

# A High Throughput cross Layer based Mobility Management for Wireless Mesh Networks

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**Abstract** The growth of low cost smart devices have led to growth of multimedia application such as skype, Netflix etc... which require a strict bandwidth to satisfy the QoS (Quality of Services) of end user. The 802.11 have been adopted by various industries but due to power constrained imposed by regulatory body has resulted in low coverage. To support a high bandwidth services multihop based communication is required. The *Task Group S* was formed in 2004 to support multi hop wireless mesh networks (*WMNs*). In recent times the multihop wireless mesh network have established itself has a future cost effective and scalable wireless infrastructure technology. Moreover the *WMN* is expected to provide a cost effective seamless mobility but still there exist a many challenges that need to be addressed. The 802.11s *MAC* (Medium Access Control) is designed using *CSMA/CA* (Carrier Sense Multiple Access) which is not efficient for dynamic nature of multimedia based application services and to overcome this many *TDMA* (Time Division Multiple Access) based protocol has been proposed for *WMN* in recent times. The failure in predicting the active user in network has resulted in drop of throughput efficiency. To address this here the author proposes a threshold based decision making algorithm for mobility management by adopting a cross layer design considering link quality. The threshold detection should minimize packet loss and maximize the throughput. The experiment evaluation is conducted for throughput efficiency and drop rate by varying mobility speed and user and the outcome shows that the proposed approach achieves better performance in term of drop rate achieved and throughput efficiency over existing *DGR-SRORA* strategy.

**Keywords** Wireless mesh network, Cross layer, *MAC*, Mobility management

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## 1. Introduction

The 802.11 LAN [3] have been adopted by various industries such as education, office, home etc... is not able to satisfy the current demand of end user need due to the transmission power constrained imposed by the regulatory body which limit the coverage of network. Since these networks are wired in nature they are inflexible and induce high deployment cost, to address this task group S was formed and wireless mesh network is standardized as 802.11s [2]. In next generation the *WMN* [19, 20] is anticipated to be the most sorted out paradigm for providing internet connectivity to its end user by complementing existing wired network. *WMNs* establishes an ad-hoc infrastructure i.e. it is self-configured and self-organized, with the devices in the network can join and leave a network and still maintaining the mesh connectivity. In existing wireless network such as Wi-Fi and 3G network are connected to AP (Access Point) through wired

infrastructure in order to access/ retrieve the information from the backhaul infrastructure which is time consuming and induce high cost of deployment. Subsequently *WMN* uses subgroup of access points to communicate with internet gateway (IGWs) through wired infrastructure, whereas the other access points, namely knowns as mesh routers (MRs) are connected through internet gateway in a multihop based communication. Thus *WMN* help in providing an economically feasible and sustainable solution for wireless internet connectivity.

To provide quality application services to wireless mesh devices by adopting an IEEE 802.11s mesh protocol standard is known mesh stations. The mesh station that offers admission to the distributed network through the wireless medium is known as mesh gate. The other Mesh stations work as MAP (Wireless Mesh Access Point) to its end devices which are mobile in nature. The MAP acts as coordinator node to the gateways as well as delivers data to its end user and they are equipped with multi radio to provide multi-channel access for robust communication. The architecture of IEEE 802.11s wireless mesh network is shown in Fig. 1.

There exist a load balancing issues in wireless mesh network backbone mesh point that act as a gateway to

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connect other mesh point which are in it routing path or to internet. Due this it is necessary to balance the load considering dynamic nature of traffic and speed of mobile user and also the nature of wireless medium transmission channel. The selection of gateway router by the mesh point is crucial since all traffic of end devices request will go through the gateway so there is high likelihood of bandwidth bottleneck resulting buffer overflow, packet loss which is result in congestion in network, so load balancing is an important requirement to improve the network performance.

There has been various protocols have been adopted to reduce network overhead on wireless link by distributing traffic [4] [5].

