CHAPTER 3

DEMAND BASED EFFECTIVE ENERGY UTILIZATION FOR MOBILE AD HOC NETWORKS

A Mobile Ad hoc Network (MANET) is a collection of mobile nodes forming an ad hoc network without the assistance of any centralized structures. These networks have introduced a new art of network establishment and can be well suited for an environment where either the infrastructure is lost or deploying an infrastructure is not very cost effective. Nevertheless, in this case, the nodes are limited to send and receive information but do not route anything across the network. It can turn the dream of getting connected "anywhere and at any time" into reality. Typical application examples include a disaster recovery or a military operation. Not bound to specific situations, these networks may equally show better performance in other places.

Nodes are connected without any centralized access point in MANETs. The underlying assumption is that the intermediate nodes cooperate in forwarding the packets. Mobile nodes collect the route information through overhearing and store this information in route caches with the use of Dynamic Source Routing (DSR) Protocol. These nodes consume power unnecessarily due to overhearing the transmissions of their neighbours. Due to this, the network performance is improved, but more energy consumption occurs unnecessarily. The main goal of the work is to reduce the effect of overhearing, using the Demand Based Energy Efficient (DBEE) algorithm. The mobility of the nodes results in stale routes, due to the lack of route cache updation. For that, a cross layer framework is implemented along with the DBEE to improve route cache performance in DSR. By using the cache timeout policy we can easily prevent stale routes from being used.

The cache timeout of individual links are found by Receiving Signal Strength Indicator (RSSI) information. By simulation results the proposed algorithm achieves better performance than the existing methods.

3.1 DYNAMIC SOURCE ROUTING (DSR) PROTOCOL

It is the opinion of Narayan et al. (2004) that in DSR, the source node starts and takes charge of computing the routes. When a node S wants to send messages to node D, it broadcasts a route request (RREQ) which contains the destination and source node's identities. Each intermediate node that receives RREQ will add its identity and rebroadcast it until RREQ reaches a node who knows a route to D or the node D. Then a reply (RREP) will be generated and sent back along the reverse path until S receives RREP. When S sends data packets, it adds the path to the packet's headers and starts stateless forwarding. During route maintenance, S detects the link failures along the path. If it happens, it repairs the broken links. Otherwise, when the source route is completely broken, S will restart a new discovery.

3.2 OVERHEARING IN DSR

Overhearing brings in several undesirable consequences in addition to the energy inefficiency. Overhearing Fang Liu et al.., (2004) means a node picks up packets that are destined for other nodes. Wireless nodes consume power unnecessarily due to overhearing the transmissions of their neighbours. This is often the case in a typical broadcast environment. For example, as the IEEE 802.11 wireless protocol defines, receivers remain on and monitor the common channel all the time. Thus the mobile nodes receive all packets that hit their receiver antenna. Such a scheme results in significant power consumption because only a small number of the received packets are destined to the receiver or needed to be forwarded by the receiver. DSR gathers the route information through overhearing. Overhearing improves the routing efficiency in DSR by eavesdropping other communications to gather route information but it spends a significant amount of energy. The main cause of the stale route problem is the node mobility.

3.2.1 Stale Route Problem in DSR

The wireless links break due to the node mobility and an upstream node propagates a RERR packet to remove stale route information from route caches of the nodes. Nevertheless, RERR information is not propagated “fast and wide” and the route caches often contain these stale route information for an extensive period of time. Now, overhearing could make the situation even worse. This is because of the reason that DSR generates more than one RREP packets for a route discovery to offer alternative routes in addition to the principal one. While the primary route is checked for its validity during the communication between the source and the destination, alternative routes may remain in route cache unchecked even after they become stale. This applies not only for the nodes along the alternative routes, but also for all their neighbours because they learned and kept them by means of unconditional overhearing, which is node S transmits packets to node D through a pre-computed routing path with three intermediate nodes but in this case each and every node overhears the transmission which results in the energy consumption as well as less network lifetime.

3.2.2 Semantic Discrepancy in DSR

Each and every node in DSR collects route information aggressively via overhearing but it introduces a semantic discrepancy. Data, RREP or RERR is a unicast packet which is intended only for the selected receiver, but the transmitter in fact wishes that other nodes in the nearness overhear it. On the other hand, the nodes do not wake up to overhear the unintended packets because they make use of 802.11 PSM, upsetting the normal operation of DSR.

In RandomCast, a desired level of overhearing can be specified for each packet and so, every communication is semantically consistent.

3.2.3 Unconditional Rebroadcast in DSR

Most of the energy consumption in DSR is mainly due to the rebroadcast of packet. An RREQ control packet is meant to every other node in the network and thus, each node is supposed to rebroadcast it whenever it receives such packet. In the case of dense network, when the network traffic increases redundant rebroadcast also increases which results in the energy wastage. If there is no or less mobility then there will be no trouble so RREQs may be rarely generated. When mobility of the nodes are high, there will be more breakage of links, which results in more broadcast packets (RREQs) as well as their flooding in the network.

