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Significance of Wireless Multi-Hop AD-HOC Networks

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Abstract— The multi-hop ad hoc networking is not a new concept having been around for over twenty years, mainly exploited to design tactical networks. In the past decade wireless multi-hop ad-hoc networks have got a tremendous amount of research focus. Mobile devices enabled with wireless short range communication technologies make possible new applications for continuous communication, interaction and collaboration. The collaboration is used to facilitate communication when mobile devices are not able to establish direct communication paths. So the communication is multi-hop with intermediate nodes acting as routers that forward the messages addressed to other nodes. The multi-hop ad-hoc networking concept was successfully applied in several classes of networks. In this paper, it reviews the categories of wireless multi-hop ad-hoc networks and discusses main evolutions of wireless multi-hop ad-hoc networks specially the opportunistic networks. This networking paradigm is well suited for a world of pervasive devices equipped with various wireless networking technologies which are frequently out of range from a global network but are in the range of other networked devices, and sometime cross areas where some type of connectivity is available. Among multi-hop ad hoc networks, wireless sensor networks have a special role.

Keywords— Delay tolerant Network, MANET, Mobile Devices, Opportunistic Network, WLAN

I. Introduction

The general-purpose Multi-hop Ad Hoc Networking have not yet achieved the envisaged impact in terms of real world implementation and industrial deployment. Previously, most of the wireless networks were wireless local area networks (WLAN) operating on the IEEE 802.11 Wi-Fi standard. The infrastructure consists of a base station, also called an access point that is owned by a company or a network operator. Such networks were centralized and the base station controls the access to the communication channel. The base station was also used to connect the WLAN to the company network or to the Internet. IEEE 802.11 offers a second mode, the ad-hoc mode. For instance, defense operations, relief and disaster recovery operations etc. In this mode, there is no base station, and devices within the same wireless LAN communicate directly hop).

An extension of wireless LAN operating in ad hoc mode are multi-hop ad hoc networks. They are typically deployed in large areas. A wireless multi-hop ad-hoc network is a network of nodes connected by wireless communication links. The links are usually implemented with digital packet radios. Some devices might not be able to communicate directly to each other because of their limited radio range. These networks need other intermediate nodes to forward messages. In such cases, intermediary devices act as relays. In other words, the communication goes through multiple hops before reaching its final destination. This networking concept was successfully applied in several classes of networks that are penetrating the mass market. These networks in various forms and under various names and intermittently connected networks, are being increasingly used in military and civilian applications too. They are not relying on existing infrastructure hence their deployment cost is low. These characteristics make multi-hop ad hoc networks a promising technology.

This article presents and analyses these emerging network technologies (mesh, opportunistic, vehicular, and sensor networks) that successfully exploit multi hop ad hoc networking. We explain the reasons why, in contrast to pure general-purpose MANET, these technologies are penetrating the mass market in a positive way.

Rest of the paper is organized as follows. Section I provides the introduction, Section II briefs about the hierarchy / categories of Wireless Ad-hoc Networks and its applications, Section III contains the evolutions of multi-hop ad hoc network and its applications with research issues, Section IV discusses about the routing challenges of multi-hop ad hoc network. We provided conclusion in section V.

II. BACKGROUND

The areas in which there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use, 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 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. Figure 1 shows the hierarchy/categories of wireless ad-hoc networks.

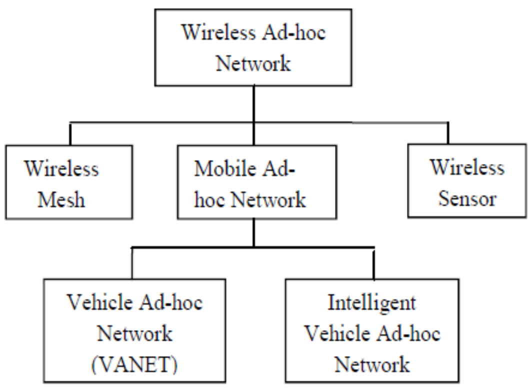

Fig. 1 Hierarchy/categories of Wireless Ad-hoc Networks

2.1 WIRELESS AD-HOC NETWORK

A wireless ad hoc network or MANET is a decentralized type of wireless network. The network is ad hoc because it does not rely on a pre-existing infrastructure, such as routers in wired networks or access points in managed wireless networks. Instead, each node participates in routing by forwarding data for other nodes, so the determination of which nodes forward data is made dynamically on the basis of network connectivity and the routing algorithm in use. Instead, each node participates in routing by forwarding data for other nodes, so the determination of which nodes forward data is made dynamically on the basis of network connectivity and the routing algorithm in use. In the Windows operating system, ad-hoc is a communication mode that allows computers to directly communicate with each other without a router. Wireless networks lack the complexities of infrastructure setup and administration, enabling devices to create and join networks "on the fly" – anywhere, anytime. Figure 2 shows the wireless ad-hoc networks.

