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Performance analysis of multilayer multicast MANET CRN based on steiner minimal tree algorithm

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ABSTRACT

In this study, the multicast mobile ad hoc (MANET) CRN has been developed, which involves multi-hop and multilayer consideration and Steiner minimal tree (SMT) algorithm is employed as the router protocol. To enhance the network performance with regards to throughput and packet delivery rate (PDR), as channel assignment scheme, the probability of success (POS) is employed that accounts for the channel availability and the time needed for transmission when selecting the best channel from the numerous available channels for data transmission from the source to all destinations nodes effectively. Within Rayleigh fading channels under various network parameters, a comparison is done for the performance of SMT multicast (MANET) CRN with POS scheme versus maximum data rate (MDR), maximum average spectrum availability (MASA) and random channel assignment schemes. Based on the simulation results, the SMT multicast (MANET) CRN with POS scheme was seen to demonstrate the best performance versus other schemes. Also, the results proved that the throughput and PDR performance are improved as the number the primary channels and the channel's bandwidth increased while dropped as the value of packet size D increased. The network's performance grew with rise in the value of idle probability (P_I) since the primary user's (PU) traffic load is low when the value of P_I is high.

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1. INTRODUCTION

The demand for radio spectrum has risen considerably because of the recent spike in wireless services. Today's wireless systems are under the regulation of a fixed spectrum assignment policy in which a specified spectrum band is allotted to a licensed user for a long term basis and for a wider geographical location. The use of spectrum is focused on specific parts of the spectrum; however, a considerable volume of the spectrum stays unutilized. As per the Federal Communications Commission (FCC), geographic and temporal variations in the usage of the allotted spectrum fall in the range of 15% to 85% [1-4]. Dynamic spectrum access (DSA), also called cognitive radio networks, is recommended for addressing these spectrum ineffectiveness issues [2, 5]. Cognitive radio (CR) is an enabling technology for facilitating cognitive users (secondary or unlicensed users) to function on the vacant segments of the spectrum allotted to licensed users (primary users). CR is broadly termed as a capable technology for handling the spectrum scarcity issue triggered by the existing inflexible spectrum allocation strategy.

This is depicted in Figure 1. It is adept at identifying its radio environment, and adaptively selecting transmission parameters as per the sensing outcomes. This enhances the performance of the cognitive radio system, improves spectrum efficacy and averts interference with primary users [6, 7]. Based on this definition, two key attributes of the cognitive radio can be outlined as follows: Cognitive capability, i.e. the competence of the radio technology to detect information from its radio environment, and configurability, which allows the radio to be dynamically programmed as per the radio environment [2]. More precisely, the cognitive radio technology will allow the users to find out which segments of the spectrum are available, sense the existence of licensed users when a user functions in a licensed band (spectrum sensing), choose the best channel on offer (spectrum management), harmonies this channel’s access with other users (spectrum sharing), and clear out the channel after a licensed user is sensed (spectrum mobility) [2]. Thus, for future wireless communications, it can be considered as a potential technique to minimize spectrum scarcity issue [8].

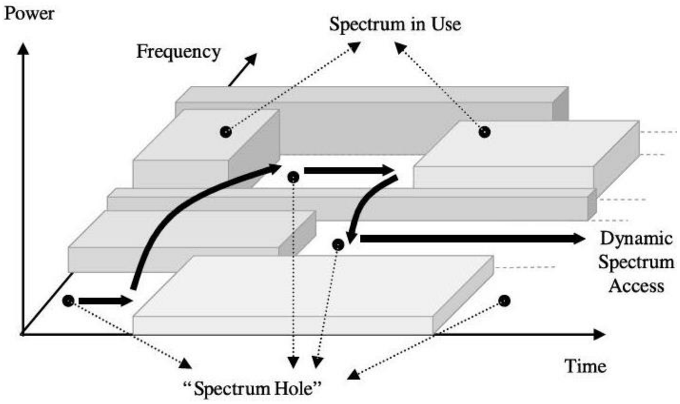

Figure 1. Spectrum for PU and SU in the network

Application of the cognitive paradigm to various scenarios pertaining to multi-hop wireless networks can be done. The cognitive radio ad-hoc network is one such scenario that includes CR nodes that are involved in peer-to-peer communication amongst each other via ad-hoc connections [9, 10]. Routing in a multi-hop cognitive radio network (CRN) is quite a difficult task and an open concern. Of late, several routing protocols for CRNs have been recommended and assessed. Commonly, these protocols focus on either selecting the best quality channel or those channels that possess the maximum average spectrum-availability time. In a CRN, both the needed transmission time, as well as spectrum-availability time, were found to considerably affect routing and network connectivity.

A considerable decrease in CRN performance could result due to spectrum-availability time, particularly when there is a smaller average spectrum-availability time for an assigned channel than the needed transmission time over that channel. In the worst case, especially for multi-hop CRNs, this issue becomes important when several links are involved. Network performance can be enhanced by making use of varied channel quality as well as spectrum availability efficiently by accounting for cognitive routing protocol design [11]. In this research work, the multicast router protocol is developed by employing the Steiner minimal tree (SMT) algorithm for mobile ad-hoc CRN that includes multi-hop and multilayer consideration. To enhance the network performance with regards to the throughput as well as packet delivery rate (PDR), probability of success (POS) is employed as the channel assignment scheme for the network after changing the network’s random topology to SMT. This is done to select an effective channel for data transmission based on channel availability as well as the needed time for transmission and make a comparison of the performance pertaining to multicast multilayer multi-hop ad-hoc CRN in the SMT protocol as well as POS scheme along with (MDR), (MASA) and random channel assignment schemes at various network parameters to describe each scheme and select the best one to achieve the best performance for the multicast multilayer multi-hop ad-hoc CRN in the SMT protocol.

The rest of the paper is structured as follows: section 2 outlines the multicast mobile ad-hoc network (MANET). Section 3 introduces the pertinent work of techniques and methodologies for multicasting network channel assignment and the routing protocol for undirected graph. The Steiner algorithm for multicasting network is discussed in section 4. The system model for the recommended multicast protocol is presented in section 5. The simulation outcomes and conclusions are presented in sections 6 and 7, respectively.

2. MULTICAST MOBILE AD-HOC NETWORK (MANET)

The ad-hoc network is the kind of wireless network that comprises a cluster of wireless nodes, which are adept enough to communicate with each other in the absence of infrastructure. Basically, there are two kinds of infrastructure-less wireless networks: static ad-hoc network and mobile ad-hoc network (MANET) [12]. A MANET can be defined as an interconnected system of mobile hosts and does not include a fixed infrastructure. In MANETs, each mobile host possesses the ability for multi-hop transmission. Also, it acts as a router, in which each and every node involved in the MANET needs to know its neighbor as well as serve as a router to advance the datagram to the specified destination [13, 14]. Multicasting is employed when there is a need for applications to send the same data to different destinations simultaneously.

