

# Improving Energy Efficiency of MANET by Enhanced Distance Based Broadcasting Protocol

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**Abstract** – Mobile Ad-Hoc Network (MANET) is wireless networks consisting of a collection of mobile nodes with no fixed infrastructure, where some intermediate nodes should participate in forwarding data packets. Energy conservation is a critical issue in ad hoc wireless networks for node and network life. Enhanced Medium Access control (eMAC) protocol prevents link/routing failures, hidden/exposed terminal problems and broadcast storm problems using an adaptive unreachability reporting mechanism with more energy consumption. Furthermore, An adaptive table broadcasting technique is proposed to facilitate topology information dissemination in mobile ad hoc networks (MANETs). In this paper, a cross layer design for enhancing the distance based broadcasting protocol is proposed in terms of energy consumption. Instead of using the distance, the reception signal strength is considered. The necessary transmission power to reach an intended device is obtained using the beacons. If the furthest node can be reached using less power than the default value, the transmission power is reduced and it saves energy. Different proposals for enhancing the algorithm are proposed, and they not only save energy but also highly reduce the number of collisions. *Keywords* – Energy efficiency, Mobile Ad-hoc Networks, cross layer design, unreachability, and distance based broadcasting.

## I. INTRODUCTION

Mobile ad-hoc network (MANET) is composed of clusters of self-organized wireless stations without a need to utilize any preinstalled infrastructure. Due to the prospective of self-organized deployment, lots of practical applications have been conceived for MANETs. On the other hand, numerous technical issues arise in such networks due to a shared wireless medium and mobility. In fact, the efficiency of MANETs depends on the performance and reliability of the medium access control (MAC) protocol applied in such environments.

The unreachability problem becomes more severe in multihop environments and results in packet dropping, starvation of part of traffic flows, and possibly unnecessarily network-layer rerouting [2]. The protocol in [1] adds a couple of new control frames to

ease the reporting of the unreachability situation to solve the receiver-blocking problem. When a station is notified about an upcoming data communication due to which it will be unreachable, it is given an opportunity to inform its one-hop neighbors about the forthcoming unreachability. In principle, right after the RTS/CTS negotiation and before commencing the actual DATA transmission phase, the stations, which will shortly become unreachable, are given the chance to report their imminent unreachability status using a designated broadcast frame called individual communication pause (ICP). Since there is no exception for participation in unreachability reporting, all potential candidates contribute in this phase; thus, in certain network topologies, collisions may occur among broadcasted ICP frames.

## RELATED WORK

### A. Introduction

Literature survey is carried out by analyzing many papers relevant to unreachability problem like hidden/exposed terminal problems, packet dropping and distance based approach to reduce energy consumption of nodes in MANETs. The researches carried out by different authors are surveyed and the analysis done by the researchers are discussed in the following paragraphs.

### B. A Dual-Channel Mac Protocol For Multihop Ad Hoc Networks

H. Zhai, J. Wang, and Y. Fang [2], proposed that IEEE 802.11 MAC protocol has been the standard for Wireless LANs and is also implemented in much simulation software for mobile ad hoc networks. However, IEEE 802.11 MAC has been shown to be quite inefficient in the multihop mobile environments. Besides the well-known hidden terminal problem and the exposed terminal problem, there also exists the receiver blocking problem, which may result in link/routing failures and unfairness among multiple flows. Moreover, the contention and interference from the upstream and downstream nodes seriously decrease the packet delivery ratio of multihop flows. The new MAC protocol uses an

out-of-band busy tone and two communication channels, one for control frames and the other for data frames, and can give a comprehensive solution to all the aforementioned problems. Extended simulations demonstrate that protocol provides a much more stable link layer, greatly improves the spatial reuse, and works effectively in reducing the packet collisions. It improves the throughput by up to 20% for one-hop flows and by up to 5 times for multihop flows under heavy traffic comparing to the IEEE 802.11 MAC.

