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PROFICIENT OPPORTUNISTIC ROUTING BY QUEUING BASED OPTIMAL CHANNEL SELECTION FOR THE PRIMARY USERS IN CRAHN

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ABSTRACT

In cognitive radio ad-hoc networks, the selection of channels for the primary wireless users transmitting delay-sensitive data has been a long-standing problem. Most existing models select the channels only based the requirement of the application layer of the users, which is not applicable in all scenarios. Hence in this paper, optimal channel selection based routing model is proposed. In the proposed model, optimal channel selection based M-SMOR (OCS-M-SMOR) first the traffic and channels conditions of the primary, as well as the secondary users are modeled and analyzed. Then the expected delay of the users' data based on the traffic priorities is evaluated using Priority virtual queue interface in which the priority queuing analysis is utilized. The users are prioritized based on the expected delay and the required spectrum frequency for the delay sensitive data. The channel selection strategies are determined using the Dynamic genetic algorithm, based on which the channels are sorted in the best possible order. For ranking the channels, the parameters namely delay; PSNR, MSE, and BER are employed while the channels are allocated to the users based on the pre-evaluated priorities. The experimental results illustrate that the proposed OCS-M-SMOR model has less delay and efficient channel transmission than the other opportunistic routing models.

Keywords: cognitive radio, channel selection, priority virtual queue interface, expected delay, dynamic genetic algorithm.

1. INTRODUCTION

The current spectrum estimation models demonstrate that the settled spectrum task strategy for remote gadgets brings about underutilization of allocated data transmission [1], [2], [3]. The shortage of remote spectrum has driven the analysts to plan savvy optional system ideas to empower entrepreneurial access to spectrum free from authorized users (Primary Users).

Towards this bearing, the Dynamic Spectrum Access (DSA) [4] approach has been proposed, in which the authorized groups are made accessible to unlicensed users (Secondary Users) while guaranteeing consistent operation for the authorized users [2], [26], [27]. With the viral utilization of new advances, for example, PDAs, portable PCs, netbook and so on with the enhanced applications like online informal communities, it has turned out to be critical to locating another innovation that enables users to send information through the best channels assigned essentially to authorized users. This enables users to viably use the assets accessible and transmit their information through the unused channel and along these lines guaranteeing viable use of the channel. The best answer to the issue confronted by the users is using the best channel accessible and in this manner expanding most extreme throughput [1], [28]. This can be accomplished with the assistance of subjective radio specially appointed innovation. It enables the users to dynamically get to the channel and transmit their information through it.

Multichannel contention based MAC [5] system make utilization of outer detecting where stationary sensors are sent for spectrum detecting. Regular control channel has been utilized for reference point communicate and in addition for channel dispute. Amid conflict period all optional battling hubs haphazardly pick one of the smaller than normal space in RTS window and send expectation for transmission. At the point when more than one auxiliary client strives for same smaller than normal space, to evade impact the impacting hub transmit in next RTS window. At that point, collector sends CTS on same small-scale space which is recognized by the transmitter. And afterward, that small-scale opening is being utilized by the transmitter for promoting communication. Statistic channel allocation [6], [10] makes utilization of insights of the channel used for channel get to basic leadership. A CR gadget must pass the edge of the fruitful transmission rate through arrangement before it can start a substantial transmission on information channels.

The arrangement between the sender and collector on transmission parameters is essential for every transmission. In Channel aggregation diversity [7], by utilizing just single information radio the optional client can use numerous channels all the while and proficiently allot upper bound assets. Dynamic slot allocation [8] strategy depends on TDMA component. Here the channels are partitioned into time slots and users send its information and control data and assigned space. The real-time information is transmitted with slightest delays and certification full utilization of accessible spectrum.

In [9], the SMOR routing model has been developed which does not utilize the throughput and other routing factors of the network. This lead to the development of modified versions of SMOR using the Sparsity exploitation named as SDS-M-SMOR [6]. However, as the channel selection for the primary users has higher scope in improving the opportunistic routing, this paper develops a routing model with queuing based optimal channel selection.

The proposed model named as OCS-M-SMOR utilizes priority queuing analysis for estimating the expected delay based on which the dynamic genetic algorithm sorts the channels for the prioritized users. The rest of the article is organized as section 2 describes some the recent research works related to the CRAHN routing. Section 3 describes the proposed system model; section 4 describes the Delay based optimal channel selection. Section 5 presents the evaluation results while section 6 makes a conclusion of this research work.