The multicast routing protocol is designed for mobile ad hoc networks (MANETs) to provide support for information dissemination from a sender to all receivers pertaining to a multicast group, while also employing the available bandwidth in an effective manner when there are frequent topology variations. For MANETs, various multicast routing protocols have been put forward. Multicasting communication is considered to be cost-effective for applications when sending the same data to various recipients simultaneously. In contrast to sending data through multiple unicast, multicasting decreases the consumption of link bandwidth, delivery delay and router processing [13, 15]. The current multicast routing protocols designed for MANETs can be majorly segmented into mesh-based and tree-based. These protocols differ with regards to the redundancy involved in the paths between receivers and senders. Tree-based protocols offer just a single path between receivers and senders, while mesh-based protocols offer multiple paths [13, 15]. Segmentation of routing protocols is done with regards to message delivery semantics as unicast, broadcast and multicast, as presented in [14].

The data stream is referred as a ‘source’ or sender while the end-user seeking to receive the data stream is referred to as a ‘receiver’. If a single receiver node is present, the routing issued is called as unicast routing, which can be addressed with computation of the shortest path between the receiver and the source in which data are sent from one source to the receiver. In the multicast routing, a source can transmit its data stream to a cluster of hosts. On the other hand, broadcast routing or simply broadcasting can be defined as transmitting of the stream from the source to all destinations node connected to the network. Multicasting involves broadcasting and unicasting as a special case, and resolves the issue of reaching of the stream to a group of nodes in the destination [16, 17].

3. RELATED WORKS

Many approaches and methodologies for channel assignment and constructing the routing tree from random undirected topology are deployed to improve the performance of the multicast cognitive radio network with regards to the throughput and various parameters [16]. The multicast network’s performance when transmitting data to multiple users relies on the way network topology’s connection is arranged. In [18], for multicast network, introduction of minimum Steiner tree algorithm was done as routing protocol and presentation was done for the method to transform undirected topology to Steiner tree in [19]. Besides utilizing the efficient tree algorithm, the choice of best channel for transmitting data in a multi-hop multicast cognitive radio network is a vital topic for improving the network’s throughput performance. The multicast routing scheme is clubbed with the allocated channel of multi-hop multicast CRN as presented in [20]. Multicast tree is employed for constructing minimum energy direct Steiner tree with the help of low-complexity approximation algorithm for CRN and the impact of primary network traffic load is evaluated to determine spectrum presence opportunities [21].

The sum rate is maximised taken from all users of CRN in terms of transmission rate as well as joint channel spectrum assignment pertaining to the arranged access channel for multiuser single-transceiver CRN opportunities as suggested in [22]. CRN’s throughput performance can be considerably improved and algorithm can be employed to decrease the end-to-end delay for channel assignment as well as for multicast routing in the mesh network pertaining to CR. This algorithm considers the switching latency and the channel’s heterogeneity as recommended in [23]. In case of the multi-hop CRN, the probabilistic routing scheme algorithm was recommended in [24]. This algorithm considers the channel’s availability time and essential transmission time. The CRN’s best throughput performance can be attained by preferring this scheme over other schemes. In addition, within Rayleigh fading channel, employing of maximum POS routing protocol was done for multi-hop CRN [11].

Overlapping as well as non-overlapping channel assignment algorithms for amplifying the throughput performance are recommended in [25]. The cross layer routing protocol process was put forward in [26] to choose the best channel from amongst the obtainable channels pertaining to multicast CRN to obtain better video quality by all receivers’ nodes within the network. In [17, 27], SPT and MST are utilized as routing protocols for the multilayer multicast multi-hop CRN with POS scheme as channel assignment. The network's performance is improved with regards to the throughput and PDR compared to other schemes. EXT with MST and SPT are deployed as routing algorithms for the multicast multi-hop CRN. The POS scheme was utilized as channel assignment for selecting an efficient channel for transmitting data in accordance with the channel availability and the requisite transmission time as recommended in [12]. Routing protocol metrics in multi route and one-way routing for wireless and cognitive radio networks are compared and analyzed its challenges as recommended in [28].

4. STEINER ALGORITHM FOR MULTICASTING NETWORK

The Steiner minimal tree (SMT) algorithm is among the several algorithms from the graph theory which have been utilized for fixing routing issues in a wireless multicasting network [16]. The Steiner network encompasses two kinds of vertices: terminals (required) vertices and nonterminal (Steiner) vertices. SMT algorithm and spanning tree are not the same, in that a spanning tree links all vertices of a specific graph, while a SMT binds a specific subset of the vertices (some of Steiner vertices and terminals vertices to decrease the tree cost) [16, 19]. A key issue with SMT is how to find a tree that not only has minimum cost but also includes all terminal vertices as well as any subset pertaining to nonterminal (Steiner) vertices.

Let G = (V, E, w) represent the undirected graph along with a set of vertices V as well as edges E along with nonnegative weights w. In Steiner minimal tree T, the needed vertices set is (L ⊂ V), in which (T ⊂ G) that has a set of vertices W that includes all the needed vertices L as well as (W-L) Steiner vertices [19, 29]. The steps to determine SMT with minimum total edge weight W are [19, 29]:

– The metric closure G_L on L is developed.
– Kruskal's algorithm is employed to determine minimum spanning tree MST T_L on G_L.
– Steiner vertices were inserted between a pair of terminal vertices in T_L as intermediate points to determine Steiner minimal tree T.
– To elucidate these steps, the following example is introduced [19]:

Figure 2 (a) demonstrates undirected graph G along with nonterminal vertices {u1, u2, u3, u4} as well as terminal vertices L = {v1, v2, v3, v4, v5}. The shortest path lengths amongst all L vertices are determined to build metric closure G_L on L, as presented in Figure 2 (b). Kruskal's algorithm is used to determine the MST T_L as demonstrated in Figure 2 (c). To determine SMT, nonterminal vertices {u1, u2} are placed in the path between terminal vertices {v1, v4} to keep the tree's total weight minimum as presented in Figure 2 (d). Based on Figures 2 (c) and 2 (d), it can be seen that the total weight of the tree is 22 prior to addition of {u1, u2}, while the tree's total weight is decreased to just 17 post addition of {u1, u2}, which indicates that the Steiner points cast an impact that decrease the total cost of tree.

