Enhanced Hybrid Scheduling Algorithm for Small Wireless Ad Hoc Networks

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ABSTRACT— The study of ad hoc wireless networks are relatively new field gaining more popularity for various new applications. Mac protocols are of significant importance since the wireless communication channel is inherently prone to errors and unique problems and also there are challenges of achieving high throughput, low jitter, low delay and good quality of service (QoS) along with the collision free transmission. This work involves an enhancement to the design of contention vector based scheduling algorithm for wireless networks. It can detect and punish non-cooperating nodes at the MAC layer. This work also involves implementation of the proposed algorithm using core java and analysis of its performance.

Keywords: - Wireless MAC, scheduling, contention resolution, Ad hoc network.

I. INTRODUCTION

In wireless communication, the medium access control plays a vital role of coordinating access to the medium among the participating wireless nodes. Medium access control (MAC) also responsible for error detection and correction. MAC protocols are divided into 2 categories, i.e centralized and distributed [1, 2].

Centralized MAC protocols use a node as coordinator to control access to the medium. In this type of protocol, the nodes must obtain permission before transmitting packets. Time Division Multiple Access (TDMA) is an example of centralized MAC protocol. TDMA is used in wireless cellular communication. TDMA provides low delay, low jitter and collision free transmission. TDMA has a limitation of network scalability. It requires adjusting of frame length and slots according to the number of participating nodes. Another example of centralized MAC protocol is IEEE 802.11 Point Coordination Function (PCF)

A distributed MAC protocol does not require a coordinator to manage wireless medium. Each node makes its own decision based on different mechanism. IEEE 802.11 Distributed Coordination Function (DCF) is an example of distributed MAC protocols. DCF uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) for medium access. DCF supports node joining and leaving, i.e network dynamics. However, because of poor efficiency of contention resolution algorithm the performance decreases gradually as the number of nodes increases.

The Contention Vector Based Hybrid Scheduling Algorithm (CVHS) [2] took the best features of both the types of protocol to provide a collision free transmission and can adapt to network dynamics. It uses efficient K-round elimination contention mechanism for contention resolution [1, 5].

The contribution of this paper is implementation of enhanced CVHS which involve enhanced security features at the Mac layer. It also proposes an energy efficient mechanism for coordinator election. The Enhanced hybrid scheduling algorithm targets small wireless ad hoc networks where each node can sense each other. Section II gives brief introduction to K-EC algorithm. Section III presents Enhanced hybrid scheduling algorithm implementation details and performance analysis of the algorithm. Section IV presents conclusion and future research scope.

II. K-EC ALGORITHM

K-EC is a distributed MAC algorithm provides efficient contention mechanism. To transmit a packet, a node needs to attend several rounds of contention. If it wins the final round, it can send packets. Node has to desist from current contention if it losses in the contention [1].

The time taken for contention resolution is called Contention Resolution Period (CRP). Contention resolution period is further divided into a number of time slots, C-slots. C-slots are grouped into k groups each corresponds to a contention round. Each contention round has m C-slots. If a node successfully transmits an energy pulse it wins the round. It moves to next round of contention. If that node wins all the rounds, node gets access to the medium. The sending of energy pulses depends on the allocated Contention Vector (CV) value. Node with smallest CV gets access to the medium quicker than other contending nodes. For example, CV [312] corresponds to 3 rounds of contention and there are 3 C-slots. It means, the node has to send energy pulse at 3rd slot of 1st round, 1st slot of 2nd round and 2nd slot of 3rd round.

III. ENHANCED HYBRID SCHEDULING ALGORITHM

Enhanced Hybrid Scheduling Algorithm (EHSA) has the following properties,

- It provides collision free transmission.
- It provides enhanced security at the MAC layer for handling non-cooperating nodes.
- It is adaptable to node dynamics.
- It provides a novel coordinator election mechanism.

In this algorithm, an energy efficient node is elected as coordinator. The elected coordinator keeps track of all the participating nodes and generates unique contention vector and node ID for the requesting nodes. The nodes participate in contentions with the help of CV assigned to it. In this algorithm, the time is divided into repeated time periods called super frames to provide collision free transmission. Each super frame has Inter Frame Spaces (IFS) between consecutive contentions. The algorithm has been implemented in a test bed using JAVA. All the functionalities are implemented into a single Java application with GUI for convenience.

A. Assignment and maintenance of CV's

The elected coordinator node is responsible for generating, assigning and maintaining of contention vectors (CV). When the coordinator receives request to join the network, it generates a unique CV and node ID for the requested node and assigns it. It also maintains a table of CV's and node ID's assigned. Coordinator removes corresponding entry from the table when the node dynamically leaves the network.

B. Coordinator election

This paper proposes a novel mechanism for coordinator election. The participating nodes are categorised into mobile nodes and stationary nodes. All the participating nodes reply with its current battery level to a broadcast request for election. The nodes then pick the node with highest energy and the node is stationary as coordinator. If all nodes are mobile in nature, then a node with highest energy among them is elected as coordinator. It is assumed that the stationary node can recharge itself by plugging into power outlet. Hence stationary nodes are given preference. The elected coordinator has to generate unique CV's and unique node ID's for the participating nodes. Also, it must maintain a table of information about all the participating nodes and update it regularly.

C. Non-cooperating node detection and punishment

The non-cooperating node detection and punishment is done at the MAC layer itself thereby reducing various overheads required to manage it at the upper layers. The algorithm works based on the message-acknowledgement mechanism. The algorithm waits for an acknowledgement (ACK) after sending a message for fixed amount time. If ACK is not received within that time, the coordinator adds the destination to non-cooperating nodes list and blacklists for a fixed amount of time. This allows the non-cooperating node to return normal mode after some time. Hence this method gives fair opportunity for the non-cooperating nodes to turn to normal mode.

