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A HYBRID ARTIFICIAL BEE COLONY BASED SPECTRUM OPPORTUNISTIC ROUTING ALGORITHM FOR COGNITIVE RADIO AD HOC NETWORKS

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ABSTRACT: Cognitive Radio (CR) is an upcoming technology by which unlicensed users can use vacant parts of the spectrum allocated to users (licensed) by creating opportunistic transmission links. It lacks systematic perceptive of dynamic opportunistic links and a consistent end-to-end transportation mechanism in network. Dynamic opportunistic routing algorithms are designed but QOS and throughput guarantee is needed. A Hybrid Artificial Bee Colony based Spectrum Opportunistic Routing (HABC-SOR) algorithm is created to deal with transmission delay over such opportunistic links. HABC-SOR algorithm is proposed to study the relationship between end-to-end delay and throughput. Using Markov chain modeling and queuing network theory, transmission delay and throughput of multi-hop communications are examined. HABC-SOR algorithm is proposed to exploit opportunistic selections for cooperative relay regarding link transmission qualities and high throughput, exploring two initialization methods to exploit opportunistic selection. A new HABC-SOR mechanism is also developed to balance the investigation and utilization. Based upon the link prediction, HABC-SOR constructs an efficient and reliable topology, by mitigating re-routing frequency and improving end-to-end network performance such as throughput and delay.

Index terms: Ad hoc networks, opportunistic routing, spectrum map, hybrid artificial bee colony algorithm (HABC), CR Ad Hoc Network (CRAHN), and end-to-end delay.

1 INTRODUCTION

Cognitive radio (CR) technology is extensively considered a capable technology to deal with the problem of dynamic spectrum sensing in current technologies. It is capable of sensing its radio environment, and dynamically choosing transmission parameters according to their sensing outcomes, which enhances CR scheme performance without interfering with primary users [1]–[2].

Recent investigation regarding the CR technology is based on spectrum sensing and their issues in infrastructure-based networks with the purpose of relying on the presence of a centralized entity used for gathering the spectrum information, making a decision of best possible spectrum for use, and allocating those channels to the CR users. Furthermore, CR architectures are usually single hop, with every CR straightforwardly communicating by means of the central unit as the end destination. Current investigative activities performed in CR are mostly focusing on the opportunistic spectrum sensing and physical layer transmission throughput. On the other hand, non-cognitive MANET's technology still has some major issues in the CR paradigm.

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Conversely, a number of diverse characteristics of CRs initiate new non-trivial issues to CRAHN [3]–[5].

One of the most significant issues in the non-cognitive MANET's technology is routing, since during the routing process data packets are routed by the use of a constant and consistent path to evade recurrent re-routing problem. Hence the re-routing might induce waste of the radio resources and decrease end-to-end performance in terms of throughput and delay [6]. Compared to traditional CRAHN, a path in MANET is particularly unbalanced, because it is not simply affected through node mobility between cognitive users but also by means of the interference to primary users. During this routing process dynamic access of spectrum bands also necessitate sophisticated sensing and signal-processing ability [7]. Motivated by means of common dynamic spectrum sensing schemas [8], sensing the information of both the CR's transmitter (CR-Tx) and the CR's receiver (CR-Rx) becomes a difficult task. Because of this, the creation of the spectrum map over feasible routing paths is recommended. The spectrum map demonstrates the obtainable spectrum by means of geographic area through sensing, and a number of sensing methods have been applied to create a spectrum map [9]–[11]. Consequently, the dynamic and the opportunistic link environment of a CRAHN introduce another significant challenge in the routing design which reduces the network performance. To solve all of these CRAHN issues, this paper proposes a new CR routing protocol (CRP) designed for CRAHN which distinctively addresses the end-to-end performance in terms of throughput and delay, using Hybrid Artificial Bee Colony based Spectrum Opportunistic Routing (HABC-SOR) algorithm to compact with transmission delay over opportunistic links. A probable investigation of HABC-SOR algorithm studies the relationship among end-to-end delay and throughput. Mathematical examination for transmission delay and throughput of multi-hop communications is studied via Markov chain modeling. The HABC-SOR algorithm is proposed to utilize opportunistic selections designed for CRAHN to achieve high throughput.

2 RELATED WORK

Akyildiz et al [12] introduces a comprehensive survey with the intention of advocating cooperative spectrum-aware communication management for its cross-layer design. At initial stage of the work some of the general spectrum management functionalities such as sensing, sharing, and mobility are established from distributed environment. Second stage of the work spectrum management functionalities results are measured at different layer protocols such as upper layer, network layer, and transport layer, from these results the research issues are also outlined.

