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Algorithm for Mobile Ad Hoc Network

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***Abstract*— A mobile ad hoc network is comprised of mobile hosts that can communicate with each other using wireless links. It is also possible to have access to some host in a fixed infrastructure depending on the kind of the mobile ad hoc network. Mobile ad hoc networks can be realized by different networks such as body area network (BAN), vehicular ad hoc network (VANET), wireless sensor network (WSN). MANETs can be realised by different wireless communication technologies such as Bluetooth, IEEE 802.11 and Ultra wide band(UWB).**

Keywords— MANET

1. INTRODUCTION

In the fourth century B.C., the Greek writer wrote the play which provides the detailed description of how fire signals were supposedly used to communicate the fall of Troy to Athens over a distance more than 450 km. Fire was the main source of coded message. Fire signal mechanism is based on fire torches that could be used to relay different messages. At that time fire signal mechanism was very first concept for data communication engineering in mobile ad hoc networks. MANET is infrastructure less network in this a route between two hop consist of many hops through one or more nodes. An important problem in a mobile ad hoc network is finding and maintaining routes since host mobility can cause topology changes. Data communication in a MANET differs from that of wired networks in different aspects. The wireless communication medium does not have a foreseeable behaviour as in wired channel. On the contrary, the wireless communication medium has variable and unpredictable characteristics. The signal strength and propagation delay may vary with respect to time and environment where the mobile nodes are. Unlike a wired network, the wireless medium is a broadcast medium i.e.,all nodes in the transmission range of a transmitting device can receive a message. The bandwidth availability and computing resources (e.g. hardware and battery power) are restricted in mobile ad hoc networks. Algorithms and protocol need to save both bandwidth and energy and must take into account the low capacity and limited processing power of wireless devices. This calls for lightweight solutions in terms of computational, communication and storage resources. An important challenge in the design of algorithms for mobile ad hoc network is the fact that its topology is dynamic. Since the nodes are mobile, the network topology may change rapidly and unexpectedly, thereby affecting availability of routing paths. Several routing algorithm for MANETs have been proposed in this paper and they differ in the way new routes are found and existing ones are modified.

2. MANETS: An Algorithmic Viewpoint

2.1 Topology Formation

2.1.1 Neighbor Discovery: The performance of an ad hoc network depends on the interaction among communicating entities in a given neighbourhood. Thus, in general, before a node starts communicating, it must discover the set of nodes that are within its direct communicating range. Once this information gathered, the node keeps it in an internal data structures so it can be used in different networking activities such as routing. The behaviour of an ad hoc node depends on the behaviour of its neighbouring nodes because it must sense the medium before it starts transmitting packets to nodes in its interfering range, which can cause collisions at the other nodes. Node discovery can be achieved with periodic transmission of beacon packets (active discovery) or with indiscriminate snooping on the channel to detect the communication activity (passive discovery). PRADA [1] adjusts dynamically its communication range, called topology knowledge range, so it leads to faster convergence of its neighbouring nodes.

2.1.2 Packet Forwarding Algorithm: An important part of a routing protocol is the packet forwarding algorithm that chooses among neighbouring nodes the one that is going to be used to forward the data packet. The forwarding algorithm implements a forwarding goal that may be, for instance, the shortest average hop distance from source to destination. In this case, the set of potential nodes may include only those in direct communication range from the current node or also the set of possible nodes in the route to the destination. The forwarding goal may also include some Quality of Service parameters such as the amount of energy available at each node. The Partial Topology Knowledge Forwarding (PTKF) algorithm [1] chooses a node using localised shortest path weighted routing where routes are calculated based on the local topological view and consider the transmission power needed to transmit in that link. The Most Forward within Radius (MFR) forwarding algorithm [2] chooses the node that maximizes the distance from node S to the point p. In this case, as depicted in Figure it is node 1. On the other hand, the Nearest Forward Progress (NFP) forwarding algorithm [3] chooses the node that minimizes the distance from node S to point q. In this case node 2. The Greedy Routing Scheme (GRS) [4] uses the nodes geographical location to choose the one that is closest to the destination node D.In this case it is node 3. The compass selected routing (COMPASS) algorithm [5] chooses the node that minimizes the angle α but consider the nodes that are closer to node D. In this case it is node 4. The random process forwarding algorithms [6], as the name suggests. chooses a random node that is in direct communication range from S.

