Service Differentiation for Achieving Fairness in Multi-Traffic Class in MANET

V. Robin Rohit, Ramaraj Eswarathevar

Abstract: Multi-access for multi-mode terminals is possible in heterogeneous networks environment that becomes a critical issue for transmission in parallel with meeting user Quality of Service (QoS) performance requirements and throughput maximization. Without considering the service type, the existing optimal resource allocation schemes may allocate the scarce radio resources inefficiently. To overcome these issues, in this paper, we propose service differentiation for achieving fairness in multi-traffic class in MANET. This proposed methodology includes three stages of solution. In the first stage, we assign priority through a well-defined structure. In the second stage, we use utility function to have more differentiation. In the last stage, we use piggy backing for data packet classification. As the proposed solution determines the priority based services, it becomes easy to assign a work with a good working scenario. A good differentiation is created among the user. The third part is able to solve data packet generation according to the space available.

Keywords: Priority assignment, utility function, piggy backing.

I. INTRODUCTION

MANET

A Mobile Ad hoc Network (MANET) is a self-configurable, self-organizing multi-hop mobile wireless network formed by a collection of autonomous mobile nodes to communicate with each other without any fixed infrastructure or central control. Each node moves randomly by limiting the transmission range and forming a dynamic topology. Each node can act as a host for sending or receiving packets and for route forwarding packets to other nodes. Their specific characteristics like rapid deployment and self-organization made them popular in military and civil applications where fixed infrastructures are unavailable or unreliable, but with fast network establishments, for example, in disaster rescue after an earthquake and collaborative computing with laptops in a classroom etc. It is used in business and commercial applications, electronic class rooms, convention centres, emergency rescue operations, law enforcement (crowd control) and military applications. Personal Area Networks (PAN), Residential Mesh Networks, Vehicular Adhoc Networks (VANET), Wireless Sensor Applications etc are few specialized MANETs [1,2 3]. The specific features like system dynamics of mobile multihop ad hoc networks, such as time-varying and error-prone wireless link, dynamic and limited bandwidth, time-varying traffic pattern and user location, and energy constraints, pose new challenges that do not exist in wired networks. Also, the error prone unstable and asymmetric nature of the wireless links decreases the reliability [1,2,3]. In order to support multimedia services, the traditional resource reservation requires adaptive QoS [2]. The salient characteristics of MANETs are time varying and error-prone wireless links, the dynamic and limited bandwidth, time-varying traffic pattern and user locations, and energy constraints in multi hop. MANET made heterogeneous traffic with different supporting QoS requirements. Heterogeneous traffic over wireless links can be handled by considering two problems. They can handle reliable mobile communications in MANETs and QoS provisioning with different QoS requirements like BER, throughput, and delay. As wireless environment has limited channel bandwidth, QoS support can be provided by any priority scheme or service differentiation mechanism where the delay sensitive traffic has higher priority to access the channel over the less time-critical traffic [1]. In addition, QoS can also be achieved by fairness among multi-classes [4].

Issues of MANET

Though MANET has many typical applications, some issues are faced which are discussed below [11]. Routing is a critical task that is used to route the packets between any pair of nodes due to continuous change in network topology. Multiple hops, which are more complex, compared to single hop are used in the routes between nodes. Various schemes of authentication and key management are needed for distributed operation. Due to limited wireless transmission range and broadcast nature of wireless medium, reliability problems may arise in the wireless link. It is quite critical for MANETs to provide QoS in different levels due to its continuously changing environment. Fixed guarantee on the device services offered is difficult in MANETs due to the inbuilt stochastic feature of communications quality. For minimum power consumption, the communication related tasks needs to be optimized for lightweight mobile terminals. In addition to the power conservation, it is necessary to consider the power aware routing.

Service Differentiation in MANET

Service differentiation, the key to today's Internet QoS, achieve QoS guarantee by sharing a common resource among multiple traffic classes [3,4,5].

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Internet Engineering Task Force (IETF) originally formulate the idea and concept of Differentiated Services (Diff-Serv) which define configurable types of packet forwarding in network core routers to provide per-hop differentiated services for large aggregates of network traffic. The model's inherent fairness and differentiation predictability made it to be accepted as an important relative DiffServ model and been applied in the Proportional Delay Differentiation (PDD) in packet scheduling [6].