Distinguishing the activities and restriction for a multi-hop CR network beginning numerous layers, Hou et al. [13] suggested a new mathematical analysis formulation toward reducing the usage of radio spectrum resources in network environment. The mathematical analysis formulation is performed based on the Mixed-Integer Non-Linear Program (MINLP).

Chowdhury and Felice [14] suggested a new SpEctrum Aware Routing protocol for Cognitive ad-Hoc networks (SEARCH) in CRAHNs, which equally carry out path and channel selection toward, avoid PSs' action regions throughout route formation. SEARCH, also adapts in the direction of the newly discovered path and vanished spectrum opportunity throughout route process .At final stage considers several cases of node mobility in a distributed setting through predictive Kalman filtering. Chowdhury et al [15] suggested new spectrum sensing schema in a Transport Control Protocol (TCP) for CRAHNs. It examines the issues of general TCP in a CRAHN environment, and develops a window-based TCP protocol. Window-based TCP protocol integrates spectrum awareness through a grouping of precise feedback between middle nodes and the destination nodes. This is achieved by means of adapting the traditional TCP rate control algorithm successively on the source to directly cooperate by means of the physical layer for channel information, the link layer for spectrum sensing to achieve high mobility to network layer.

Abbagnale and Cuomo [16] developed a new connectivity based Gymkhana routing protocol with the intention of routing the information by avoiding network zones and not considering high connectivity. To this end make use of a Laplacian spectrum based mathematical framework with the intention of permitting widespread evaluation of the different routing paths in CRAHNs. Sharma et al [17] describe the remuneration of developing Cooperative Communication (CC) in multi-hop wireless networks. To demonstrate the benefits of CC in multi-hop wireless networks, it proposed a branch-and-cut framework. Proposed branch-and-cut framework speed-up shows the significant network performance in terms of the end to end delay and high throughput.

Feng and Yang [18],[30] analyzed the throughput of secondary networks in Dynamic Spectrum Access (DSA) at the network level. It presented a new mathematical model to measure the impact of primary network and secondary network simultaneously to increase the performance of a secondary network in DSA. The correlation among primary and secondary networks is confined through the integration of spectrum sensing and interference evasion method in the mathematical representation.

Yazane et al [19] introduced a new spectrum sensing opportunistic routing based on the three-node chain topology and achieve high throughput examination for multi-hop wireless networks. Khalifé et al. [20] proposed a new opportunistic routing schema in CR technology that relies on proportional timescale algorithm in cognitive communication duration. Our proposed opportunistic routing is mainly based on this schema. On the other hand, it is still deficient in a practical routing schema designed for CRAHNs by means of practical network size, relying on theoretical numerical examination of data transportation by means of opportunistic communication links appropriate to wireless fading, access, and operations.

3 PROPOSED HYBRID ARTIFICIAL BEE COLONY BASED SPECTRUM OPPORTUNISTIC ROUTING ALGORITHM

The difference between CR Ad Hoc Network (CRAHN) from classical Adhoc networks is of primary users and dynamic spectrum availability. In CR Ad Hoc Network (CRAHN), there are two factors which greatly affect the spectrum accessibility. The primary factor is primary user activity. Since Cognitive Users (CUs) are measured as low precedence and these users also considered as secondary users of the spectrum allocation to primary users, CUs must sense the spectrum to distinguish PUs activity. The second factor which affects spectrum accessibility is CUs in dynamic opportunistic links. This secondary factor affects the performance of CRAHN network, in terms of the end to end delay and throughput. So, appropriately supporting a dynamic opportunistic links in efficient routing is extremely significant in CRAHN [12]. To solve all of these CRAHN issues, this paper proposes a new CR routing protocol (CRP) designed for CRAHN with the purpose of distinctively addressing the end-to-end performance in terms of throughput and delay. Hybrid Artificial Bee Colony based Spectrum Opportunistic Routing (HABC-SOR) algorithm to compact with transmission delay over opportunistic links. Investigate using HABC-SOR algorithm to be able to study the relationship among end-to-end delay and throughput. Mathematical examination for transmission delay and throughput of multi-hop communications is studied via Markov chain modeling .The HABC-SOR algorithm is proposed to utilize opportunistic selections designed for CRAHN to achieve high throughput, first defining a network model.

