A Study on Quality of Service requirements in MANET especially focusing efficient routing procedures

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Abstract *—To achieve QoS, independently of the routing protocol, each mobile node participating in the network must implement traffic conditioning, traffic marking and buffer management (Random Early Drop with in-out dropping) or queue scheduling (Priority Queuing) schemes. MANET routing protocols can be table-driven or on demand, proactive versus reactive, symmetric versus asymmetric, and unicast versus multicast. It is observed by detailed performance comparison between DSR and AODV that the relative merits of the aggressive use of source routing and caching in DSR, and the more conservative routing table and sequence number driven approach in AODV. AODV outperforms DSR, in terms of throughput and end-to-end delay in more "stressful" situations (higher mobility and higher traffic load). On the other hand, DSR outperforms AODV for low loads (less sources) with small (less than 20) number of nodes. There are two known approaches that utilize routing protocols in order to provide QoS in MANETs. The first one tries to embed end-to-end minimum QoS guarantees (delay, bandwidth) in the computation of the routing algorithm. The routing protocol will request for a connection with a minimum required bandwidth and find the optimum route that can best satisfy that requirement. Core-Extraction Distributed Ad-Hoc Routing (CEDAR) is an example of use of this approach. The second approach is an extension to AODV that takes routing into account to satisfy QoS requirements.*

Keywords— *MANET, DSR, AODV, ZRP, CEDAR, QoS, DSDV, TCP.*

I. INTRODUCTION

In wireless networks, resources are quite limited and available channel capacity is low with poor channel quality. So, providing QoS under these conditions is a difficult task. It is more important factor in case of network congestion, which likely to happen in MANETs frequently due to limited available bandwidth. There are the research challenges in MANET like efficient routing procedures, efficient bandwidth utilization schemes and computing for increasing the communication capacity, information security, and developing more powerful mobile devices.

To achieve QoS, independently of the routing protocol, each mobile node participating in the network must implement traffic conditioning, traffic marking and buffer management (Random Early Drop with in-out dropping) or queue scheduling (Priority Queuing) schemes. In MANETs, since the mobile nodes can have simultaneous multiple roles (ingress, interior and destination), it was found that traffic conditioning and marking must be implemented in all mobile nodes acting as source (ingress) nodes. Buffer management and queue scheduling schemes must be performed by all mobile nodes.

The mobile nodes participating in a MANET must implement traffic conditioning and buffer management or packet scheduling schemes. Traffic packets are conditioned and marked as high or low priority before being sent to the wireless channel. By utilizing the buffer management or the packet scheduling scheme in each node's buffer, the mobile nodes are able to prioritize the service of packets pre-defined as high priority.

In principle, in the case of MANET, a single mobile node can simultaneously perform two roles during traffic exchange: host and router [2]. In the role of a host, a node can be the source or the destination of different types of traffic. As a router, it is responsible for relaying packets to the intended destinations and to maintain the routing paths. If a MANET has interfaces with a fixed network infrastructure, it typically operates as a "stub", carrying traffic that is either sourced or terminated within the MANET, but not permitting external traffic to "transit" through the stub network.

MANETs have four unique characteristics that differentiate them from the fixed multi-hop networks [1]: dynamic topology, bandwidth constraints, energy constraints and limited physical security. The first characteristic implies that nodes can move arbitrarily, changing the topology randomly and rapidly depending on the scenario. The second means that wireless links have significantly lower capacity than wired links, which intensifies congestion problems and requires special consideration for the bandwidth delay characteristics. Also, the effective throughput of wireless communication channels is often much less than a radio's maximum transmission rate due to multiple access, fading, noise, and interference effects. The third refers to the fact that some or all nodes in a MANET may rely on batteries for energy, making power conservation a critical design criterion. Finally, wireless networks are generally more prone to information and physical security threats than are fixed, hardwired networks. Thus, security threats must be taken into account in the design and selection of the protocols and in the development of applications.

II. CATEGORIZATION OF MANET ROUTING PROTOCOLS

MANET routing protocols can be classified in several different ways. They can be table-driven versus on demand, proactive versus reactive, symmetric versus asymmetric, and unicast versus multicast.

