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HB-SOR: Hybrid Bat Spectrum Map Empowered Opportunistic Routing And Energy Reduction For Cognitive Radio Ad Hoc Networks (CRAHNs)

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ABSTRACT: Cognitive Radio becomes a new technology for increasing the spectrum efficiency by means of creating opportunistic transmission links. Maintaining the routing information to opportunistic links is designed for packet transmission in a CR Ad Hoc Network which consists of cooperative relay multi-radio systems. this paper proposes a new CR routing Protocol (CRP) for CRAHN with the purpose of distinctively addresses the end-to-end performance in terms of throughput and delay. Hybrid Bat Spectrum map empowered Opportunistic Routing (HB-SOR) algorithm to compact with transmission delay over opportunistic links. A probable investigate HABC-SOR algorithm be able to study the relationship among end-to-end delay and throughput. Based on the theoretical definition of HB-SOR protocol, it is simulated to normal and large-scale CRAHNs among wireless fading channels, utilize a cooperative networking procedure to allow multipath communication between nodes with consistent end-to-end transportation. In addition the proposed HB-SOR protocol also calculates the energy value of the received signal inside the bandwidth threshold and time period. Here the computed energy is compared to a predefine threshold to find the current status (presence/ absence) of the transmitted signal. From the simulation results it confirm that proposed HB-SOR protocol results less end to- end delay , high throughput and less communication overhead appropriate to theoretical examination.

Keywords: *Cognitive Radio (CR) networks, cooperative relay, Dynamic Spectrum Access (DSA), opportunistic routing, spectrum map, Hybrid Bat based Spectrum map empowered Opportunistic Routing (HB-SOR).*

I. INTRODUCTION

Advanced development and usage of wireless technologies and wireless communications such as 3G cellular phone, laptop, and tablet PC in the world, they require more spectrum resources. But in the present spectrum structure, each and every one of the frequency bands are completely assigned to particular services, and it is easily destructed by unlicensed users. The Federal Communications Commission (FCC) has designated with the intention of the percentage of the assigned spectrum with the purpose is occupied simply from 15 to 85 percent; it should be varied commonly based on their time and places [1]. To address the problem of spectrum insufficiency, the FCC has been recently proposed by authors to allocate spectrum bands for unlicensed devices in licensed bands. This motivates to focus on the development of new Cognitive Radio Networks (CRNs) technology to improve the spectrum efficiency.

"CR" is a radio with the purpose of has the sensing capability, and be able to modify its transmitter parameters based on their interaction in CR Ad Hoc Network (CRAHN). Thus, CR preserve make use of the existing wireless spectrum opportunistically. The functions in the CRNs is performed between two users generally that is Secondary users (SUs) also named as unlicensed users, and Primary users (PUs) also named as licensed users are absent, however they require to free the band once the primary user is distinguished. Furthermore, a method called Cooperative Communications (CC) has been introduced in [2] to defend against the fading effects, and might enhance the channel capability. In [3] shown with the purpose of CC could provides some remuneration in CRNs. For example, SU could communicate the traffic of a PU in the direction of the intended destination or preserve the signal-to-noise ratio at CR receiver in the location with the purpose of CR sender by means of low transmission power subsequently as to defend the PUs. Since spectrum is expensive resources in CRNs, the major aim of this work is to use the available resources as many as probable during this cooperative technology with the purpose of can increase the throughput among SUs. However many of the researchers in CRNS is performed based on the single-hop communications. Accordingly, reducing end-to-end delay and increasing the throughput in CRAHN becomes a promising research field.

In CRAHN, Dynamic Spectrum Access (DSA) permits several CRs users with the direction to access the transmission prospect subsequent to distinguishing the spectrum hole from exploitation of Primary System(s) (PS) [1]. Once successful DSA is obtained, the packets appropriate in the direction of successful influence of transmission opportunities might be related to the destination node, applied to multi-hop networking. On the other hand, CRAHN routing still becomes a very challenging task. In the recent work research investigation is performed based on the homogeneous ad hoc networks, start-networks, or mesh networks for spectrum utilization of CRN to assist routing in CRAHN [4-6]. On the other hand, they might not perform based on the stochastic and dynamic nature of CR links into routing. In the direction of dynamically right to use the preassigned spectrum bands, CR must gather and process information regarding co-existing users inside the spectrum of interests, which needs advanced sensing and signal-processing qualifications [7].

By the motivation of spectrum sensing [8], sensing information among CR's transmitter (CR-Tx) and the CR's receiver (CR-Rx) becomes a very challenging task. This motivates the development of spectrum map over probable routing paths. The spectrum map demonstrates the obtainable spectrum through geographic area, during sensing and locationing, and several methods have been proposed in the recent work regarding spectrum map [9]–[10] in the dynamic and the opportunistic nature of a CRAHN. The spectrum map provides an information aggregation in the direction of preserve cumulative information in a consistent manner and in a resource-efficient manner. From the obtainable link and heterogeneous CRAHN [11] present an additional challenge in the routing algorithm, cooperative communication in the direction of preserve transmissions in a dynamic manner become very challenging task.

