A Singular Energy and Load Aware Node-Disjoint Multiple Paths Scheme

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Abstract : Today, wireless networks have been very popular in the computing industry. In this work, a singular energy and load aware node-disjoint multiple paths scheme have been introduced, The main purpose of this scheme is to extend the average lifetime for each node while balancing the total energy consumption, by using the truthful distribution of loads among all nodes within the network. AODV protocol's implementation in ns2 has been modified to include this proposed scheme and called it the energy and load aware Ad-hoc On Demand Routing protocol (ELA-AODV). The usage of ns2 simulator, two experiments have been introduced to compare ELA-AODV towards pure AODV, primarily based on energy and load aware related performance metrics, after which ELA-AODV against pure AODV and based on energy and delay aware associated performance metrics.

Index Terms **– Congestion control, Load aware technique, Load balancing, MANETs, Multipath routing.**

I. INTRODUCTION

Congestion in routing leads to high energy consumption, packet loss, and longer delays, and it may decrease the network service quality. So that energy and load aware technique in routing is used to identify the optimal nodes in network. These optimal nodes using to find an optimal path from the source to the destination [1]. The proposed method increasing the throughput ratio and decreasing the end- to- end delay.

There are a number of situations that might be put into overcrowding but are not restricted to traffic volume, the fundamental network architecture, and the requirement of devices in the network such as buffer space, transmission rate, processing power, etc. An effective manner or approach to manage the resource in communication network might enrich the quality of service of the mobile ad-hoc network. In mobile ad hoc network (MANET), congestion is one of the most important restrictions that deteriorate the performance of the whole network. Multipath routing can balance the load better than the single path routing in ad hoc networks, thereby reducing the congestion by dividing the traffic in several paths [2].

This paper is to present the energy efficient and routing efficient load balancing approach for MANET mobile ad hoc networks with goal of overcoming the limitations of methods presented in literature review. The main objectives of this research study is to study and analyze existing load balancing and energy efficient protocols for mobile ad-hoc networks (MANETS), to propose load balancing and energy efficiency protocol in MANET and to present the comparative study between proposed load balancing Technique as well as energy efficiency method with existing techniques [3].

II. ENERGY AND LOAD AWARE NODE-DISJOIINT MULTIPLE PATHS ROUTING SCHEME

W The proposed routing scheme depends on three mechanisms that integrate with each other through the routing discovery and route maintenance phases to discover, establish and maintain a multiple power and load aware reliable disjoint connections between source nodes and their destinations that can extend the network's nodes operational life and maximize the network lifetime [4]. These mechanisms are listed below:

2.1 Energy and load aware cost function

A cost value that is based on nodes estimated lifetime will be calculated for each node that participates in the route discovery processes. According to this value, the optimal paths will be selected. The optimal path is a path with the lowest cost and with a higher cost of the bottleneck node [5].

2.2 Node-disjoint paths

Although establishing multiple paths between source and destination pairs has many benefits over unipaths, multiple paths may intersect in one or more common nodes. Although the traffic is separated between these paths, these common nodes will get depleted faster as the traffic load on these nodes will be much higher than the other nodes of the paths, thereby more route discovery processes will be initiated and more resources will be consumed [6]. Besides, with the increase of the dynamicity of the network, the probability of path failure increases, these common nodes may move away from its one hop neighbor's transmission. Range at any time due its mobility nature. To avoid this problem, the node disjointness between the two optimal paths will be granted at the selection paths process, i.e. two optimal paths that don't have any common nodes except the source and the destination will be selected. This protects the network from the partitioning problem and saves more resources.

III. COST VALUE OF THE NODE

In this proposed scheme; route selection process considered as a part of the route discovery phase, the main target of this process is to select the optimal paths from a set of available paths that can connect a specific source node to its desired destination [7]. The cost function is defined as follows:

$$\mathrm{F(C_j)} = \frac{1}{\mathrm{Lt_j(t)}}$$
$$\mathrm{Lt_j(t)} = \frac{\mathrm{E_j(t)}}{\mathrm{ETR_j} * \mathrm{P}_{\mathrm{ji(t)}}}$$
$$\mathrm{ETR_j} = \left(1 - \mathrm{e}\frac{\mathrm{timegap}}{\mathrm{k}}\right)\left(\frac{\mathrm{pktsize}}{\mathrm{timegap}}\right) + \left(\mathrm{e}\frac{\mathrm{timegap}}{\mathrm{k}} * estrate\right)$$