Table-driven versus on-demand is the most common classification [3]. Table driven algorithms can be interpreted as adaptations of the conventional distance vector and link-state techniques. The routing updates, types of tables, distributions, and techniques have been adapted to increase efficiency in MANET. In contrast, on-demand protocols attempt to reduce overhead and are more responsive to MANET by having the sender node dictate requirements. On-demand means that routes are created on an as required basis by the sender node. This "lazy routing" approach reduces overhead by eliminating unnecessary periodic updates and by letting the changes in the network dictate overhead [3]. Current routing updates are not maintained at every node, because the routes are created on an as-required basis and expire with a time metric.

Table driven protocols are also known as proactive, i.e., the routes are determined independent of the traffic pattern so that when a packet needs to be forwarded, the route is already known and can be immediately used. On the other hand, on-demand protocols are reactive because routes are established and maintained only if needed. There are also hybrid protocols, such as Zone Routing Protocol (ZRP) and Ad Hoc On-Demand Distance Vector Routing (AODV), which aim to combine proactive and reactive behaviour, according to the context.

The routing protocols may also be classified according to the capabilities of the nodes. Symmetric protocols assume that all the nodes have the same responsibilities and capabilities. Asymmetric protocols, such as Core-Extraction Distributed Ad-Hoc Routing Protocol (CEDAR), may assume that the transmission ranges or the battery life at different nodes may differ, or only some nodes can route packets and act as leaders (cluster heads) of nearby nodes.

Dynamic Destination-Sequenced Vector (DSDV), Wireless Routing Protocol (WRP), Global State Routing (GSR), Fisheye State Routing (FSR), Hierarchical State Routing (HSR), Zone-Based Hierarchical Link State Protocol (ZHLS), and Cluster-Head Gateway Switch Routing Protocol (CGSR) are examples of table driven or proactive MANET protocols. Cluster Based Routing Protocol (CBRP), Dynamic Source Routing Protocol (DSR), Associative Based Routing (ABR), Signal Stability Routing (SSR) and Temporally Ordered Routing Algorithm (TORA) are examples of on-demand or reactive MANET protocols. The intention of this coverage is to provide an understanding of how the routing protocols affect QoS in MANETs [4].

A. Zone Routing Protocol (ZRP)

The ZRP protocol, developed by Haas and Pearlman [5], incorporates a localized zone approach to routing. The approach is to incorporate a hybrid protocol that exploits the benefits of both a reactive and a proactive protocol. ZRP limits the scope of the proactive procedure to only the node's local neighbourhood. Global searches for nonlocal nodes then use an efficient reactive scheme that queries only selected network nodes, as opposed to querying all of the network nodes.

As shown in Figure 3.7, each mobile node has a proactive routing zone around it that is dictated by an adjustable zone routing radius. The zone routing radius is directly related to hop counts from the node. In Figure 3.7, nodes D, C, F, B, and E are in Zone A with a zone routing radius of 2. Routes outside the zone are determined by an on-demand protocol query which "bordercasts" the out-of-zone query to the peripheral nodes (D, F, and E), which in turn leverage the zone structure of the network to reduce query detection time. The intent behind this MANET routing approach is to utilize the routing knowledge in a localized region and obtain a route to a distant node on-demand. Intrazone Routing Protocol (IARP), Interzone Routing Protocol (IERP), and routing optimization are the main algorithms implemented within ZRP and explained in detail in [6].