Some of the work proposed in the literature for opportunistic routing in CRAHN is discussed as follows: Spectrum-Tree base On-Demand routing protocol (STOD-RP) [12] is proposed in the literature and spectrum-tree is created to each spectrum band. The development of the spectrum-tree addresses the problem of spectrum sensing and route selection for dynamic nature of CRAHN. However new route metric is also proposed in the literature to solve the problem of spectrum-adaptive route recovery method. It shows that the proposed STOD-RP protocol decreases the communication overhead and decreases the average end-to-end delay considerably. Hou et al [13] designed a new mathematical framework for minimizing the essential network-wide radio spectrum resource proposed for a position of user sessions. Since this formulated representation is worked based on the Mixed-Integer Non-Linear Program (MINLP), which is generally NP-hard problem, develop a lower bound designed for the purpose by means of relaxing the integer variables via linearization technique. Consequently, propose a near-optimal algorithm to solve MINLP problem. This MINLP is implemented based on the novel sequential fixing procedure, where the integer variables are computed in iteration manner by means of using sequence of linear programs. Simulation results demonstrated that the proposed relaxation provides near-optimal results via the use of lower bounds when compare to existing methods.

Chowdhury et al [14] study the problem of TCP newReno in a CRAHN by proposing window-based TCP protocol. This proposed TCP protocol integrates the spectrum awareness by means of a combination of explicit feedback beginning the in-between nodes and the destination. This have been obtained by adapting TCP rate control algorithm from source to destination via physical layer channel information .In the link layer stage spectrum sensing and buffer management is performed , and a analytical mobility framework with the purpose is introduced at the network layer. An examination of the predictable throughput in TCP CRAHN is presented, and experimentation results provides considerable improvements when compare to other methods for CRAHN. Gymkhana routes the information across paths with the purpose of avoids network zones with the intention of do not assurance steady and high connectivity [15]. Based on this objective, new Laplacian spectrum of graphs based mathematical framework is developed which permits a complete evaluation of the different routing paths in CRAHN. This approach is used to determine effective routes under high connectivity. They use a distributed protocol in the direction of gather some key parameters connected to candidate paths beginning a source to a destination. The parameter is feed addicted to a basic statistical formation which is second hand to calculate capable routing paths not including high stable and high connectivity.

Cooperative Communications (CC) has been also used in the literature that considerably enhances the channel capacity of wireless networks. On the other hand, many of the work in the literature are applied to only single-hop wireless networks [16]. In order to use the benefits of CC in multi-hop wireless networks, a new joint optimization model is proposed in the literature for node allocation and optimal routing for current sessions. Here the problem of CC in multi-hop wireless networks is solved via the use of the branch-and-cut framework that reduces the computation time and increase the network size. Feng and Yang [17] solves the problem of throughput of secondary networks for DSA networks. They proposed a new mathematical model to measure the collision of together primary network and secondary network settings based on their network performance. The correlation among both networks is measured via the use of spectrum sensing and interference avoidance model. Simulation design demonstrated that the proposed work performs well when compare to existing models in terms of throughput and less connectivity capacity.

Yazane et al [18] solves the problem of throughput and coding overhead simultaneously. By consideration of neighboring nodes in the three-node chain topology via the use of single-server queuing model between two buffers. Here the results of the increased throughput value are measured via the use of continuous-time Markov chain model, and the examination is validated during simulation. Simulation results demonstrate that the three-node chain topology results high throughput and less coding overhead. Khalifé et al. [19] designate with the purpose of the proper time designed for opportunistic forwarding in CRAHN relays on the proportional timescale of the primary bands' idle time through cognitive communication time period. It is noted with the intention of the opportunistic routing related in [18]. On the other hand still there is lack of problem occurs in realistic routing algorithm for CRAHNs such as network size ,depending on their mathematical examination of data transportation via the use of opportunistic communication links appropriate to wireless fading, access, and operations.

The remainder of this paper is organized as follows: in section 2, proposed hybrid bat based spectrum opportunistic routing algorithm and energy detection are presented, and section 3 focuses on the performance evaluation.

II. PROPOSED HYBRID BAT BASED SPECTRUM OPPORTUNISTIC ROUTING ALGORITHM AND ENERGY DETECTION

In CR Ad Hoc Network (CRAHN), two factors which majorly affects the performance of dynamic spectrum accessibility. The first factor is primary user activity. Here Cognitive Users (CUs) are considered as low priority and those users are named as secondary users for spectrum accessibility to primary users, CUs should sense the spectrum to differentiate PUs activity. The second factor is spectrum accessibility in CUs via dynamic opportunistic links. This factor majorly affects the performance results of CRAHN, in terms of end to end delay and throughput. So, appropriately supporting a dynamic opportunistic links in efficient routing is extremely significant in CRAHN [20]. Solve above mentioned problems in CRAHN, new CR routing protocol (CRP) is proposed for CRAHN by satisfying network parameters like less end-to-end, high throughput and less delay. Hybrid Bat Spectrum Opportunistic Routing (HB-SOR) algorithm is designed to compacted with less transmission delay in CRAHN. A possible examine HB-SOR algorithm is able to study the relationship among end-to-end delay and throughput of multihop communications via Markov chain modeling to considerably keep the less communication overhead in CRAHN . Proposed HB--SOR algorithm is used to utilize opportunistic links for CRAHN to obtain high throughput, for this purpose first need to define a system model.

System model: To simulate and develop the procedure of spectrum map for HB-SOR algorithm, make assume a CRAHN paradigm [7], [27], [28] by considering concurrent PSs' and CRs' transmissions minimally if the interference created through CR-Txs at the PS's receivers (PS-Rxs) is less than the threshold. For performing this task first formulate a network model and define four types of traffic models which are applied to large-scale CRAHNs.