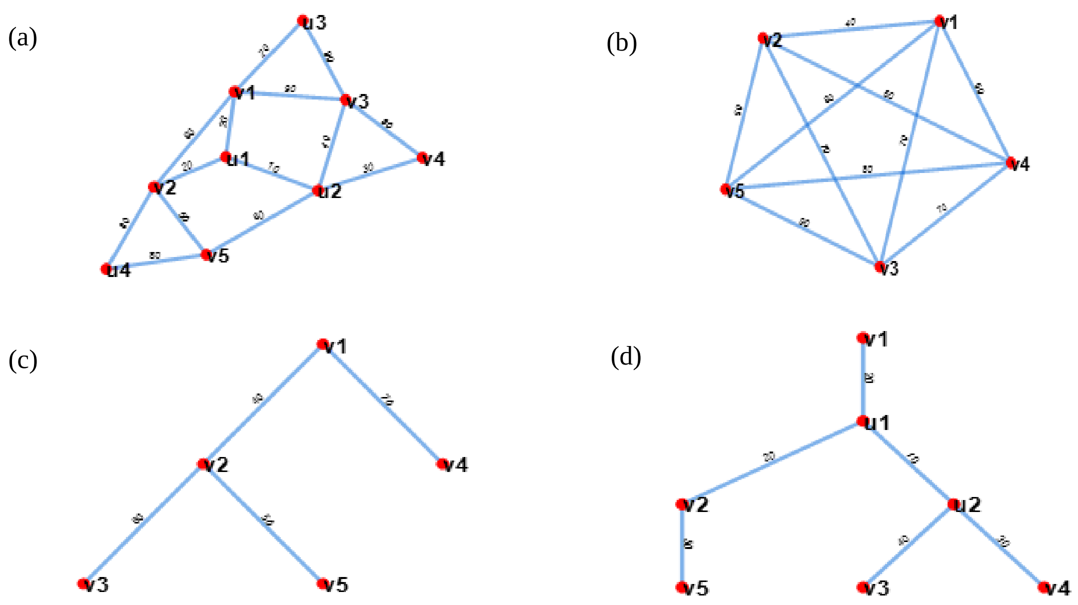

Figure 2. Steiner minimal tree algorithm: (a) undirected graph G, (b) the metric closure GL, (c) the MST TL, d) the SMT T

5. SYSTEM MODEL FOR PROPOSED MULTICAST CRN

To enhance the efficiency of total spectrum as well as increase the overall throughput of the CRN, numerous approaches and techniques have been employed. At most, establishment of the current protocols was done on either the process of path selection or the channel scheme assignment [12]. In addition, the selection of channels by current channel assignment schemes relies only on the spectrum's average availability such as Maximum Average Spectrum Availability (MASA) scheme or based on the channel's quality such as Maximum Data Rate (MDR) scheme, or selects the channel randomly with no limitation [12, 17]. This paper considers both the probability of success (POS) channel assignment scheme as well as the path selection process that employs the Steiner minimal tree (SMT) algorithm. Employing POS scheme as channel assignment is helpful for performance enhancement of the multilayer multicast multi-hop CRN environment system with regards to the throughput as well as packet delivery rate (PDR) subject to various network parameters as this scheme considers the needed time for transmission and the channel availability when selecting the best channels for effective data transmission to all destination nodes from the source. In this research work, for video transmission to destination nodes from source node over a single session, multilayer multicast multi-hop CRN routing protocol is employed.

At first, generation of undirected graph is done with a set of nonterminal Steiner (*Nnt*) as well as terminal (*Nt)* vertices within the square area, and then determination of Steiner minimal tree (SMT) is done employing the algorithm as mentioned in section (IV). Between each destination node and the source node, there are numerous available PU channels (*M)* and the Markov model is the status model pertaining to each primary user (PU) channel, which keeps interchanging between the two states (idle and busy). The idle state suggests that SU can use the channel as it is not used by PU, while busy state implies that PU uses the channel and SU cannot use the same. For all channels, identical bandwidth (*BW*) is fixed. Applying of the POS scheme is done to the network as channel assignment to improve network performance as well as to organize the CRN transmissions so as to make available common control channel (CCC) [12, 17]. The probability of success ($POS_j^{(i-k)}$) between any of the two nodes, *i* and *j*, in SMT tree with regards to channel *j* for the available channel (*C*) of CRN can be expressed as in [11]:

$$POS_j^{(i-k)} = exp^{\left(\frac{-T_{r_{(j)}}^{(i-k)}}{\mu_j}\right)} \tag{1}$$

where μ_j denotes the average availability time pertaining to spectrum in (in sec) for channel j and ${T_r}_j^{(i-k)}$ represents the required transmission time in (in sec/packet) to transmit a packet to node k from i over channel j, which can be expressed as in [11]:

$${T_r}_j^{(i-k)} = \frac{D}{R_j^{(i-k)}} \tag{2}$$

where *D* signifies the packet size (in bits) and $R_j^{(i-k)}$ denotes the data rate (in bit/sec) between *i* and *k* nodes over channel j, as expressed in [11]:

$$R_j^{(i-k)} = (BW)\ log_2(1 + \frac{P_{r_{(j)}}^{(i-k)}}{BW*N_0}) \tag{3}$$

where N_0 denotes the thermal power density in (Watt/Hz), BW represents the channel bandwidth and ${P_r}_{(j)}^{(i-k)}$ represents the received power to receiver j from transmitter i, as expressed in [11]:

$${P_r}_j^{(i-k)} = \frac{p_t}{d^n}\left(\frac{\lambda}{4\pi}\right)^2 (\xi_{(j)}^{(i-k)}) \tag{4}$$

where p_t denotes the CR's transmission power, d signifies the distance between any two nodes, n represents the path loss exponent, and $\xi_{(j)}^{(i-k)}$ implies the channel power gain between i and k nodes over channel j. With regards to Rayleigh fading, exponential distribution of $\xi_{(j)}^{(i-k)}$is done with mean 1 [11].

To explain how the POS channel assignment scheme is used to choose the best channel from available channels for primary and secondary users to transmit data from source node to all destination nodes Figure 3 is used. We have one source node (v1) and six nodes (four nodes are the destination (v2, v3, v4 and v5). Three available channels are used (CH1, CH2 and CH3).

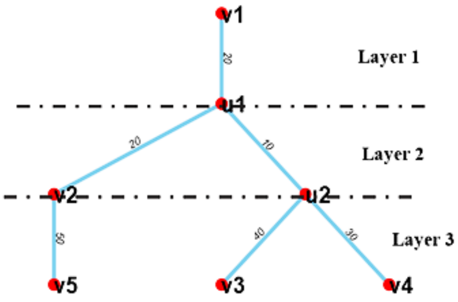

Figure 3. Steiner minimal tree with three layers

From Figure 3 one can note that the SMT tree has three layer and the process of POS channel assignment is applied to each layer as follows:

a. The transmission of layer 1:

The unicast transmission is used to transmit data from source node (v1) to node (u1) and the channel with maximum value of POS is the best channel that used for data transmission (Channel 3 with POS=0.9080 is used in this case) as Table 1. Note that the CH2 has (POS=0) this mean that this channel is occupied by PU and cannot be used by SU.

Table 1. POS for the transmission of layer1

Channel / Receiver	CH1	CH2	CH3	POS for best channel
v1-u1	0.7555	0	**0.9080**	0.9080

b. The transmission of layer 2:

The multicast transmission is used to transmit data from (u1) node to (v2, u2) nodes. Minimum POS value is choosing from each channel then maximum value of this minimum values is choosing for data transmission (Channel 3 with POS=0.8853 is used in this case) as Table 2. Also, it should be noted that CH2 cannot be used for transmission because it used by PU.

