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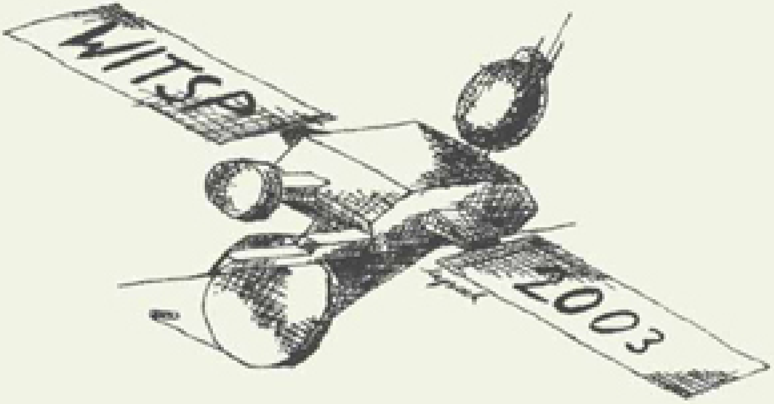

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PREFACE

We live in the era of information revolution triggered by a widespread availability of Internet and Internet based applications, further enhanced by an introduction of wireless data networks and extension of cellular networks beyond traditional mobile telephony through an addition of the mobile Internet access. The Internet has become so useful in all areas of life that we always want more of it. We want ubiquitous access (anywhere, anytime), more speed, better quality, and affordability. This book aims to bring to the reader a sample of recent research efforts representative of advances in the areas of recognized importance for the future Internet, such as ad hoc networking, mobility support and performance improvements in advanced networks and protocols. In the book, we present a selection of invited contributions, some of which have been based on the papers presented at the 2nd Workshop on the Internet, Telecommunications and Signal Processing held in Coolangatta on the Gold Coast, Australia, in December 2003.

The first part of the book is a reflection of efforts directed towards bringing the idea of ad-hoc networking closer to the reality of practical use. Hence its focus is on more advanced scalable routing suitable for large networks, directed flooding useful in information dissemination networks, as well as self-configuration and security issues important in practical deployments. The second part of the book illustrates the efforts towards development of advanced mobility support techniques (beyond traditional "mobile phone net") and Mobile IP technologies. The issues considered here range from prediction based mobility support, through context transfer during Mobile IP handoff, to service provisioning platforms for heterogeneous networks. Finally, the last part of the book, on performance of networks and protocols, illustrates researchers' interest in questions related to protocol enhancements for improved performance with advanced networks, reliable and efficient multicast methods in unreliable networks, and composite scheduling in programmable/active networks where computing resources are of as much importance to network performance as transmission bandwidth.

The editors wish to thank the authors for their dedication and lot of efforts in preparing their contributions, revising and submitting their chapters as well as everyone else who participated in preparation of this book.

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PART 1:

ADVANCED ISSUES IN AD-HOC NETWORKING

Chapter 1

HIGHLY SCALABLE ROUTING STRATEGIES: DZTR ROUTING PROTOCOL

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Abstract In this paper we present a simulation study of a hybrid routing protocol we proposed in our previous work [4] [3]. Our hybrid routing strategy is called Dynamic Zone Topology Routing protocol (DZTR). This protocol has been designed to provide scalable routing in a Mobile Ad hoc Networking (MANET) environment. DZTR breaks the network into a number of zones by using a GPS. The topology of each zone is maintained proactively and the route to the nodes in other zones are determined reactively. DZTR proposes a number of different strategies to reduce routing overhead in large networks and reduce the single point of failure during data forwarding. In this paper, we propose a number of improvements for DZTR and investigate its performance using simulations. We compare the performance of DZTR against AODV, LAR1 and LPAR. Our results show that DZTR has fewer routing overheads than the other simulated routing protocols and achieves higher levels of scalability as the size and the density of the network is increased.

Keywords: Ad hoc Networks, Routing, DZTR, Scalability.

1. INTRODUCTION

Mobile Ad hoc Networks (MANETs) are comprised of end user nodes, which are capable of performing routing in a distributed fashion. This means that these networks do not require a central coordinator or a base station to perform and establish routes. These networks are particularly useful in areas where an infrastructure is not available or difficult to implement. Such areas include the highly dynamic battle field environment, which requires a mobile networking solution and in the search-and-rescue operations where a large rescue team may be searching through a remote area such as a jungle or a desert.

