An improved load balancing adaptive QoS buffer scheduler (I-LABS) for streaming services over MANET

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Abstract—**Large variations in network Quality of Service (QoS) in terms of bandwidth, latency, jitter may occur during media transfer over Mobile Ad-hoc Networks (MANETs). Researchers have identified that complex computing applications experience "bursty" QoS behavior during their execution. Applications have to adapt their functions to any change in network status. Moreover, on enhanced software platform is necessary to provide adaptive network management services to upper software components. I-LABS, middleware architecture for service adaptation, are based on ad hoc network and service awareness. I-LABS is structured in such a way as to provide both QoS awareness to streaming applications and manage dynamic ad hoc network resources in an adaptive scheduler fashion. The overall architecture of I-LABS framework includes core components to connection establishment, connection monitor, policy manager and connection controller. Adaptive scheduler mechanisms are introduced as object based components such that I-LABS has been implemented using ns2 simulator toolkit to demonstrate the performance of mobile setup as a conference application.**

Keywords- Adaptive; channel load balancing; MANET; QoS; scheduler.

I. INTRODUCTION

Streaming applications depend much on the underlying communication infrastructure to provide access to remote services and resources. Ideally these applications do not concern anything about the networks used and could only focus on the service functionalities they provide, but in practice this can never be true. Large variations in network Quality of Service (QoS) (e.g. bandwidth, latency, jitter, reliability) may occur during media transfer over ad hoc networks.

In this paper, an optimal buffer scheduler based QoS scheme Improved -Load balancing Adaptive Buffer Scheme (I-LABS) over Mobile ad hoc networks (MANET) is presented, which identifies an optimal service-based load balancing scheme which supports applying and binding quality during dynamic runtime environment. The objective of the model is to explicitly deal with the coexistence of ad-hoc networks built by distinct devices supporting distinct technologies and aiming to exchange media streaming messages. Based on this model, it is assumed that in general case nodes are not able to directly communicate with each other; we have devised a set of resource awareness services necessary to achieve communications among nodes through media gateways and wireless routers. The proposed set of services takes into account policies for sharing resources as well as user profile preferences, allowing thus to tailor services according to user needs. Resource awareness services are layered under a set of communication services in a middleware architecture enabling communications among nodes belonging to distinct ad-hoc networks.

Mobile ad-hoc networks are typically very dynamic networks in terms of available communication partners, network resources, connectivity, location management, etc. Furthermore, the end-user devices [3] [17] are highly heterogeneous, ranging from high-end mobile nodes to low-end PDAs and mobile phones. Traditionally, middleware [6] [10] is used to abstract from this heterogeneity and to enable the application programmer to focus on application issues. The research work proposes to develop scheduler supported services approach which can provide quality services for information sharing in MANETs, due to the possibility that sharing information is mission critical for critical network applications. Our ultimate aim is to identify solutions for this realistic setting and to quantify the QoS which can be provided to the users.

In particular, following issues are addressed:

1. To design an architectural organization of mobile ad-hoc systems and distributed policy indexing mechanisms that allow for efficient scheduler policy inducement and approval.
2. To distribute location and routing mechanisms that allows for uniform and highly-available access to routing resources and optimizes scheduler performance.
3. To deal with the dynamic aspects of the systems, such as arrival and departure of mobile nodes through publishing and withdrawal of the corresponding resources through scheduler activity.
4. To distribute management mechanisms that aggregate resources at multiple peers and satisfy end-to-end QoS and real-time response time requirements for the applications.

A. An Improved Load balancing Adaptive Buffer Scheme (I-LABS)

An improved load balancing adaptive QoS priority-based scheduler at the network layer for multiple connections should support diverse QoS requirement. Each connection employs dynamic buffer allocation for packets based on their service type and bandwidth in use. The Priority Function (PF) for flow 'x' is defined such that for any connection 'c', which is supported by variable services, can be prioritized dynamically based on wireless traffic channel quality, QoS correction factors and service priority across network layers. Hence, any connection with desired priority is scheduled first at any instance, while other connections with low priority service rate would be scheduled later. I-LABS scheduler works on packet type and allocates buffer at each node based on flow, QoS satisfaction (correction factor) for service and QoS threshold at network layer. The prescribed QoS guarantees are delivered for MANET setup while utilizing the wireless bandwidth efficiently as well as providing support for low implementation complexity and scalability.

