ISSN:0975-9646
Ashish Kumar et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 2 (5) , 2011, 2421-2425

A Survey of Link Failure Mechanism and Overhead of Routing Protocols in MANET

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Abstract— **The nodes in Mobile Ad Hoc Network (MANET) are mobile resulting in dynamic topology with high rate of link breakage and network partitions leading to interruptions in the ongoing communication. In contrast to wired network, MANET has increased possibility of packet loss and congestion resulting in energy consumption. Routing techniques help in path establishment for transmission. The existing routing protocols suffer from overhead causing energy loss which may be further aggravated by link failures. This survey discuss about the conventional routing protocols that are prime candidates for the study of overhead and link failure problems. And also reviewed the various approaches proposed in the literature to make conventional routing protocols energy efficient.**

***Keywords*-Ad hoc network; energy consumption; routing protocols; overhead; link**

I. INTRODUCTION

Traditional wireless networks are having infrastructure such as access point, to handle the communication among nodes. This type of network is single hop network. A MANET is a self organized network of mobile nodes connected by wireless links and requires no infrastructure for communication. The nodes can move freely and in arbitrary manner. All nodes within the range of each other can communicate without the need of a central access point. Each node can act as both a router and as a host for multihop messages. The nodes in the network forward messages on behalf of other nodes which are not in the transmission range of each other. Hence separate schemes are required for such dynamically changing network. It is anytime, anywhere type of network. Because of this such a network can be quickly deployed in emergence services such as disaster recovery like fire and search and rescue operation, and the ease of data acquisition in inhospitable terrains makes it suitable for military operations.

An accelerating energy crisis in the oil and gas industry is driving development and investment in MANET technologies. MANET is a key investment area across the whole oil and gas industry. The importance of MANET in oil and gas industry can be understood from the following: The availability of crude oil is in the remote area of seas and there it is very difficult to implement *infrastructure* oriented network for communication, sometimes the working staff faces catastrophic situations in such remote areas and it is very difficult for them to communicate with each other without any infrastructure, hence required a infrastructure less network (MANET). This is not the only sector; many other projects are going on for its success with huge investment.

MANET was designed to work in the situations such that whenever certain number of nodes come together i.e. within transmission range of each other, they should be able to communication. Its aim was not as for the fixed network i.e. not for long time. So generally in MANET nodes are equipped with low power and computing, having routing capabilities. Because, in MANET, topology frequently changes, and nodes have got limited power so its routing is challenged by these factors. So conventional routing protocols employed for wired networks cannot be used.

Initial routing protocol considered minimum number of hops as metric, but the problem of overuse of nodes on a path may result in disruption in communication. It is very serious problem consider the rescue operation where all nodes need to be connected. This may lead to delay in communication and looking at the demand of real time applications this may be a serious concern and motivated us to investigate into this field.

Most of the energy related study in MANET has been done at routing layer to reduce energy consumption in either transmission or suggesting a different routing approach altogether but following the same concepts being used by existing routing protocols. Few have explored the idea to reduce the energy consumption due to routing overheads [14]. This may be because it requires the cross layer design approach. If during an ongoing transmission link failure occur either due to over utilization, node movement, or congestion etc. the transmission interrupts for a significant amount of time because before finding or using another route, the source node of the link failure has to wait for timeout interval and also has to inform all the nodes using that link in their path through RERR packets. In performing these activities as is expected a significant amount of energy is consumed. So this survey gives an insight by studying the various routing techniques from energy consumption point of view due to overheads and mainly due to link failures.

Most of the surveys do not provide clear –cut notion of their objectives and there is always a lack of clarity in the research quality to be searched for. Therefore, in section 2 the problem is explained with clearly mentioning the research targets. Section 3 gives the description of the general purpose routing protocols which are of prime importance in the study of our work. In Section 3.1, 3.2, 3.3 and 3.4 the classification of routing techniques is given based on different approaches used.