Similar to most infrustructured or wired networks such as the Internet, MANETs employ a TCP/IP networking model. However, the need to provide end-to-end communication in a dynamic environment, along with the limited resources such as bandwidth and power, demands a redefinition of the layers used in the TCP/IP. Currently, research is being carried out across all layers of the TCP/IP model, to design an infrastructure, which will provide reliable and efficient end-to-end communication for MANETs. One challenging, yet highly researched area in MANETs is routing. In MANET, an intelligent routing strategy is required to provide reliable end-to-end data transfer between mobile nodes while ensuring that each user receives certain level of QoS. Furthermore, the routing strategy must minimise the amount of bandwidth, power and storage space used at each end user node. Therefore, traditional routing strategies, such as the link-state and distance vector algorithm, which where intended for wired or infrastructured networks will not work well in dynamic networking environment.

To overcome the problems associated with the link-state and distance-vector algorithms a number of routing protocols have been proposed for MANETs. These protocols can be classified into three different groups: Global/Proactive, On-demand/Reactive and Hybrid. In proactive routing protocols such as FSR [8], DSDV[13] and DREAM[6], each node maintains routing information to every other node (or nodes located in a specific part) in the network. The routing information is usually kept in a number of different tables. These tables are periodically updated and/or if the network topology changes. The difference between these protocols exists in the way the routing information is updated, detected and the type of information kept at each routing table. Furthermore, each routing protocol may maintain different number of tables. On-demand routing protocols such as AODV[7], DSR[11] and LAR[12] were designed to reduce the overheads in proactive protocols by maintaining information for active routes only. This means that routes are determined and maintained for nodes that require to send data to a particular destination. Route discovery usually occurs by flooding a route request packets through the network. When a node with a route to the destination (or the destination itself) is reached, a route reply is sent back to the source node using link reversal if the route request has travelled through bi-directional links, or by piggy-backing the route in a route reply packet via flooding. Hybrid routing protocols such as ZHLS[10], ZRP [9] and SLURP[14] are a new generation of protocol, which are both proactive and reactive in nature. These protocols are designed to increase scalability by allowing nodes with close proximity to work together to form some sort of a backbone to reduce the route discovery overheads. This is mostly achieved by proactively maintaining routes to nearby nodes and determining routes to far away nodes using a route discovery strategy. Most hybrid protocols proposed to date are zone-based, which means that the network is partitioned or seen as a number of zones by each node. Others group nodes into trees or clusters. Hybrid routing protocols have the potential to provide higher scalability than pure reactive or proactive protocols. This is because they attempt to minimise the number of rebroadcasting nodes by defining a structure (or some sort of a backbone), which allows the nodes to work together in order to organise how routing is to be performed. By working together the best or the most suitable nodes can be used to perform route discovery. For example, in ZHLS only the nodes which lead to the gateway nodes rebroadcast the route discovery packets. Collaboration between nodes can also help in maintaining routing information much longer. For example, in SLURP, the nodes within each region (or zone) work together to maintain location information about the nodes, which are assigned to that region (i.e. their home region). This may potentially eliminate the need for flooding, since the nodes know exactly where to look for a destination every time. Another novelty of hybrid routing protocols is that they attempt to eliminate single point of failure and creating bottleneck nodes in the network. This is achieved by allowing any number of nodes to perform routing or data forwarding if the preferred path becomes unavailable.

Most hybrid routing protocols proposed to date are zone-based. In zone-based routing protocols, the network is divided into a number zones, which can be overlapping ones, such as in ZRP, or non-overlapping such as in ZHLS. The disadvantage of ZRP is that if the zone radius is too large the protocol can behave like a pure proactive protocol, while for a small zone radius it behaves like a reactive protocol. Furthermore, the zones are overlapping, which means that each node can belong to a number of different zones, which increases redundancy. The disadvantage of a non-overlapping zone-based protocols such as ZHLS is that the zone partitioning is done at the design stage. This means that all nodes must have preprogrammed zone maps, which are identical for all nodes in the network, or they must obtain a copy of the zone map before routing can occur. Static zone maps can be used in environments where the geographical boundaries of the network are known (or can be approximated). Such environments include: shopping malls, universities or large office buildings, where physical boundaries can be determined and partitioned into a number of zones. However, in environments where the geographical boundaries of the network are dynamic (i.e. can change from time to time as nodes may travel to different regions), a static zone map cannot be implemented. Examples of such networks include: the battlefield where the battle scene may constantly move from one region to another or in search-and-rescue operations in remote areas. In these environments, a dynamic zone topology is required.