Table 2. POS for the transmission of layer 2

Channel / Receiver	CH1	CH2	CH3	POS for best channel
u1-v2	**0.7205**	0	**0.8853**	
u1-v2	0.8165	0	0.9197	
Min POS	0.7205	0	**0.8853**	0.8853

c. The transmission of layer 3:

– Part1: The unicast transmission to transmit data from node v2 to v5 node is used. The channel with height value of POS is choosing (Channel2 with POS=0.8661 is used in this case) as in Table 3.
– Part2: The multicast transmission from node u2 node to (v3, v4) nodes is used. As in Layer 2 minimum values of POS for each channel is used then for data transmission maximum value of POS from minimum is choosing (Channel3 with POS=0.8547 is used in this case) as in Table 4.

Table 3. POS for the transmission of layer 3 part 1

Channel / Receiver	CH1	CH2	CH3	POS for best channel
v2-v5	0.7726	**0.8661**	0	0.8661

Table 4. POS for the transmission of layer 3 part 2

Channel / Receiver	CH1	CH2	CH3	POS for best channel
u2-v3	**0.6215**	0.8436	0.8739	
u2-u4	0.6215	**0.7681**	**0.8547**	
Min POS	0.6215	0.7681	**0.8547**	0.8547

6. COMPUTER SIMULATION AND RESULTS

In this section, computer simulations are carried out to assess the performance pertaining to multilayer multi-hop multicast mobile ad hoc CRN by employing the SMT algorithm for constraining the network with POS channel assignment scheme. This allows selecting an efficient channel for data transmission based on the channel availability and the needed time to carry out transmission. A comparison is carried out to evaluate the performance of the put forward protocol along with POS scheme versus maximum data rate (MDR), maximum average spectrum availability (MASA) and random channel assignment schemes with regards to the packet delivery rate (PDR) and throughput, subjected to various network parameters within the Rayleigh fading channel model. We have accounted for three idle probability (i.e. P_I=0.3, 0.6, 0.9) to assess the impact cast by primary users traffic load on the performance of cognitive radio network. MATLAB (R2018a) is deployed for computer simulation. For comparison purpose, the system model parameters are depicted in Table 5.

Table 5. System parameters

Parameter	Value/Type
Network area	200*200m
No. of Terminal nodes (Nt)	20
No. of Nonterminal nodes (Nnt)	10
Topology tree	SMT tree
No. of CR source	One source
No of primary channel (M)	15
PU channel model	Markov model
Idle probability P_I	[0.3 0.6 0.9]
Average availability time (μ_j)	Range from 2 ms to 45 ms
Bandwidth (BW)	1 MHz
Packet size (D)	4 KB
Transmission power (Pt)	0.1 Watt
Channel used	Rayleigh fading channel
Path loss exponent (n)	4
Thermal noise power (N_0)	10^{-8} W/Hz

6.1. Performance evaluation of Steiner minimal tree (SMT) multicast CRN under the impact of channel bandwidth

As presented in Figures 4 (a-c) and Figure 5 (a-c), the throughput as well as PDR performance pertaining to multilayer multi-hop multicast CRN is compared with channel bandwidth possessing various types of channel assignment schemes as well as three values of Idle probability $[P_I = 0.3, 0.6, \text{and } 0.9]$, respectively. The figures indicate that as the channel's bandwidth rose, the performance of all schemes enhanced as the data rate (channel capacity) corresponds to the channel's bandwidth. However, based on Figures 4 (a) and 5 (a), it can be seen that the channels are busy most of the time for small value of Idle probability ($P_I = 0.3$) due to high primary user traffic load. Also, under this value of P_I, it was seen that the POS's throughput performance was similar to that of MASA scheme by 16.4%, which outpaced even MDR and RS schemes by 53.4% and 92.7%, respectively, while with regards to PDR, it was by 15.8%, 124% and 168.5% respectively. From Figures 4 (b, c) and Figures 5 (b, c), it can be seen that as the idle probability rose (P_I = 0.6 and 0.9), the throughput performance of the POS scheme was better than MASA, MDR and SR by 27.9%, 88.7% and 149.1% at P_I = 0.6 and by 35.1%, 85.1% and 148.5% at P_I = 0.9. For PDR performance, the POS scheme outclassed at P_I =0.6 by 18.7%, 213.8% and 29.16% and at P_I =0.9 by 22.81%, 217.5% and 326.02%, respectively. This could be due to increase in P_I value that increases the probability of suitable channels being available to CR users for transmission as the PU traffic load is at a lower level.

6.2. Performance evaluation of Steiner minimal tree (SMT) multicast CRN under the impact of packet size

Figures 6 (a-c) and Figures 7 (a-c) present the throughput and PDR performance pertaining to multilayer multi-hop multicast CRN when compared with packet size with various kinds of channel assignment schemes as well as three values pertaining to Idle probability $[P_I = 0.3, 0.6, \text{and } 0.9]$, respectively. The figures indicate that the PDR performance and throughput dropped as the value of packet size *D* rose. This happens since to transmit the packet date of CR user effectively, high availability of time for the channel is required for high value of *D*, which makes it difficult to find the best channel. Figures 6 (a-c) indicate that the enhanced throughput gains for POS scheme as against MASA, MDR and RS schemes at $P_I = 0.3$, 0.6 and 0.9 are [12.5%, 56.6% and 102.1%], [16.9%, 100.5% and 155.3%] and [26.2%, 93.7% and 170.8%], respectively. According to Figures 7 (a-c), the enhanced PDR gains for POS scheme as against MASA, MDR and RS schemes at P_I = 0.3, 0.6 and 0.9 are [16.5%, 118.6% and 183.2%], [14.3%, 213% and 298.6%] and [23.4%, 228.9% and 367.2%], respectively. Also, with rise in the value of P_I, the POS scheme's performance improves as the PU's traffic load is low at high value of P_I.

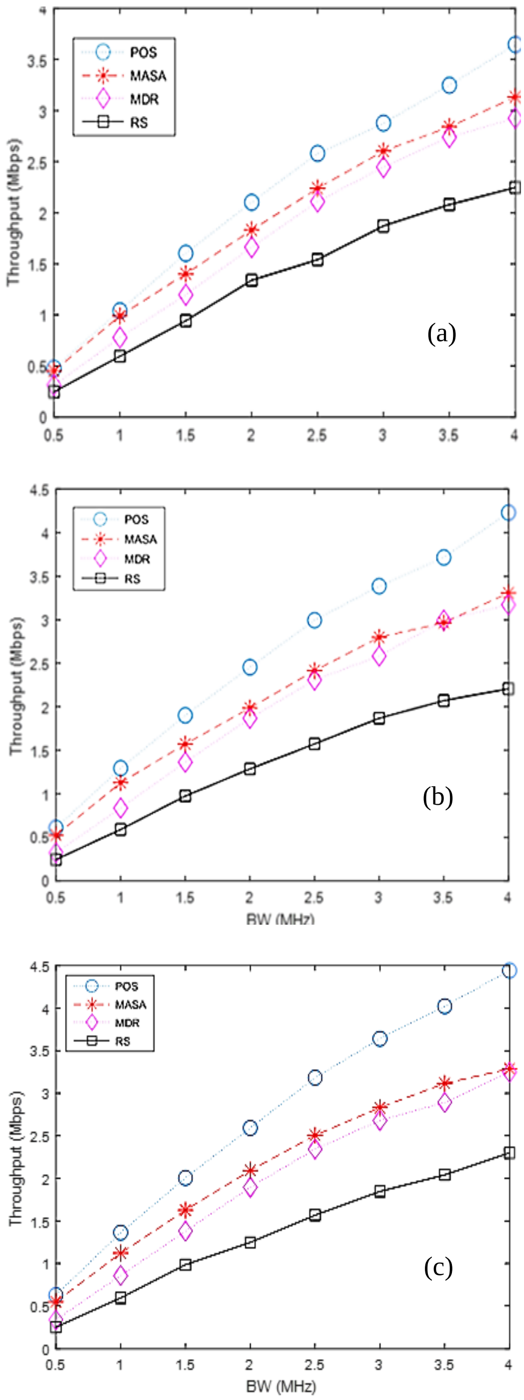

Figure 4. Throughput vs channel bandwidth: (a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