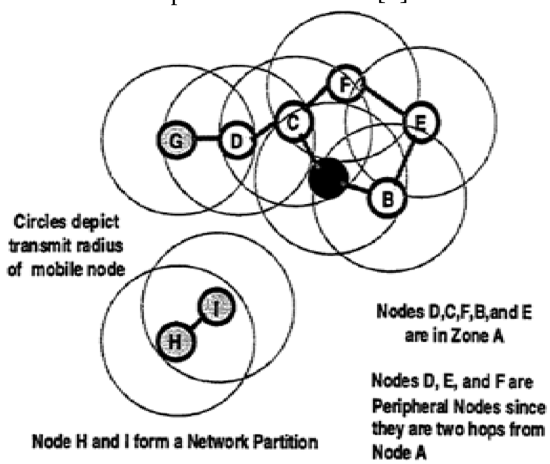
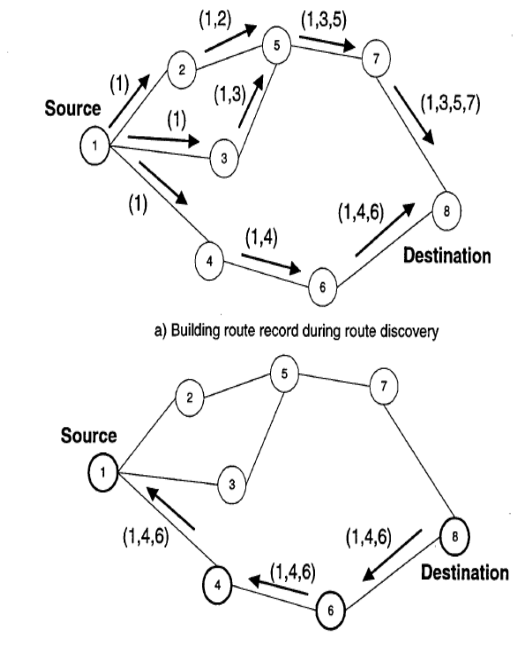


Figure 1: ZPR Example with a Zone Routing Radius of 2

B. Dynamic Source Routing (DSR)

Broch, Johnson and Maltz developed Dynamic Source Routing (DSR) in 1998 [7]. DSR is a pure on-demand protocol based on source routing. The source specifies the complete path to the destination in the packet header and each node along this path simply forwards the packet to the next hop indicated in the path. DSR utilizes a route cache approach, where the source routes acquired by the nodes are cached (Figure 2.a).



b) Propagation of route reply with source route record

Figure 2: Creation of Route Cache in DSR

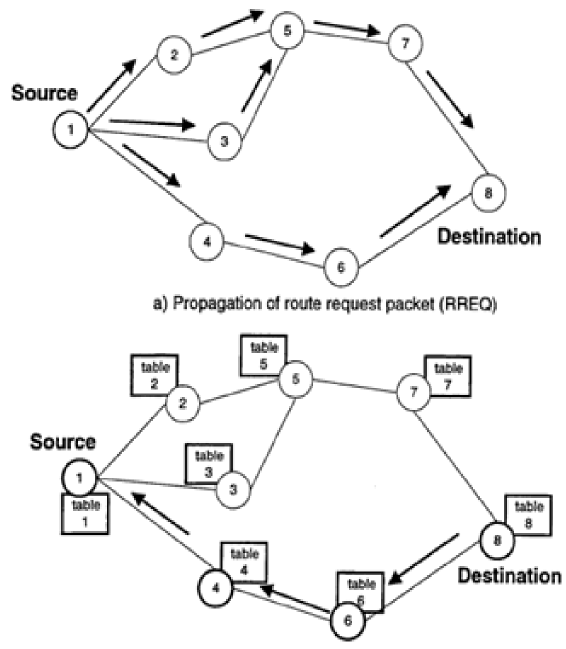
A source first checks its route cache to determine the route to the destination. If a route is found, the source uses this route. If a route is not found, the source uses a route discovery protocol to discover a route. In route discovery, the source floods a query packet or route request packet (RREQ) through the ad hoc network. Either the destination or another host that can complete the query from its route cache returns a route reply (RREP) (see Figure 2.b). Each query packet has a unique identifier (ID). When receiving a query packet, if a node has already seen this ID (a duplicate ID), or it finds its own address already recorded in the list, it discards the copy and stops flooding. Otherwise, it appends its own address on the list and broadcasts the query to its neighbours. If a node can complete the query from its route cache, it may send a reply packet to the source without propagating the query packet further. Any node participating in route discovery can learn routes from passing data packets and gather this routing information into its route.

In DSR, no periodic control messages are used for route maintenance, and there is little or no routing overhead when a single or few sources communicate with infrequently accessed destinations. The on-demand, flooding-based nature of DSR's route discovery process eliminates the need for periodic router advertisement and link status packets, which significantly reduces the overhead of DSR during periods when the network topology is stable.

