On the Use of Position Information of Nodes in Mobile Ad hoc Networks

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***Abstract* - In contrast to today's cellular networks mobile ad-hoc networks are characterized by autonomous nodes, which may move arbitrarily without any prior notice. The interconnection patterns among nodes may change dynamically so that links between nodes become unusable. New routes must be considered and maintained using routing protocols. In this paper we will discuss use of node's position information for routing purposes. Further we propose a novel network layer approach for quality of service (QoS) routing in mobile ad hoc networks.**

1 INTRODUCTION

In recent years, widespread availability of wireless communication and handheld devices has stimulated the research and development on self-organizing networks that do not require a pre-established infrastructure and any centralized architecture. Those spontaneous networks -called ad hoc networks- should provide mobile users with ubiquitous communication capability and information access regardless of their location.

A mobile ad hoc network (MANET [1]) consists of a collection of mobile wireless and autonomous hosts –in this sense simply referred to as "*nodes*"– which spontaneously form a temporary network. The devices may be of various types (e.g. notebook computers, PDAs, cell phones, etc.) and various capacities (e.g. computing power, memory, disk, etc.). The most important characteristic of such a network is its independence of any fixed infrastructure (e.g., base station or access point) or centralized administration. Actually, the idea of ad hoc networking is sometimes also called infrastructureless networking. An ad hoc network is capable of operating autonomously and is completely self-organizing and self-configuring. Therefore, it can be easily and rapidly installed. In an ad hoc environment people and vehicles can thus be interworked in areas without a pre-existing communication infrastructure, or when the use of such infrastructure requires wireless extension.

In contrast to conventional wireless networks, ad hoc networks have no fixed network infrastructure or centralized administrative support for their operations. Autonomous nodes may move arbitrarily so that the topology changes frequently without any prior notice. Consequently, topology of the network and the interconnection patterns among nodes may change dynamically so that links between nodes become unusable. Because of dynamic nature ad-hoc networks new routes must be considered and maintained using routing protocols. In this paper we will discuss use of node's position information for routing purposes. The rest of this paper is organized as follows: In section 2 we will describe mobile ad hoc networks briefly and outlines routing issues in mobile ad hoc networks in section 3. We will discuss so-called position-based routing protocols and gives an overview. Further a novel reliable position-based solution for quality of service (QoS) routing in mobile ad hoc networks is proposed. Finally, section 4 concludes with a summary.

2 MOBILE AD HOC NETWORKS

The idea of mobile ad-hoc networks has been under development from 70s and 80s in the framework of Mobile Packet Radio Technology (PRNET-1973) und Survivable Adaptive Networks (SURAN-1983) [2]. In the middle of '90, with the definition of standards, commercial radio technologies have begun to appear and the wireless research community identified in ad-hoc networks a challenging evolution of wireless networks. Today's emerging standards and technologies for constructing a mobile ad hoc network are IEEE 802.11, Bluetooth and ETSI Hiperlan/2. The deployment of mobile ad hoc networks opens a wide-range of potential utilisation from military to miscellaneous commercial, private and industrial scenarios.

Mobile ad hoc networks have several salient characteristics. An important characteristic is the dynamic topology. Nodes are free to move arbitrarily; thus, the network topology--which is typically multi-hop--may change randomly and rapidly at unpredictable times and may consist of both bidirectional and unidirectional links.

Another important property of ad hoc networks is the multihop capability. In general, the cellular networks -also called single-hop networks- rely on a fixed wired infrastructure to achieve and maintain an end-to-end connection. In contrast, a mobile node in an ad hoc network that cannot reach the destination directly because of node's limited transmission range, unless the destination node is the neighbour node. This will need to relay the information flow through other nodes. This implies the mobile hosts to incorporate routing functionality so that they can act both as routers and hosts (cf. Fig. 1).

The dynamic network topology will influence the design of routing protocols. The routing protocol must maintain connectivity in the face of route disconnection caused by effects, such as node motion, node breakdown (e.g. in a hostile environment). It must also be able to adapt to failure of the connected link due to wireless interference and changes in signal propagation condition.