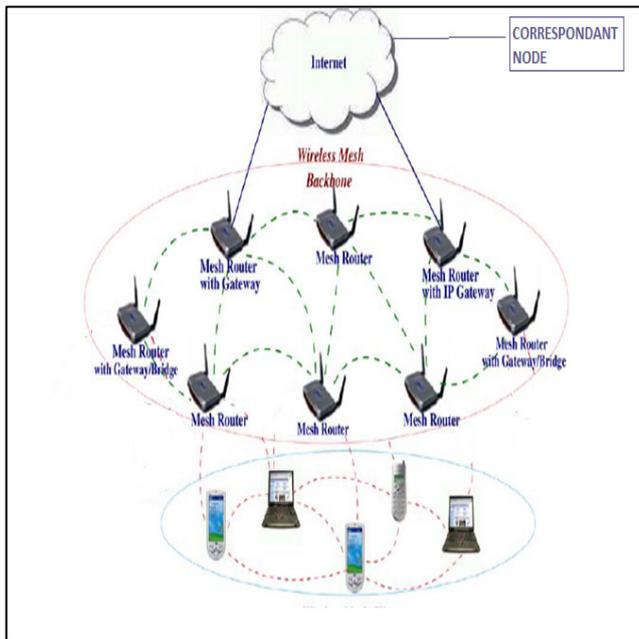


Figure 1. The IEEE 802.11s wireless mesh network architecture

In [11] they showed hybrid wireless mesh protocol is not efficient enough for random access *MAC*, and to overcome this they evolved a flexible model that properties of random access for hybrid wireless mesh protocol. In [12] they proposed a prototype namely *HWMP+* which is an enhancement of [11] which consider the channel condition and load in network for selection of root. Their method improved the network performance but they did not considered the multi radio channel allocation scenario. In order to address the channel allocation issues in wireless mesh networks. In [13], [14], [15] they considered fixed channel width adaptation for a single-radio multichannel, their outcome are not suitable to the *OFDMA*. In [16] [17] they extended the protocol by considering multiradio multichannel and this is also not suitable for *OFDMA* due to issues of each device can either transmit or receive data on sub channels at a slot time, while this issue is not bid factor for multiradio multichannel circumstances. In [18] they adopted energy dissipation and improve the network performance author considered the power against network

data rate by the tradeoff curve. Physical interference involved where device used for controlling the power. Author work is based on single channel or single device; it is not suitable for multi-channel or multiple user scenarios.

The fixed data rate contention based *CSMA* [6] is not efficient in providing high throughput services in order to achieve this *OFDMA* or *TDMA* is adopted. The issue with *OFDMA* [7] [9] based protocol is that it has transmitting and receiving in a slotted time, and sub channel allocation of radio can either be used by receiver or transmitter. Channel width adaptation [8] consider adaptation of time and frequency domain. To overcome this *TDMA* is been used. The issue with *TDMA* based approach is that improper measure of active user will result in improper usage of frequency as a result throughput performance is affected to overcome this spatial reuse based *TDMA* [10] is adopted but it was not suitable for multi-channel and multi user scenario due to interference of user. To overcome these challenges here the author propose threshold selection based decision making algorithm for efficient mobility management by adopting a cross layer design considering link quality and evaluate the performance of proposed approach with existing work *DGR-SRORA* [9].

The organization of the work is as follow: In section two the literature survey is briefed. In section three the list of symbol and notation use is tabulated. In section four the proposed threshold selection algorithm is presented. In section five the experimental study and evaluation is done. In penultimate section the concluding and future remark is discussed.

## 2. Literature Survey

Here the author surveys some of the existing protocol that tries to improve the *QoS* issue of *WMN*. The intrinsic issues of *WMNs*, such as power limitation, high BER and interference, considerably limit the *WMNs* performance. In the past many studies and methodologies [21-26] have been presented by researcher to enhance the time slots for channel allocation and throughput in channel utilization of *WMNs*. Nevertheless, these methodologies do not consider collision detection mechanism considering the mobility nature of user in mesh network.