There are several issues in alleviating the conflict between throughput and fairness for different prioritized traffic, especially avoiding bandwidth starvation problem for low priority traffic when the high priority traffic load is very high [1]. However, the assumptions like static network topology and stability of links make the direct application of DiffServ in MANET unfeasible [3].

To describe the paper in a well-defined procedure, this paper first gives a suitable algorithm. Then, a number of literature works is done in the section two to find the problem definition. This paper gives a proposed method with problem definition in section three. At last, a suitable conclusion is given, followed by simulation results.

II. LITERATURE REVIEW

Hannah Monisha. J and RhymendUthariaraj .V [2] have proposed a proportional share scheduling and MAC protocol (PS2-MAC) model that distinguishes the users according to their profile as High Profiled users (HP), Medium Profiled users (MP) and Low profiled users (LP) and assigns the proportional weights. Rationed dequeuing algorithm, variable inter frame space, proportionate prioritized backoff timers and enhanced RTS/CTS control packets achieve the Service Differentiation for these three service classes. However, the delay of LP is increased.

Amrit Kumar and Aura Ganz [7] have presented a collision free MAC protocol for wireless ad-hoc networks with Multiple Input Multiple Output (MIMO) links, which provide proportional service differentiation to various classes of traffic according to their respective bandwidth demands. The spatial multiplexing and interference suppression capability of MIMO links were utilized for multiple links activation in the same collision domain. The MAC protocol can achieve strict fairness in maintaining the proportional service differentiation among contending links. However, the tuning knob increases the service charge paid by the user.

Lijun Chen et al [8] have proposed distributed algorithms to attain Nash equilibria. A general analytical framework was provided, which could model a large class of system-wide QoS models using per-node utility functions' specification where system-wide fairness or service differentiation can be achieved in a distributed manner as long as each node executes a contention resolution algorithm. Contention resolution algorithm is designed to achieve the Nash equilibrium. Thus, a novel medium access method derived from Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) was proposed based on distributed strategy update mechanism to achieve the Nash equilibrium of random access game. However, the channel error can cause higher degradation of throughput.

Jie Miao et al [9] have proposed an optimal resource allocation algorithm, which divides the services traffic into two classes: Delay-Constraint (DC) and Best-Effort (BE).

A mathematical optimal model was formulated for supporting such heterogeneous service requirements in multi-radio access scenario.

Then, an optimal radio resource allocation algorithm was developed to enhance the total system throughput in heterogeneous networks, while efficiently satisfying the QoS requirement for DC services traffic and fairness for BE services traffic.

Li Yang [10] have proposed a new route protocol for Mobile Differentiated Service Route Protocol (MANET-MDSRP) as a solution to load balancing, differentiated priority of service and guaranteeing the QoS performance of high priority service.

MDSRP employed Expected Waiting Delay Metric (EWDM).

EWDM along with MDSRP can measure and evaluate the end-to-end delay of every candidate route and offer different strategies for service with different priorities.

MDSRP can also balance the traffic load of networks to avoid the congestion in regional area. However, this scheme enables more services to converge in a small area leading to congestion.

III. PROBLEM IDENTIFICATION AND SOLUTION

In our previous work [12], we have proposed an Adaptive Bandwidth Reservation technique using Cross-layer Approach for MANET. This approach adaptively estimates the bandwidth depending on the type of MAC protocol.

It involves a Bandwidth Estimation Agent (BEA) that resides in each node and interacts with MAC and routing layers to perform the following activities.

In resource reservation technique, the service provider acts in two different ways for CSMA and TDMA modulation.

Simulation results show that this technique can improve the throughput and received bandwidth.

But, the problem is to alleviate the conflict between throughput and fairness for different prioritized traffic, especially how to avoid the bandwidth starvation problem for low priority traffic when the high priority traffic load is very high.

In this extension work, we propose to design a service differentiation scheme for multi-user environment in MANET.

