Cross-layer Support for Optimal Power Control Approach using Received Signal Strength (RSS) in Mobile Ad Hoc Network

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Abstract

A Mobile Ad hoc Network (MANET) is a bunch of nodes especially wireless and mobile, operate over external low powered battery devices. Energy draining is the primary concern in the wireless network. This paper introduces a cross-layer optimal power control (XOPC) approach to save battery power based on Received Signal Strength (RSS) and transmission power to enhance the usage of energy, and to increase packet delivery ratio. This cross-layer approach simulated by the NS2 simulation tool and results are evaluated and compared with Energy Consumption Routing (ECR) and Max-Min Battery Cost Routing (MMBCR), which shows that the proposed cross-layer approach has better results as compared to other protocols.

Keywords: *MANET, Cross-layer, RSS, Transmission power, Energy conservation, Power control.*

1. INTRODUCTION

MANET is the bunch of wireless nodes that communicates with other neighbor nodes with the help of a shared medium. In MANET, nodes can establish communication without the help of centralized infrastructure anytime, anywhere. Such network is called as Ad-hoc network, since each node can transfer data to neighbor nodes. The selection of which node will transfer data to which another node depends on network topology and connectivity [1].

In MANET, each node can behave as the host as well as the router. MANET has various possible applications, including health care, business, military battlefield, animal monitoring, and disaster management. The nodes are smaller in size, mobile, and powered by an external battery. Manet has the following limitations.

- Limited battery capacity: Nodes work on limited battery power; therefore, it is crucial to utilize battery power efficiently, which will be exhausted after prolonged use.
- High node mobility: Nodes with high mobility, causing routing paths, must be reestablished and updated.
- Decreased throughput: Noise, signal fading, and multiple access may cause reduced throughput in the ad hoc network [2,3].

In such a network, some nodes will behave as as intermediate nodes to dispatch the packets to the neighbor nodes; the working capacity of the network will be reduced as if anyone intermediate node fails. Much research is carried out to design power-aware protocols to moderate the energy consumption by the node [21,22].

In MANET, the source node broadcasts the transmission signal to all its neighboring nodes. The transmission power may affect the functionality of the wireless network in the field of signal strength and transmission range, which degrades the overall reliability of the wireless network. The transport layer is mainly concerned with transmission power and network congestion. The problems associated with transmission power may affect the physical layer to transport layer, including longer delay, loss of data packet, and reduced throughput [4,5].

The architecture and design of protocols associated with the ad hoc network are based on "layered architecture." In a layered architecture, various protocols and algorithms implemented on a particular

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one layer without knowing details of other subsequent layers of the stack, which causes minimal performance of the various applications [1,23].

To minimize this, the "cross-layer approach" has been designed to solve the problems associated with transmission power in MANET. The cross-layer approach differs from the layered approach, where each layer works independently and shares information among subsequent layers.

In the cross-layer approach, information sharing is possible among subsequent layers, optimizes the overall functioning of the network. The layers having following some issues:

i) Physical layer: Nodes require energy to transmit and receive the routing protocol data, user's data, and network information. The battery may exhaust due to excessive energy consumption. The low battery can affect network performance. Therefore, it is required to minimize energy consumption.

ii) MAC layer: This layer is responsible for accessing the wireless medium, fair utilization of it, contention control, and collision control. The failure of the MAC layer results in packet retransmission, causes more energy consumption.

iii) Network layer: This layer is useful in routing the packets. The frequent node mobility changes the network topology, which causes the regular updates of routing information in routing table. Route reconfiguration may consume more energy, drains the node's battery power.

iv) Transport layer: This layer is responsible for congestion control. Congestion may affects the overall network performance.

The cross-layer approach accustomed to optimize the overall network performance by using nonadjacent layer's information. A typical cross-layer design approach depicted in figure 1, in which the physical layer, MAC layer, Network layer, and transport layer can exchange their information to the subsequent layers.