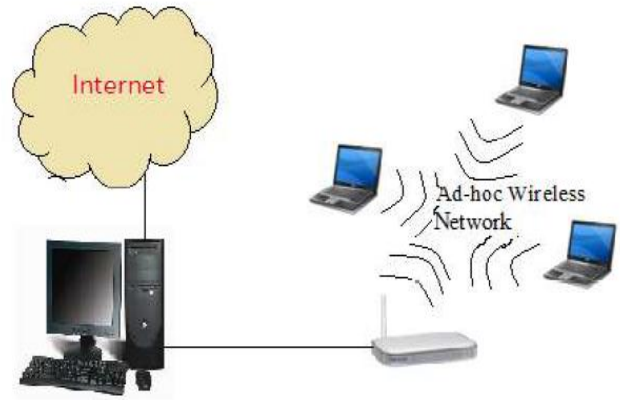

Fig. 2 Wireless Ad-hoc Network

APPLICATIONS

The decentralized nature of wireless ad-hoc networks makes them suitable for a variety of applications where central nodes can't be relied on and may improve the scalability of networks compared to wireless managed networks, though theoretical and practical limits to the overall capacity of such networks have been identified. Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations like natural disasters or military conflicts.

2.2 MOBILE AD-HOC NETWORK

A mobile ad hoc network (MANET), also known as wireless ad hoc network or ad hoc wireless network, is a continuously self-configuring, infrastructure-less network of mobile devices connected wirelessly. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. They may contain one or multiple and different transceivers between nodes. This results in a highly dynamic, autonomous topology.

MANETs are a kind of wireless ad hoc network (WANET) that usually has a routable networking environment on top of a Link Layer ad hoc network. Different protocols are then evaluated based on measures such as the packet drop rate, the overhead introduced by the routing protocol, end-to-end packet delays, network throughput, ability to scale, etc. Figure 3 shows the Mobile ad-hoc networks.

Fig. 3 Mobile Ad-hoc Network

APPLICATIONS

The applications of MANETs include search-and-rescue operations. Such scenarios are characterized by a lack of installed communications infrastructure because all the equipment might already be destroyed or the region could be too remote. MANETs can also provide communications between autonomous vehicles, aircraft and ground troops in the battlefield where a fixed communication infrastructure is always unavailable and infeasible. The applications of MANET are diverse ranging from emergency services, commercial environment, home and enterprise networking, educational environment etc.

RESEARCH ISSUES

Ad hoc networking has been a popular field of study during the last few years. In MANET use of broadcasting and shared transmission media introduces a greater probability of packet collision and media contention. Irrespective of routing, variety of research issues are there including energy conservation, reliability, scalability, Quality of service, security, power control, node cooperation etc.

2.3 WIRELESS MESH NETWORK

A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. It is also a form of wireless_ad_hoc_network. A mesh refers to rich interconnection among devices or nodes. Wireless mesh networks often consist of mesh clients, mesh routers and gateways If nodes were to constantly or frequently move, the mesh will spend more time updating routes than delivering data. In a wireless mesh network, topology tends to be more static, so that routes computation can converge and delivery of data to their destinations can occur. Hence, this is a low-mobility centralized form of wireless_ad hoc network. Also, because it sometimes relies on static nodes to act as gateways, it is not a truly all-wireless ad hoc network.

The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may, but need not, be connected to the Internet. The coverage area of the radio nodes working as a single network is sometimes called a mesh cloud. Access to this mesh cloud is dependent on the radio nodes working in harmony with each other to create a radio network. A mesh network is reliable and offers redundancy. Wireless mesh networks can self-form and selfheal. Wireless mesh networks work with different wireless technologies including 802.11, 802.15, 802.16, cellular technologies and need not be restricted to any one technology or protocol.

Network capacity in wireless mesh network is an important issue. The capacity of mesh network is affected by many factors such as network topology, node density, traffic patterns, number of radios/channels used for each node, transmission power level, carrier sensing threshold, node mobility, and environment etc. A clear understanding of the relationship between network capacity and the above factors provides a guideline for protocol development, architecture design, deployment and operation of the network. Figure 4 shows the wireless mesh networks.