### C. Dual Busy Tone Multiple Access -A Multiple Access Control Scheme for Ad-Hoc Networks

Z. J. Haas and J. Deng [3], proposed that the dual-BT multiple access (DBTMA), where two out-of-band Busy tones (BTs), i.e.,  $BT_t$  and  $BT_r$ , are deployed to protect RTS and DATA frames, respectively, the former is always activated by the source station when an RTS frame is being transmitted, while the latter is triggered by the destination station when it is receiving a DATA frame. In contrast, DUCHA utilizes two channels separately for control and data frames. RTS and CTS are transmitted in a separate control channel to avoid collisions with the data packets. Negative Clear to send (CTS) is used to solve the receiver-blocking problem and is also transmitted in the control channel. An out-of-band receiver-based BT is used to solve the hidden-terminal problem. To address the frame error due to the imperfect wireless channel, the negative ACK (NACK) signal, which is a continuing BT, is introduced when the receiver determines that the received data are corrupted.

### III. ENHANCED MEDIUM ACCESS (eMAC) PROTOCOL

For reducing the unreachability problem, the general architecture of eMAC protocol is chosen and it is analysed. The main aim is to introduce a technique to avoid the spread of unnecessarily simultaneous unreachability reports, and therefore, the Double Hop Neighbourhood (DHN) graph is maintained by every station. Each station can be either mobile or stationary. The DHN graph of each station gives an estimate of its DHN topology. This may be accomplished by overhearing Request to Send / Clear to Send (RTS/CTS) control frames if the unreachable station is situated in the communication range of the un-reachability cause.

In this case, the unreachable station of type II broadcasts an ICP frame of type II for which there are two address fields: The first address field carries the MAC address of an unreachable station of type I from which an ICP frame of type I has been received, and the second address field carries the MAC address of the unreachability cause. In this architecture, an ICP frame generated by an unreachable station of type I is referred to as an ICP frame of type I. Similarly, an ICP frame generated by an unreachable station of type II is referred to as an ICP frame of type II. The former has only one address field used for carrying the MAC address of the unreachability cause, while the latter has two address fields used for carrying 1) the MAC address of the unreachable station of type I from which an ICP frame of type I

has been received and 2) the MAC address of the unreachability cause.

In addition, its duration/ID field is used to indicate the duration of unreachability. the announcement of an upcoming unreachability status is performed either right after an overheard RTS and/or CTS frame (unreachability of type I) or upon overhearing an ICP frame of type I received right after a BT of a particular duration (unreachability of type II).

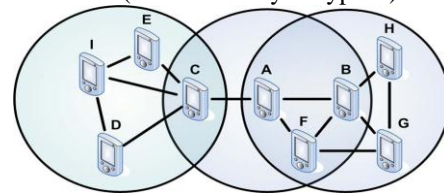


Fig.1. Exchange of Topology Information using eMAC.

In addition to the DHN graph, each station maintains an eMAC table, which keeps track of all its immediate one-hop neighbors. Basically, the eMAC table is generated from the DHN graph. On the other hand, upon reception of all one hop neighbors' eMAC tables, each station either constructs or updates its local DHN graph as well. To clarify this issue, consider the network topology illustrated in Fig.1. In this configuration, station "A" can receive eMAC tables from all its immediate one hop neighbors, i.e., stations "B," "C," and "F." Similarly, station "B" is able to obtain tables from stations "A," "F," "G," and "H." Station "A" is able to easily construct a DHN graph to mimic its DHN topology. Now, Assume that stations "G" and "H" are willing to perform a long-term data exchange using packet fragmentation. In this scenario, "G" is supposed to serve as the source station, and "H" is assumed to be the destination station. Apparently, this leads to the unreachability of both "B" and "F." When station "A" receives an ICP frame sent by either "B" or "F," it verifies the appended field indicating the unreachability cause and using its DHN graph, it concludes that all one-hop neighbors of station "G" will be unreachable as well. By this approach, "A" needs to receive only one ICP frame to be informed about the unreachability of "B" and "F."

