Energy Aware Congestion Adaptive Reactive Routing Protocol with Dynamic Power Control

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Abstract- MANETs are typically composed of limited capability battery operated wireless communication nodes with limited bandwidth. Routing in MANETs is a complex task because of these limitations. A few issues that can be addressed for routing optimization are energy uses of the nodes, congestion control and node mobility in dynamically changing topology. Energy drained node will cause path breaks and packet loss. Similarly congestion will cause packet drops and high delay which negatively affects Quality of Service (QoS). Node mobility can degrade link quality and break existing paths to cause packet loss. This paper proposes a new routing protocol (EACARP-DPC) to address these issues by including node energy and congestion status in routing decisions. A cross layer approach is used to further increase energy saving by dynamically changing the transmission power based on the Received Signal Power (RSP). The RSP is also used to address the issue of node mobility and link quality in dynamic topology environment. This cross-layer design approach is implemented in NS2 simulator and its performance is compared with the traditional AODV routing protocol, which indicates the better QoS parameters.

Keywords – Energy aware, Congestion adaptive, Dynamic power control, EACARP-DPC, MANET Routing

I. Introduction

Mobile Ad hoc networks do not require pre established infrastructure network or backbone network to operate. The infrastructure networks need the uses to remain inside coverage area of the base station, which act as a central master node and handle connectivity and data transfer operations. In MANET there is no central node. The node uses cooperative routing to forward data from source to destination. Here each node works as a host as well as router. Such networks have some advantages over infrastructure based network like it supports mobility of the nodes, can be setup easily in no time, allow users to use network resources and services from any location etc. This makes MANETs highly dynamic and deployable in many applications like human or nature induced disasters, battlefields, meeting rooms or other cases where either a wired network is unavailable or deploying a wired network is inconvenient.

There are certain issues related with the inherent properties of the nodes and dynamic nature of the network in MANETs. Routing becomes more complex because of these issues/limitations. These issues include energy efficiency, congestion and mobility.

Energy efficiency of the routing protocol is one important factor for battery operated limited power nodes. If a node goes to battery drain state then it will shutdown itself and any ongoing data transfer through it will suffer packet loss. This will increase routing overhead to find new path between source and destination [1].

Congestion control is another important factor for resource and channel bandwidth limited wireless nodes in MANETs. Network congestion is a situation where the incoming network traffic increases beyond the capacity of the nodes, thus packets start dropping because of buffer overflow. Packets will also suffer from higher than normal delays because the waiting time in queues increases in between source and destination. The congestion thus negatively affects network performance by packet loss and higher delays. The problem of congestion is one of the main reasons of packet drop in MANETs [2].

Node mobility is also one of the issue and reason for packet loss in MANETs. The dynamic nature of MANETs causes change in existing routes and packet loss. The route change also increases overhead in finding new path between source and destination. High mobility causes more path breaks and makes the network unstable. Thus for higher network performance, detection and proactive actions are required against node mobility [3].

The issue of mobility, congestion and energy are related with each other when addressing the problem of packet loss and routing overhead. Congestion causes packet loss, which is energy wastage in transmission and reception power used by the packet. Similarly mobility causes path breaks and increases routing overhead which is again energy loss. Thus all of these issues must be addressed together to increase network performance.

The current routing protocols for MANETs can be divided in three groups: Proactive like DSDV [4], reactive like AODV [5] and DSR [6] and hybrid like ZRP [7]. As the name suggest, proactive protocol tries to keep complete network information and paths even before it is needed. For example, DSDV protocol exchanges network information periodically about network. As a result the proactive routing protocols are not scalable and suffer from high overhead. Reactive routing protocol uses passive strategy and do not maintain network information. Routing path is searched only when it is needed, which increases the performance of protocol by reducing overhead and make it scalable. The hybrid routing protocol combines both proactive and reactive approach. The protocol defines a zone which acts like a boundary network. Inside the zone it uses proactive policy and outside the zone it uses reactive policy. Thus the performance if such protocols depends on zone size, initial path requests and network topology.