2.2 Topology Control: An inherit characteristic of an ad hoc network, which makes this problem much more difficult, is that its topology is dynamic. Topology algorithms select the communication range of a node, and they construct and maintain a network topology based on aspects such as node mobility, routing algorithm and energy conservation [7]. Broadly speaking, topology control algorithms for ad hoc networks can be classified in hierarchical or clustering organization, as well as in power-based control organization [7,8].Furthermore, these algorithms can be either centralized, distributed or localized.

2.2.1 Clustering Algorithms: The clustering process consists in defining a cluster head node and the associated communication backbone, typically using a heuristic. The goal s to avoid redundant topology information so the network can work more efficiently. Clustering algorithms are often modeled as graph problems such as the minimum connected dominating set (MCDS)[9].This problem asks ffor the minimum subsets of nodes V' in the original graph G=(V,E) such that V' form dominating set of Gand the resulting subgraph of the MCDS has the same number of connected components of G. It means that if G is a connected graph, so is the resulting subgraph. MCDS is an NP-complete problem [10], and thus we must look for approximate solutions [7].In the case of clustering algorithm, nodes in the dominating set represent the cluster heads and the other nodes are their neighbours.The cluster heads can be elected using either deterministic or non deterministic approaches. A deterministic solution is similar to a distributed synchronous algorithm in the sense that it runs in round. In this case there is just one round, and after finishing it the cluster heads are chosen. Suppose we have a node and its neighboring nodes-i.e..its on hop neighbourhood. The lowest ID solution selects the node with the lowest identifier among them to create the minimal dominating set (MDS) [10].The max degree solution selects the node with the highest degree among them [11,12].The MOBIC solution examines the variations of RSSI(received signal strength indicator) signal among them to select the cluster head [13].

A nondeterministic solution run multiple incremental steps to avoid variations in the election process and to minimize conflicts among cluster heads in their one-hop neighbourhood. Examples of this approach CEDAR [11], SPAN [14] and solutions based on a spanning tree algorithm [9].

2.3 Power Based control Algorithms: A mobile node in MANET must rely on a energy sources (typically battery) to execute all its tasks. Batteries need to be recharged to provide continuous energy supply for a node. To extend the lifetime of the node in an ad hoc network, we need algorithms to determine and adaptively adjust the transmission power of each node so as to meet a given minimization goal and at the same time maintain a an given connectivity constraints are a simplex communication or a full duplex communication (bi-connected). In [2] Hain et al propose a topology control algorithm that dynamically adjusts its transmission pwer such that the maximum power used is minimised while keeping the network bi-connected.

3. Routing : The main goal of an ad hoc network routing algorithm is to correctly and efficiently establish a route between a pair of nodes in the network so a message can be delivered according to the expected QoS parameters [15, 16]. The establishment of a route should be done with minimum overhead and bandwidth consumption. In the current wired networks, there are different link state [17] and distance vector [18] routing protocols, which were not designed to cope with constant topology changes of mobile ad hoc environments. Link-state protocols update their global state by broadcasting their local state to every other node, whereas distance-vector protocols exchange their local state to adjacent nodes only. Their direct application to a MANET may lead to undesired problems such as routing loops and excessive traffic due to the exchange of control messages during route establishment. An ad hoc network has a dynamic nature that leads to constant changes in its network topology. As a consequence, the routing problem becomes more complex and challengeable, and it probably is the most addressed and studied problem in ad hoc networks. This reflects the large number of different routing algorithms for MANETs proposed in the literature [15]. Ideally, a routing algorithm for an ad hoc network should not only have the general characteristics of any routing protocol but also consider the specific characteristics of a mobile environment—in particular, bandwidth and energy limitations and mobility. Some of the characteristics are: fast route convergence; scalability; QoS support; power, bandwidth, and computing efficient with minimum overhead; reliability; and security. Furthermore, the behavior of an ad hoc routing protocol can be further complicated by the MAC protocol. This is the case of a data link protocol that uses a CSMA (Carrier Sense Multiple Access) mechanism that presents some problems such as hidden stations and exposed stations. In general, routing algorithms for ad hoc networks may be divided into two broad classes: proactive protocols and reactive on-demand protocols, as discussed in the following.