3.3 IMPLEMENTATION OF CROSS-LAYER APPROACH WITH DBEE ALGORITHM

The proposed work is based on the Random Cast Sunho Lim et al. (2009) and the design is carried out based on DBEE – Cross Layer Approach. A node in an ad-hoc network learns routing information by overhearing or forwarding packets to other nodes and keeps the learned routes in the route caches. The frame format of RandomCast for both unicast and broadcast packets have been used and discussed below.

3.3.1 The Modified ATIM Frame

The mechanism enables a transmitter to choose no overhearing, randomized and unconditional overhearing for its neighbours, specified in the ATIM frame and is available to its neighbouring nodes. The Modified ATIM frame format is shown in Figure 3.1. For practicality, it is implemented in the context of IEEE 802.11 specification by slightly modifying the ATIM frame format. ATIM frame is a management frame (type 00_2) and its subtype is 1001_2 according to the 802.11 standard. The RandomCast protocol utilizes two unused subtypes, 1101_2 and 1110_2, to specify randomized and no overhearing, respectively. An ATIM frame with the original subtype 1001_2 is recognized as unconditional overhearing and thus confirms to the standard.

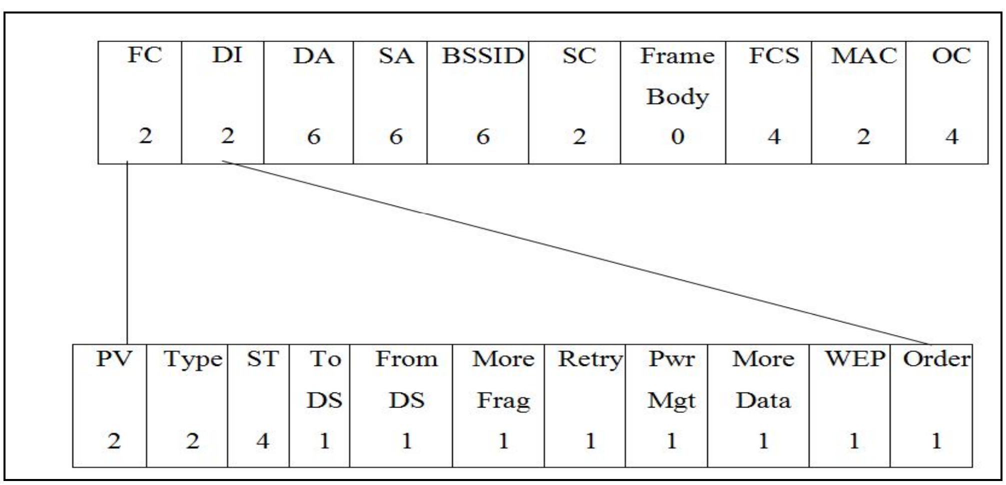

Figure 3.1 Modified ATIM Frame format

When a node (its MAC address MA) wakes up at the beginning of a beacon interval, it receives an ATIM frame or a unicast packet. The ATIM frame contains the receiver address (DA) and subtype (ID). The node decides whether or not to receive/overhear the advertised packet in the following data transmission period based on DA and ID. MAC is used for accessing the medium. OC means Overhearing Count, which is used for measuring the overhearing from the source to destination node. It would remain awaken to receive it if one of the following conditions is satisfied:

1. The receiving node is the anticipated destination.
2. The node is not the destination the sender chooses unconditional overhearing.
3. The node is not the destination, the randomized overhearing is opted.

As a transmitter, it is to be considered which level of overhearing is desirable for various types of unicast packets. DSR employs three control packets: RREQ, RREP and RERR. RREQ is a broadcast, and RREP, RERR, and data are unicast packets. For each of the unicast packets, DSR uses the following overhearing mechanism, they are as follows,

a. Randomized overhearing for RREP packets
b. Randomized overhearing for data packets
c. Unconditional overhearing for RERR packets

3.3.2 An Overhearing and Forwarding Mechanism for Broadcasting Packets

This overhearing and forwarding mechanism can be applied to the broadcast packets such as RREQ to allow randomized overhearing; this avoids redundant rebroadcast of the same packet in dense mobile networks. On the other hand, the rebroadcast decision must be made conservatively. This is because a broadcast packet may not be delivered to all nodes in the network when conditional rebroadcast is used. The rebroadcast probability (P_F) is set higher than overhearing probability (P_R). In overhearing, different broadcast packets are given, they are as follows

i. Randomized rebroadcast for RREQ packets

ii. Unconditional rebroadcast for ARP (Address Resolution Protocol) request

Even though RandomCast reduces energy consumption by allowing the sender to specify the desired level of overhearing, the problem arises due to node mobility since the node mobility results in stale routes in route caches. This stale route problem will again be a cause for energy consumption.

To make the RandomCast mechanism more effective stale route avoidance is necessary and this is done by implementing the cross layer framework which depends on cache timeout policy.

3.3.3 Stale Route Avoidance in DSR by Cache Timeout Policy

Nodes movements results becomes stale route cache entries. Cache staleness is a big problem in link cache scheme, where individual links are combined to find out best path between source and destination. A cache timeout policy is required to terminate a route cache entry, when it is likely to become stale. DSR makes aggressive use of route cache to avoid route discovery. The performance of DSR heavily depends on efficient implementation of route cache. In this chapter, a new cross-layer approach for predicting the route cache lifetime is presented. This approach assigns timeouts of individual links in route cache by utilizing Received Signal Strength Indicator (RSSI) values received from wireless network interface card.