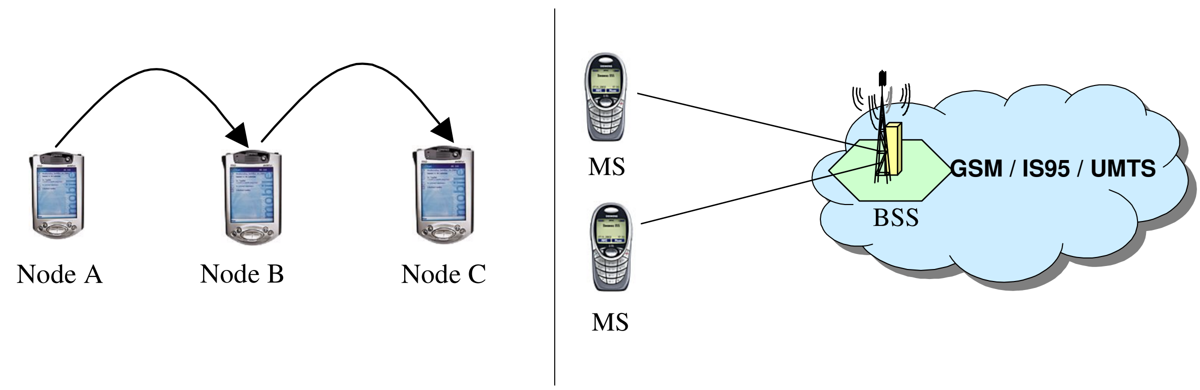

Figure 1: Multi-hop (hop-by-hop) routing is one of the essential characteristics of mobile ad hoc networks in comparison to today's cellular (single-hop) networks

3 ROUTING IN MOBILE AD-HOC NETWORK

Routing is the process of finding a communication path from a source station to a destination using suitable methods and algorithms to achieve high performance in the whole network. Different categories can be used to classify the routing protocols such as static and dynamic, centralised and decentralised. In this paper we consider the routing task, in which a message is sent from a source node to a destination node. The task of finding and maintaining routes in mobile ad hoc networks is nontrivial since nodes mobility and changes in node's activity cause frequent unpredictable topological changes. The destination node is known and addressed by means of its location. Routing is performed by a scheme based on this information, generally classified as a position-based scheme.

In contrast to conventional wired networks, ad hoc networks have some characteristic limitations, such as low bandwidth, high power consumption, high error rates and memory constraints of the mobile nodes. Additionally, changing topology and the mobility of the nodes have to be considered. Therefore, the routing protocols used in conventional networks are not well suited for ad-hoc radio environments. Hence, route construction should be done with a minimum of overhead and bandwidth consumption. The route can be selected using specific characteristics as metrics. Among the metrics proposed are conventional ones, such as path length and hop count, but also more radio specific ones like bandwidth, delay and communication cost of the network. In this paper we will not intend to give an overview about the advantages and weaknesses, characteristics and requirements of a variety of ad hoc routing protocols. There exist a lot of research articles in the literature. In this article, we only discuss use of position information on nodes in ad hoc networks mainly for routing purposes.

Several routing protocols for ad-hoc networks have been proposed in recent years. These protocols consider typical limitations of these networks, such as mobility, high power consumption, low bandwidth, high error rates etc. Therefore, for successful operations, it is very essential to ensure functional correctness and completeness of the designed routing protocols. The Internet Engineering Task Force (IETF) formed a working group named Mobile Ad-hoc Networks (MANET) to develop and standardize a framework for an IP routing protocol for mobile ad-hoc networks. Numerous routing protocols have been submitted to the MANET group as RFC or Internet-Drafts [1]. Basically, the protocols developed for routing mechanism are mainly based available shortest path algorithms and limited flooding for forwarding. These protocols can be divided into proactive, reactive and hybrid schemes.

These approaches mentioned above are summarised as topology-based routing protocols [4] since they use the information about the links that exist in the network to perform packet forwarding. Since these routing principal as based on flooding, they cause so-called *broadcast storm problem* in the network. In recent years, many works is done to review and study key properties and evaluate the performance of each particular routing protocol. Topology-based protocols are the most evaluated and studied protocols [3, 5, 6]. Results show that in networks with a dynamic topology, proactive approaches have considerable difficulties in maintaining valid routes and lose many packets.