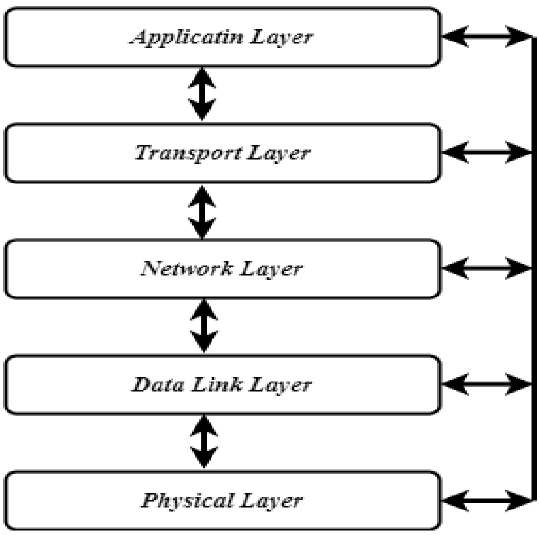

Figure 1. interaction among different layers in a cross-layer approach

In this paper, we have proposed a cross-layer power control protocol (XOPC) that collects the information of the RSS value of a particular node. With the help of an optimal power control mechanism, every node calculates RSS_{min}, $RSS_{avg,}$ and $RSS_{max.}$ This information is useful to know its neighbor location as well as manage its power consumption levels.

The remaining part of this paper has arranged as follows: Section 2 targets the related work. Section 3 includes the proposed cross-layer design approach. Section 4 includes performance analysis, and

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section 5 covers the results and discussion. Finally, section 5 includes the conclusion of the work proposed in this paper.

2. RELATED WORK

C. K. Toh [9] have introduced Minimum Transmission Power Routing (MTPR) based on transmission power control, minimizes energy consumption by the node. The author also proposed MMBCR algorithm identifies the weakest node based on the threshold value. The node has power more than the threshold value as a best-case to select the route and the node having power less than the threshold value chosen for better functionality of the network by increasing the network lifespan.

Conti M, Masseli G et al. [10] have explained MobileMan cross-layer architecture, exploits cross-layer design for MANETs. The MobileMan Cross-layer architecture provides strict local interaction between layers in the stack. This architecture divides the various functionalities and responsibilities among the layers. This architecture optimizes the overall functioning of the network by increasing the local interactions, saving network bandwidth, and decreasing the remote communications. The MobileMan cross-layer architecture enhances the performance of 802.11 MAC by using an optimal back-off algorithm.

Ramachandran et al. [11] have introduced a cross-layer design for energy conservation implemented using GloMoSim, the global Mobile Simulator. Transmission power control increases the number of collisions due to heterogeneous power handling. This cross-layer approach reduces routing overhead and improves the AODV routing protocol. An efficient collision reduction technique used to achieve higher spatial reuse and network capacity. This cross-layer approach establishes reliable routes between the nodes, enhances network connectivity, and the overall network performance.

S. Mahlknecht et al. [12] have explained the Energy-Aware Distance vector (EADV) routing algorithm for WSN. EADV algorithm is well suited for battery-powered wireless sensor nodes. This algorithm based on route failure prediction and preserving energy consumption. In EADV, every node looking for the low cost incurred route towards the nearer sink node for many to one communication and reverse path from the sink node to the sensor node possible with the broadcast. EADV uses location estimation routing by using the values of the Received Signal Strength Indicator (RSSI).

S. Sergi et al. [13] have explained a contemporary approach for coordination and cooperation between various subsequent layers in the ad hoc network. This approach offers low latency and reliable network services. In this approach, the routing decision is depends on the value of cost metric, residual power, and available bandwidth of particular individual node. Also, it uses cooperative techniques to exploit spatial reuse, improves energy efficiency, and decreases the burstiness of data traffic.

Quoc-Tuan Vien et al. [14] have discussed an NC-based LCRT algorithm that calculates transmission power, data transfer rate, and residual energy of the intermediate node. This algorithm reduces control overhead, enhance network lifetime and throughput.