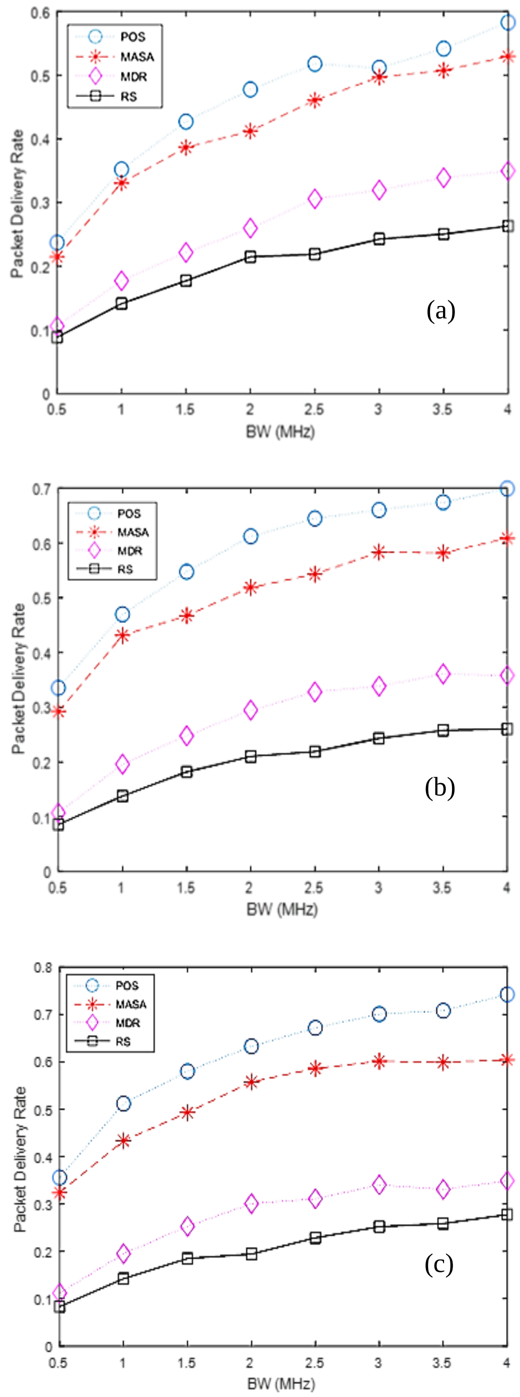

Figure 5. PDR vs channel bandwidth: (a) PI = 0.3, (b). PI = 0.6, (c) PI = 0.9

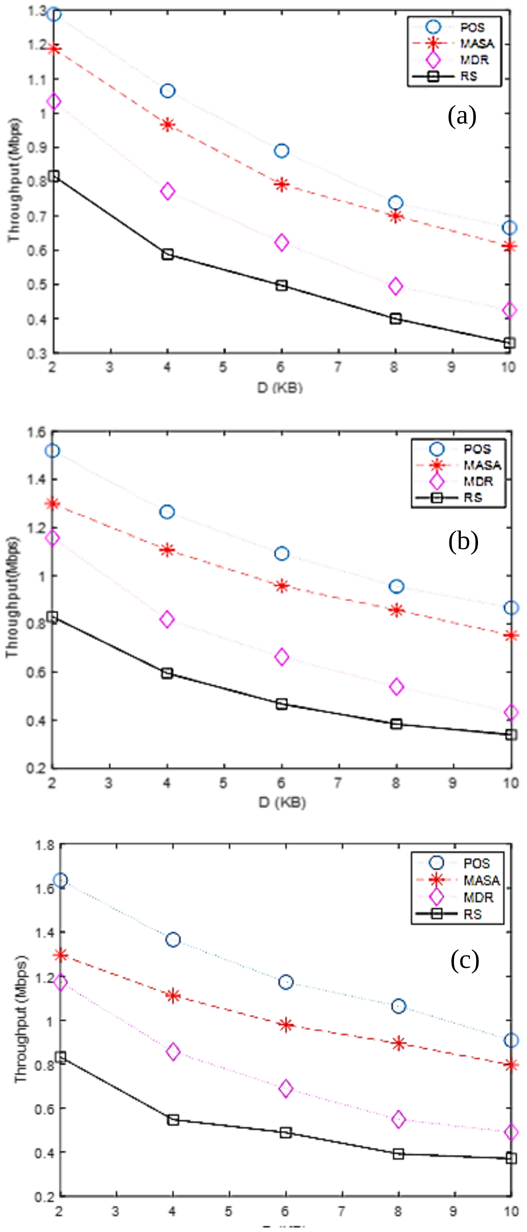

Figure 6. Throughput vs data packet size:
(a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

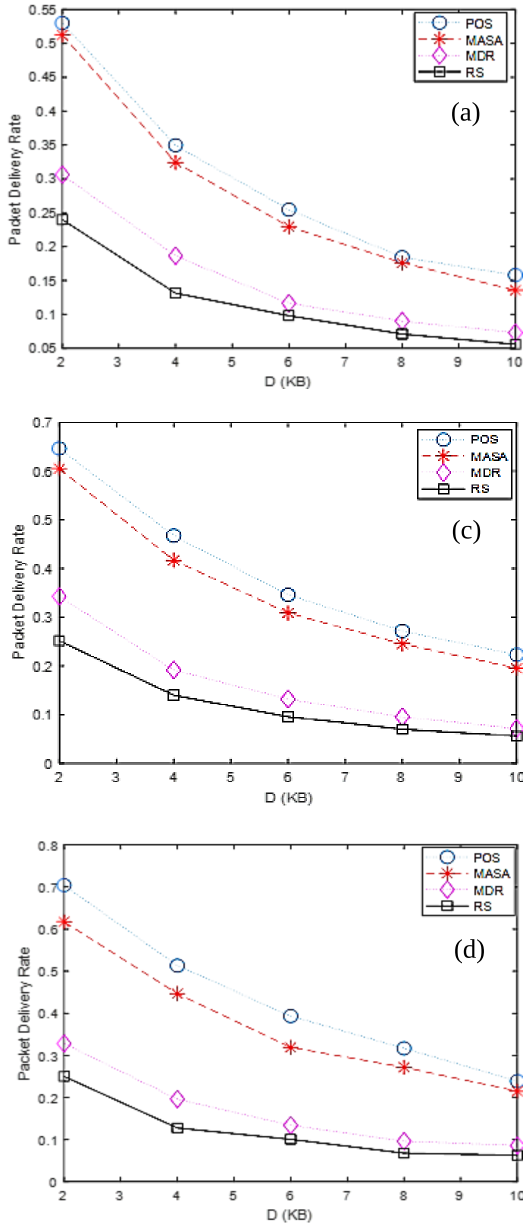

Figure 7. Throughput vs data packet size:
(a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

