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Energy Aware Congestion Control Multipath Routing: A Survey

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***Abstract*— Mobile An ad hoc network (MANET) is a collection of wireless mobile hosts forming a temporary network without the aid of any established infrastructure or centralized administration. The life time of the network is an important criterion. The nodes in an ad hoc wireless network are powered by batteries. These will have limited power supply. The conservation of energy and the improvement in lifetime of the network are the most important issues. Many energy aware routing protocols have been proposed from variety of considerations. The multipath routing is new method to reduce the possibility of congestion by that also reduces the packet dropping and energy consumption. Multipath procedure moves traffic from the most congested paths to the more lightly loaded paths, as well as from higher energy cost paths to the lower ones, thus achieving load- balancing and energy-savings. The work is a study of the energy aware routing protocols in mobile ad hoc wireless networks and classification of the protocols.**

Keywords: MANET, congestion, energy, multipath routing.

I. Introduction

A wireless mobile ad hoc network [1] is usually defined as a set of wireless mobile nodes dynamically self-organizing a temporary network without any central administration or existing network infrastructure. Since the nodes in wireless ad hoc networks can serve as routers, they are movable so they can form any type of topology. They forward packets for other nodes if they are on the route from source to the destination (like intermediate node. Besides other issues, routing is an important problem in need of a solution that not only works well with a small network, but also sustains scalability as the network gets expanded and the application data gets transmitted in larger volume. Since mobile nodes have limited transmission capacity, they mostly intercommunicate by multi hop relay. Multi hop routing is challenged by limited wireless bandwidth, low device power, dynamically changing network topology, and high vulnerability to failure, to name just a few. To answer those challenges, many routing algorithms in MANETs [1] were proposed. There are different dimensions to categorize them: proactive routing versus on-demand routing, or single-path routing versus multipath routing. In proactive protocols, routes between every two nodes are established in advance even though no transmission is in Demand and in reactive routing routes between every two nodes are established when needed.

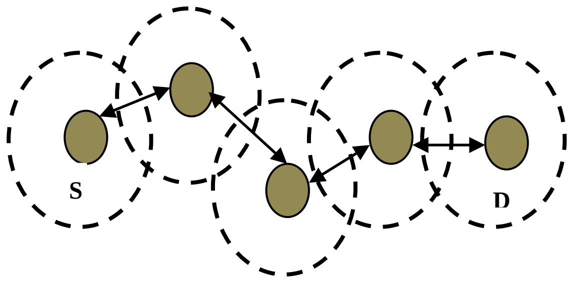

Figure 1. An Example of Ad hoc Network

Figure 1 represents the ad hoc network, here first connection will established in between sender S and destination D then transfer data through intermediate nodes.

Due to unawareness of energy and congestion is a cause for packet loss in MANETs [1]; mostly packets will loss cause of congestion only. Our aim is to control congestion in MANETs [1]. Typically, reducing packet loss involves congestion control. Congestion in routing in MANETs may lead to the following problems:-

- Long delay: It takes time for a congestion to be detected by the congestion control mechanism. In severe congestion situations, it may be better to use a new route. The problem with an on-demand routing protocol is the delay it takes to search for the new route.
- High overhead: In case a new route is needed, it takes processing and communication effort to discover it. If multipath routing is used, though an alternate route is readily found, it takes effort to maintain multiple paths.
- Many Packet Losses: Many packets may have already been lost by the time congestion is occurred or detected. A typical congestion control solution will try to reduce the traffic load, either by decreasing the sending rate at the sender or dropping packets at the intermediate nodes or doing both.

II. Applications of Ad hoc Networks

Ad hoc networks are specially designed to cater to a particular application. This section discusses potential applications to motivate the reasons for deploying ad hoc networks. The essential characteristic of an ad hoc network is the ability of forming spontaneous networks between nodes

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that are in range of each other. This is a feature of a number of military, commercial, and social applications [2].

- Military Application

Military applications require the war fighters and their mobile platforms to be able to move freely without any restrictions imposed by wired communication devices. These applications should thus be self-configuring, independent of any centralized control stations, and should be infrastructure independent in nature. These networks need to be robust in nature, i.e., they should not have a single point of failure. Ad hoc networks are thus an appropriate solution for such applications.

- Commercial Application

The lack of infrastructure in ad hoc networks is a motivating factor for deployment in commercial applications as it reduces the cost of infrastructure investments. Ad hoc networks also have other commercial advantages due to the ease of network re- configuration and reduced maintenance costs.

