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Cross Layer Energy Improvement in MANET

Raghavendra Gowada, Ramanna S. Havinal
PG, Student M.B.E Society's College of Engineering, Maharashtra,
Professor, CSE Dept., M.B.E Society's College of Engineering, Maharastra

***Abstract*— Most of current routing protocols working on the congestion problem and energy drain in wireless ad hoc networks are affected, because a mobile device has a limited battery and a considerable amount of energy is consumed in wireless interfaces. Many of routing protocols use the shortest path route from source to destination with minimum hop count as optimal route selection. However minimum end to end delay from source to destination may not always achieved through shortest path because of high collision rate and congestion. Here we propose enhancement of end to end delay using multipath routing through cross layer approach that determines the best path selection than shortest path by considering congestion and energy constrains. The contention window doubles its value and packets get transmitted successfully and use the buffer which reduces the overhead in the network. Path selection is mainly based on least cost matrix using contention window, queue size and remaining energy. Along with this use of multipath routing and traffic splitting, lifts the efficiency of network. Performance results shows increase in the packet delivery ratio, throughput and decrease in overhead and latency when compared with pure AODV protocol.**

***Index Terms*— Adhoc on Demand Distance Vector (AODV), Cross Layer Design, Contention Window (CW), Distributed Co-Ordination Function (DCF), Energy Consumption, Mobile Adhoc Networks (MANET), Quality of Service (Qos).**

I. INTRODUCTION

The term MANET stands for Mobile Ad-hoc Network which enables mobile devices to form a temporary community without any planned installation, or human intervention. A MANET is an ever-changing dynamic wireless network established by a group of mobile users needs not necessarily taking any pre-existing infrastructure or using any centralized administration. These networks are very useful in disaster recovery situations or where there is not enough time or resources to configure a wired network. In wireless ad hoc networks, a mobile device has a limited battery and a considerable amount of energy is consumed in wireless interfaces. These characteristics limit the network lifetime of the wireless ad hoc networks. Therefore, many power management schemes have been proposed to reduce [1] the power consumption in the wireless interfaces and thereby increase the network lifetime in the MAC layer using 802.11 standards.

Research in this area is becoming popular due to wide ranging applications supported. MANET's are characterized by fast changing topology, limited battery power and constrained resources. MANET's enable easy deployment as they do not need any infrastructure like base stations. Multipath routing schemes are often seen as a better alternative in not only providing parallel fail safe paths but also seen as a good choice for facilitating network provisioning and realizing QoS guarantees. However, the advantages of multipath routing come at a price as concurrent data transmission along multiple paths interfere with each other. Further, when network traffic starts increasing, there will be increased level of contention among nodes coupled with higher collision level consequently leading to packet drops and network level congestion. So a routing metric needs to be judiciously selected while constructing multiple paths that avoid high interference areas and high contention areas.

A set of ad hoc routing protocols has been proposed in the IETF'S MANET [2] group to ensure the network connectivity. They operate in either proactive or reactive modes. Building such routing algorithms poses a significant technical challenge, since the devices are battery operated. The devices need to be energy conserving so that battery life is maximized. The shortest path is the most common criteria adopted by the conventional routing protocols proposed in the MANET working Group. The problem is that nodes along shortest paths may be used more often and exhaust their batteries faster. The consequence is that the network may become disconnected leaving disparity in the energy, and eventually disconnected sub networks.

Therefore, the shortest path is not the most suitable metric to be adopted by a routing decision. Other metrics that take the power constraint into consideration for choosing the appropriate route are more useful in some scenarios (e.g. sensor networks).

Research on cross-layer design in ad-hoc networks has recently attracted a significant interest [4][5]. It is

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concerned with sharing information between various protocol layers. A simple cross layer design between PHY and MAC layers for power conservation based on transmission power control is proposed in [7]. In this paper we propose a simple but efficient approach based on cross layer design that rejects the paths with nodes having less battery power than the specified threshold value. We investigate by implementing needed changes in the route discovery process using cross layer approach in the well known on demand routing protocol AODV, as a case study. This cross layer design is suitable to implement with all reactive protocols which use a route request/query packets in the route discovery phase. Using OMNET++, we evaluate the performance of our cross layer design energy improvement to AODV in mobile AdHoc networks. The rest of the paper is organized as follows. Section II reviews on related work, section III presents proposed AODV, we study performance evaluation in section IV and finally section V summarizes conclusion.