Various methodologies have been proposed in recent times for performance enhancement of IEEE 802.11s wireless mesh network that adopt *CSMA/CA MAC* protocol [27] [28] that include tuning the carrier-sense range [29] by adopting out of band control message [30] or local coordination [31] in order to improve the channel slot utilization. The *CSMA/CA* protocol used in *IEEE 802.11* [32], are compromised by the issues of application service unfairness and inefficiency to address the packet delays. Though these issues have been addressed in [33] the *Bidirectional-DCF (BDCF)* protocol, on *IEEE 802.11 DCF* protocol, the issue still persists in multi-hop wireless mesh networks [34], [35].

The *TDMA* based *MAC* protocols [36] [37], offers collision-free transmission and provide good access control of throughput and delay of network traffic. With the institution of *TDMA*-based scheduling the *IEEE 802.11s* [38] was drafted for mesh network. By using the mesh coordination function (MCF) in *IEEE 802.11s*, each link can reserve a slot time for data transmission without competing with other links for transmission opportunities. However, the end-to-end *QoS* for delay sensitive services is still an open issue. To address the resource-allocation issue of multihop *OFDMA* for wireless mesh networks has been developed in [39-42]. Nevertheless, these methodologies focused on a relay-based two-hop network prototype which is not suitable for mobility nature of mobile user in WMN. The *MAC* protocols based on distributed scheduling [43], [45], [46] have been proposed to address the interference free [44] *TDMA* schedules. Yet these methodologies allocate equal slot access on time basis for each user request irrespective of traffic demand or load which affect the end to end performance. Along with this there has been various cross layer design have been adopted to solve the routing, interference and *MAC* contention for better path selection [47] but they suffer in identifying alternative path and failed to address the interference problem.

It is seen from literature survey there is need for new protocol design that consider load among mesh point, mesh gateway, link quality and mobility of user end device. To address this here the author proposes a threshold based mobility management protocol. The ideal threshold should satisfy maximizing the throughput and minimize the packet loss/drop which is briefed in section three.

### 3. Proposed Threshold Based Mobility Management Model

This work proposes a cross layer threshold based decision making strategy for mobility management by considering the link quality and threshold detection strategy based on collision detection algorithm to detect the set of active user in wireless mesh point. Here the author consider a wireless mesh network that has a set of devices  $D = \{1, 2, 3, \dots, D\}$  that associates with wireless mesh access points  $a$  and  $a \notin D$ . Here the author consider a multi radio *TDMA* based channel and also consider infinite buffer size for obtaining packet drop due to failed or wrong transmission. To optimize the data transmission in wireless mesh network for packet collision avoidance here the authors consider an *OTS* (optimization transmission stage) as in [1] and the threshold selection algorithm for efficient decision making strategy for mobility management is presented in below subsection.

#### 3.1. Threshold Selection Algorithm for Mobility Management

Here the author considers a case were every wrong judgment taken by the wireless mesh access point will outcome in failure of packets in *OTS* so an effective

threshold selection algorithm is needed to detect the set of active user in the network for efficient mobility management for wireless mesh networks. Once the mesh point detects the collision correctly it helps in improving the throughput of the network. So it is important to find the best threshold selection to assure a promising max throughput.

$$\frac{dH}{dL_R} = 0 \quad (1)$$

where  $H$  is the Promising Throughput,  $L_R$  is the likelihood of Rayleigh flat fading channel as in [1].

$$\frac{dL_A}{dL_R} = \frac{L_b L_A [DT_2(1-T_1^{D-1}) + (D-1)(D-DT_1+T_1^D)]}{(D-DT_1+T_1^D)T_3 - DL_A(1-L_b)I_2(1-T_1^{D-1})} \quad (2)$$

Where  $L_b$  is likelihood of buffer being empty for user at initialization of *OTS*,  $L_A$  is the likelihood of detection under Raleigh flat fading channel as in [1],  $T_1 = (1 - L_b)(1 - L_A) + L_b(1 - L_R)$ ,  $T_2 = (1 - L_b) + L_b(1 - L_R)$ ,  $T_3 = L_b(1 - L_R) + DL_A(1 - L_b)$ .

