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Procedia Engineering 38 (2012) 2463 – 2472
Procedia Engineering
www.elsevier.com/locate/procedia

ICMOC-2012

RSS based Energy Efficient Scheme for the Reduction of Overhearing and Rebroadcast for MANET

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Abstract

In MANET, reducing the amount of overhearing and rebroadcast based on Received Signal Strength (RSS) value can reduce the energy consumption. A cross layer framework is designed by combining the physical, MAC and network layer. In order to reduce the energy consumption, 802.11 PSM is integrated with DSR. Overhearing in DSR will improve the routing efficiency by expending some amount of energy. The main causes for energy consumption are unconditional overhearing and unnecessary rebroadcast of RREQ to the nodes which are having less Received Signal Strength (RSS). Here, RSS is used to predict the mobility of nodes. The less value of RSS indicates that the nodes are far away from the sender and this may lead to many path breakages. Probability of overhearing reduction (P_{OR}) is determined in order to limit the amount of hearing for the unicast packets. The proposed mechanism R-ROR avoids unnecessary overhearing and rebroadcast using cross layer design aiming to achieve energy consumption. Rebroadcast based on the RSS can reduce the number of path breakages, energy consumption and overhead. Simulation results are compared for Packet Delivery Ratio (PDR), energy consumption and delay. The analysis shows that R-ROR is energy efficient compared to 802.11, 802.11PSM, ODPM and RandomCast.

Keyword: DSR; RSS value; probability of overhearing; rebroadcast and unicast.

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doi:10.1016/j.proeng.2012.06.291

1. Introduction

In mobile ad-hoc network, the nodes are mobile and can communicate dynamically without any infrastructure in an arbitrary manner. This flexibility helps to design a network anywhere and anytime. This makes it suitable for many different applications especially in battle zones, disaster and rescue operations. The major problem with MANET is that it depends on batteries for power. The criterion for the design is to develop an energy efficient routing mechanism by reducing the amount of overhearing and rebroadcast. The main objective here is to make the 802.11 PSM [6] suitable for MANET in multi-hop with Dynamic Source Routing (DSR). The problems with DSR arise due to broadcast flood of control packets [10] and unconditional overhearing. So to overcome this, a RSS based Reduction of Overhearing and Rebroadcast (R-ROR) is designed and is based on the concept given in RandomCast [11[13]]. Routing protocol performance depends solely on the network conditions. The parameters that have an impact on the routing protocol are mobility of the nodes, volume of traffic, busy / idle time of the shared medium and the received signal strength. The on-demand routing protocols DSR [8, 9] and AODV [4], before sending a packet to the destination, discovers a route. The performance of routing protocol, such as packet end-to-end delay, throughput, and routing overhead, is significantly influenced by node mobility [2].

The proposed work can decide based on the probability value (P_{OR}) not to overhear a unicast message. In order to prevent the flooding of RREQ, RSS based rebroadcast mechanism is designed not to rebroadcast a broadcast message when the node receives an advertisement during ATIM window, thereby reducing the energy cost without affecting the network performance. This mechanism is based on the factor mobility. Mobility of the nodes in a network can be predicted by using RSS value. If the RSS is small, then it is assumed that the nodes are moved away due to mobility. The work is done based on the assumption that RSS value determines the distance of the node from the sender. Based on the results given in [12], the distance between two nodes affects the transmission power. Thus, transmission power increases and it leads to energy wastage [11]. The energy consumption for transmission and reception can be specified as $E_{tx}(L) = P_{tx}Lt_{byte}$ and $E_{rx}(L) = P_{rx}Lt_{byte.}$ Where E represents energy consumption, L is data packet length and t_{byte} is time cost for transmitting a byte. The relationship between energy and distance from [12] is expressed in eq. 1.1 as,