II. Related Work

Developing core protocols (at different layers, e.g., MAC and network layers) for MANETs has been an area of extensive research in the past few years. Ivan Stojmenovic and Xu Lin [6] developed a new power cost-metric based on the combination of both nodes' life time and distance based power metrics. This provides basis for power, cost and power-cost localized routing algorithms where nodes make routing decisions solely based on the location of their neighbors and destination. The power aware routing algorithm attempts to minimize the total power needed to route a packet between source and destination. The cost-aware routing algorithm is aimed at extending the battery's worst-case lifetime at each node. The combined power-cost routing algorithm attempts to minimize the total power needed and to avoid nodes with a short remaining battery life time. S. Singh and C. S. Raghavendra [7] proposed the PAMAS protocol, a new channel access protocol for ad hoc networks. PAMAS uses two different channels, separate data and signaling channels. The signaling channel tells the nodes when to power off their RF devices if a packet is not being transmitted nor received. Recently some routing protocols to efficiently utilize energy power have been proposed. The MTPR (Minimum Total Transmission Power Routing) [8] was initially developed to minimize the total transmission power consumption of nodes participating in the acquired route. Chansu Yu, Ben Lee and Hee Yong Youn [9] overviews on energy efficient routing approaches such as transmission power control approach, load distribution approach, sleep/power-down mode approach. For transmission power optimization, Flow Augmentation Routing (FAR) , Online Max-Min Routing (OMM), Power aware Localized Routing (PLR) protocols and minimum energy routing(MER) were discussed. For load Distribution Approach Localized Energy-Aware Routing (LEAR) and Conditional Max-Min Battery Capacity Routing (CMMBR) protocols were discussed. For sleep/power-down mode approach, SPAN protocol and the Geographic Adaptive Fidelity (GAF) protocol employ the master-slave architecture and put slave nodes in low power states to save energy. Unlike SPAN and GAF, Prototype Embedded Network (PEN) protocol saves more energy when the devices put into sleep state according to the need. Finally research on cross-layer design in ad-hoc networks has recently attracted a significant interest. It is concerned with sharing information between various protocol layers. In [10] impact of routing protocols and channel conditions on the link layer ARQ is studied. A simple cross layer design between PHY and MAC layers for power conservation based on transmission power control is proposed in [11][12] and it has been shown that the amount of power conserved dependent on the accompanying routing protocol.

III. PROPOSED SCHEME

In wireless network there are different protocols used in estimation of end to end delay like load aware routing protocol which concern about fast transmission and accuracy. Queue aware routing for measurement of traffic have been used for minimizing delay and also try to avoid the congestion occurrences in the network to improve the performance. In this proposed scheme we use Mac contention window which selects path with high CW along with that Queue size is used. When transmission is busy and packets are stored in buffer and forwarded when channel becomes idle. The use of energy consumption is major concern so we try to avoid much drain energy among the nodes. Energy consumption depends on the communication mode of a node. A node may be either in a mode of transmit, receive or idle and transmission consumes more energy than the other two modes. We use directional antennas for better power consumption as it consumes power in a single direction between a sender-receiver pair and the transmission power of the sender is adjusted based on the receiver power for every link in MANET.

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Once the receiver receives data, it calculates minimum receiving power of it and this power information is sent back to the sender then the sender alters its transmission power. It means that the sender have to send the further data using this power information. The nodes which have required minimum transmission power and the nodes with high remaining battery power is considered for stability. In MANET, there is high power consumption for sending RTS and CTS signals. Here the RTS/CTS handshaking happens after the route discovery but before the data transmission. For sending the RTS signal, the node has to wait for 5ms and then data transmission occurs.
MANET is dynamic nature and less centralized control over the performances. Therefore the quality of the service is found to be very low at times like at very high load or mobility that is, as mobility increases the delivery of packets decrease which need to be considered.
The main objective of proposed scheme is:

- To improve the End to End delay from source to sink. This is done by using contention window CW by selecting less contending nodes in given path.
- Improving the lifetime of the network which is done by minimizing energy consumpti on.
- Controlling of congestion occurring in the network.
- Maximizing throughput and thereby decreasing latency.
- Use of traffic split for parallel transmission.