The issue with these protocols is that they are not adaptable to energy status, congestion status or node mobility while making routing decisions. Due to this reason, these protocols find the shortest path between source and destination, which does not provide optimal performance of the network. This paper present a new routing protocol based on reactive policy (AODV), which includes these metrics while selecting a path by using cross layer concept.

The design of these protocols is based on traditional layered approach. In layered approach, each layer acts as a complete unit and performs one operation without sharing its information to other layers. The complete operation is achieved by these sub operation. This results in sub optimal performance, especially in wireless scenario in which challenges are quite different form wired scenario [8].

To achieve higher performance, the information about channel conditions must be passed to higher layers and QoS requirements must be passed to lower layers. This is known as "Cross layer Design" approach and enforces the information sharing across the protocol stack. For example the rate, coding and power at physical can be adapted to meets the requirements of the applications, given the current channel and network conditions. The information must be shared between layers to achieve highest level of adaptability [9].

Figure 1 shows a cross layer based design where MAC layer information about Received Signal Power (RSP) is taken into network layer as link quality estimator which indicates the node mobility. If the nodes move further from one another than RSP value decreases and the link quality between them degrades. Thus RSP value is used to address node mobility problem. RSP is calculated in NS2 simulation tool at MAC layer [10].

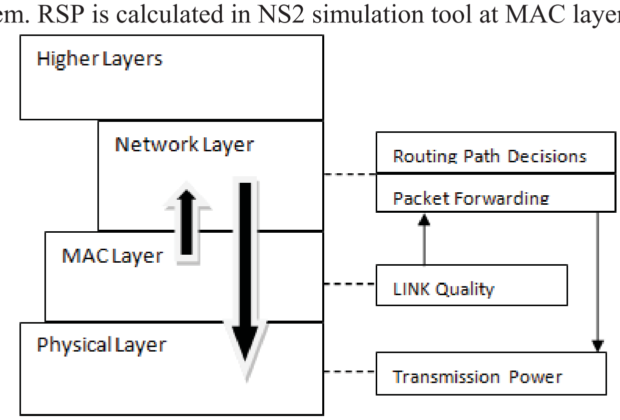

Figure 1. Cross layer information exchange across layers

The same RSP value is also be used to adjust transmission power level of a node, if the node can receive RSP information from its one hop neighbours. The adjusted transmission power level help node to adjust its propagation range dynamically, as transmission power is proportional to propagation range.

This paper proposed a new reactive routing protocol which is energy aware, congestion aware and uses cross layer optimization for addressing mobility issue and dynamic power control.

The rest of the paper is organized as follows: Section II describe related work and approaches towards the issues of power, congestion, mobility and dynamic power control. Section III briefly describes the proposed (EACARP-DPC) schema based on AODV reactive routing protocol to enhance network performance. Section IV explains the simulation details and results. Section V draws the conclusion and future scope of the work.

II. RELATED WORK

V. Rishiwal et al. [11] proposed QoS based power aware routing protocol (Q-PAR). The route selection metrics are energy and bandwidth. DSR routing protocol is modified to include these two requirements. In case of a link failure an alternate path is searched locally to handle the situation, which enhanced the network lifetime.

P.K. Suri et al. [12] proposed a bandwidth-efficient power aware routing protocol “QEPAR”. The routing protocol addresses the issue of delay and bandwidth. QEPAR will help in increasing the throughput by decreasing the packet loss due to non availability of node having enough battery power to retransmit the data packet to next node. The proposed protocol is also helpful in finding out an optimal path without any loop.

T.S. Kumaran et al. [13] proposed another congestion control protocol for controlling congestion in AODV named as Early Detection Congestion and Control Routing in MANET (EDAODV) which detects congestion at the node. It calculates queue status value and thus finds the status of the congestion. Further, the non-congested predecessor and successor nodes of a congested node are used by it for initiating route finding process bi-directionally in order to find alternate non-congested path between them for sending data. It finds many alternate paths and then chooses the best path for sending data.

