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AN EFFICIENT MULTICAST ROUTING PROTOCOL WITH QUALITY OF SERVICE FOR MOBILE AD-HOC NETWORKS

[1]Mohammad Qabajeh, [1]Aisha-Hassan A. Hashim, [1]Othman Khalifa and [2]Liana Qabajeh.
[1]Department of Electrical and Computer Engineering, IIUM, Malaysia.
[2]Faculty of Computer Science and Information Technology, University of Malaya, Malaysia.
Email: m_qabajeh@yahoo.com

ABSTRACT

Mobile ad hoc networks (MANETs) are networks consist of a group of mobile nodes autonomously establishing connectivity via multi-hop wireless communication without any pre-infrastructure or central administration. Multicasting communication serves as one critical operation to support many applications of Ad-hoc networks that achieve group communication rather than pairs of individuals. Multicast routing protocols becomes increasingly important in mobile Ad hoc networks because they effectively coordinate a set of nodes. Also, it provides efficient routing for multimedia applications such as video conferences, military, rescue operations and multi-party games. Such applications are highly demand for Quality of Service (QoS), which makes an efficient QoS multicast routing protocols is very important. The limitations of wireless networks make it necessary to develop a QoS multicast routing protocol that supports multiple QoS constrains with rational overhead. Recently, the availability of inexpensive, less power and small GPS receivers realizes the position-based multicast routing and improves routes stability. In this work we proposed a model that searches for QoS paths from a single source to a set of destinations. The physical area is partitioned into equal size hexagonal cells and a leader and backup leader nodes is elected to maintain up-to-date information about the network topology. The election process considers several metrics including node mobility, energy and memory. The multicast groups are separated into segments based on their geographical positions and each multicast group has a coordinator. The proposed model is expected to be scalable for large area networks with large number of multicast members. Also, it is expected to achieve a significant reduction in packet and processing overhead.

***Keywords**: MANETs, QoS, Multicast*

INTRODUCTION

Mobile Ad hoc NETworks (MANETs) are collections of mobile nodes that communicate with each other over wireless links in the absence of any infrastructure or centralized administration. Each node acts as a router and responsible to forward messages to its neighbors. Adjacent nodes (1-hop) can communicate directly and multi-hop communication requires cooperation between nodes to relay packets to their targets.
Group communication becomes increasingly important in MANETs because a lot of applications relay on cooperation between a team. Video conferencing, interactive television, temporary offices and network gaming are common examples of these applications (Bu¨r & Ersoy, 2005). As a consequence, multicast routing has received significant attention over the recent days.

Multicast communication is emerged to support applications that facilitate effective and collaborative communication among groups of users with the same interest. In multicasting, a source is sending the same data to a certain set of nodes in the network. This is efficient in saving the bandwidth and improving the scalability, which is essential in MANETs (Tebbe, Kassler, & Ruiz, ACM 2006).

The increasing popularity of using multimedia and real time applications in different potential commercial in MANETs, make it logical step to support Quality of Service (QoS) over wireless network. QoS support is tightly related to resource allocation and reservation to satisfy the application requirements; the requirements include bandwidth, delay, delay-jitter and packet to loss ratio. It is a challenge to support QoS in MANETs due to rapidly changing environment, centralized design of the medium access layer and limited resources. So, combine QoS with Multicasting facing several challenges, due to the difficulty in finding paths between the source and all the destinations that satisfy certain QoS requirements.

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This paper proposes a new QoS multicast protocol for multi-hop wireless network. Due to the dynamic network topology, we use the geographical positions of the nodes to forward the data packets in order to provide robustness and scalability (Mauve, Fuessler, Widmer, & Lang., 2003). We consider bandwidth and delay as QoS parameters; the available bandwidth is measured on the link between two successive nodes. The remainder of this paper is structured as follows: section 2 gives an overview on related work on multicast routing. Section 3 presents our model and finally a conclusion will be proposed.

INTRODUCTION

Multicasting in MANETs is relatively unexplored research area, when it is compared with unicast routing (Ko & Vaidya, 1999). Based on our work we will give an overview about QoS multicast routing protocols and position based multicasting protocols.