The scheduling algorithm I-LABS has been designed such that high priority packet in service is identified among all the control, media and data packets in the queue which needs to be served

II. LITERATURE SURVEY

From a researcher's perception, the provisioning of bandwidth is not a major constraint for wireless networks [15], since even though a large bandwidth is allocated to a connection, the expected delay or throughput performance may not be satisfied [1], and the allocated bandwidth is wasted when the wireless channel experiences issues related to signal to noise in channel, interference issues, and fading.

From our literature survey, it has been identified that Time Division Multiple Access (TDMA) and Carrier Sensing Multiple Accesses (CSMA) [5] are two major medium access approaches adopted in MANETs. An improved version of Weighted Fair Queuing (WFQ) [3] for MANETs supports multiple services called I-LABS to provide end-to-end statistical bounds on required delay guarantees to provide effective QoS. A working model of WFQ and related survey shows that, if nodes adopt a WFQ-like service discipline and the source traffic follows highly best effort service, then an upper bound on the end-to-end delay and bandwidth guarantees can be provided [18].

Most current research on design of scheduler for MANET [10] [18] uses a simple packet queuing scheduling algorithm for simulations in ns2 [17]. An overview of scheduling techniques defined by Chen, et al. for wireless networking can be found in [9], where a multiple desirable features have been summarized, and many classes of schedulers have been compared on the basis of these features [4]. To schedule wireless resources (such as bandwidth and power) efficiently for diverse QoS guarantees, the interactive queuing behavior induced by heterogenous traffic as well as the dynamic variation of wireless channel should be considered in scheduler design [21]. Arunkumar, et al. [2], adopt an adaptive QoS for media streaming services, but specific scheduling techniques are not employed at each node, due to which packet sequence and its related delay are not discussed.

The self-similarity issues in network traffic [16] have brought exciting challenge into its modeling and need for effective bandwidth utilization to develop an adaptive scheduling scheme. Many self-similar traffic simulating methods have been well known to the research community such as Fractional Gaussian Noise (FGN) [9], Fractional Brownian Motion (FBM) [9] and Fractional Auto Regressive Integrated Moving Average (FARIMA) [8]. Policies that attempt to control rate and power separately may fall into this category. The RT scheduling algorithm in wireless networks is Max-Weight based algorithms including Largest Weighted Delay First/Modified Largest Weighted Delay First (LWDF/MLWDF) [2], Exponential Rule (EXP) [9] and Modified Exponential Rule [3].

Research work carried out by Byung-Gon [4] evaluated packet scheduling algorithms by using DSR [2] and GPRS [19] routing protocol in MANET and pointed that the benefit of giving priority of control packets over data packets depends on using routing protocol. It has been noticed that setting priorities among data packets could decrease end-to-end packet delay significantly. Xu, et al. [21] considered the relationship between a node and its interfering nodes as “neighborhood” and extended Random Early Detection (RED) concept to a distributed neighborhood queue. They aimed to solve the TCP unfairness in MANET. The research work [22] discusses an energy efficient load scheduled queue support routing scheme which identifies the route based on each flows load capacity. The scheduling algorithm I-LABS has been designed such that high priority packet in service is identified among all the control, media and data packets in the queue which needs to be served.

III. SYSTEM MODEL APPROACH

QoS requirements in traditional data networks mainly result from the rising popularity of end-to-end bandwidth-hungry multimedia applications [7]. The network is thereby required to provide better services than original best effort service, such as guaranteed services and differentiated services. Based on the expected system behavior, the system model needs to be achieved by the equation 1,

$$PF_X = \sum\sum T(Sij)\left(\frac{1}{1-\alpha_n}\right) + \sum \beta_i QE(Pn),\ f(i, j) \geq 0 \qquad (1)$$

Here,

PFx - Priority function of connection provided for specified flow ‘x’ service S

P - Transmission range of MANET node, where each node can send information or receive information.