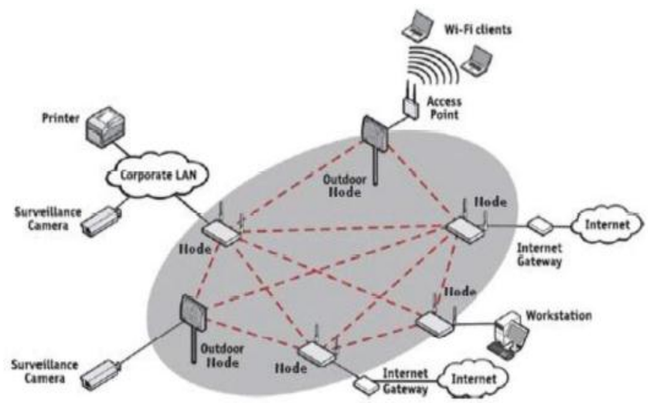

Fig. 4 Wireless Mesh Network

APPLICATIONS

An important possible application for wireless mesh networks is VoIP. By using a Quality of Service scheme, the wireless mesh may support local telephone calls to be routed through the mesh. Some applications of wireless mesh networks are:

1. U.S. military forces are now using wireless mesh networking to connect their computers, mainly ruggedized laptops, in field operations.
2. Electric meters now being deployed on residences transfer their readings from one to another and eventually to the central office for billing without the need for human meter readers or the need to connect the meters with cables.
3. The laptops in the one laptop per child program use wireless mesh networking to enable students to exchange files and get on the Internet even though they lack wired or cell phone or other physical connections in their area.
4. Google Home, Google Wi-Fi, and Google On Hub all support Wi-Fi mesh (i.e., Wi-Fi ad hoc) networking.

RESEARCH ISSUES

The available MAC and routing protocols applied to wireless mesh network do not have scalability as throughput drops significantly as the number of nodes or hops increases. Existing security schemes may be effective for certain types of attacks, but they lack a comprehensive mechanism to prevent attacks from different protocol layers. Similar problems exist in other networking protocols. Due to this, existing communication protocols, ranging from routing, MAC, and physical layers in the wireless mesh networking, need to be revisited and must be enhanced to ensure good routing performance as well as security problems.

2.4 WIRELESS SENSOR NETWORK

Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. WSNs measure environmental conditions like temperature, sound, pollution levels, humidity, wind, and so on. WSNs are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main locations. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. Fig 5 shows Wireless sensor network. The information collected by the sensor nodes is delivered in a multi-hop fashion to a sink node and through this to the nodes connected to the internet. Energy efficiency is therefore the primary concern and key challenge in wireless sensor network. The sensors are typically static but some more powerful sensor nodes may have mobile capability. The aim of WSN is to collect information about events occurring in the sensor field, rather than to support the communication between nodes.

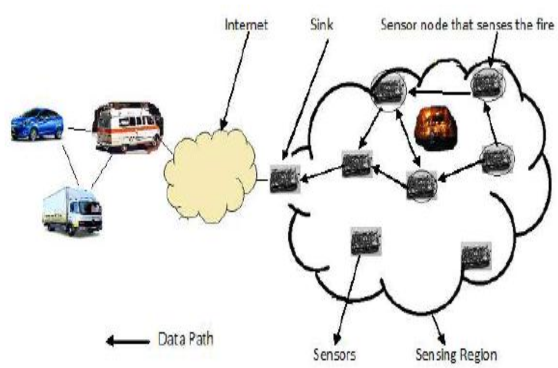

Fig. 5 A Wireless Sensor Network

APPLICATIONS

Wireless sensor networks will not only enhance existing sensor network applications such as tracking, home automation, and environmental monitoring, health applications, but they will also enable several new applications such as multimedia surveillance sensor networks, advanced health care delivery, person locator services, industrial control and automation, security and public safety, agricultural monitoring, iButton etc.

RESEARCH ISSUES

There is need to developed new protocols to address higher topology changes and higher scalability issues as well as to allow easy communication between the sensor networks and external networks.

2.5 VANETs AND InVANETs

Vehicular ad hoc networks (VANETs) are created by applying the principles of mobile ad hoc networks (MANETs) – the spontaneous creation of a wireless network for data exchange – to the domain of vehicles.[1] VANETs were first mentioned and introduced [2] in 2001 under "car-to-car ad hoc mobile communication and networking" applications, where networks can be formed and information can be relayed among cars. It was shown that vehicle-to-vehicle and vehicle-to-roadside communications architectures will co-exist in VANETs to provide road safety, navigation, and other roadside services. VANETs are a key part of the intelligent transportation systems (ITS) framework. Sometimes, VANETs are referred as Intelligent Transportation Networks. By 2015, the term VANET became mostly synonymous with the more generic term inter-vehicle communication (IVC), although the focus remains on the aspect of spontaneous networking, much less on the use of infrastructure like Road Side Units (RSUs) or cellular networks.