$F(C_j(t))$ = cost of node j at time t
$L_{tj}(t)(s)$ = estimated life time of node i at time t
$E_j(t)$ = battery capacity of node j at time t
ETR_j(bits/sec) = estimated incoming traffic rate of node j at time t
$P_{ij}(t)$ = transmission energy of node j to send a packet at time t
Timegap(s) = difference between current time and the time of last packet arrival
K(s) = average interval for rate estimation in seconds
Pktsize(bit) = length of the packets
Estrate (bits/sec) = current flow of estimated rate

3.1 Calculation for cost value of the node

$$\mathrm{ETR_j} = \left(1 - \mathrm{e}\frac{\mathrm{timegap}}{\mathrm{k}}\right)\left(\frac{\mathrm{pktsize}}{\mathrm{timegap}}\right) + \left(\mathrm{e}\frac{\mathrm{timegap}}{\mathrm{k}} * estrate\right)$$
$$\mathrm{ETR_j} = \left(1 - \mathrm{e}\frac{0.5(\mathrm{sec})}{2\mathrm{sec}}\right)\left(\frac{512}{0.5}\right) + \left(\mathrm{e}\frac{0.5}{2} * 5\right)$$
$$\mathrm{ETR_j} = (1 - \mathrm{e}^{0.25})(1024) + (\mathrm{e}^{0.25} * 5)$$
$$\mathrm{ETR_j} = (1 - 1.2840)(1024) + (1.2840 * 5)$$
$$\mathrm{ETR_j} = (0.2840)(1024) + (6.42)$$
$$\mathrm{ETR_j} = 297.326\mathrm{bits/sec}$$
$$\mathrm{Lt_j(t)} = \frac{\mathrm{E_j(t)}}{\mathrm{ETR_j}*\mathrm{P}_{\mathrm{ji(t)}}} \qquad \mathrm{Lt_j(t)} = \frac{10}{297.236*0.2}$$
$$\mathrm{Lt_j(t)} = \frac{10}{59.4472} = 0.16821$$
$$\mathrm{Fc_j(t)} = \frac{1}{\mathrm{Lt_j(t)}} = \frac{1}{0.16821} = 5.9449$$

This proposed cost value function considers not only residual battery capacity and transmission signal energy of specific node but additionally estimated incoming traffic rate [8]. So that it may be used to estimate the arrival rate for both entire queues as well as flows. The estimation of the incoming traffic rate of a specific node has a direct effect on its energy depletion rate, due to the energy consumption in processing, receiving and retransmitting this traffic.

3.2 On-demand multipath routing:

This proposed scheme depends on selecting multiple optimal routes between the source and its destination that guarantees the reliability of connections and increases the fault tolerance. Source nodes always have alternative paths to their destination nodes, and this will reduce the frequency of initiating route discovery processes, thereby energy consumption in route discovery process will be reduced [9]-[13]. In On-Demand routing strategy, the initiation of route discovery process occurred only when the source node needs to route data packets to a specific destination and does not have any cached route to it, thus saves energy and other network's resources which can be wasted through the periodic exchange of information that occurs in other routing strategies. Besides that, using multipath routing technique with the On-Demand routing will minimize the number of route discovery process, as in most cases, source node has an alternative optimal path to its desired destination.

IV. LOAD AWARE ALGORITHM

Load aware algorithm is based on AODV, where protocol messages extensions are used to accomplish QoS and load-balancing features. The current average load is computed and is made available to the network layer through the cross layer approach. The current average load of a node is defined as the ratio of time in which the channel observed busy to a specific observation time [14]-[17]. Load aware follows the basic steps as the original AODV; however it utilizes the accumulated path load indicator as routing metric instead of the hop count used by AODV. Load aware starts the route discovery phase when a node needs to transmit a packet to a destination. The node begins to transmit when the route to the destination is known. The node floods RREQ packets in case of unknown route to the destination to the neighbor nodes. These packets contain the Path indicator. When intermediate node receives a RREQ packet, it checks firstly if it is the first time to have this RREQ packet [18]. In first time case, the node adds a new routing entry in its own routing table and its current average MAC load to the value of path indicator of the RREQ packet and then propagates the RREQ packet.

If not, the node compares the Path indicator value of the RREQ packet with the value of Routing table path indicator in its own routing table. The RREQ packet is dropped, when the value of PI is greater. The value of Routing table path indicator is changed to the value of Path indicator. Then adds the node its current average load to the value of Path indicator filed of the RREQ packet and propagates the RREQ packet.