C. Ad-Hoc On-Demand Distance-Vector Routing Protocol (AODV)

Perkins and Hoyer developed the AODV routing protocol in 1999 [8]. It is considered to be a hybrid protocol, because it combines features of a pure on-demand protocol (DSR) with a table-driven protocol (DSDV). Specifically, AODV uses the same features as DSR for route discovery, and from DSDV it uses the hop-by-hop routing, sequence numbers, periodic update packets and loop free routing [8].

The process of finding a path to the destination is quite similar to DSR. The source node first broadcasts a route request packet (RREQ) (See Figure 3.a). Nodes receiving this packet update their information for the source node and set up backwards pointers to the source node in the route tables. In addition to the source node's IP address, current sequence number, and broadcast ID, the RREQ also contains the most recent sequence number for the destination of which the source node is aware. A node receiving the RREQ may send a route reply (RREP) if it is either the destination or if it has a route to the destination with a corresponding sequence number greater than or equal to that contained in the RREQ. If this is the case, it "unicasts" a RREP back to the source. Otherwise, it rebroadcasts the RREQ. Nodes keep track of the RREQ's source IP address and broadcast ID. If they receive a RREQ, which they have already processed, they discard the RREQ and do not forward it.



b) Path taken by the route reply (RREP) packet

Figure 3 : Route Discovery in AODV

As the RREP propagates back to the source, nodes set up forward pointers to the destination (see Figure 3.b). Once the source node receives the RREP, it may begin to forward data packets to the destination. If the source later receives a RREP containing a greater sequence number or contains the same sequence number with a smaller hop count, it may update its routing information for that destination and begin using the new best route.

AODV maintains routing tables (see Figure 3.b) at the nodes so that data packets do not have to contain routes in its headers, which could increase the overhead when data packets are small. Similar to DSR, as long as the route remains active, AODV will continue to maintain the route. A route is considered active as long as there are data packets periodically traveling from the source to the destination along that path. Unused routes expire even if the topology does not change. Once the source stops sending data packets, the links will time out and eventually be deleted from the intermediate node routing tables. If the source moves, then it can reinitiate route discovery to the destination. If one of the intermediate nodes moves, then the moved nodes' neighbour realizes the link failure and sends a link failure notification to its upstream neighbours until it reaches the source, upon which the source can reinitiate route discovery if needed. If a link break occurs while the route is active, the node upstream of the break propagates a route error (RERR) message to the source node to inform it of the now unreachable destination(s). After receiving the RERR, if the source node still desires the route, it can reinitiate route discovery.

D. DSR vs AODV

By extensive use of simulation under different scenarios, [9] establishes a detailed performance comparison between DSR and AODV. It presents the relative merits of the aggressive use of source routing and caching in DSR and the more conservative routing table and sequence number driven approach in AODV.

When DSR is used in large networks (more than 20 active source nodes) the packet header size grows with route length. The resultant overhead implies degradation in performance. Also, if the network topology changes a lot (higher mobility cases), a cached route in DSR may become invalid, forcing the sender host to try several stale routes before finding a usable one. On the other hand, in small (less than 20 nodes) and lower mobility networks, the advantage of DSR can be significant because the above mentioned problems will not be in evidence and also because route caching can potentially speed up route discovery and reduce propagation of routing requests [9].

AODV outperforms DSR, in terms of throughput and end-to-end delay in more "stressful" situations (higher mobility and higher traffic load). On the other hand, DSR outperforms AODV for low loads (less sources) with small (less than 20) number of nodes.

III. IMPORTANT FINDINGS ON QOS OF ROUTING PROTOCOLS

From the variety of routing protocols discussed above and proposed by many researchers for MANET, it is obvious that efficient routing means efficient tracking of the changes in the network conditions and position of the nodes (may ingress, interior, or destination) under the available network resources and constraints.