II. PROBLEM FORMULATION

The nodes in MANET are mobile so may result in dynamic topology with high rate of link breakage and network partitions interrupting the ongoing communication or transmission. The nodes in MANET are dependable upon

the exhaustible power supply. Also because of shared nature of medium, the transmitted packets may also cause energy loss in the surroundings nodes due to overhearing. And compared to wired network there is increased possibility of packet loss and congestion in MANET resulting in energy consumption. Energy consumption can also be due to receiving of data, transmitting the data, traffic, mobility and size of the network. While the problem of network partitioning due to the movement of nodes cannot be handled by routing protocol, partitioning due to outage of battery can be solved by routing decisions. Routing techniques helps in path establishment for communication. MANET consists of different types of overheads such as routing overhead (route request, route reply and route error packets). The overhead caused in managing the link failure is a significant contributor of energy consumption. As the start node of the broken link has to wait/ retry for a time out interval before deciding that the link is failed and cannot be used further and has to inform through ROUTE ERROR (RERR) packet to all other nodes using the failed link in their path. Also the packets following this path experience large delays and the source node has to find a new route to destination. And this problem occurs more frequently in wireless networks. Hence the problem of energy consumption due to overheads and link failure in routing protocols requires special attention.

III. LITERATURE SURVEY

Routing protocols can be classified according to various approaches which are relevant to our problem of research. The following sections describe these protocols.

A. *Description of Selected Routing Protocols*

TORA: Temporally ordered routing (TORA) algorithm [1] is based on link reversal approach. In it every node has information regarding its adjacent nodes. The algorithm provides multiple routes between pair of nodes. The protocol is highly adaptive, efficient, and scalable, and is well suited for use in large, dense, mobile networks. The protocols reaction to link failure [2] involves only localized single pass of the algorithm. When a source node has to discover route to destination it sends a QUERY message with destination address information. The message travels through the network until it either reaches the destination or received by a node having the path to destination. The receiving node broadcast the UPDATE packet with the information of number of direct link used to reach the destination. As packet travels through the network, each node updates its list by adding another pair of nodes (source- destination). This results in a series of directed links from source to destination. During the discovery phase if destination is unreachable then the intermediate receiving node sends a CLEAR message to resets all the routing states and remove all invalid routes from the network. The protocol operates on top of the Internet MANET Encapsulation Protocol (IMEP).

AODV: Ad hoc on-demand distance vector (AODV) is based on DSR and DSDV algorithms. The basic route discovery and route maintenance is based on DSR and uses the hop-by-hop sequence numbers and beacons of DSDV [2]. During route discovery the source node broadcast a ROUTE REQUEST (RREQ) message with broadcast id and node sequence number. Intermediate node forwards the RREQ if it is not already received or does not have the route to the destination. The forwarding node also creates reverse route for itself from the destination. When the RREQ is received by a node with route to the destination, if sends ROUTE REPLY (RREP) with the number of hops (required to reach destination) information. All the intermediate nodes which forwards this RREP creates forward route to the destination. This protocol is adaptable to highly dynamic network but may experience large delays during route construction and link failure may further introduce extra delay due to rediscovery of route.

DSR**:** Dynamic source routing (DSR) protocol composed of two mechanisms namely route discovery and route maintenance that work together to allow the discovery and maintenance of source routes in MANET [3]. DSR protocol requires each packet to carry the full address (every hop information) from source to destination. The destination piggybacks the route information in RREP packet avoiding infinite recursion of route discoveries. The protocol does not require periodic beaconing so nodes may conserve power. Another advantage of DSR is that nodes cache may contain multiple routes to destination and it is very advantageous for low mobility networks [2].

ARA: Ant Colony Based Routing Algorithm (ARA) attempt to reduce routing overhead by adopting the food searching behaviors of ants [3]. In search of food ant walk towards the food and leaving behind a transient trail called pheromone. The concentration of pheromone determines the usage of path. The concentration of pheromone decreases with the time due to diffusion effects. This protocol also works in two phases (route discovery and route maintenance). During route discovery a forward ant is propagated through the network and during the travel at each hop, each node calculates pheromone value depending on how many number of hops the forward ant has traveled. Once the destination is reached it creates a backward ant and returns it to the source. When the source receives the backward ant, a path is determined and data transition begins. As the size of forward ant and backward ant is small the amount of overhead per control packet is also minimized [4]. However the route discovery process is based on flooding so suffer with scalability problem.