Proposed Methodology

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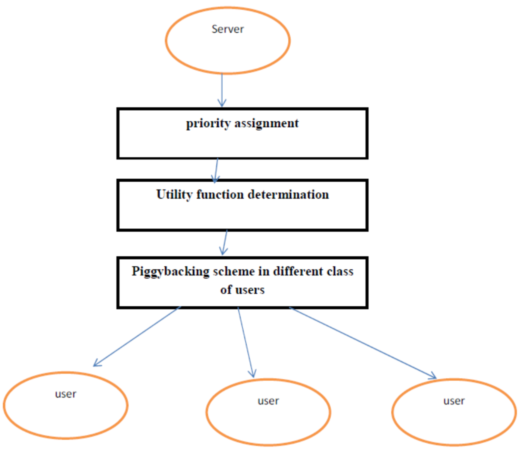

Figure 1. Proposed architecture diagram

Priority Assignment Phase

The users are classified as High Profiled user (HP) with good QoS, Medium Profiled user (MP) with moderate QoS and Low Profiled user (LP) with Best effort service. A static priority is assigned to each user based on the above classification relying on their user profile or requested QoS level. Then, a proportional weight is assigned to each user for satisfying their service requirements and also to favor the fairness among the competing nodes in a differentiated services environment. An additional field called priority field is added to each packet header generated at the source node to store the priority of the node including priority codes 0,1 and 2 of HP, MP and LP. It is assumed that the reserved field in packet header is used as a priority field.

802.11 DCF uses a backoff counter at each node in such a way that every node can choose a random number between zero and maximum contention window size. After sensing the channel to be idle for an IFS, the nodes start counting their backoff counters to zero. If the channel is found to be busy, they freeze their backoff counters.

The value of contention window is assigned between minimum and maximum contention window. IEEE 802.11 DCF is a random access mechanism, where a node selects a backoff value based on the formula (1).

$$Backoff = integer(2\ 2 + k * random() * slot - time)(1)$$

Where random () is the random number evenly distributed between 0 and CW, where CW is the contention window which varies between minimum (CWmin) and maximum contention window (CWmax) and k is the number of attempts made for transmission. To further support prioritization and reduce collision, differentiated backoff timers for HP, MP and LP are proposed, proportionate to their access ratios, using formula (1) as in the following equation (2).

$$Backoff - Prio = integer(PFi\ 2 + k * random() * slot - time)(2)$$

Where PFi is the priority factor for HP, MP, LP. The authors propose the user defined priority factor. Since this paper already has the user defined weights, we calculate PF proportionate to the weights. When the weight assigned is high, the share of bandwidth allocated will be high.

When the PF is low, the waiting time will be low. Hence, PF should be arranged as follows: 0<PF0<PF1<PF2<1. The following formula (3) calculates the PF for HP, MP, and LP proportional to their weights.

$$PF_i = 1 - \frac{w_i}{\sum w_j} \quad (3)$$

Once, the backoff reaches zero, before the data is transmitted, the source station sends a RTS and receives a CTS following which it transmits DATA and gets an ACK. RTS-CTS-DATAACK transmissions takes place. RTS, CTS and ACK are called control packets.

In the event of not receiving a CTS or ACK, the source is led to believe that a collision has occurred. In order to avoid further collisions, the backoff timer is increased. The CWmin doubles after every collision till it reaches CWmax. The RTS-CTS exchange is optional in 802.11. But, it is widely used with wireless networks to avoid the hidden terminal problem.

Algorithm for priority assignment phase

Step-1
1. Divide the users into three part
Step-2
2. Assign them in high priority, medium priory and low priory group.
Step-3
3. Get the back off time.
Step-4
4. Go for the iteration till the backoff time becomes 0.
Step-5
5. Transmit the data packet.

Utility Function Determination Phase

For each class of users, different utility functions were chosen for different class of users so as to provide service differentiation to different wireless nodes [8]. The utility functions are continuously differentiable, strictly concave, and with finite curvatures bounded away from zero, i.e., existence of some constants. The desired utility function constraints achieve the maximal throughput under the weighted fairness constraint at the nontrivial equilibrium.

A0: The utility function $U_i(.)$ is continuously differentiable, strictly concave, and with finite curvatures that are bounded away from zero, i.e., there exist some constants μ and λ such that

$$1/\mu \geq -\frac{1}{U_i''}(p_i) \geq 1/\lambda > 0 \quad (4)$$

A1: Let

$$\gamma(p) = \prod_{i \in N} (1 - p_i) \quad (5)$$

and denote the smallest eigenvalue of

$$\nabla^2 \gamma(p) \quad (6)$$

over P by $v_{\min}$. Then,

$$-\mu - v_{\min} < 0 \quad (7)$$

A2: Functions are

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$$\Gamma_i(p_i) = (1-p_i)(1-U_i^{'}(p_i)), i \in N \quad (8)$$

all strictly increasing or all strictly decreasing.