This model is similar to network model [15],[28], it is a whole CRAHN topology which consists of a CR source (CR_S), a CR destination(CR_D), number of Cooperative Relay Nodes (CRRs) is able to forwarding the packet(s) from source to destination and primary mobile stations (PSs) during its communications. Destination nodes in the CRAHN forward the traffic via relay nodes without consideration of PSs' support and check PSs' transmission at initial stage of interruption itself. Let us consider there are n CR nodes with limited CRD in CRAHN. The ith CR node has T_i feasible opportunistic paths where, the jth opportunistic path in $P_{ij} = \{P_{i1}, P_{i2}, \ldots, P_{iT_i}\}$, which is called as the opportunistic paths . These opportunistic paths consist of L_{ij} links to CRD. Here spectrum map substitute as an information aggregation platform for all kinds of sensing and inference results .This platform is applied to CRAHN functions and specify the available spectrum through the geographic area.

In the existing spectrum map, CR-Tx will keep the power level and check the interference to the PS-Rx via the reciprocal inference model as illustrated in Fig. 1. In wireless communication during transmission, communication may be eavesdropped by CR-Tx from a PS-Rx's location, while PS devices are in RTS-CTS. In order to obtain the interference to PS-Rx and CR-Tx we need to measure the distance from the channel model for PS-Rx to CR-Tx .This results position the distance into the conversely channel model.

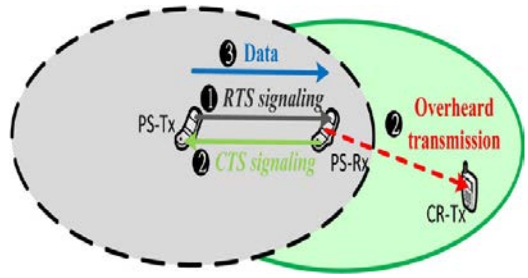

Fig.1. Wireless overhearing phenomenon between heterogeneous CR and PS devices

The CRs' observation is used to take system view as slotted and unslotted, which differentiate the interaction between PSs' and CRs' traffic. Here CRS and CRD are synchronous with time slot, and the sth time slot $[t_s, t_{s+1})$ is equal to Δ_s, where $s \in I$. PS's transmission activity is modeled via two-state Discrete-Time Markov Chain (DTMC), here spectrum accessibility is denoted with state "1" and spectrum unavailability is denoted with state "0" to opportunistic link [19]. In each slot (i.e.,Δts), for every CR transmission when PS is dynamic/ inactive, the entire Δ_s is occupied/ presented. Conversely, the traffic flow concept is implementing for the unslotted view with the purpose of interruption of CR's link utilization should be achieved by PS's traffic. Thus, each CRAHN has either slotted or unslotted system view. Here any two types of types of data packet patterns are transmitted by PSs' and CRs' transmitter–receiver pairs. The deterministic packet size propose with the purpose of Δts is equivalent to Δt for all time slots. This means to facilitate in each time slot, a single packet is able to be transmitted for PS's or CR's traffic, let us consider that the PS and CR have the equal packet size. Here variable packet in unslotted system is communicated by exponential distributed packet size.

A. *Spectrum Availability via Markov Chain Modeling*

In this step transmission might not be interrupted by other's traffic patterns from the CR-Tx over opportunistic link. Particularly, PSs' second-hand spectrum blocks should not be affected by CR-Tx's transmitted power next to the route to CR-Rx. Furthermore, PSs should not use the CR-Rx's unavailable block for successful reception from CR-Tx. Here the spectrum block length is computed by the area with the purpose of CR-Rx be able to perform successful signal reception, even under interference. Thus, the blocks that are required to be vacant by Mk for CR's transmitter–receiver pair of the kth link follows $\frac{d}{l} \leq Mk \leq \left[\frac{d^2}{l^2}\right]$, where d is the distance between source to destination. It presents the orthogonal property among PSs' and CRs' spectrum procedure in the spatial domain to underlay paradigm. For this spectrum blocks, three statistics of spectrum measurement are calculated as described as follows: traffic load φ correlated spectrum block for PS η; and usage dependence for PS ξ. φ states the ratio of the spectrum block which are occupied and be able to be known related to the direct decision from the location in the map i.e., φ is either 0 or 1 or φ= NPS/N single spectrum block is selected in a uniform way. η and ξ specify the spectrum block usage dependency for PS[27],[28].

B. *Wireless fading schema*

transmit a packet of the kth link of the Pij path for the ith CR's transmission and it is modeled using a Bernoulli process .During this some parameters need to be considered that is successful transmission rate γ_k, received Signal-To-Noise Ratio (SNR) SNR_r is not lower than the threshold k. For path-loss and shadowing environment, the received power at known distance from the transmitter is lognormally distributed and,

$$\gamma_k = 1 - Q\left(\frac{\left[P_{min} - P_s - 10\log_{10} K + 10\alpha\log 10\left(\frac{d}{d_0}\right)\right]}{\beta_{dB}}\right) \quad (1)$$

where P_s is transmitted power level at source, and Pmin is minimum received power level at source. d_0 is a reference distance for antenna, and d is the distance between the transmitter and the receiver. K is a threshold related to antenna characteristics and the average channel attenuation. α is the path loss component and β is the shadowing parameter is modeled via lognormal distribution with mean 0 dB and standard derivation β_{dB}.

