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Energy Efficient Ad-hoc on-Demand Distance Vector Routing Protocol for MANETs'

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Abstract- A group of wireless devices forms a self-configured MANET. The Mobile Nodes make communication over the wireless links without any prefixed administration. The nodes in ad-hoc networks are battery operated and have limited energy resources. This makes energy efficiency a key concern in ensuring system durability. This paper suggests an Energy Efficient AODV to the MANET. It illustrates the energy conservation technique to improve the routing protocol efficiency. The energy conservation is attained in the MAC layer. It deals with the proposed energy conservation scheme. It explains the relation of routing overhead and energy conservation and it deals with the routing overhead reduction. It calculates the available and required energy of communication node and it evaluates the conserved energy level. It simulates the consuming energy in EE-AODV and, it compares the simulation result with AODV protocol.

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I. Introduction

The nodes in ad-hoc networks are battery operated and have limited energy resources. This makes energy efficiency a key concern in ensuring system longevity. Further, studies have shown that the communication subsystems consume a large fraction of total energy and therefore, solutions for energy efficient communication are of great interest. Moreover, under some circumstances, MANET has to be deployed in remote or hostile areas [1] [2]. This makes it impossible to replace or recharge the batteries. Therefore, it is desirable to keep the energy-dissipation level as low as possible to avoid frequent battery replacement. Energy conservation has posed a big challenge due to MANETs' nature of distributed control, constantly changed network topology and the fact that mobile nodes in MANETs usually are hand-held devices[3][17].

In mobile ad hoc networks, energy efficiency is more important than other wireless networks. Due to the absence of an infrastructure, mobile nodes in ad hoc network must act as a router. Since a MANET is a 'cooperative' network, the nodes join in the process of forwarding packets [4]. Therefore, traffic loads on nodes are heavier than in other wireless networks with fixed access points or base stations. A communication- related energy consumption function is needed to design a system to limit unnecessary power consumption [5][14]. Energy efficiency design issue must consider the trade-offs between different network performance criteria. For example, routing protocols usually try to find a shortest path from a source to a destination. It is likely that some nodes which are on so called 'key positions' will over-serve the network and their energy will be drained quickly, and thus causes the network to 'break'. To avoid this, the energy-efficient design should balance traffic load among nodes such that low- power nodes can be idle while traffic is routed through other nodes [6][13].

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II. Energy Management

One of the basic characteristics of MANET is the multi-hop connection, in which the Mobile Nodes cooperate to relay traffic to the distant Destination Node. Hence, the Mobile Nodes in MANET serve not only as hosts, but also as routers. The multi-hop connection can also increase the network capacity and decrease the energy nodes to fulfill the multi-hop transmission. Basically, the routing protocol chooses the best route between the source and Destination Node in the network topology and strictly limited resources [7] [12] [16]. However, the single path routing is not the best solution. The Multi-Path AODV protocol is then introduced, which provides redundant and alternative routes to assure successful data packet transmission. At the same time, it does not reduce the key relay nodes' power consumption and the energy exhaustion is alleviated in the network partitioning problem. However, due to the frequently changing network topology and limited resources of energy and wireless bandwidth, routing in MANET is an extremely challenging. Hence, the EE-AODV is proposed.

III. Related Work

For conserving energy, many energy-efficient routing protocols have been proposed [8], [9], [10]. These protocols can be generally classified into two categories: Minimum Energy routing protocols [3], [4], [5] and Maximum Network Lifetime routing protocols [9]. Minimum Energy routing protocols search for the most energy-efficient path from the source to the destination, while Maximum Network Lifetime routing protocols attempt to balance the remaining battery-power at each node when searching for the energy-efficient path. Since Minimum Energy routing scheme is also an important part in most recent Maximum Network Lifetime routing protocols such as Conditional Max-Min Battery Capacity Routing (CMMBCR) [9] and Conditional Maximum Residual Packet Capacity (CMRPC) routing [10], we will focus on developing more efficient Minimum Energy routing protocols in this research work.