The equation (2) can be simplified by considering peak  $N$  signal to noise ratio (*SNR*) by considering  $L_A \approx 1$  and  $L_R \approx 0$ .

$$\frac{dL_A}{dL_R} = \frac{L_b(D-L_b^{D-1})[D-(D-1)L_b]}{D(D-1)(1-L_b)^2 + [D-(D-1)L_b^2]L_b^{D-1}} = \gamma \quad (3)$$

$$L_A = L_R^{1/(1+N)} \quad (4)$$

$$\frac{dL_A}{dL_R} = \frac{1}{1+N} L_R^{-N/(1+N)} \quad (5)$$

From the equation (4) & (5) the author computes the likelihood of ideal threshold on Rayleigh flat fading channel as follows

$$L_{R,ideal} = [(1+N)\gamma]^{-(1+N)/N} \quad (6)$$

The Ideal threshold for efficient mobility management is stated as follows.

$$I_{ideal} = \sqrt{2\sigma_v^2 \frac{1+N}{N} \log[(1+N)\gamma]} \quad (7)$$

Based on equation (7) the maximum throughput can be obtained for the mesh point but to obtain ideal threshold detection for realistic mesh environment the author consider a scenario were few packet that are collided can be recovered by the mesh access point makes a false decision. I.e. when  $P - u$  sources are lost in detection, out of that at least  $u$  packets that are collided can be recovered correctly in the *OTS*. The mean probable packet recoverable is as follows

$$\bar{I}_l = \sum_{P=0}^D L(P) \sum_{u=0}^P \sum_{v=0}^{D-P} u L_{det}(u, v) = D(1 - L_b)L_A(8)$$

The probable throughput under this scenario is

$$H = \bar{I}_l / \bar{C} \quad (9)$$

Considering when  $N \rightarrow \infty$ , the author expect that  $L_R \rightarrow 0$  and  $L_A \rightarrow 1$ , therefore  $H \rightarrow D(1 - L_b) / [D(1 - L_b) + L_b^D]$ .

To obtain ideal threshold detection under this scenario the author considers that let  $aH/aL_R = 0$ . Based on above Eqs. (8), (9) and also Eq. (21) from [1] the author obtain

$$\frac{dL_A}{dL_R} = \frac{DL_b L_A (1-T_1^{D-1})}{D-DT_1+T_1^D - D(1-L_b)L_A(1-T_1^{D-1})} \quad (10)$$

When considering good  $N$ , the Eq. (10) is simplified when

$L_R \approx 0$   $aL_A \approx 1$  is approximated is as follows

$$\frac{dL_A}{dL_R} = \frac{D(1-L_b D^{-1})}{L_b D^{-2}(L_b + D(1-D_b))} = \gamma \quad (11)$$

Now let consider Eq. (12) form [1] the likelihood packet loss is formulated as follows

$$L_c = 1 - L_A[(1 - L_b)L_A + L_b(1 - L_R)]^{D-1} \quad (12)$$

The function can be changed to likelihood packet loss  $L_c$ . i.e. let  $dL_c/dL_R = 0$ . Therefore based on Eq. (12) we obtain

$$\frac{dL_A}{dL_R} = \frac{(J-1)L_b}{L_b \frac{1-L_R}{L_A} + D(1-L_b)} \quad (13)$$

When considering good  $N$ , the Eq. (13) is simplified when  $(1 - L_R)/L_A \approx 1$  is approximated is as follows

$$\frac{dL_A}{dL_R} = \frac{(D-1)L_b}{L_b + D(1-L_b)} = \gamma \quad (14)$$

Based on this the ideal threshold can be improved from Eq. (7) and based on this the selection of mesh point for user is considered.