C. *Link service rate:*

Traffic patterns are second-hand to develop transmission, which consist the service time of opportunistic links. On related to deterministic packet size, the service time is predefined and is equal to Δt for each CRs' packet transmission. On the other hand, for variable packet size, diverse fundamental wireless fading channels [11] such as lognormally distributed model for large-scale fading, Rayleigh fading for small-scale fading, and the fast-fading model are considered to obtain the service rate.

Deterministic Packet Size in Slotted or Unslotted System (DS or DU) follows the model of opportunistic link as $M/D/1/\infty/FCFS$ queue. In $M/D/1/\infty/FCFS$ model wireless fading channel is named as an erasure channel and has packet loss. Consequently packet is transmitted from source to destination via a Bernoulli process with successful transmission rate υ Let us consider $Y \sim Geo(v)$ represents the successful transmission rate and $X \sim Geo(\phi)$ represents the obtainable probability from opportunistic nature. Here X and Y are uncorrelated from independent events, and total service time S which sum of X_1 to X_Y for slotted systems. Similarly for unslotted systems, the successful transmission rate for PSs' or CRs' traffic is represented as v_{PS} or v, correspondingly. The spectrum accessibility is a Bernoulli procedure by means of probability

$$\sigma_{DU} = \prod_{M_k} (\omega_{DU}\, \varsigma_{DC}) \quad (2)$$

ω_{DU} is the probability of a wireless fading channels during transmission at the observation time, and

$$\omega_{DU} = 1 - \frac{\lambda_{PS}\Delta t}{v_{ps}} \quad (3)$$

Δt is the period of time . ς_{DC} is the probability of the residual available time during transmission time is described as follows,

$$\varsigma_{DC} = 1 - \sum_{k=1}^{\infty}[(1 - \exp^{\lambda_{PS}\Delta k})v(1 - v)^{k-1} = v\exp^{-\lambda_{PS}\Delta}/((1 - \exp^{\lambda_{PS}\Delta} + v\exp^{-\lambda_{PS}\Delta}) \quad (4)$$

Consequently, assume the $M/Geo/1/\infty$ FCFS queue model through Geo(cDU), where cDU is equivalent to $\sigma_{DU}v$

Variable Packet Size in Slotted or Unslotted System (VS or VU) follows the model of $M/M/1/\infty$ FCFS queue vas opportunistic link with successful transmission rate. Here consider μ represents the exponential service rate and spectrum accessible probability σ in Bernoulli distribution, the $\mu\sigma$ is service rate is geometrical sum of exponential distribution. Have $M/M/1/\infty$ FCFS queue with service rate μ_{cS} for the slotted case. In unslotted systems, spectrum accessibility follows the procedure of Bernoulli distribution which is described as follows,

$$\sigma_{V} = \prod_{M_k} (\omega_{VU}\, \varsigma_{V}) \quad (5)$$

Where $\omega_{VU} = 1 - \lambda_{PS}/\mu_{PS}$ and $\zeta_{U} = \mu_{CR}/(\lambda_{PS} + \mu_{CR})$

Accordingly, $M/M/1/\infty$ FCFS have the queue model results μc_{VU} service rate , where c_{VU} is equal to σ_{Uv} .

D. Opportunistic Link Delay:

In the unslotted system, CR's traffic might be intervened via PS's traffic in the current slot of CR's transmission. Here λ is denoted as CR's traffic arrival rate for successful transmission rate v and the λ_{PS} traffic arrival rate of PS's . For known packet size, the spectrum access probability for CR's traffic is denoted as σ_{DU}, and the successful transmission rate of PS's traffic is v_{PS}. For variable packetsize, the traffic service rate of the CR's is denoted as μ with spectrum access probability σ_{VU}, and the μ_{PS} is denoted as PS's traffic service rate . The Opportunistic link delay within the VU case is defined as follows,

$$\frac{1}{\mu c_{VU}} + w_q = \frac{1}{\mu c_{VU} - \lambda} \quad (6)$$

As mentioned above, for the DS case

$$\frac{\lambda(2 - \lambda)\Delta}{2(c_S - \lambda)} \quad (7)$$

As mentioned above, for the VS case

$$\frac{1}{\mu c_s - \lambda} \quad (8)$$

E. Opportunistic Path Delay:

In this work multi-hop communication is performed between paths in the CRAHN. Derive the multihop path delay through considering two-hop opportunistic paths and then expanding to N-hop opportunistic paths. So initially, two-hop opportunistic path delay for the DU case is defined as follows,

$$\left(\frac{\lambda(2 - \lambda)\Delta}{2(c_{DU} - \lambda)}\right) + \left(1 + \frac{E(S_2) - 1}{1 - \lambda E(S_2)}\right) \quad (9)$$

packet arrival rate of λ, Then, the delay is defined as follows,

$$E[w_1 + w_2] = \frac{1}{\mu_1 c_{VU_1} - \lambda} + \frac{1}{\mu_2 c_{VU_2} - \lambda} \quad (10)$$

It follows from unslotted cases, for the DS and VS case, the path delay is respectively defined as follows,

$$\left(\frac{\lambda(2 - \lambda)\Delta}{2(c_S - \lambda)}\right) + \left(1 + \frac{E(S_2) - 1}{1 - \lambda E(S_2)}\right) \quad (11)$$

and

$$\frac{1}{\mu_1 c_{s_1} - \lambda} + \frac{1}{\mu_2 c_{s_2} - \lambda} \quad (12)$$

Large-scale CRAHNs make use of large size network, which might be differentiating by spatial distribution of nodes [21], [27], [28]. They define four kinds of node deployment scenarios such as primary interference protocol model, n interferences protocol model, physical model, and per-node based model, important

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fundamentals such as power control and radio resource allocation for networking under CRAHN and applied them to one-hop forwarding ability of CR relay via stochastic geometry examination as follows, 1) Power Control schemas is used to attain an underlay model under large-scale CRAHNs, power control schemas are used in CRs' transmissions by considering two steps as which is described as follows: i) The maximum power with the purpose of CR-Tx is determined from the reciprocal inference. ii) CR-Rx's Signal-to-Interference-plus-Noise Ratio (SINR) is determined via the spectrum map.