Position-Based and Multicast Routing

Location Guided overlay multicasting protocol is proposed in (Chen & Nahrstedt, 2005). It is a stateless scheme based on packet encapsulation in a unicast envelops to be transmitted to group of nodes. It builds an overlay packet distribution on top of the underling unicast routing protocol based on the geometric locations of the group nodes only. In LGK scheme, the sender first selects the nearest *k* destinations as children nodes, then the rest of the nodes are grouped to its k children according to close geometric proximity. In LGD tree, the sender partition the space into multiple cone areas centering about itself, the nearest node in each cone is selected as its child. And in LGS tree, based on the geometric distance a measurement of closeness, a Steiner tree is constructed by using the multicast group members as tree nodes.

A generalization of position-based unicast forwarding has been discussed in (Mauve, Fuessler, Widmer, & Lang., 2003). The sender includes the address of all the destinations in the header of the packet. Based on the nodes position information, each node determines the neighbors that should forward the packet to. When the current node selects more than one next hope node, then the multicast packet is split. Also, when there is no direct neighbor to make progress toward one or more destination a repair strategy is used. PBM is limited for small groups because the address of the destinations is included in each data packet. Also, it remains open how the sender is able to maintain the position information.

In Dynamic Source Multicast (DSM) (Basagni, Chlamtac, & Syrotiuk, 2001), each node floods the network with information about its own position, thus each node knows the positions of all other nodes in the network. The source node constructs a multicast tree from the position information of all receivers and encodes the paths in the header of the packet. In DSM, the periodic flooding of position information for all the nodes on the network reduces the scalability of the system and increase the processing overhead of the nodes.

QoS and Multicast Routing

The Lantern-Tree-Based (LTB) in (Chen & Ko, 2004) is a bandwidth constrain QoS multicast routing protocol. A lantern is defined as one or more sub-paths with a total bandwidth between a pair of two neighboring nodes. A lantern path is a path with one or more lanterns between a source and a destination. The multicast tree contains at least one lantern path between any of its source-destination pairs. Lantern-tree protocol measures the bandwidth as the available amount of free slots based on CDMA-over-TDMA channel model at MAC layer. One drawback of LTB is the long time needed to find all the paths and to share and schedule the time slots. Another drawback is the use of high number of links, which increase the contention at the MAC layer.

On-demand QoS multicasting protocol is proposed in (Wu & Jia, 2007). This protocol simultaneously use multiple paths or trees in parallel to meet the required bandwidth of a single QoS request within a delay bound between the source and the destination. The bandwidth is considered as the number of free slots using CDMA-over-TDMA channel model. They propose three multiple path construction strategies to enable the source node to aggregate the bandwidth over the links. The source computes the optimal routes to the destinations and manages the group membership, which overload the source with extra processing overhead. Using flooding to discover the paths add the processing overhead for non-member nodes and waste the network resources.

QoS Multicast Routing Protocol (QMR) (Saghir, Wan, & Budiarto, AINTEC 2005) is a hybrid scheme for supporting QoS routing. It is an on-demand mesh protocol connects group members using QoS paths. QMR define forwarding nodes that provide at least one path from each source to each destination. CDMA-over-TDMA is used to estimate the available bandwidth. A distributed admission control is used to enable intermediate nodes to reject the routes that not satisfy QoS requirement. The forwarding nodes are updated when multiple sources sending to the multicast group simultaneously. This prevents congestion and performs load balancing in the network.

DESIGN OF THE PROPOSED ARCHITECTURE

Network Setup

The first step in our model is the network setup phase. This step describes the organization of the network into cells and how the nodes are arranged in that cell structure.