Li and Wan [20] described a distributed protocol to construct a minimum power topology and developed an algorithm which directly finds a path whose length is within a constant factor of the shortest path. The length of the path is measured in term of energy consumption. This proposed algorithm used only local information. A topology based on minimum spanning tree, called localized minimum spanning tree (LMST) was proposed by Li et al. [21]. It is a localized distributed protocol with the following properties: (1) the protocol generates a strongly connected communication graph; (2) the degree of any node is at most six, and (3) the topology can be made symmetric by removing asymmetric links without impairing connectivity.

An energy efficient dynamic path is maintained to send data from source to destination for MANET is proposed in Sheu, Tu, and Hsu [22]. Due to mobility existing paths may not be energy efficient. So, each node in a data path dynamically updates the path by adjusting its transmission power. Each node in the networks determines its power for data transmission and control packets transmission according to the received beacon messages from its neighbors. In dynamic path optimization technique protocols dynamically select energy efficient path as per the requirement of dynamic topological changes in the network [23][15.

Localized Energy Aware Routing (LEAR) Protocol is based on DSR but modifies the route discovery procedure for balanced energy consumption. In LEAR, a node determines whether to forward the route-request message or not depending on its residual battery power (Er). Conditional max-min battery capacity routing (CMMBCR) Protocol uses the concept of a threshold to maximize the lifetime of each node and to use the battery fairly [6].

IV. Materials and Methods

a) *Energy Efficient Ad-Hoc On-Demand Routing Protocol*

The Energy management issues are very important in the context of MANET. The node energy needs to be optimally utilized so that the nodes can perform their functionality satisfactorily. MANETs are energy constrained as most Ad-Hoc nodes to day operate with limited battery power [11]. So, it is important to minimize energy consumption of the entire network in order to maximize the life time of the network. Hence, a new on-demand routing protocol (EE-AODV) is proposed. As per the method, the EE-AODV selects a route at any time based on the minimum energy availability of the routes and the energy consumption per packet of the route at that time.

i. *Selection of Minimum Energy Node*

The energy efficiency is attained through the energy conservation and the routing overhead reduction in network. A new power-aware routing protocol is suggested to balance the traffic load using distributed energy control. Since, it aids to increase the battery lifetime of the nodes. Hence, the overall useful life of the MANET is increased. These protocols are based on the conventional AODV. Congested node is able to serve the flows at a higher rate, and then sources are automatically able to send packets at a higher rate. These EE-AODV extensions increase the network survivability and lead to a longer battery life of the terminals. They achieve the balanced energy consumption with minimum routing overhead.

ii. *Calculation of Node Energy Level*

The main objective is to balance energy consumption among all participating nodes. In this approach, each mobile node relies on local information about the remaining battery level. It aids to decide whether to participate in the selection process of a routing path or not. An energy-hungry node can conserve its battery power through the activation of sleeping during the idle time. The available energy level and the required transmit power level of a node are taken into account while making routing decision. The subtraction of current available energy levels and the required transmit power levels of nodes indicate how likely these nodes are depletes battery energy. In order to do that a Source Node finds a minimum energy route at a time t such that the following cost function is maximized.

$$C(E, t) = \max \{Erem\} \quad (1)$$

$$Erem = Eavailable(t) - Erequired(t) \quad (2)$$

Where, Erem is the remaining energy of node, Eavailable(t) is the available energy of node, Erequired(t) is the required transmit power of a packet at node. The energy required in sending a data packet of size D bytes over a given link can be modeled as:

$$E\ (D) = K1\ D + K2 \quad (3)$$

$$K1 = (Pt\ Packet + P\ back) \times 8/BR \quad (4)$$

$$K2 = ((Pt\ MAC\ DMAC + Pt\ packet\ D\ header) \times 8/BR) + E\ back \quad (5)$$

Where, Pback and E back are the background power and energy used up in sending the data packet, Pt MAC is the power at which the MAC packets are transmitted, DMAC is the size of the MAC packets in bytes, D header is the size of the trailer and the header of the data packet, Pt packet is the power at which the data packet is transmitted and BR is the transmission bit rate. Typical values of K1 and K2 in 802.11 MAC environments at 2Mbps bit rate are 4μs per bytes and 42μs respectively.

iii. *Algorithm For Overhead Reduction*

Step 1: Source broadcasts RREQ packets are forwarded to its neighbor nodes within the coverage area

Step 2: The neighboring nodes re-broadcast the RREQ packet

Step 3: Destination forwards the RREP packet only to the first received RREQ packet

Step 4: Source address, destination address and previous node addresses are stored during RREP packet

Step 5: The data packet contains only source & destination addresses in its header.

