EION WIRELESS

White Paper

Adaptive Intelligent Ad-Hoc Networks

Introduction

The Wireless network has seen an exponential growth due to its ability to free its user from the expenses and hassles in setting up their infrastructure. Such growth is more spectacular in the emerging economies where there was minimal or no presence of wired communication infrastructure in the past. Reputable market research firms have identified that the wireless network users will grow by a factor of 8 by 2007 (Gartner, Inc., March 26, 2003), while wireless product shipments grew by 73% in 2002 (Dataquest Inc., September 19, 2002). Even a small fraction, such as 1%, of the broadband network market is a significant figure for a viable medium sized business. Despite many new advances in technology, consumers are dependent on the infrastructures of large companies to satisfy their need. The performance of centralized and large-scale networks could be significantly curtailed at a time of congestion, or completely lost due to natural or unnatural disasters. There are numerous applications of a communication network whose operation does not depend on such large-scale infrastructure and does not require any network administrator to configure the system at the end-user premises.

However, not much breakthrough has been made in this area and the ad-hoc networking industry is in its infancy. Self-organizing wireless networks can extend the power of computing technology to dynamic and harsh environments. To achieve this, network protocols need to extract relevant information from the environment (i.e., sense the environment), and make intelligent decisions about how best to support the requirements of an individual user or application. This is done while maximizing overall system utilization. This significantly extends current network technology, which was designed for more predictable and stable environments. Applications such as remote community communications, battle management, emergency responses and tough terrain communications in oil-field exploration need to take advantage of self-organizing networks.

What is Ad-Hoc?

Mobility

In the last decade, developments in wireless data communication, such as GSM, GPRS, WLAN and mobile devices, including PDAs and mobile phones, were combined into a trend—mobile communication. The movement of mobile nodes in the network could be random or predictable, static or fast moving. They may move as individual or as a group.

Ad-Hoc Networks

Ad-hoc networks are formed by users or devices wishing to communicate without the necessity or existence of any centralized administration or infrastructure. Total Mobility is one of the most common reasons to apply ad-hoc topologies.

Wireless Ad-Hoc Networks:

Wireless Ad-Hoc networks are mobile by virtue of their characteristic. Each node in a wireless ad-hoc network has a wireless access interface, e.g. Bluetooth, WLAN, UWB, etc., and is free to enter or leave the network at any time. Ad-hoc networks can function as standalone networks meeting direct communication requirements of their users, or as an addition to existing infrastructure based networks to extend or enhance their coverage. This kind of communication becomes a valuable solution, especially in situations of missing or incomplete network. Regardless of application and technology, the following are the main features of ad-hoc networks:

Dynamic network topology: Due to node mobility and wireless radio propagation, network topology is constantly changing. This requires specific designed network protocol functions for topology construction and maintenance

Distributed nature: As there is no permanent central administrator or authority, all networking functions have to be distributed across participating nodes

Multi-hop communications: Due to limited range of wireless interfaces, usually it is not possible to setup direct communication links between all nodes. The nodes must

run routing algorithms to establish routes in the network and to forward packets destined for other nodes; as well as route packets with real-time constraint in some cases (e.g. voice transmission)

Limited bandwidth: Wireless technologies that are envisaged to be suitable for ad-hoc networks provide throughputs of a few hundreds kilobits per second to a few megabits per second that is suitable for many applications.

Limited energy resources: Nodes in ad-hoc networks will be usually battery driven and hence optimized energy consumption is very important.

Why Ad-Hoc Networks?

Self-Configuring

An ad-hoc network is self-organizing and does not require manual configuration. Therefore, adding new gear or relocating existing gear is as simple as plugging it in and turning it on. The network should discover the new node and automatically incorporates it into the existing system.

Reliability

An ad-hoc network could be reliable and highly adaptable. If a device or its link in an ad-hoc network fails, messages are sent around it via other devices. Loss of one or more nodes does not necessarily affect the network's operation. An ad-hoc network, with its associated relaying of nearest neighbor's data, reduces the problems frequently found in attenuation dominant locations since you can place additional network nodes to reroute the data signal through such an attenuation maze. Similarly, an ad-hoc network can reduces the problems of multi-path by reducing the power radiated from each node. If the distance is reduced by a factor of two, the requiring signal is four times less powerful at the sender.

Redundancy

In an ad-hoc network, the degree of redundancy is essentially a function of node density. A network can be deliberately over-designed for reliability simply by adding extra nodes, so each device has two or more paths for sending data. This is a simpler way of obtaining redundancy than is possible in most other type of systems.