Area Partitioning

The area containing the Ad-Hoc network is partitioned into equal size cells, this partitioning must be known to all participating nodes. The cell shape are chosen to be hexagonal, this is because this shape can completely cover a two-dimensional region without overlap. Also, it enables communication with more neighbors than the other shapes because it is closely resemble the nearly circular coverage area of a transmitter.
The availability of small, inexpensive low power GPS receiver makes it possible to apply position-based in MANETs.
We denote the transmission range of a node as *R* and the side length of the hexagon cell as *L*. The relation between *R* and *L* is set as $L=\frac{R}{2}$ to guarantee that each pair of nodes in the same cell are always within the effective transmission range. So, each two nodes inside the cell can communicate with each other directly.
Each cell has a Cell Identity (Cell-ID), Cell Leader (CL) and Cell Leader Backup (CLB). The CL node is responsible for maintaining information about all the nodes in that cell including their positions and IDs. Also, it is responsible to maintain information about the CLs of the neighboring cells as shown in the figure below. The responsibility of CLB node is to keep a copy of the data stored at the CL in order not to be lost when the CL node is off or moving the cell.

Election OF CLs AND CLBs

An election algorithm is developed to elects the node that satisfies different metrics in order to keep the leader role to serve the cell as much as possible. These metrics include the node position with respect to the cell center, the residual energy, CPU computing power, the available memory and mobility speed.
Each of the above mentioned metrics is assigned an equal weight of 20%. By adding the weights of each metric a final score from 100% will be obtained for each node. So, each node performs the following calculations locally, and then broadcasts a final value that represents its probability to be a leader in the current cell.

Position of the node in the cell

Let we assume that the node position in the cell is (x_i,y_i). We can define the distance between node *i* and the hexagonal center (x_c,y_c) as:

$$D_i = \sqrt{(x_c - x_i)^2 + (y_c - y_i)^2}$$

When the node position is closer to the center it is opportunity to be a leader will increase. If we assumed that the maximum distance of a node from the center point of a hexagonal cell is D_{cmax} , then the weight of the position metric which ranges from 0 to 20 can be calculated as:

$$P_i = \frac{D_{cmax} - D_i}{D_{cmax}} * 20$$

Residual energy at each node

Let we assume that the residual energy of a node *i* is given as the remaining serving time of the battery and equal to Eng_i. As the node energy increase its opportunity to act as a leader increase. If we assume that the maximum service time of a battery is Eng_{max} . Then the weight of the residual energy metric which ranges from 0 to 20 can be calculated as:

$$E_i = \frac{Eng_i}{Eng_{max}} * 20$$

Computation power of the node

We assume that the computation power of a node *i* is given as a number of instructions per second and equal to CPU_i. The computation power of the node increases its chance to be a leader. If we assumed that the maximum computation power exists in the market is CPU_{max} , then the weight of this metric that ranges between 0 and 20 can be calculated as:

$$C_i = \frac{CPU_i}{CPU_{Max}} * 20$$

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Memory available at each node

Let we assume that the memory capacity for a node i is equal to Memi and the maximum memory capacity that can be exists in the market is Memmax. Then the weight of this metric can be calculated as:

$$M_i = \frac{MEM_i}{MEM_{max}} * 20$$

Mobility speed of each node

If we assume that the maximum mobility speed of a node in the network is equal to Mob_{max} and the node mobility is Mob_i. Since the chance of a node to be a leader decreases as its speed increases. Then the weight of this metric is calculated as:

$$S_i = \frac{Mob_{max} - Mob_i}{Mob_{max}} * 20$$

Each node *i* after computing P_i, E_i, C_i, M_i and S_i locally, it computes its probability to be a leader. This probability ranges from 0 to 1 and calculated as $(P_i + E_i + C_i + M_i + S_i)/100$. After that, all the nodes broadcast their probability to all the nodes inside their cell.

The node with the highest probability will be the *CL* and the node with the probability that comes immediately after it will be the *CLB*. After the election algorithm is executed inside each cell, the elected *CL* node has to broadcast the election result to all the nodes inside the cell. After a predefined time, all the cells finish the election process and elect a leader and backup nodes. Each *CL* node maintains information about the 6-neighboring cells to be used in route discovery and maintenance. The *CL* node should announce its leadership role by broadcasting a message to the nodes inside the cell and for the CL nodes of the 6-neighbor cells rather than flooding it to all the *CLs* in the network in order to reduce the number of control packets and reduces the overhead produced from maintaining information about the global network. Each node upon the reception of the message it replies to the *CL* by sending a message that contains its current location and the multicast groups it is interested to join. We assume that all the nodes are aware of the existing multicast groups.