A. Network Architecture

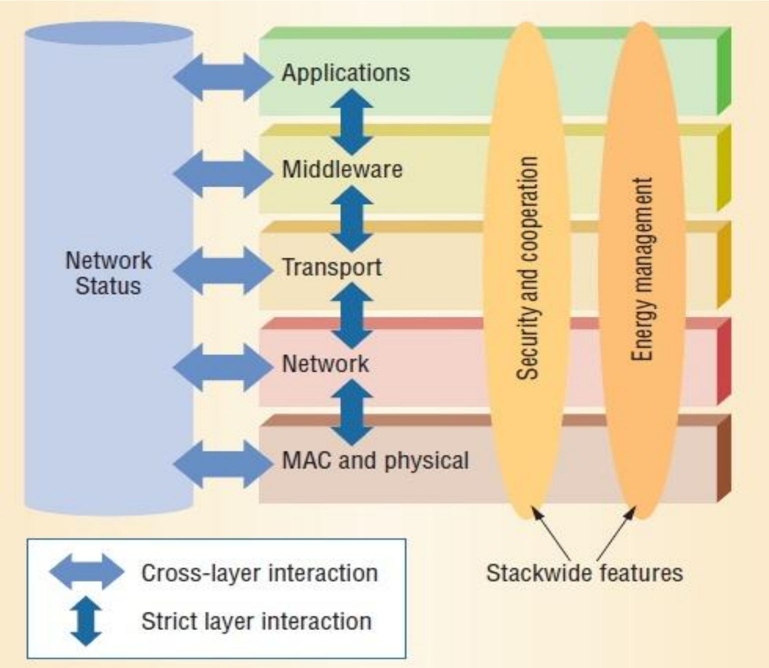

Fig. 1: Network Architecture in MANET [12]

A full cross-layer design introduces stack wide layer interdependencies to optimize overall network performance. In cross- layering, protocols use the state information flowing throughout the stack to adapt their behavior accordingly. For example, given current channel and network conditions, the physical layer can adapt rate, power, and coding to meet application layer requirements. The Ad Hoc research community [12] recognizes that cross-layering can provide significant performance benefits, but also observes that a layered design provides a key element in the Internets success and proliferation. Strict layering guarantees controlled interaction among layers because developing and maintaining single layers takes place independently of the rest of the stack. On the other hand, an unbridled cross-layer design can produce spaghetti-like code that is impossible to maintain efficiently because every modification must be propagated across all protocols. Further, cross-layer designs can produce unintended interactions among protocols, such as adaptation loops, that result in performance degradation. Hence to overcome the potential MANET performance problems, it is necessary to introduce inside the layered architecture the possibility that protocols belonging to different layers can cooperate by sharing network-status information. Fig.1 shows that some network functions, such

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as energy management, security, and cooperation are cross-layer by nature. MobileMan seeks to extend cross-layering to all network functions through data sharing. The architecture presents a core component, *Network Status* that functions as a repository for information that network protocols throughout the stack collect. Each protocol can access the Network Status to share its data with other protocols. This avoids duplicating efforts to collect internal state information and leads to a more efficient system design

B. Contention window (CW)

The contention window (CW) size is a value chosen from the range between the minimum contention window (CWmin) and the maximum contention window (CWmax). CWmin and CWmax are PHY dependent value, e.g. in 802.11b, the CWmin and CWmax are 15 and 1023 respectively. The initial value of CW is CWmin. The size of contention window should be chosen very carefully. If the CW is too small, the back off time chosen between the range of zero and contention window will be close together and there will be higher probability that the random value chosen has the same value. With the same CW, nodes will transmit at the same time after waiting for the same CW period of time. Collision will happen in this situation.
If the size of CW is too big, there might be some unnecessary high delay. For each of the retransmission, Contention Window size will be increased to the value twice of the previous used CW. The contention window selects the path from source to destination with less contending nodes and while transmission other contending nodes store in queue size and use of Remaining Energy is to check for drain energy and selects path with less energy consumed and traffic split used for parallel transmission [13]. An AdHoc network uses Distributed Co-ordination Function (DCF) as the medium access mechanism supported by IEEE 802.11 MAC layer protocol. When one or more nodes try to access the channel simultaneously collision is experienced following which contention window is set to $CW_{min.}$ .The size of the contention window determines how long a node would back-off before attempting to gain access to the channel. In other words CW[14] indicates the busyness of the medium and can be considered as a useful metric for contention and traffic interference. A large CW would mean more amount of traffic interference. As nodes transmit using the same channel, they have to contend with each other for sharing bandwidth causing traffic interference. The level of interference depends on the amount of load generated by the interfering nodes.
In order to capture the effects of neighboring node transmissions we use average size of contention window and the queue size of the current node and its neighboring nodes. Traffic conditions of the neighboring nodes are propagated using Hello packets periodically. Hence the use of contention window mechanism is to select the path with less contending nodes which results in that shortest path is not always guaranteed because of CW when that path has more contending nodes in given path then it selects the next path even though it's not shortest route. As use of route cache to store in it and can be accessed to find path from source to destination which leads to some limitations. Route cache increases overhead along with number of nodes increases. The overhead of route discovery in multi-path routing is much more than that of single path routing. Use of multipath increases routing updation and need extra memory.