$$u(d) = \varepsilon d^{\alpha} + c \tag{1.1}$$

Where u(d) represents power consumption, d is the distance, ε is a coefficient that depends on physical environment, unit of length and the nit size of a signal and α is a constant between 2 and 4. From eq. (1.1), it can be seen that if the distance increases, energy consumption also increases and it implies that the received signal strength is low. So, in a MANET, under mobility scenarios, distance has to be updated quite often in order to improve the liveliness of the network. When the mobility is high, there will be more link breaks, causing the network flooded with more RREQs [15]. In forwarding the RREQ, it may select a neighbour whose RSS value is lesser compared to the sender node. This leads to path breakages and energy consumption. To overcome this, rebroadcast is also made based on RSS. RSS based Reduction of Overhearing and Rebroadcast (R-ROR) can reduce the amount of overhearing and control the rebroadcast. Also it can reduce further the energy consumption and overhead.

The proposed work is based on DSR protocol. AODV protocol is not chosen because it takes a conservative approach to gather route information [4]. It does not allow overhearing and eliminates existing route information using timeout. But AODV creates more RREQ messages which in turn results in more control overheads in routing compared to DSR**.** The paper is organized as follows. The Section 2 describes the previous works that are carried out in this area and the basic requirements. Section 3 describes the proposed cross layer design implementation. Section 4 describes the performance analysis and the last section concludes the work.

2. Related Works

In this section, we introduce here On - demand routing protocol DSR, the background of the proposed design IEEE 802.11 PSM and energy efficient communication schemes. It is assumed here that mobile nodes use the IEEE 802.11 PSM for energy-efficient communication and DSR for route discovery and maintenance. An overview of the DSR routing protocol is discussed in section 2.1. Section 2.2 summarizes the 802.11 PSM. Section 2.3 and 2.4 summarizes the popular energy efficient schemes.

2.1. Dynamic Source Routing(DSR)

Basic Operation

When a node wants to communicate with another node, it first checks its route cache where the nodes store the route routes it has previously learnt. If a route is found in its route cache, the sender puts this route in the packet header and transmits it to the next hop in the path. Each intermediate node examines the header and retransmits it to the node indicated after appending its id in the packet route. If no route is found, the sender buffers the packet and finds a route using the route discovery process.

Route Discovery and Maintenance

For finding a path for the transfer, a source node broadcasts a route request (RREQ) packet to all nodes within its radio transmission. RREQ packet contains the addresses of the source, destination nodes, and a route record which contains a list of nodes visited by the route request packet. When a node receives a route request, it does the following.

- If the destination address present in the RREQ matches its own address, then the route with the visited node details is sent back to the source in a route reply (RREP) packet.
- If the address does not match, then the node is an intermediate node and it checks in its cache, it creates a route reply packet with the route from its cache, and sends it back to the source. If the route is not present in the cache, it adds its own address to the route record; increments hop count by one, rebroadcasts the request.
- The wireless link 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.

The DSR is designed specifically for use in multi-hop mobile ad-hoc networks. Due to the mobility of the nodes, topology is changing quite often. DSR operate in promiscuous listening mode. So, at any time, the node can check its route cache for the desired routes. In DSR, Route Discovery and Route Maintenance each operate entirely "on demand". That is why, DSR comes under on – demand routing protocol. Overhearing improves the network performance by allowing nodes to collect more route information. But, it could make the situation even worse by generating more 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.

2.2. IEEE 802.11 PSM

IEEE 802.11 consists of PCF and DCF. PCF is called as Point Coordination Function which is a centralized medium access control protocol suitable for infrastructure based networks. DCF is distributed coordination function which is a fully distributed protocol [19] suitable for ad-hoc. Each node remains awake for a short interval at the start of the beacon interval. This short interval is called the ATIM (Ad-hoc Traffic Indication Message) window. In PSM, the source node buffers packets for the destination node that is in the doze/sleep state, and these buffered packets are announced during a subsequent ATIM.