6.3. Performance evaluation of steiner minimal tree (SMT) multicast CRN under the effect of increased the primary channels number

Figures 8 (a-c) and Figures 9 (a-c) present the throughput as well as PDR performance of multilayer multi-hop multicast CRN as compared with the number of primary channels along with various kinds of channel assignment schemes as well as three values of Idle probability [$P_I = 0.3, 0.6,$ and 0.9], respectively. The PDR performance and throughput enhanced as the number of primary channels rose. This is due to increase in the chance of raising the number of available channel pertaining to CR user as presented in Figures 8 (a-c) and 9 (a-c), respectively. The enhanced throughput gains for POS scheme in comparison to MASA, MDR and RS schemes at $P_I = 0.3$, 0.6 and 0.9 are [13.6%, 14.4% and 47%], [23.3%, 26.1% and 68.0%] and [24.7%, 32.5% and 73.3%] respectively. The enhanced PDR gains for POS scheme in comparison to MASA, MDR and RS schemes at $P_I = 0.3$, 0.6 and 0.9 are [13.3%, 44.96% and 82.1%], [13.9%, 68.8% and 116.5%] and [14.6%, 91.5% and 138.7%], respectively.

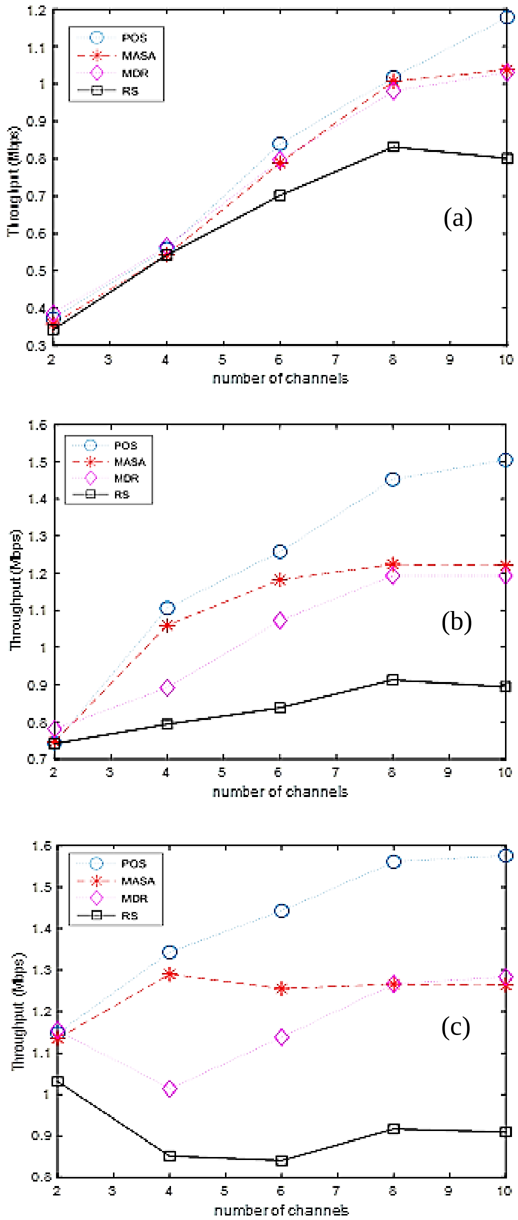

Figure 8. Throughput vs number of channels:
(a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

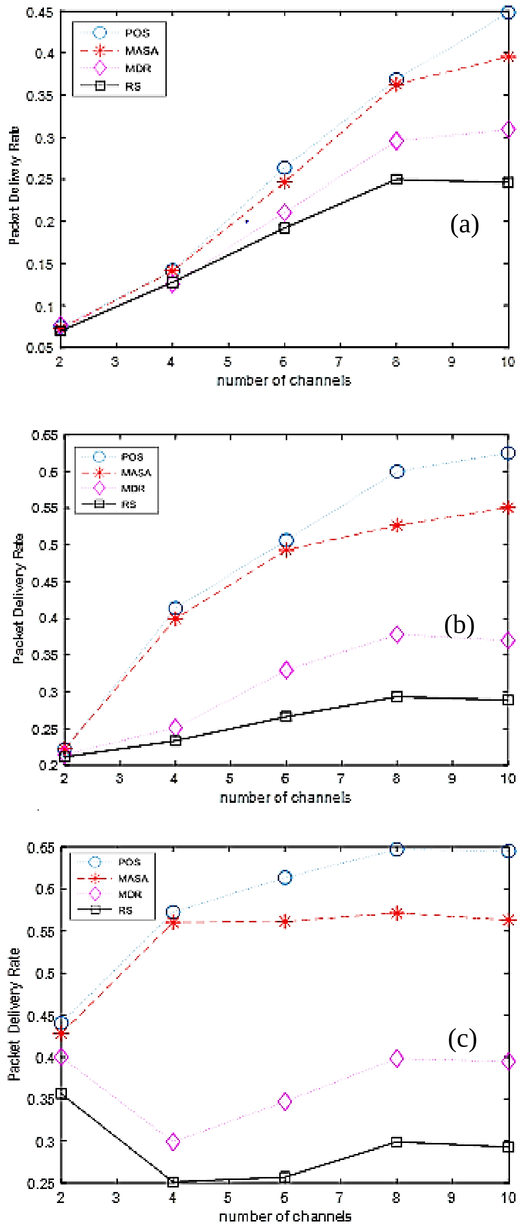

Figure 9. PDR vs number of channels:
(a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

6.4. Performance evaluation of steiner minimal tree (SMT) multicast CRN under the effect of transmission power

Figures 10 (a-c) and Figures 11 (a-c) present the throughput as well as PDR performance of multilayer multi-hop multicast CRN when compared with transmission power along with various kinds of channel assignment schemes as well as three values pertaining to idle probability [$P_I = 0.3, 0.6,$ and 0.9], respectively. With a rise in the transmission power, the PDR performance and throughput enhanced. This is because there is a decrease in the time needed for data transmission, thus allowing more data to be transmitted over each channel. Also, in the case of high value of idle probability, there is enhancement in the performance of POS schemes as mentioned in the earlier sections. The enhanced throughput gains for the POS scheme as against MASA, MDR and RS schemes at $P_I = 0.3$, 0.6 and 0.9 are [7.5%, 49.1% and 74.4%], [15.1%, 56.9% and 110.2%] and [24.9%, 62.1% and 148.9%], respectively. The enhanced PDR gains for POS scheme in comparison to MASA, MDR and RS schemes at $P_I = 0.3$, 0.6 and 0.9 are [6.9%, 122.2% and 158.5%], [12.9%, 151.7% and 232.1%] and [20.8%, 165.7% and 292.7%], respectively.