2. RELATED WORKS

The channel selection algorithms (CSA) for multichannel CRN MAC conventions can be generally grouped into (i) learning based CSAs and (ii) ON-OFF distribution construct CSAs depending with respect to whether the measurements of a channel is known from the earlier or assessed on run-time. In learning based CSAs, the measurements of PU's channel utilization are not known to the optional client and subsequently, they need to take in these parameters [11]. Since it is exceptionally hard to take in the ON-OFF time distribution of PU at run-time, these calculations depend on the first and second request measurements of ON-OFF time distributions [12]. In ON-OFF distribution based CSAs, the ON-OFF time distribution of PUs are utilized and they have a tendency to be more productive than learning based CSAs.

Kim et al. [13] have ascertained the likelihood of channel being inactive in future for the exponential ON-OFF time distribution utilizing the learning of past detecting result (both detecting time moment and result). The ascertained likelihood is utilized as a part of requesting the channels for detecting in multichannel intellectual systems.

Yang *et al.* [14] have adjusted the above calculation for PUs with settled ON - exponential OFF time distribution. The Partially Observable Markov Decision Process (POMDP) based Greedy CSA system has been proposed by Zhao et al. [15] where the PU channel inhabitancy is displayed as discrete time ON-OFF Markov chain. This structure has been reached out to unslotted PU with exponential ON-OFF time distribution in [16].

A large portion of these CSAs in writing [13], [16] expect exponential sit still time distribution which is not reasonable for channels with low PU obligation cycle. The primary client action design on cell band has been described in [17] where the creators report log-typical sort of distributions for the call term.

The creators of paper [18] have likewise talked about the birthplaces of overwhelming followed distribution in the auxiliary system in light of the perception of PU's ON times. Miguel et al. [19] propose isolate distribution fits for low and high time determination. The low-time determination of idle times is fitted with summed up Pareto distribution while the distribution of high-time determination sit without moving circumstances relies upon the innovation sent in the spectrum band [20].

The authors of [21] demonstrate says 802.11 MAC conduct as persistent time semi-Markov process and scientifically determine summed up Pareto distribution for channel sit out of gear times in a controlled domain with just WLANs. Stabellini [22] considers heterogeneous traffic from WLANs/Bluetooth on 2.4 GHz band and fits spectrum follows with hyper-exponential distribution (HED) for sit out of gear times.

Liu *et al.* [23] demonstrate that the Complementary Cumulative Distribution Function (CCDF) of channel sit without moving time has control law rot up to some basic time after which it has exponential rot. The informational index with above conduct can be all around demonstrated with hyper-exponential distributions (HED) [24]. Delay sensitive transmission is mainly the multimedia transmission for which many efficient routing protocols have been analyzed by Al-Ariki and Swamy [25].

From the literature, it can be found that the idle time distribution is not realistic and also the channel selection of other models consume high power and high cost. The proposed model considers these limitations and develops the methodology to resolve them.

3. SYSTEM MODEL

Consider a primary client and a number, N, of potential channels having IDs from 1 to N. The client is worked in a time-slotted design, where the length of each time slot is T. The client likewise has a detecting request (s1, s2, ..., sN), which is a stage of the set {1, 2, ...,N}. In a given time slot, the optional client detects the channels successively as indicated by the detecting request, until the point when it stops at a channel in light of a particular standard (e.g., the channel is detected to be free and it has satisfactory channel quality), and transmits its data in that channel amid the rest of that time slot. It is accepted that exact channel detecting is accomplished, and there is no detecting error. Figure-1 shows the system model.

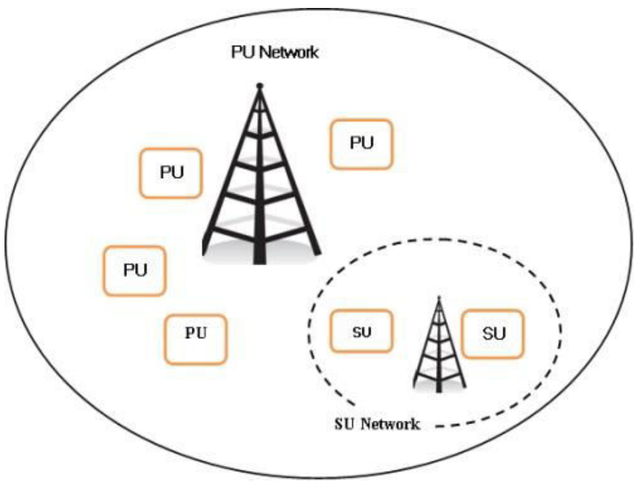

Figure-1. System model.