B. *Preemptive Routing Protocols*

In the existing routing protocols, if during an ongoing transmission link failure occurred either due to over utilization, node movement or congestion etc. the transmission interrupts for the significant amount of time because before finding another route or using another route the source node of the link failure has to wait for timeout interval and also has to inform other nodes using failed link. In performing these activities a significant amount of energy is consumed. Hence the protocols based on preemptive routing were proposed. In preemptive routing the algorithms based on early warning being detected by the source node of likely link failure, another route discovery is started by the source node so switching to

more stable path and avoiding the delay and energy consumed in tackling the link failure.

A technique to improve delay caused due to link failure resulting in route rediscovery has been proposed in [6]. In the technique the power levels of the nodes are computed. And during a transmission whenever the power level of the node N (likely to cause link failure) goes below a certain threshold value, it sends warning message to predecessor of N for determining an alternative path so that remaining packets can be transmitted through alternative path. The DSR protocol performance under preemptive routing has been evaluated in [7]. To generate warning message required to start the discovery of an alternative path the signal strength threshold is used. And it is based on the concept of preemptive region width given in [8]. In [9] author proposed enhanced power based multipath routing protocol. In the technique if the signal strength falls below threshold value triggering warning message being sent to source node. And source node has multiple paths to destination being found during initial route discovery phase. The [10] proposed the preemptive multipath ad hoc on demand distance vector routing (PMAODV) based on the concept of AODV with multipath routing and preemptive routing protocol. [11] Improves AODV by adding the concept of preemptive routing and proposed the predictive preemptive AODV (PPAODV) routing technique. When a node moves to preemptive region, its signal strength falls below threshold. So to predict when to send warning message it uses three consecutive signal strengths of the packets received from predecessor in lagranges interpolation formula i.e. it measure P0, P_1 and P_2 at t_0, t_1 and t_2 respectively and put the values in lagranges formula to compute received signal strength (formula describes in paper in detail) P. When P falls below threshold value, a warning message is sent to predecessor and it starts local route repair by finding alternative path to destination. Author evaluated protocols performance on Glomosim simulator. [12] Proposed Cache-enabled Preemptive Dynamic Source Routing (CPDSR) technique. This method suggests the solution to the problem of stale routes available in nodes caches. As preemptive routing produces early warning so RERR packets are not being broadcasted hence nodes are still with that stale route information in their cache. The warning node send warning message to source node in turn source node refreshes its local route cache and finds new available route in its cache to destination if exist then uses that route and if not then broadcast RREQ packets with unstable link (likely to break soon) information to find the new route. Unstable link information is kept in RREQ so that all the nodes on the path may refresh their cache with this and any new replied route does not contain such unstable link. After this source node sends RERR message to the warning node so that all the nodes on this path may refresh their route cache and warning node may know that route has changed. The author has also proposed a method to determine reaction time. It is the time to determine when a link is regarded as unstable.
The [13] presented a technique to hand-off the router in case of weak link. It is determined by considering the power difference table and neighbor power list which is kept by every node. Based on these tables values warning node determines neighbor node which is reachable from source and destination node both so that the data can be diverted through that path and warning node broadcast a hand-off packet containing the address of predecessor and successor to make the path. If the neighbor node with sufficient link stability cannot be determined then allow the link fail to occur and later route repair is done as per AODV protocols standard mechanism.

C. *Routing Protocols based on Energy as Metric*
Many algorithms considering energy as metric have been proposed in the literature [5].