C. Retransmission

Packets are retransmitted using binary exponential back-off mechanism. BEB used to schedule retransmission after collision. The retransmission is delayed by an amount of time derived from the slot time and the number of attempts to retransmit. After c collisions, a random number of slot times between 0 and $2c - 1$ is chosen.
For the first collision, each sender will wait 0 or 1 slot times. After the second collision, the senders will wait anywhere from 0 to 3 slot times. After the third collision, the senders will wait anywhere from 0 to 7 slot times and so forth. As the number of retransmission attempts increases, the number of possibilities for delay increases exponentially. The 'truncated' simply means that after a certain number of increases, the exponentiation stops; i.e. the retransmission timeout reaches a ceiling, and thereafter does not increase any further.
For example, if the ceiling is set at i = 10, then the maximum delay is 1023 slot times and the expected back-off time for the third (c = 3) collision, one could first calculate the maximum back-off time, N :

$$N=2^c-1=2^3-1$$

$$N=7$$

In a typical on-demand single path routing protocol like DSR or AODV, the source node, when it does not have the route to send data to a destination node, initiates a route discovery process using flooding. The source node broadcasts a route-request (RREQ) message, tagged with a sequence number, in its neighborhood. An intermediate node receiving a RREQ message will broadcast the message in its neighborhood exactly once. The RREQ messages will propagate along different routes to the destination. The destination will pick up the RREQ

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message that propagated along a route that best satisfies the route selection metrics of the routing protocol and send a unicast route reply (RREP) along the selected route back to the source.

Multi-path routing protocols proposed for ad hoc networks make use of the propagation of the RREQ messages along several paths to the destination and let the destination to send RREP along more than one path. The routing protocols avoid the RREP storm by selecting only few of the different paths. Since nodes communicate through the shared wireless medium, the selected paths need to be as independent as possible in order to avoid transmissions from a node along one path interfering with transmissions on a different path. Use of multi-path routing is much efficient than single path because of congestion and collision in network.

D. Energy Model

Energy model allows to study network algorithms and applications in simulation model with high quality energy estimation. Energy model considers all individual algorithms and techniques analyzed regarding their performance like overhead. Faster adaption for environment changes energy consumption and end to end performance. In general to calculate energy consumed by radio in real time, energy model tracks every state to switch in the physical module using OMNET++ notification board and here we use the idle time sleep, transmitting and receiving for energy calculation and energy is consumed much due to overhearing and results with more overhead in network, so the goal is to select the paths with high energy rate. During initialization phase every node collects information about the size of its CW, its buffer occupancy level, and remaining battery level. In order to contain transient bursts the size of contention window found is averaged out using exponential weighted moving average method. Similarly average size of the interface buffer and energy values are calculated. Each node then constructs a neighbor table which stores the list of its neighboring nodes along with their respective traffic load which is again expressed by its contention window size. AODV's Hello messages are modified to convey information about neighbor node's contention window size, queue size and battery level. Using the information from the Hello messages each node constructs a neighbor table. Format of a neighbor table is shown below.

Table 1. Neighbor Table contents [14]

TimeStamp
Avg-CW_{size}
Avg-$Queue_{size}$
Rem Energy Level
Node-Id

Using the information from the neighbor table, each intermediate node stores the cost found using the equation 1 where *i* refers to an intermediate node, n refers to number of neighbor nodes of *i* .

$$Cost_i = CW_i * Q - Size_i * {}^{1}/_{Rem - Energy} + \sum_{j=0}^{n} (CW_j * Q - Size_j) \qquad (1)$$

