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Energy Efficient Buffer Management for Group Communication in MANETs

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***Abstract*:** Performance of a multicast routing protocol may be degraded due to huge packet loss caused by various factors i.e. Contention, Congestion, inefficient buffer management, dynamic topology, mobility and node density etc. Each factor has its own impact over the limited resources. In case of communication failure, various operations are repeated simultaneously that results in excessive resource consumption. Many researchers have tried to investigate the level of resource consumption and suggested various solutions according to the identified issues. In this paper, an energy efficient buffer management scheme (EEBM) is proposed for multicast group communication. PUMA and MAODV multicast routing algorithm are extended to optimize the energy consumption. Simulation results show the performance of EEBM in terms of enhanced network performance with optimal energy consumption.

Keywords: components; Energy Optimization; Multicast; MAODV; PUMA; Group Communication; MANET.

I. INTRODUCTION

MANETs are infrastructure less, self-organizing collection of limited battery powered mobile nodes. Node's battery energy is one of most important resource that should be managed effectively to avoid the early shutdown of nodes [1]. These low powered mobile nodes suffer from unfair utilization of limited resources and excessive energy consumption can reduce the life time of the node that may interrupt some critical ongoing communication, even worse, can cause network partitioning [2]. In order to minimize the delay, a temporary storage space is used by nodes, called buffer and unfair buffer management can increase the cost of group communication in terms of packet retransmission, congestion and frequent routing table updates. Some traditional buffer management techniques were developed to resolve all these issues which are given below:

1. Drop Trail: Router drops all new packets, if buffer is full. Packet Congestion level may be increased due to packet retransmission.
2. Fair Queue Scheduling: It can manage multiple buffers at same time and packet switching is also possible for shared channel.
3. Deficit Round Robin: It uses a round robin algorithm to handle multiple packet size but it is not suitable for real time application due to excessive delay.
4. Random Early Detection: It uses the concept of congestion avoidance and probability to drop a packet increases as the buffer space is occupied. It shows its compatibility with TCP protocol but it is not suitable for multimedia traffic.
5. Stochastic Fair Queuing: It uses hash based fair queue allocation logic to subdivide the traffic load into number of possible queues.

Multicast routing protocols in MANETs do not depend upon these buffer management techniques due to its dynamic topological behavior. In MANETs buffer overflow occurs at mobile nodes which may increase the congestion level that causes packet loss. Packet retransmission phase is used to overcome from these losses but it consumes unnecessary energy too. Therefore, an energy aware multicast routing that must consider the topological behavior of routing protocols is required. Tree based routing will consume the resources to manage the multicast tree whereas mesh based protocol will utilize it for mesh establishment and maintenance etc. So there is need to develop a scheme which will optimize the energy consumption for tree and mesh based routing protocols. In Table I we have shown different modes and operations in which node's energy is consumed [3, 4, 5]:

Table I: Energy consumption

Mode	Description
Reception	Energy required to receive a packet
Transmission	Energy required to transmit a packet
Sleep	Energy required to retain sleep mode
Transition	Energy required to switch the State from sleep mode to idle mode

The organization of paper is the following: the section II gives brief overviews about proposals to achieve energy efficient buffer management for MANETs; section III illustrates about the proposed scheme; section IV presents the simulation result and analysis; section V discusses the conclusion and future scope.

II. RELATED WORK

MANETs are becoming most growing fields due to its unique applications in the field of battle field, military networks, disaster management and rescue operations. One of most important constraint in MANETs is limited battery life of mobile nodes. These nodes consume lot of energy in communication and many times communication gets failed due to dead nodes in between. Therefore, during the past several years, many researchers worked to achieve the energy efficient communication in MANETs.

G. A. Walikar et al. [3] investigated that due to large scale resource consumption, intermediate nodes can be exhausted and may cause link breaks and can interrupt the end to end communication. To ensure the end point connectivity, authors introduced an energy aware multicast routing solution, called EAMRP. It builds the multiple shortest routes by estimating the residual energy of each intermediate node. Alternate routes can be discovered to overcome from link breaks. Simulation results show that it can manage the resources at node level to ensure the reliable group communication, with minimum delay and higher PD/Throughput.