The transmission of an ATIM frame is performed using the CSMA/CA mechanism specified in IEEE 802.11. When a node has sent an ATIM frame to another node, it remains awake for the entire beacon interval. The node that receives an ATIM frame replies by sending an ATIM-ACK. Such a node remains awake for the entire beacon interval after transmitting the ATIMACK. Transmission of one or more data packets from sender to receiver can now take place during the beacon interval, after the end of the ATIM window. A node that has no outstanding packets to be transmitted can go into the doze state at the end of the ATIM window if it does not receive an ATIM frame during the ATIM window. All dozing nodes again wake up in PSM at the start of the next beacon interval. A power management mode is mainly to reduce the energy costs of the idle state, but it exhibits poor latency performance in multi hop infrastructure less environments. Many methods to improve the performance of multi hop ad-hoc networks under power management have been proposed. Monarch version [5] of the network simulator is used for the 802.11 power management in ad hoc networks. By using the DCF mechanism, enabling the features of PSM is difficult, because it does not contain an access point. Nodes in the PS mode are expected to synchronize among themselves in a distributed way [7] and [16]. In ad-hoc environment, source should inform by giving an advertisement through ATIM during the packet advertisement period. Source will transmit the data during the data transmission period. Here in PSM, every node operates in power save mode and it is not switching between Active Mode (AM) and Power Save Mode (PS). It is operated so to minimize the energy consumption and this in turn increases the life time of the network. Packet latency is high in PSM, because every time a node has to wait for the next beacon interval.

2.3. On Demand Power Management(ODPM)

ODPM [19] is an energy efficient scheme for multi-hop networks. Here, a node switches between the AM and PS mode frequently, and it is based on communication events and event-induced time-out values, which leads to non-negligible overhead. The authors found out that the main problem is that each node must know the power management mode of its neighbors. In ODPM, a node remains in AM for 5 seconds until it receives an RREP and for 2 seconds if it receives a data packet or it is a source or a destination node. So, it requires an additional energy cost or an extended packet delay. Also, its performance greatly depends on time-out values and it has to be improved based on the routing protocol and traffic conditions. If data traffic is infrequent, the node either stays in AM for all the consecutive intervals without receiving any further data packets or switches to a low-power sleep state. Compared to RandomCast, ODPM has less delay because some packets are transmitted immediately. But the energy cost is higher compared to RandomCast, because some nodes remain in AM for an extended period of time.

2.4. RandomCast

RandomCast [11] is an energy efficient communication mechanism, in which a sender can specify the desired level of overhearing and makes a good balance between energy and routing. The authors proved that this mechanism, based on number of neighbours, is highly energy efficient compared to conventional 802.11, 802.11 PSM-based schemes and ODPM in terms of total energy consumption, energy goodput, and energy balance. This paper utilized the values of ATIM window size and beacon interval as 0.05 and 0.25 seconds. Overhearing and rebroadcast are determined based on the probability value. The overhearing probability assumed here is inversely proportional to the number of neighbours. The author gave directions for further research based on four factors that can be considered for deciding the amount of overhearing / rebroadcast. They are sender ID, number of neighbours, mobility, and remaining battery energy. RandomCast is designed based on the second factor (number of neighbours). Our proposed work is based on the RandomCast and the design is carried out based on the mobility prediction which is found out using the RSS value. The proposed cross layer design is discussed in the following section.

3. Cross-Layer Design

The main focus of the cross layer design is to reduce the energy consumption during route discovery by reducing the overhearing and rebroadcast. It is framed in order to obtain the value of RSS from the physical and pass it on to MAC and network layer. Mobility can be determined based on the connectivity changes with the neighbors. Connectivity change is found out using the value of RSS of the selected links. RSS is used as the distance predicting factor. When mobility is high, path breakages occur frequently and this results in more stale route information in the route cache in DSR. It adversely affects the node connectivity. For ensuring the stability of the route for a certain period of time, RSS value is selected. The level of overhearing is determined for the proposed design based on the distance which in turn depends on RSS value. The RSS in dBm for free space propagation of the links is computed using the equation (3.1) as,