CW indicates average size of the contention window ,*Q- Size* represents the average size of the MAC Buffer [14]. Quality of a path is taken as the cumulative cost of intermediate nodes that form a path. Let $cost_A$ be the cost of path *A*, $cost_B$ the cost of path *B* and *N be* the total amount of data to be forwarded from a source to a particular destination. Let the total cost of two paths *A* and *B* be *Total-cost*, then the number of data packets N_A Forwarded along the first path *A* would be

$$N_A = \left(\frac{cost_A}{Total - cost}\right) * N \qquad (2)$$

E. Route Discovery

Route Discovery procedure is initiated by the source when it does not have a route in its cache to a destination by broadcasting a RREQ packet. When an intermediate node receives a RREQ packet it forwards the packet only if the node has energy beyond a threshold value. While a RREQ is forwarded, each intermediate node inserts its cost which is computed as in *(1)*. Similarly every intermediate node checks if it has enough energy and subsequently appends its cost in to the RREQ packet. When the RREQ reaches the destination it will have the cumulative cost of the path. When additional RREQ's arrive destination selects four least cost paths [15]. Destination then generates

RREP for the four selected best paths. Source, after receiving the best paths starts with data transmission by distributing the packets proportional to the quality of each path found as in *(2)*. Only two paths with best cost is selected for data transmission.

F. Route Maintenance

Route Maintenance is initiated when a link break is detected by a node by transmitting a RERR packet . Data transmission is continued along the next prediscovered path stored by the source[16]. Number of packets forwarded along this new path is proportional to its cost. If all prediscovered paths fail a new route discovery procedure is initiated by the source.

G. Methodology

First node checks the route cache for path from source to destination and each node in network fights for the transmission slots by generating RTS packets. If no other node is trying to access the channel, current node can access the channel with Maximum Contention Window. If other nodes also attempts to access the channel, current node decrease its contention window which means it will attempt to acquire the channel for lesser interval of time. At the same time Back-off time of the node is increased. Back-off time value specifies when the node can again try for channel acquisition. Periodically the nodes broadcast hello packets to the neighbors. In the hello packet, the current contention window value, remaining energy, queue size is embedded. Hence in routing table, node stores the node ID, Hops and contention window value, remaining energy, queue size of its neighbor. When a source node generates RREQ, it is broadcast to all the neighbors. Initially RREQ will have Contention window value of the Source node. All the nodes add its contention window with that of CW of RREQ packet before forwarding the packets to it's neighbors. At the destination all the RREQs are cached and the path in which CW is maximum is selected and the destination select some 4 multiple best paths based on cost and send back to source node. The source node select two best path based on minimum cost and send the data. By using traffic splitting there is an increase in parallel transmission and mobility. Thus data is transmitted through the path where maximum data can be transmitted each slot.

IV. PERFORMANCE EVALUATION

A. Simulation Environment

Evaluation of the proposed protocol is carried out using OMNET++, a discrete event simulator which supports complete physical, data link and MAC layer models for simulating wireless ad hoc networks. We simulated a network of 50 mobile nodes placed randomly in an area of 1500 x 600 square meters. Each node is assumed to use IEEE 802.11b radio interface. A source and a destination is selected randomly. Free space propagation model is assumed as the channel model. Each node is assumed to have a constant transmission range of 250 meters and a channel capacity of 2Mbps. Source destination pairs are spread randomly over the network. Mobility pattern of the mobile nodes is generated using Random waypoint model. Speed of a mobile node is assigned as 5 meters/sec. Energy level of all nodes is initialized as 100mJ. Amount of energy expended while transmitting and receiving is assumed to be 0.0003mJ and 0.0001mJ respectively.

We evaluate the performance of the proposed work using following parameters:

Packet Delivery Ratio (PDR): This is defined as ratio of number of packets that have successfully reached the destination to the total number of packets sent by the source. This metric is expressed in percentage.

Control Overhead: *The* number of routing packets transmitted per data packet delivered at the destination. Each hop wise transmission of a routing packet is counted as one transmission. The number of control packets for the routing protocol over the number of data packets sent increases with speed.

Throughput: The measure of number of packets passing through the network in a unit of time. This metric shows the total number of bytes that have been successfully delivered to the destination nodes.

Both proposed - AODV and AODV have higher throughput when nodes move at low speeds, and when speed increases all routing protocols suffer a decrease in throughput. Higher speed causes frequent link changes and connection failures. Proposed AODV shows better throughput as it integrates cross layer decision.

End -to- End Delay: This includes all possible delays caused by buffering during route discovery latency, queuing delay during other processes, transmission delay at the MAC and propagation delay. There is significant increase in time taken for packets to reach destination (End to End delay).