3.3.4 Routing Cache Strategies

In on-demand routing schemes, every mobile node maintains a cache table, which is a representation of the topology graph of the network. The cache may store complete paths or a set of known links in the network. The cache is obtained via route discovery or by overhearing route information from forwarding packets. The information in the cache may no longer be valid as continual node movement breaks links in the cache then the information was received. When a source node attempts to send a data packet to a destination node, it executes a graph search algorithm, such as the Dijikstra's shortest path algorithm, to find a route to the destination using the links in the cache. The node then attempts to use the path, but the attempt will be unsuccessful if one of the links in the path no longer exists. In this case the link is removed from the cache. If no alternative path is available in the cache, the source node will initialize a route discovery process to search the entire network.

Removing the stale caching information automatically can reduce delay in the network significantly, as the nodes do not waste time trying to use a path that is no longer valid. Therefore, whenever a valid link is entered into the cache, it can be assigned a link timeout. Until the timeout is reached, the link is considered active. The link timeout is reset each time; the link is used successfully by the node. When the link timeout expires, the corresponding link is deleted from the link cache.

Route caching strategy is important in on-demand routing protocols applied for MANETs. While high routing overhead usually has a significant performance impact on low bandwidth wireless networks, a good route caching strategy can reduce routing overheads by making use of the available route information more efficiently. In DSR, in order to remove stale routes residing in the cache, explicit error notification has to be sent through the route error packets (RERR).In such a case, the node removes all paths and all links that the failure link uses from its cache and forwards RERR. Before the creation of RERR the data packets should be salvaged in the node prior to the link failure. Forwarding of RERR and initiating route discovery increases the latency and overhead.

A cache timeout policy is required to be implemented in link cache due to time varying topology of the ad hoc network caused by node's mobility that can cause stale routes in the cache over period of time as stated in Hu et al.., (2000), He et al.., (2002), Shukla (2007) and Garrido et al.., (2007) Deriving proper cache timeout policy is crucial to ensure cache freshness. Cache timeout policy in link cache gives a timeout that may be static or adaptive to remove the stale routes from the cache. Stale routes is a big issue in link cache structure, where individual links are combined together to find out the best path between source and destination.

However, cache timeout policy is not possible to setup timeout in path cache structure due to the limitation capacity of the storage space. According to Hu Y.C and Johnson D.B. et al.., (2000) there are two kinds of cache timeout used namely: static timeout approach and adaptive timeout approach. Static timeout is assigned the same timeout value for every link cache entry; each link is removed from its cache after specific value of time has elapsed since the link was added to the cache. In contrast, adaptive timeout is assigned a timeout value, based on the stability of the link endpoints. The timeout can be calculated based on the elapsed time since the link was last used and the last time the link was observed.

Every node maintains a route cache containing the source routes that it is aware of. A node updates the entries in the route cache when it learns of new routes. The complete source route is placed in the packet header. A node receiving a packet establishes from the header whether it is an intermediate hop in the route or in the final destination. If it is an intermediate node, it forwards the packet to the next hop as specified in the source route.

When a node needs to send a data packet it looks up its route cache to see if it has a destination path. If in the cache there is an unexpired route it sends the packet using this path. However, if the node does not have such a path, it initiates route discovery by broadcasting a route request. Every node that receives this packet checks its cache to see if it has the required destination route. If not, it includes its own address in the packet's route record and transmits the packet on its outgoing links. Nodes only forward Route Requests if the node has not seen the request previously and the node's address is not contained within the route record. This lessens the number of Route Requests need to be propagated throughout the network for route discovery. A route reply is generated when either a route request arrives at the destination node or at some transitional node that has an unexpired route to the destination.

At this stage, contained within the route request route record will be the sequence of hops from source to destination and this is used to establish the path from source to destination with this route being cached. Caching is used to limit the need for frequent route discoveries and to minimize packet delivery latency incurred as a result of such discoveries.

3.4 ROUTE CACHE STRUCTURE AND MANAGEMENT POLICY

The optimum cache design is based on cache structure, capacity and management policy. The route cache structure presented here relies on a primary/secondary cache structure. The primary cache, labelled the active cache (AC), stores routes that are realised through self initiated route discoveries. The AC is further divided into AC_F and AC_O parts that are used as a means of separating frequently used active paths from recently discovered routes. Snooping and tapping can be used to acquire routing information indirectly and this is recorded in the IC cache portion and may be promoted to the AC.

3.4.1 Active Cache (AC)

The AC acts as a source of fresh routing information and is used to store current routing information along with paths resolved through self-initiated route discoveries. The AC is subdivided into AC_F and AC_O parts. The AC_F portion contains paths for the most frequently requested destinations and the AC_O holds all other current routing information. The AC is periodically updated so that the AC_F holds routes to the most frequently required destinations (above some threshold value). All other information is removed to the AC_O. For some predetermined period of time *t*, each node gathers a list of destination addresses that it communicates with and the frequency of the source-destination paths used for this communication. After time *t* has elapsed, a destination frequency analysis is performed and those source-destination paths with the largest frequency (greater than some predefined value) are retained in the AC_F with all other cache contents being placed in AC_O.