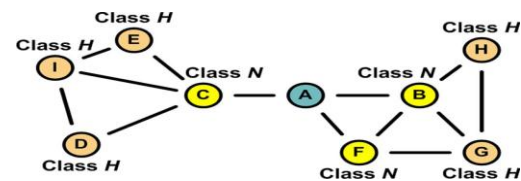


Fig.2. DHN Graph Maintained by station 'A'.

### B. eMAC Table Structure

Each station maintains two different versions of the eMAC table at any time. One is called the synchronous eMAC table and is denoted by  $\Xi(t)$ . This table is directly generated from the local DHN, whenever it is updated. The second table is denoted by  $\Xi$  and represents the latest version of the eMAC table that has been broadcasted over the air interface. Basically, each

station should broadcast its synchronous eMAC table  $\Xi(t)$  in a regular fashion; whenever the synchronous eMAC table  $\Xi(t)$  is broadcasted in its corresponding due beacon interval (BI), the existing  $\Xi$  table is simply replaced by  $\Xi(t)$ . Note that  $\Xi$  is replaced by the synchronous eMAC table  $\Xi(t)$  only when  $\Xi(t)$  is being broadcasted in its due BI and not when  $\Xi(t)$  is updated due to the reception of new topology information.

### C. eMAC Table Maintenance and Broadcasting Rules

When the DHN graph is updated due to the reception of new neighborhood topology information, the synchronous eMAC table  $\Xi(t)$  is consequently regenerated. This means that the DHN and  $\Xi(t)$  keep the most up-to-date information about the DHN and one-hop neighborhood of the local station, respectively. As stated earlier, the most up-to-date version of the eMAC table should be broadcasted in a regular fashion. To determine how frequent and when the eMAC tables are broadcasted, the number of BIs that have to elapse before broadcasting the latest version of the eMAC table is specified. When the synchronous eMAC table  $\Xi(t)$  is broadcasted in its due BI, it is also saved as  $\Xi$  to represent the last version of the local eMAC table that has been broadcasted over the air interface.

## IV. DISTANCE BASED (DB) BROADCASTING ALGORITHM

Distance Based (DB) is one of the different schemes proposed for minimizing the effects of the broadcast storm problem when disseminating information in wireless networks. The protocol makes use of the distance between the source node and the receiver. The idea is that a node receiving a broadcast message for the first time will compute the distance to the source node. If this distance is small, the contribution to the dissemination performing this forwarding is negligible and therefore, the message is not resent.

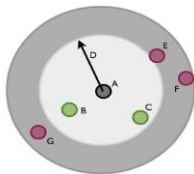


Fig.3. Mechanism of DB.

Fig.3. represents the functioning of the algorithm. Considering node A broadcasts a message  $m$ , nodes B and C will not resend  $m$  because the distance from those nodes to A is smaller than D. Nodes E, F and G will wait for a random number of slots. If node F finishes the waiting time first, it will forward the message and, thus, node E will hear it and calculate the distance from node F. as the distance is smaller than D, node E will drop the packet. The pseudocode of the protocol is shown in Alg.1.

### A. Enhanced DB

In this section we explain the procedure followed to implement the broadcasting algorithm, and also the improvements introduced to the original protocol, DB.

#### 1) Implementation

For calculating the distance between a source and a destination, the signal strength of the received packets is used to estimate how far two nodes are.

In this implementation, the threshold  $D$  is not in terms of distance (m) but power (dBm). It is called *borders Threshold* as it defines the nodes that are considered to be far from the source and therefore close to the border. The value used for this parameter is  $-90$  dBm. This value was experimentally chosen, and any value below it supposes that the source and destination nodes are separated at least  $2/3$  of the maximum coverage. A node is not able to decode a received packet if the reception power is lower than  $-95$  dBm, this is called the *end Threshold*. Therefore, all nodes whose reception energy vary from  $[-95, -90]$  dBm are candidates of forwarding the broadcasting message.