$$RSS = P_t(\lambda/4\pi d)^n G_t G_r \tag{3.1}$$

Where 'λ' is wavelength in meters, 'P_t' is transmit signal strength in dBm, 'G_t and G_r' denotes the unity gain of the transmitting and receiving antennas. 'd' is the distance between transmitter and receiver in meters. 'n' is path loss coefficient and takes a value of 2 to 4. 2 for free space model and 4 for two ray ground propagation model. The above equation is modified as given in the equation (3.2) as follows,

$$RSS = P_t / d^2 \tag{3.2}$$

From the eq. (3.2), it can be seen that if RSS value is more, link quality will be good, otherwise link will likely to be broken soon. And also, the less value of RSS indicates that the nodes are far away from the sender and this may lead to path breakage. RSS_{thres} is selected as half of the transmit power level, by assuming that at least to forward the data, the node should have some optimum power. RSS value is used for fixing the overhearing and rebroadcast. Normally, as the distance increases, the received signal strength starts decreasing. This increases the chances of link breakage between two nodes. Mobility model is Random Way Point (RWP) model [3]. Overhearing reduction probability (P_{OR}) is calculated based on the following formula and it is shown in table .1,

$$P_{OR} = 1 - (RSS_{thres} / RSS) \tag{3.3}$$

Table 1. P_{OR} Values for RSS > RSS_{thres} Values

RSS (dBm)	RSS_{thres} /RSS	P_{OR}
13	0.92	0.08
14	0.86	0.14
15	0.80	0.20
16	0.75	0.25
17	0.71	0.29
18	0.67	0.33
19	0.63	0.37
20	0.60	0.40
21	0.57	0.43
22	0.55	0.45
23	0.52	0.48
24	0.50	0.50

Because the nodes are in motion, higher probability value for unicast packets is considered for setting the overhearing moderately by assuming RSS as one third of the P_t. Broadcasting decision is done for nodes which are having RSS greater than the threshold value. This is so, because the rebroadcast decision does not miss the destination node. It is desired that the nodes P_{OR} is kept higher, meaning that a higher RSS value is present in the network, and it can withstand for some time. And RSS is selected approximately greater than or equal to 18 dBm. One problem arises is that if the neighbour node has RSS value higher than the RSS_{thres}, then RREQ is broadcasted for discovering new routes and it may not lead to path failure.

The packets considered for the analysis are broadcast and unicast. A device in PS mode periodically wakes up during the packet advertisement period, called ATIM window, to see if it has any data to receive. ATIM frame format shown in fig 3.1 is modified a little to specify the level of overhearing for the nodes. The frame control field of ATIM frame format is given in fig 3.2.

FC (2)	DI (2)	DA (6)	SA (6)	BSSID (6)	SC (2)	FRAME BODY (0)	FCS (4)

Fig. 3.1. ATIM Frame Format (Length in Bytes)

FC – Frame Control; DI – Destination ID; DA – Destination Address; SA – Source Address; BSSID – IBSS addresses; SC – sequence control; FRAME BODY – NULL for ATIM Frame

PV (2)	T (2)	S.T (4)	To DS (1)	From DS (1)	M.F (1)	R (1)	P.M (1)	M.D (1)	W (1)	O (1)

Fig. 3.2. Frame Control Field (Length in bits) of ATIM Frame Format

PV – Protocol Version; T – Type; M.F – More Flags; R – Retry;
P.M – Power Management; M.D – More Data; W – WEP; O – Order;
S.T – Sub Type; Values – 1001_2 – Original ATIM subtype value (Unconditional overhearing);
1101_2 – MP based Conditional overhearing; 1110_2 – No overhearing