T (S) - Function of average bit per packet transmission per second for prioritized in a channel T

α_n - Packet Loss (bytes)

βi - Dynamic buffer being allocated based on variable QoS threshold, Where $\beta i >= 0$

n - Total packets in queue

QE - Function to evaluate QoS in a channel T

The primary objective of I-LABS is to improve the data rate by adjusting transmission nodes ‘n’ to channel variations while maintaining a prescribed packet error rate T(Pn), using the design procedure as proposed in Equation (1).

A. I-LABS QoS Architecture at The MAC

At MANETs MAC layer, it can be assumed that each connection belongs to a singular service class and it is associated with a set of QoS parameters that quantify its characteristics. Four QoS classes are provided by the MAC in the IEEE 802.11 [23] and IEEE 802.16 standard which are adopted in I-LABS**.**

1. Constant Bit Rate (CBR) or Unsolicited Grant Service (UGS) [20] supports applications which possess CBR or fixed throughput connections such as E1/T1 lines and voice over IP. This service provides the required guarantees on throughput, latency and jitter. The service specific QoS metrics used in this work are Packet Error Rate (PER) and the Service Rate (SR).

2. Real-Time Polling Service (RTPS) [13] provides guarantees on throughput and latency, but with better tolerance on latency relative when compared with UGS. Service based applications such as MPEG video conferencing, streaming video, content delivery systems can be considered. Packets delayed are dropped. The QoS metrics are the PER and maximum delay (msecs).

3. Non-Real time polling service (NRTPS) supports mission critical data applications, such as File Transfer Protocol (FTP) since it guarantees throughput only. An FTP file can be downloaded within a bounded waiting time only if and only if the minimum reserved QoS rate is guaranteed. The QoS metrics are PER and the minim un-reserved rate (MR). These applications are time-insensitive; hence, they require minimum throughput.

Best Effort Service (BES) provides no guarantees on delay or throughput and is used for Hypertext Transport Protocol (HTTP) and electronic mail. These applications work based on the residual bandwidth after its allocation to the connections. Hence, such services highly depend on throughput compared to previous three service classes. Although no delay and rate is specified for BE connections, a prescribed PER should be maintained over wireless channels.

Let n denote the total number of transmission modes available. As in [5], we assume constant power transmission (P) and partition the entire SNR range in n + 1 non overlapping consecutive intervals (See in Figure 1), with boundary points denoted as α_n for $\exists\ \alpha$ being a value within 0 to n here node 'm' is chosen when $\alpha \in (\alpha_n, \alpha_{n+1})$. PER for a node n_k is designated by the equation (2)

$$T(Pn)_k = \alpha_k \qquad (2)$$

Where 'k' is the node 'k' distance from 'n+1'