Every device sends a *hello* message (or beacon) to alert devices within a close area about their presence. A device receiving these beacons is able to keep track of all neighbors around. Here, a cross layer design is considered where the physical layer informs the upper layers about the received signal strength of each beacon. In this situation the algorithm is able to take decisions depending on this value. When a broadcast message is sent, the receiving node will check the reception power, if it is below the *borders Threshold* ( $-90$  dBm), it will consider itself as a bordering node and thus, sets the delay.

#### 2) Enhancements

An ad hoc networks, and devices depend on battery, saving energy supposes one critical aspect. One of the new features added to DB is reducing this energy consumption using transmission power reduction.

#### Reducing Transmission Power

In any wireless transmission, as the electromagnetic wave propagates through the space, the power of the signal suffers from path loss attenuation causing a reduction in the signal power. The relation between the transmitted power and the power finally received at the destination directly depends on the loss suffered during the transmission. This relation in terms of dB is expressed as, *received Power = transmitted Power - loss* ----- (1)

Assume all nodes send the *hello* message with the same transmission power (16.02 dBm). Thus, a node receiving a beacon will be able to estimate the loss that packet suffered during the transmission, using the reception power detected at the physical layer.

Every node keeps and updates the reception power of each of its neighbors in a list. When a device wants to send a broadcast message, it will be able to estimate the the packet loss. If a node can estimate the loss the packet is going to suffer, it will be able to reduce its transmission power and use only the necessary one to get the furthest one hop neighbor. so that the furthest node is receiving the packet with the minimum reception power allowed to correctly decode the message. The new reduced transmission power can be calculated as,

*transmission Power = loss + end\_Threshold* ----- (2)  
 from the above equation, it is possible to estimate the maximum transmission power needed to reach the furthest neighbor in the one hop neighborhood. If it is less than the default transmission

power, It is reduced in order to save energy, Therefore, reducing the transmission range from  $r$  to  $r'$  decreases the energy consumption with no detriment of the network connectivity as shown in Fig.4..

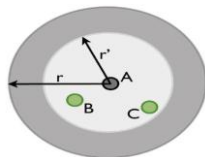


Fig.4. Reducing the Transmission Power of Nodes.

Reducing the transmission power for sending broadcast messages not only improves the energy consumption in wireless networks, but also reduces the interference level of devices in a close area. Each device has the *end Threshold* from which on, if the received signal strength is lower, the device will not be able to recover the data transmitted, but this reception will be considered as noise and will increase the interference level of the device.

#### Using Different Delay Techniques

DB stops the random delay when a repeated message is heard. Then, if the distance from the new source node is smaller than the threshold  $D$ , the message is discarded and no retransmission is performed. Otherwise, the forwarding starts.

Instead of stopping the delay when a repeated message is heard, the possibility of keeping track of the received energy and continue the delay are considered. Once it is finished, the forwarding decision is taken according to maximum received power.

In this section, the behavior of two different techniques are considered and comparing them to the original proposal of DB,

1. In the first one a fixed delay inversely proportional to the received power is considered. the procedure to calculate the delay in terms of the reception power is shown as,  $Power\ Delay = -1/rxPower - borders\_Threshold - 1$  (3) If a node is setting a delay, it means, the node is a *border* node, otherwise the node is not considered as a candidate to forward the message, and therefore, no delay is set. All *border* nodes receive the message with a reception power that can vary between the *borders Threshold* (-90 dBm) and the *end Threshold* (-95 dBm).
2. The second proposal considers a random delay chosen from an interval whose size also varies with the reception power. That is, the waiting time will be chosen between [0, *powerDelay*] and the delay varies from 0 to 1 second.