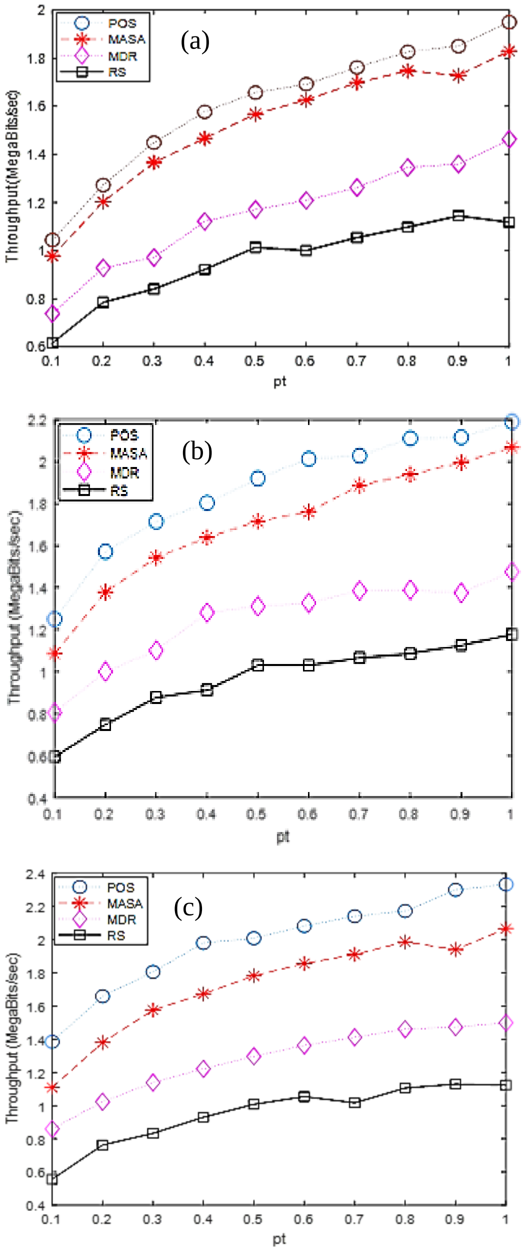

Figure 10. Throughput vs transmission power:
(a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

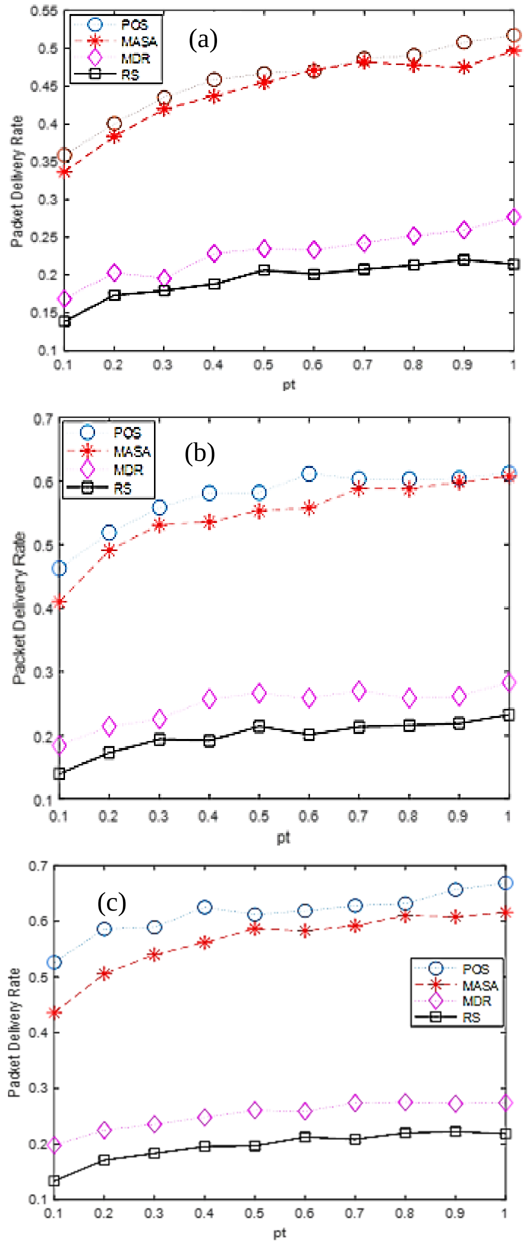

Figure 11. PDR vs transmission power:
(a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

6.5. Performance evaluation of steiner minimal tree (SMT) multicast CRN under the effect of path loss exponent

Figures 12 (a-c) and 13 (a-c) depict the throughput and PDR performance of a multilayer multi-hop multicast CRN as against a path loss exponent with various kinds of channel assignment schemes and three values of idle probability [$P_I = 0.3, 0.6,$ and 0.9]. With increase in the value of path loss exponent (n), there is a decrease in the throughput as well as PDR performance and comparable performance was seen with all schemes at high value of n which was due to the effect of Rayleigh fading channel. There is a lesser chance of finding the best channel for CR user to conduct data transmission as the channel is negatively affected by noise. The enhanced throughput gains for the POS scheme in comparison to MASA, MDR and RS schemes at $P_I = 0.3$, 0.6 and 0.9 are [10.5%, 47.3% and 75.5%], [16.8%, 55.2% and 115.5%] and [23.3%, 58.4% and 131.8%], respectively. The enhanced PDR gains for the POS scheme as against MASA, MDR and RS schemes at $P_I = 0.3$, 0.6 and 0.9 are [11.5%, 122.3% and 166.6%], [19.8%, 150.02% and 245.8%] and [16.8%, 161.9% and 267.6%], respectively