- Collaborative Networks

A typical application of a collaborative ad hoc network can be considered a conference room with participant's wishing to communicate with each other without the mediation of global Internet connectivity. In such a scenario, a collaborative network can be set up among the participant's devices. Such networks involve exchange of data between devices such as laptops, palmtops, PDAs, and other information devices. Each participant can thus communicate with any other participant in the network without requiring any centralized routing infrastructure. These networks are thus collaraborative in nature and are useful in cases where business network infrastructure is often missing or in scenarios where reduction in the cost of using infrastructure links is important.

- Home Networks

These networks involve communications between PCs, laptops, PDAs, cordless phones, smart appliances, and entertainment systems in and around the home. Peer-to-peer communication among these devices will reduce the overhead of going through a centralized node and thus makes ad hoc networks a natural choice for implementing home networking applications.

- Distributed Control Systems

Ad hoc wireless networks allow distributed control with remote plants, sensors and actuators linked together through wireless communication. These net- works help in co-ordinating unmanned mobile units and lead to a reduction in maintenance and re-configuration costs. Ad hoc wireless networks are used to co-ordinate the control of multiple vehicles in an automated highway system, co- ordination of unmanned airborne vehicles, and remote control of manufacturing units.

- Community Networks

The concept of a general purpose ad hoc network is identified as a step to- ward next-generation ad hoc network development [3]. An open community network is a novel information infrastructure for local communities based on wireless multi- hopping technologies, which may support an advanced information-oriented society in the twenty-first century. A community network consists of one or more computers providing services to people using computers and terminals to gain access to those services and to each other. Community network terminals can be set up at public places like libraries, bus stations, schools, Laundromats, community and senior centers, social ser-vice agencies, public markets, and shopping malls. Community networks can also be accessible from home via computers and, increasingly, from the Internet. Such networks are excellent example.

III. Congestion in MANET

Congestion is a problem that occurs on shared networks, when multiple users access to the same resources (bandwidth, buffers, and queues). When numbers of packets are present in a network is greater than capacity of network then this situation is called as congestion. Congestion in a network may occur when the load on the network i.e. the number of packets sent to the network is greater than the capacity of network.

Congestion Control Mechanisms:

- End-system flow control: This is not a congestion control mechanism scheme, but it is a way to prevent the sender in network from overflow the buffers of the receiver.
- Network congestion control*:* In this scheme, end systems choke back in order to avoid congesting the network. The mechanism is similar to end-to-end flow controls, but the main intention is to reduce congestion in the network, not the receiver.
- Network-based congestion avoidance: In this scheme, a router detects that congestion may occur and attempts to slow down senders before queues become full.
- Resource allocation: This technique involves scheduling the use of physical circuits or other resources, for a specific time period. A virtual circuit, built across a series switches with a guaranteed bandwidth is a form of resource allocation. This technique is difficult, but can eliminate network congestion by blocking traffic that is in excess of the network capacity.

IV. Multipath Routing In MANET

Multipath routing has been explored in several different contexts. Traditional circuit switched telephone networks used a type of multipath routing called alternate path routing. In alternate path routing, each source node and destination node have a set of paths (or multi-paths) which consist of a primary path and one or more alternate paths. Alternate path routing was reposed in order to decrease the call blocking probability and increase overall network utilization.

In alternate path routing, the shortest path between exchanges is typically one hop across the backbone network; the network core consists of a fully connected set of switches. When the shortest path for a particular source destination pair becomes unavailable (due to either link failure or full capacity), rather than blocking a connection, an alternate path, which is typically two hops, is used. Well known alternate path routing schemes such as Dynamic

Non-hierarchical Routing and Dynamic Alternative Routing are proposed and evaluated in [6] [7].

Multipath routing has also been addressed in data networks which are intended to support connection-oriented service with QoS. For instance, Asynchronous Transfer Mode (ATM) [8] networks use a signaling protocol, PNNI, to set up multiple paths between a source node and a destination node. The primary (or optimal) path is used until it either fails or becomes over-utilized, and then alternate paths are tried. Using a crank-back process, the alternate routes are attempted until a connection is completed. Alternate or multipath routing has typically lent itself to be of more obvious use to connection-oriented networks; call blocking probability is only relevant to connection oriented networks. However, in packet-oriented networks, like the Internet, multipath routing could be used to alleviate congestion by routing packets from highly utilized links to links which are less highly utilized. The drawback of this approach is that the cost of storing extra routes at each router usually precludes the use of multipath routing. However, multipath routing techniques have been proposed for OSPF [9], a widely used Internet routing protocol.