When the destination node receives the RREQ packet, it sends a RREP packet to the reverse route created by the intermediate nodes. Each node in the reverse route adds its current average load to the Path indicator of the RREP packet. Load aware AODV drops the RREP packet in the node receiving the packet, when the current average load of the node is greater than a maximum threshold. The source node starts to transmit its packets, when it receives the RREP packet Load Aware AODV deals with route maintenance as the original AODV [19][20].

4.1 Load aware algorithm for RREQ

```
1.BEGIN
   (When a node receives a routing message)
2.IF (message type = RREQ){
    IF (the node is the source of RREQ)
         THEN {(drop RREQ)
           END }
          ELSE IF (RREQ has been received before)
3.ELSE {Drop RREQ
4.END
  } ELSE {Adding of new routing entry
5.RTPI = PI
 }(Reverse Route Creation in Routing Table)
6.IF ( the destination)
 Then (Sending Of  RREP Packet)
7.ELSE {PI = PI + CURRENT LOAD
8.Forward RREQ
 }
9. END
```

4.2 Load aware algorithm for RREP

```
1.IF (message type = RREP)
2.IF (RREP has been received  before)
   THEN
    ELSE {Drop RREP
    END }
3.ELSE {Adding of new routing entry
4.RTPI = PI
}
5.IF ( the destination)
6.Then (send packet)
 ELSE {
7.IF (CURRENTLOAD < MAX_THRESHOLD)
8.PI = PI + CURRENT LOAD
THEN (Forward RREP)
 ELSE (drop RREP)
}
9. END
```

V. NODE DISJOIINT RATION PROCEDURE

The Disjoint ratio procedure assessments the disjointness between paths, or in this situation between the primary path and different stored paths, if two or more paths have the same disjoint ratio with the number one path, the route with the bottom Pcost is chosen as the secondary one. The disjointness between the primary route and some other route may be calculated using the following equation:

Disjoint ratio = $(|P_r - P|)/(|P| - 2)$

where:

P_r: is the set of nodes of the primary path.

P: is the other path.

Note that Disjoint ratio is a value between 0.0 and 1.0.

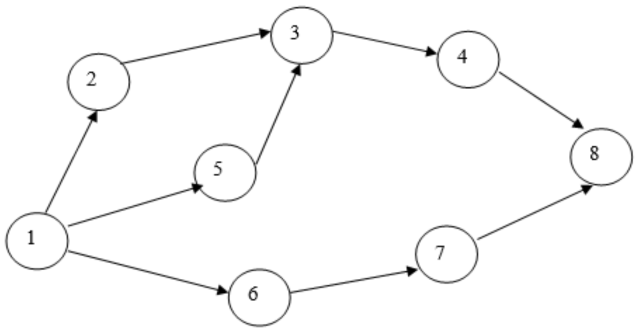

Fig.1 An example of finding optimal path using disjoint ratio.

Fig.1 depicts a simple MANET. Node 1 (source node) wants to find more than one disjoint paths to node 8 (destination node). Node 1 will initiate a route discovery process and RREQ packets may be flooded through this network to discover a path from node 1 to node 8. At the end of this process, node 8 will receive 3 RREQ packets with 3 paths from node 1 to itself.

The three paths are:

P1 = {1, 2, 3, 4, 8}.

P2 = {1, 5, 3, 4, 8}.

P3 = {1, 6, 7, 8}.

Assume that P1 is the route with the lowest Pcost value, so node 8 will select it as the primary path, an RREP packet will be generated and can be sent back with the primary path to node 1. Node 1 has a clean and a valid optimal path to its destination, and data transmission can be started immediately. After that, node 8 has to check the disjointness among P1and (P2, P3) the use of disjoint ratio procedure as follows.

1) P1 = {1, 2, 3, 4, 8}, P2 = {1, 5, 3, 4, 8}

Disjoint ratio = (|P1 – P2|)/(|P2| − 2) = (1)/(5 – 2) = 0.3

2) P1 = {1, 2, 3, 4, 8}, P3 = {1, 6, 7, 8}

Disjoint ratio = (|P1 – P3|)/ (|P3| − 2) = (2)/ (4 – 2) = 1.0

Primarily based on these disjoint ratio values, node 8 will consider P3 as an ultimate node disjoint path, another RREP packet can be generated and sent back to node 1. Now source node has an alternative path to 8 in the case of P1 failure. From the previous two cases, it's clear that the extra the quantity of common nodes between two paths decreases, the more disjoint ratio value receives high, and when the disjoint ratio value equals to 1.0, that means that those paths are completely node-disjoint paths. Note that the concern is to select a path without common nodes with the primary one, even though it isn't always the path with the lowest Pcost value most of the candidate paths. The process of disjoint ratio is provided in Fig. It takes paths and calculates the disjoint ratio value of them. Wherein P1 is the primary path, P2 is the secondary path to examine with the primary route, remember is a counter to record how many nodes differs and disjoint ratio is the disjoint ratio of P1 and P2.