3.1 Proactive Protocols. Proactive routing algorithms aim to keep consistent and up to-date routing information between every pair of nodes in the network by proactively propagating route updates at fixed time intervals. Usually, each node maintains this information in tables; thus, protocols of this class are also called table-driven algorithms. Examples of proactive protocols are Destination-Sequenced Distance Vector (DSDV) [19], Optimized Link-State Routing (OLSR) [20], and Topology-Based Reverse Path Forwarding (TBRPF) Protocols [21]. The DSDV protocol is a distance vector protocol that incorporates extensions to make its operation suitable for MANETs. Every node maintains a routing table with one route entry for each destination in which the shortest path route (based on the number of hops) is recorded. To avoid routing loops, a destination sequence number is used. A node increments its sequence number whenever a change occurs in its neighborhood. When given a choice between alternative routes for the same destination, a node always selects the route with the greatest destination sequence number. This ensures utilization of the route with the most recent information. The OLSR protocol is a variation version of the traditional link state protocol. An important aspect of OLSR is the introduction of multipoint relays (MPRs) to reduce the flooding of messages carrying the complete link-state information of the node and the size of link-state updates. Upon receiving an update message, the node determines the routes (sequence of hops) to its known nodes. Each node selects its MPRs from the set of its neighbors such that the set covers those nodes that are distant two hops away. The idea is that whenever a node broadcasts a message, only those nodes present in its MPR set are responsible for broadcasting the message. The Topology-Based Reverse Path Forwarding is also a variation of the link-state protocol. Each node has a partial view of the network topology, but is sufficient to compute a shortest path source spanning tree rooted at the node. When a node receives source trees maintained at neighboring nodes, it can update its own shortest path tree. TBRPF exploits the fact that shortest path trees reported by neighbor nodes tend to have a large overlap. In this way, a node can still compute its shortest path tree even if it receives partial trees from its neighbors. In this way, each node reports part of its source tree, called reported tree (RT), to all of its neighbors to reduce the size of topology update messages, which can be either full or differential. Full updates are used to send to new neighbors the entire RT to ensure that the topology information is correctly propagated. Differential updates contain only changes to RT that have occurred since the last periodic update. To reduce further the number of control messages, topology updates can be combined with Hello messages so that fewer control packets are transmitted.

3.2 Reactive Protocols. Reactive on-demand routing algorithms establish a route to a given destination only when a node requests it by initiating a route discovery process. Once a route has been established, the node keeps it until the destination is no longer accessible, or the route expires. Examples of reactive protocols are Dynamic Source Routing (DSR) [22] and Ad Hoc On-Demand Distance Vector (AODV) [23]. The DSR protocol determines the complete route to the destination node, expressed as a list of nodes of the routing path, and embeds it in the data packet. Once a node receives a packet it simply forwards it to the next node in the path. DSR keeps a cache structure (table) to store the source routes learned by the node. The discovery process is only initiated by a source node whenever it does not have a valid route to a given destination node in its route cache. Entries in the route cache are continually updated as new routes are learned. Whenever a node wants to know a route to a destination, it broadcasts a route request (RREQ) message to its neighbors. A neighboring node receives this message, updates its own table, appends its identification to the message and forwards it, accumulating the traversed path in the RREQ message. A destination node responds to the source node with a route reply (RREP) message, containing the accumulated source route present in the RREQ. Nodes in DSR maintain multiple routes to a destination in the cache, which is helpful in case of a link failure. The AODV protocol keeps a route table to store the next-hop routing information for destination nodes. Each routing table can be used for a period of time. If a route is not requested within that period, it expires and a new route needs to be found when needed. Each time a route is used, its lifetime is updated. When a source node has a packet to be sent to a given destination, it looks for a route in its route table. In case there is one, it uses it to transmit the packet. Otherwise, it initiates a route discovery procedure to find a route by broadcasting a route request (RREQ) message to its neighbors. Upon receiving a RREQ message, a node performs the following actions: checks for duplicate messages and discards the duplicate ones, creates a reverse route to the source node (the node from which it received the RREQ is the next hop to the source node), and checks whether it has an unexpired and more recent route to the destination (compared to the one at the source node). In case those two conditions hold, the node replies to the source node with a RREP message containing the last known route to the destination. Otherwise, it retransmits the RREQ message.