Benefits of Multipath Routing

As mentioned before, multiple paths can provide load balancing, fault-tolerance, and higher aggregate bandwidth. Load balancing can be achieved by spreading the traffic along multiple routes. This can alleviate congestion and bottlenecks.

From a fault tolerance perspective, multipath routing can provide route resilience. To demonstrate this, consider Figure 2, where node S has established three paths to node D. If node S sends the same packet along all three paths, as long as at least one of the paths does not fail, node D will receive the packet. While routing redundant packets is not the only way to utilize multiple paths, it demonstrates how multipath routing can provide fault tolerance in the presence of route failures.

Since bandwidth may be limited in a wireless network, routing along a single path may not provide enough bandwidth for a connection. However, if multiple paths are used simultaneously to route data, the aggregate bandwidth of the paths may satisfy the bandwidth requirement of the application. Also, since there is more bandwidth available, a smaller end-to-end delay may be achieved. Due to issues at the link layer, using multiple paths in ad hoc networks to achieve higher bandwidth may not be as straightforward as in wired networks. Because nodes in the network communicate through the wireless medium, radio interference must be taken into account. Transmissions from a node along one path may interfere with transmissions from a node along another path, thereby limiting the achievable throughput.

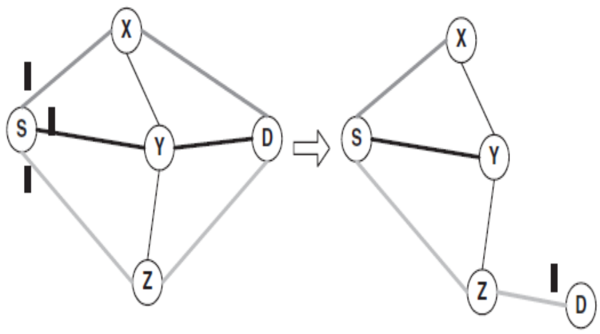

Fig. 2. Source node S routes the same packet to destination node D along the routes SXD, SYD, and SZD. When node D moves routes SXD and SYD break, but route SZD is still able to deliver the packet to node D.

V. Ad hoc On-demand Multipath Distance Vector routing (AOMDV)

The AOMDV uses the basic AODV route construction process. In this case, some extensions are made to create multiple link-disjoint paths. The main idea in AOMDV is to compute multiple paths during route discovery. It consists of two components:

- A route update rule to establish and maintain multiple loop-free paths at each node.
- A distributed protocol to find link-disjoint paths.

AODV, when a source needs a route to a destination, it initiates a route discovery process by flooding a RREQ for destination throughout the network. RREQs should be uniquely identified by a sequence number so that duplicates can be recognized and discarded. Upon receiving a non-duplicate RREQ, an intermediate node records previous hop and checks whether there is a valid and fresh route entry to the destination in routing table. If such entry is found, the node sends back a RREP to the source; if not it rebroadcasts the RREQ message. A node updates its routing information and propagates the RREP upon receiving further RREPs only if a RREP contains either a larger destination sequence number or a shorter route found.

In AOMDV [4] each RREQ, respectively RREP arriving at a node defines an alternate path to the source or destination. Just accepting all such copies will lead to the formation of routing loops. In order to eliminate any possibility of loops, the "advertised hop count" is introduced. The advertised hop count of a node i for a destination node d, represent the maximum hop count of the multiple paths for node d available at node i. The protocol only accepts alternate routes with hop count lower than the advertised hop count, alternate routes with higher or the same hop count are discarded. The advertised hop count mechanism establishes multiple loop-free paths at every node. These paths still need to be disjoint. We use the following:

When a node S floods a RREQ packet in the network, each RREQ arriving at node I via a different neighbour of S, or S itself, define a node-disjoint path from I to S.

In AOMDV this is used at the intermediate nodes. Duplicate copies of a RREQ are not immediately discarded. Each packet is examined to see if it provides a node-disjoint path to the source. For node-disjoint paths all RREQs need to arrive via different neighbours of the source. This is verified with the first hop field in the RREQ packet and the first hop-list for the RREQ packets at the node.