Scalability

An ad-hoc network is also scalable and can handle hundreds or thousands of nodes. The network's operation does not depend on a central control point. For example, in the application of sensor networks, adding multiple data collection points or gateways is convenient.

Applications of Ad-Hoc Networks

Applications of ad-hoc communication include sensor networks, commercial and educational networks, emergency situations and military mobile communication. Some examples include:

Sensor Networks: For communication between or with sensors in an intelligent data collecting system.

Commercial Use: For setting up communication in conferences, exhibitions, or other sales presentations

Personal Use: For non-commercial transferring data between devices or persons; for communication in areas without adequate wireless coverage or for short range peer-to-peer communications in an ad-hoc group in which it doesn't make economic sense to use an operator network, such as a group of hikers wishing to communicate.

Search and Rescue Operations: For communication in areas without established wireless coverage or when the existing communication infrastructure is non-operational due to a global war or a natural disaster.

Risks and Challenges

The behavior of wireless ad-hoc networks is complicated. Research issues cover many different areas and multidisciplinary expertise is required to tackle these problems. The main research areas are the following:

Network organization

Ad-hoc networks will be widely used only if mechanisms for automatic network formation and maintenance are provided. Users have to be able to discover existing networks or potential network participants and to automatically configure devices and communication links so that application level communication can start Network address assignment. Before a node can join an existing ad-hoc network, a network address has to be assigned to the node. The protocol has to ensure that assigned address is unique in the network.

Service Discovery

As network is organized "on-the-fly", opportunistically, users will not know what services are available in the network or which device in the network offers a specific service. Hence, a service discovery protocol should exist to provide required information about available services.

Obviously, as there is no permanent central authority that could serve as a service information database, this protocol has to be 'distributed' across all network nodes.

Security

Wireless environment is in general very susceptible to security threats. Security problem is even more visible in ad-hoc networks because all nodes have access to other user's data while forwarding messages for them. The absence of a trusted third party certification body is one the main problems for development of appropriate security protocol.

Routing

Routing in ad-hoc networks is a very demanding problem due to node's mobility, limited throughput and high exposure of wireless links to various interference sources that can cause variable quality of communication links. Routing protocols have to satisfy sometime contradictory requirements like request for the minimum number of routing messages in order to save bandwidth and at the same time request for quick route establishment and efficient route maintenance.

Relaying

As a direct link can not be granted between two nodes trying to communicate, a relay function with real-time capability has to be provided.

Air Interface

The air interface requirements for ad-hoc networking are different and can range from very low power, low data rate telemetry and sensor requirements, where a small battery may be required to give over 10 years of connectivity, to very high data rates for high quality multimedia distribution in home. In addition, as the data rates will be very different between the targeted applications, the MAC protocol will be composed of different MAC procedures.

Message Forwarding Motivation

All nodes in an ad-hoc network are taking part in routing and are forwarding messages for other nodes. Each packet transmission consumes power from already limited power resources and may cause their depletion. It may then affect user's own transmissions and may cause disruptions in node's functionality. Evidently, the network cannot function if nodes are not forwarding messages for each other, but certain nodes can be more exploited, while others could generate more traffic and yet be less active in forwarding. Hence, a mechanism is required to ensure fairness and equal load for all nodes or to introduce certain "motivation" tools for forwarding nodes. However, this aspect has already been considered in some projects and is generally based on virtual tokens and the assumption that a node can be statically in the two modes: either relay or transmitter.

Billing and charging

If some of the services are commercial, then appropriate billing/charging mechanism has to be provided. Usually, nodes will access commercial services via several other nodes and the node that is directly communicating with the service provider will only relay messages. A suitable protocol should be devised that will ensure that the proper node is charged

Summary

In order to accomplish an end-to-end communication among heterogeneous backbone networks in such applications, various technologies are required such as data packet adaptive routing technology, wireless communication between nodes, Quality of Service (QoS) to meet unpredictable environmental conditions, network management and security.

The two key enablers that are required to establish an always-available end-to-end communication in such applications are:

1. Ability to self-organize wireless network elements without dropping mission critical data packets
2. Establishing a link from the self-organizing network to the network backbone through satellite, microwave or cellular infrastructure.

EION Inc. is dedicated to offer adaptive intelligent routing solutions to these specialized areas of applications that require Wireless Ad-Hoc Networking, Quality of Service and Traffic Engineering capabilities, which are not integrally available in today's routers and networks. These features will be the key enablers for the successful deployment of this technology. It will be able to capture market opportunities through these capabilities.

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