VI. Simulation Results

As mentioned before, the main target of this evaluation is to compare the energy and delay related performance under different traffic loads of ELA-AODV protocol against AODV protocols. The simulation was repeated 10 times with a different number of nodes (50 nodes) for each protocol. Through the first five times, simulation scenarios were run under static networks, then repeated for another five times under dynamic networks, using a maximum node speed equal to 10m/s to study the effect of the node mobility on performance indexes. For each five times, the traffic loads were escalated from light to heavy loads After running the simulation scenarios, trace files were generated then results were extracted. Results of the first experiment are depicted in compares how many nodes are died at the end of the simulation, due to the expiration of the battery capacity in static and dynamic networks. Observed that at the end of the simulation above 50% of the simulated nodes still alive even with high traffic loads**.** Fig 2 the contrast between the number of dead nodes for each protocol in dynamic and static networks is expected, ELA-AODV registered better results in static networks than pure AODV did, due to the composite cost metric and the predefined threshold. ELA-AODV eliminates nodes with high traffic load or with low residual battery capacity in the route discovery process. Such behavior is closely related to the network's lifetime. In dynamic networks ELA-AODV showed an enhanced performance closed to pure AODV in case of static network, and better in some cases, that could led us to the fact that the dynamicity of the network does not have a great effect on ELA-AODV, as in most cases source node has an alternative paths to its destination and does not have to consume more energy in initiating route discovery processes and broadcasting control Packets.

Regardless of the number of dead nodes at the end of the simulation, ELA-AODV takes more time than pure AODV do, until the failure of the first node occurs. This is due to, 1- the distribution of traffic loads in a balanced manner between all possible paths, 2- the decrease of the need to initiate the route discovery processes, in case of alternative paths existing, 3- and the predefined threshold that protect exhausted nodes from participating in any route discovery processes and consuming more energy during forwarding control packets, so each node keeps its energy as long as possible. Fig. 3 shows that the increase of traffic loads led to an increase of average end-to-end delay, AODV registered close results, but because of the energy and delay aware algorithm that reduces the delay for packets, it registered a better performance. ELA-AODV registered lower results with light traffic loads due to the time that nodes take in processing data at route discovery processes, this wasted time lost its influence with the increase of traffic loads, as the delay during a single route discovery process that could be initiated one time or twice does not affect the performance of the network as other two protocols do during initiating more and more routing discovery processes with the increase of traffic loads.