Based on IEEE 802.11 standard, ATIM frame is a management frame of type 00_2 and its subtype is 1001_2 which in general denote unconditional overhearing. The proposed conditional overhearing takes two unused subtypes such as 1101_2 and 1110_2, to specify RSS based conditional and no overhearing. The Subtype field which is included in the frame control header specifies the management frame (e.g., a beacon frame, authenticate request, or disassociate notice). When a node receives an ATIM frame for a unicast packet, it goes to its wake up state at the beginning of a beacon interval. Frame contains the Destination Address (DA) and subtype value. DA defines unicast and broadcast. Subtype value, the node concludes whether or not to overhear the advertised packet in the following data transmission period. The node can be in wakeup / doze or sleep state based on whether the node is the correct destination or it has to undergo unconditional overhearing or RSS based conditional overhearing.

DSR make use of RREQ, RREP and RERR as control packets for route discovery and maintenance and DATA packet for data transfer. In our cross layer approach, a node receiving RREQ, appends its measured received signal strength and passes this to upper layers as broadcast for further process. The RSS based overhearing mechanism is proposed as follows for the DSR packets.

Overhearing
- No overhearing – Direct communication
- Unconditional – Sending ARP, RERR
- Conditional – RREP, DATA

Rebroadcast
- Conditional – RSS based RREQ

RSS based conditional overhearing for RREP packets - DSR creates RREP from almost all nodes which are undesirable. It is not necessary that RREP packets should be overheard unconditionally by all the nodes in the network.

RSS based conditional overhearing for data packets - Data packets contain the entire route information and this can be controlled, so that all the nodes cannot overhear.

Unconditional overhearing for RERR packets - broadcasting the RERR packets unconditionally will improve the network performance by removing the stale route in route cache and thus by eliminating the broken links. ARP is assumed to be unconditionally broadcasted in order to find out the corresponding IP address for a given MAC address (here as NA).

RSS based rebroadcast for RREQ packets - Number of nodes that can overhear RREQ packets, can be controlled based on the RSS in order to reduce the path breakage.

The following fig. 3.3 shows the procedure for the implementation of RSS based conditional overhearing algorithm. UC denotes the unicast packet. NA denotes the MAC address.

```
when a node receives an ATIM frame
checks if (DA ==  UC) then
wake up and listen
else (Unicast)
{
        checks If (DA == NA) then
        the node is the correct destination
         wake up and receive
         else if (SID == 1001) then
         unconditional overhearing
         else
         if (SID == 1101) then
         {
         if (P_OR >= 0.33) then
         RSS based conditional overhearing
         continue to wake up and overhear
         else
        go to sleep state ;
          }
 go to sleep state ;
}
endif
```

Fig. 3.3 RSS based Overhearing Reduction Mechanism for Unicast Packet

The following fig. 3.4 shows the implementation of RSS based rebroadcast algorithm for RREQ.

```
When a node receives a RREQ
       checks for its received signal strength
       compute RSS = RSS_rec
       if RSS > RSS_thres then
       continue to wake up and Rebroadcast ;
       else
       go to sleep state ;
       endif
```

Fig. 3.4 RSS based Rebroadcast for RREQ Packet

The key element in designing the algorithm is RSS value based on which mobility is predicted. The above algorithm does not consider the other factors like node ID and residual energy of the nodes. Node ID will help in finding the redundant request very soon, so that delay in finding the routes is avoided. The rebroadcast verifies the links based on received RSS. RSS of the neighbours are compared and the forwarding node selects the one which has higher RSS for rebroadcasting the RREQ.

4. RESULTS AND DISCUSSION

Analysis of the cross layer design is done using the network simulator [17] and set up has been done based on the idea given in [5]. The network topology with 50 nodes in a square area of 1000x1000m^2 was taken. The transmission range is 250m. Data rate is assigned as 2 Mbps. Traffic is Constant Bit Rate (CBR). The packet rate injected in the network varies from 1 to 5 packets / sec. Packet size is 256 bytes. Mobility model is Random waypoint with a maximum node speed of 5 m/s and a pause time of 0-600 seconds. Simulation time is 600 seconds and the results are taken after 10 runs to obtain steady state value.