Intelligent vehicular ad hoc networks (InVANETs) use Wi-Fi IEEE 802.11p (WAVE standard) and WiMAX IEEE 802.16 for easy and effective communication between vehicles with dynamic mobility. InVANETs is not foreseen to replace current mobile (cellular phone) communication standards. Within the IEEE Communication Society, there is a Technical Subcommittee on Vehicular Networks & Telematics Applications (VNTA). The charter of this committee is to actively promote technical activities in the field of vehicular networks, V2V, V2R and V2I communications, standards, communications-enabled road and vehicle safety, real-time traffic monitoring, intersection management technologies, future telematics applications, and ITS-based services.

APPLICATIONS

The most important usage of these networks is to inform other vehicles in emergency situations such as car accidents, urgent braking or traffic jams. In such cases, a vehicle can inform other vehicles by broadcasting safety messages before facing the event. Applications of VANET are mainly oriented towards safety issues for example traffic services, alarm and warning messaging. Non-safety applications are expected to create new commercial opportunities by increasing market penetration of the technology and making it more cost effective.

RESEARCH ISSUES

Currently there is ongoing a lot of research in the field of InVANETs for several scenarios. The main interest is in applications for traffic scenarios, mobile phone systems, sensor networks and future combat systems. Recent research has focused on topology related problems such as range optimization, routing mechanisms, or address systems, as well as security issues like traceability or encryption. In addition, there are very specific research interests such as the effects of directional antennas for InVANETs and minimal power consumption for sensor networks. Most of this research aims either at a general approach to wireless networks in a broad setting or focus on an extremely specific issue. From the very beginning, the VANET research area received strong support from the government as well as from industry.

III. EVALUTION OF MULTI HOP AD HOC NETWORK

The development and deployment of commercial ad-hoc applications have a slow pace. The reason behind that is the original ad-hoc applications scenarios were not directed to mass users. An important new concept has emerged which may help to extent ad-hoc networking to commercial applications, namely the concept of opportunistic ad-hoc networking. There are two main evolutions of multi-hop Ad-hoc networks, The mesh networks and opportunistic networks.

Opportunistic networks emerged as one of the interesting evolution of multi-hop ad-hoc networks. Current scenario in networking-architecture developments, like delay and disruption tolerant networks, and opportunistic networking, intended to deal with the disconnections that naturally and frequently arise in wireless environments. Their objective is to allow communication in dynamic networks, like in a MANET, even if a direct route between source and destination does not exist in the network. Because of this, multi-hop communication is provided through opportunistic links, in which the route of a message is followed one link at a time, as other links in the route become available. When the next link is not available, the message is held in a node. With opportunistic communication, strong connectivity requirements are no longer needed.

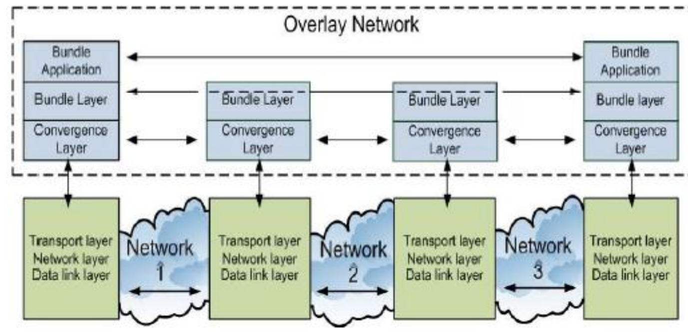

Fig. 6 DTN Architecture (From DTNRG)

In some scenarios complete end to end path rarely or never exist between sources and destinations within the MANET, due to high node mobility. These networks may experience frequent partitioning, with the disconnections lasting for long periods. As a consequence, the end-to-end transfer delays in these intermittently connected networks (ICNs) are much greater than typical IP data transfer delays in conventional networks such as the Internet. In the literature, intermittently-connected networks are often referred to as delay or disruption tolerant networks (DTN) [19]. Fig. 6 shows the architecture for delay tolerant network. It was developed by the Internet Research Task Force (IRTF) DTN Research Group (DTNRG).

This architecture considers intermittently connected networks that suffer from frequent partitions. The opportunistic networks are an important class of DTNs [21] in which contacts appear opportunistically without any prior information. They cover many similar aspects of delay tolerant networks, which can be characterised by intermittent connectivity, frequent end-to-end path disruption and topology changes. Fig. 7, shows an example of DTN [17] connecting the ad-hoc network among the soldiers on a battlefield to the LAN on the nearest aircraft carrier. A helicopter is in charge of providing periodic connection between these two internets. Many of the concepts behind opportunistic networks comes from the studies of delay tolerant networks. In opportunistic network it is not mandatory to have a priori knowledge about the network topology whereas, DTN assumes the knowledge of Internet-like topologies in which some links between gateways could be available just at certain (possibly unspecified) times.