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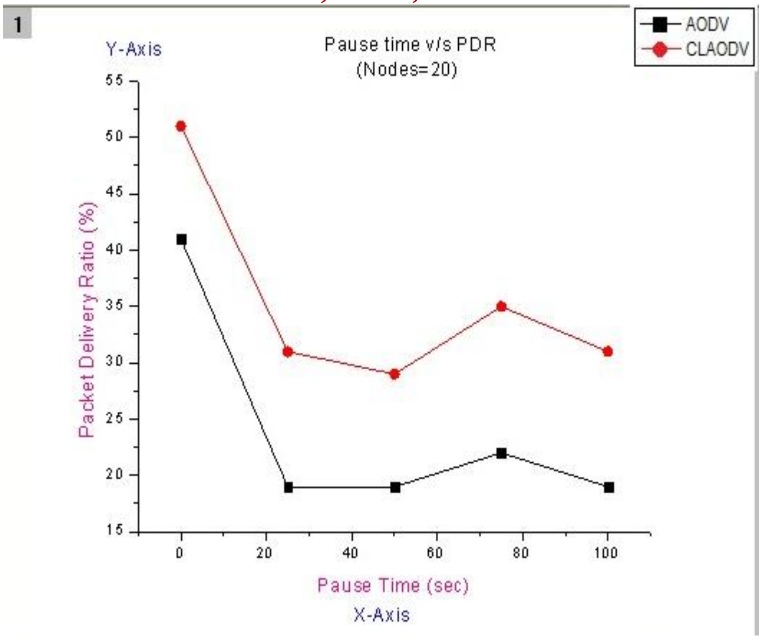
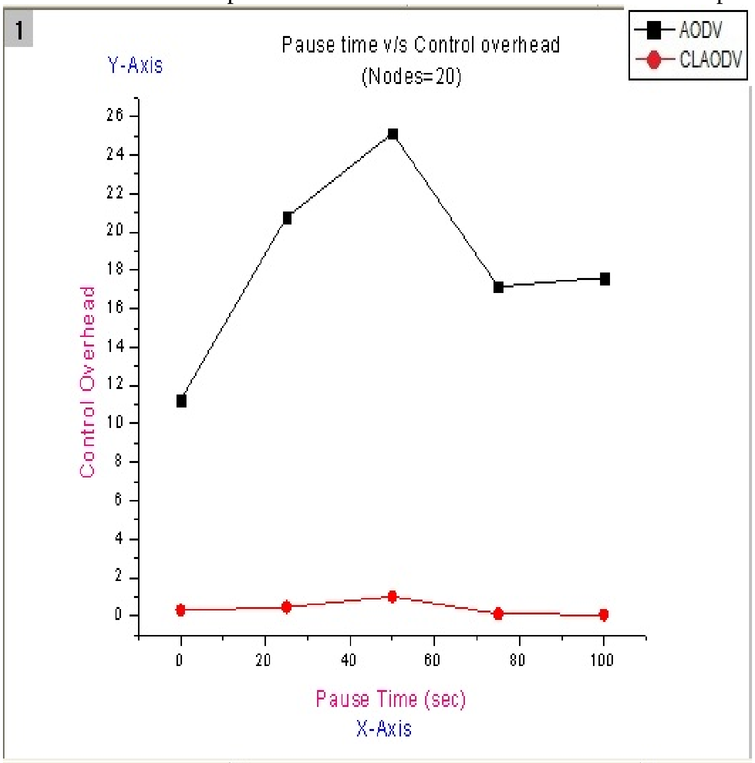