A. Nedumaran and V. Jeyalakshmi [14] proposed a combined energy and congestion metric based routing protocol Congestion and Energy Aware Routing Protocol (CAERP). It is based on DSR and uses variable data rates of nodes to control congestion. The protocol uses cross layer information, Received Signal Strength Indicator (RSSI) for distance estimation and queue size of node for congestion estimation. The nodes with high queue size, which are under congestion, are excluded from data rate variation. For other nodes, the data rate is changed according to the queue size and RSSI value. The results indicate reduce in congestion, energy utilization and improvement in throughput.

A.S. Ahmed et al. [15] proposed a cross layer based transmission power control routing protocol (CLPC) which is based on AODV. The protocol uses Received Signal Strength (RSS) from MAC layer at network layer to adjust nodes transmission power. The RSS information is exchanged with one hop neighbours using hello packets. Each node calculates Average RSP value and adjusts its transmission power according to this average. Furthermore each node uses this average RSS value to find a reliable path between source and destination. The results indicate increase in packet delivery ration and reduction in delay and routing overhead.

Duc A. Tran and Harish Raghavendra [16] proposed CRP, a congestion-adaptive routing protocol for MANETs. A key in CRP design was the bypass concept. A bypass is a sub path connecting a node and the next non congested node. If a node is aware of a potential congestion ahead, it searches a bypass and uses it in case the congestion actually occurred. Also some part of the incoming traffic is redirected to bypass route to reduce congestion on next node. The congestion was avoided as a result.

B. Ramchandran et al [17] used received signal strength as a parameter in cross layer design. The Received signal strength measured at the physical layer is communicated to MAC and network layer. The results indicate that using this feedback, issues like energy conservation, unidirectional link rejection and reliable route formation can be addressed efficiently.

Feng Xie et al [18] proposed a cross-layer reactive routing protocol that focuses on node residual energy in order to decide the routes (EARR). Each node checks if it has enough energy to complete the task will take part in routing. RREQ packets carry additional information regarding traffic which is gathered from application layer. Source node picks the maximum energy path from all available routes. Hello messages and RREQ are modified to carry additional traffic and energy information.

E. Nttarajan and L. Devi [19] present cross layer based energy aware routing and congestion control algorithm in MANET. The standard AOMDV protocol is modified with cross layer approach. The results indicate reduced packet retransmissions and losses and increase in network QoS parameters. Also the energy utilization is reduced and network life time increased.

III. PROPOSED WORK

The proposed EACARP-DPC routing algorithm requires following steps:

A. *RSP calculation and dynamic transmission power control* -

The RSP value is calculated by MAC layer. A node gets this information from MAC layer and under cross-layer design approach, uses it at network layer. Hello packets are modified to contain this RSP information which is broadcasted to the one hop neighbours. Each neighbour stores this information in a neighbour table. Every node also maintains an alternate Routing table beside primary routing table which is used to find alternate path. Each node calculates Average Received Signal Power (Avg_RSP) and divides the neighbours in two groups: below Avg_RSP nodes (Far nodes, MAX Transmission range) and above Avg_RSP (Near nodes, Min. Transmission range). The transmission power is calculated based on average of the RSP values of all near nodes (Avg_HIGHRSP). The transmission power corresponding to Avg_HIGHRSP indicates the minimum communication range for the current node. All nodes dynamically adjust their transmission power according to Avg_HighRSP value. Thus the transmission range is reduced and transmission power is also reduced compared to the original transmission range and power.

B. *Link monitor*-

Each Node also calculates Avg_LOWRSP, which is the average of the RSP values of all Far nodes. Avg_LOWRSP indicates the minimum RSP that should be received for good link stability. If a RREQ is received with RSP value below Avg_LOWRSP, then it is dropped. Similarly if a data packet is received with RSP value below Avg_LOWRSP, it means the nodes are moving further from each other. The node will initiate alternate path discovery to find alternate nodes for data transfer between source and destination.

