A Case Study on Pervasive Computing in MANET

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Abstract— In the near future, a pervasive computing environment can be expected based on the recent progresses and advances in computing and communication technologies. Next generation of mobile communications will include both prestigious infrastructure wireless networks and novel infrastructure less mobile ad hoc networks (MANETs). Mobile Adhoc Network is designed for mobile http://www.teluguone.com/tmdb/http. The special features of MANET bring this technology has great opportunities together with severe challenges. This paper describes the fundamental problems of ad hoc networking by giving its related research background including the concept, features, status, and applications of MANET. Some of the technical challenges MANET poses are also presented, based on which the paper points out some of the key research issues for ad hoc networking technology that are expected to promote the development and accelerate the commercial applications of the MANET technology. Special attention is paid on network layer routing strategy of MANET and key research issues include new X-cast routing algorithms, security & reliability schemes, QoS model, and mechanisms for interworking with outside IP networks.

Index Terms - Mobile Communications, Wireless Networks, Adhoc Networking, Pervasive Computing, Routing Algorithm.

1. INTRODUCTION

In this paper, we describes the fundamental problems of ad hoc networking by giving its related research background including the concept, features, status, and applications of MANET. Some of the technical challenges MANET poses are also presented based on which the paper points out the related kernel barrier. Some of the key research issues for ad hoc networking technology are discussed in detail that are expected to promote the development and accelerate the commercial applications of the MANET technology.

The people's future living environments are emerging based upon information resource provided by the connections of various communication networks for users. New small devices like Personal Digital Assistants (PDAs), mobile phones, handhelds, and wearable computers enhance information processing and accessing capabilities with mobility. Moreover, traditional home appliances, e.g. digital cameras, cooking ovens, washing machines, refrigerators, vacuum cleaners, and thermostats, with computing and communicating powers attached, extend the field to a fully pervasive computing environment. With this in view, modern technologies should be formed within the new paradigm of pervasive computing, including new architectures, standards, devices, services, tools, and protocols.

Mobile networking is one of the most important technologies supporting pervasive computing. During the last decade, advances in both hardware and software techniques have resulted in mobile hosts and wireless networking common and miscellaneous. Generally there are two distinct approaches for enabling wireless mobile units to communicate with each other:

1) Infrastructured. Wireless mobile networks have traditionally been based on the cellular concept and relied on good infrastructure support, in which mobile devices communicate with access points like base stations connected to the fixed network infrastructure. Typical examples of this kind of wireless networks are GSM, UMTS, WLL, WLAN, etc.

2) Infrastructureless. As to infrastructureless approach, the mobile wireless network is commonly known as a mobile ad hoc network (MANET) [1, 2]. A MANET is a collection of wireless nodes that can dynamically form a network to exchange information without using any pre-existing fixed network infrastructure. This is a very important part of communication technology that supports truly pervasive computing, because in many contexts information exchange between mobile units cannot rely on any fixed network infrastructure, but on rapid configuration of a wireless connections on-the-fly. Wireless ad hoc networks themselves are an independent, wide area of research and applications, instead of being only just a complement of the cellular system.

The paper is structured as follows. In Section II, the background information related to ad hoc wireless networks is introduced, including the MANET concept, features, current research status, and some of its applications. The technical
Challenges of MANET, together with relevant kernel barrier, are presented in Section III. Section IV mainly

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discusses the key research issues of MANET with the emphasis on network layer routing strategies. Finally, we summarize the paper by conclusions in Section V.

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2 Related Background

2.1 MANET Concept

A mobile ad hoc network is a collection of wireless nodes that can dynamically be set up anywhere and anytime without using any pre-existing network infrastructure. It is an autonomous system in which mobile hosts connected by wireless links are free to move randomly and often act as routers at the same time. The traffic types in ad hoc networks are quite different from those in an infrastructured wireless network [3], including:

1) Peer-to-Peer. Communication between two nodes which are within one hop. Network traffic (Bps) is usually consistent.

2) Remote-to-Remote. Communication between two nodes beyond a single hop but which maintain a stable route between them. This may be the result of several nodes staying within communication range of each other in a single area or possibly moving as a group. The traffic is similar to standard network traffic.

3) Dynamic Traffic. This occurs when nodes are dynamic and moving around. Routes must be reconstructed. This results in a poor connectivity and network activity in short bursts.