3.1 Position-based routing

A different scheme used in routing mechanism in ad-hoc networks are the position-based routing protocols which do not need to maintain routes to destinations. These routing protocols use the geographic position information of the nodes to perform packet forwarding. In this approach each

Position-based routing	
Location service	**forwarding**
Grid Location Service	*(limited) flooding*
Homezone Location Service	*greedy forwarding*
Quorum Based Location Service	*hierarchical*

Figure 2: Position-based routing components

node determines its own geographic position using a mechanism such as GPS or other type of positioning services. Position-based routing algorithms promise to eliminate some of the limitations of topology-based routing by using additional information. They require that information about the physical position of the participating nodes be available. The routing decision at each node is then based on the destination's position contained in the packet and the position of the forwarding node's neighbors. Position-based routing does thus not require the establishment or maintenance of routes. The nodes neither have to store routing tables nor do they need to transmit messages to keep routing tables up-to date. A position-based protocol consists of two main processes to send a packet between the nodes in the network.

- location determination of nodes and providing of node's location address to others
- packet forwarding based on destination's location address

In Fig. 2 some examples for location service and forwarding strategy in position-based routing is given [4]. In order to determine the position of a distant node the existence of a location service is an essential requirement. A location service is used by the sender of a packet to determine the position of the destination and to include it in the packet's destination address. To maintain location information on other nodes in the network, each mobile node maintains a location table. This table contains an entry on every node in the network whose location information is known, including the node's own location information.

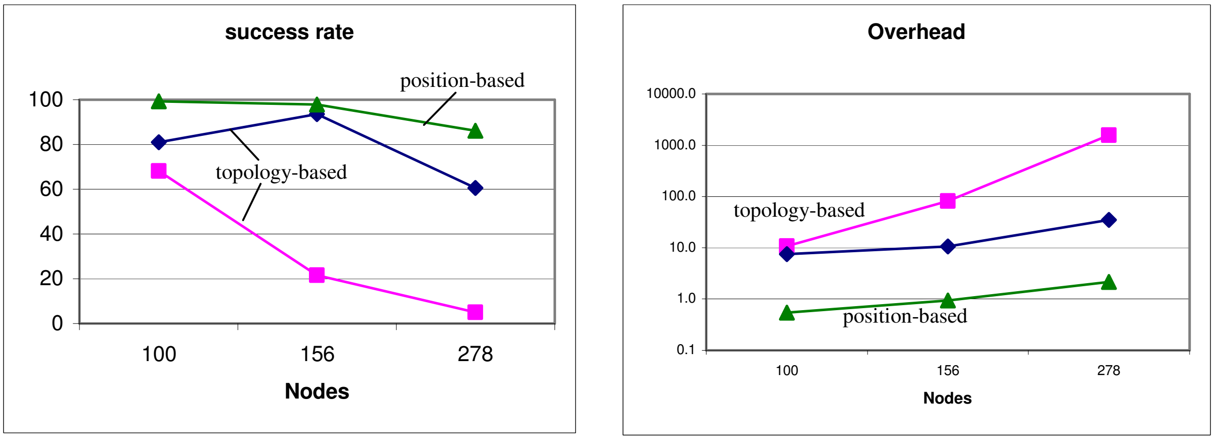

Figure 3: Success rate and overhead comparison of a position-based routing protocol with two topology-based routing protocols

A table entry may contain, for example, node identification, the coordinates of the node's location based on some reference system, the current speed of the node, and the time this location information was obtained from the node. Using a forwarding strategy data packets can be send from sender node to destination. The simplest one is the flooding. However, to restrict the area and limit the number of packets, restricted flooding schemes can be used, in which the data packets are send to only selected network part. In greedy forwarding scheme node forwards packets to only one neighbour that is located closer to the destination than the forwarding node itself. The selection of the neighbor in the greedy case depends on the optimization criteria of the used routing protocol. In Fig. 3 a comparison between two topology-based routing protocols (AODV, DSR [2, 3]) and a position-based routing protocols (GPSR [9]) is given exemplary. Without going into the protocols details (interested reader is referred to e.g. [5, 6]) In terms successful data delivery and number of overhead position-based protocols are superior to their topology-based counterparts. Also, the results show that the routing protocols that do not use geographic location in the routing decisions are not scalable. The effects on broadcast storm problems in topology-based protocols can be observed very clearly in Fig. 3b.

