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Nomenclature of Multipath Routing Protocols in Mobile Ad Hoc Networks

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***Abstract*—** Mobile Ad-hoc Networks (MANETs) have dynamic and unpredictable environment. In MANETs nodes are movable and there is no centralized management. Hence, routing is an important factor in MANETs which works well in small networks as well as in the network which expanded dynamically. MANETs have several challenges such as link connectivity, congestion, routing, QoS, Power (Energy) consumption, interference etc. and routing in MANETs is a main factor considered among all these issues. In MANETs There are two variations in routing – unipath and multipath routing. Multipath routing scheme is superior to traditional unipath routing scheme. All routing protocols in MANETs are by virtue unipath routing protocols. Standard unipath routing protocols in ad-hoc networks, such as Ad-hoc on demand Distance Vector (AODV) and Dynamic Source Routing (DSR) are mainly intended to discover a single route between source and destination. Unipath routing protocols needs modification, optimization and alteration to formulate multipath routing protocol. In this paper, multipath routing protocols are surveyed and it further thoroughly investigates performance of MANETs.

***Index Terms*—**mobile ad-hoc networks, unipath routing, multipath routing, ad hoc on demand distance vector, dynamic source routing, Quality of Service

I. INTRODUCTION

A. Mobile Ad-hoc Networks (MANETs)

Mobile Ad hoc Network is an autonomous system of mobile nodes connected by wireless links. There is no static infrastructure such as base stations. All communication messages between them must pass through one or more intermediate hosts, if two hosts are not within radio range, all that acts as routers. These hosts move around randomly, thus change the network topology dynamically. Such networks are very useful in military and other tactical applications such as emergency rescue or exploration missions, where fixed network infrastructure is not available.

MANET [1] is self-configuring, self-organizing and self-maintaining dynamic network. Designing an efficient routing protocol for MANETs is an arduous task and it has been an active area of research. Therefore, exploitation of multi-path routing mechanism is to provide improved throughput and QoS as compared with single-path. The main objective of multipath routing protocol is to provide congestion-free reliable communication and to ensure improved QoS.

II. WIRED AND WIRELESS ROUTING PROTOCOL

Routing protocols are broadly categorized into two major categories: wired and wireless routing protocols. In wired networks there are variety of routing protocols implemented on IP protocol, while on the other hand wireless routing protocols needs modification, optimization and alteration so that these wireless routing protocols are suitable for mobility

III. MULTIPATH ROUTING PROTOCOLS

Multipath Routing protocols create multiple routes from source to destination. The main advantage of discovering multiple paths are that bandwidth between links is used more effectively with greater reliability.

It also helps during times of network congestion. Multiple paths are generated on-demand or using proactive approach and have a great significance as routes generally get disconnected quickly due to node mobility.

1. *Multipath Routing in Reactive Protocols*
   - a. AODV Family
     - i. Ad-hoc on Demand Multipath Distance Vector (AOMDV)
     - ii. Node Disjoint Multipath Routing (NDMR)
   - b. DSR Family
     - i. Split-Multipath Routing (SMR)
     - ii. Multipath Source Routing (MSR)

2. *Multipath Routing in Proactive Protocols*
   - i. Destination Sequence Multipath Routing (DSDV)
   - ii. Tree Exchange Routing Algorithm (TERA)

3. *Multipath Routing in Hybrid Protocols*
   - i. Zone Routing Protocol (ZRP)
   - ii. Ant Agents for Hybrid Multipath Routing (AntHocNet)

4. *Multipath Routing in Hierarchical Protocols*
   - i. Hierarchical Max-Flow Routing (HMFR)

ii. Hierarchical State Routing (HSR)
iii. Zone-based Hierarchical Link State (ZHLS)

5. *Multipath Routing in Power-Aware Protocols*
   i. Multipath on-demand Routing (MDR)
   ii. Energy and Mobility aware Geographical Routing (EM-GMR)
   iii. Braided Multipath Routing (BGR)