C. *Energy monitor* –

Each node monitors its remaining battery power. If the remaining node power is less than 20% of the initial power then RREQ is drop, to stop including low power nodes in new routing paths. If the power level further reduces to 10% or less than the node initiate alternate path discovery to bypass such low power nodes.

D. *Congestion monitor* –

Congestion monitor: Each node monitors its current queue size as an estimator for congestion on the node. If the queue size is greater than 80% of total buffer capacity then all RREQs are dropped, to stop including high congestion nodes in new routing paths. If the queue size is further increased to 90% or more than the node, then initiate alternate path discovery to bypass such high congested nodes.

Routing Algorithm:

- For Each node for dynamic power control:

1. Exchange Hello packets for RSP information.
2. Updates neighbour table with RSP values.
3. Calculate Avg_RSP value and divide neighbours in two: Far node and near nodes.
4. Calculate Avg. RSP of Far Nodes (AVG_LOWRSP)
5. Calculate Avg. RSP of Near Nodes (AVG_HIGHRSP)
6. Adjust Transmission power according to AVG_HIGHRSP.
7. END

- For each RREQ received:

IF RSP value>AVG_LOWRSP & Remaining power>20% & Queue size< 80%

Follow normal AODV Flow and exit. (Drop if duplicate else forward.)

ELSE

DROP RREQ to stop including such node in new routing path and exit.

END

- For each data packet received:

IF RSP value>AVG_LOWRSP & Remaining power>10% & Queue size< 90%

Follow normal AODV Flow and exit. (Forward the packet.)

ELSE

Forward the current packet and Initiate alternate path discovery and exit. If the neighbours find the alternate path, routing tables will be updated to bypass the current node, else continue with the current path.

END.

IV. EXPERIMENT AND RESULT

The proposed EACARP-DPC protocol is implemented in NS2 and compared with traditional AODV. Energy model is used in NS2 to initialize maximum transmission range (250 m), initial power (100J) etc. Table1 shows the parameters setting for the simulation setup. The channel bandwidth is set to 2Mbps. The traffic type is CBR with packet size 512 bytes. The Two-ray ground reflection model is used as radio signal propagation method. Random waypoint mobility model is used for node mobility model. Table 1 shows the simulation parameters.

Table -1 Experiment Result

Type	**Values**
Channel	**Channel/Wireless Channel**
Radio Propagation Model	**Propagation/Tworayground**
Network Interface	**Physical/Wirlessphy**
MAC	**MAC/802_11**
Interface Queue	**Queue/DropTail/PriQueue**
Antenna	**Antenna/Omniantenna**
Link Layer	**LL**
Mobility Model	**Random Way Point**
Interface Queue Length	**50**
Application	**CBR**
Packet Size	**512 Byte**
Simulation Area	**1000m X 1000m**
Simulation Time	**100s**

Two different scenarios are used for experiments:

A. Variable no of nodes (20 to 50)

B. Variable node mobility(0 to 30)

A. Variable number of nodes (20 to 50):

Here number of nodes is variable from 20 to 50, which are randomly scattered in a region of 1000m X 1000m. The load on the network is kept constant, 15 connections. The cbrgen.tcl and setdest utility is used for traffic and mobility model generation. The performance of the proposed algorithm is evaluated and compared with the traditional AODV.