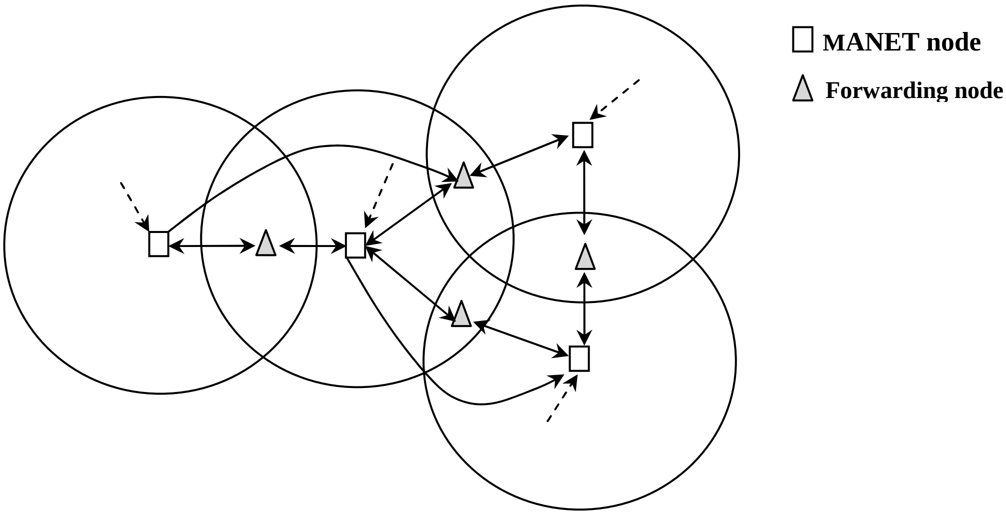

Figure1. MANET Nodes with Defined Coverage Range

B. Bandwidth Estimation

In MANET - distributed network setup, the source nodes bandwidth in use is identified by the raw channel bandwidth in use along with the neighbor's bandwidth usage as well interference issues caused by node sources, each of which reduces the host's available bandwidth for transmitting data. Hence, bandwidth sensitive applications cannot identify an optimized solution to their coding rate without knowledge of the status of the entire network. Thus, bandwidth estimation is a fundamental function that is needed to provide QoS in MANETs. However, bandwidth estimation and provisioning is difficult, due to imprecise knowledge of the network status at host and links change dynamically.

Therefore, an effective bandwidth estimation scheme at MAC and network layer is required. Bandwidth estimation can be carried out using (i) bandwidth estimation is a cross-layer design of the routing and MAC layers, (ii) the available bandwidth is estimated in the MAC layer and is sent to the routing layer for admission control. Therefore, bandwidth estimation can be performed in several different network layers, as shown in Figure 2. The region boundary (bandwidth threshold) is set as α_n for the transmission node 'n' to be the minimum SNR required to guarantee T(Pn). Inverting the PER expression by applying initially α_0=0 and α_0 denoted in equation (3).

$$\alpha_n = \sum\left(\left(\frac{1}{n}\right)\ln T(Pn)\right) \qquad (3)$$

$\forall$ Nodes within the boundary α_0 to α_n

The pseudo-codes of optimal buffer utilization algorithm to assign the required buffer 'β' are discussed using Dynamic buffer allocation and optimal node identification based on sensing and transmission energy. First Algorithm identifies the node communication range for transferring the data through the flow identified. Secondly Algorithm identifies the optimal buffer path. The following definitions are used to explain I-LABS for MANET node under dynamic mobility.

Definition 1: Any node n can communicate with another node n+1, only within its feasible communication range 'maxCoverage'

Assumption: A node ‘n’ is communicatable with another neighboring node ‘n+1’ only when it is within its coverage range α_n. First Algorithm explains the communication range of node within the defined boundary.

C. Algorithm 1: Dynamic Buffer Allocation

```
for i = 0 to total number of bytes – 1      // total buffer at source node
        maxCoverage αn = 0
        for each byte βi NOT Available in Qj
   selected_Byte[i] = Byte
   value = % of maxcoverage of Selected_Byte
    if αn < value then
        αn = value
        nextByte = byte ++
     endif
   endfor
        Selected_Byte[i] = nextByte
Endfor
```

Definition 2: Any node ‘n’ at any time ‘Tx’ the node is considered to be active only when it transmits or receives.

Assumption:

For any given active time ‘Tx’ of a MANET node T*active*, the data receiver consumption and transmission power of node E(T*active*) is expressed as the sum of the sensing and transmission data. As T(Pn) is transmission power for any node ‘n’, the negligible sensing power *Ps* is relative to transmission power T(Pn).