Inside the cell, all the nodes need to store the required information about the *CL_ID*, *CL_Pos* and *CLB_ID*. While, each *CL* of every cell maintains the *ID* and the location information of all the nodes inside that cell, the election result information and the *Cell-ID* of the 6-neighbor cells. In the announcement process, the normal nodes (non-leader nodes) in each cell just forward the packet without storing any information about the neighbor *CLs*.

Location Service Algorithm

This algorithm enables the source to map the geographical positions of the destinations, this is done as follows:

The source node sends an invitation message to the *CL* node where the source is located to ask for nodes that are interested with this multicast group. This message needs only one hop unicast operation. When the *CL* node in the local cell receives this message, it checks its multicast table to check if there are nodes interested in joining this multicast group, then it reply by sending a reply packet directly to the source node. The search for additional destinations is continued by sending an invitation message to the *CL* of the 6-neighbor cells, and then it propagated cell by cell until it covers the entire network.

When the *CL* node receives reply packets from all the cells, it forwards the position and *IDs* of the destination nodes to the source node. The source node waits for a predefined time to aggregate the reply packets from the *CL* nodes in the network in order to determine the nodes that want to participate in the group.

QoS and Multicast Routing

In our model we provide an on-demand multicasting protocol to satisfy a certain bandwidth requirements from one source node to a group of destinations. Also, we will consider the delay as another QoS parameter. This is because bandwidth and delay are critical requirements for real time applications. Due to bandwidth constrains and dynamic topology of mobile ad hoc networks, provide QoS routing with multi-constrains is NP-complete problem (Wang & Crowcroft, 1996).

The proposed model will integrate bandwidth reservation into multicast routing protocol with the assumption that the bandwidth information is available from the underling well known IEEE 802.11 MAC layer.

Route Discovery

Multicasting in general refers to the communication with multiple participants. In our model, we consider the special case of point to multipoint communication, or source multicast. In source multicast the same packet is sent from the source node to a specified subset of nodes in the network (the multicast group) (Wang X. X., 2006).

In this model a QoS path which satisfies a given bandwidth and delay requirements has to be found from the source to each destination from the destination list. The bandwidth requirement is represented in the request as an amount in Mb/s which represents the available bandwidth on a link between two successive nodes. The delay is represented as the number of hops which is the upper limit of the delay value from the source node to any destination. The source node partitions the network into sub-groups and chose a coordinator for each group. A QoS path is discovered between the source and coordinators, and then a QoS is discovered between the each coordinator and the destinations of his group.

Route Setup

By the end of route discovery phase, different routes have been discovered between the source node and the coordinator of each sub-group and between the coordinator and the rest of the destinations. The request packets that reach the coordinator and the destinations comes from the paths that satisfy the delay bound. So, the coordinator needs to select a route that has the needed end-to-end bandwidth. If the first route arrived to the coordinator satisfies the required bandwidth at all the path nodes, then the coordinator select this route to be the optimal route, then it sends back this route to the source. Otherwise, the coordinator will search for a segment that is parallel to the link that does not satisfy the bandwidth in the previous route in order to satisfy the requested bandwidth. If a parallel segment is found, then it will take the required amount of the bandwidth and splits the data on that branch node into two parallel paths. This process is continued path by path until a best route is chosen.

When the route reply traverses back to the source and the coordinator, each node along the chosen paths reserves the amount of the bandwidth that is considered to be used in the route and relies the message to the node send to it in route discovery. During constructing the routes between the coordinator and its destinations, the source node start forwarding the data over the QoS route to coordinator. When the coordinator receives the data packets from the source node, it sends a copy of the data packet to each member of the sub-group.

CONCLUSION

A new QoS multicast routing protocol is presented to connect group members and provide QoS paths to the multicast group. The proposed protocol integrates bandwidth reservation into multicast routing protocol. Distributed multicast routing strategy is used to search for feasible paths and maintain the information state. The proposed protocol will be scalable for large area networks with large number of multicast members. Also, it will achieve high throughput and significant reduction in processing overhead.

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