Step 6: When the data packet travels from source to destination, through intermediate nodes, for re-broadcasting of data packet, the node verifies source and destination addresses in its cache. If it is present, the data packets are forwarded, otherwise it is rejected.

Step 7: After re-broadcasting the data packet, acknowledgement are sent to the previous node

In AODV, each mobile node has no choice and must forward packets for other nodes. In EE-AODV, the Source Node forwards the packet to the Destination Node. During this process, the Source Node forwards a RREQ packet to the intermediate nodes. The intermediate nodes initially in the sleeping state, awakens when the RREQ packet arrives and it forwards to the next node and again it is going to the sleep node.

In EE-AODV algorithm, the intermediate nodes are sleeping during idle time and the only antenna of the nodes consumes power. All other parts of the nodes are in the doze mode. So, whenever a packet is arrived at the intermediate node, the node awakens and it transfers the packet to the next node according to the AODV algorithm and then again goes to the sleep mode. So using this way, the intermediate nodes consumes its energy.

V. Performance Evaluation

The performances of the proposed algorithms are evaluated using ns2 simulator. The traffic pattern and the metrics are described which are used for the experiments. The scenarios can also be exported for the network simulators ns-3, GloMoSim/QualNet, COOJA, MiXiM, and ONE.

Table 4.1 : List of Simulation parameters

Parameter	Value
Simulator	Ns2 - 2.26
Number of nodes	30 , 50, 100
Simulation Time	20 min
Packet Interval	0.01 sec
Simulation Landscape	1000 x 1000
Traffic Size	CBR
Packet Size	1000 bytes
Queue Length	50
Initial Energy	10 Joules
Node Transmission range	250 m
Initial Energy	100 Joules
rxPower	0.3 W
txPower	0.6 W
Antenna Type	Omni directional
Mobility Models	Random-waypoint (030m/s)
Routing Protocol	AODV
MAC Protocol	IEEE 802.11
Background Data Traffic	CBR

a) *Simulation Environment*

The size of environment is 500 x 500 m2, and every node moves at random as well as its position. Radio transmission range of node is 250 m and its way of wireless communication is free space. In addition, MAC protocol is set to 802.11. The number of nodes is variable for different measurement, which is illustrated specially.

b) *Mobility Pattern*

The mobile movement is set as per random way point model. In the node mobility, the Mobile Nodes selects the random way point to move, and a node stay its location for a pause time before the next move. The simulation is varied under different size and mobility model. The varied pause time of Mobile Nodes is 600 and 300 seconds and node velocity is 0-25 m/s.

c) *Traffic Pattern*

The data traffic is generated using CBR. The number of source and destination pairs is varied. The battery capacity for each node is five units.

d) *Simulation Metrics*

i. *Packet Delivery Fraction (PDF):*

It is the ratios of total number of packets successfully received at the Destination Nodes to the number of packets are forwarded from the Source Nodes throughout the simulation.

$$\text{PDR} = \frac{\text{Number of Received Packets}}{\text{Number of Sent Packets}}$$

PDF estimate gives us an idea of how successful the protocol is in delivering packets to the application layer. A high value of PDF indicates that most of the packets are being delivered to the higher layers and is a good indicator of the protocol performance.

ii. *Average End to end delay of data packets:*

$$AED = \sum_{i=0}^{n} \frac{(\text{Time of packet Recived} - \text{Time of Packet Sent})}{\text{Total Number of Packets Received}}$$

The AED is defined as the average time from the beginning of a packet transmission at a Source Node until the packet is delivered to a destination. The data packets buffering during the route discovery, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times are included in the data delay. Calculate the send(S) time (t) and receive (R) time (T) and average it.