System model: To develop the concept of spectrum map for HABC-SOR algorithm, assume a CRAHN paradigm [7] with the intention of directive concurrent PSs' and CRs' transmissions simply if the interference generated through CR-Txs at the PS's receivers (PS-Rxs) is below some acceptable threshold. In the following CRAHN paradigm, first define a network model and give four types of traffic models for large-scale CRAHNs.

Network Model: Related to [16], a complete CRAHN topology consists of a CR source (CR_S), a CR destination(CR_D), several number of Cooperative Relay Nodes (CRRs) with the intention of be able to forward the packet(s) beginning CR_S to CR_D, and primary mobile stations (PSs) through its communications. CRs forward the traffic all the way through relay nodes not including PSs' assist and shall prevent PSs' transmission beginning interruption.

Assumption is made that there are n CR nodes with exclusive CRD in CRAHN. The ith CR node T_i has possible 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 for the ith CR node to CRD consisting of L_{ij} links to CRD. It is clear that the spectrum map acting as an information aggregation platform of all kinds of sensing and inference results to serve CRAHN functions and indicates the available spectrum with the geographic area.

With the available spectrum map, CR-Tx will keep the power level and prevent the interference to the PS-Rx through the reciprocal inference as in Fig. 1.

In wireless communication in every same medium transmission, the transmission may be eavesdropped by CR-Tx from a PS-Rx's location, while PS devices are in RTS-CTS or some other control signaling period. In order to obtain the interference to PS-Rx, CR-Tx measures the distance to the PS-Rx from the channel model for PS-Rx to CR-Tx and deploys the distance into the conversely channel model.

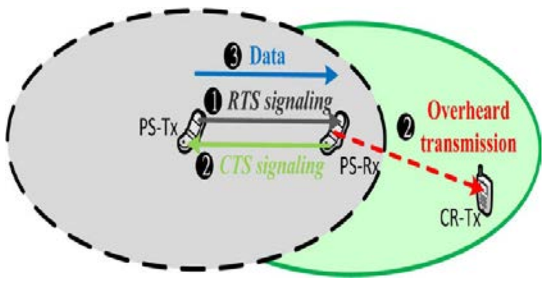

Fig. 1. Wireless overhearing phenomenon between heterogeneous CR and PS devices

There are four patterns of data packet for both regular and large-scale CRAHNs as follows:

- Size of deterministic packet in slotted system (DS);
- Size of variable packet in slotted system (VS);
- Size of deterministic packet in unslotted system (DU);
- Size of variable packet in unslotted system (VU).

The CRs' observation is used to take system perspective (i.e., slotted and unslotted), which differentiate the interaction between PSs' and CRs' traffic. As shown in Fig.(2) the slotted perspective is shown and it is clear that CRS and CRD are synchronous with time slot, and the s^{th} time slot $[t_s, t_{s+1})$ is equal to Δt_s, where $s \in I$. PS's transmission activity is modeled as an embedded two-state Discrete-Time Markov Chain (DTMC), where spectrum availability is represented with state "1" and spectrum unavailability is represented with state "0" represented when considering opportunistic link [21]. In each slot (i.e., Δts), for every CR transmission when PS is active/ idle, the entire time slot is unavailable/ available. On the other hand, the traffic flow concept is adopted for the unslotted perspective that interruption of CR's link utilization can be achieved by PS's traffic. Therefore, each studied CRAHN has one system perspective. There are two types of packet sizes are transmitted by PSs' and CRs' transmitter–receiver pairs. The deterministic packet size suggests that Δts is equal to Δt for all time slots. This means that in each time slot, a single packet can be transmitted for PS's or CR's traffic, assuming PS and CR have the same packet size. The variable packet size deals with the exponential distributed packet size to generalize our study. Hence, all possibly traffic patterns are thoroughly included by our four traffic patterns.

Spectrum Availability via Markov Chain Modeling: The transmission should not be interrupted by other's traffic from the CR-Tx aspect for a successful transmission over opportunistic link. Specifically, PSs' used spectrum blocks should not be affected by CR-Tx's transmitted power along the route to CR-Rx. Moreover, PSs should not use the CR-Rx's occupied block for successful reception from CR-Tx. The length of the spectrum block is calculated by the area that CR-Rx can conduct successful signal reception, even under interference. Thus, the blocks that are needed to be unoccupied by Mk for CR's transmitter–receiver pair of the kth link follows $\frac{d}{l} \leq Mk \leq \left[\frac{\pi d^2}{l^2}\right]$, where d is the distance between the CR's transmitter and receiver. It provides the orthogonal property between PSs' and CRs' spectrum usages in the spatial domain for the considered underlay paradigm. For a single spectrum block, three statistics of spectrum measurement are obtained from the map as follows:

- traffic load φ;
- correlated spectrum block for PS η; and
- Usage dependence for PS ξ.