3.3 Multicasting and Broadcasting

An important aspect in the design of a routing protocol is the type of communication mode allowed between peer entities. Routing protocols for a MANET can be unicast, geocast, multicast, or broadcast. Unicast is the delivery of messages to a single destination. Geocast is the delivery of messages to a group of destinations identified by their geographical locations. Multicast is the delivery of messages to a group of destinations in such a way that it creates copies only when the links to the destinations split. Finally, broadcast is the delivery of a message to all nodes in the network. Notice that, broadly speaking, there are two types of physical transmission technology that are largely used: broadcast links and point-to-point links. In a network with a single broadcast channel, all communicating elements share it during their transmissions. In a network that employs a wireless medium, which is the case of a mobile ad hoc network, broadcast is a basic operation mode whereby a message is received by all the source node's neighbors. In a MANET, the four communication modes that can be implemented by a routing protocol are realized by a wireless broadcast channel. A multicast routing protocol is employed when a mobile node wants to send the same message or stream of data to a group of nodes that share a common interest. If there is a geographical area (location) associated with the nodes that will receive the message or stream of data, we use a geocast protocol. Thus, a geocast protocol is a special type of multicast protocol, such that nodes need their updated location information along the time to delivery a message. In a multicast communication, nodes may join or leave a multicast group as desired, whereas in a geocast communication, nodes can only join or leave the group by entering or leaving the defined geographical region. In a MANET, a multicast communication can possibly bring benefits to the nodes such as bandwidth and energy savings. However, the maintenance of a multicast route, often based on a routing tree or mesh, is a difficult problem for mobile ad hoc multicasting routing protocols due to the dynamic nature of a MANET. In particular, the cost of keeping a routing tree connected for the purpose of multicast communication may be prohibited. In a multicast mesh, a message can be accepted from any router node, as opposed to a tree that only accepts packets routed by tree nodes. Thus, a multicast mesh is more suitable for a MANET because it supports a higher connectivity than a tree. The method used to build the routing infrastructure (tree or mesh) in a mobile ad hoc network distinguishes the different multicasting routing protocols. Some of the route-tree-based multicast protocols for MANETs are AMRoute (Adhoc Multicast Routing Protocol) [25], DDM (Differential Destination Multicast) [26], and MAODV (Multicast Ad-hoc On-Demand Distance Vector routing) [27]. AMRoute uses an overlay approach based on bidirectional unicast tunnels to connect group members into the mesh. DDM is a stateless multicast protocol in the sense that no protocol state is maintained at any node except for the source node. Intermediate nodes cache the forwarding list present in the packet header. When a route change occurs, an upstream node only needs to pass to its downstream neighbors the difference to the forwarding nodes since the last packet. MAODV is the multicast version of the AODV protocol [23]. It uses a multicast route table (MRT) to support multicast routing. A node adds new entries into the MRT after it is included in the route for a multicast group. MAODV uses a multicast group leader to create an on-demand core-based tree structure. Different from the previous route-tree-based multicast algorithms, LGT (Location- Guided Tree Construction Algorithm for Small Group Multicast) [28] uses the location information of the group members to build the multicast tree without the knowledge of the network topology. Two heuristics are proposed to build the multicast tree using location information: the Location-Guided *k*-rray tree (LGK) and the Location-Guided Steiner tree (LGS). Some of the mesh-based multicast routing protocols for MANETs are CAMP (Core-Assisted Mesh Protocol) [29], FGMP (Forwarding Group Multicast Protocol) [30], and ODMRP (On-Demand Multicast Routing Protocol) [31]. CAMP generalizes the notion of core-based trees introduced for Internet multicasting. It uses core nodes for limiting the control traffic needed for the creation of a multicast mesh avoiding flooding. On the other hand, both FGMP and ODMRP use flooding to build the mesh. In the FGMP protocol, the receiver initiates the flooding process, whereas in the ODMRP the senders initiates it.

4 Conclusion

A mobile ad hoc network is one of the most innovative and challenging areas of wireless networking and tends to become increasingly present in our daily life [69]. An ad hoc network is clearly a key step in the next-generation evolution of wireless data communication when we consider the different enabling networks and technologies. An ad hoc network inherits the traditional problems of wireless and mobile communications, including bandwidth optimization, power control, and transmission quality enhancement. In addition, MANETs pose new research problems due to the multihop nature and the lack of a fixed infrastructure. These problems are related to algorithms for different aspects such as network configuration, topology discovery and maintenance, and routing. The problems in ad hoc networks face a very important and fundamental question that is the dynamic network topology. This has a serious impact on the design of algorithms for ad hoc networks since they are expected to work properly under different and unpredictable scenarios. Similar to other distributed problems, a designer can start reasoning about an algorithm for this type of network, initially considering a static version of the problem. In a static version, it is reasonable to assume that there is a global topological information of the network, the computation happens just once, and the proposed solution is a centralized algorithm. On the other hand, when we consider a dynamic solution for the same problem, it is reasonable to assume that there is only local information, the computation happens continuously along the time the network is operational, and the proposed solution is a distributed algorithm. Clearly, the dynamic solution is more useful for ad hoc networks. However, a detailed study of the static solution tends to provide valuable insight for the design of a distributed version, is useful to determine the upper bound on the performance of the algorithm, can even be applied to stationary ad hoc networks such as commercial mesh-based broadband wireless solutions, and is simple to understand.

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