Young Deok Park et al. [15] has proposed a RAMCAST algorithm. RAMCAST enables access points (AP) to retransmits MPDU. RAMCAST responsible for reliable multicast transmission using physical and MAC layers. The access points (AP) used to verify channel conditions and avoids extra control overhead.

Ashok Kumar et al. [16] have introduced light tree base logical topology to resolve the issue of multicast traffic, impacts on the resource utilization. It can impact on the routing decision. In light tree topology, the direct links are used for the purpose of communication and heuristic approach are useful to know the data flow conditions and avoiding traffic blocking conditions.

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Tien Anh L et al. [17] have discussed a cross-layer multi-variable cost method for optimizing resources at various layers. It dynamically updates the values of all available resources required to reach a particular node. Each layer has different resource requirements, and it varies from different conditions. It gives a better set of suitable routes to select optimal routing. This method deals with jitter, packet error, and bit error.

Chilamkurti N et al. [18] have discussed a cross-layer design with DSR. DSR can not distinguish between packet loss induced by congestion or node failure, causes excessive consumption of energy. This cross-layer approach checks only the last RSS value to know the availability of destination node within the transmission range. With the help of this cross-layer method, route estimation determined if the packet losses are due to node failure.

Zehua Wang et al. [19] have proposed a Proactive Source Routing Protocol (PSR) based on the opportunistic data forwarding concept. PSR facilitate the source routing by maintaining network topology information. PSR has smaller control overhead as compared to traditional DSDV, OLSR, and DSR. Each node is constructing a spanning tree by exchanging information periodically between its neighbor nodes.

Ya Xu et al. [24] have introduced a novel algorithm Geography-informed Energy Conservation (GAF) saves the energy of nodes. In this approach, location information collected through GPS devices. The whole network partitioned into the minimum sized virtual grid. Power saving techniques are placed into nodes to achieve energy saving. Nodes will enter into three states, route discovery, active mode, and sleep mode.

3. PROPOSED WORK

The proposed cross-layer optimal power control approach (XOPC) based on transmission power at the physical layer of the node. The modification in transmission power carried out after knowing the RSS value of the node's neighbor. This modified transmission power value used by the node for adjusting its propagation range. It is the reason of propagation distance value are related to transmission power value—such information transferred from the layer 1 (physical layer) to higher layers, especially the layer 3 (network layer), to make decisions instantly in routing protocols. The main benefit of this approach is that it can directly access various information available at the physical layer, MAC layer, and network layer. Fig. 1 depicts the interaction among different layers in a cross-layer approach.

Packet transmission may be affected by weak RSS value, unstable link, and network interference. The RSS value is always related to the transmission power of the broadcasting node. The signal generated from the broadcasting node can propagate to its neighbor node (1-hop) omnidirectionally.

This paper considers that all nodes in the network having the same value of the propagation range. This propagation range can be modified based on the coverage range of the neighbor node (1-hop). The RSS value has taken from the MAC layer. RSS value is useful to know the exact position of the node, whether it is in high signal strength or low signal strength.

Algorithm: Cross-layer Optimal Power Control (XOPC)

1. Source node broadcasts the Hello packet to determine the RSS value of neighbor nodes.

2. For every node i=1, 2, 3 ……m, calculates neighbors nodes and its RSS value.

3. Compare the neighbor's RSS value in the routing table.

4. If RSS value already present

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Update value in the routing table

Else

Store value as a new record

5. Determine RSS_{avg} of 1-hop neighbor nodes

6. For every i=1, 2, 3, …..m

If ($RSS_i < RSS_{avg}$)

Calculate RSS_{min}

Else

Calculate RSS_{max}

7. Classify transmission regions into

1. RSS_{min} region
2. RSS_{max} region
3. RSS_{avg} region

8. Each node adjusts its transmission power depends on RSS_{max} value

9. Proceed with packet transmission

10. Repeat the steps 1 to 9, for every neighbor nodes

11. Update the routing table and terminate the algorithm.

The Hello packet used to broadcast this information to its 1-hop neighbor node (see algorithm). This Hello packet useful to update the RSS value of nodes available in the routing table. Then each node identifies its three regions (RSS_{min}, RSS_{avg}, RSS_{max}) and determines the average RSS value of its neighbor nodes.