At the destination a slightly different approach is used, the paths determined there are link-disjoint, not node-disjoint. In order to do this, the destination replies up to k copies of the RREQ, regardless of the first hops. The RREQs only need to arrive via unique neighbours.

AOMDV properties

- Extension of AODV.
- RREQs from different neighbours of the source are accepted at intermediate nodes.
- Multiple link-disjoint routes are created (with modification at the destination they can be node-disjoint).
- Maximum hop count to each destination ("advertised hop count") is used to avoid loops.
- Multiple routes are established in single route discovery process.
- Nodes maintain next-hop info for destinations (multiple next-hops possible).

VI. Previous Work

The Predictive Energy-efficient Multicast Algorithm (PEMA) [10] take the advantage of the network statistical properties in resolving scalability and overhead issues caused by large scale MANETs as opposed to relying on route details or network topology. The running time of PEMA depends on the multicast group size instead of network size, hence, this resulted in PEMA to be fast enough for MANETs that consisting of 1000 or more nodes. The results of simulation shows that PEMA post appreciable power savings compared to other existing algorithms, it also attains good packet delivery ratio in mobile environments. What makes PEMA so different is its speed, it is extremely fast because its running time is independent of its network size and the routing decision does not rely on the information about network topology or route details [11].

Power-aware routing (PAR) [11] maximizes the network life span and minimizes the energy utilization by selecting less congested and more stable route, during the source to destination route establishment process to transmit data packets, hence, providing energy efficient routes. The three parameters focused by PAR protocol are: Accumulated energy of a path, status of battery lifetime and type of data to be transmitted. These core metrics are the focus of PAR during route selection time, hence, less congested and more stable routes for data delivery are considered. Thus, network lifetime are increased if different routes for different type of data transfer are provided. The results from the simulation shows that PAR outperforms related protocols such as DSR [12] and AODV [13], with respects to diverse energy-related performance metrics even in high mobility scenarios. Nevertheless, PAR incur increased latency during data transfer, but it discovered route will last for a long time, and enormous energy saving.

The proposal by [14] has 3 phases: RREQ (Route Request) phase, RERR (Route Errors) phase and local repair phase. Power related function occurs with RERP (Rout Reply) only because in the beginning all the nodes will be in fresh mode so there is a full power to find the route and send the request message and also all the nodes which are not participating in route request go to sleep mode.

A Triangular energy-saving cache-based routing protocol by sieving (TESCES) was proposed by [15], it is a kind of energy aware and location aware grid based protocols in MANETs. It was based on two protocols: a fully energy aware and location aware protocol (FPALA) [16, 17] and an energy saving cache based routing protocol (ESCR) [18]. In this protocol the network is divided into grids depending on GPS. TESCES has three procedures:

- GLEES to elect leader node with maximum energy for each grid in the network, while some nodes join a grid leader election, other nodes will be in sleeping mode.
- CGLM for maintain grid leader and new grid leader is candidate from cache table directly.
- TESRD for saving routing discovery and chose path with minimum nodes.

In modified DSR [19] algorithm, destination chooses the path through which the first RREQ message arrived to destination, and send the RREP message through the same path while ignoring the other paths, and this path also will be chosen by source to send the data packets because this is the fastest path. This leads to decrease the end-to-end delay, reduce control packets generated and maximize packet delivery ratio. The modified DSR also overcome overheads drawback of existing DSR, by reducing the header of data packet. Header of data packet now includes only source and destination address, while previously it includes source and destination address as well as all intermediate nodes address between source and destination.

Rajib Mall et al [20] proposed a novel power and battery aware routing protocol, which not only incorporates the effect of power consumption in routing a packet and recent traffic density at each node but also exploits the charge recovery effect phenomenon observed in batteries. Route selection is based on a cost metric, which captures the residual battery capacity and drain rate of mobile nodes in the network .

Thomas Kunz et al [21] presented some results on integrating energy-efficiency aspects into a standard MANET routing protocol, OLSR. In particular, they are exploring the impact of nodes having only inaccurate/imprecise knowledge of the energy levels of other nodes. They use two different energy efficient variants of the OLSR protocol and simulate a wide range of scenarios.

P.K. Suri et al [22] proposed a bandwidth-efficient power aware routing protocol "QEPAR". The routing protocol is presented to minimize the bandwidth consumption as well as delay. QEPAR will help in increasing the throughput by decreasing the packet loss due to non availability of node having enough battery power to retransmit the data packet to next node. The proposed protocol is also helpful in finding out an optimal path without any loop.