3.4.2 AC Route Entry Timeout/Replacement Policy

Due to the potentially frequent changes in a MANET's topology, it is necessary to associate each cache entry with an expiry time so as to expunge stale routing information Marina and Das (2001). As paths recorded in the AC_F are repeatedly used for communication they are known to be reliable. In order to retain these route records in the AC_F beyond their expiry time it is necessary to verify the complete source-destination path link to confirm that the path still exists. For the cache management policy presented here the method of path detection is used to preserve existing AC_F entries. Existing paths are retained beyond their expiry time if path detection is successful and their previous expiry time is updated. When a link is deemed to be invalid all route records concerned are erased from both the AC and IC and an alternate path must be used if it exists in the AC_F. If not, then the AC_O is checked for an entry. If no such route record exists then the IC is examined and if an entry is found it is promoted to the AC_O and used, failing this the route discovery process is invoked. If a route can be established it is recorded in the AC_O. If during an AC_F update the number of possible entries exceeds the existing cache size then those entries with the lowest frequency are demoted to the AC_O section. AC_O entries are erased based on their expiry time and if necessary the oldest records i.e. those that are closest to expiration are replaced if any need arises.

3.4.3 Indirect Cache

The IC is used to record routing information that is extracted through the processes of snooping and tapping. These routes record also have an expiry time associated with them and are deleted or replaced as in the AC_O. The IC is also used as a source of new routes for the AC. If there is no route available in the AC then the IC is searched and if it contains a path the route is removed to the AC_O.

3.4.4 To Cache or Not to Cache

When route discovery is performed multiple routes for a single destination are often found, for the cache structure presented here these routes are stored in the AC in descending order based on the associated path cost. As the cache is of a fixed size it may not be possible to cache all routes. Consequently, a decision to select routes for caching must be made.

In conjunction with the number of hops between the source and destination the link stability among these hops should also be considered, as stable links will lead to long-lived routes.

The caching of stable links for the purpose of routing is used in protocols such as SSA and ABR. (Hu et al.,2000). These are associated with each AC entry with a path cost metric. This metric is assigned based on the link cost for a route and the number of hops necessary. To cache a route, its associated path metric must exceed some predefined threshold value. The measure of link strength for use in the routing decision is extracted via cross communication between the link and network layers.

3.5 DEMAND BASED ENERGY EFFICIENT (DBEE) CROSS-LAYER APPROACH

An ad hoc network is a wireless network formed by wireless nodes without any help of infrastructure. In such a network, the nodes are mobile and can communicate dynamically in an arbitrary manner. The network is characterized by the absence of central administration devices such as base stations or access points. Furthermore, nodes should be able to enter or leave the network easily. In these networks, the nodes act as routers. They play an important role in the discovery and maintenance of the routes from the source to the destination or from a node to another node. This is the principal challenge to such a network. If link breakages occur, the network has to stay operational by building new routes. The main technique used is the multi-hopping, which increases the overall network capacity and performances. By using multi-hopping, one node can deliver data on behalf of another one to a determined destination. Thus, the problem of radio range is solved.

MANET is a self-configuring system of mobile routers linked by wireless links which consequently combine to form an arbitrary topology. Thus, the network's wireless topology may alter rapidly and unpredictably. However, due to the lack of any fixed infrastructure, it becomes complicated to exploit the present routing techniques for network services.

This provides some huge challenges in providing the security of the communication, which is not done effortlessly as the number of demands of network security conflict with the demands of mobile networks, largely due to the nature of the mobile devices, for instance, Low power consumption and low processing load.

In the proposed demand based energy efficient algorithm (DBEE), the topology is changed dynamically according to the network traffic requirements. DBEE is integrated with the cross layer approach Shukla (2007) to predict the route cache life time and find the stale route information. Initially a small set of nodes is computed which form a connected set, while the other nodes are put off to conserve energy. This connected set is used for routing the packets under low network load. If bulk data is transferred between a pair of nodes, the topology dynamically changes along the path between these nodes to minimize the power consumption.

Various steps involved in the modified DBEE - Cross layer approach are listed as follows:

Step 1: The first phase chooses a small set of nodes that constitutes independent set of the network. Here, we have considered 3 factors like energy factor, mobility factor and utility factor.

In energy factor, Let E_0 denotes the initial node's energy and E_t be the amount of energy of a node at time t. So the energy factor Ei of the node i is calculated as : $\frac{E_o - E_t}{E_o}$.

Mobility factor (M_i) can be derived as the ratio of Received signal strength and Probability of overhearing rate to the energy consumption at the source to be transmitted.

Utility factor is derived as nodes that have a large number of neighbour nodes which have less conditional overhearing. It is denoted as U. By forming the above mentioned three factors within the limitation of region R, the node moves independently with the reducible amount of overhearing.

Step 2: The second phase is electing more nodes to ensure that the selected nodes form a connected set. Other nodes go to sleep state to conserve energy.

Step 3: In the third phase, the redundant nodes are removed from each region R.