e) Simulation Results

The Simulation results are illustrated in the aspects of packet delivery fraction and End-to-End delay. The effect on PDF and AED is described.

f) Effect on packet delivery ratio

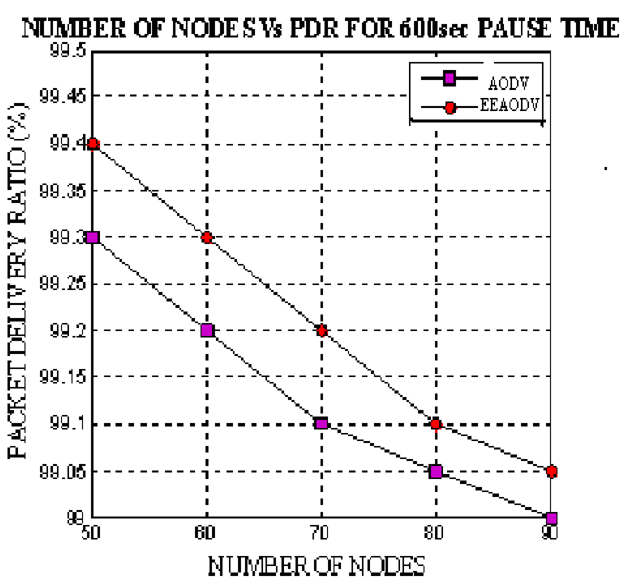

Figure 1 : Packet Delivery Ratio Vs Number of Nodes (Pause Time=600s)

The graph Figure 1 and 2 describes the packet delivery ratio for EE-AODV and AODV is analyzed. From the graph, the EE-AODV packet delivery ratio is higher than the AODV. This is because the AODV is not maintaining the alternative route to the communication path. It rediscovers a route to the destination, when the communication path is failed to transmit the data packets.

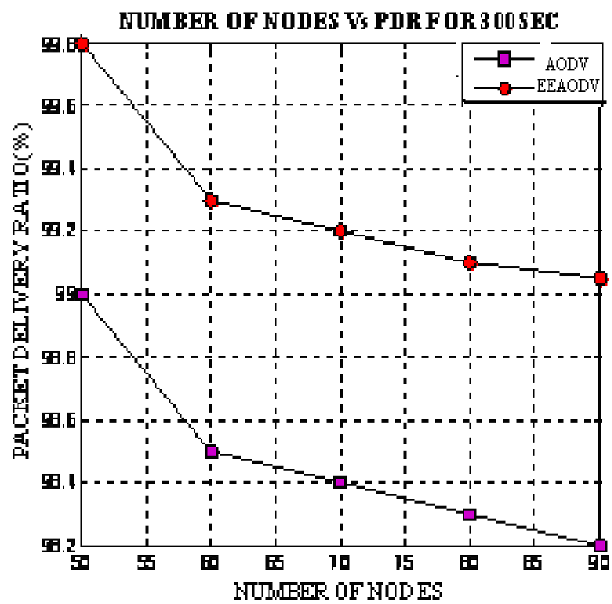

Figure 2 : Packet Delivery Ratio Vs Number of Nodes (Pause Time=300s)

The Packet Delivery Ratio is the ratio of the number of packets received at the destination to the number of packets transmitted from the source. Packet Delivery Ratio reduces as the pause time decreases from 600 seconds to 300 seconds. It is due to the mobility of the network and the probability of link failures increases as the pause time decreases. It is observed that the EE-AODV maintains a better Packet delivery Ratio than the existing AODV. Since, the EE-AODV preemptively selects the alternative path to the communication route. Hence, the communication does not interrupt. It improves the packet delivery ratio under a network with highly dynamic network. From the simulation results, the packet delivery ratio for AODV is 99.3% over the 600 sec pause time, and the 300 sec pause time, it is 98%. The packet delivery ratio for EE-AODV is 99.4% over the 600 sec pause time, and the 300 sec pause time, it is 99.8%.

g) Effect on End-to-End delay

The Figure 3 and 4 describes the packet delivery delay for AODV and EE-AODV. The delay time is high for AODV. Since, it consumes more time to rediscover the routes when the communication path is failed to transmit the data packets. The increased number of nodes also increase the data delivery delay. The End-to-End delay is the time of the transmitted data packet takes to reach destination from the source. As the number of nodes increases, the complexity of the network increases and hence the End-to-End delay increases. As the pause time decreases, the mobility increases, which increases the probability of link failures and hence the End-to-End delay increases.