X. Shen et al. [6] considered the energy consumption for group communication over wireless networks and proposed a method which can preserve the energy by grouping the multiple sessions. Experimental results show that it can improve the Throughput and also optimize the energy.

Q. Zhao et al. [7] investigated the issues related to efficient resource utilization for multi-view video transmission over wireless networks and developed a scheme, called multicast fractional frequency reuse, to optimize the energy consumption as well as to manage the bandwidth. It can allocate the resources under the QoS constraints. Results show that its performance in terms of energy efficiency and bandwidth conservation for video transmission.

K.C. Rajani et al. [8] explored the performance issues of multicast routing protocols over MANETs. These are: Tree construction, maintenance, group Join/Leave and impact of mobility over wireless links etc. Study shows behavior of each routing protocol changes according to the variations in each parameter and it also opens the new horizons for researchers.

D. Jiang et al. [9] investigated the traditional ways of energy conservation and developed a new scheme to optimize the energy consumption for multicasting. In order to achieve energy efficiency, it defines four different modes for each node i.e. SLEEP, WALK, SEND and RECEIVE etc. Probability of energy consumption is estimated in each individual mode and simulation results validate it and this data is used to switch the mode, as per the requirement.

Z.T. Chou et al. [10] investigated the issues related multicast scalable video transmission over wireless networks and proposed a scheduling scheme for layers. It regulates admission control and greedy approach is used for scheduling the packets at base layer and enhanced data layer. Simulation results show its performance in terms of optimal energy consumption and stable Throughput under the constraints of network dynamics and uniform/non-uniform traffic conditions.

F. Chiti et al. [11] developed a method for reliable and efficient network coding scheme for multiple group communication. Rate adapted network coding does not use feedback channels for reliable content delivery, thus enhances the overall efficiency of network as well as it also preserve the network resources.

D. N. Minh Dang et al. [12] enhanced the network efficiency by combing the multichannel MAC and power saving scheme. Control information is exchanged using directional antennas and channel is selected using window and beam directions. Simulation results shows that proposed scheme can enhance the Throughput, PDR, energy consumption and fairness distribution etc.

Z. Zhu et al. [13] proposed method to secure the multicast channels over wireless networks. It uses a beam formation design to minimize the energy consumption for transmission and at for receiver side, energy harvesting constraint is used. Simulation results show that it can manage the network performance by adopting the channel uncertainty.

P. Sujitha et al. [14] addressed the power consumption at routing level and proposed a solution to conserve the energy at node level by minimizing the number of Hops. In case of group communication, data is forwarded using intermediate nodes, from sender to destination. Forwarding nodes are selected on the basis of a calculated optimized angle (60^0) and other nodes are ignored, in order to preserve the energy. Ns-2 was used for simulation purpose and results show its performance in terms of enhanced Throughput, PDR and energy optimization etc.

K. Subramaniam et al. [15] investigated the issues related to real time data streaming over multicast ad hoc networks. Study shows that inefficient buffer management introduces delay and Jitter and cause quality degradation also. Authors resolved this issue by caching the frequently required data at multicast tree which is created for group communication purpose. Highest priority for real time data is set and buffer level is adjusted dynamically as per requirements. Simulation results show that its performance in terms of less control overhead, latency, energy consumption and higher PDR etc.

P. Jain et al. [16] proposed a RED queue based buffer management scheme for ad hoc routing. A buffer space is maintained between sender and receiver. During packet transmission, packets are stored in a temporary buffer managed by each intermediate node. Each coming packet is marked with a probability that it must survive till a Threshold value which may vary according to the current queue size. Simulation results show that packet drop can also occur due to other reasons also i.e. Contention/Congestion etc. Results show that it performs well as compared to DROP Trail and PAQMAN scheme.

C. Yang et al. [17] explored the factors which can consume the energy over heterogeneous networks and these are: Traffic Load, Antenna‘s Ports, Cooling system and power supplies etc. and developed an energy efficient model for multicast services to be deployed over heterogeneous environment. Energy consumption is optimized by estimating the ratio of number of current users and the total available resources. After that load is distributed using multicast channels, thus reduces the total energy requirements. Simulation results validate this model under the constraints of dense network.