Step 4: In the fourth phase, the topology is dynamically changed with the use of power control technique to minimize the total power consumption. In this technique, all nodes consume more power when it receives full transmission power. This can be reduced by choosing low energy cost path. The minimum receiving power is calculated using the formula of free space propagation model (T.S. Rappaport, Wireless Communications: Principles and Practice, Prentice Hall),

$$P_r = P_t\, G_t Gr\, h_t^2\, h_r^2 / d^4 \qquad (3.1)$$

h_t, h_r, - Antenna height of the transmitter and receiver.

G_t, G_r - Transmitter and Receiver Antenna gain.

d is the distance between transmitter and receiver.

P_t, P_r – Transmission and Reception power.

The actual power is given as, $\zeta p, q = \mathrm{K}\ \frac{P_t}{P_r} + W$ (3.2)

K is function of h_t, h_r & d. W is the energy consumed by each receiving node. In DBEE algorithm, the energy consumption is minimized along the routing path using the power control technique during the transmission.

Step 5: Route cache strategy in DSR protocol was proposed by Johnshon et al. (1998). It is used to store the routes that have learned from the source node and to avoid unnecessary route discovery operation each time a data packet is to be transmitted. As the reinitiating of a route discovery mechanism in On-Demand routing protocols is very costly in terms of battery power and bandwidth consumption due to flooding of the network, it can cause long delay before the first data packet is sent. The performance of DSR protocol mainly depends on an efficient implementation of route cache as stated by Hu et al.., (2000), Marina et al.., (2001), Lou et al.., (2002). The first study is on the effect of the route cache in the performance of DSR protocol was stated in Johnson, D. and Maltz, D. (1998). From their observation, the majority of Route Replies (RREP) packets are based on route cache, and only 59 percent of (RREP) packets carry correct routes. In addition, they have also discovered that even (REPP) packets from the destination are not 100 percent correct, since routes may break down while (RREP) packet is sent back to the source node. Thus, efficient route maintenance is important for all reactive protocols with route cache.

Route caching is the major approach to decrease the flooding of the network by avoiding route discovery operation as much as possible. Thus, route cache is a vital component in DSR protocol. However, if there is a mechanism that can expire with the routes or determine the freshness of routes in the route cache, it will improve the DSR performance significantly. Specially, with high mobility environments and high load network traffic, a route cache may contain stale routes that can affect the performance of DSR protocol.

The stale routes in the route cache of DSR protocol can have several adverse effects such as packet loss, long delay, increase the routing overhead during generation of RERR packet and decrease the performance of TCP protocol as stated in Johnson and Maltz (1998).

The steps proposed for removing stale route information are as follows and as shown in Figure 3.2.

1. RREQ packet will be broadcast to all the nodes.
2. The overhearing level will be set in the frame type field of ATIM for RREP and RERR packets.

3. Nodes in the network may overhear the RREP and are able to store the route information in route caches.

4. If there is any link break, RERR is propagated to the source node by an upstream node, so that it can be deleted these stale route from route cache.