Beyond this threshold the packet loss increases and the throughput is dropped. This indicates that the user is moving away from the Mesh Point. Below in the next section the experimental analysis study of our proposed approach is evaluated and compared with existing algorithm namely *DGR-SRORA* [9].

**Table 1.** List of Symbol and Notation Used

Notation	Description
$a$	wireless mesh access points
$H$	Promising Throughput
$L_R$	Likelihood of Rayleigh flat fading channel
$L_A$	Likelihood of detection under Raleigh flat fading channel
$N$	Signal to noise ratio
$L_b$	Likelihood of buffer being empty for user at initialization in <i>OTS</i> .
$D$	Set of devices
$L_c$	Likelihood of packet Collision
$I_{ideal}$	Ideal threshold

## 4. Experimental Analysis

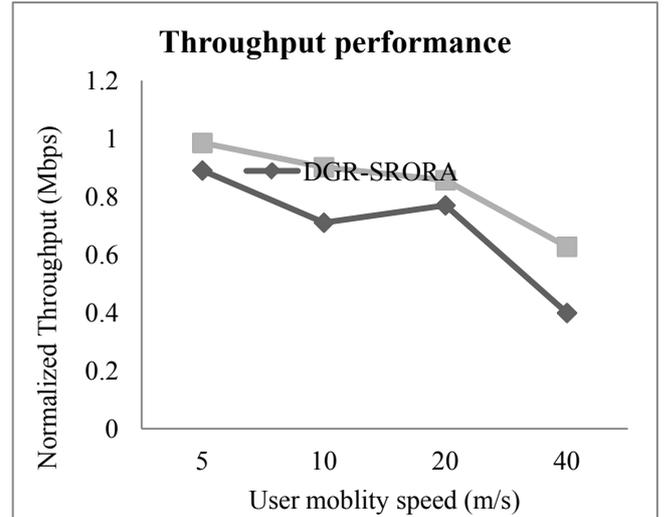
The operating system used is 64-bit windows 10 single language, 64-bit quad core processor 64-bit with 12GB of *RAM*. We have used MATLAB 2015 framework. We have conducted experimental analysis on following parameter for drop rate for varied user speed and throughput for varied user and speed and compared our proposed approach with existing algorithm *DGR-SRORA* [9] and conducted experimental analysis.

In Fig. 2, the user speed is varied from 5 to 40 m/s and the throughput performance is shown. The throughput performance improvement of proposed approach over existing *DGR-SRORA* when speed is 5 m/s is 9.76%, for 10 m/s is 21.20%, for 20 m/s is 20.11% and for 40 m/s is

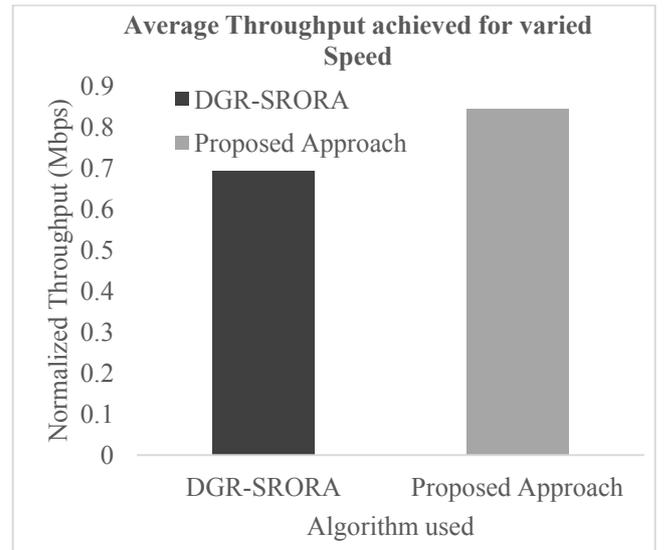
36.38%. It is seen from the graph the throughput achieved is decreasing with increasing in speed for both the approaches which proves Eq. (11) and the average throughput improvement of proposed approach is 17.83% over existing *DGR-SRORA* which is shown in Fig. 3.