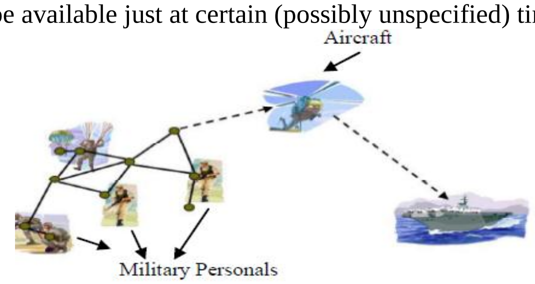

Fig. 7 Example of Delay Tolerant Network.

Routes in DTNs are typically computed via Legacy-Internet techniques by taking into consideration the link unavailability. But in opportunistic networks, routes are computed at each hop while a packet is forwarded. So, each node receiving a message for an eventual destination exploits local knowledge of a node to decide which is the best next hop, among its current neighbours, to reach the final packet destination. Opportunistic networks (OppNets) overcome one of the main limitations of legacy MANET, in which network partitioning causes the failure of ongoing communications, and/or nodes that are temporarily disconnected from the network cannot communicate. Opportunistic networking tries to simplify the aspect of ubiquitous computing by removing the assumption of physical end-to-end connectivity while providing connectivity opportunities to pervasive devices when no direct access to the Internet is available. Ubiquitous computing is an advanced computing concept where computing is made to appear everywhere and anywhere.

APPLICATIONS

Opportunistic networking has several application scenarios. The IRTF (Internet Research Task Force) Delay Tolerant Networking (DTN) Research Group3 is working to standardize architecture and protocols for enabling Internet services in networks with intermittent connectivity, where continuous end-to-end connectivity cannot be assumed. DakNet or Saami network connectivity (SNC) is a good example of this approach. DakNet aims to provide low-cost connectivity to rural villages in India, by exploiting mobile relays passing by the village kiosks and exchanging data with them wirelessly. SNC uses DTN architecture to provide network connectivity to the nomadic Saami population.

RESEARCH ISSUES

Disconnection of nodes and high churn rates are thus normal features of opportunistic networks. This sporadic connectivity of nodes is not only the challenge in opportunistic networks. Also routing, information dissemination, buffer capacities, jamming are some of the main challenges in disconnected environment of these networks. These challenges can limit the contribution of nodes in data forwarding, which in turn, effect the performance of network. So efficient routing protocols must be there which can manage the forwarding of data in disconnected environment.

IV. ROUTING CHALLENGES

The communication networks have become an integral part of our society to meet the needs of fast and reliable information exchange. Wireless ad- hoc networks will enhance communication capability significantly by providing connectivity from anywhere at any time. Routing protocol design in wireless multi-hop ad-hoc networks faces a great challenge mainly due to the facts that wireless link is unreliable, wireless medium is broadcast in nature, mobility, battery power constraints etc. These are some of the factors behind the research on routing protocols in wireless multi-hop ad hoc networks. There are lot of protocols in the literature for wireless multi-hop ad-hoc networks to cope with different problems and meet different application requirement. These protocols are divided into different categories using different criteria. Routing scheme in multi-hop ad-hoc network. Routing algorithms have to cope with the typical limitations of wireless networks: high power consumption, low wireless bandwidth, high error rates. In case of opportunistic networks, the design of efficient routing strategies is generally a complicated task due to the absence of knowledge about the topological evolution of network. Routing performance improves when more knowledge about the topology of the network can be exploited. But this kind of knowledge is not easily available in opportunistic networks due to unpredictable topology.

V. CONCLUSION

In this article we have reviewed and discussed various categories of wireless multi-hop ad-hoc networks, their application and research issues. In the early stages, the ad-hoc networks were expected to be used for specific applications by a limited set of users. The involvement of end users are the key elements of mesh, vehicular, sensor and opportunistic networks. There are a number of applications of these types of networks, ranging from small, static networks that are constrained by power sources to large-scale mobile, highly dynamic networks. We discuss the applicability and fundamental underlying ideas of opportunistic networks i.e. one of the main evolutions of wireless multi-hop ad-hoc networks. Research challenges specific to opportunistic networks are discussed and it requires a lot of research for improving the routing performance in these network. The requirements of the opportunistic networks make these networks a promising and challenging research field.

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