Classification of Routing Protocols in Wireless Ad hoc Networks

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Abstract— **Mobile Ad-Hoc Network (MANET) is a wireless network without infrastructure. Self configurability and easy deployment feature of the MANET resulted in numerous applications in this modern era. In order to facilitate communication within the network, a routing protocol is used to discover routes between nodes. Routing protocols used in wired network cannot be used for mobile adhoc networks because of node mobility. Efficient routing protocols will make MANETs reliable .Routing is a core issue in networks for delivering data from one node to another in ad hoc network. This Paper deals with number of ways of categorization of protocol and also present some specified protocols according to that classification.**

The emphasis of this paper is not to present protocol in detail but present main feature of wide variety of different protocols and discuss their suitability.

Keywords—**Routing protocols, Mobile Ad hoc network, routing schemes Classification of protocols, Comparison of protocols.**

I. INTRODUCTION

Ad hoc network is a multi-hop wireless network, which consists of number of mobile nodes. These nodes generate traffic to be forwarded to some other nodes or a group of nodes. Due to a dynamic nature of ad hoc networks, traditional fixed network routing protocols are not viable. Based on that reason several proposals for routing protocols has been presented. Ad hoc radio networks have various implementation areas. Some areas to be mentioned are military, emergency, conferencing and sensor applications. Each of these application areas has their specific requirements for routing protocols. For example in military applications low probability of detection and interception is a key factor such is routing efficiency during fading and disturbed radio channel conditions. At sensor applications low or minimum energy consumption is a precondition for an autonomous operation. In conference applications a guaranteed quality of service for multimedia services is a needed feature. All application areas have some features and requirements for protocols in common. The routing protocol overhead traffic is not allowed to drive the network to congestion nor a local change in link is not allowed to cause a massive control traffic storm throughout the network.

Ad-hoc networks are wireless networks where nodes communicate with each other using multi-hop links. There is no stationary infrastructure or base station for communication. Each node itself acts as a router for forwarding and receiving packets to/from other nodes. MANET [1], [2], [3], is an autonomous system which consists of many mobile hosts that are connected by multi-hop wireless links [4]. The original idea of MANET started out in the early1970s. Some examples of the possible uses of ad hoc networking include students using laptop computers to participate in an interactive lecture, business associates sharing information during a meeting, soldiers relaying information for situational awareness on the battlefield and emergency disaster relief personnel coordinating efforts after a hurricane or earthquake. The use of wired networks routing protocols in a dynamic network is not good because they place a heavy computational burden on mobile computers and they present convergence characteristics that don't suit well enough the needs of dynamic networks[15]. For instance, due to the dynamic nature of environment in ad hoc networks any routing scheme must consider that the network topology can change at the time of packet is being routed [15], and that the quality of the wireless links between nodes is highly variable. In wireless link failure is more common then as compare to wired network. Therefore, routes in MANET must be calculated much more frequently or time to time in order to keep up the same performance as of wired networks. Routing schemes in MANET are classified in four major groups, namely, Proactive routing, Reactive routing, and Hybrid routing ,Flooding. Flooding is used in MANET [1],[2],[3], to propagate control messages. Flooding is a distributed process in which a node transmits a message to all its neighbours and these transmit the message consecutively to their neighbours and so on until the message has been disseminated to the entire network. Although flooding is the simplest way to establish communication in MANET, it is not a efficient method and it generates big overhead on the network due to a big redundancy, wastage of bandwidth and increase in collisions in the network In proactive routing protocols maintain routes to all destinations, regardless of whether or not these routes are needed, valid routes are maintained to every node all the time.

II. A TAXONOMY FOR ROUTING PROTOCOLS

Because of multiple and diverse ad hoc protocols there is an obvious need for a general taxonomy to classify protocols considered. Traditional classification is to divide protocols to table-driven and to source-initiated on-demand driven protocols [1]. Table-driven routing protocols try to maintain consistent, up-to-date routing information from each node to every other node. Network nodes maintain one or many tables for routing information. Nodes respond to network topology changes by propagating route updates throughout the network to maintain a consistent network view.