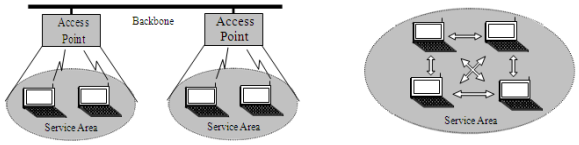

Fig. 1. shows the examples of both infrastructured and infrastructureless ad hoc wireless networks.

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2.2 MANET Features

MANET has the following features:

1) Autonomous terminal. In MANET, each mobile terminal is an autonomous node, which may function as both a host and a router. In other words, besides the basic processing ability as a host, the mobile nodes can also perform switching functions as a router. So usually endpoints and switches are indistinguishable in MANET.

2) Distributed operation. Since there is no background network for the central control of the network operations, the control and management of the network is distributed among the terminals. The nodes involved in a MANET should collaborate amongst themselves and each node acts as a relay as needed, to implement functions e.g. security and routing.

3) Multihop routing. Basic types of ad hoc routing algorithms can be single-hop and multihop, based on different link layer attributes and routing protocols. Single-hop MANET is simpler than multihop in terms of structure and implementation, with the cost of lesser functionality and applicability. When delivering data packets from a source to its destination out of the direct wireless transmission range, the packets should be forwarded via one or more intermediate nodes.

4) Dynamic network topology. Since the nodes are mobile, the network topology may change rapidly and unpredictably and the connectivity among the terminals may vary with time. MANET should adapt to the traffic and propagation conditions as well as the mobility patterns of the mobile network nodes. The mobile nodes in the network dynamically establish routing among themselves as they move about, forming their own network on the fly. Moreover, a user in the MANET may not only operate within the ad hoc network, but may require access to a public fixed network (e.g. Internet).

5) Fluctuating link capacity. The nature of high bit-error rates of wireless connection might be more profound in a MANET. One end-to-end path can be shared by several sessions. The channel over which the terminals communicate is subject to noise, fading, and interference, and has less bandwidth than a wired network. In some scenarios, the path between any pair of users can traverse multiple wireless links and the link themselves can be heterogeneous.

6) Light-weight terminals. In most cases, the MANET nodes are mobile devices with less CPU processing capability, small memory size, and low power storage. Such devices need optimized algorithms and

mechanisms that implement the computing and communicating functions.

2.3 MANET Status

Ad hoc networking is not a new concept. As a technology for dynamic wireless networks, it has been deployed in military since 1970s. Commercial interest in such networks has recently grown due to the advances in wireless communications. A new working group for MANET has been formed within the Internet Engineering Task Force (IETF) [2], aiming to investigate and develop candidate standard Internet routing support for mobile, wireless IP autonomous segments and develop a framework for running IP based protocols in ad hoc networks. The recent IEEE standard 802.11 [4] has increased the research interest in the field.

Many international conferences and workshops have been held by e.g. IEEE and ACM. For instance, MobiHoc (The ACM Symposium on Mobile Ad Hoc Networking & Computing) has been one of the most important conferences of ACM SIGMOBILE (Special Interest Group on Mobility of Systems, Users, Data and Computing). Research in the area of ad hoc networking is receiving more attention from academia, industry, and government. Since these networks pose many complex issues, there are many open problems for research and significant contributions.

2.4 MANET Applications

With the increase of portable devices as well as progress in wireless communication, ad hoc networking is gaining importance with the increasing number of widespread applications. Ad hoc networking can be applied anywhere where there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use. Ad hoc networking allows the devices to maintain connections to the network as well as easily adding and removing devices to and from the network. The set of applications for MANETs is diverse, ranging from large-scale, mobile, highly dynamic networks, to small, static networks that are constrained by power sources. Besides the legacy applications that move from traditional infrastructure environment into the ad hoc context, a great deal of new services can and will be generated for the new environment. Typical applications include:

1) Military battlefield. Military equipment now routinely contains some sort of computer equipment. Ad hoc networking would allow the military to take advantage of commonplace network technology to maintain an information network between the soldiers, vehicles, and military information head quarters. The basic techniques of ad hoc network came from this field.

2) Commercial sector. Ad hoc can be used in emergency/rescue operations for disaster relief efforts, e.g. in fire, flood, or earthquake. Emergency rescue operations must take place where non-existing or damaged communications infrastructure and rapid deployment of a communication network is needed. Information is relayed from one rescue team member to another over a small handheld. Other commercial scenarios include e.g. ship-to-ship ad hoc mobile communication, law enforcement, etc.