Algorithm for Utility function determination phase-

1. Take two constants μ and λ.

2. Derive the first function as given in 4.

3. Get the eigenvalue as given in equation 5**.**

4. Get the second function. As given in equation 8.

5. Divide the users.

Piggybacking Scheme in Different Class of Users

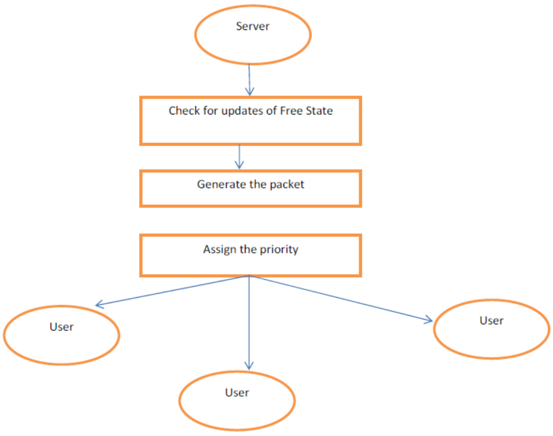

Figure 2. Modular diagram for Piggybacking scheme in different class of users

This paper employs courtesy Piggybacking scheme in LP and HP users [1]. For MP users, the transmission happens similar to the one in traditional protocols. Hence, we discuss only about the LP and HP users. First, the mobile node checks the status of channel, as if there is any free state relying on fixed fragmentation threshold and maximum packet size. If there is free-state, piggy backing is allowed if they intend to the same next hop irrespective of different priority classes. Otherwise, fragmentation will be performed. They check out for free state. After that, service packing is enabled. The objective is to enable the high priority traffic that helps the low priority traffic by sharing unused residual bandwidth.

The size of a packet generated by an application may vary from a minimum allowed size to a maximum value PKmax. We argue that the PKmax should be properly chosen to reduce the overall overhead. If we want to transmit c Mbits traffic, the packets are generated according to the PKmax. We assume that each packet can be correctly received without any retransmission. Then, the overall overhead should be the total of the overheads Oip at the IP layer (e.g., 20 bytes for IPv4), Omac at the MAC layer (e.g., 34bytes for IEEE 802.11) and Ophy at the PHY layer (e.g., 16 bites). Thus, the total overhead to transmit the c Mbits traffic can be written as where $\lfloor \bullet \rceil$ is the function to round the element to the nearest integer greater than the element. We show the relationship of overhead vs. PKmax and FT when c=1.

After identifying the existence of the free space, the most fundamental part in the Courtesy Piggybacking scheme is to design rules that guide the MAC layer to assemble enough and proper bits from the Tx queues (HOW MANY- WHO problem) and piggyback them to the next hop to alleviate the conflict that we intend to address.

The basic idea for such piggybacking rules is that under different channel states, we assemble multiple MSDUs that may have different priorities but share the same next hop in the routing table, to form an MPDU whose length is channel dependent. In this way, we can achieve some extent of fairness between different prioritized services. When the channel is not in a free-space-effective state, only the highest priority service in the Tx queues is supported, and the packets are fragmented if needed and are treated as usual. When the channel changes to a free-space effective state, according to the rules, we can pack other services possible with lower priority to share the residual bandwidth with the high priority traffic. One of such rules prefers the high priority services. If possible, it packs the high priority services destined to the same next hop in queue(s). Only when there are no more bits from the high priority traffic fitting into the free-space, will the bits from the lower priority queue(s) be considered for piggybacking. Other rules may not prefer the high priority service, for example, a high priority service may scarify some of its own performance for more efficient channel utilization by its courtesy--piggybacking the low priority service. One of such rules is to always piggyback the MSDUs from the longest Tx queue.

Algorithm for Piggybacking scheme in different class of users

1. Mobile node checks the status of the free state
2. If there is any free status
3. {
4. Generate a data packet of size PK_{max}.
5. Assign the works to the MAC layer
6. }
7. Else
8. {
9. Fragment the packets.
10. Assign them in the Ques.
11. Assign priority
12. Scarify some of the parameters.
13. }

IV. SIMULATION AND RESULTS

Simulation Model and Parameters

The Network Simulator (NS2) [13], is used to simulate the proposed architecture.

In the simulation, 50 mobile nodes move in a 1000 meter x 1000 meter region for 50 seconds of simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR) and TCP.