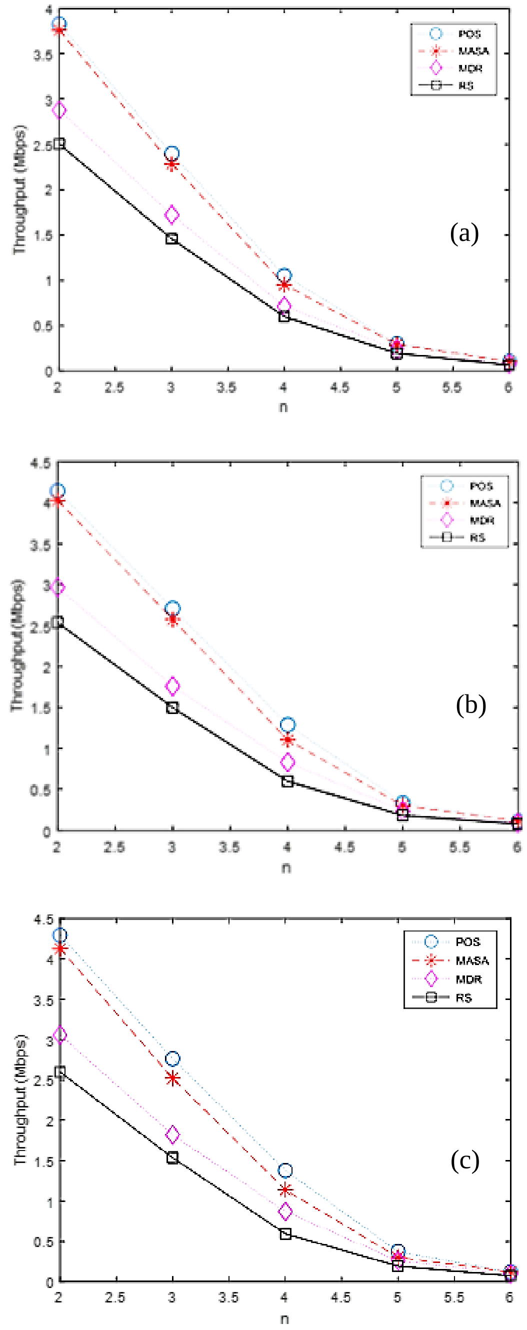

Figure 12. Throughput vs path loss exponent:
(a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

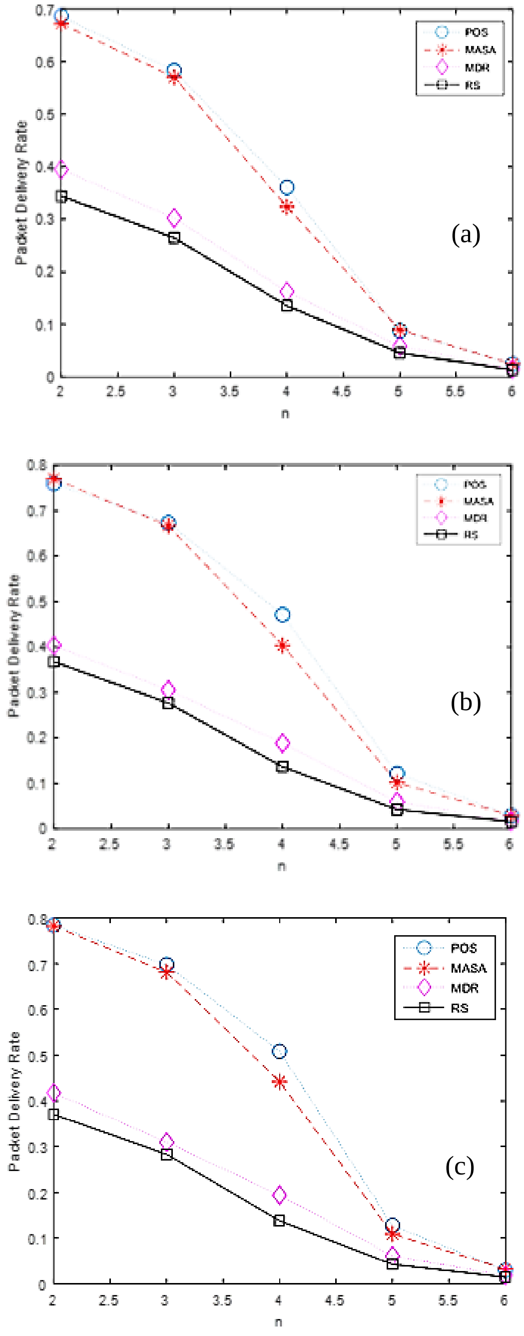

Figure 13. PDR vs path loss exponent:
(a) PI = 0.3, (b) PI = 0.6, (c) PI = 0.9

6.6. Performance evaluation of steiner minimal tree (SMT) multicast CRN under the effect of Idle probability

Figures 14 and 15 depict the throughput and PDR performance of multilayer multi hop multicast CRN as against the values of idle probability with various kinds of channel assignment schemes. The figures indicate that as the idle probability rose, the PDR and throughput performance of the POS scheme turned better than the MDR, MASA and SR schemes. This happens with increase in P_I value, which increases the probability of making suitable channels available to CR users for transmission as the PU traffic load is low.

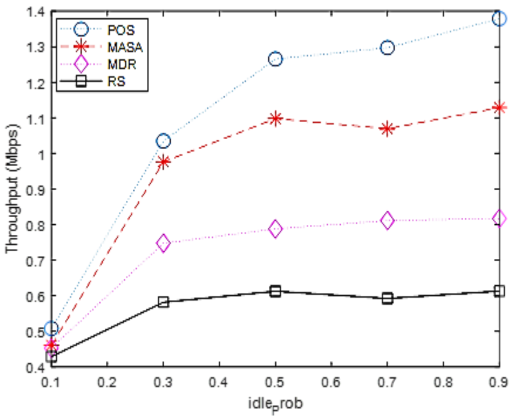

Figure 14. Throughput vs Idle probability

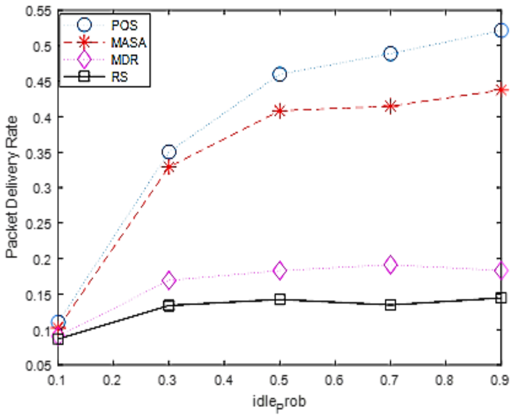

Figure 15. PDR vs Idle probability

7. CONCLUSION

This study deploys the Steiner minimal tree (SMT) algorithm for building the multicast router protocol for mobile ad-hoc CRN which has multilayer and multi-hop factors. For enhancing the network's performance, the probability of success (POS) is deployed as the channel assignment scheme which is applied to the network after converting the network's random topology to SMT for choosing an efficient channel to transmit data in accordance with the channel's availability and the requisite transmission time. Under various network parameters, a comparison of the performance is done for the CRN with regards to the throughput as well as PDR along with POS channel assignment with maximum data rate (MDR), maximum average spectrum availability (MASA) as well as random channel assignment schemes by taking into account Rayleigh fading channel model and three idle probability (i.e., P_I = 0.3,0.6,0.9) cases.

The simulation results proved that the throughput and PDR performance are improved as the number the primary channels and the channel's bandwidth increased because the chance of increasing the number of available channel for CR user is increased and also because that the data rate is proportional to the bandwidth of the channel. Also, the performance of CNR dropped as the value of packet size D rose. However ,the CRN with POS scheme have the best performance than using other schemes and as the value of P_I increased the performance of POS scheme improved because the chance of finding suitable available channels for CR users transmission increased because the traffic load of PU is low at high value of P_I. As a proposal for future work is constructing SMT tree by using the expected transmission count (ETX) rather than using distance for building multicast tree. Also, suggest using algorithm that select the path that having minimum hop between source node and distention node for data transmission purpose in an efficient manner.

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