3) Local level. Ad hoc networks can autonomously link an instant and temporary multimedia network using notebook computers or palmtop computers to spread and share information among participants at a e.g. conference or classroom. Another appropriate local level application might be in home networks where devices can communicate directly to exchange information. Similarly in other civilian environments like taxicab, sports stadium, boat and small aircraft, mobile ad hoc communications will have many aplications.

4) Personal Area Network (PAN). Short-range MANET can simplify the intercommunication between various mobile devices (such as a PDA, a laptop, and a cellular phone). Tedious wired cables are replaced with wireless connections. Such an ad hoc network can also extend the access to the Internet or other networks by mechanisms e.g. Wireless LAN (WLAN), GPRS, and UMTS. The PAN is potentially a promising application field of MANET in the future pervasive computing context

3.C HALLENGES AND KERNAL BARRIER

3.1 MANET Challenges

1) Routing. Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Most protocols should be based on reactive routing instead of proactive. Multicast routing is another challenge because the multicast tree is no longer static due to the random movement of nodes within the network. Routes between nodes may potentially contain multiple hops, which is more complex than the single hop communication.

2) Security and Reliability. In addition to the common vulnerabilities of wireless connection, an ad hoc network has its particular security problems due to e.g. nasty neighbour relaying packets. The feature of distributed operation requires different schemes of authentication and key management. Further, wireless link characteristics introduce also reliability problems,

because of the limited wireless transmission range, the broadcast nature of the wireless medium (e.g. hidden terminal problem), mobility-induced packet losses, and data transmission errors.

3) Quality of Service (QoS). Providing different quality of service levels in a constantly changing environment will be a challenge. The inherent stochastic feature of communications quality in a MANET makes it difficult to offer fixed guarantees on the services offered to a device. An adaptive QoS must be implemented over the traditional resource reservation to support the multimedia services.

4) Internetworking. In addition to the communication within an ad hoc network, internetworking between MANET
nd fixed networks (mainly IP based) is often expected in many cases. The coexistence of routing protocols in such a mobile device is a challenge for the harmonious mobility management.

5) Power Consumption. For most of the light-weight mobile terminals, the communication-related functions should be optimised for lean power consumption. Conservation of power and power-aware routing must be taken into consideration.

3.2 Kernel Barrier

It has been widely recognized that routing strategy is the most important research problem among others. To determine viable routing paths and deliver messages in a decentralized environment where network topology fluctuates is far less than a well-defined problem. New models are needed to describe the mobile ad hoc feature of the target wireless networks, while new algorithms are required to safely and efficiently route information to mobile destination in order to support different types of multimedia applications. Factors such as variable wireless link quality, propagation path loss, fading, multiuser interference, power expended, and topological changes become relevant issues that add more difficulties and complexities to the routing protocol design.

Many routing protocols have been proposed with the form of IETF working documents of both Internet Drafts and Request For Comments (RFC) [2]. Numerous projects related to different aspects of MANET are employed by academics and institutes all over the world, with individual standards being presented occasionally in literatures [5-9]. They serve the purpose of demonstrating the functionality and performance of ad hoc routing with comparatively simple protocols, whereas very few of them can be regarded to really fulfill the requirements of a real application scenario. There are still many relative aspects to be deeply researched before the wide deployment of the commercial ad hoc systems.

4.KEY RESEARCH ISSUES

This section analyses key Research issues concerning MANET network layer routing strategies, including four selected key problems in MANET: X-cast routing, security & reliability, QoS, and interworking with outside IP networks. These issues are currently main challenges of ad hoc wireless networks. The lack of robust solutions to these problems prevents MANET from wide commercial deployment.

4.1 X-cast Routing Algorithms

As in the infrastructured wireless networks, all kinds of X-cast communication schemes should be supported in an ad hoc mobile environment. These include unicast, anycast, multicast, and broadcast. MANET also brings new X-cast modes into communications, e.g. geocast and content-based. In particular, multicast is desirable to support multiparty wireless communications [11]. Since the multicast tree is no longer static (i.e. its topology is subject to change over time), the multicast routing protocol must be able to cope with mobility, including multicast membership dynamics (e.g., leave and join).