Source-initiated on-demand protocols create routes only when these routes are needed. The need is initiated by the source, as the name suggests. When a node requires a route

to a destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutations have been examined. After that there is a route maintenance procedure to keep up the valid routes and to remove the invalid routes. This classification has though some drawbacks because of its rough granularity. To that classification it is possible to make some modifications (e.g. in [2]). These modifications can make some assumption about if the routing is flat or hierarchical and if any means to obtain global positioning information is in use. One very attractive taxonomy has been introduced by Feeney [3]. This taxonomy is based on to divide protocols according to following criteria, reflecting fundamental design and implementation choices:

Communication model: What is the wireless communication model? Multi or single channel?

Structure: Are all nodes treated uniformly? How are distinguished nodes selected? Is the addressing hierarchical or flat?

State Information: Is network-scale topology information obtained at each node?

Scheduling: Is route information continually maintained for each destination?

This model does not take an account for if a protocol is unicast, multicast, geocast or broadcast. Also the taxonomy doesn't deal with the question how the link or node related costs are measured. These properties are however worth to be considered in classification and evaluating applicability of protocols. Based on that lack the taxonomy has been slightly modified by adding such features as **type of cast** and **cost function**. Type of cast feature is an upper level classification and so the protocols to be classified must firstly divide by type of cast and after that the more accurate taxonomy can be applied. The above mentioned taxonomy is applied to unicast protocols, while in the context of multicast and geocast protocols a specified taxonomy has been introduced. The overall taxonomy and specially the unicast protocol classification can be seen in figure 1.

The cost function is a classification to be concatenated after presented taxonomy. It is like a remark to be noticed when considering the applicability of the protocol to be chosen.

2.1 Communication Model

Protocols can be divided according to communications model to protocols that are designed for **multi-channel** or **single-channel** communications. Multi-channel protocols are routing protocols generally used in TDMA or CDMA-based networks. They combine channel assignment and routing functionality. That kind of protocol is e.g. Cluster head Gateway Switched Routing (CGSR) [4]. Single - channel protocols presume one shared media to be used. They are generally CSMA/CA-oriented, but they have a wide diversity in which extend they rely on specific link-layer behaviors.

2.2 Structure

Structure of a network can be classified according to node uniformity. Some protocols treat all the nodes uniformly, other make distinctions between different nodes. In **uniform protocols** there is no hierarchy in network, all nodes send and respond to routing control messages at the same manner. In **non-uniform protocols** there is an effort to reduce the control traffic burden by separating nodes in dealing with routing information. Non-uniform protocols fall into two categories: protocols in which each node focuses routing activity on a subset of its neighbors and protocols in which the network is topologically partitioned. These two different methods for non uniformity are called **neighbor selection** and **partitioning** respectively. With neighbor selection mechanism, every node has its own criteria to classify network nodes to near or to remote nodes. In partitioning protocols that differentiation is to use hierarchical node separation. Hierarchical protocols have some upper-level and lower level nodes and certain information difference between them.

2.3 State Information

Protocols may be described in terms of the state information obtained at each node and / or exchanged among nodes. **Topology-based protocols** use the principle that every node in a network maintains large scale topology information. This principle is just the same as link-state protocols use. **Destination-based** protocols do not maintain large-scale topology information. They only may maintain topology information needed to know the nearest neighbors. The best known such protocols are distance-vector protocols, which maintain a distance and a vector to a destination (hop count or other metric and next hop).

2.4 Scheduling

The way to obtain route information can be a continuous or a regular procedure or it can be trigged only by on demand. On that basis the protocols can be classified to proactive and on-demand protocols. **Proactive protocols**, which are also know as table-driven protocols, maintain all the time routing information for all known destinations at every source. In these protocols nodes exchange route information periodically and / or in response to topology change.

In on demand i.e. in **reactive protocols** the route is only calculated on demand basis. That means that there is no unnecessary routing information maintained. The route calculation process is divided to a route discovery and a route ma intenance phase. The route discovery process is initiated when a source needs a route to a destination. The route maintenance process deletes failed routes and re-initiates route discovery in the case of topology change.

2.5 Type of Cast

Protocols can be assumed to operate at unicast, multicast, geocast or broadcast situations. In **unicast protocols** one source transmits messages or data packets to one destination. That is the most normal operation in any network. The unicast protocols are also the most common in ad hoc environment to be developed and they are the basis on which it is a possibility to construct other type of protocols. Unicast protocols have thought some lacks when there is a need to send same message or stream of data to multiple destinations. So there is an evitable need for multicast protocols.