Performance Metrics

The proposed Service Differentiation for Achieving Fairness in Multi-traffic Class (SDAF) is compared with the Mobile Differentiated Service Route Protocol (MDSRP) [10].

The performance is evaluated mainly, according to the Throughput, Packet Drop and End-to-End Delay.

Results

1) Based on Rate

a) Case-1: CBR

The CBR transmission rate is varied as 500, 1000, 1500, 2000 and 2500Kb.

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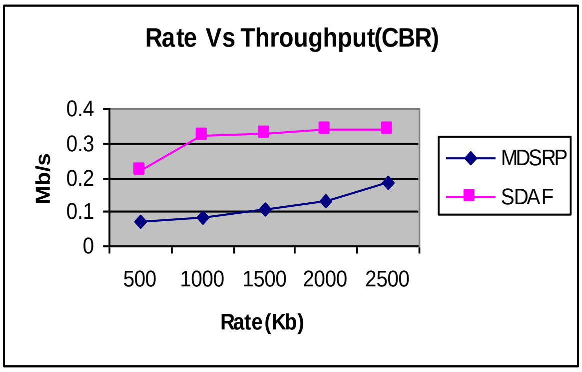

Figure 3. Rate Vs Throughput

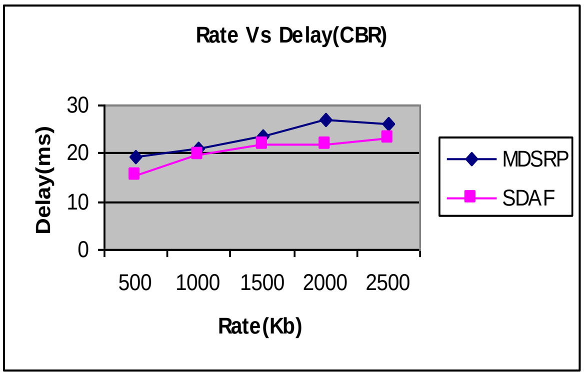

Figure 4. Rate Vs Delay

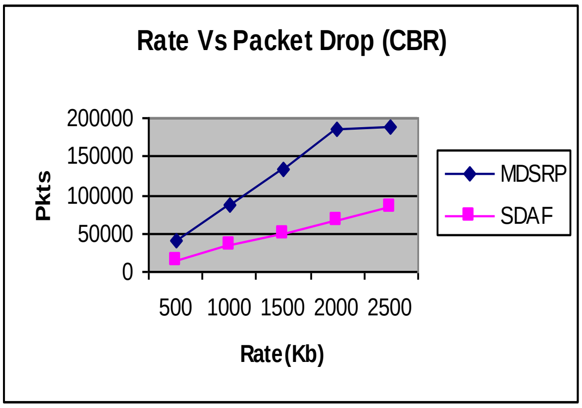

Figure 5. Rate Vs Packet Lost

Figure 3 to 5 shows the throughput, delay and packet drop of CBR traffic for both the techniques. From the results, it can be seen that SDAF outperforms MDSRP by 62%, 13% and 60% in terms of throughput, delay and packet drop, respectively.

b) Case-2: TCP

The transmission rate is varied for TCP traffic as 500, 1000, 1500, 2000 and 2500Kb.