$E\ (T_{active}) \approx \sum T(Pn) * Ps$, where $Ps \leq 1$ and Tx varies from 1 to ∞

$QE = Ps * T_{active} * \alpha_n$

D. Algorithm 2: Optimal Node Iidentification based on Sensing and Transmission Eenergy

```
% Initialize - for n = 1, . . . ,N  and Q = i,j,k
Set Queue size Qni = 0, Qnj = 0 and Qnk = 0
∀ node targets n do step 04 to 07
Find overlapping and non-overlapping nodes ‘n’ that cover T(Pn) & Ps
Select a optimal node buffer n ∈ Q(i)OR Q(j) OR Q(k)
% Update for selected responsible node ‘ni’
∀ Nodes n, where n can be ⊆ E (Tactive)
if and only if node n transmits T(Pn) at ttx
Update T(Pn) in  Qi
If node n ≠ Qi then remove node ‘ni’
loop
return
```

The signaling and procedure for the service setup and maintenance of each connection are defined as in the IEEE 802.16 standard [3]. However, the standard does not define the scheduling mechanism or the admission control and traffic policing processes. The signaling overhead is not included in our design and analysis. Each host node’s available bandwidth is estimated based on the bandwidth used by itself as well as each of its two hop and multiple hop neighbors. Either an admission control scheme is used during route discovery, or adaptive feedback is embedded in the route reply packets. This procedure is an extension to AODV [6], a standard MANET routing protocol, since it can be easily implemented in an adaptive MANET setup. I-LABS scheme adopts similar route information where the best neighbor is identified based on the energy of a neighbor.

The Improved Load Balancing Adaptive Buffer Scheduler (I-LABS) for providing on demand QoS for MANET networks is as shown in Figure 2. The complete functionality takes up seven steps:

1. The MAC discriminator identifies the buffer size and organizes the QoS scheduler as per the service in use for node ‘n’ used for transmission based on T(S) and E(Pn).
2. The Queue Manager allocates each packet into queue based on Bandwidth Estimated as per service on demand and buffer βi available in queue Qi.

3. The QoS manager as part of Route Update identifies the route with prioritized service as Queue on priority and assigns the queue Qi to route update to destination.
4. The traffic similarity is identified in Queue Qi and classified, which is also used to determine the effective QoS on demand.
5. The QoS on demand is identified using function QE at specific time Tx.
6. Any queue Qi whose queue buffer limit exceeds has an overflow or dropped packets, which leads to reduced QoS for service S.
7. Number of packets dropped, queue variable size and information on service in use are updated to Queue Manager.