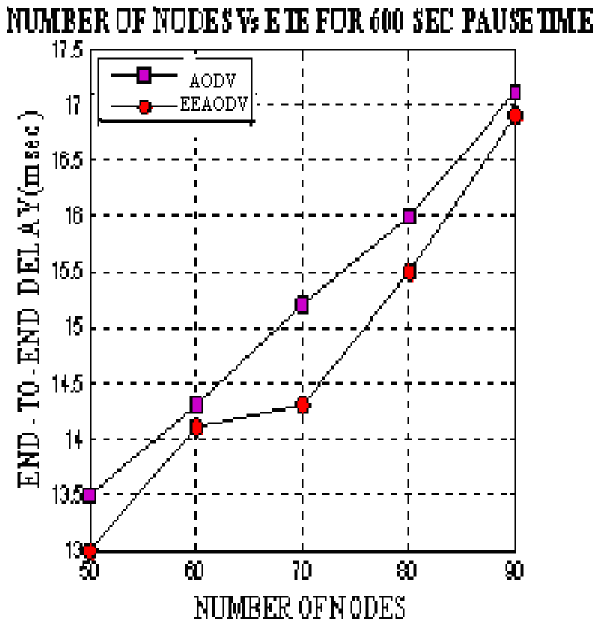

Figure 3 : Delay Vs Number of Nodes (Pause Time=600s)

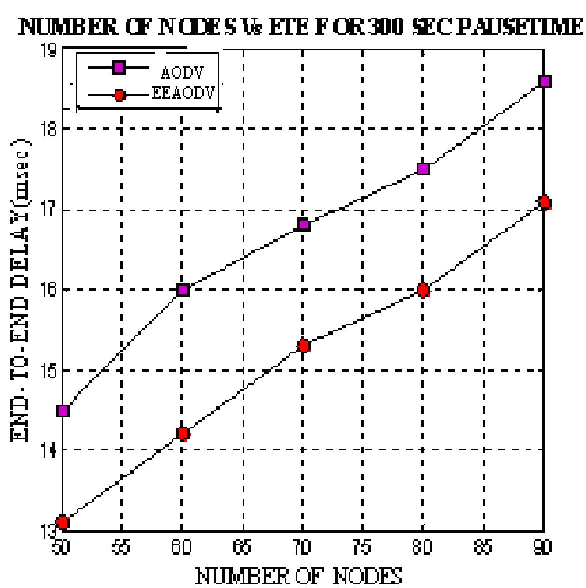

Figure 4 : Delay Vs Number of Nodes (Pause Time=300s)

In EE-AODV, the data packets are delivered using alternative route when the primary path is fail. However, the link failure of alternative routes incurs the data delay but, it is less than the packet delay of AODV. From the simulation results, it has been observed that the End-to-End delay for AODV is 13.5 ms over the 600 sec pause time, and the 300 sec pause time, it is 14.5 ms. The End-to-End delay for EE-AODV is 13.0 ms over the 600 sec pause time, and the 300 sec pause time, it is 13.1 ms.

VI. Conclusion

This paper clearly explained the performance of EE-AODV Protocol. Initially, the energy management and the performance of EE-AODV protocol are described. It clearly explained the minimum energy node selection procedure for EE-AODV. It successfully calculated the node energy level in the selected communication path. It explained the relation between the energy conservation and the routing overhead and also it explained the routing overhead reduction algorithm. It aided to conserve the node energy. This paper simulated the comparative performance of EE-AODV and AODV. It clearly explained the energy efficient performance of EE-AODV is better than the existing AODV.

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