3.2 Position-based QoS Routing in Mobile Ad Hoc Networks

Routing solutions above-mentioned deal only with the best-effort data traffic. Finding a suitable route through the network between source and destination while considering quality of service (QoS) aspects concerning e.g. delay and bandwidth constraints are not supported. Despite some research efforts QoS scheme is not fully addressed and it is still one of the major open issues in MANET [7]. Many aspects have to be considered to overcome lots of limitations in ad-hoc networks. Inspired by unsolved quality of service (QoS) problem in ad hoc networks and the location server concept used in position-based routing scheme we propose a novel reliable approach for QoS routing in ad hoc networks. Since QoS routing is dependent on the accurate availability of current network state information, we use distributed location server architecture to provide not only node's positions but also information about the links and other information necessary for QoS routing. This is the basic idea behind our concept, which is different from most of other publications. Furthermore, in our work the network is divided into a grid structure.

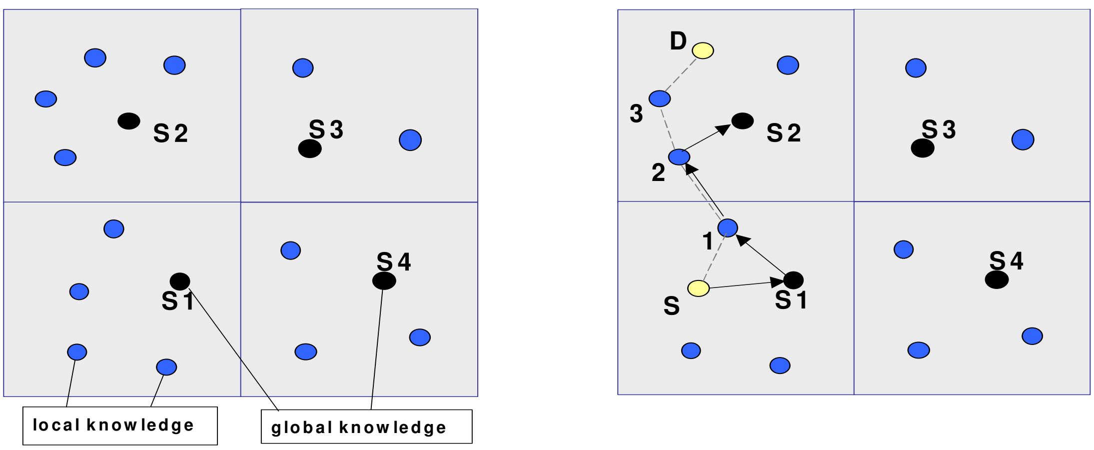

Figure 4: Proposed network architecture with location server for QoS routing

Each grid partitioning is observed and controlled by a node acting as a server node (cf. Fig.4a). Differently from solutions mentioned in the literature (e.g. [8]) the bandwidth on the path from sender to receiver is not calculated hop-by-hop. During the set-up phase (network formation) node with smallest ID will be selected as serving node for this grid. The information about node's position, theirs neighbors and link status between nodes are also held in server nodes. Nodes in each grid exchange position, neighbour list but also its slot status to its neighbours periodically or event-driven based on network activity. As next, server nodes in the network exchange their information each other to achieve global network knowledge. What happens when a node wants to set up a QoS connection? In fact, it does not need to flood the whole network with request packets or even calculate the required bandwidth hop by hop. It only needs to contacts the server node in its grid, since they have global knowledge of the network. Calculation, reservation and also multiple path selection will be done by these server nodes. An example is illustrated in Fig 4b. Flooding and periodic update are not needed. Using distributed network architecture we propose the accumulated information in server nodes reflects the knowledge of global connectivity in the whole network [10]. Storing global connectivity information at each node would require a large database and this would consume significant bandwidth for connectivity information updates.

4 CONCLUSION

In this paper we outlined use of position information for routing in mobile ad hoc networks. Position-based routing algorithms promise to eliminate some of the limitations of topology-based routing by using additional information. The routing decision is then based on the destination's position contained in the packet and the position of the forwarding node's neighbors. Further, we a new network layer architecture for QoS routing using distributed location server is presented. Use of location server concept promise to deliver global connectivity information, which is essential for setting up a quality of service connection.

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