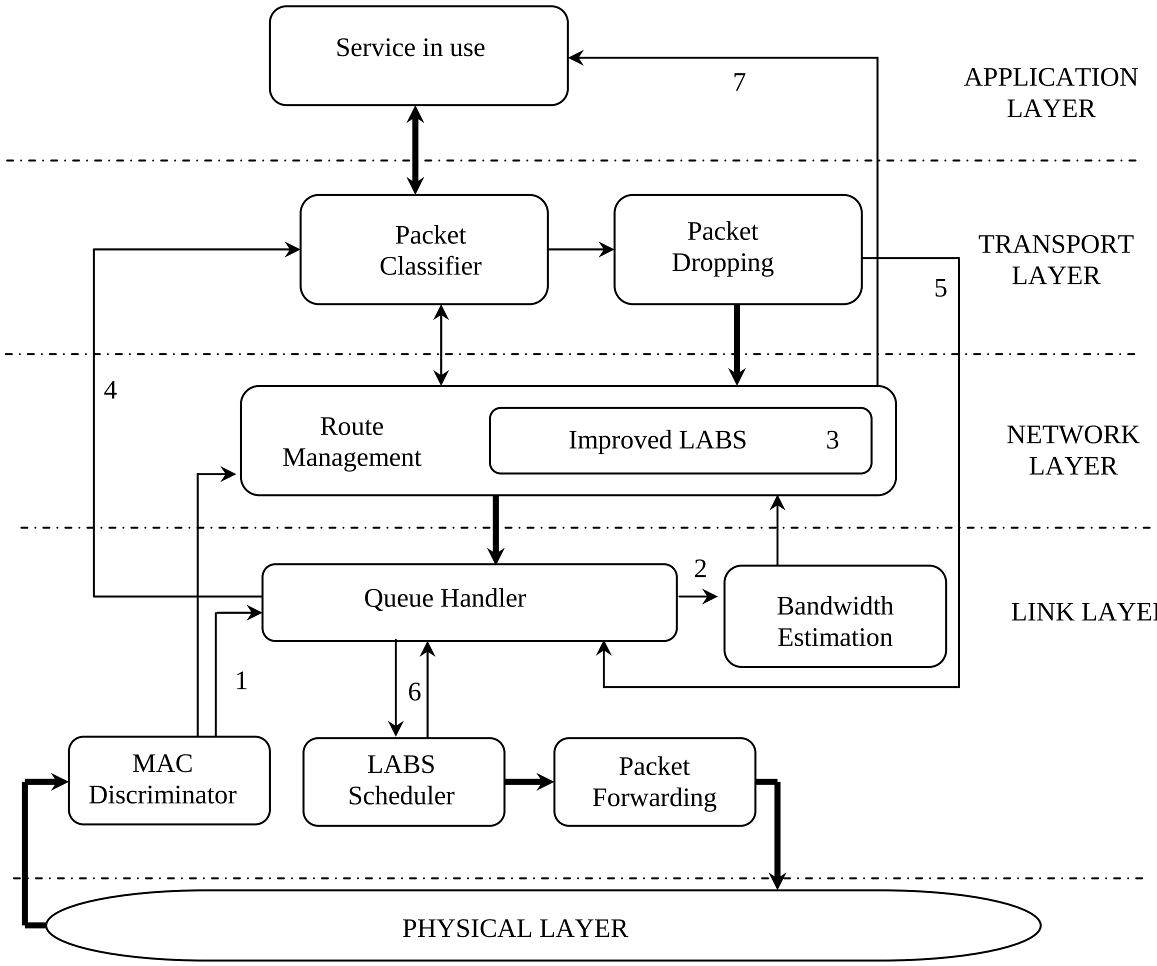

Figure2. I- Load balancing Adaptive Buffer Scheduler Architecture with QoS Aware

I-LABS scheduler maintains this update for the next service required. Packet scheduling algorithm based on queue scheduling is a QoS technique to maximize bandwidth utilization to improve flow of service packets. The scheduler specifies the queue service discipline at each node, such that the order in which queued packets is actually transmitted. Since packets of multiple services depart from the same outgoing node, I-LABS packet scheduler enforces a set of rules in sharing the link bandwidth. Packet scheduling prioritizes a user's traffic into two categories: delay priority for real-time traffic and loss priority for data type traffic. Survey carried out for many packet scheduling algorithms [14] [15] [18], RR (Round Robin), WFQ, WF2Q, VC (Virtual Clock), SCFQ (Self-clocked Fair Queuing), FFQ (Frame-based Fair Queuing), EDF (Earliest Deadline First) and SCED (Service Curve-based Earliest Deadline), shows various mechanisms to control congestion at queue, but not methods to control high priority services. I-LABS chooses the simple RT-WFQ (Real Time Weighted Fair Queue[11] [12]) to add some QoS control approaches to adapt to varying ad hoc setup under self-similar traffic due to its simplicity in implementation and robustness towards congestion management for real time services.

IV. RESULTS AND DISCUSSIONS

In ns-2 test simulations are conducted and 50 MANET nodes are placed randomly within a 1000 m x 1000 m area, where twenty different random scenarios are simulated. The packet size used in our simulations is 500 bytes and the raw channel bandwidth is 2 Mbps. Three source destination pairs S1, S2, S3 and S4 are randomly chosen to simultaneously transmit video on demand real-time data packets, and one randomly chosen non real-time data flow joins in after 10 seconds. The total simulation time is 200 seconds. UDP is used as the underlying transport layer protocol for both real-time and non-real-time streams.