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The client stops at channel *sk*, and τ indicates the time required for detecting a channel and assessing the channel pick up, which is thought to be the same in every one of the channels. In each time slot, channel $i(1 \le i \le N)$ is free (i.e., no client activity) with probability $\theta i(\in(0,1))$, which is the accessibility probability of that channel. With little loss of sweeping statement, we accept that no two channels have a similar accessibility probability. For each channel, the occupied/free status in each slot is thought to be autonomous of the status in different slots, and furthermore to be autonomous of the status in different channels too. For each channel, the signal-to-noise ratio (SNR) is settled inside a time slot, and changes haphazardly toward the start of whenever slot.

The channel SNRγ is thought to be free and indistinguishable appropriated crosswise over time slots and crosswise over various channels, with a typical probability density function (pdf) indicated by *hSNR(γ).* Opportunistic transmissions are utilized. In the event that the auxiliary client chooses to transmit in a free channel i, the achievable transmission rate is *f(SNRi)* where *SNRi* is the SNR of the optional client in channel i, and *f(*)* is a non-diving capacity mapping SNR to the transmission rate.

4. PROPOSED METHODOLOGY

In this section, the proposed routing model is explained by providing the conceptual ideas. First, the prioritization of users is done followed by the evaluation of the channel conditions and traffic conditions. The routing model is developed to suit both regular as well as large-scale CRAHN.

Prioritization of the users

It is expected that there are K priority classes of users in the framework. The most astounding priority class C_1 is constantly saved for the primary users PU in every frequency channel. The heterogeneous auxiliary users SU can be arranged into remaining of K-1 priority classes $(C_2, \ldots C_K)$ to get to the frequency channels. We accept that the users in higher priority classes can pre-empt the transmission of the lower priority classes to guarantee an impedance free condition for the primary users.

The priority of a client influences its capacity of getting to the channel. Primary users in the most astounding priority class C_1 can simply get to their comparing channels whenever. Optional users, then again, need to detect the channel and sit tight for transmission open doors for transmission (when there are no higher priority users utilizing the channel) in view of their needs. We expect that there are Nk users in each of the class C_k. Consequently, there are $N_1 = M$ (number of total primary users) and $\sum_{k=1}^{K} N_k = N$ (number of secondary users). Different various get to control plans can be embraced for the optional users to share the spectrum asset. For effortlessness, MAC convention is utilized to guarantee that optional users in the lower priority class will quit getting to the channel and hold up in the line or change its activity (channel selection) if a higher priority client is utilizing the frequency channel.

Channel conditions of the primary users

For a specific recurrence channel F_j, the users can encounter different channel conditions for a similar recurrence channel. We indicate T_{ij} and e_{ij} as the subsequent physical transmission rate and packet error rate for the primary client transmitting through a specific recurrence channel F_j. Give $R_{ij} = [T_{ij}, e_{ij}] \in \mathcal{R}$ a chance to be the channel states of the channel for the primary client. We signify the channel condition lattice as $R = [R_{ij}] \in \mathcal{R}^{M \times N}$.

The normal physical transmission rate and packet error rate can be approximated as sigmoid elements of measured signal-to-impedance noise ratio (SINR) and the embraced regulation and coding plan. A few sorts of targets for the users can be considered practically speaking, for example, limiting the end-to-end delay, misfortune probability, or amplifying got quality, and so forth. For effortlessness, only two sorts of the utility function u_i, the delay-based utility for delay-sensitive applications and the throughput-based utility for delay-insensitive applications.

The delay-based utility function is given as

$$u_i^{(1)}(a_i, a_{-i}) = Prob(D_i((a_i, a_{-i}) \le d_i) \quad (1)$$

Where $(D_i((a_i, a_{-i})$ represent the end-to-end packet delay (transmission delay plus the queuing delay) for the primary user, d_i represents the delay deadline of the application of the primary user. The throughput-based utility function is given as

$$u_i^{(2)}(a_i, a_{-i}) = \begin{cases} \frac{T_i^{eff}(a_i, a_{-i})}{T_i^{max}} & \text{if } T_i^{eff}(a_i, a_{-i}) \le T_i^{max} \\ 1 & \text{if } T_i^{eff}(a_i, a_{-i}) > T_i^{max} \end{cases} \quad (2)$$

Where T_i^{eff} represents the effective available throughput and T_i^{max} is the physical throughput required by the primary user.