S.L. Wu et al. [18] explored the resource consumption issues related to wireless communication and proposed a solution to optimize the resources for low powered mobile devices. Proposed method allocates the limited radio resources in such a way that maximum Throughput can be ensured. After this, rescheduling of video layers is performed as per the ratio of allocated resources to satisfy the energy constraints. Simulation of multicast group communication was performed using LTE wireless networks and results show its performance in terms of efficient resource allocation, optimal energy consumption and enhanced network Throughput etc. It can be further extended by introducing multiple resource allocation and scheduling algorithms, in order to achieve higher degree of energy conservation.

S.Othmen et al. [19] tried to enhance the network life time and delivered the data by selecting energy constrained multipath routes. To minimize the delay, Routes with higher congestion level and less residual energy are avoided. Simulation results show its performance in terms energy efficiency, traffic handling, QoS and minimum End to End

Delay etc. Proposed scheme can be extended to support the VoIP communication.
H. Al-Mahdi et al. [20] developed a solution to manage the buffer using dynamic Hops for ad hoc networks. Buffer is subdivided into partitions and its size varies according to the number of current Hops. Threshold constraint is used for size and Hops. Simulation results show that it can reduce the packet loss as well as it offers minimum end to end delay.
X. Luo et al. [21] developed an analytical framework based equation to manage the buffer for MANETs. Each node uses a Threshold value for its current buffer that is used to define the limit for number of packets, to be hold for processing. Analytical model show that it can manage the buffer's occupancy ratio for each node. Simulation validates the developed logic under the constraints of buffer occupancy over execution time

III. PROPOSED SCHEME FOR ENERGY EFFICIENT BUFFER MANAGEMENT

In case of group communication, a sender can share the data with multiple receivers. Data transmission rate and data processing rate of sender and receiver may vary for sender and receiver. If data transmission rate is higher and its processing rate is low, it may lead to huge packet drop at receiver end due to buffer overflow. One possible solution is to retransmit data packets but it consumes significant amount of resources and may increase congestion level. Node's energy consumption can be optimized by regulating the data transmission or reception rates and buffer overflow can be avoided. EEBM sets the following constraints for buffer management:
1. Buffer capacity is delimited by defining minimum and maximum range for packet processing.
2. A Threshold value is used for buffer's size management
3. A data processing rate is defined at receiver's end in such a way that it should consume all packets to avoid the packet loss and meanwhile sender must wait for current packet processing and should hold the next transmission.
4. A Time Out interval is used for transmission and reception, to avoid the congestion and packet loss.
At initial stage, EEBM waits for enough packet loss, so that it can manage the buffer space. When packet loss Threshold is reached, EEBM increases the transmission interval of packets at sender side, so that recently transmitted packets at receiver's side can be processed.
If waiting time exceeds than the allowed Threshold, packet transmission is rescheduled, at sender side. If packets to be rescheduled are more than the allowed limit, some of these are dropped to maintain the buffer level. EEBM repeat all these steps, in order to regulate the buffer space and results show that it can reduce the extra control overhead as well, as it can optimize the energy consumption by avoiding the unnecessary packet retransmission. Pseudo code for the proposed scheme is as follows:

Initialization phase:

Proc_init()
{

Initialize nodes : n
Set initial energy : ex
Set routing protocol : rp
Set initial packet transmission: Tx
Set initial packet reception: Rx
Set initial packet transmission power: Txp
Set initial packet reception power: Rxp
Initialize total_buffer size
buffer size_MAX : Bs_mx
buffer size_MIN: Bs_Mn
buffer size_Threshold: Bs_Th
Packet Drop_Threshold: $PKT->Th$
Packet Loss: Pl
MAX. rate of possible packet transmission : Mr
//Limit to process No. of packet in current buffer
Packet_Size_MAX_allowed
Packet_Size_MIN_allowed

//Sender Side:

Set $Tx->PKT\_Tx\_interval$;
Set $Tx->PKT\_Tx\_TimeOut$

//Receiver Side:

Set $Rx->PKT\_Rx\_interval$;
Set $Wait\_Time$;
Set $Rx->PKT\_Rx\_Timeout$;
}

// Group initialization Phase:

If ($n->ex$)
{
Group_Join($ni->ID$, True);
}

If (Group_Leave($ni->ID$)
{
$ni->$ Membership=false;
};