There are two known approaches that utilize routing protocols in order to provide QoS in MANETs. The first one tries to embed end-to-end minimum QoS guarantees (delay, bandwidth) in the computation of the routing algorithm. The routing protocol will request for a connection with a minimum required bandwidth and find the optimum route that can best satisfy that requirement. Core-Extraction Distributed Ad-Hoc Routing (CEDAR) is an example of use of this approach. The second approach is an extension to AODV that takes routing into account to satisfy QoS requirements.

While there are indications that both approaches can be successfully applied to provide routing with QoS in MANETs, it is also true that routing protocols should not be burdened with the computation associated with providing QoS functionality at the network layer.

It is common knowledge that, in the transport layer, User Datagram Protocol (UDP) provides unreliable data packet delivery, while Transmission Control Protocol (TCP) offers reliable ordered delivery and also congestion avoidance/flow control mechanisms. The use of either in MANET will depend on the characteristics (requirements) of the traffic (voice, video, images, data) to be transmitted. In multi-hop wireless networks, both UDP and TCP perform in a much less predictable way than in wired networks. The main reason for that is the interaction with the MAC layer [10].

In the application layer, the traffic is generated and received. In the application layer, the performance metrics (throughput, end-to-end delay, etc.) are collected, and hence the high level QoS mechanisms can be effectively applied here. Each node in a MANET can potentially represent a source of different types of traffic.

There are basically two types of traffic that can be sent by a mobile node: congestion-controlled and non-congestion-controlled traffic.

Congestion-controlled refers to traffic for which the source "backs-off' in response to congestion. Reliability is an important issue for this type of traffic. In this case, TCP and its flow control and congestion avoidance mechanisms are used. The nature of this traffic allows accepting a variable amount of delay in the delivery of the packets.

Interactive traffic and transfer of large files (using FTP) are good examples of this type.
Non-congestion-controlled refers to traffic for which a relatively smooth data rate and delivery delay are desirable. Examples are real-time video and audio. In this case, UDP is used because typically no retransmissions are feasible for real-time data packets and it is important to maintain a smooth delivery flow. The concern in this case is how much the quality of the received traffic will deteriorate due to lost packets. Typically, real-time traffic contains a fair amount of redundancy, which implies that the loss of a few packets will not be noticeable.

IV. CONCLUSION

MANET is a layered architecture of quality of services : User, Application, and Network. At the application layer, QoS describes arrival patterns and sensitivity to delivery delays. End-to-end protocols (RTP/RTCP), application specific representations and encoding (FEC, interleaving) are implemented in MANET. Application arrival patterns may be predictable or unpredictable. If the arrival pattern is in the form of stream, it is a predictable delivery at a relatively constant bit rate (CBR) for example audio. But if the arrival patter is in the form of Burst, it is unpredictable delivery of data at a variable bit rate (VBR), for example, MPEG which move data in bulk.
At network layer, there are four quality factors: Bandwidth, Latency, Jitter, and Loss. Bandwidth is the range of frequency in which traffic must by carried by the network. Latency is the delay that an application can tolerate in delivering a packet of data. Jitter is the variation in latency and Loss is the percentage of data loss.

In networking, there are two types of services: ***Integrated services and Differentiated services.*** An integrated service provides closest circuit emulation on IP networks. Network resources are apportioned according to an application's QoS request, and subject to bandwidth management policy. Differentiated services provides a simple and coarse method of classifying services of various applications and differentiates between them as Expedited Forwarding and Assured Forwarding. Expedited forwarding minimized delay and jitter, and provides the highest level of aggregated quality of service. Any traffic that exceeds the traffic profile is discarded. In Assured forwarding, excess traffic is not delivered with as high probability as the traffic "within profile", which means it may be demoted but not necessarily dropped.

QoS routing is a routing process that guarantees to support to a set of QoS parameters during establishing a route. The QoS routing supports QoS-Driven selection and QoS Reporting and provides path information at each router. The goals for QoS routing are : (1) The QoS routing schemes can help admission control, and (2) QoS routing scheme that considers multiple constraints provide better load balance by allocating traffic on different paths subject to the QoS requirements of different traffics. Hence, it is evident that the QoS routing algorithms must be adaptive, flexible, and intelligent enough to make a fast decision.

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