Traffic model for primary users

It is accepted that the stationary measurements of the traffic examples of primary users can be demonstrated by every auxiliary client. The packet landing procedure of a primary client is demonstrated as a Poisson procedure with normal packet entry rate λ_j^{PU} for the primary client utilizing the recurrence channel F_j. The m-th snapshots of the administration time distribution of the primary client in recurrence channel F_j depends on an M/G/1 show for the traffic portrayals. Since the procedure p_{ij} speaks to the probability of the primary client taking action a_{ij} meant as

$$E[(X_j^{PU})^m] \quad (3)$$

Traffic model for secondary users

It is accepted that the normal rate necessary for the secondary user is B_i (bit/s). Let λ_{ij} signify the normal parcel landing rate of the secondary user utilizing the frequency channel F_j. Since the technique s_{ij} speaks to the likelihood of the secondary user taking action a_{ij} (transmitting utilizing the frequency channel F_j),

$$\lambda_{ij} = s_{ij}\frac{B_i}{L_i} \quad (4)$$

Where L_i denotes the average packet length of the secondary user. If a certain secondary user can never use the frequency channel F_j, its strategy is fixed to $s_{ij} = 0$, and hence, $\lambda_{ij} = 0$. The packet arrival process of the secondary users is also modelled using a Poisson process.

Priority virtual queuing analysis

In order to evaluate the expected utility for delay sensitive applications, the distribution of the end-to-end delay for the user to transmit its packets has to be calculated. The expected end-to-end delay of the user can be expressed as

$$E[D_i((a_i, a_{-i})] = \sum_{j=1}^{M} p_{ij} \, . E[D_{ij}\left(R_{ij}(A)\right)] \quad (5)$$

Where $E[D_{ij}\left(R_{ij}(A)\right)]$ is the average end-to-end delay if the user chooses the frequency channel F_j

Utilizing the queuing model, each arriving packet of will choose a physical line to join (action a_{ij}) as indicated by the technique strategy p_{ij}. There are physical lines from primary users for a frequency channel. Just a single of them can transmit its packets whenever. Henceforth, a "virtual line" is framed for a similar frequency channel. In a virtual line, the bundles of the distinctive primary users hold up to be transmitted. Essentially, the aggregate sojourn time of this virtual line turns into the real service time at each of the physical lines.

Since the quantity of the primary users in a customary CRAHN is typically little, the virtual line is approximated utilizing prioritized M/G/1 queuing model. The normal landing rate of the virtual line of the frequency channel is $\sum_{i=1}^{N} \lambda_{ij}^{PU}$. Give us a chance to indicate the initial two moments of the service time for the virtual line of the frequency channel as $E[X_j]$ and $E[X_j^2]$. For a packet in the virtual line of frequency channel, the likelihood of the packet originating from the user is resolved as

$$f_{ij} = \frac{\lambda_{ij}^{PU}}{\sum_{k=1}^{N} \lambda_{kj}^{PU}} \quad (6)$$

Assume that $E[D_{jk}]$ and $E[W_{jk}]$ represent the average virtual queuing delay and average virtual queue waiting time experienced by the users in class C_k in the virtual queue of the frequency channel. By applying the mean value analysis,

$$E[D_{jk}] = E[W_{jk}] + E[X_j] \quad (7)$$

For delay-sensitive primary users

Maximize $E[(X_j^{PU})^m]$
Minimize $\sum_{k=1}^{N} p_{ij} \lambda_{kj}^{PU} \; E[D_{jk}]$

Optimal channel selection with a dynamic genetic algorithm

In this section, the best response strategy is selected for the decentralized optimization by considering the strategy that yields the highest utility of the primary user. The decentralized optimization is modelled as

$$p_i^* = \arg max_{p_i} E_{(p_i, p_{-i})}[\, u_i^{(1)}(a_i, a_{-i})] \quad (8)$$

The dynamic memory plot expects to upgrade the execution of GAs dissimilar to general GA. The put away data can be reused later in new environments. For instance, for the express memory plot, when the environment changes, old arrangements in the memory that fit the new environment well will be reactivated and consequently may adjust GAs to the new environment more specifically than irregular settlers would do. Particularly, when the environment changes consistently, memory can work exceptionally well.

This is on account of in cyclic dynamic environments, with time going, the environment will come back to some old environment definitely and the arrangement in the memory, which has been improved as for the old environment, will momentarily move the GA to the returned ideal of that environment. The memory in Dynamic GA is re-assessed each generation to recognize environmental changes.