Let us assume that these different deployment scenarios have been performed under a fixed region. In addition, the mathematical model handles over receiver SINR, which gather the effects from every interferer via location. The avoidance region is not predefined anymore and should rely on node density. The per-node based schema depends on effective distance determined from the given map and might not need any location information of nodes. It gives each specific transmitter by means of dedicated power control in a distributed way, certifying its achievability.

Link Service Rate from Radio Resource Allocation: From different type of traffic patterns between CRs' and PSs', consider radio resource allocation designed for the service process of opportunistic links following power control procedures. From mathematical point of view, the outage probability is qT , and service rate of opportunistic link by means of capacity C designed for CR's packet is $\tilde{\mu}_T = qTBC$, where B is denoted as packet per bit which rely on packet size. Let us consider this under engineering modeling, qP is second hand for the geometric service rate in known packet size, and the service rate is denoted as $\tilde{\mu}_P = BW \log_2(1 + SINR)$ derived from Shannon formula. Let us assume that unslotted systems is varied from regular CRAHNs with the purpose of accept accessible probability to differentiate the opportunistic nature, actual PS's arrival traffic is accurately disturbed in large-scale CRAHNs. With the intention of CR's link transmission can be interrupted by PS's traffic anytime. This kind of link transmissions, non-preemptive priority queue [22] is implemented, while PS's traffic is Poisson arrival rate λ_{PS}, and its service rate is q_{PS} for known packet size and μ_{PS} designed for variable one.

Protocol Model of n Interferences is applied to PS-Rxs and CR-Rxs given ε and τ_{PR}, the successful transmission probability,

$$\exp\left(-\frac{H_{PP}\tau_{PR} H_{PT-PR}}{P_{PT} H_{PT-PR}{}^{-\alpha}}\right) \times \prod_i \frac{H_{SP_i} P_{PT} H_{PT-PR}{}^{-\alpha}}{H_{SP_i} P_{PT} H_{PT-PR}{}^{-\alpha} + H_{PP}\tau_{PR} P_{ST_i} d_{ST_i}^{-\alpha}} \quad (13)$$

Obtain P_{ST}^* ,given τ_{CR}

$$qT = \exp\left(-\frac{H_{SS}\tau_{CR} N_{ST-SR}}{P_{ST}^* d_{ST-PR}^{-\alpha}}\right) \times \prod_j \frac{H_{PS_j} P_{ST}^* d_{ST-PR}^{-\alpha}}{H_{PS_j} P_{ST}^* d_{ST-PR}^{-\alpha} + H_{SS}\tau_{CR} P_{PT_j} d_{PT_j-SR}^{-\alpha}} \quad (14)$$

where i(j) is P for PS and S for secondary CR. It involves two major steps to conclude qT for a CR's transmitter–receiver pair.

Per-Node-Based Model is performed based on the "effective distance" under geographic area to signal propagation in fading channels. Known power level of transmitter PTx, the power at receiver PRx, and the interferences from other transmitters being ignored in the spectrum map, the successful distance is determined as follows,

$$f(x) = d_{eff} = \left(\frac{P_{Rx}}{P_{Tx}}\right)^{-\frac{1}{\alpha}} \quad (15)$$

Transferring the original map into an optimal distance among the transmitter–receiver pair, straightforwardly obtain the necessary location information and make use of the power control in the per-node-based model. By considering different node deployments, the above descriptions gives the details about one-hop forwarding capability of CR relay in terms of delay applied to large-scale CRAHNs.

F. Develop Hybrid Bat Spectrum Opportunistic Routing (HB-SOR) for routing under large-scale CRAHN's.

The Bat algorithm use sonar echoes to determine the power range with effective distance and avoid obstacles. It is commonly identified with the intention of pulses rates are transformed into a frequency which reproduce from obstacles [23]. The pulse rate is defined under 10 to 20 times per second, wavelengths is defined between 0.7 to 17 mm or inbound frequencies of 20-500 kHz. The pulse rate under the range of 0 to 1, where 0 means that is less effective distance and 1 means that is maximum [23]. The bat behavior [23], [29] used three generalized rules during implementation:

1) All the nodes in the CRAHN utilize an echolocation to determine the power range with effective distance and by considering their objective function (d_{eff}) with their conditions barriers in a fairly magical manner.
2) When searching to explore the power range with effective distance, the nodes fly randomly with velocity vi at nodes position xi with fixed frequency fmin .At the same time as with varied wavelength λ , loudness A0. Based on these value pulse emission rate r ∈ [0, 1] is adjusted automatically with their power range.
3) Although the loudness could be varied depending on their power range, initially it varies from a positive A0 to a minimum constant value Amin