The H.263 TMN package [19] is used to show the video quality improvement using a QoS architecture in ad hoc networks. A source S1, S2, S3 and S4 maintain Q1, Q2 and Q3 as the queuing buffer allocated and used (Table 1). Each queue is allocated the priority function PFx. Queue with maximum weight gets the highest flow while minimum weight queue gets the least flow for connection in use. The minimum weight should be greater than zero and is set to be 0.5 for Q1 and 0.01 for Q2 while 0.001 for Q3.

TABLE1. QUEUE PRIORITY AND SERVICE IN USE

Service Type	**Queue Average Delay**		
	Q1	***Q2***	***Q3***
Real Time	0.0054	0.0024	0.0009
Real Time	0.0125	0.0073	0.003
NonRT	0.0126	0.011	0.001
NonRT	0.382	0.12	0.023

Simulation time is 200 seconds where delay and packet loss between original WFQ and I-LABS scheme is shown in Figure 3. The compared results are given in (Table 2). Random Early Detection (RED) is used as the basic queue management method for understanding purposes. Compared to WFQ, I-LABS scheme reduces the queuing delay. Even though Q1 and Q2 possess the minimal priority PFq parameter, Q1 has the highest priority; so it gets the lowest delay.

TABLE2. COMPARISON USING EXPERIMENTAL TEST BED FOR LABS, I-LABS, AODV AND WFQ

Movie for Experiment	**Video Streaming**							
	Ave Bandwidth Required Mbps	***Ave. Bandwidth Used Mbps***	***Multicast Groups / User***	***Delay ms***	***RTT ms***	***Hops***	***Loss %***	***Jitter ms***
File A 1000Mbps	1000							
WFQ		160	5	30.0	16.0	6	26	425
LABS		110	5	23.3	14	6	20	384
I-LABS		135	5	27.0	20.9	8	20	450
AODV		210	5	34	23.6	12	31	502
Audio File B 1200Mbps	1200							
AODV		220	7	39.0	17	7	42	521
I-LABS		197	7	31.5	12	5	34	504
LABS		206	6	37.7	19	5	44	600
WFQ		245	7	39.8	17.2	6	68	628
Movie -C 2000Mbps	2000							
AODV		232	6	31.0	14.2	6	31	500
I-LABS		204	6	28.8	13.6	5	30	478
LABS		249	6	29.1	14.8	5	42	507
WFQ		210	6	34.0	16.1	6	58	578

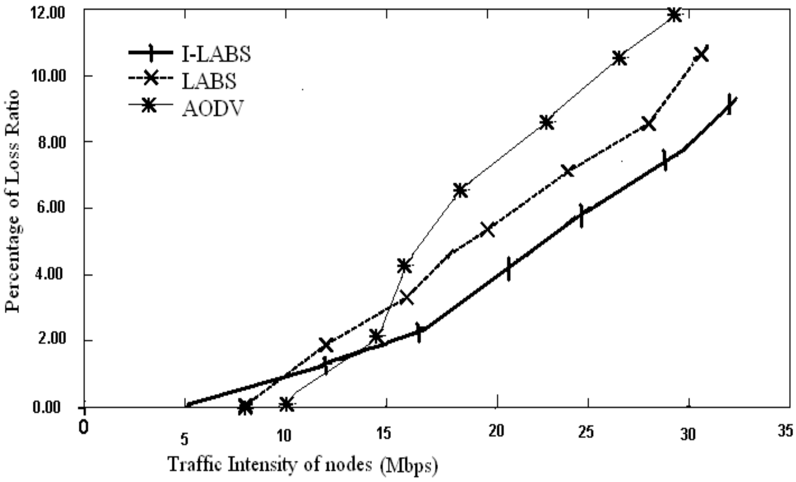

Figure3. Packet Loss Ratio of I-LABS

Percentage of packet loss ratio with respect to the amount of background traffic for AODV, LABS and I-LABS is shown in Figure 3. This graph indicates that an average of 4% of packet loss ratio is observed.