The environment is distinguished as changed if no less than one individual in the memory has been recognized to have changed its wellness. In the event that an environmental change is distinguished, the memory is converged with the present population and the best n-m people are chosen as an interval population to experience genetic operations for another population while the memory stays unaltered.

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Algorithm: Dynamic Genetic Algorithm

t:=0 and $t_M := rand(5,10)$
Initialize population P(0) and memory M(0) randomly
Repeat
Compute population P(t) and memory M(t)
Replace the worst individual in P(t) by elite E(t-1)
If change detected then
$P'(t) :=$
$retrieveBestMembers\ from\ (P(t), M(t))$

Else $P'(t) := P(t)$
// Update memory
If $t = t_M$ ‖ change detected then
If $t = t_M$ then
$B_P(t) := retrieveBestMember\ from\ (P'(t))$
If change detected then
$B_P(t) := E(t-1)$
If still any random point in memory then
Replace with $B_P(t)$
Else // replace the most common memory point
If $t = t_M$ then
Find memory point $C_M(t)$ closest to $B_P(t)$
If $f(B_P(t)) > f(C_M(t))$ then
$C_M(t) := B_P(t)$
If change detected then
Find memory point $C_M(t-1)$ closest to $B_P(t)$
If $f(B_P(t)) > f(C_M(t-1))$ then
$C_M(t-1) := B_P(t)$
$t_M := t + rand\ (5,10)$
// Standard genetic operations
$P''(t) := selectForReproduction\ P'(t)$
Crossover $(P''(t), p_c)$ //p_c is the crossover probability
Mutate $(P''(t), p_m)$ //p_m is the mutation probability
$P(t+1) := P''(t)$
Until termination conditions satisfied

Suppose a memory updating happens at generation t, then the next memory updating time is $t_M = t + rand(5,10)$. In order to store the most relevant information to an environment in the memory, each time an environmental change is detected, the memory is also updated according to the population just before the environmental change.

When the memory is due to update if any of the randomly initialized points still exists in the memory, the best individual of the current population (if the memory update is due to $t = t_M$) or the elite from the previous population (if the memory update is because an environmental change is detected) will replace one of them randomly; otherwise, the best individual or the elite will replace the closest memory point if it is fitter according to the current environment or the previous environment, respectively.

5. PERFORMANCE EVALUATION

The performance of the optimal channel selection based SMOR opportunistic routing model is simulated both for regular and large-scale CRAHN using MATLAB tool and the results are compared with that of SMOR, M-SMOR, and SDS-SMOR models. The comparisons are made in terms of end-to-end delay (EED), BER, Throughput, path loss ratio, PSNR, and MSE.

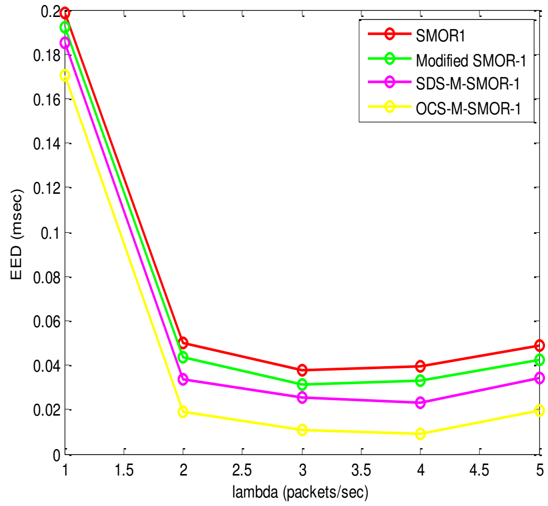

Figure-2. End to end delay of regular CRAHN.

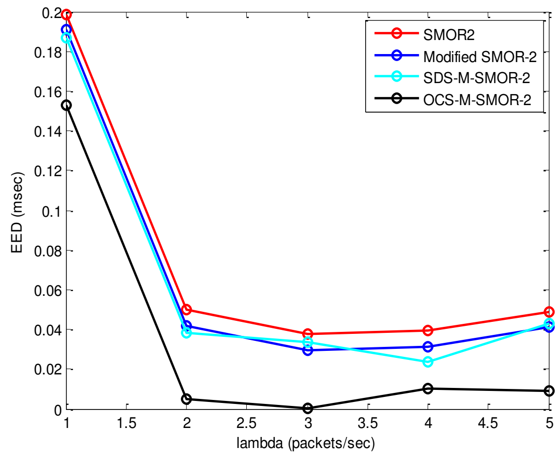

Figure-3. End to end delay of large-scale CRAHN.

