some beep mechanism should be incorporated to indicate that the node is not functioning properly.

(b) Scalable: The system should support large number of sensor nodes to cater for different applications.

(c) Long life: The node's life-time entirely defines the network's life-time and it should be high enough. The sensor node should be power efficient against the limited power resource that it have since it is difficult to replace or recharge thousands of nodes. The node's communication, computing, sensing and actuating operations should be energy efficient too.

(d) Programmable: the reprogramming of sensor nodes in the field might be necessary to improve flexibility.

(e) Secure: the node should support the following:

  (i) Access Control: to prevent unauthorized attempts to access the node.

  (ii) Message Integrity: to detect and prevent unauthorized changes to the message.

  (iii) Confidentiality: to assure that sensor node should encrypt messages so only those nodes would listen who have the secret key.

  (iv) Replay Protection: to assure that sensor node should provide protection against adversary reusing an authentic packet for gaining confidence/network access, man in the middle attack can be prevented by time stamped data packets.

(f) Affordable: the system should use low cost devices since the network comprises of thousand of sensor nodes, tags and apparatus. Installation and maintenance of system elements should also be significantly low to make its deployment realistic.

IV. CONCLUSION

In this paper we have presented the taxonomy of computer networks, and it has been categorized into wired networks and wireless networks. Based on their characteristics wireless ad hoc networks in turn classified into mobile ad hoc networks, wireless mesh networks and wireless sensor networks. Further we discussed briefly about the scalability and cross layer design issues of wireless mesh networks. This paper will help the readers to get better understanding on different types of ad hoc networks.

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