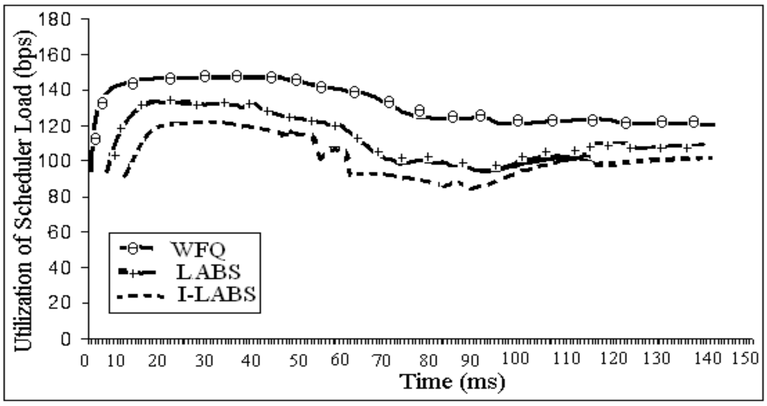

Figure4. Utilization of Scheduler Load in I-LABS

Figure 4 shows the Utilization of Scheduler load with respect to time for Adaptive Weighted Fair Queue, LABS and I-LABS. The Utilization of Scheduler load has increased by 20% in I-LABS.

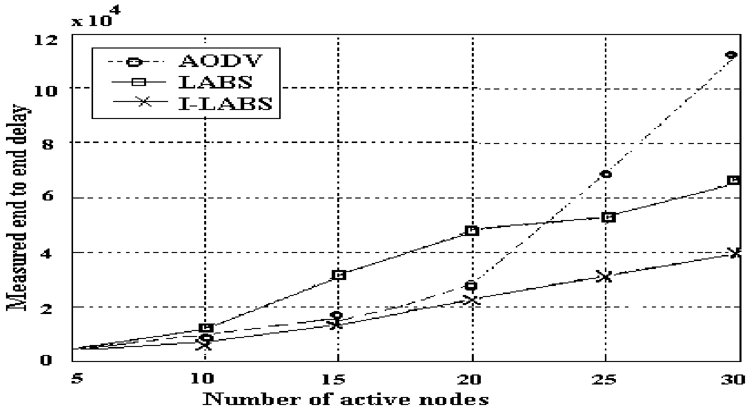

Figure5. End to End Delay Performance in I-LABS

Figure 5 shows the End to end delay performance with respect to the number of nodes for AODV, LABS and I-LABS. The end to end delay has decreased by 20% in I-LABS. The delay curve for protocol AODV [6] with WFQ, RED [21] is shown in Figure 4. I-LABS show an improvement of minimal delay over WFQ approach. This scheme is preferred since it is commonly adopted for Best Effort Services in a wireless scenario. The traffic intensity of I-LABS scheme over ADOV utilizes dynamic buffer utilization; hence, demonstrated utilization of minimal traffic intensity compared to RED and WFQ schemes. The performance of WFQ acknowledges better on comparison with RED, but I-LABS exhibit other schemes. The throughput performance is shown in Fig. 5 for varying service types. The performance gain is evaluated and plotted, which shows higher throughput for I-LABS scheme.

V. CONCLUSION

This study investigated packet drop and priority scheduling policy, with focus on improving the aggregate best-effort traffic performance. A congestion aware scheduling algorithm I-LABS has been proposed. I-LABS scheme focuses on design and development of a QoS adaptive scheduler for highly variable queue management for MANET. A delay optimized scheduling policy tries to optimize the rate and power in order to pritorize the queue length. When a node has packets to schedule, it primarily takes into account the traffic load of its neighbor nodes. Packets diverted to neighbor nodes have priority over those sent to “busy” nodes.

I-LABS scheme outperforms RED and WFQ schemes with respect to delay, traffic intensity at queue, and throughput. This scheme can be improved as well experimented with other MANET routing protocols, so that its performance and were acceptable ratio.

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