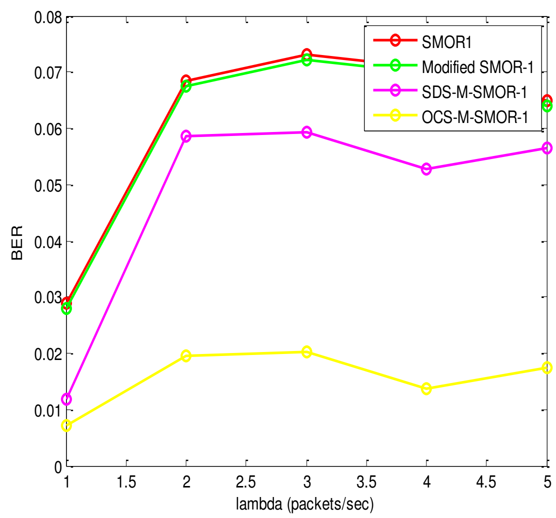

Figure-4. BER for regular CRAHN.

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Figure-2 shows the EED of regular CRAHN while Figure-3 shows EED of large-scale CRAHN comparing SMOR, M-SMOR, SDS-SMOR and the proposed OCS-M-SMOR. OCS-M-SMOR shows a lower delay in all level of the offered load because of the optimal channel allocated to the user. M-SMOR and SMOR show comparatively higher delay because of the limited spectrum recourses availability.

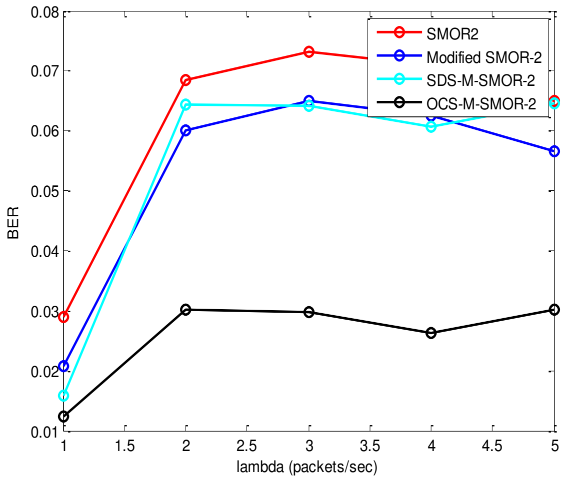

Figure-5. BER for large-scale CRAHN.

Figure-4 shows the BER of regular CRAHN while Figure-5 shows BER of large-scale CRAHN comparing SMOR, M-SMOR, SDS-SMOR and the proposed OCS-M-SMOR. OCS-M-SMOR shows lower error rate while other models have comparatively higher BER. In SMOR and M-SMOR, increasing the length of training sequence increases bit error rate as a signal to noise ratio value is very less. However, on increasing the signal to noise ratio the bit error rate reduces which is done by the optimal channel selection in the proposed model.

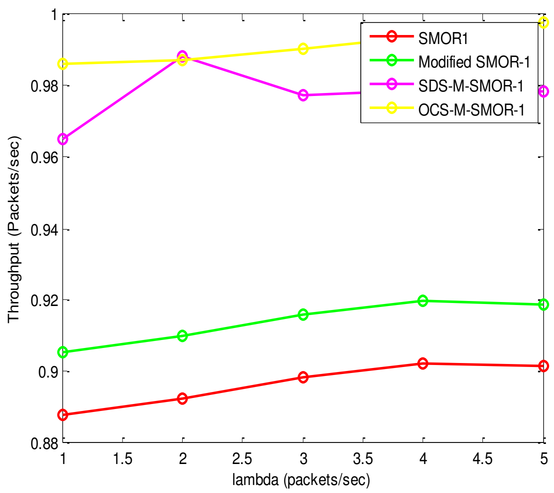

Figure-6. Throughput for regular CRAHN.

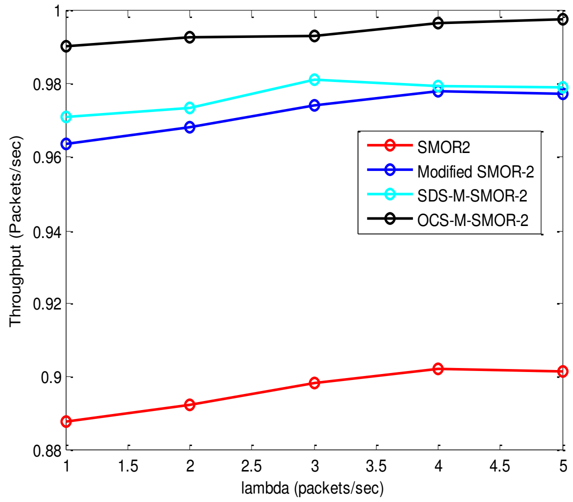

Figure-7. Throughput for large-scale CRAHN.