The proposed design is compared with 802.11 without PSM, 802.11 with PSM, RandomCast and ODPM. The ATIM window size and beacon interval selected for the design is 0.05s and 0.25s. It is so, to obtain a reasonable throughput. Fig. 4.1 presents Packet Delivery Ratio (PDR) in % for the packets injected per second.

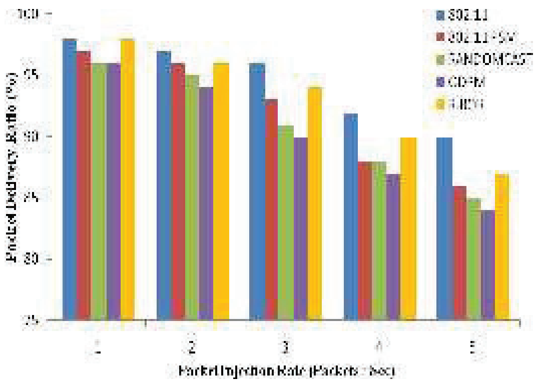

Fig. 4.1. Packet Delivery Ratio Analysis

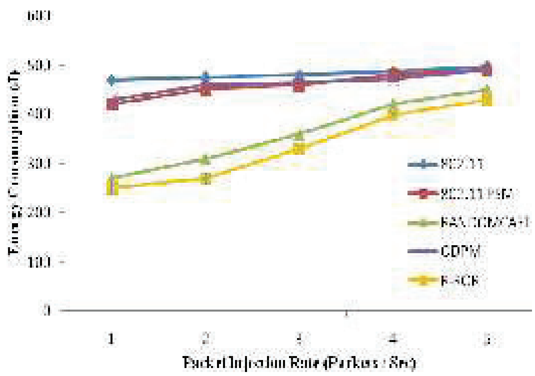

Fig. 4.2. Energy Consumption Analysis

Packet delivery ratio is above 90 percent up to the packet injection rate of 3 packets / sec in almost all the cases. Above this packet rate, only 802.11 show a high packet delivery ratio because all active nodes participate in transmission. The decrease in PDR value for 802.11 PSM, RandomCast and R-ROR are due to the power save mode of operation. ODPM shows a gradual decrease in PDR. R-ROR based conditional overhearing shows an improvement of 3.2% over RandomCast. This is due to the elimination of the links below the RSS_{thres} value.

Fig 4.2 shows energy consumption analysis by varying the packet rate. It is seen that the energy consumption of R-ROR method is lesser compared to 802.11 and 802.11 PSM. Proposed achieves approximately 30 joules of lesser energy compared to RandomCast. ODPM shows a lesser energy consumption compared to RandomCast and R-ROR. The nodes are switching between AM and PS.

Fig 4.3 represents the energy consumption of all the 50 nodes in a network by injecting the packet at a rate of 2 packets/sec. The graph shows energy consumption for the pause time of 0 s. The rebroadcast is done based on the node distance, so energy consumption under this condition is almost same as that of RandomCast.