1) *Transmission Power Based*: The minimum total transmission power (MTTP) based protocols [14] use the summation of the transmission powers of all hops on the path. So it selects the path having minimum transmission power. But as the transmission power is directly proportional to distance, hence it prefers shorter distance hops resulting in more hops on the path. Therefore these algorithms suffer from more end to end delay also does not consider battery residual energy (nodes energy capacity).

2) *Residual Energy Based*: Minimum Battery Cost Routing (MBCR) [15] selects the path that avoid the node having less residual battery capacity. But because it considers the total path battery cost so still are the chances of being considering a node with less remaining battery capacity. The problem of MBCR is being tried to solve in Min-Max Battery Cost Routing (MMBCR) but still it does not guarantee that minimum energy route will be selected under all circumstances. Conditional Min- Max Battery Cost Routing (CMMBR) [5] uses MTPR if the node residual energy on the path is above a certain threshold otherwise uses MMBCR.

3) *Estimated Node Lifetime (Battery Drain Rate)*: Residual energy based algorithms does not give guarantee that a node will exhaust its battery capacity. Hence [16] proposed energy drain rate based algorithm which means with what speed battery capacity is being consumed. Based on this nodes lifetime is estimated. While selecting routes, node lifetime is being taken into account; if it falls below a certain threshold then an alternative node is selected to pass the traffic.

4) *Local Routing*: In Local Energy Aware Routing [17] the intermediate nodes forward the route request only when their energy is above certain threshold otherwise drops the message. In it the responsibility of decision (in on demand it is being taken by source or destination) is distributed to intermediate nodes. It avoids the overhead of periodic exchange of information.

5) *Expected Energy Consumption:* In [18] work presented is designed from extending operational life time perspective and is found on expected energy consumption idea. It proposed maximum residual packet capacity (MRPC) which uses battery residual energy and expected energy spent metric (the main contribution) in route selection. Thus the cost metric includes the node parameter (battery capacity) and link parameter (packet transmission energy). The main motivation is that link characteristics can influence the energy consumption and can lead retransmission of packets.

6) *Battery Sensitive Routing:* The work of [19, 20] study the lifetime of the battery and had proposed algorithms to improve battery capacity.

D. *Load Balancing*

Load balancing techniques may improve network performance through traffic spread. It also helps in balancing the power consumption among nodes in addition to reduction in end to end delays, robustness of data delivery. Load balancing techniques is advantageous for ensuring the even distribution of traffic thereby may help in efficient energy utilization may affect network lifetime. Two types of load balancing techniques have been proposed [5].

1) *Single Path Routing*: In this, algorithm finds more than one paths but according to some criterion such as minimum hops only one is selected. All single path routing algorithms (WAL, LBAR etc.) apply suppression or prevention policy. In both policies intermediate nodes do not respond for route requests. Suppression policy avoids the use of most loaded nodes while prevention policy is used to obtain fresh routing information. Though suppression policy is not being implemented for energy reasons but may be used to save energy.

2) *Multipath Routing:* Being a load balancing technique it may be advantageous for extending network lifetime. It is found to be a promising fault tolerance technique [5] for MANET. The use of backup paths may lead to less packet loss, makes communication sessions last longer and provides robustness to mobility and fading. And all these factors result in less energy consumption so there is a potential benefit that network lifetime can be increased. But the shared nature of radio medium may influence the execution of multipath techniques because paths need to be node and link disjoint so making it difficult compared to single path routing.

E. *Other Approaches*

Ad hoc backup node setup protocols had been proposed to improve DSR performance in case of link failure. This is achieved by adding backup routes [25]. But the backup routes may have changed due to topological changes by the time is required as an alternative means in case of a link failure in the primary route. And the changes in the topology are not reflected in backup route [25]. Way point routing protocol (WPR) divides the network into segments through waypoints (some intermediates nodes) and DSR is used for inter segment and AODV for intra-segment routing. WPR suffers significant overhead to re-establish a new global route discovery [25]. Generalized Salvaging Mechanism (GSM-DSR) uses two optimization techniques called “Generalized salvaging mechanism and cache update of intermediate nodes. GSM search for an alternative route in upstream nodes cache. Localized route repair (LRR) scheme can be implemented on any on demand routing protocols. LRR defines a neighbor node as a node, which is on the route and is in the instant neighborhood of the moved node. The approach repairs the broken link locally. Repaired backup approach tackles link failure by backup routes and these routes are generated from the destination node to the source node along with the best route during route discovery.