Multicast routing protocols try to construct a desirable routing tree or a mesh from one source to several destinations. These protocols have also to keep up with information of joins and leave ups to a multicast group. The purpose of **geocast protocols** is to deliver data packets for a

group of nodes which are situated on at specified geographical area. That kind of protocol can also help to alleviate the routing procedure by providing location information for route acquisition. Broadcast is a basic mode of operation in wireless medium. Broadcast utility is implemented in protocols as a supported feature. Protocol only to implement broadcast function is not a sensible solution. That is the reason not to classify protocols to broadcast protocols. But it is worth to mention if a protocol is not supporting that method.

2.6 Cost Function

When making routing decisions in ad hoc environments, it is normally not enough to take only considerations to hop count. In ad hoc networks there is a wide variety of issues to consider such as link capacity, which can vary in large scale, latency, link utilization percentage and terminal energy issues to mention a few most relevant. That is why there is a need to adapt cost functions to route calculations.

Rough classification of protocols according to cost function can be based on **hop count** approach (no special cost function applied) and to **bandwidth** or **energy** based cost functions. Also quite a different approach to routing metrics is used by Associability Based Routing (ABR) protocol, which uses **degree of association stability** for a metric to decide for a route. That means that presumably more permanent routes are preferred. [5]

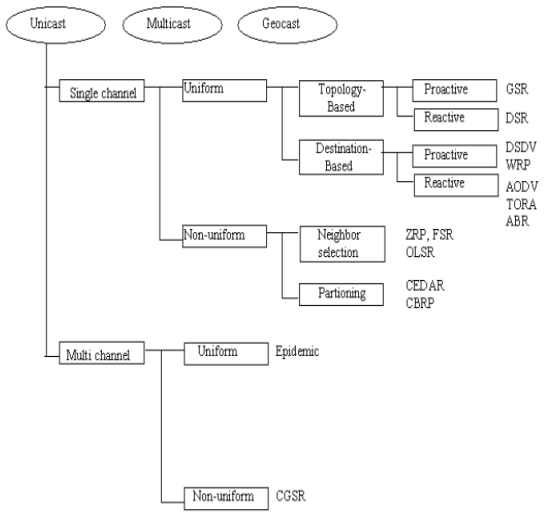

Figure 1: Taxonomy of Protocols. Classification of unicast protocols shown.

III. On-Demand Routing Protocols

In contrast to proactive approach, Protocols that fall under this category do not maintain the network topology information. They obtain the necessary path when it is required, by using a connection establishment process. in reactive or on demand protocols, a node initiates a route discovery throughout the network, only when it wants to send packets to its destination. For this purpose, a node initiates a route discovery process through the network. Hence these protocols do not exchange routing information periodically. This process is completed once a route is determined or all possible permutations have been examined. Once a route has been established, it is maintained by a route maintenance process until either the destination becomes inaccessible along every path from the source or until the route is no longer desired. In reactive schemes, nodes maintain the routes to active destinations. A route search is needed for every unknown destination. Therefore, theoretically the communication overhead is reduced at expense of delay due to route research. Some reactive protocols are Cluster Based Routing Protocol (CBRP), Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), Associatively-Based Routing (ABR), Signal Stability Routing (SSR) and Location Aided Routing (LAR).

IV. Hybrid Routing Protocols

Protocols belonging to this category combine the best features of the above two categories. Nodes within a certain distance from the node concerned, or within a particular geographical region, are said to be within the routing zone of the given node. For routing within this zone, a table-driven approach is used. For nodes that are located beyond this zone, an on-demand approach is used .Hybrid Routing, commonly referred to as balanced-hybrid routing, is a combination of distance vector routing, which works by sharing its knowledge of the entire network with its neighbors and link-state routing which works by having the routers tell every router on the network about its closest neighbors. Hybrid Routing is a third classification of routing algorithm. Hybrid routing protocols use distance vectors for more accurate metrics to determine the best paths to destination networks, and report routing information only when there is a change in the topology of the network. Hybrid routing allows for rapid convergence but requires less processing power and memory as compared to link-state routing. An example of a hybrid routing protocol is the Enhanced Interior Gateway Routing Protocol (EIGRP), developed by Cisco, ZRP protocol etc.