In this work BAT algorithm, initialization of the nodes in the CRAHN is randomly performed. Optimal power range with effective distance is determined via moving virtual nodes (bats) related to the following equations:

$$Q_i^{(t)} = Q_{min} + (Q_{max} - Q_{min})U(0,1) \quad (16)$$

$$v_i^{(t+1)} = v_i^t + (x_i^t - d_{eff})Q_i^{(t)} \quad (17)$$

$$x_i^{(t+1)} = x_i^t + v_i^{(t)} \quad (18)$$

where U(0, 1) is a uniform distribution. A random walk with shortest utilization is used for exploring the power range with effective distance that modifies the current best power optimal solution related to following equation:

$$x^{(t)} = d_{eff} + A_i^{(t)}(2U(0,1) - 1) \quad (19)$$

With the power level of transmitter PTx, the power at receiver PRx, and the effective distance is considered as the cost value of the ith solution. where is the scaling factor, and $A_i^{(t)}$ the loudness. The local search is performed based on pulse rate ri which increases or decreases depending on the cost value and the loudness Ai decreases or increases respectively. Precisely, these characteristics are performed based on the following equations:

$$A_i^{(t+1)} = \alpha A_i^{(t)}, r_i^{(t)} = r_i^{(0)}[1 - \exp(-\gamma)] \quad (20)$$

where α and γ are constants. These parameters are optimized using differential crossover and a differential selection thus adds a scaled difference among these operations to determine mutation. Final operation is mathematically expressed as follows:

$$u_i^{(t)} = w_{r0}^{(t)} + F(w_{r1}^{(t)} - w_{r2}^{(t)}) \quad (21)$$

where F ∈ [0.1, 1.0] denotes the scaling factor , r0, r1, r2 real numbers. Mathematically, uniform crossover can be expressed as follows:

$$z_{i,j} = \begin{cases} u_{i,j}^{(t)} \; rand_j(0,1) \le CR \forall j = j_{rand} \\ w_{i,j}^{(t)} \; \text{otherwise} \end{cases} \quad (22)$$

where CR ∈ [0.0, 1.0] controls the fraction of parameters . Note, the relation j = j_{rand} confirms that the trial vector is varied from the original solution Y(t) . Mathematically, differential selection is defined as follows:

$$w_i^{(t)} = \begin{cases} z_i^{(t)} \text{ if } f(Z^{(t)}) \le f(Y_i^{(t)}) \\ w_i^{(t)} \text{ otherwise} \end{cases} \quad (23)$$

G. Algorithm 1 (HB-SOR)

1) Traffic is partitioned and encrypted by source into batches of packets for transmissions.
2) At each available time slot of sources, Source collects link information (i.e., δ_{ij} and v_{ij}, $\in \{CR_S, n, CR_D\}$) from the map to prioritize forwarders into the candidate list regarding node metric mi, $i \in n$, randomly mixes packets in a batch via HB( ) , and broadcasts coded packet with the list.
3) The ACK message is not sent by Destination,
   a) Step 2 is repeated by source until it receives ACK.
   b) For each relay node z, if a packet is received by z from node y, it splits the packet, collects unheard information and saves in its buffer, as well as checks the list.
      i) If z lies before y in the list, z advances its counter by its triggering ratio ϕ_z
   c) At each z's available time slot, z examines whether its counter is positive.
      i) If so, z randomly mixes its buffered packets, broadcasts coded packet with the list, and decrements its counter by one.
4) Destination continuously decodes the collection of coded packets to verify whether it gets all packets of the batch. If so, Destination broadcasts ACK back to Source, eliminating the packets buffered in relay nodes and enabling the next transmission batch.

HB ( )

Step 1: Initialize effective distance sources x_i and v_i.

Step 2: Define pulse frequency $Q_i \in [Q_{min}, Q_{max}]$ to find new effective distance.

Step 3: Initialize pulse rates r_i

Step 4: while ($t<T_{max}$).

Step 5: Generate new effective distance by adjusting frequency and updating velocities and locations/solutions.

Step 6: if(rand(0, 1) > ri)

Step 7: Modify the solution using "DE/rand/1/bin"

Step 8: end if

Step 9: Generate new effective distance by flying randomly

Step 10: if(rand(0, 1) < Ai and f(xi) < f(x))

Step 11: Accept the new solutions

Step 12: Increase ri and reduce Ai

Step 13: end if

Step 14: Rank the bats and find the effective power distance

Step 15: end

Step 16: Postprocess effective power distance results and visualization.

The scheme makes use of opportunistic relay selection concerning transmission qualities of cooperative links into packet delay. Particularly, it proposes triggering ratios with counters and candidate lists in delay point of view.

H. Spectrum Sensing via Energy Detection

An energy detector is a mechanism with the purpose of might choose whether the transmitted data packets is not present or nearby in the transmission range setting. This detector might not need any prior information of the transmitted data packets that is size, shape, frequency. The traditional energy detector calculates the energy level of the received data packets over specified time duration and bandwidth. The energy is then compared to threshold value to find the presence or the absence of data transmission [30].

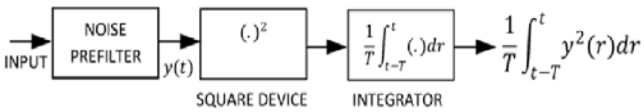


Fig. 2. Energy Detector

1. Analog energy detector schema is illustrated in Fig. 2 .It includes of a finite time integrator. Here finite time integrator limits the transmission bandwidth. The output of the integrator is equal to the energy of the received signal of the square law machine.