Let m represents the number of neighbor nodes (1-hop) of node N_i, and the RSS_i is the RSS value of all neighbor nodes (1-hop) of node N_i. The value of the average RSS (RSS_{avg}) calculated as in Eq (1):

$$RSS_{avg} = \frac{\sum_{i=1}^{m} RSS_i}{m} \quad (1)$$

In Eq. (2), Nmin represents the minimum RSS value of the node, which is less than RSS_{avg} value.

$$RSS_{min} = \frac{\sum_{i=1}^{Nmin} RSS_i}{Nmin}, \ RSS_i < RSS_{avg} \quad (2)$$

In Eq. (3), Nmax represents the maximum RSS value of the node, which is higher than the RSS_{avg} value.

$$RSS_{max} = \frac{\sum_{i=1}^{Nmax} RSS_i}{Nmax}, \ RSS_i > RSS_{avg} \quad (3)$$

The RSS values (RSS_{min}, RSS_{avg}, RSS_{max}) are related to transmission distance. The RSS_{min} represents maximum coverage area and transmission distance, while RSS_{max} represents minimum coverage area and transmission distance.

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4. PERFORMANCE ANALYSIS

4.1 Simulation Setup

The NS2.34 [25] network simulator is useful in performance analysis and implementation of proposed XOPC. We have used Energy consumption routing (ECR) as a base protocol to implement the proposed XOPC. Table 1 depicts the simulation parameters:

Table 1: Simulation Parameters

Simulation area	1000m * 1000m
Number of nodes	35, 45, 55 and 65
Simulation duration	90s
Propagation Model	Two Ray Ground
Mobility Model	RWP
Network Protocol	ECR and proposed XOPC
Antenna type	Omni-directional
Traffic type	CBR
Transport protocol	UDP
MAC protocol	802.11
Initial energy	100J

4.2 Performance Metrics

We have considered the following performance parameters for the evaluation of the proposed approach.

Packet delivery ratio (PDR): It is calculated by the ratio of the total number of data packets received by the receiver to the total number of the data packets transmitted by the sender in a specific time.

End-to-end delay: It is the time needed by the transmitter to deliver the data packet successfully to the receiver.

Energy Consumption rate: It is the rate at which energy exhausted by the nodes while performing routing of data packet. The rate of energy consumption will decide the lifespan of particular node.

Control overhead: This can be determined by the total number of control packets transmitted in the simulation time. With the increase in node's mobility, the value of control overhead can increase.

5. Results and Discussion

5.1 Energy efficiency

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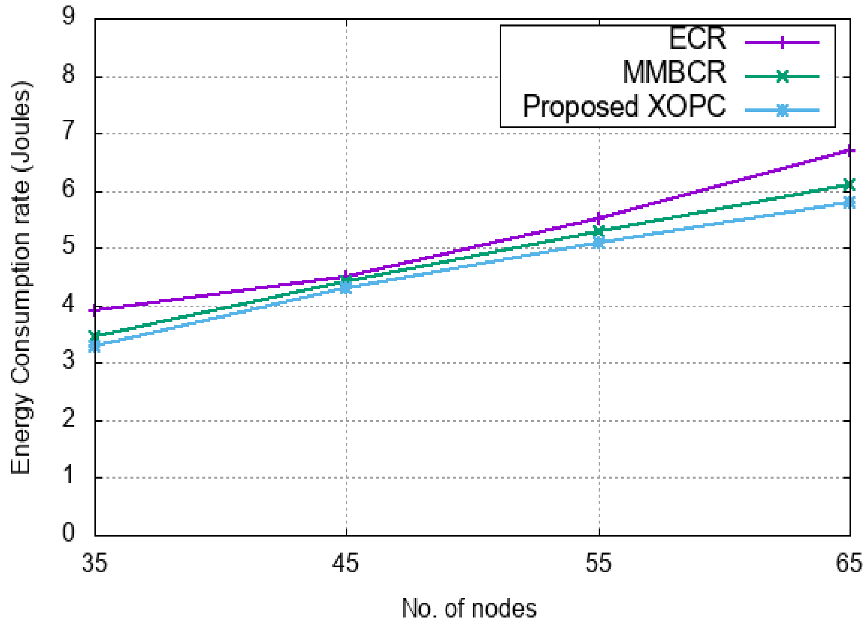