V. Existing Routing Protocols

A communications protocol is a formal description of digital message formats and the rules for exchanging those messages in or between computing systems and in telecommunications. Protocols may include signaling, authentication and error detection and correction capabilities. A protocol describes the syntax, semantics, and synchronization of communication and may be implemented in hardware or software, or both. The protocols can be arranged on functionality in groups, for instance there is a group of transport protocols. The nature of the communication, the actual data exchanged and any state-dependent behaviors are defined by the specification. This approach is often taken for protocols in use by telecommunications. There are a lot of popularly used routing protocols. Some of them are explained below: -

5.1 AODV: Adhoc On–Demand Distance Vector

AODV [9],[12], is a distance vector routing algorithm which discovers route whenever it is needed via a route discovery process. It adopts a routing algorithm based on one entry per destination i.e., it records the address of the node which forwards the route request message. AODV

possesses a significant feature that once the algorithm computes and establishes the route between source and destination, it does not require any overhead information with the data packets during routing. Moreover the route discovery process is initiated only when there is a free/available route to the destination. Route maintenance is also carried out to remove stale/unused routes.

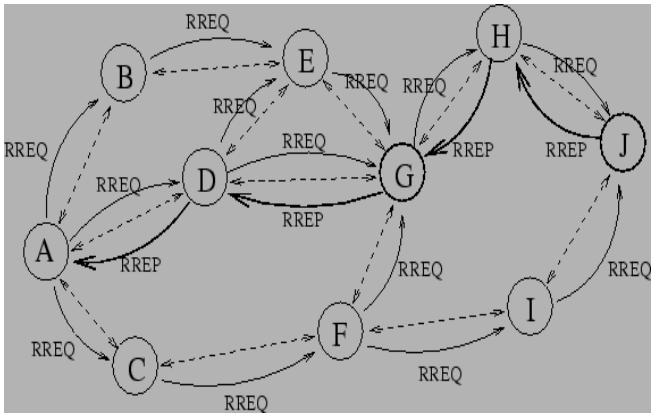

Fig. 2 AODV messages

The algorithm has the ability to provide services to unicast, multicast and broadcast communication. AODV routing algorithm has two phases i.e. Route Discovery and Route Maintenance [9],[12]. The AODV routing protocol is a reactive routing protocol; therefore, routes are determined only when needed.

VI. NEIGHBOR SELECTION PROTOCOLS

Optimized Link State Routing (OLRS) [8] is a topology based, neighbor selection protocol, in which each node only maintains a subset of network topology information. OLRS is a proactive protocol, because it exchanges the topology information with other nodes regularly to maintain information required for routing. OLRS reduces the cost of distributing network-scale link-state information by two ways. First, it uses multipoint relays (MRP) [9] to reduce redundant rebroadcasting during flooding operation. That is the key concept of the protocol. MRPs are selected nodes, which forward broadcast messages during the flooding process. In figures 3 (a) and 3 (b) there is an illustrative example what is the cost difference between broadcast by flooding and by multipoint relays.

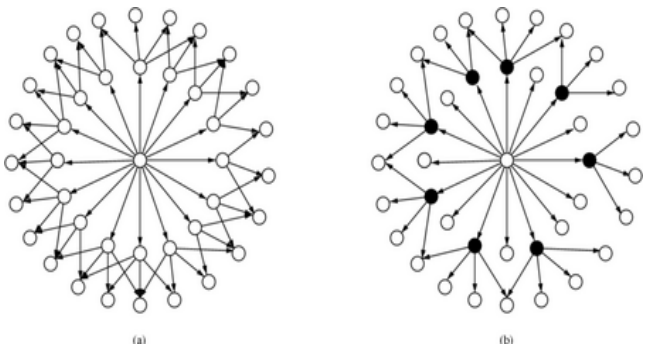

Figure 3: Diffusion of broadcast message using pure flooding (a) and multipoint relays (b)