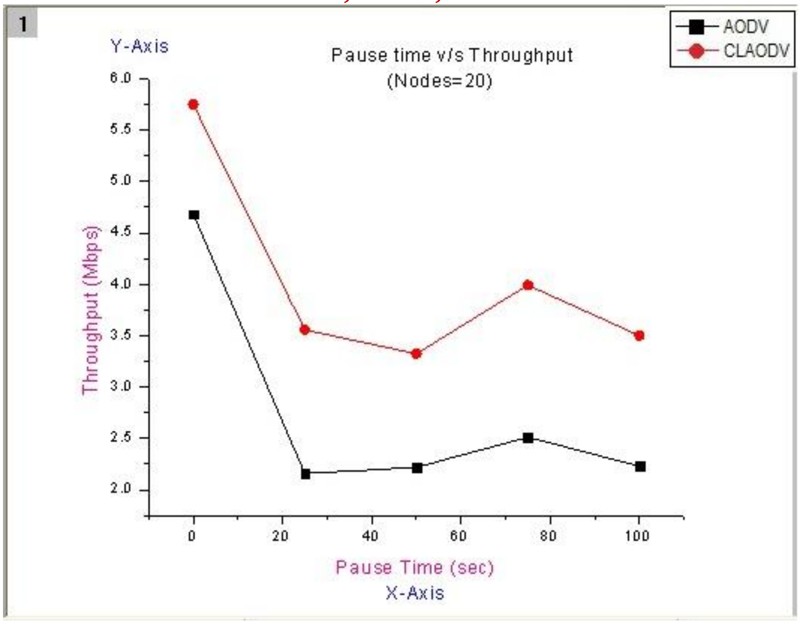
Graph 1: Pause time V/s PDR

To achieve High packet delivery ratio in any network we need to know stability of links in the route to ensure high PDR and also lifetime. The stability of link is ensured by using Random Waypoint in Omnet++ mobility model. RandomWP is set Tpause=high, Vmax=low results in stability and Tpause=low, Vmax=high results in dynamic. In 20 nodes in Graph 1: PDR increases as pause time increase and results are better compare to pure AODV.



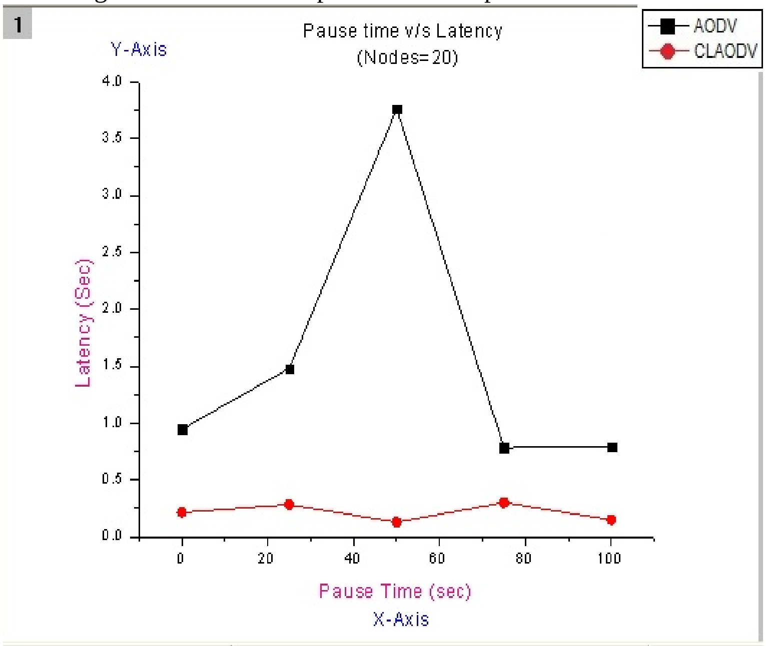
Graph 2 : Pause time V/s Control Overhead

The overhead in network observed due to loss of packets in network and more retransmission this leads much overhead so we use the queue buffer for storing data packet when transmission taking place when channel become idle first packet gets channel and this controls overhead in network. In Graph 2: the CLAODV which is having less overhead compare to the AODV.



Graph 3 : Pause time V/s Throughput

The throughput decreases due to factors like distance, TCP window size, and packet loss. As the distance increases more time needs so selecting path based on least cost with best path and use of contention window mechanism adjust window size and loss of packets are retransmitted using exponential back-off mechanism and CW doubles from previous value when transmission is successful then CW which set to minimum and increases throughput. Because of best path selection based on least cost matrix From the above Graph 3: throughput of CLAODV routing is much high as the increase in pause time compare to AODV.



Graph 4 : Pause time V/s Latency

From above Graph 4: we can see that latency is much high in AODV for 20 nodes but CLAODV has very less latency. PDR is best parameter to evaluate the performance of network. When the number of nodes increases the ratio of packet delivery decreases because of congestion and collision rate increases compared to less nodes. In collision either contents of the data packets are modified or the contents are completely lost and the data packet is of no use for the destination, so the source has to transmit those data packets again to the destination. PDR matrix is used to measure that how many collision occur during transmission.