Figure 2. Energy Consumption rate (Joules)

Fig. 2 represents the energy consumption by the proposed XOPC is lower than ECR and MMBCR. The deviation in network topology will update the routing table. This is used to analyze the energy values for different simulation environments. The energy consumption varies as the number of nodes varies from 35 to 65. In fig. 2, the total average rate of energy consumption by ECR is 82.06%, MMBCR is 76.7%, and the proposed XOPC is 64.6%, with the initial energy of 100 joules.

5.2 End to end delay

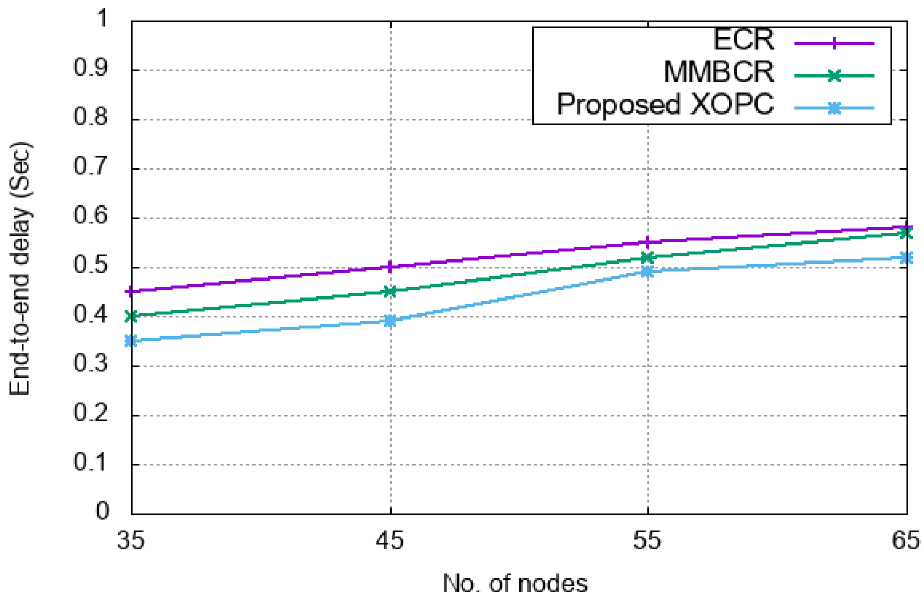

Figure 3. End to end delay (Sec)

Fig. 3 depicts the simulation result of an end to end delay of the proposed approach. The value of delay varies with the number of nodes. The ECR has a higher delay than MMBCR and proposed XOPC.

5.3 Control overhead

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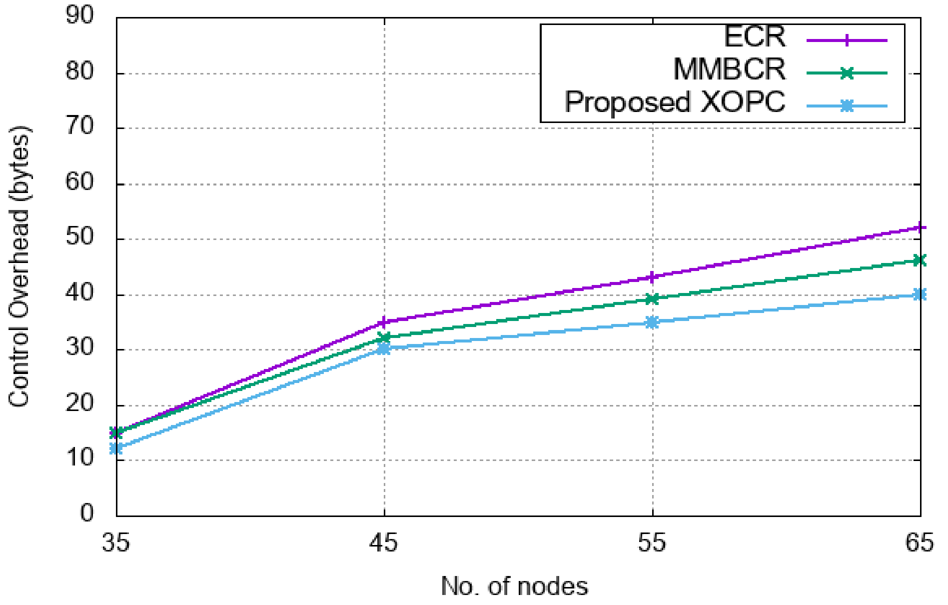

