A CROSS-LAYER ROUTING OPTIMIZATION TECHNIQUE FOR WIRELESS MESH NETWORK

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Abstract— Rapid growth of Smart phone devices have resulted in various multimedia based application which required strict QoS to guarantee services to its end user which the existing wireless local area network could not cope with it due to coverage restriction imposed by the regulatory body. To address this multihop based WMNs have been adopted as back haul to connect to the internet. Scheduling of slot for data access in multihop wireless is challenging task, many contention and contention less based protocol have been proposed in recent times, but they are not efficient, since they did not consider the link quality for scheduling of slot. To address this, in this work, a routing scheme is developed that consider link quality parameter by using the proposed cross layer optimization technique. The proposed cross layer design reduces packet loss and improves the QoS parameters of the network. The results show that the proposed approach effectiveness of the QoS parameters such as throughput and delay compared to existing approaches.

Keywords— Mesh Network, Network layer, Radio channel measurement, TDMA, Wireless network.

I. INTRODUCTION

Wireless Mesh network (WMN) in recent time has gained popularity due to cost effective and flexible deployment. WMN provides multihop based communication services to it end user. WMN addresses the coverage issue of single hop based wireless local area network for service provisioning to its end users. High service availability is provided by the WMN through multiple route, if one point or one route is dead or fail to communicate in that case other route is available. High demand of this WMN due to its flexible architecture to support this many mesh standards are given [1-3].

In upcoming wireless technologies mesh network play a very important role it has new generation of wireless architecture. Mesh client and mesh router is two important parts of Wireless mesh networks. User can interact with mesh devices for Internet through mesh router, which is connected to the wired network. The mesh network can adopt any of these IEEE 802.11a/g/n standards to form a backhaul mesh network. Mesh network also has many restriction or issues in terms of number of user in specific location, movement or speed, transmission rate for a given QoS, data packet retransmission etc. using only above standard is some time seems like inefficient, and it require some alternative or some changes, for particular task [5].

Large community of user needs large bandwidth better QoS, wireless mesh networks ($WMNs$) are hope emerging technologies which give a hope to researcher to full feel the need of people. $WMNs$ has capability to scale their capacity, WMNs has multi-channel, multi-radio capability. WMNs consist of three things

1. Stationary or mobile nodes
2. Mesh routers
3. Internet Gateway (IGW)

$WMNs$ are dynamically self-configurable in nature, as per need $WMNs$ changes their approach. Mesh router are connected through wireless link and it generally static in nature. Stationary or mobile node access internet through IGW, which act as central point for these nodes in mesh network. Most of mobile or stationary node request of accessing internet is directed to the Gateway node which may lead to the congestion in network. Large number of user presence in $WMNs$ increases the chances of network congestion. Providing QoS in transmission of multimedia in $WMNs$ has an issue because high interference in multi-radio in mesh network. To provide better QoS researchers are working on it for fine grain transmission in multimedia. Selection of path for transmission of data and rate adaption is very important for QoS.

Routing metric is a process of creation of routing table or routing decision by which transmission of data path is selected. Routing metrics create route table by capturing the network quality, it also takes the various parameter from network and MAC layer which helps to estimate a better path. Cross layer approach is used to exchange the parameter between various layers. Various cross layer approaches are developed in recent time such as Expected transmission time (ETT), Expected Transmission count etc. Here author approach to address the drawback of these routing metric by considering the delay and using single interference. Network interference is used by cross-layer approach in MAC layer. At network layer delay and interference is computed.

Rate of data transmission is plays a very important role in estimation of link quality in mesh network. So the author extends their work by choosing rate adaption parameter in routing metric. Packet loss or

Signal to noise ratio (SNR) is generally used for computation of rate adaption.
In [11] to achieve a high data rate service provisioning for multihop based mesh network it requires a $TDMA$ based methodology. They adopted a $TDMA$ based medium access control (MAC) scheduler to supports multi-channel based communication and routing integration. Their outcomes shows that it is not affected interference and it reduces the control overhead of the network, but for large network there method is not efficient. In [10] they adopted an iterative model for by using $TDMA$ MAC to find the best feasible path for scheduling by exchanging the link status among the mesh devices.
Author raise the following points like what is best routing path, traffic demands, placement of wireless node, network scheduling and capacity assignment for network which can reduce the delay of packet transmission in the network. To overcome or find the answer of these question we design a cross-layer optimization model, it involves MAC, network and physical layer. Our designed model is useful for capacity management, take routing decision and scheduling. Poisson process is used for packet arrival process in data transmission. $TDMA$ system [6] is used for result of average packet delay, it allows the multiple slot assignment in a network which is useful to determine the delay in network.