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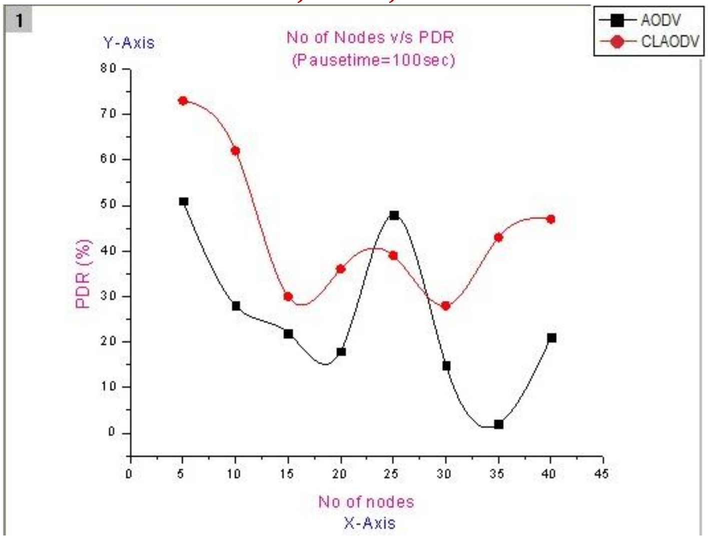
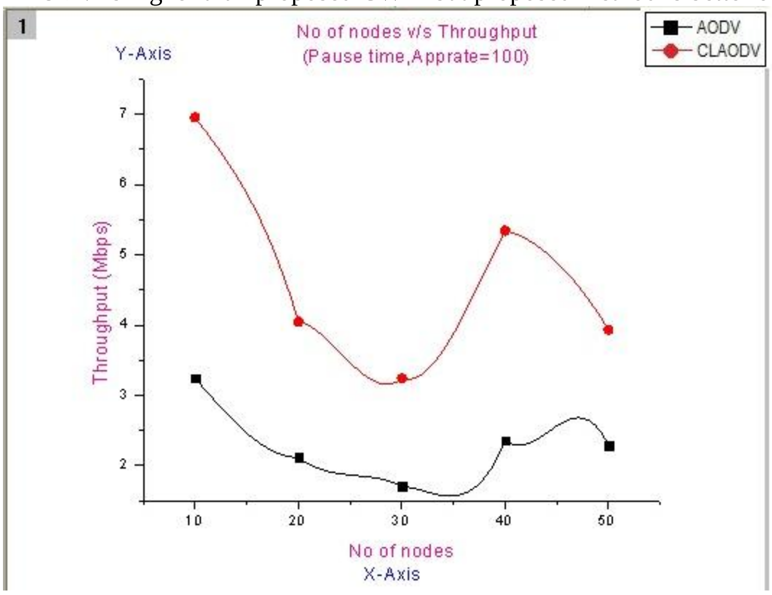


Graph 5 : No. of Nodes V/s PDR

From above graph by keeping the pause time and packet rate as constant to 100 and as the number of nodes increases the delivery ratio is slightly dropping but the proposed CWM routing has better PDR than the AODV at some point the pdr of AODV is higher than proposed CWM but proposed method is better overall delivery ratio.



Graph 6 : No. of Nodes V/s Throughput

From the above Graph 6: by keeping pause time and packet rate as constant to 100 and increasing the number of nodes the throughput of proposed method is better compared to AODV.

V. CONCLUSION

As load increases in network, maintaining high packet delivery ratio and throughput is difficult and lot of control overhead is observed due to route maintenance. So to overcome these problems new cross layer AODV protocol is introduced. In proposed approach all paths are cached at the beginning only so that source select best multi-path route from source to destination based on cost matrix with maximum CW and with cross layer approach every layer information can be shared. The contention window which selects the path with less contending nodes and in case of retransmission it doubles the window size and when successful it set CW to minimum which overcomes the problem of control overhead with increase of network lifetime and considering the energy consumption of each intermediate node. The use of multipath routing is more efficient compared with single path and traffic split

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method is used for parallel transmission because, if there is any link failure in the current path it can immediately select next best path based on least cost.

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AUTHOR BIOGRAPHY

Raghavendra Gowada is working in M.B.E.S College of Engineering as Lecturer in the department of CSE. He received the B.E degree in Computer Science and Engineering from M.B.E.S College of Engineering, Ambajogai under Dr. BAM University Aurangabad in 2008. He had published 01 paper in international journal and attended various national level workshop in field of wireless network. He is an active member of ISTE and his areas of interest are computer network and wireless communication.

Ramanna.S.Havinal is working in M.B.E S College of Engineering as Head of Department in Computer Science and Engineering. He received M.E degree in Digital Electronics and B.E degree in Electronics and Communication. Engineering from Karnataka University, Dharwad in 2000 and 1991 respectively. He had presented five-international conferences and five national conferences. He is member of ISTE and his areas of interest are Digital signal/ Image processing and Wireless Communication.