6. *Multipath Routing in Multicasting Protocols*
   i. Multipath Multicast Routing Protocol (MRPM)
   ii. Multi-Objective Multipath Routing Algorithm for Multicast Flows (MMRAM)

7. *Multipath Routing in Security Protocols*
   i. Multipath TCP Security (MTS)

A. Multipath Routing in Reactive Protocols

These are on-demand routing protocols as they determine route when it is actually needed. They are relatively faster and perform efficient recovery from the route failures. By virtue *Dynamic Source Routing* (DSR) and *Ad-hoc on-demand Distance Vector Routing* (AODV) [2] are basic reactive single-path routing protocols. *Split Multipath Routing* (SMR) [6] and *Multipath Source Routing* (MSR) are direct descendents of DSR, while *Ad-hoc On Demand Multipath Distance Vector* (AOMDV) [6] and *Node-Disjoint Multipath Routing Protocol* (NDMR) [6], both extends multi-path capability and evolved from AODV.

MSR distributes traffic over multiple paths to achieve minimum mean delay; it also makes decision when to use single-path and when to use multiple paths. Issue with MSR is processing overhead of originating the packets.

SMR reduces the frequency of route discovery process thus is reduces control overhead in the network. The basic router discovery mechanism of DSR is used in SMR protocol, but an intermediate node is not allowed to reply from its route cache if it has some routes available to the destination. The drawback of SMR is redundant overhead of packets since intermediate node is not dropping duplicate request messages.

NDMR [6] is modification of AODV. It avoids overlapping of paths by formation of node-disjoint paths and link-disjoint paths. In node-disjoint path no node is common while in link-disjoint path, no link is common. This is accomplished during route discovery process. Issue with NDMR is, if there are fewer nodes in the path, this path is likely to break. Destination has the responsibility to choose the node-disjoint path. In order to limit the overhead packets, the number of path is restricted to three. AOMDV is also modified version of AODV. Destination node selects a path that passes through more reliable nodes. If node hears route request message and also hears broadcast of this message from another node, it does not broadcast this message.

This is the way to reduce large number of broadcasts during route discovery process.

B. Multipath Routing in Proactive Protocols

Proactive routing protocols are table driven and maintain route updates among all nodes at all time. *Destination Sequenced Distance Vector Routing* (DSDV) [4] is proactive, table-driven routing protocol. Like reactive routing algorithms, proactive protocols are capable of repairing broken routes in short time. To repair the broken routes it continuously monitors the topology. It needs periodic update at regular time intervals.

Another extension to standard distance vector routing is *Tree Exchange Routing Algorithm* (TERA) [18]. TERA is based on asynchronous distributed distance vector routing but uses several additional tables to allow path construction. This avoids count-to-infinity problem which causes a very slow adaptation to the new network topologies.

C. Multipath Routing in Hybrid Protocols

A hybrid protocol combines pros of both on-demand and proactive routing protocols. *Zone Routing Protocol* (ZRP) [19] it uses proactive protocol in the neighborhood of a node and reactive protocol for routing between neighborhoods. It acts like cluster based network where a node acts as a cluster head. As it is combination of proactive and on-demand protocol it gives better performance. ZRP was proposed to reduce the control overhead of proactive routing protocol and decrease the latency caused by the route discovery in reactive strategy. If source and destination are in the same local zone, the packet destined for the destination delivered immediately, else reactive route discovery is used to construct the routes.

Let us describe another familiar hybrid routing algorithm, *Ant Agents for Hybrid Multipath Routing in Mobile Ad-hoc Network* (AntHocNet) [20] Specifically, the algorithm is reactive in the sense that it does not try to maintain up-to-date routing information between all the nodes in the network, but instead concentrates its efforts on the pairs of nodes between which communication sessions are taking place. It is proactive in the sense that for those ongoing communication sessions, it continuously tries to maintain and improve existing routing information.