5. The stale route information will be present in some of the neighbouring nodes due to the overhearing of RREPs.

6. Route cache is updated based on RSS by cache timeout policy to remove stale routes from the neighbouring nodes.

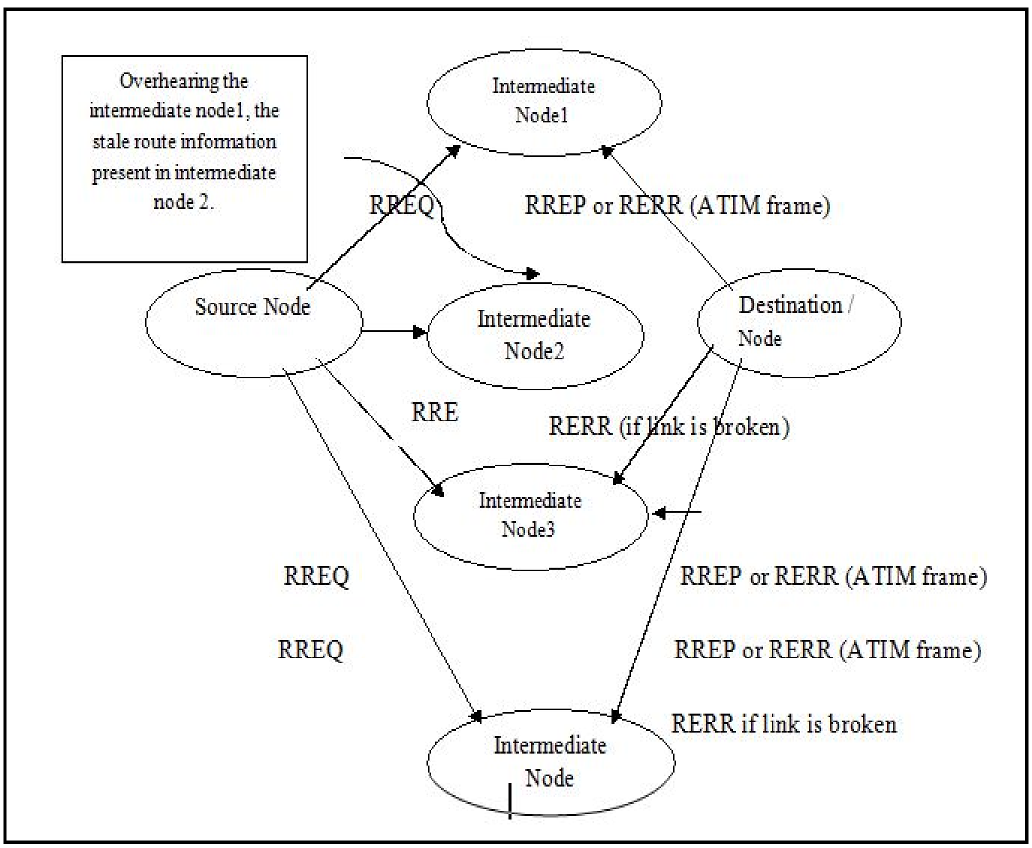

Figure 3.2 Case scenario of DBEE – Cross Layer Approach

3.6 PERFORMANCE ANALYSIS

Network Simulator (NS2) is used to simulate the proposed algorithm. In the simulation, the common simulation parameters of NS2 with different mobility scenario are used. Considering 101 mobile nodes move in a 1000 meter square X 1000 meter square region for 50 seconds simulation time the experiment is simulated. All the nodes have the same transmission range of 100 meters. The simulated traffic is Constant Bit Rate (CBR). The simulation settings and parameters are summarized in Table 3.1. In this table, Mac id is used to locate the channel. Here only wireless channel is focused. The IEEE standard for Wireless LAN is 802.11.

In NS2 Network Animator (NAM) window, nodes are arranged in a random manner. The area size is chosen as 1000 x 1000 meter^2 to view a clear random motion of the mobile nodes. Radio range is varied from minimum 50m to 500m. In this simulation, 100m is chosen to know the status of nodes transmission range. Packets are sent from source to destination at a constant rate to ensure correct connectivity of nodes. So Constant Bit Rate (CBR) traffic source is selected. Simulation time is chosen as 50 sec to get clear motion and transmission of packets. Size of packets is 80 bytes. It contains source id (4 bytes), destination id (4 bytes), energy level (10 bytes), mobility status (10 bytes), route cache status (20 bytes), hop count (10 bytes), overhearing status (20bytes) and cyclic redundancy code (2 bytes).

In ad hoc networks, so many mobility models available like random way, random walk, random way point and Manhattan mobility model. The reason for choosing random way point mobility model is to provide unlimited restriction on mobility of nodes. To be more specific, the destination, speed and direction are all chosen randomly and independent of other nodes. Random walk model and the Random direction model are variants of the Random waypoint model.

Table 3.1 Simulation settings and parameters of DBEE-CLA

No. of Nodes	101
Area Size	1000 X 1000 m^2
Mac	802.11
Radio Range	100m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	80 bytes
Mobility Model	Random Way Point

3.6.1 Performance Metrics

The proposed scheme was evaluated for its performance according to the following metrics.

Control overhead: The control overhead is defined as the total number of routing control packets normalized by the total number of received data packets.

End-to-end delay: The end-to-end-delay is brought to an average over all surviving data packets from the sources to the destinations.

Packet Delivery Ratio: It is the ratio of the number .of packets received successfully and the total number of packets transmitted. The percentage scale is used.

Energy Consumption: The energy consumed per node from source to destination in the network.

Throughput: It is defined as the average rate of successful packet delivery over a communication channel. It is measured in bits per second (bps)

The simulation results are presented below. The DBEE – CLA is compared with the RANDOMCAST and 802.11PSM in presence of overhearing environment. In IEEE 802.11 Power Saving Mechanism (PSM), a packet must be advertised before it is actually transmitted. When a node receives an advertised packet that is not destined to itself, it switches to a low power sleep state during the data transmission period, and thus, avoids overhearing and conserves energy. However, since some MANET routing protocols such as Dynamic Source Routing (DSR) collect route information via overhearing, they would suffer if they are used in combination with 802.11 PSM. Allowing no overhearing may critically deteriorate the performance of the underlying routing protocol, while unconditional over hearing may offset the advantage of using PSM.

In RANDOMCAST, a sender can specify the desired level of overhearing, making a prudent balance between energy and routing performance. In addition, it reduces redundant rebroadcasts for a broadcast packet and thus saves more energy.

In proposed scheme DBEE-CLA, stale route cache is removed using cross layer approach. The energy and mobility status of all nodes are monitored. Power is reduced using the low cost energy path.

Figure 3.3 shows the results of average end-to-end delay for varying the nodes from 20 to 100. From the results, it is seen that DBEE-CLA scheme has slightly lower delay than the RANDOMCAST and 802.11PSM scheme because of authentication routes.