In a multihop ad hoc context, the routing problem becomes more complex because of the mobility of both hosts and routers. The random movement of the nodes and the uncertainty of path quality render the traditional routing protocols
impractical. Trade-off between reactive and proactive schemes in terms of latency and overhead of route discovery and maintenance are to be considered depending on different traffic and mobility patterns. Issues to be taken into account include routing discovery and flooding, caching, data delivery, location-aided and power-aware, broadcast storm issue, route request and reverse path.

4.2 QoS Supporting Model

Just like in wired networks, QoS protocols can be used to prioritize data within ad hoc networks in order to reserve better connections for high data rate applications while still maintaining enough bandwidth for lower bit rate communication. The support of multimedia services will most likely be required within and throughout the MANET, for which different QoS classes (e.g. voice, video, audio, web, and data stream) are needed to facilitate the use of multimedia applications.

In such a stochastic changing environment involving dynamic nodes, hidden terminals, and fluctuating link characteristics, supporting end-to-end QoS at different levels will be a great challenge that requires in-depth investigation. An adaptive QoS must be implemented over the traditional plain resource reservation to support the multimedia services. Special emphasis should be put on achieving a new QoS model for MANETs by taking into account the ad hoc features of the target networks: dynamic node roles, data flow granularity, traffic profile, etc.

4.3 Security, Reliability, and Availability Schemes

Security, reliability, and availability are three crucial aspect of MANET, especially in security-sensitive applications. Since ad hoc relies on wireless communication medium, it is important to deploy a security protocol to protect the privacy of transmissions. The requirements regarding confidentiality, integrity, and availability are the same as for any other public communication networks. However, the implementation schemes of key management, authentication, and authorization are quite different because there is no aid of a trusted third-party certification authority to create trusted relationships by exchanging private/public keys [13]. Different types of threats and attacks against routing in MANET should be analysed leading to the requirement of ad hoc routing security, and advanced solutions are needed for the secure routing of MANET.

Wireless communication is subject to many types of problems due to interference and poor signals. As for reliability and availability issues, besides low level error masking and recovery mechanisms (i.e. link layer error detection and correction coding), special attention should be paid to studying fault-tolerant routing algorithm. In multihop ad hoc wireless networks, there exists an inherent attribute of redundant routing paths between nodes. Exploiting this property, it's possible to provide a fault-tolerant routing scheme [14], for increasing the reliability and security of the target routing algorithm. Since overhead occurs in this reliable-increasing algorithm, research should also study the tradeoff between performance and reliability in order to calculate the most efficient solution.

4.4 Internetworking Mechanisms

To integrate the two mobility management schemes in the domains of both traditional infrastructured wireless networks and the new mobile ad hoc networks is an important issue. The mobility mode of an ad hoc network is quite different from that of infrastructured networks. In infrastructured networks only the nodes (terminals) at the very edges (the last hop) of fixed networks are moving, whereas an ad hoc network can be completely mobile, since a device can serve both as router and host at the same time. Consequently, in an ad hoc network mobility is handled directly by the routing algorithm.

In many cases, device accesses both within the ad hoc network and to public networks (e.g. the Internet) can be expected to form a universal communication scenario. In other words, a terminal in an ad hoc wireless network is able to connect to nodes outside the MANET while being itself also accessible by external nodes. The interworking between ad hoc and fixed networks is necessary. In particular, the coexistence and cooperation with the public IP based wireless networks is necessary to many contexts. The Mobile IP protocol for MANET should be deeply studied in order to give nodes in ad hoc networks the ability

Mobile ad hoc networking is one of the most important and essential technologies that support future pervasive computing scenario. The special characters of MANET bring this technology great opportunities together with severe challenges. Currently MANET is becoming more and more interesting research topic and there are many research projects employed by academic and companies all over the world. Various interesting issues are investigated that cover all aspects of ad hoc wireless networks. Meanwhile, many routing protocols designed for ad hoc networks have been proposed as Internet Draft and RFC of IETF. MANETs can be exploited in a wide area of applications, from military, emergency rescue, law enforcement, commercial, to local and personal contexts

5. CONCLUSIONS

This article describes the fundamental issues and analyses key research problems of MANET. Firstly, the background information of MANET are introduced, including the MANET concept, features, current status, and application areas. Then the main challenges of MANET are discussed that lead to the analysis of relevant kernel barrier. Finally, four key network layer research issues of MANET routing strategies are described in detail. The novel and advanced solutions to these issues are necessary to fulfill the requirements of wide commercial deployment of MANET.

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