//packet loss count

If (Rx ->Error)
{
Pl ++;
}

If ($Pl < Pl->Th$)
{
Process_PKT ($Tx->p$);

}
Else
{
Buffer_mgmt(regulate_state)
}

```
Proc Buffer_mgmt(regulate_state)
{
   If (regulate_state)

   {
   Set PKT_Size_allowed
   If
   (PKT_Tx_interval != PKT_Tx_Timeout &&
    PKT_Rx_interval != PKT_Tx_TimeOut)
   {

      If Rx->pkt.Size() > PKT_Size_allowed)
      {
      Drop(Tx->p);
      }

      If (Tx->np <= Bs_Th)
      Process_PKT(Tx->p);
      else
      Tx->Wait_Time++;

   If (Tx->Wait_Time > Bs_Th)
   {
      reschedule(Tx->p);
   }

} else {
      Terminate (Tx, Rx);
      }
}
}

Proc reschedule(Tx->p)
{
   If(count(Tx->p > Bs_mx)
   {
     Drop(Tx->p, buffer);
   }

   If (!Tx->PKT_Tx_TimeOut && !
   Tx->PKT_Rx_TimeOut)
   {
   For each p in Tx
   Tx->p.PKT_Tx_TimeOut =
 CURRENT_TIME +1;
   }
}
```

IV. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

NS-2.35 is used for perormance analysis of MAODV and PUMA multicast routing protocols with EEBM scheme. Table II given below shows the simulation configuration.

Table II: Simulation configuration

Simulation Parameters	
Node(s)	30
Sender	1
MAC Protocol	802.11
Terrain	1200x1200
Ad Hoc Multicast Routing Protocol(s)	MAODV, PUMA
Simulation Time	10 Seconds
Group Size	1
Propagation Model	TwoRayGround
Simulator	NS-2
Node's Speed	120ms
Queue Type	DropTrail/Priority Queue
Initial Energy	10.0j
Traffic Type	CBR
Packet Size	512 Bytes
IFQ Length	50
Simulation Scenario(s)	1. Normal Execution Environment: MAODV-N PUMA-N
	2. Using EEBM: MAODV-EEBM PUMA-EEBM

Following graphs show the performance of normal MAODV and PUMA with EEBM. We have studied the throughput, Packet delivery ratio, routing load and energy consumption parameters to show the superiority of EEBM [22].

A. Throughput

Throughput is the measure of strength of any wireless communication system. It can be defined as the ratio of number of data packets received successfully over the total simulation time. Fig. 1 shows the throughput analysis of MAODV and PUMA with EEBM and without it. It can be observed that EEBM enhanced the overall throughput of MAODV and PUMA.

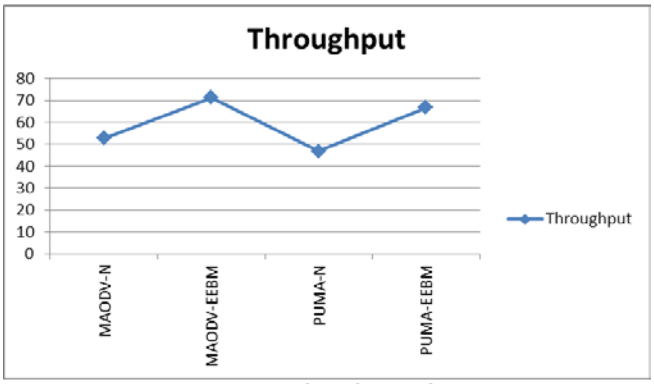

Figure 1. Throughput analysis

B. Packet Delivery Ratio

Packet Delivery Ratio (PDR) is defined as the ratio of total data packets received by the receiver node to the total number of data packets transmitted by the sender node. Mathematically, it can be calculated with the following formula,

$$PDR= \frac{1}{k}\sum_{i=1}^{k}\frac{nPr}{nPs}$$

Where nPr represents total number of data packets received by the receiver node and nPs represents total number of packets sent by the sender node. Fig. 2 shows the PDR analysis of our proposed scheme with the normal scenario of MAODV and PUMA. This figure shows the variations in PDR using different scenarios. It can be observed that EEBM improved the PDR of MAODV and PUMA.

