CHAPTER ONE

1. INTRODUCTION

1.1 Reconfigurable Wireless Ad Hoc Networks

Among many possible ways of grouping, networks can be split into two main categories. The wired networks which use physical links or connections through wires, and the wireless networks, which make use of wireless links. The second category can further be sub-divided into infrastuctured, whereby there is a pre-existing infrastructure, and infrastructureless where the infrastructure is formed spontaneously when required “on the fly”. The second sub-category is also referred to as ad hoc network.

Ad hoc networks are therefore self-organizing, rapidly deployable, and require no fixed infrastructure. They comprise of wireless nodes that can be deployed anywhere and must cooperate to dynamically establish communications using limited network management. Nodes in an ad hoc network may be highly mobile or stationary and may vary widely in terms of their capabilities and use.

One of the main objectives in designing recent network architectures is to achieve increased flexibility, mobility and ease of management relative to wired networks. In relation to infrastructure networks, ad hoc networks can be termed as “peer-to-peer” in the sense that all nodes have equal roles in terms of topology management i.e. the roles of base station and router are played by all nodes. These kinds of networks are highly dynamic and require adaptive control schemes that can respond to the high mobility and network changes without administrative intervention. The result of such schemes is what is referred to as “Reconfigurable Wireless Networks” (RWN)[1]. A more descriptive name to such a network with reference to this work would be “Reconfigurable Wireless Ad hoc Network (RWAN)”.

Nodes in a RWAN dynamically join and leave the network frequently, often without warning and possibly without disruption of other nodes’ communication. These nodes can be highly mobile and thus can rapidly change their constellation in presence or absence of a link. The main features in such networks are increased mobility, large number of nodes, and a large network span. For realization of such networks, certain requirements have to be met. These include robust routing and mobility management algorithms. Such algorithms are meant to increase the network reliability and availability. Adaptive algorithms and protocols for adequate adjustments to frequently changing radio propagation network and traffic conditions are also necessary. Low overhead algorithms and protocols that allow conservation of available resources and reduce congestion in multiple routes between source and destinations would allow longer survivability of the network while increasing its efficiency of information delivery. Algorithms that would reduce susceptibility to single point network failures and ease congestion around high level nodes thus increasing routing efficiency are also needed. In this dissertation, management of overheads due to routing, based on mobility parameters, has been addressed. Since routing packets are dispatched either with a single hop (only to the neighbors) or with multiple hops (to other destinations outside a node’s transmission range), overhead reduction has been considered at two levels. These are: node level (single hop packets) and Network level (multi-hop packets). The issue of routing overhead has been discussed in more details in chapters two and three.

1.2 Problem statement and Motivation

The issue being addressed in this dissertation is the problems associated with routing overheads in reconfigurable ad hoc routing protocols. Since routing overheads form the backbone of the connectivity and maintenance of an ad hoc network, they cannot be done without. However, better management of the overheads would lead to savings in the network's energy and bandwidth. This would also effectively increase the lifespan, efficiency, scalability and possibly the overall performance of both the protocol and the network.

In order to design an efficient algorithm or method of handling and managing these crucial overheads, it is important to understand a number of features associated with these overheads. The features that were analyzed leading to the problem statement of this dissertation are: The different forms of overheads that exist, how they are generated, how they are propagated, how they are used, where the different types are needed, what effects they have on different parts of the network among other important features. These features are addressed in more details in chapter two. The analysis hinted the points that while these overheads are crucial to the running of the network and the protocol, all the nodes in the network do not always need them. It is therefore necessary to design schemes that will allow the nodes to generate the overheads only when they are needed and direct them to the areas where they are required. This would allow the protocol to handle information packets more efficiently, use available resources more economically and increase both scalability and lifetime of both the protocol and the network without compromising their performances.