The experimental parameter considered is shown in below Table 2

Parameter	Value
Speed of mesh devices	5, 10, 20 & 40 m/s
Total number of mesh user	32
Number of user	5, 10, 15 & 20
Simulation range	10
Packet length	80,000 bytes
Doppler frequency	2.4 GHz
Data rate	312500 bps
Monte-Carlo iteration	1
Number of sub-channel	4
Simulation slot	500



**Figure 2.** Throughput performance for varied speed



**Figure 3.** Average throughput performance for varied speed

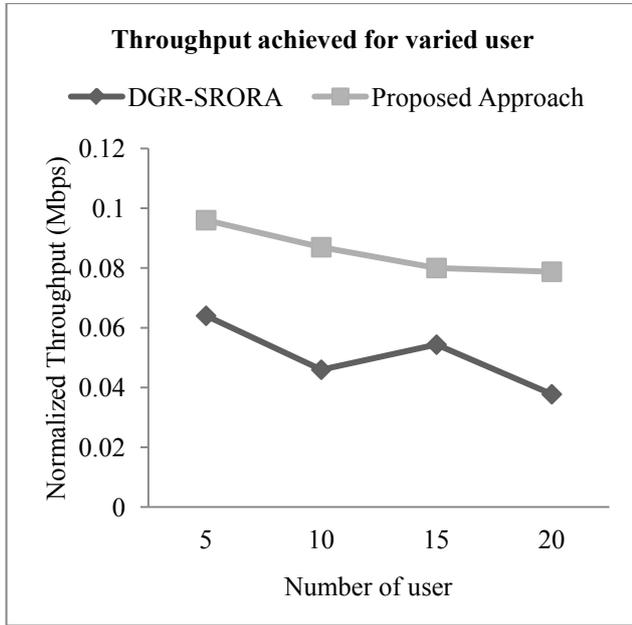


Figure 4. Throughput performance for varied user

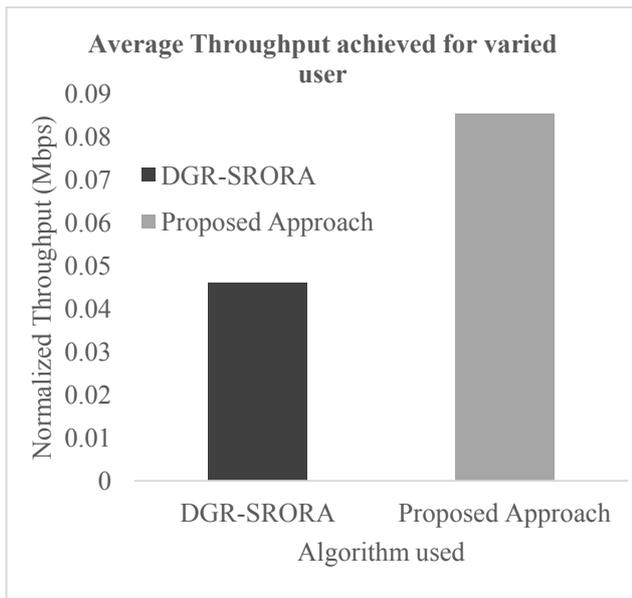


Figure 5. Throughput performance for varied user

In Fig. 6 below, the user speed is varied from 5 to 40 m/s and the drop rate performance is shown. The drop rate performance improvement of proposed approach over existing *DGR-SRORA* when speed is 5 m/s is 30.88%, for 10 m/s is 40.05%, for 20 m/s is 37.02% and for 40 m/s is 33.78%. It is seen from the graph the drop rate achieved is increasing with increasing in speed for both the approaches and the average drop rate proposed approach is reduced by 35.09% over existing *DGR-SRORA*.