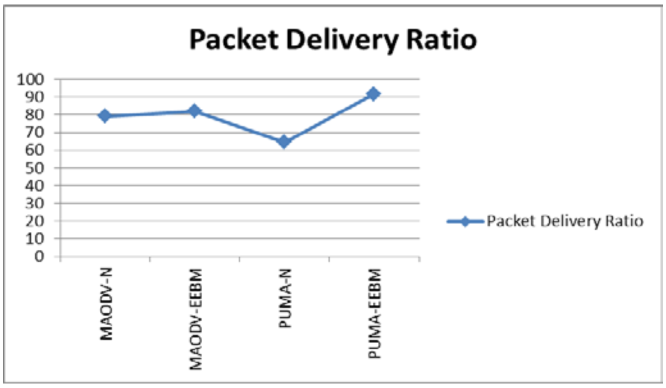

Figure 2. Packet Delivery Ratio analysis

C. Routing Load

Routing load can be calculated with the help of following formula,

$$RO= \frac{1}{k}\sum_{i=1}^{k}\frac{ncp}{ndp}$$

Where ncp represents the number of control packets and ndp represents number of data packets. Fig. 3 shows the variations in Routing Load using diffeent scenarios. It can be observed from the figure that EEBM has reduced the routing overload for MAODV and PUMA.

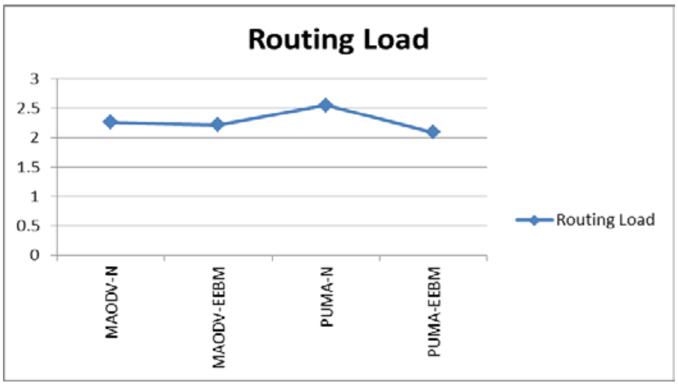

Figure 3. Routing Load analysis

D. Energy Consumption

As stated earlier, nodes in MANETs have limited battery life, and if used efficiently may cause the communication failure or sometime network partitioning. Form Fig. 4, it is clear that our proposed scheme EEBM has consumed less energy by managing the node's buffer efficiently.

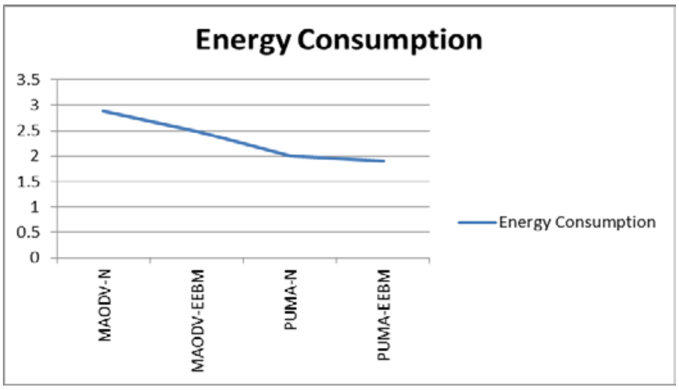

Figure 4. Energy Consumption analysis

V. CONCLUSION AND FUTURE SCOPE

- In this paper, various issues related to resource consumption and buffer management were discussed and an energy efficient buffer management method was introduced which can manage the buffer during packet transmission for group communication. MAODV and PUMA, multicast routing protocols are used for simulation purpose and results show that EEBM enhanced the Throughput and PDR for each protocol while minimizing the routing load and total energy consumption.
- It can be observed that even without using EEBM, Throughput/PDR of MAODV higher than PUMA and EEBM enhanced these for both protocols. Performance of PUMA suffered from excessive routing load but EEBM reduces it and enhanced the performance of PUMA and it is less than then MAODV. EEBM also reduced the level of energy consumption for PUMA and MAODV. PUMA consumed less energy as compared to MAODV.

In future, EEBM can be extended to minimize the energy consumption for other multicast routing protocols.

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