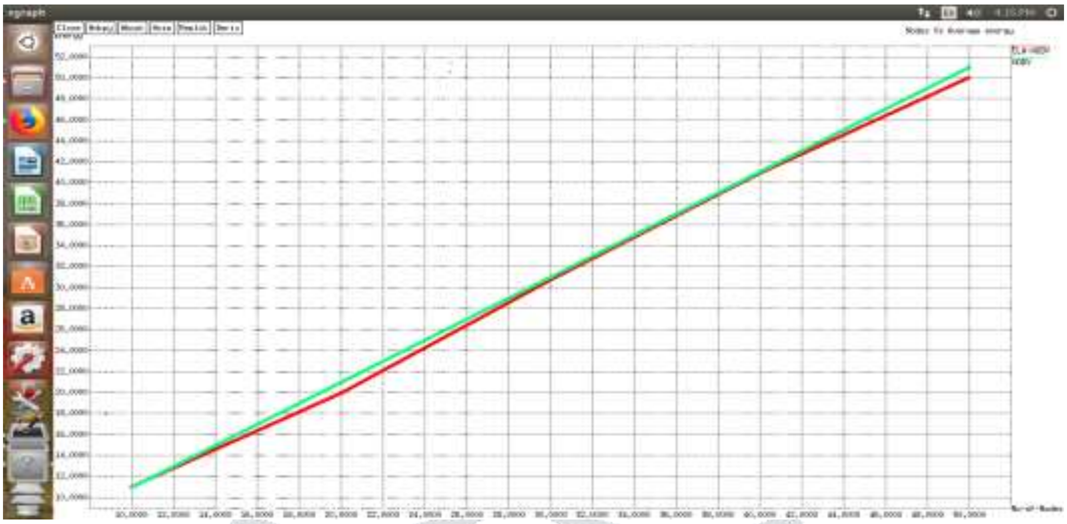

Fig. 2 energy consumption vs number of nodes

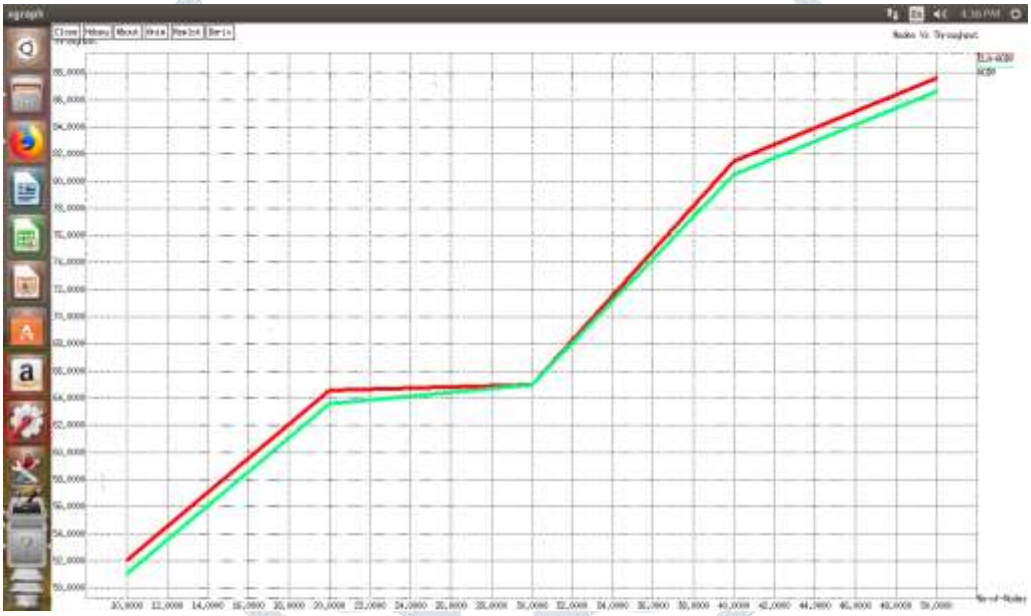

Fig. 3 Average end to end delay vs packet Rate.

Fig. 4 Network Throughput vs. number of nodes

Summarizing all performance results of the previous two experiments in our simulation, concluded that ELA –AODV protocol is able to extend the operational life of network's nodes and thus its lifetime, by avoiding the exhaustion of node power resources, that are usually consumed in processing streams of control packets, and also by the fair distribution of traffic loads among all nodes of the network. During the simulation time ELA-AODV works in two main directions to achieve its goal.

First, it tries to decrease the number of control packets by minimizing the need of initiating route discovery process, in the case of link failure, whether because of the dynamicity of the network or the overloading on the path. This has been achieved by 1- providing an altar- native path to the source node to use when the failure of the primary path occurs. 2- The predefined threshold that prevents the exhausted node from participating in more route discovery processes. Second, it tries to distribute traffic loads in a balanced manner by 1- using the proposed cost metric, that consider the remaining energy and the estimated incoming traffic loads of the node. 2- Comparing the candidate paths using Pcost and Mcost values, which are based on the cost metric. 3- Applying the node-disjoint manner to avoid paths that intersect in one or more nodes.

VII. Conclusions

In this work, a singular energy and load aware node-disjoint multiple paths scheme have been introduced, The main purpose of this scheme is to extend the average lifetime for each node while balancing the total energy consumption, by using the truthful distribution of loads among all nodes within the network. AODV protocol's implementation in ns2 has been modified to include this proposed scheme and called it the energy and load aware Ad-hoc On Demand Routing protocol (ELA-AODV).The usage of ns2 simulator, two experiments have been introduced to compare ELA-AODV towards pure AODV, primarily based on energy and load aware related performance metrics, after which ELA-AODV against pure AODV and based on energy and delay aware associated performance metrics. As expected ELA-AODV registered a higher performance in maximizing network's lifetime regardless of the load in this network increases, because of its enhanced route discovery phase that includes an energy and load conscious associated value function rather than hop count, to distinguish among available paths from specific source to its destination, and also, due to the predefined threshold that exhausted nodes from taking part in route discovery processes. Results also discovered that networking. Results also discovered that networks that use ELA-AODV as a routing protocol showed an advanced capacity to evolve to the growth of their nodes mobility over the ones whose use natural AODV. This next step is to use this scheme to wireless sensor networks, and implement it in NS3 simulator.

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