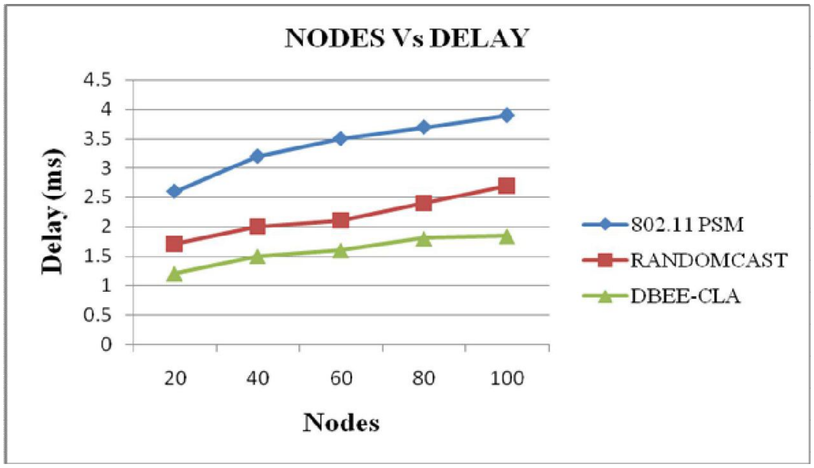

Figure 3.3 Nodes vs. Delay

Figure 3.4, presents the energy consumption. The comparison of energy consumption for DBEE-CLA, RANDOMCAST and 802.11 PSM is shown. It is clearly seen that energy consumed by DBEE-CLA is less compared to Random Cast and 802.11PSM.

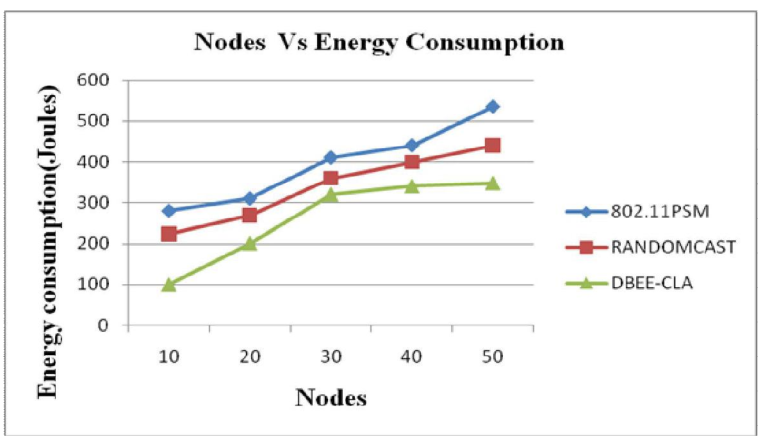

Figure 3.4 Nodes vs. Energy Consumption

Figure 3.5 presents the comparison of overhead. It is clearly shown that the overhead of DBEE-CLA has low overhead than the RANDOMCAST and 802.11PSM.

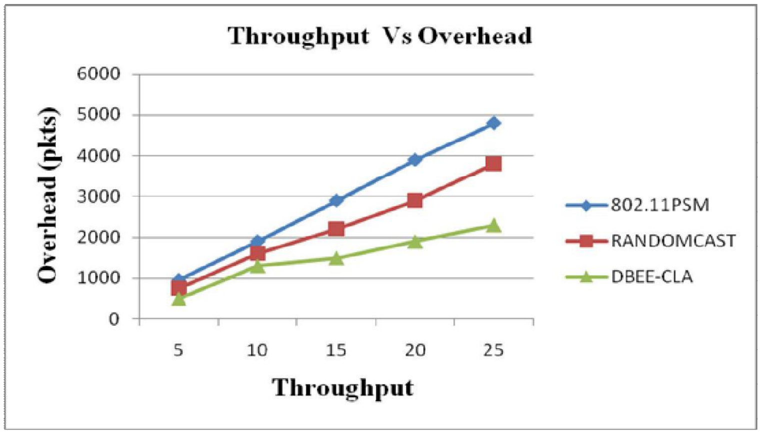

Figure 3.5 Throughput vs. Overhead

Figure 3.6 shows the results of Mobility Vs. Delay. From the results, it is clearly seen that proposed scheme DBEE-CLA scheme has slightly lower delay than the RANDOMCAST and 802.11PSM scheme while increasing speed of nodes because of authentication routes. Since stale routes are avoided using cross layer approach routes, whatsoever route used is considered to be authenticated routes.