1.1. Issues and challenges faced in WMN

Using $IEEE$ 802.11s WMN for scheduling has the following main issues and challenges [12] [13]:

Distance: The $IEEE$ 802.11s is adopt a multihop based communication through wireless channel, the wireless mesh devices can communicate with each other over short to long distance in meters. Since these devices are wireless in nature they are prone to noisy channel.
Mobility nature of Mesh Devices: the mesh devices are generally has fixed topology which consists of mesh gateway router which connected to internet backhaul and mesh point which provide services to its connected end user. The user are generally mobile in nature which result changing channel condition that result in loss of frames due to the Rayleigh fading channel [4].
Handover management in WMN is a difficult task due to mobility nature and user dynamic application service requirement, handover in such network will result in change of route selection of mesh point service delivery of its end user.
There exist following difficulties in prototyping mesh network, to forecast the total subscriber user in the mesh networks. To predict the current link condition/status of the wireless mesh link. To predict the current traffic requirement of end-user in mesh network due to wireless dynamic nature.

Due to dynamic nature of wireless mesh network [7] the static rate implementation is not suitable for such network. To address the above design challenges and issues this work proposes a cross-layer adaptation medium access control prototype that takes advantage optimized rate implementation, considering $OFDMA$ to handle frequency selective fading considering the mobility of device and provide enhanced transmission performance for multi-radio mesh networks.
The work is organized as follows: In section two, the proposed models are presented. In section three, the simulation and experimental analysis are presented. The final section the work is conclude with future work.

II. PROPOSED MODEL

Here the author adopts a $TDMA$ based channel for wireless mesh network where a group of devices i.e. $S = \{1,2, \ldots, S\}$ and Communicates with the mesh point (MP) i.e. m and $m \notin S$ and also considers that the devices operates with full duplex mode and are fortified with multi radio. The author also considers that it requires one slot time per data or packet transmission and all packet that are transmitted have same length. In order to get packet loss due to improper transmission here the author consider infinite buffer for each user.
To optimize the transmission strategy for packet collision avoidance here the author considers that at t slot let D devices collides. When the occurrence of packet collision arises the MP then predicts the collision in order to obtain the number of active devices and the collision order and through control channel it notifies its decisions to all its devices in the mesh network.
Now the authors consider that let $\hat{J}(t)$ represent decision of group of active device $J(t)$ and Let $\hat{D}$ represent the decision of collision order of D. The system enters the optimization transmission stage (OTS) in order to get the collided signal and the OTS length is obtained as $\hat{D}$ -1 which are fixed.
Now let consider in a period of slot $t + d(1 \leq d \leq \hat{D} - 1)$ one device arbitrarily chosen as a non- regenerative intermediate device and retransmit its collision period slot signal. The OTS is stopped or terminated after the slot $t + \hat{D} - 1$.

In the proposed scheme let consider the data transmitted by device x is represented as $a_x(t) = [a_{x,0}(t), \ldots\ldots, a_x, H - 1(t)]$, that has H number of signal queues and the obtained signal queues power is σ_a^2. Therefore the signal obtained by all the idle devices and by the destination devices is obtained by following equation

$$b_i(t) - \sum_{x \in J(t)} y_{xi}(t) a_x(t) + z_i(t), i \epsilon \{m\} \cup K(t), i \notin J(t) \quad (1)$$

