Mobile Ad-Hoc Networks

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INTRODUCTION

Within the coming years, it is inevitable that mobile computing will flourish, evolving toward integrated and converged next generation wireless technology (Webb, 2001), and an important role to play in this technological evolution is mobile ad hoc networks (Liu & Chlamtac, 2004). In short, mobile ad hoc network (MANET) is a self-configuring network that consists of a number of mobile communication nodes that are interconnected by wireless links. The communication nodes are free to move in random manners, which include stationary as a special case. Due to the dynamic movement of the nodes, the ad hoc network topology is normally formed in a decentralized manner and on an ad hoc basis. MANET is in fact a peer-to-peer wireless network that transmits from a client node to another without the use any preexisting network infrastructure-based centralised base stations to coordinate the communications. This type of network is particularly favourable when the information is to be transmitted to other nodes in the locality or the individual communication node has limited radio ranges. The self-configuration, stand alone and quick deployment nature make MANETs suitable for emergency situations like disasters, wars, sporting events, and so forth. Other examples of MANETs with other functionalities include wireless sensor networks and vehicular ad hoc networks.

A wireless sensor network (WSN) is a network formed by a collection of small computers, which are employed in the processing of sensor data (Hać, 2003). These small computers have limited capabilities in terms of the processing and communication power. They usually consist of sensors, a communication device, and a power supply. WSNs find many and varied applications in various fields ranging from industrial monitoring of dangerous environments to agriculture monitoring.

A vehicular ad hoc network (VANET) is a network formed by a collection of vehicles with communications capabilities and also having the potential to support various intelligent transport services. This class of traffic telematics applications ranges from emergency warnings, for example, in the case of accidents, via floating car data gathering and distribution, to more advanced applications, like platooning and co-operative driving (Festag et al., 2004).

In the future, communication devices, communication-capable devices or sensors and home electronic appliances will have the capability to form various MANETs, and interoperate with the global communication networks. These MANETs play an important role in supporting various visions toward the creation of a world of ubiquitous computing where computation is integrated into the environment, rather than having computers that are distinct objects. One of the goals of ubiquitous computing is to enable devices to sense changes in their respective surroundings and to automatically adapt and act on these changes based on user needs and preferences. With ubiquitous computing, people can move around and interact with computers, devices and home appliances more naturally than they currently do.

BACKGROUND

The earliest MANETs were called packet radio networks, and were sponsored by Defense Advanced Projects Agency (DARPA) in the early 1970s (Mobile ad-hoc network, 2006). It is interesting to note that these early packet radio systems predated the Internet, and indeed were part of the motivation of the original Internet Protocol suite. Later DARPA experiments included the Survivable Radio Network (SURAN) project, which took place in the 1980s (Mobile ad-hoc network, 2006). The third wave of academic activity started in the mid-1990s with the advent of inexpensive wireless sensor devices, and Wi-Fi or IEEE 802.11 family of radio cards for personal computers, notebooks and smartphones.

The existing cellular-based broadband access for mobile communications is foreseen to be inefficient due to a number of reasons. Firstly, as the bandwidth required is getting higher approaching hundreds of MHz or tens of GHz range, higher carrier frequency (at least ten times the bandwidth as a rule of thumb) is expected. For a same transmit power level, the wireless channel suffers from greater attenuation as a results of using higher carrier frequency (Etoh, 2005). This calls for the research into the use of multihop communication for the provisioning of broadband access where each hop can support high bandwidth transmission over a short range. Hence MANETs, which is multihop in nature, promise to be one of the most innovative and challenging areas of wireless networking in the future. As mobile technologies are growing at an ever-faster rate, therefore higher reliability and capacity, better coverage and services are required.

The future MANETs will likely evolve along the following directions:

- Different MANETs such as wireless sensor networks, VANETs and infrastructure ad hoc networks are interconnected to form a bigger MANET for better exchange of information.
- The emergence of various radio technologies, such as Bluetooth, UWB, ZigBee, Wi-Fi, WiMAX, and so forth, which are optimized for different functions and with the affordable price of radio cards due to economic of scale, made it practical to install more than one radio card, either of the same type or different, or in a single device. When the communication nodes communicate with each other using more than one radio interface type or channel frequency, it is called multi-radio communication or multi-channel communication.

CHALLENGES OF MANETS

There are a number of technical challenges that need to be addressed in order to ensure good connectivity and quality of service (QoS) for the end-users or client nodes in future MANETs. In the following paragraphs we discuss a few of them.

Dynamic Routing Protocol

Basically, routing protocols with different characteristics may be required for different types of MANETs or under different operating environments. Alternatively, a dynamic routing protocol that can adapt itself to different operating environment is required. For example, conventional routing protocols that have been proven to work fine in MANETs with communication nodes in random movement patterns may not be optimum to support inter-vehicular communications (e.g., VANET) within close proximity that may be moving in cluster form in a specific direction but with micro randomness. Meanwhile, in the case of WSN, conventional MANET protocols such as AODV and DSR may not scale well as the network size increases due to the reservation of large bandwidth for control messages. In addition, the energy limitation of the communication nodes has not been considered (Hać, 2003). The presence of multiple or heterogeneous network interfaces posed a need for an efficient routing mechanism such as multi-radio routing when multiple types of radio technologies are used, or multi-channel routing when different channels of a common radio technology is used. Meanwhile, an appropriate rewarding scheme that helps to accelerate the sharing of resources, which include bandwidth and processing time, among communication nodes in a client ad-hoc network is required.

Network Topology Control

In contrast to wired networks, which typically have fixed network topologies, each communication node in a MANET can change the network topology by adjusting its transmit power or selecting specific nodes to forward its messages, thus controlling its neighbor list. In conjunction with the use of optimum routing algorithms, the challenges of topology control in MANETs are to maintain network connectivity, and optimized network lifetime, throughput, and delay with high scalability, minimum overhead, and high fault tolerance.

In order to achieve high scalability and reduce overhead, formation of sub-groups of nodes among the MANET nodes that perform the routing has been proposed in many algorithms (Perkins et al., 2001; Stojmenovic et al., 2002). In this method, a virtual backbone is formed by using the connected dominating set. The relatively smaller sub-network size helps to reduce the amount of routing information.

A good fault tolerance network may require a fully integrated mesh solution among all communication nodes or through the use of higher transmit power. However, the interference generated may correspondingly degrade the overall network performance in terms of throughput and delay. Thus, there is a trade-off between fault tolerance and capacity performance. In a heterogeneous network environment, the problem becomes worst, as the network topology is governed by the capabilities of diverse types of radio interfaces.

Radio Resource Management

The decentralized nature of MANETs makes it difficult for coordinating the sharing and utilization of radio resources. For each communication node, a large amount of physical parameters are involved, which include the number of radio channels, the type and capability of radio interfaces, the channel conditions (channel quality) that determine the performance of the radio transmission, current communication state (busy or not), and so forth. The collection of communication nodes within a MANET may have different amount of resources for use. Hence, a scheme for the discovery, optimum utilization and scheduling of available resources is required, where further information can be found in Chin et al., 2006.

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