In our previous study [3], we proposed DZTR, where we introduced two dynamic zone creation algorithms, which use a number different location tracking strategies to determine routes with the least amount of overheads. In this paper, we propose a number of improvements for DZTR and investigate its performance using simulation technique. We also compare the performance of DZTR with AODV, LAR1, and LPAR[5], under a number of different network scenarios and comment on their scalability in large networks. The rest of this paper is organised as follows. Section II briefly describes the DZTR routing protocols. Section III describes the simulation tool and the parameters used in our simulations. Section IV presents a discussion on the results we obtained from the preliminary simulations, and section V presents the concluding remarks for the paper.

2. DYNAMIC ZONE TOPOLOGY ROUTING

DZTR is a zone based routing protocol is designed to provide scalable routing in large networks with high levels of traffic. The advantage of DZTR over some of the other zone-based routing protocols described in the previous section includes:

- Zones are created dynamically rather than using a static zone map such as in ZHLS. This means that a preprogrammed zone map is not required.

- Each zone only belongs to one zone, which means that information redundancy is reduced, while a more collaborative environment is defined.

- Single-point of failure is reduced, since there is no cluster-head or a root-node. All nodes within each zone work together to determine the best routes with the least amount of overheads, and data forwarding between each zone can still occur without a route failure as long as there is one gateway connecting the two zones.

- A number of location tracking strategies is proposed to determine routes with minimum amount of overheads for a number of different scenarios.

The DZTR routing protocol is made up of three parts. These are Zone Creation, Topology Determination and Location Discovery. The following sections describe each part.

2.1 Zone Creation

In DZTR two different zone creation algorithms are proposed. These are referred to as DZTR1 and DZTR2. In DZTR1, all nodes in the network start off by being in single state mode, which means that they are not members of any zone. When two nodes come within each others transmission range and form a bi-directional link, a zone is created if the following conditions are satisfied:

- Neither node has a zone ID which maps within their transmission range.

- At least one of the nodes are not a gateway node of another zone[1].

To create a zone ID, each node records its current location, speed and battery power and exchange it with the other using a Zone-Query packet. The coordinates of the node with the lower speed will be used as the zone centre point, which is used to create and reserve the zone boundary. If the nodes have the same velocity, then the node with the higher battery power will be used as the centre point. The aim here is to select the node which is expected to last the longest in the calculated zone. This means that the calculated zone will be active for a longer time.

When the node which has the higher stability of the two is determined, each node will then calculate the boundary using the centre point and the transmission range of that node. Note that when a node sends a Zone-Query Packet, it also keeps a copy of this packet and waits for the other node to send its Zone-Query Packet. When the neighbours Zone-Query packet is received, it uses the two packet to create the zone. The node will then exchange the calculated zone ID to ensure that they have agreed on the same zone ID. If the zone IDs are different the zone ID of the least mobile node is used based on the mobility information exchanged during the zone ID exchange phase. The zone ID will be a function of the centre point and the zone radius. We have chosen the zone ID to be the concatenation of the zone centre point and the zone radius. [2]

$$Z_{ID} = f(C, R) = C|R \tag{1}$$

Similar to DZTR1, the zones are geographically bounded by a zone radius. However, in DZTR2, the boundary of the zone is chosen in such a way that all nodes are within transmission range [3]. The advantage of this strategy is that there is no partitioning in each zone. Therefore, there is all nodes within each zone are aware of each other. Another advantage is that each node can update its intrazone with just one beacon message, as there is no need for further rebroadcast to reach all different parts of each zone. However, the zones created in DZTR2 are smaller than DZTR1, which means that the number of zones in DZTR2 maybe significantly higher than DZTR1. This can increase the number of interzone migration when mobility is high, which will require each node to become affiliated with different zones more frequently. Hence, processing overhead and intrazone update may be higher than in DZTR1.

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[1] One of the two nodes have a neighbouring node which is a zone member

[2] C = coordinates of the centre node (x,y,z), R = transmission range and the | means concatenation. Note that if we assume that R for all nodes are equal, then $ZID = C$