Vinay Rishiwal et al [23] proposed QoS based power aware routing protocol (Q-PAR). The selected route is energy stable and satisfies the bandwidth constraint of the application. The protocol Q-PAR is divided in to two phases. In the first route discovery phase, the bandwidth and energy constraints are built in into the DSR route discovery mechanism. In the event of an impending link failure, the second phase, a repair mechanism is invoked to search for an energy stable alternate path locally. Moreover the local repair mechanism was able to find an alternate path in most of the cases enhanced the network lifetime and delayed the repair and reconstruction of the route.

Yanyong Zhang et.al [24] have proposed new a two-level congestion detection scheme that provides an accurate node-level and flow-level congestion measurements in an energy-efficient way in ad hoc networks. Simulation results show the node-level congestion measurement, which uses the set of buffer occupancy, packet drop rate, and channel loading as an indication of congestion, accurately portrays the congestion level by decoupling the measurement from various MAC protocol characteristics. The flow-level congestion measurement based on the node-level congestion measurement provides sfined-grained congestion information in the network. For energy-efficiency, the lazy channel loading measurement saves a lot of energy needed to accurately measure the channel loading while maintaining the same level of accuracy as synchronous measurements. Simulation results show the proposed mechanism significantly cut down the energy needed to accurately measure congestion while maintaining high level of accuracy needed for timely congestion control.

Mr.S.A.Jain et.al [25] have proposed Ant Colony algorithm which has been used in Mobile Network since long because of isomorphism between them In MANET, routes may fail due to failure of links that may be caused by movement of nodes. In addition when mobility speed is high, link failures occur more causing delivery ratio to decrease. So the problem of packet losses and delays can be solved to a certain extent by detecting the link failures. Packet delivery failures due to wireless link collisions may incur unnecessary route reestablishments from the source node. Thus this type of route reestablishment can be prevented if there exists a mechanism different mechanisms for the link failure detection by using alternate route finding from the nearer of the faulty node resulting into improvement in throughput, and end to end delay parameters. Thus performance of MANET will be significantly increased, along with TCP throughput.

Xiaoqin Chen et.al [26] have proposed congestion-aware routing (CARM). CARM utilizes two mechanisms to improve the routing protocol adaptability to congestion. Firstly, the weighted channel delay (WCD) is used to select high throughput routes with low congestion. The second mechanism that CARM employs is the avoidance of mismatched link data-rate routes via the use of effective link data-rate categories (ELDCs). In short, the protocol tackles congestion via several approaches, taking into account causes, indicators and effects. The decisions made by CARM are performed locally.The simulation results demonstrate that CARM outperforms DSR due to its adaptability to congestion protocol for mobile ad hoc networks which uses a metric incorporating data-rate, MAC overhead, and buffer delay to combat congestion.

Consolee Mbarushimana et.al [27] have proposed a Type of Service Aware routing protocol (TSA), an enhancement to AODV, which uses both the ToS and traditional hop count as route selection metrics.TSA is a cross-layer congestion-avoidance routing protocol in which the routes through nodes engaged with delay sensitive traffic for extended periods are only selected as the last resort, even when they are shorter. Avoiding busy nodes alleviates congestion, results in less packets drop and in a short end-to-end delay. In addition, TSA distributes the load on a large area, thus increasing the spatial reuse. Simulation study reveals that TSA considerably improves the throughput and packet delay of both low and high prior.

VII. Conclusion & Future Work

The purpose of congestion control is to control the delay and buffer overflow caused by network congestion and provide better performance of the network. The customary congestion control mechanism, applied by the transport control protocol is unable to catch up the network dynamics of ad hoc networks because of their end to end working. Congestion control supposed all losses induced by congestion. The nodes with maximum power level are chosen as supposed to live nodes which will always be in active mode and remaining nodes are chosen as non active nodes which will aware in broken up manner. The status of live nodes keeps varying in every time phase. The source transmits the data packets to the destination through the selected path. We conclude that there is not a single scheme that control congestion and reduce energy consumption which can give the best performance in ad-hoc network. We have also discussed the factors that can be improved to increase the routing efficiency.

In future we try to proposed, if the node receiving the packet is wakeful, the packet is transmitted to that node otherwise node checks for the adjacent listening for transmitting the packet. In this manner, the packets are transmitted in hop-by-hop manner with reduced power consumption.

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