In Fig. 7 below, the user speed is varied from 5 to 40 m/s and the packet processing delay performance is shown. The packet processing delay is reduced by proposed approach over existing *DGR-SRORA* when speed is 5 m/s is 33.3%, for 10 m/s is 33.41%, for 20 m/s is 17.32% and for 40 m/s is 14.78%. It is seen from the graph the packet processing

achieved is increasing with increasing in speed for both the approaches and the average packet processing delay of proposed approach is reduced by 24.16% over existing *DGR-SRORA*.

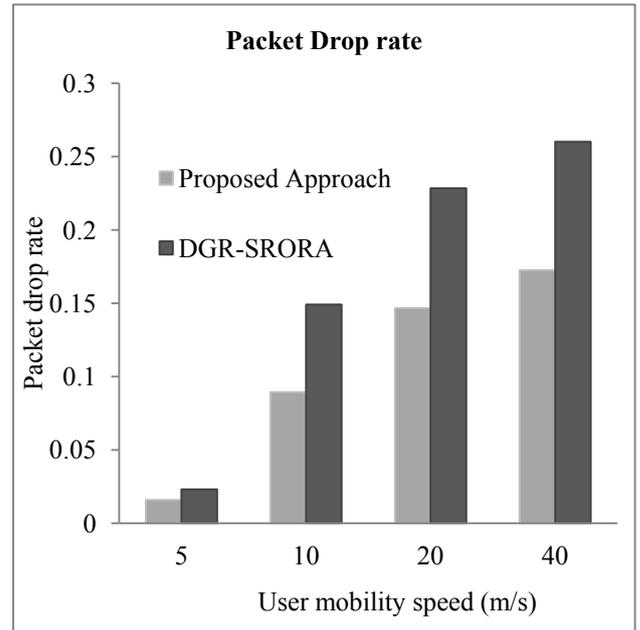


Figure 6. Drop rate performance varied speed

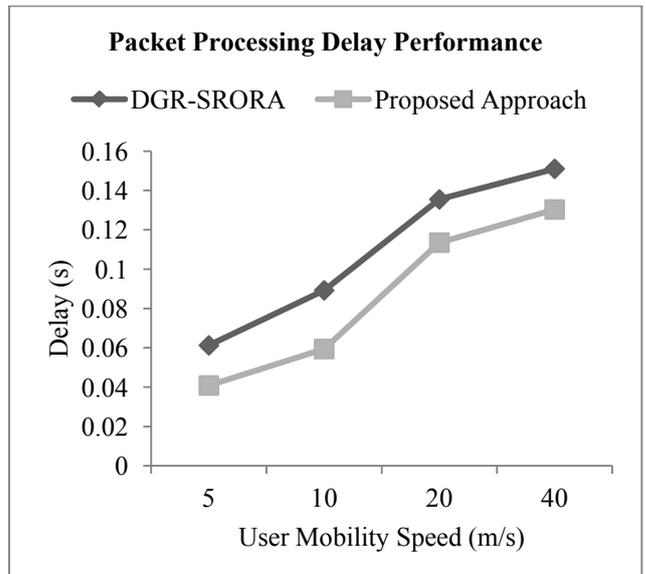


Figure 7. Packet processing delay performance for varied speed

## 5. Conclusions

Here the author presented an efficient mobility management scheme for *WMNs* that meets the *QoS* necessities of the end devices. Here in this work the author have presented threshold based decision making algorithm for efficient mobility management in mesh networks by adopting a cross layer design. The proposed model minimizes the packet drop, reduces the packet processing delay and improves the throughput performance in *WMNs*

due to the adopted threshold selection technique. The experimental result shows that the proposed model reduces drop rate by 35.09% for varied speed, reduces the packet processing delay by 24.16% and improves the throughput performance by 17.83% for varied speed and 46.13% for varied user over existing *DGR-SRORA*. The outcome shows that the proposed model is robust and scalable considering network density and mobility of user. In future the author considers evaluating the performance of proposed model for varied load density.

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