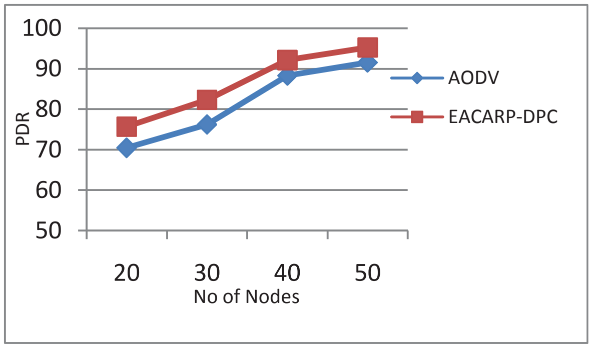

Figure 2. PDR and No of Nodes

Figure 2 indicates the PDR of both the protocols is low in initial high load network condition (20 nodes and 15 connections). As the number of nodes increases the load on the network is reduced and PDR increases. The EACAR-DPC performs better than traditional AODV.

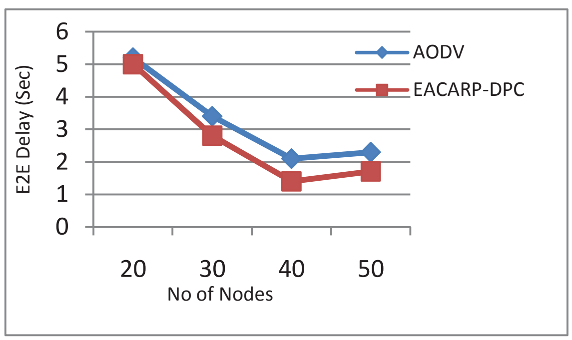

Figure 3. E2E delay and No of Nodes

Figure 3 indicates the E2E delay and number of nodes of both the protocols. Initial the delay is high because of high load. As the number of nodes increases the delay decrease, but at 50 nodes the delay again increases slightly. The EACAR-DPC has lower delay compare to traditional AODV because it adaptive to congestion and monitor link quality to chooses better path.

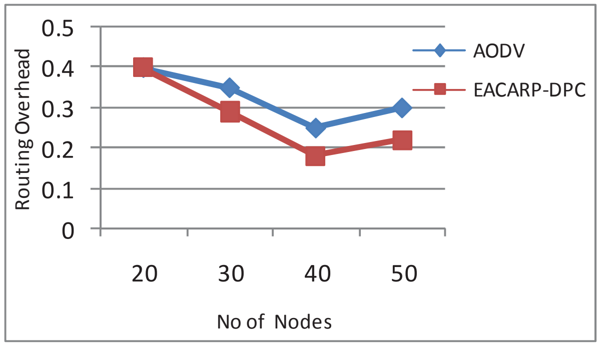

Figure 4. Routing Overhead and No of Nodes

Figure 4 indicates the normalized routing overhead and number of nodes. The overhead is initially high which reduces as nodes increases. The overhead increases again slightly when number of nodes increases from 40 to 50. The overhead of proposed EACAR-DPC is less compare to AODV.

B. Variable node mobility (0 to 30):

Here 50 nodes are used which are randomly scattered in a region of 1000m X 1000m. The load on the network is kept constant, 10 connections. The mobility of the nodes is increased from 0 to 30 m/s in step size of 10 m/s. The cbrgen.tcl and setdest utility is used for traffic and mobility model generation. The performance of the proposed algorithm is evaluated and compared with the traditional AODV.

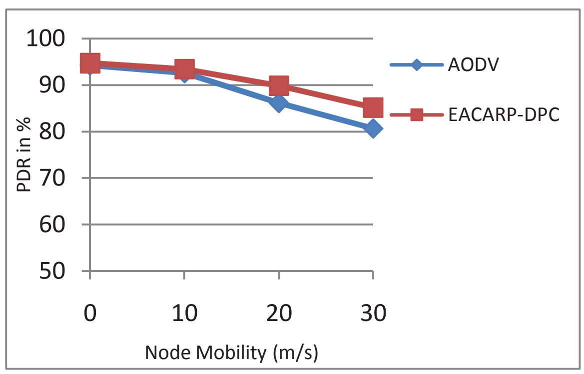

Figure 5. PDR and Node Mobility

Figure 5 shows the results for PDR and node mobility. Initially with low mobility, the PDR is high. As the node mobility increases the PDR decreases because more number of path breaks and overhead in finding new path increases. EACARP-DPC performs well in such cases due to link monitoring and energy monitoring.