Although it has been suggested in literature that a "one fit all" kind of solution to the routing protocol problems is not feasible, a solution that handles one particular problem and overlooks others may not be ideal. The reason for such an argument is that real life situations, especially the current target application area of ad hoc networks (see chapter 5), are very dynamic in nature and require dynamic protocols that would self configure to cope with the changes experienced by the scenarios.
Another question to ask when solving routing problems would be, which routing protocol is most appropriate for the tasks at hand. In the view of this work, a full analysis of the existing types of routing mechanisms would be required before answering such a question. It is evident that the ideas contributed in this fast moving research area, have not been fully investigated and utilized. It is for this reason that this dissertation details designing of schemes that would take advantage of features of the existing protocols and add features that would benefit a large cross section of protocols.

This dissertation addresses two types of overheads that were found common in most of the traditional protocols. These are the neighborhood discovery and maintenance broadcasts (specifically the hello messages), and the route discovery messages (specifically the route request messages).

When hello messages are broadcasted periodically, this leads to poor knowledge of the neighborhood if the network is highly dynamic. A highly dynamic network here refers to a network that changes dynamically in terms of topology, traffic load, node density, among other network parameters. When these dynamics increase, the configuration of the network changes more frequently due to a more frequent break and make of links between nodes. These periodic updates of node identities lead to poor and inaccurate identification of its neighborhood. The scheme designed in this dissertation aims at minimizing sending these messages by sending them only when a node discovers that it is at a risk of loosing a link on an active route.

In case of the route request messages, the conventional method of broadcasting them is flooding. While this method ensures optimum selection of route, these messages are processed by all nodes in the network most of who should never have participated in the route creation. This leads to waste of crucial resources like bandwidth and energy. The scheme hereby proposed ensures that route requests are sent only to the regions where the route is likely to be found. While this scheme introduces other types of packets, the overall effect is reduction of the routing messages and avoiding areas where the messages would otherwise lead to waste of resources.

The understanding that better management of the overheads can lead to savings in reconfigurable wireless ad hoc network resources motivated us to this research.

1.3 Objectives

Ad hoc networks emerged to increase flexibility in the mobile computer field. These networks are considered suitable for applications where there is no pre-existing infrastructure or an existing one has been disabled due to some reasons. Such a network may be static, or dynamic. There has been tremendous success in the static network area. However the dynamic network continue experiencing challenges which have not been easy to alleviate. Notable challenges range from network performance to protocol efficiency that includes low overheads. These challenges are discussed in more details in chapter 2. They are unique in wireless networks unlike in wired network. The limited wireless channel and the mobile nature of nodes are probably the basic challenges. The mobility of nodes may result in continuous and unpredictable link breakages between participating nodes, which may lead to network fragmentation. Such link breakages are normally associated with increase in network overheads as nodes try to repair the broken links or establish new links. If these breakages can be foreseen, such undesired consequences can be avoided.

Our main objective in this research is to identify various features in existing routing protocols and exploiting underutilized features that can be used in reduction of overheads generated by RWAN routing protocols during normal network operations. Routing Overheads (RO) that are normally generated at two levels will be handled separately. At node level, the overheads generated only affect the node and its neighbors and has no direct impact on the entire network. While this has an indirect impact, it would however have undesired consequences if it happens more frequently on busy routes or many parts of the network. The packets involved in this level are mainly neighbor discovery and maintenance packets, which are normally broadcasted with hop counts limited to node's neighbors. This problem is addressed with the "link availability forecast" scheme. At Network level, overhead packets are generated either through flooding or broadcasted possibly with multiple hops. The packets are mainly route discovery packets, maintenance packets, error packets, or acknowledgement messages. Since these packets pass through a great portion of the network, they have more impact on the operation of the entire network than individual nodes. These are addressed with the network level routing overhead management schemes. Reliability improvement methods on the suggested schemes have also been addressed in chapter three.

