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Energy efficient zone based routing protocol for MANETs

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ABSTRACT

Mobile Ad Hoc Networks (MANET) are self-configuring infrastructureless networks of mobile devices connected via wireless links. Each device can send and receive data, but it should also forward traffic unrelated to its own use. All need to maintain their autonomy, and effectively preserve their resources (e.g. battery power). Moreover, they can leave the network at any time. Their intrinsic dynamicity and fault tolerance makes them suitable for applications, such as emergency response and disaster relief, when infrastructure is nonexistent or damaged due to natural disasters, such as earthquakes and flooding, as well as more mundane, day-to-day, uses where their flexibility would be advantageous.

Routing is the fundamental research issue for such networks and refers to finding and maintaining routes between nodes. Moreover, it involves selecting the best route where many may be available. However, due to the freedom of movement of nodes, new routes need to be constantly recalculated. Most routing protocols use pure broadcasting to discover new routes, which takes up a substantial amount of bandwidth. Intelligent rebroadcasting reduces these overheads by calculating the usefulness of a rebroadcast, and the likelihood of message collisions. Unfortunately, this introduces latency and parts of the network may become unreachable. This paper discusses the Zone based Routing with Parallel Collision Guided Broadcasting Protocol (ZCG) that uses parallel and distributed broadcasting technique (Basurra et al., 2010) [8] to reduce redundant broadcasting and to accelerate the path discovery process, while maintaining a high reachability ratio as well as keeping node energy consumption low.

ZCG uses a one hop clustering algorithm that splits the network into zones led by reliable leaders that are mostly static and have plentiful battery resources. The performance characteristics of the ZCG protocol are established through simulations by comparing it to other well-known routing protocols, namely the: AODV and DSR. It emerges that ZCG performs well under many circumstances.

1. Introduction

Routing protocols for a MANET can be categorised into three groups: reactive, proactive and hybrid [40]. In reactive routing, nodes have no prior location knowledge of the destination nodes and routes are determined on request, typically by flooding, such as in the Ad-hoc On-Demand Distance Vector (AODV) protocol [38]. The

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drawbacks of reactive protocols are the high cost of broadcast to establish routes and the latency inherent in the process of finding a route to the destination. In proactive routing, each node in the network continuously checks and evaluates paths to every node in the network to establish a complete or partial view of the network, such as in the destination-sequenced distance-vector (DSDV) routing protocol [39]. Consequently, routing latency is low, because paths to destinations can be calculated locally and quickly. The costs in a proactive approach are the high channel usage overheads for route update control messages and the time to convergence of the network path data. Thus, hybrid techniques have been conceived, using zone and cluster-based routing, that aim to exploit the strengths and minimise the weaknesses of reactive and proactive approaches [2,24,44].

In a MANET, many routing protocols, such as the Ad hoc on-demand Distance Vector (AODV) [38], Dynamic Source Routing (DSR) [27], Zone Routing Protocols (ZRP) [23,24], Location Aided Routing (LAR) [29] and Geographical Routing Protocol (GRP) use broadcasting to establish routes. Pure flooding guarantees high reachability and good routing time latency in low density networks. However, pure broadcasting uses a lot of network capacity and is prone to broadcast storms in dense networks, thus increasing routing delay. One solution to the storm problem is to send fewer redundant rebroadcasts by selecting a small set of forwarding nodes while ensuring broadcast coverage, but this may cause the rebroadcast chain to break and critical intermediate nodes not to receive rebroadcasts, resulting in reduced reachability [2]. Smart rebroadcast algorithms aim to reduce overheads by computing the usefulness of rebroadcasting and the likelihood of packet collisions, such as in counter/location based schemes[42,31].

Many broadcasting approaches have been proposed to allow mobile nodes to estimate neighbourhood density and trade off low broadcast redundancy with reachability, which in turn leads to the best possible network throughput, reachability level and low broadcast latency. However, most of the existing routing protocols in a MANET see lowering broadcasting latency in terms of efficient broadcasting [42] and not as a protocol design objective. The view here is that both can be reduced by addressing them in the protocol design phase.

The objective of this paper is to evaluate the efficiency of the ZCG routing protocol when being implemented in ad hoc wireless networks that consist of highly mobile nodes where the communications between them are short and frequently repeated. Such network traffic behaviour can be found in many ad hoc applications, such as mobile file/data sharing and Push to Talk (PTT), also known as Press-to-Transmit. Such applications, in contrast to Voice over IP (VoIP) and gaming, do not require users to use all their communication links all the time. That is, they may not send any traffic on a particular path for long periods during an active communication session. During a long silence, the communication channel can be kept active by sending small control packets to the destination node to remind the intermediate nodes along the path that the route is still in use. This will keep the forwarding route available whenever required to relay actual data, but it does consume network resources, i.e. network bandwidth and node power. However, if these control packets are not sent frequently enough they can cause the routing table entries at intermediate nodes along the path to expire, which will require route discovery procedures to be activated that use high amounts of pure broadcasting (also known as blind flooding). This can lead to a broadcast storm problem, which also wastes large network throughput and causes high power consumption in network nodes.

This paper describes the design of the ZCG protocol and provides a summary of some of our current simulation results for ZCG performance when compared against other standard routing protocols namely AODV and DSR.

We selected the aforementioned protocols to compare their performance against ZCG, for the reasons outlined below: (i) they are the most popular protocols used in mobile ad hoc networks. These protocols are standardised by the Internet Engineering Task Force (IETF), and are the most surveyed protocols in the literature; (ii) they are widely used and well tested for real world applications. For example, Microsoft mesh networks use dynamic source routing (DSR) [28]. Also, AODV routing protocol is already available for the Linux and Microsoft Windows operating systems [12].

This paper begins with a brief introduction about the ZCG protocol in Section 2. Then, there is more detailed explanation of the phases of the its zone construction protocol in Section 2.1. This covers the methods used to identify zone leaders, and how nodes calculate and distribute their Fitness Factor (FF) as described in SubSection 2.3. Subsequently, in Section 4 the experimental plan which includes a description of the three main scenarios used to test the protocols' performance is explained and justified. These scenarios' description and the obtained results from simulating each scenario are discussed in Sections 6.1 and 6.2. These results provide various aspects of protocol performance, which are: the total routing traffic received, route discovery delay, network delay and routing broadcast retransmission. Section 7 includes the conclusion, and a brief summary of the research and description of the way forward are provided in Section 10.

2. The ZCG protocol

ZCG protocol relies on the decomposition of the network into contiguous zones, with one node being selected from a group of nodes to be the zone leader, denoted ZL(X), which is selected based on fitness criteria similar to those used in [35], such as high battery power and zero/low mobility. The ZLs eventually establish connectivity amongst themselves directly or via reliable intermediate nodes, that is, nodes in the overlap of two or more zone coverage areas and therefore, these connectivity links are not necessarily the shortest available routes (see Fig. 1).

Nodes in the ZCG have one of three roles: Zone Leader (ZL), member or idle. By default, idle nodes can only hold