Figure-6 shows the throughput of regular CRAHN while Figure-7 shows throughput of large-scale CRAHN comparing SMOR, M-SMOR, SDS-SMOR and the proposed OCS-M-SMOR. OCS-M-SMOR shows higher throughput in both cases. In the figures, measured the aggregate throughput (the sum of individual routes throughput), which is defined as the data traffic received by the destinations in Mbps by varying the offered load. When the offered load increases, aggregate throughput increases up to message generation rate and then slightly decreases. It is seen that the OCS-M-SMOR-1 and OCS-M-SMOR-2 have high throughput values because of the ability to utilize the whole resources of the multichannel.

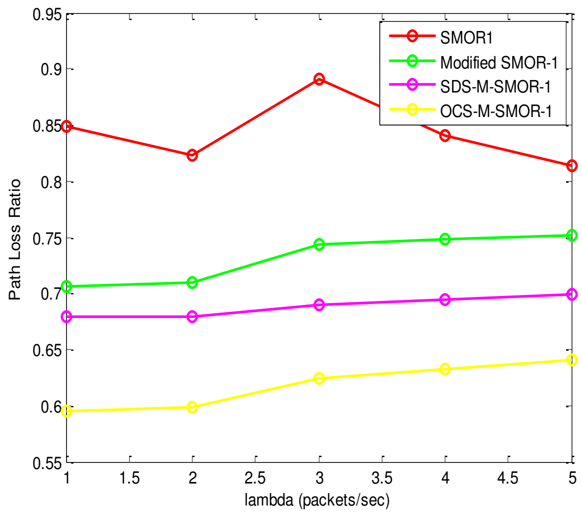

Figure-8. Path loss ratio for regular CRAHN.

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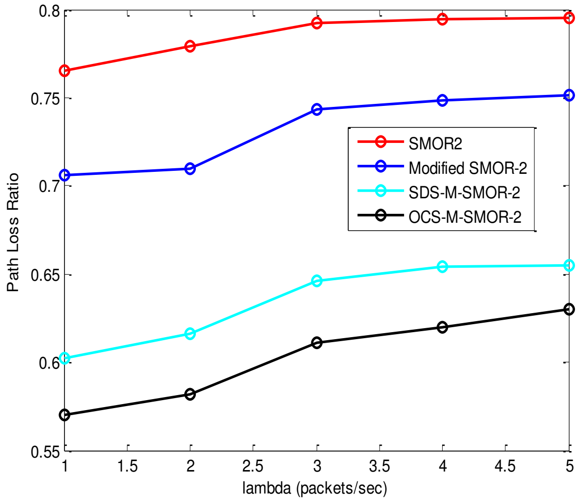

Figure-9. Path loss ratio for large-scale CRAHN.

Figure-8 shows the path loss ratio of regular CRAHN while Figure-9 shows path loss ratio of large-scale CRAHN comparing SMOR, M-SMOR, SDS-SMOR and the proposed OCS-M-SMOR. From this evaluation, it is proved that the proposed model of OCS-M-SMOR is significantly efficient than the existing models in both the cases. The priority-based channel allocation reduces the loss considerably.

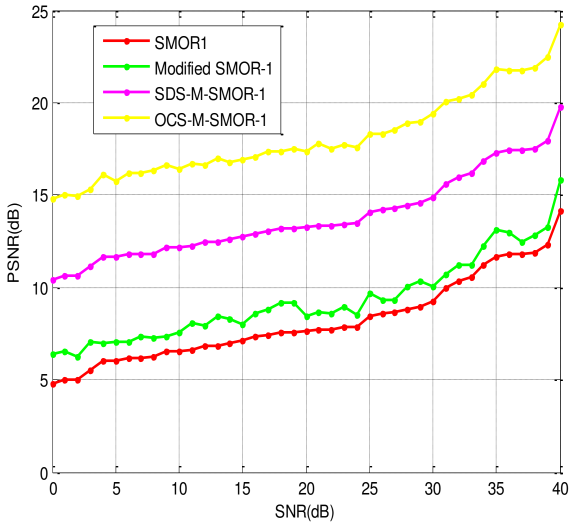

Figure-10. PSNR for regular CRAHN.