To achieve the main objective in this research, merits of certain routing mechanisms have been extracted. This has been done with the motivation that a better understanding of relative merits serves as a cornerstone for development of more effective routing protocols for mobile ad hoc networks that adapts to network dynamics and other parameters. It has been identified in this research that neighborhood discovery algorithms based on nodes' history of movement that will allow routing protocols to make intelligent decisions about routing and network level routing overhead reduction schemes would greatly benefit the research for more efficient routing protocols. Such schemes will allow the ad hoc networks to experience reduced overheads both at each node's neighborhood and network level since the nodes will be sending overhead packets only when it is vital and to regions requiring them. This would also result to an increase in delivery ratio since packets will be sent with relatively higher certainty of delivery. The overall throughput is expected to increase because time will be saved though reduction of the number of route requests and reduction of congestion of packets. A combination of parameters necessary for deciding the most appropriate route to take will be investigated and an algorithm on how to effectively use such parameters derived. In the "link availability" scheme, parameters that are needed to establish whether a link will be available between two communicating nodes before they can start transmitting information packets are derived. These parameters help in the forecast of the reliability of the entire path that the packets will follow so as to guarantee improvement in their delivery. Parameters needed in the case of network level RO reduction are also derived.

1.4 Related work

The idea of link and path availability is not absolutely new to the field. It has however not received full exploitation and detailed analysis that it deserves. Moreover the objective of the concept has not been RO reduction but knowledge of neighborhood for correct route selection. Researchers have made suggestions in the past on ways of predicting availability of a link between communicating nodes. An example is the use of mobility prediction used in the multicast ad hoc routing protocol [3]. In this paper, further analysis on the effects of unpredicted motion parameter change (e.g. speed and direction) should have been considered in more details. In this dissertation, motion parameters have been considered in terms of epochs, minimizing the error that could arise from unpredicted change in motion characteristics. The author of the referred work [3] mentions that there are other possible methods for future research. Modifications have hereby been suggested in order to take care of an extended number of parameters for consideration in link availability forecast. Other similar work done in this area include that on probabilistic link predictions. In the paper [4], the author concludes with the remarks that "the expressions for link availability provide the basis for a novel routing metric". These remarks actually support the need for our research. The author gives an evaluation, exposing the need for knowledge of link availability forecast.

On route availability, there have been suggestions on independent metrics that should be used in determining the validity of a path. A good example is the analysis done by Bruce [5] in the paper on path availability. All the suggested methods seem to favor a particular feature e.g. one method may favor shortest path, another may favor most economical path in terms of power consumption etc. Harmonization of multiple parameters for a more comprehensive conclusion of the best route has been done in this research and presented in chapter three.

On Network level reduction of routing overheads, certain algorithms have been suggested in the location based protocol area. The Location Aided Routing (LAR) protocol [6] uses an approach similar to our first scheme (link availability forecast) but differs in the restriction of the expected zone. The definition of R (radius of expected region) in LAR also differs since it is based on the time differences and node movement while the "R" in this research is based on specific locations known from historical behavior of the node (reactively passed on by the destination) plus its radius. Greedy Perimeter Stateless Routing (GPSR) [7] is another geo-protocol with features that offer reduction of overheads. This protocol makes forwarding decisions using only information about a router's immediate neighbor in the network topology or the region's perimeter. The schemes hereby developed use information obtained from the destination node and information gathered by the "DestSearch" packet along an old route. The Optimized Link State Routing (OLSR) Protocol [8] uses the multipoint relay (MPR) method for reduction of message overheads as compared to flooding method by limiting flooding to MPRs only. The scheme in this thesis reduces flooding effects by limiting flooding to a predetermined region.

1.5 Scope and limitations

The Scope of coverage in this research is mainly dictated by time and the availability of resources for testing the algorithms designed. As mentioned in section 1.2, there are numerous types of overheads that contribute to the overall routing overheads. Only two types (hello and route request) are however investigated in details and tested in this dissertation. Other vital overheads like the negotiation packets have been left as a future research issue. However the results of the research gives the evidence needed to support the solutions proposed. It is worth mentioning at this point that the results are based on the network's mac and routing layer and little reflection at the application layer.

This research details the routing overhead. While we feel the importance of optimization and/or preservation of optimal routes this topic is outside the scope and objectives of this particular research. We however suggested ways way of ensuring that established route do not exceed reasonable lengths.

The tool used for testing the schemes is the ns2 simulation tool which is a freeware tool used by many universities for research purposes only. It is however a new tool and weak in some real world application features. It however offers a degree