Figure 4. Control overhead (bytes)

Fig. 4 depicts the control overhead values for varying numbers of nodes. In ECR, the control overhead is more than MMBCR and proposed XOPC. The value of control overhead increases with number of nodes varies from 35 to 65.

5.4 Packet delivery ratio

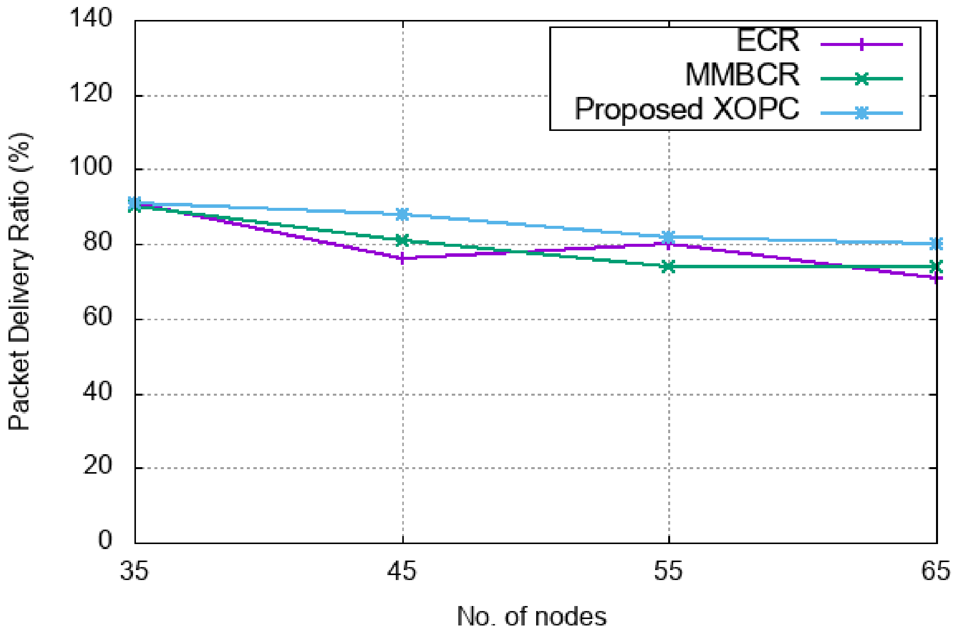

Figure 5. Packet delivery ratio (%)

In fig. 5, ECR preserves the packet delivery ratio approximately 73%, whereas MMBCR has a packet delivery ratio of about 71% with the changing number of nodes from 35 to 65. The proposed XOPC maintains a nearly 94% packet delivery ratio.

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6. CONCLUSION

In this paper, the cross-layer optimal power control (XOPC) proposed. This paper aggravated by the use of optimal power in the MANET. Firstly, Energy draining can tamper the network's overall performance. In the proposed XOPC approach, each node determines the RSS value of its neighbor nodes and classifies three transmission regions (RSS_{min}, RSS_{avg}, RSS_{max}). Secondly, every node will modify its transmission power depends on the value of transmission range. The simulation results presents the proposed XOPC saves the total energy approximately 35%, reduction in control overhead, and increase in the value of packet delivery ratio up to 20% as compared with ECR and MMBCR protocols.

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