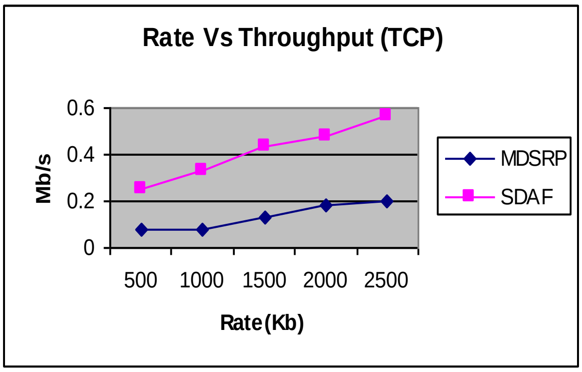

Figure 6. Rate Vs Throughput

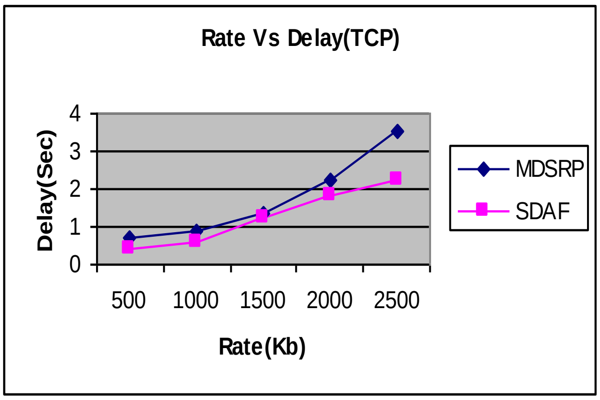

Figure 7. Figure 7. Rate Vs Delay

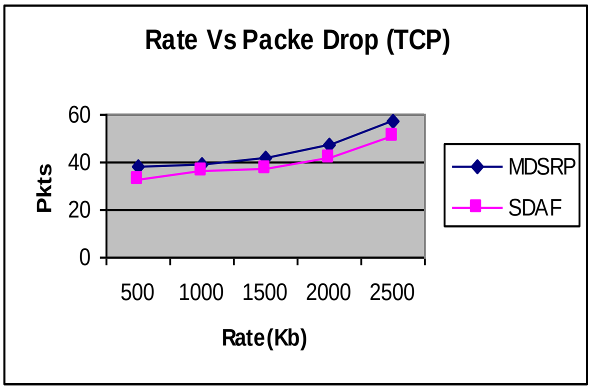

Figure 8. Rate Vs Packet Lost

Figure 6 to 8 shows the throughput, delay and packet drop of TCP traffic for both the techniques. From the results, it can be seen that SDAF outperforms MDSRP by 68%, 27% and 10% in terms of throughput, delay and packet drop, respectively.

2) Based on Simulation Time

In our second experiment, we vary the simulation time as 10, 20, 30, 40 and 50 sec.

a) Case-1: CBR

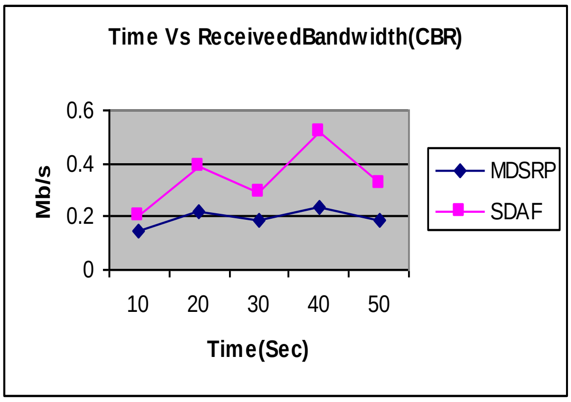

Figure 9. Time Vs Received Bandwidth

Fig 9 shows the received bandwidth of SDAF and MDSRP techniques for different time scenario. We can conclude that the received bandwidth of our proposed SDAF approach is 42% higher than MDSRP approach.

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b) Case-2: CBR

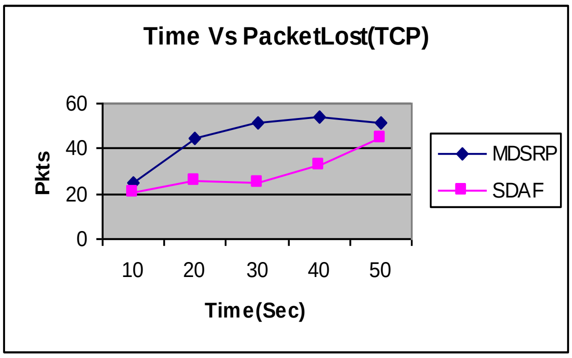

Figure 10. Time Vs Packets Lost

Fig 10 shows the Packet Lost of SDAF and MDSRP techniques for different time scenario. We can conclude that the Packet Lost of our proposed SDAF approach is 32% of less than MDSRP approach.

V. CONCLUSION

In this paper, we have addressed the problems to alleviate the conflict between throughput and fairness, for different prioritized traffic, especially how to avoid the bandwidth starvation problem for low priority traffic when the high priority traffic loads is very high. We have proposed a service differentiation scheme for multi user environment in MANET. In the first section, we assigns priority through a well-defined stricter, use the utility function to have more differentiation and finally use piggy backing for data packet classification. The proposed solution determines the priority based services. So it is easy to assign a work with a good working scenario. After that, we create a good differentiation among the user. Finally, the data packet generation is performed according to the space available.

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