2. Digital energy detector schema is illustrated in Fig. 3. It includes of Analog-to-Digital Converter (ADC), which converts continuous transmission packets data to discrete samples, and a square law device followed by an integrator.

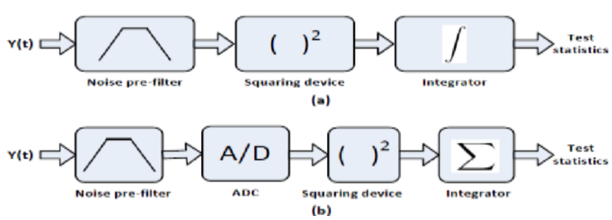


Fig.3: The conventional energy detectors: (a) analog and (b) digital

The integrator output of any detection schema is named as decision statistic or test statistic. This result is compared to predefined energy threshold device by decision device to make the final decision of the existence/nonexistence of transmitted packets.

III. PERFORMANCE EVALUATION

Listing all simulation parameters and values, evaluate HB-SOR, HABC-SOR, SMOR-1 and SMOR-2 simultaneously. All of these algorithms depend upon the size (network models). When the network is small, HB-SOR, HABC-SOR serves as great feasible data transportation. When the network grows larger and local information is not enough for reliable end-to-end routing HABC-SOR takes charge of packet delivery with the aid of global information, for validation the HB-SOR deliberate it over a three-node relay network for variable packet size in a slotted system (i.e., the VS case). Though it is simple, it clearly reveals the practicability of HB-SOR over opportunistic fading links in regular CRAHNs and the advantage of opportunistic forwarding than a predetermined route strategy through further study in a wireless relay network. Given the area and density settings for PS and CR in Table I, the Poisson network topology is established.

TABLE I: PARAMETER SETTING FOR PERFORMANCE EVALUATION OVER LARGE-SCALE CRAHNS

HB-SOR with VS case in regular CRAHN	
Parameter	**Value**
$n+1$	3
σ_{SD}	[0.1,1] in CRAHN, 1 in Wireless Network
σ_{SR} and σ_{RD}	1
v_{SD}	0.45
v_{SR} and v_{RD}	0.97
Λ	[0,9] (pkt/sec)
M	200(pkt/sec) in CRAHN, 50 (Pkt/sec) in wireless network

In this work to measure the simulation results of various routing methods we use the topology shown in Fig.4, which is same like as [27], [28] and [29]. A square region of side 1200 m is categorized into 9 square cells of side 400 m. In the simulation setup, totally there are 9 Primary User (PU) locations. In each PU location, totally there are 10 Primary User (PU) locations; it might be designed for data transmissions. Every one PU has an interfering range of 250 m. 49 SUs are positioned in a grid design; the distance among any two neighboring SUs is 160 m. Every one SU has a greatest transmission range of 250 m on every one channel.

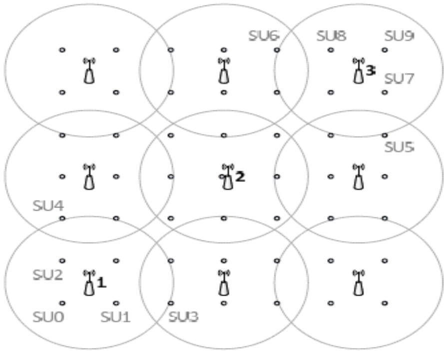


Fig.4. Simulation topology

Throughput comparison: In order to measure routing methods such as HB-SOR ,HABC-SOR, SMOR-1 and SMOR-2 result, first use the throughput performance metric for comparison, in which make an assumption that all PUs be have equivalent ranger of average ON and OFF times. For every one grouping of average ON/OFF times, replicate the simulation 20 times, by means of every time a diverse start to create PU activities, i.e., ON/OFF intervals subsequent an exponential distribution. Throughput comparison results of various routing methods with respect to time is measured based on the following formula.

$$\text{Throughput} = \frac{\text{packet received}}{\text{amout of packet forwared}} \quad (23)$$

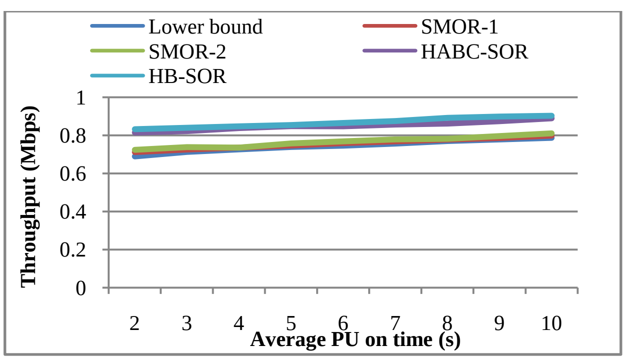
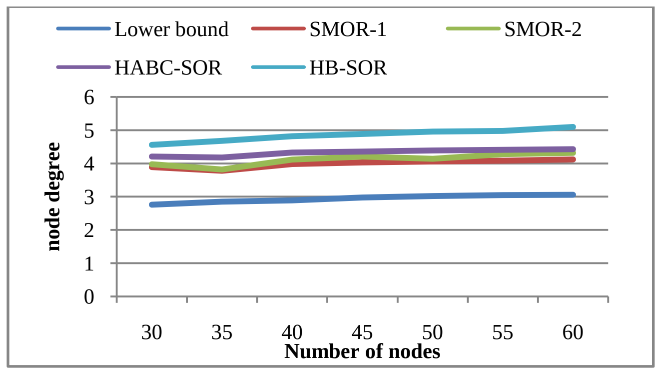