The comparison of different techniques as explained as,

- a) the delay is chosen randomly from the interval [0, 1]s.
- b) the delay is fixed with the value *powerDelay*, and finally
- c) the delay is chosen randomly from the interval [0, *powerDelay*]s.

## V. SIMULATION RESULTS

To evaluate the performance of proposed protocol, extensive simulations are provided for the system throughput,

delay, jitter, and overhead and compare the achieved results with Enhanced MAC (eMAC) protocol. The propagation model is the two-ray ground model, the transmission range of each station is approximately 250 m, the carrier sensing range is approximately 400 m. The channel rate is set to 2 Mb/s and mobile nodes exist in an area 2,500 [m] x 2,500 [m]. In this simulation study, the following performance metrics are evaluated.

### A. End-to-End Delay

The term the average delay is a data packet experiences to cross from source to destination. This delay includes all possible delays caused by buffering during route discovery delay, queuing at the interface queues and retransmission delays at the MAC, propagation and transfer times.

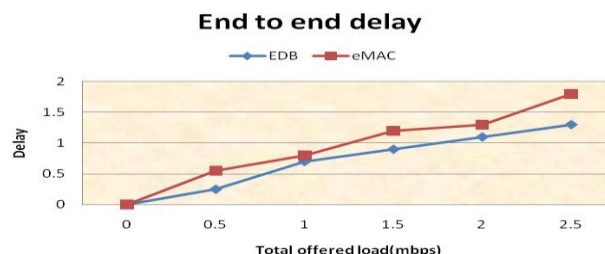


Fig.5. Total offered load Vs Delay.

The Fig.5 shows the comparative delay analysis for eMAC and Enhanced Distance Based (EDB) protocol on varying the offered load. The graph shows that eMAC protocol has less end to end delay compared to EDB protocol even if the end to end delay increases.

### B. Normalized Overhead

This overhead is the ratio of number of routing control packets to delivered data packets. Each packet requires extra bytes of format information are stored in packet header, which combined with assembly and disassembly of packets, reduces the overall transmission speed of raw data.

Fig.6 illustrates the normalized control overhead for two different MAC protocols versus the total offered load. The proposed EDB shows indeed better results in comparison with eMAC scheme,

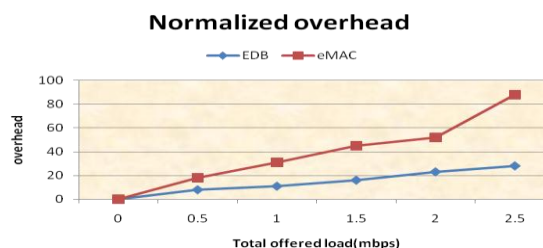


Fig.6. Total offered load Vs Overhead.

due to the fact that it avoids unsuccessful link-layer connection establishment requests to the unreachable terminals.

### C. Jitter

This jitter is defined as the variation in the packet delay. High jitter means the difference between delays is large and low jitter means the variation is small.

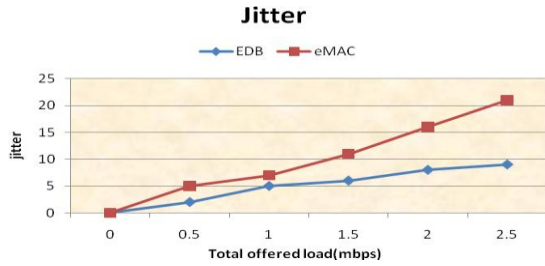


Fig.7. Total offered load Vs Jitter.

Fig.7 shows the average frame jitter versus the total offered load in megabits per second. The EDB protocol shows the best performance compared with eMAC protocol when the offered load varies between 0.5 and 2.5 Mb/s.

#### D. Energy consumption

Fig.8 presents the energy consumption. The Comparison of energy consumption for EDB with that of the eMAC protocol is shown. It is clearly seen that energy consumed by Enhanced DB protocol is less compared to other schemes.