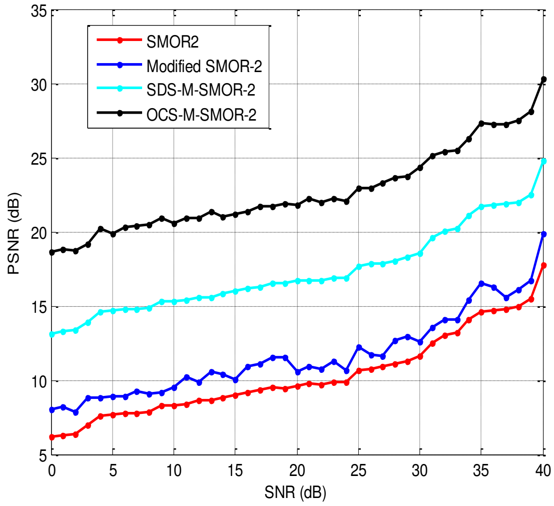

Figure-11. PSNR for large-scale CRAHN.

Figure-10 shows the PSNR of regular CRAHN while Figure-11 shows PSNR of large-scale CRAHN comparing SMOR, M-SMOR, SDS-SMOR and the proposed OCS-M-SMOR. OCS-M-SMOR has higher PSNR ratio due to the fact the error rate is reduced considerably by selecting the efficient channel for opportunistic routing. The same can be applied to MSE comparison in Figure 12 & 13.

Thus from the evaluation results, it can be verified that the optimal channel selection can enhance the opportunistic routing. Moreover, the proposed model of channel selection reduces the cost and energy of the routing system.

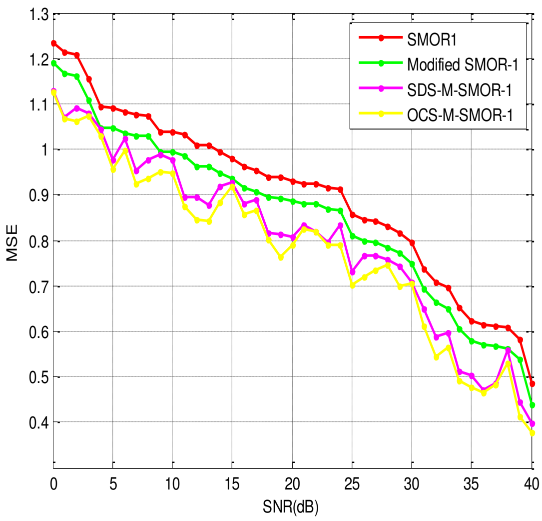

Figure-12. MSE for regular CRAHN.

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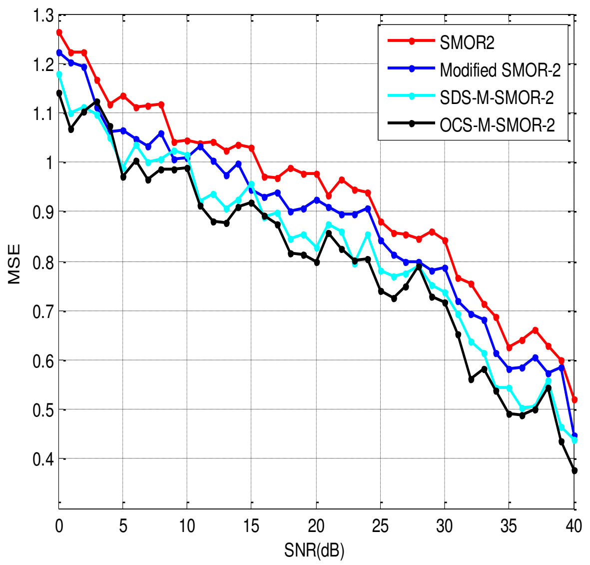

Figure-13. MSE for large-scale CRAHN.

6. CONCLUSIONS

This paper developed an efficient routing model by utilizing the concept of selecting the best channels and allocating them to the primary users based on their priorities. The proposed OCS-M-SMOR model utilizes the expected delay computed by priority queue analysis for the data application to select the channels in the best possible order. The sorting process is achieved by employing the dynamic genetic algorithm. The results showed that the proposed model has less delay, BER, path loss ratio and MSE while higher values of throughput and PSNR, thus justifying the overall research model. Since the cost and energy problem can be minimized through optimal channel selection, the security of transmission is an area of research for future.

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