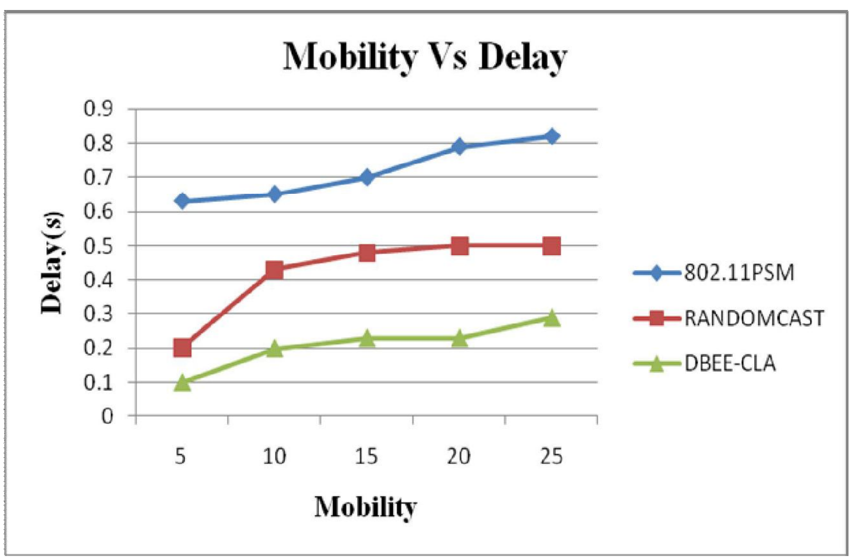

Figure 3.6 Mobility vs. Delay

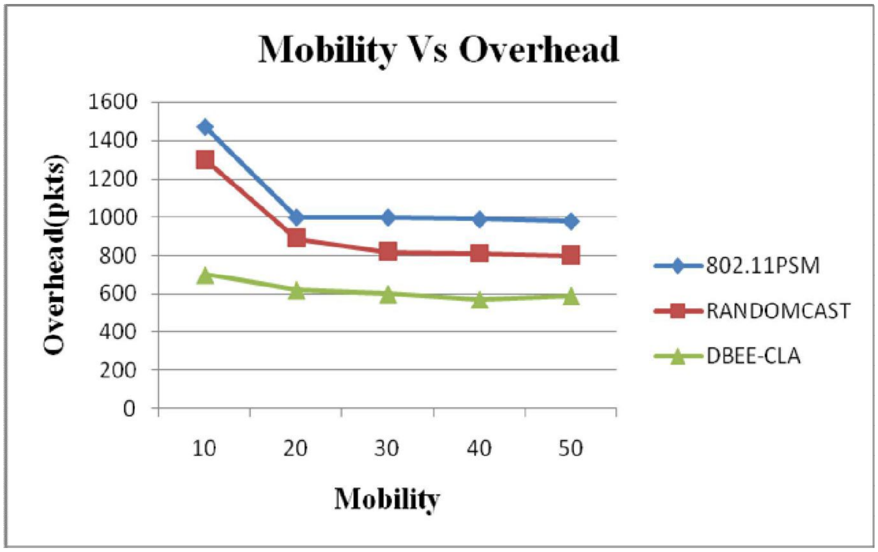

Figure 3.7 Mobility vs. Overhead

Figure 3.7 presents the comparison of overhead while varying the mobility from 10 to 50. It is clearly shown that the overhead of DBEE-CLA has low overhead than the RANDOMCAST and 802.11PSM.

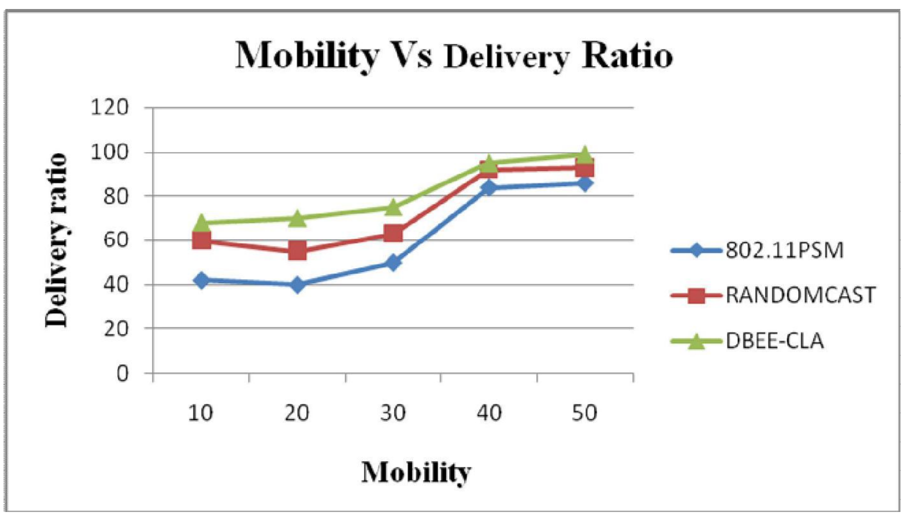

Figure 3.8 Mobility vs. Delivery ratio

Figure 3.8 shows the results of average packet delivery ratio for the mobility 10, 20…50 for the 100 nodes scenario. Clearly the DBEE-CLA scheme achieves more delivery ratio than the RANDOMCAST and

802.11PSM scheme since it has both reliability and security features. In DBEE-CLA, stale route avoidance and low energy consumption path are achieved. So in DBEE-CLA scheme a node can choose more reliable and secure path to forward packets with more secure. The graph also justifies the statement.

3.7 SUMMARY

In the DBEE-CLA approach three factors are used. In demand-based energy algorithm, the cross layer approach is employed to improve the cache freshness and avoid stale route problem. So the algorithm is more efficient and more secure. This scheme presents a solution to node energy consumption without requiring any pre-deployed infrastructure. If DBEE-CLA is implemented as a routing protocol, it gives better performance than DSR protocol based on energy consumption and route cache strategy. It is independent of underlying routing protocol. By simulation results, it is observed that the demand based energy efficient approach achieves high packet delivery ratio while attaining low delay, energy consumption and overhead than the Random cast, 802.11PSM.