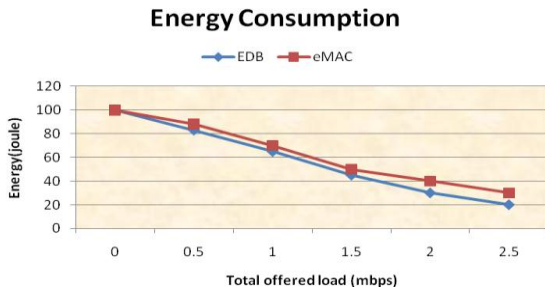


Fig.8. End to end throughput Analysis.

#### E. Throughput analysis

The term throughput is the ratio of the total amount of data that a receiver receives from a sender to a time it takes for receiver to get the last packet. A low delay in the network translates into higher throughput.

##### One-hop throughput

One hop throughput is the number of data packets transmitted between two successive nodes.

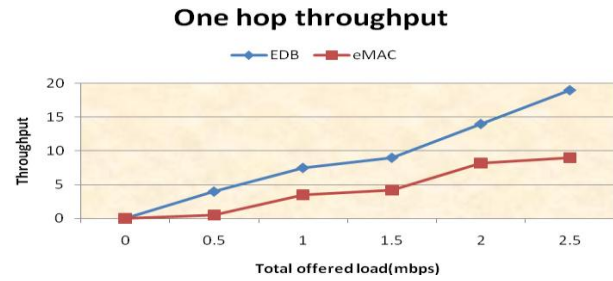


Fig.9. One-hop throughput Analysis.

Fig.9 illustrates the one hop throughput for different schemes when the total offered load varies. It shows that EDB has high throughput compared to eMAC protocol even if the one hop throughput increases.

##### End-to-End throughput

The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

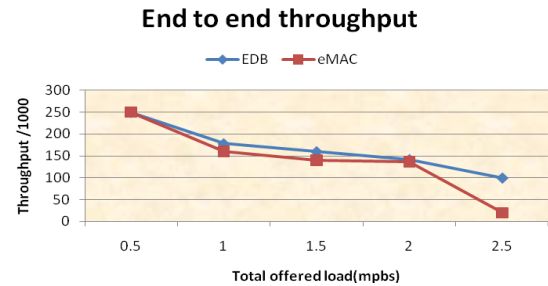


Fig.10. End-to-end throughput Analysis.

Fig.10 shows the aggregate end-to-end throughput versus the total offered load in megabits per second. eMAC shows the worst performance compared with EDB protocol when the offered load varies between 0.5 and 2.5 Mb/s.

## VI. CONCLUSION

The unreachability problems have addressed here without deployment of more than one communication channel. The proposed eMAC protocol scheme prevent the unreachability problem, resulting in much more efficient channel utilization and higher transmission capacity by implementing topology-awareness and smarter decision-making algorithms into the MAC protocol. It has been shown that the unreachability problem can be addressed in a better way, leading to an adaptive and robust topology-aware protocol with more energy consumption. An energy saving strategy for the well known distance based broadcasting algorithm DB is proposed

For decreasing the energy consumption, a reduction in the transmission power is performed when possible. This is really useful when the network is not very dense reducing up to 86.97% in the best case, but when the number of devices is big, the node does not reduce the transmission power so much since there are

usually nodes close to the border. This strategy of reducing the transmission power is saving at least 7.55% of energy per forwarded message. As a result from the experiments performed, The enhanced distance based (EDB) protocol is the one that generally behaves better than the enhanced medium access (eMAC) protocol. In this work enhanced distance based protocol is able to reduce energy without degrading the network connectivity and that also reduces the number of collisions in a 95.41%. The simulation results have showed that the EDB protocol has better performance than enhanced medium access protocol in terms of end to end delay, jitter, throughput analysis and overhead.

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