Where $J(t) \cup K(t) = S$ and $y_{xi}(t)$ represent the $TDMA$ channel coefficient among x^{th} source devices

and i^{th} receiving devices, $J(t)$ represent the collection of idle devices, $J(t) = \{x_1, \ldots, x_D\}$ represent the collection of source collides and $z_i(t)$ represent the communication channel noise.
Here the author consider a mobility based wireless mesh network, since these devices are wireless in nature they are prone to noisy nature of wireless medium which affects the data transmission and handover efficiency. To overcome this here the author adopt Rayleigh fast fading channel for communication among devices and it is represented by following equation

$$y_{xs}(t) = Y_{xs}(t)e(s\delta_{xs}(t)) \quad (2)$$

Where $Y_{xs}(t)$ is the Rayleigh distribution considering the variance $2\sigma_Y^2$, $\delta_{xs}(t)$ is evenly distributed in $(0,2\pi)$ and they are identical and uncorrelated considering the Gaussian variance and the signal strength received by the receiver devices in the period of slot $t+d$ is denoted by following equation

$$r_m(t+d) = y_{im}(t+d)l(t+d)b(t) + z_m(t+d), i \in I(t) \quad (3)$$

Where $y_{im}(t)$ represent the $TDMA$ channel coefficient among i^{th} intermediate devices and the correspondent devices, $l(t+d)$ represent the signal scaling constant, $z_m(t+d)$ represent the noise parameter of channel and $I(t) = \{i_1, \ldots, i_{D-1}\}$ represent the collection of intermediate devices. If an intermediate device selected is other than the source i.e. if $i \notin J(t)$,

$$b(t) = b_i(t), \quad l(t+d) = \sqrt{\sigma_d^2 / D\sigma_Y^2 + D\sigma_U^2} \quad (4)$$

If $i \in J(t)$ then

$$b(t) = b_i(t), \quad l(t+d) = 1 \quad (5)$$

Here considering the equation (4) and (5) the collection of active devices and collision order can be established. For the case let $\tilde{D} = D$ and $\tilde{J}(t) = J(t)$ represent the signal obtained by corresponding devices in overall slots which can be represented by following equation

$$R = [r_m^c(t), r_m^c(t+1), \ldots, r_m^c(t+D-1)]^c \quad (6)$$

Where $r_m(t) = b_m(t)$ which represent the signal transmitted by source devices which is obtained by following equation

$$A = [a_{x_1}^c(t), a_{x_2}^c(t), \ldots, a_{x_D}^c(t)]^c \quad (7)$$

The signal obtained by the corresponding node can be obtained by the following matrix

$$R = UA + Z \quad (8)$$

Where Z represents the matrix of noise, U represent the matrix of channel coefficient among source devices and corresponding device and the original packet are recovered by following matrix equation

$$\hat{A} = U^{-1}R \quad (9)$$

Where U^{-1} represent the pseudoinverse of U.
The simulation sturdy of our proposed approach is evaluated in the below sub section of this paper.

III. SIMULATION RESULTS AND ANALYSIS

The system environment used is windows 7 enterprises 64-bit operating system with 8GB of RAM. We have used MATLAB tool. We have conducted simulation study on following parameter for throughput and delay and compared our proposed model with existing algorithm [14] and conducted simulation study.
The simulation parameter for channel generation is shown in below Table 1.

Table1: The simulation parameter for channel generation

Parameter	Value
Speed of nodes	1-5m/s
Doppler frequency	2.4 GHz
Data rate	312500 bps
Total number of user	32
Packet length	80,000 bytes

The simulation parameter for throughput and delay analysis is shown in below Table 2.

Table1: The simulation parameter for throughput and delay analysis

Parameter	Value
Number of sub-channel	4
Simulation slot	500
Number of user	15 & 30
Simulation range	10
Monte-Carlo iteration	1

In Fig. 1 shows the performance of proposed model in terms of Average delay and speed. In this simulation study speed variation is considered as 2, 3, 4 and 5 and with respect to the speed variation average delay is computed for 15 users and 30 users. This can be concluded from the figure that when speed and number of users increases, overall delay also increases.
Similarly we perform the throughput computation by considering the same scenario of the user and speed. Results of this are depicted in Fig. 2 in this case the average throughput by considering 15 users and 30 users is achieved 1.226 and 1.29 respectively. It can be concluded from the above figure that when the number of users are increasing, throughput also increasing by using proposed approach.