In [21] MEDSR (Minimum energy dynamic source routing) and HMEDSR (Hierarchical minimum energy dynamic source routing) protocols are proposed. The MEDSR uses different power levels (two) during route discovery process to identify low energy paths. After finding the path, the transmit power levels of the nodes along those routes are adjusted link by link to the minimum required level. But it uses flooding during route discovery process resulting overhead in large networks. This affects routing performance severely. Although overhead packets are not in large number but consume significant amount of energy. So to overcome this (routing control and MAC packets) HMEDSR is proposed. It is the combination of HDSR (hierarchical dynamic source routing) and MEDSR. HDSR helps in reducing overhead packets and MEDSR saves energy in transmitting data packets. Author has not tested the influence of mobility on the proposed protocols. In [22] the author quantitatively measures the inaccuracy of state information of nodes in optimized link state routing (OLSR) routing protocol. State information may be such as residual energy level, queue length and link attribute such as bandwidth, delay and error rate etc. A node may have outdated information about the residual energy of other nodes. So the author measured the inaccuracy present and also proposed two approaches to improve inaccuracy prediction and smart prediction. In prediction last two values are taken to determine the consumption rate of other nodes at a particular instant of time. And smart prediction is applied in case information about other nodes is absent. So its residual energy value is predicted by taking the average consumption rate of others (if present) or itself. In [23] author has proposed new cost function for determining the cost of the route from source to destination. The cost function includes many variables like unstable_nodes_count (a), number_of_neighbors (b) and buffered_packets (c). These variables are added to route request packet in addition to amount of data source wants to send. During route discovery intermediate nodes adds their values of these variables to the existing values in route request packet. Over the route, nodes have different number of neighbors, buffered packets and different number of unstable nodes. A node is called stable if its certain number of neighbors (40%) does not change during a fixed time interval (say 3 seconds). The destination receives the route request with cost function value calculated for the traveled path and stores it in the buffer for the fixed time. If in the mean time another route request comes with smaller cost function value then previous route request is discarded. Otherwise wait for the fixed time to expire and retrieve the stored route request and send the route reply. In it the nodes over the path with more number of neighbors are discouraged as they will do overhearing and will loss energy soon. Similarly path with stable nodes is encouraged otherwise path breaks are likely to occur and cause maintenance phase to start will result in energy loss. In continuation to this nodes with buffer queues cause timer expired causing retransmission resulting in energy loss. In the technique a node forwards the route request if nodes remaining lifetime is more than the needed to send the packet. Otherwise it drops the request packet. The nodes lifetime is calculated by its residual energy and drain rate. [24] Has proposed the method to minimize broadcasting overhead. Three different techniques are being used namely

flooding, probability based flooding and clustering. The flooding is used to find the location information of nodes and clustering (K Mean algorithm) is used to minimize overhead which in turn will result in energy efficiency. Several other techniques have proposed to improve the performance of on demand routing protocols in case of link failures such as Backup source routing, modification of DSR protocol, packet received time and link expiration time etc.

IV. CONCLUSION AND FUTURE WORK

Most of the energy related study in MANET at routing layer has been done to reduce energy consumption in either transmission or suggesting a different routing approach altogether but following the same concepts as being used by standard routing protocols. Few have explored the idea to reduce the energy consumption due to routing overheads. So this study gives an insight by reviewing the various routing techniques so that the energy consumption due to overheads and mainly due to link failures can be investigated. In the investigation, efforts can also be put to analyze the stability of links along with the proposal of some measures to reduce the energy consumption. Thus, necessitating the investigation of various routing techniques in view of link failure and overhead.

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