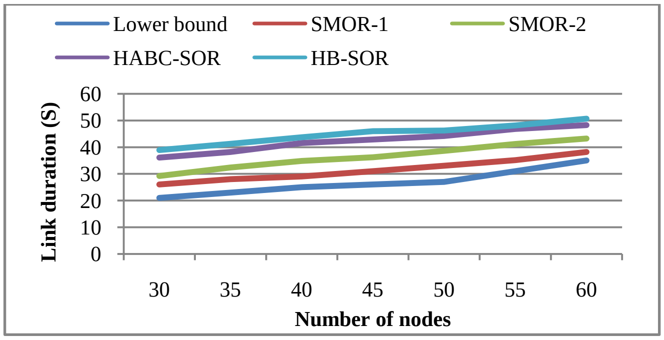
FIG. 5. BASELINE THROUGHPUT COMPARISON, THE DATA POINTS FOR METHODS, AVG. PU ON TIME = 6 SEC

In Fig.5, measure the throughput comparison results by predetermining the average PU ON at sec and differ the normal OFF time beginning time from 3-10 sec. Examine the throughput of all routing methods such as Lower Bounds, Spectrum Mapping Opportunistic Routing 1(SMOR 1), Spectrum Mapping Opportunistic Routing 2(SMOR 2) and Hybrid Artificial Bee Colony based Spectrum Opportunistic Routing (HABC-SOR), HB-SOR respectively. Again, HB-SOR outperforms when compare to other routing protocols. Since the research HB-SOR algorithm might be to study the relationship among end-to-end delay and throughput.



(a) NODE DEGREE

Fig. 6 shows detailed performance comparison results of the various routing methods such as Lower Bounds, SMOR 1, SMOR-2 and HABC-SOR methods respectively, results are measured in terms of node degree and link duration. From Fig. 6(a) examines the resulting of various routing Lower Bounds, SMOR 1, SMOR-2 , HABC-SOR and HB-SOR methods under average node without topology control. It observed that the results of HB-SOR with average node degree retains small in the network increases, which moreover build network scalable. In adding together to node degree, the topology control algorithm as well results in longer link duration is shown in Fig. 6(b).



(B) LINK DURATION

FIG.6. BASELINE THROUGHPUT COMPARISON, THE DATA POINTS FOR METHODS

This designate that the resulting topology is more stable and it is probable toward decrease re-routings in the network To exhibit the success of HB-SOR and HABC-SOR with the further challenge of large-scale CRAHNs, compare SMOR-2, SMOR-1 and Lower bound, which aims to route packets within the shortest path. Under different opportunistic routing algorithms in the network is characterized by activity of PS-Txs.

Fig.7 shows the better performance of HB-SOR from its cooperative variety gain through the aid of cooperative relays.

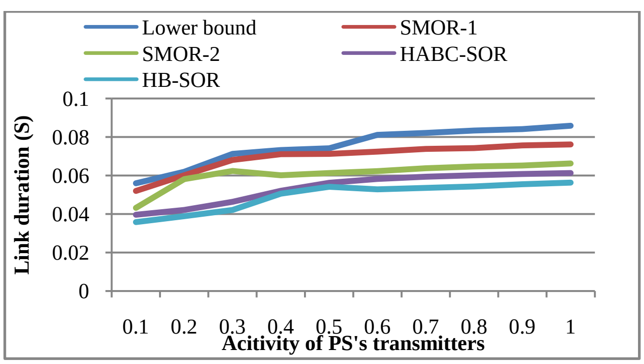


FIG. 7. END-TO-END DELAY WITH RESPECT TO PS-TXS' ACTIVITIES

IV. CONCLUSION AND FUTURE WORK

Cognitive Radio (CR) have been become a new emerging key technology to increase dynamic spectrum utilization via opportunistic transmissions in CR transmitter-receiver link(s). On the other hand, CRs should form a Cognitive Radio Network (CRN) consequently with the purpose of the messages be able to be forwarded from source to destination, on dynamic opportunistic links to multi-radio systems. However, suitable dynamic opportunistic routing in CRN for multi-radio systems still becomes a challenging problem. Hybrid Bat Spectrum Opportunistic Routing (HB-SOR) is proposed to condition cognition ability to the routing protocols in CRAHN, aggregation platform, interference, time duration and end-to-end transmission for wireless fading channels. It also presented the absolute examination with reliable transmission delay CRAHNs via wireless fading channels. An HB-SOR protocol is used to find an end-to-end minimum cost path between a pair of source and destination. Cogitating the dynamic opportunistic nature, the spectrum map is considered as information aggregation platform toward dynamically revise all kinds of sensing and inference results. The simulation results show that proposed HB-SOR not only obtains higher throughput, but also reduces the end-to-end delay and the amount of energy consumption reduces compared to previous work. A simulation result analyzes the throughput and end to end delay performance metrics between proposed HB-SOR protocol and existing protocols by considering the activities of PU and CR nodes. In future work apply this HB-SOR protocol to CC technology; be able to go one step additional to influence the presented recourses in CRNs so as to improve their performance.

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