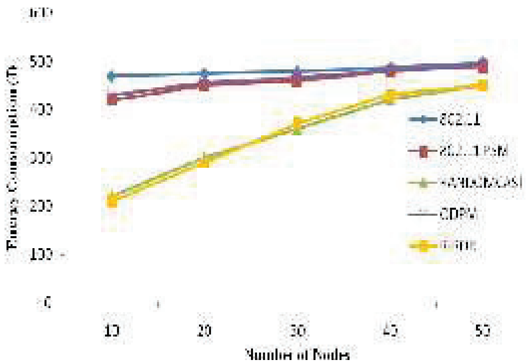

Fig. 4.3. Energy Consumption vs. No. of Nodes at Pause Time = 0 Seconds

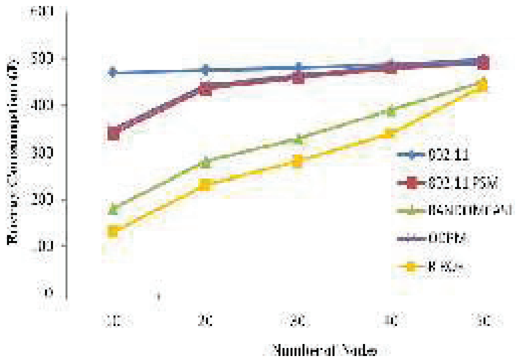

Fig. 4.4. Energy Consumption vs. No. of Nodes at Pause Time = 600 Seconds

Energy consumption of all the 50 nodes in a network by injecting the packet at a rate of 2 packets / sec is given in Fig.4.4. The node pause time is kept as maximum (600s). There is no mobility in the network. It results in less route discovery and link breakage. R-ROR achieves energy consumption of almost 50 joules lesser compared to RandomCast. It is seen from graph 4.5 that as the pause time increases, there is a reduction in average energy consumption.

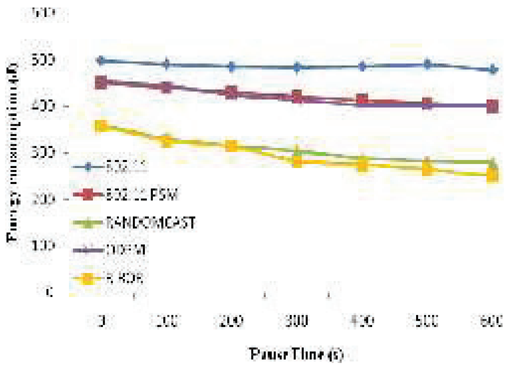

Fig. 4.5. Energy Consumption vs. Pause Time

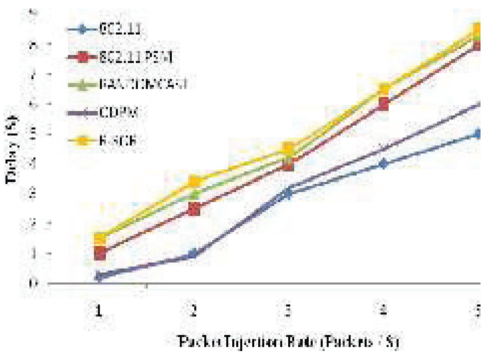

Fig. 4.6. Delay Analysis

Under low mobility, beyond the pause time of 300s, R-ROR outperforms RandomCast and results in an average additional energy saving of 20%. This is due to the reason, that the design takes into consideration only the paths with high RSS value. Fig.4.6 shows delay analysis, it is seen that delay is higher in all the PSM based schemes. ODPM and 802.11 shows lesser delay because it transmits data immediately. Here, no need to wait for the beacon interval. But the other schemes have to wait for the beacon interval for transmitting the data. So, it is a disadvantage.

5. Conclusion

It is concluded from the simulation analysis that energy is utilized effectively in MANET by the use of cross layer framework. R-ROR is designed in such a way that the sender can specify the desired level of overhearing based on the RSS of the link for the unicast packets. All the nodes will calculate its probability of overhearing reduction (P_{OR}) once it receives RREQ. Broadcast mechanism reduces the frequency of failures and route discoveries and in turn decreases the overhead also. PDR of R-ROR achieves 3.2% improvement compared to existing 802.11, 802.11 PSM, RandomCast and ODPM. It achieves a significant power saving, if the pause time crosses 300seconds. For the packet injection rate of 2 packets / sec, under no mobility condition, proposed method achieves approximately 50 joules lesser energy consumption compared to RandomCast and ODPM. Under high mobility condition, it works more or like the RandomCast. The drawback in the design is the delay, because a packet is advertised before an actual delivery and the announcement can be made only one hop at a time in each beacon interval (0.25sec). As a future work, this proposed method can be analyzed by considering other mobility metrics for the evaluation of the mobility parameter for defining the overhearing level.

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