Secondly each node only broadcast the state of nodes in its own multi-point relay set. That is a method to reduce the contents of the control messages. A node's multipoint relay set is the minimal subset of its one-hop neighbors, which must rebroadcast a message so that it is received by all of its two-hop neighbors. When a node sends a broadcast message, all of its neighbors receive and process the data. However, only those neighbors, which belongs to the source node's MPR set and have not previously received the message re-broadcast it. This reduces the number of broadcast messages needed to flood a message through the network. Since each node selects its MPR set independently, it must know the topology of its two-hop neighborhood, but additional inter-nodal coordination is not required. In the OLSR protocol, each node uses this flooding technique to distribute the link-state of its own MPR set. This is done periodically. The update period is in its minimum when there is detected a change and when the network is in its stabile state there is a updates only between refresh intervals. Each node uses the attained topology information to construct its routing tables. For the neighbor sensing purposes the OLSR uses HELLO-messages, because each node should detect the neighbor interfaces with which it has a direct and symmetric link. OLSR supposes bi-directional links and so the connectivity must be checked in both directions. HELLO-messages are broadcast to all one-hop neighbors, but are not relayed to further nodes. OLSR is well suited to large and dense mobile networks, as the optimization achieved using the MRPs works well in this context. The larger and more dense the network, the more optimization can be achieved. OLSR is well suited for networks, where traffic is random and sporadic between several nodes rather than being almost exclusively between a small specified set of nodes. [8]

3.3.2 FSR

Fisheye Source Routing (FSR) [10], [11] is based on a method to divide each node's neighborhood to blurred zones so that the information details and accuracy is better for nodes to be near. The name's basis is on the phenomenon of fish eye's ability to see objects the better the nearer they are. In FSR zones are classified according to the distance, measured by hops, from the node. In figure 4 there can be seen three differed zones.

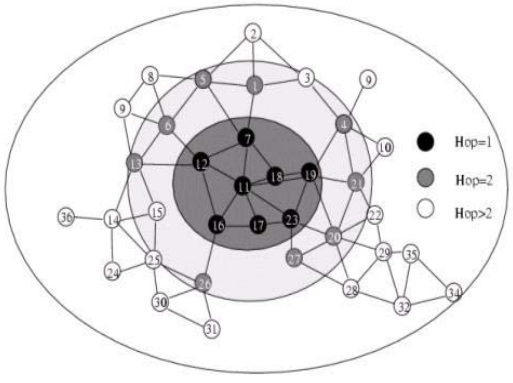

Figure 4: Scope of fisheye

VII. MULTICHANNEL PROTOCOLS

The main distinct feature for multichannel protocols is the ability to support different communications channels. Some nodes may have access to more than one physical medium or a node may be allowed to change the channel during routing operation. Multichannel protocols may also be divided at the same way as single channel protocols to different subclasses. They can be treated as uniform or non-uniform as is the case with the two protocols presented in here. The two protocols appearing here is CGSR (Clusterhead Gateway Switch Routing) protocol and quite an exceptional protocol called Epidemic. CGSR is a non-uniform hierarchical protocol, which is based to forming clusters among nodes and selecting a cluster head to control routing to outside the cluster area. Epidemic is a uniform protocol where routing is based to "infect" a node with a message and spread the message over nodes by that way.

7.1 CGSR

Clusterhead Gateway Switch Routing protocol [4] is a multichannel operation capable protocol. It enables code separation among clusters. The clusters are formed by cluster head election procedure, which is quite intensive process. On that reason the protocol uses so called Least Cluster Change (LCC) algorithm for that election. By using LCC can cluster heads only changed when two cluster heads come into contact with each other or when a node moves out of contact of all other cluster heads. CGSR is not an autonomous protocol. It uses DSDV as the underlying routing scheme. The DSDV approach is modified to use a hierarchical cluster head-to-gateway routing

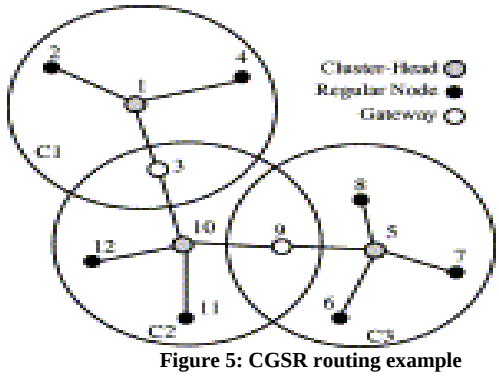

Figure 5: CGSR routing example

A packet sent by a node is first routed to its cluster head, and then the packet is routed from the cluster head to a gateway to another cluster head, until the destination node's cluster head is reached. That destination cluster head then transmits the packet to the destination node.