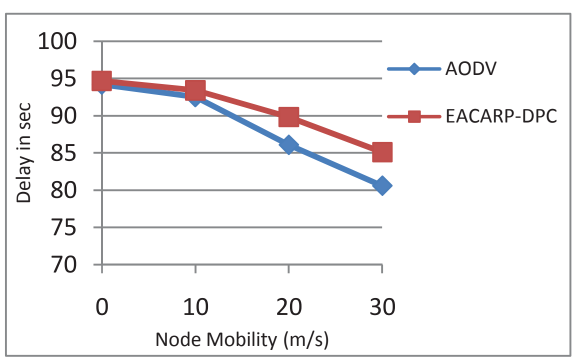

Figure 6. Delay and Node Mobility

Figure 6 shows the results of E2E delay and node mobility. Initially the node mobility is low, thus the delay is also low. As the mobility increases, the network becomes unstable and the delay increases. Again, the performance of EACARP-DPC is better than AODV because of link monitoring.

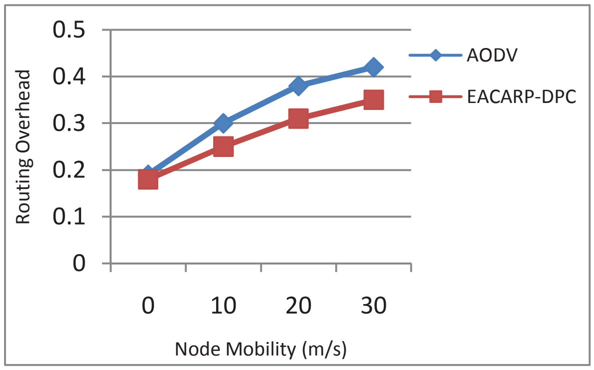

Figure 7. Routing Overhead and Node Mobility

Figure 7 shows the results of Normalized routing overhead and node mobility. Initially the node mobility is low, thus the overhead is also low, which increases with the node mobility. The EACARP-DPC gives lower routing overhead compare to AODV.

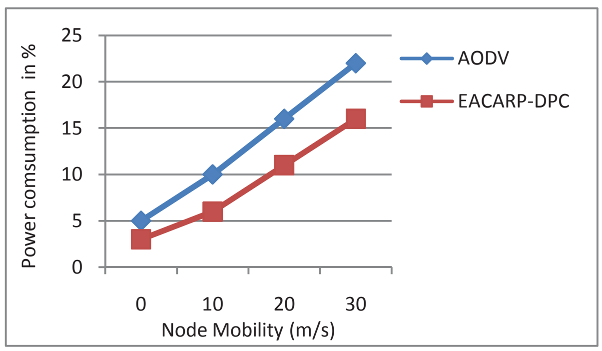

Figure 8. Power consumption and Node Mobility

Figure 8 shows the results of Energy consumed and node mobility. With less mobility, less energy is consumed, which increases with node mobility. The EACARP-DPC gives lower energy consumption compare to AODV because of dynamic power control mechanism and energy aware routing, which reduces the overall network energy consumption.

V. CONCLUSION

The paper presents a new cross layer based dynamic transmission power control protocol which considers link status, energy status and congestion status of the nodes for providing optimal network performance. The proposed EACARP-DPC is implemented in NS2 simulator and compared with traditional AODV protocol. The combined energy, congestion and link metric leads to achieve higher packet delivery ratio, lower delay and lower routing overhead as indicated in results. The dynamic adjustment of transmission power further saves node energy used for packet transmission. Thus proposed protocol improves the network QoS parameters and reduces energy consumption. Broadcast control technique can be added in proposed protocol to further reduce congestion in the network at the time of new connection setup which will further improve network QoS.

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