D. Multipath Routing in Hierarchical Protocols

Hierarchical routing protocols avoids excessive overhead by restricting the local traffic to the local management and only global movements are reported between hierarchical layers or zones. Hierarchical Max-Flow routing forwards the packets and reduces the failure impact. It is stated that computational complexity of Max-Flow routing is high hence it is not used in moderate size networks. *Hierarchical State Routing* (HSR) [21] based on multilevel clustering levels such as physical and logical. Hierarchical address of every node is stored in an HSR table, merit of HSR is as it maintains the hierarchical information about the networks, and it automatically reduces size of routing table. Challenges in HSR are exchanging the information concerned to all the levels of the hierarchy and election of leader in every cluster is cumbersome.

In *Zone-based Hierarchical Link State Routing* (ZHLS) [22], cluster heads are not defined. Creation of Zone-Level topology information is distributed to all nodes and reduces the traffic and avoids single-point-of-failure. Maintaining Zone-Level topology produces additional traffic which degrades the performance of the algorithm.

E. Multipath Routing in Power-Aware Protocols

A multipath routing protocol that improves energy efficiency of a network falls into this category. A mobile node is usually equipped with a battery of limited capacity. These protocols maximized network life by efficiently using the battery of mobile node. Nodes they consume power while sending, processing and forwarding data as well as control packets. Low power of node also leads to failure of connectivity and node. As power consumption of mobile nodes is another area of research there is need of energy-efficient algorithms for seamless connectivity. Energy and power related issues are primarily at physical layer; this gives rise to cross-layer approach which is relatively new topic.

Multipath on-demand Routing (MDR) [6] evolved from DSR but it has different route maintenance option. Unlike DSR, the route request packet does not collect the routing information; hence route request packet does not get larger as it travels along the possible path.

Energy and Mobility aware Geographical Multipath Routing Protocol (EM_GMR) [6] is another protocol in which while selecting next hop, a mobile node should consider the remaining battery capacity, mobility and distance of that next hop to the destination. Fuzzy logic system is developed and applied to the next hop to the destination.

Braided Multipath Routing (BGR), [6] as node-disjoint multipath routing is not energy efficient, because a node-disjoint path may have longer hops compared to the shortest hop paths.

F. Multipath Routing in Multicasting Protocols

Multipath Multicast Routing Protocol (MRPM) [13] is an example of this category. A method chooses the next hop when multiple equal cost next hops are present. It is quick distributes dynamic algorithm that manages network resources efficiently. *Multi-Flow Real Time Transport Protocol* (MRTP) [14] is mesh-based ad hoc based protocol that offers multipath routing for multicast application. It is based on *Real-Time Protocol* (RTP) and *Real-Time Transport Control Protocol* (RTCP). RTP is by virtue multicast-oriented protocol for real-time applications. MRTP improves effective path discovery and data partitioning techniques by improving queuing performance of real-time traffic.

Multi-Objective Multipath Routing Algorithm for Multicast Flows (MMRAM) [15] proposes multi-objective traffic engineering scheme using different distribution trees to multicast several flows. It combines maximum link utilization, hop count, total bandwidth consumption and total end-to-end delay into single aggregated flow. Therefore, MMRAM is suited for *Multiprotocol Label Switching* (MPLS).

G. Multipath Routing in Security Protocols

MANETs are vulnerable to external attacks or threats that compromised the security of communication in MANETs. Therefore, there is need to devise end-to-end security mechanism by exploiting use of multipath routing. The existence of multiple paths used to increase robustness and data confidentiality. The scheme is presented in [16].

Multipath TCP Security (MTS) is multipath routing algorithm for data security discussed in [17], source node chooses the available routes adaptively rather than testing the “stored routes” one by one exhaustively. This algorithm is tested against AODV, DSR and concluded security level is good.

IV. CONCLUSION

In this work, we have highlighted merit and demerits of several variations of multipath routing protocols with different topologies. There is need of modification, optimization and alterations for the deployment of these protocols in real-time environment. Major concern is how to choose suitable multipath routing protocol? Choosing suitable multipath routing protocol is challenging and arduous task. Several factors are taken in consideration while selecting suitable multipath routing protocol such as, the size of network, the lifetime of network, environmental conditions and types of application. Hence, choosing suitable multipath routing protocol is another interested area of research in Mobile Ad-hoc Networks.

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