In figure 5 there is a example how the protocols manages to transmit a packet from node A to node C in CMDA network:

1. Node A (cluster head of C1) must get the permission to transmit (receives a token) in cluster C1.
2. Node B (gateway) must select the same code as node A to receive the packet from node A.
3. Node B must select the same code as node C (cluster head of C2) and get the permission to transmit in cluster C2 (receives a token from node C).

VIII. INTERZONE ROUTING PROTOCOL (IERP)

The Interzone Routing Protocol (IERP) is responsible for reactively discovering routes to the destination beyond a node's routing zone. This is used if the destination is not found within the routing zone. Fig.6

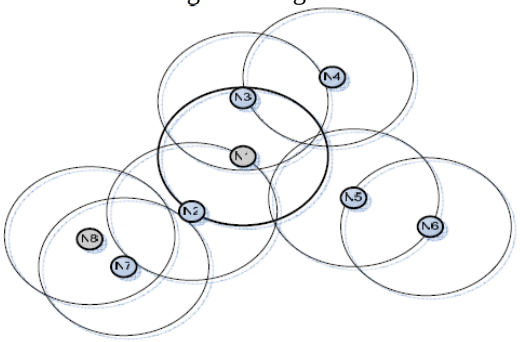

Fig. 6 An example of IERP operation

Bordercast Resolution Protocol (BRP)

The Bordercast Resolution Protocol, or BRP, is used in the ZRP to direct the route requests initiated by the global reactive IERP to the peripheral nodes, thus removing redundant queries and maximizing efficiency. Unlike IARP and IERP, it is not so much a routing protocol, as it is packet delivery service.

Advantage

Less control overhead as in a proactive protocol or an on demand protocol.

Disadvantage

Short latency for finding new routes.

IX. CONCLUSION

As it can be seen, there is vast number of different kinds of protocols. Only minority of the presented protocols will attain a technical or commercial success, one would forecast. Each of these protocols has some common goals. Every protocol has the ability of distributed routing calculations and every protocol try to manage the consequences caused by mobility of nodes. But the means are such different as they can be. The presented taxonomy of routing protocols is a meaningful attempt to clarify the vast field of ad hoc routing protocols. It is so because it tries to reveal the main design and implementation principles behind protocols. The taxonomy is a little bit complicated and it is not always an easy task to classify a protocol according to that taxonomy, but the meaning of classifying is try to get some rough basis for protocol's performance evaluation. It should be assumed that same kinds of protocols behave quite the same way in simulations.

When comparing the simulation result of presented protocols, there is a little difficult situation to reach a common understanding about the results. This is because of every simulation has been conducted according to different premises. One question arises if there should be a common framework for tests and simulations. That definition could be a part of e.g. RFC 2501, which concentrates to routing performance issues and evaluation of protocols. When choosing a protocol to a specified network one should consider the following issues:

- What is the size of the network. If the network could be considered or forecasted to be large, the chosen protocol should support scaling issues.

- What is the degree of mobility; how often links are assumed to cut off. Some protocols (usually reactive) have better performance over some other protocols (usually proactive) when mobility is high

- What are the requirements of user applications for the underlying network. Real-time applications require quite different services compared to non-time critical message delivery.

When the network structure and the node behaviors are understood, the right or at least near optimal protocol could be chosen. It is quite inevitable that inside the same network many different protocols should be implemented to cover all the networks states. Some kind of mixture of mutually compatible protocols could be needed. The other way to reach the goal is that protocols will merge and form a protocol, which has all the wished properties, but none of the weak ones. This can be a way to make a giant protocol to be good at theory, but in practice not a viable solution.

To fulfill all different demands some kind layer-based approach would be a considerable solution. One layer of the protocol stack could perform the task of managing scalability, as is the case with FSR, the other layers could handle the needs for power consciousness, multi or geocast operations and unicast respectively.

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