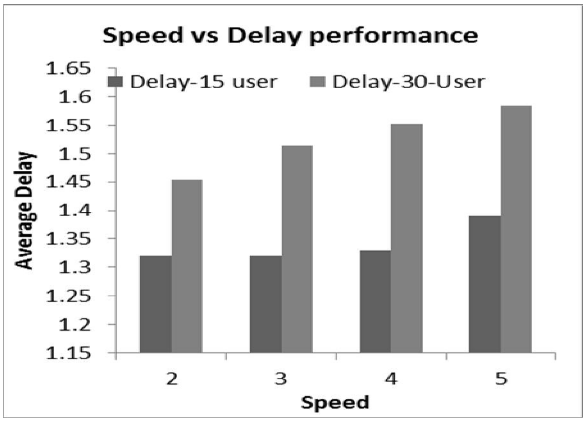

Fig.1. Speed and delay performance for varied speed

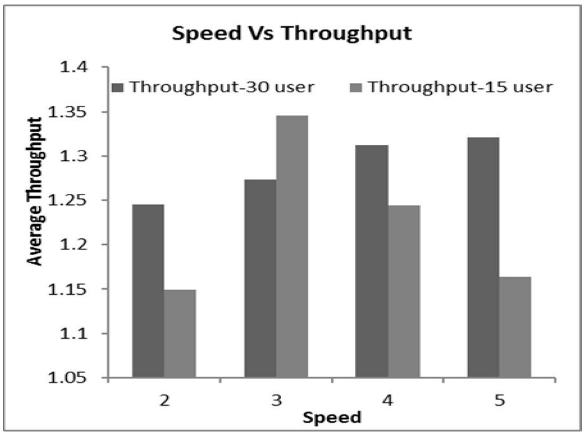

Fig.2. Speed and throughput performance for varied speed

In another simulation study we consider variation in the number of hops and compute the average delay performance for the given speed variation. From this simulation scenario it can be concluded that when the number of hops are increasing then the delay also increases as shown in Fig. 3.
Similarly we perform the throughput computation by considering the same scenario as considered in Fig. 3. Results of this are depicted in Fig. 4 in this case the average throughput by considering 10 hops, 20 hops and 30 hops(speed variation is also considered) is achieved 1.162, 1.237, 1.267 and 1.345 respectively.

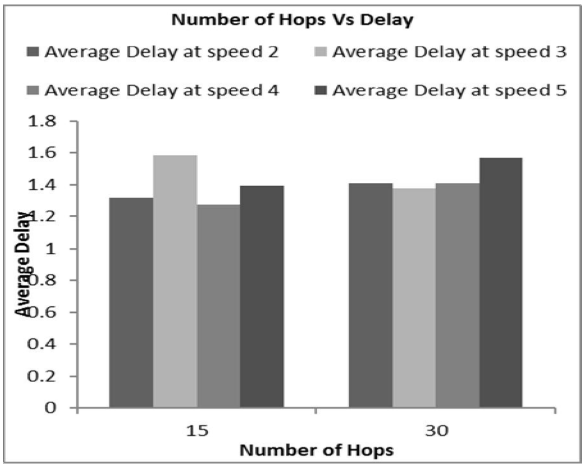

Fig.3. Number of Hops and delay performance

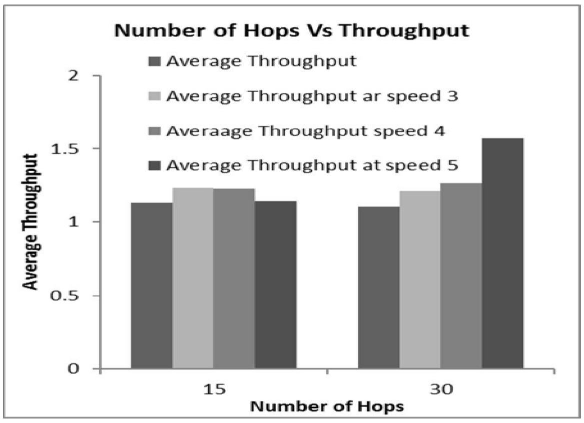

Fig.4. Number of Hops and throughput performance

CONCLUSIONS

The paper presented a model that help in the design of WMNs that reduces the delay and improves the throughput of mesh network and assures QoS of the end devices. This work presented a model that minimizes the average packet delay and improves the throughput performance in WMNs due to the adopted cross layer optimization technique. The experimental result shows the impact of proposed model on delay and throughput in term of mobility speed and hop when compared to existing model. In future this would consider developing an effective mobility management considering varied load and user dynamic in order to evaluate the proposed model.

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