D. Performance analysis

The process of evaluation and efficiency analysis of this implementation involves recording of network performance parameters. Since the proposed algorithm is based on the wireless ad hoc network and involves real atmosphere as medium, the metrics used for performance evaluation are [2, 6]*:*

– *Throughput*: It is defined as ratio of amount of time for transmitting a data frame to the total medium access time for transmitting a frame. Mathematically,

Throughput, Tr = t_{data}/t_{access}

Where, t_{data} corresponds to time for transmitting a data frame.

t_{access} corresponds to total medium access time.

$t_{access} = (L_{crp} + t_{data} + 2*SIFS + CrpIFS)/n$.

L_{crp} corresponds to average length of contention resolution period.

SIFS corresponds to short inter frame space.

CrpIFS corresponds to CRP inter frame space.

n corresponds to number of backlogged nodes.

– *Delay*: It is defined as duration of time taken by a packet from transmitter buffer until the acknowledgement is received for the same packet Mathematically,

$$Delay, d = \sum_{i=1}^{n} t_{access}(i)$$

– *Jitter:* It is defined as delay difference between 2 consecutive packets of a session.

Jitter of a session at time t is

$$J_t = |d_k - d_{k-1}|$$

Where, d_k *and* d_{k-1} are two consecutive packet delays of a session.

The implemented algorithm has been run several times on a test bed. Network throughput, delay and jitter are computed by measuring the time taken using stopwatch function provided by the apache timer. The values are then plotted using MATLAB plot function. The results are as shown below,

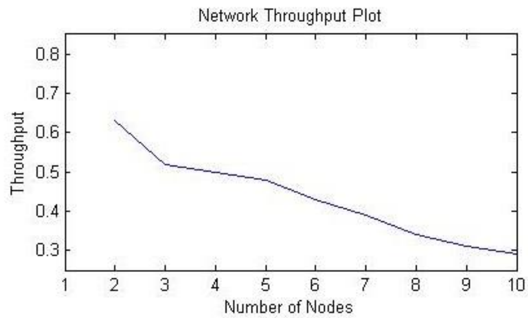

Fig. 1: Network throughput plot for Enhanced hybrid scheduling algorithm.

Figure 1 depicts the network throughput for enhanced hybrid scheduling algorithm for wireless ad hoc networks. It is evident from the plot that the network throughput decreases as the number of nodes are increased. Since the target was a small network, number of nodes considered varied from 2 to 10.

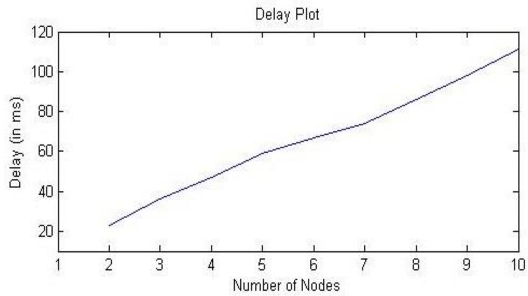

Fig. 2: Network delay plot for Enhanced hybrid scheduling algorithm.

Figure 2 depicts the network delay for enhanced hybrid scheduling algorithm for wireless ad hoc networks. It is evident from the plot that the delay gradually increases with the increase in the number of participating nodes. Since each contending nodes contribute to the total network delay, network delay is additive in nature.

Figure 3 depicts the jitter for enhanced hybrid scheduling algorithm for wireless ad hoc networks. It is evident from the plot that the jitter is directly proportional to the number of nodes. The jitter increases as the number of nodes participating increases.

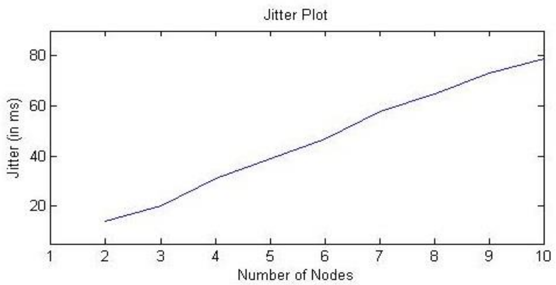

Fig. 3: Jitter plot for Enhanced hybrid scheduling algorithm.

It has been observed that the number of participating nodes in contention effects directly on performance and efficiency of the algorithm. The results are satisfactory as this algorithm apart from providing collision free transmission mechanism, it can take decision on non-cooperating nodes at the MAC layer there by reducing the overhead that is required if non-cooperating nodes are handled at the higher layers.

IV. CONCLUSION AND FUTURE SCOPE

The proposed enhanced hybrid scheduling algorithm for wireless ad hoc networks has been implemented in a test bed. The algorithm provided collision free transmission and dynamic node leaving and joining the network, error detection using 32 bit cyclic redundancy check, novice method of coordinator election considering mobile and stationary nodes and detection and punishment of non-cooperating nodes in the network.

The network behavior is satisfactory. The throughput decreases as number of nodes increases, delay and jitter increases as number of nodes increases. It is observed that the algorithm works better for small wireless ad hoc networks. The implementation analysis shows that the results are relatively good when compared to the standard algorithms. The algorithm requires further modifications before commercial use.

The algorithm can be further enhanced to bring out better performance and efficiency.

- The proposed algorithm can be enhanced to work with multi-hop networks.
- The algorithm can be made more secure by securing coordinator and its election process.
- The throughput can be improved further when number of nodes keeps increasing.
- The commercial implementation issues can become an area research.

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