φ specifies the ratio of the spectrum block which are unavailable and can be given according to the direct decision from the location in the map (i.e., φ is either 0 or 1) or φ = NPS/N with the assumption that a single spectrum block is picked in a uniform manner. η and ξ specify the spectrum block usage dependency for PS.

Wireless fading: Each attempt to transmit a packet of the k^{th} link of the Pij path for the ith CR's transmission is modeled as a Bernoulli process with a successful transmission rate ν_k (i.e., the opposite of outage probability for the received Signal-To-Noise Ratio (SNR) SNR_r lower than the threshold k). For path-loss and shadowing environment, the received power at given distance from the transmitter is lognormally distributed and,

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

Where P_s is power transmitted, and Pmin is minimum received power level of target. d_0 is a reference distance for antenna far field, and d is the distance between the transmitter and the receiver. K is a unitless constant that depends on the antenna characteristics and the average channel attenuation. α is the pathloss exponent and β is the shadowing effect parameter and is modeled as lognormal distribution with mean 0 dB and standard derivation σ_βdB.

Link service rate: Traffic patterns are used to develop transmission, which involve the service time (or rate) of opportunistic links. With regard to deterministic packet size, the service time is fixed and is equal to Δt for each CRs' packet transmission. On the other hand, for variable packet size, different fundamental wireless fading channels [22] (e.g., 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): Model the opportunistic link as $M/D/1/\infty/FCFS$ queue. A wireless fading channel is called as an erasure channel and has packet loss. Therefore, each attempt to transmit a packet is a Bernoulli process with successful transmission rate υ. Assuming $Y \sim Geo(v)$ accounts for a successful transmission rate and $X \sim Geo(\sigma)$ accounts for available probability from opportunistic nature, X and Y are uncorrelated from independent events, and total service time S is summation time from X_1 to X_Y for slotted systems. As for unslotted systems, the successful transmission rate for PSs' or CRs' traffic is v_{PS} or v, respectively.

The spectrum availability is a Bernoulli process with probability

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

ω_{DU} is the probability of a channel being available for 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 being larger than the transmission time as

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

Therefore, adopt the $M/Geo/1/\infty/FCFS$ queue model with Geo(cDU), where cDU is equal to $\sigma_{DU}v$.

Variable Packet Size in Slotted or Unslotted System (VS or VU): Model such an opportunistic link as $M/M/1/\infty/FCFS$ queue v still represents the successful transmission rate. For exponential service rate μ and Bernoulli process with available probability σ, the equivalent service rate is μσ by the formulation of 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 availability follows a Bernoulli process with

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

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

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

Opportunistic Link Delay: In the unslotted perspective, CR's traffic can be intervened by PS's traffic even in an

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available slot of CR's transmission. The CR's traffic arrival rate is λ under successful transmission rate ν, and the PS's traffic arrival rate is λ_{PS}. For deterministic packet size, the available probability for CR's traffic is σ_{DU}, and the successful transmission rate of PS's traffic is ν_{PS}. For variable packetsize, the CR's traffic service rate is μ with available probability σ_{VU}, and the PS's traffic service rate is μ_{PS}. The delay for opportunistic link within the VU case is

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

From above, for the DS case

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

From above, for the VS case

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

Opportunistic Path Delay: Since one-hop opportunistic paths as direct links, derive the multihop path delay by first considering two-hop opportunistic paths and then extending to N-hop opportunistic paths. It is noted that to derive path delay for a multihop opportunistic path, consider single-path transmission as such single chain link assumption simplifies the calculations for metrics and are well fitted for a highly dynamic CRAHN, without loss of generality. Therefore, two-hop opportunistic path delay for the DU case is

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

The Packet arrival rate of λ, Then, the delay is obtained as

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

It follows from unslotted cases, for the DS or VS case, the path delay is, respectively

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

Or

$$\frac{1}{\mu_1 c_{S_1} - \lambda} + \frac{1}{\mu_2 c_{s_2} - \lambda} \quad (12)$$

Large-scale CRAHNs uses large size network, which can be characterized by spatial distribution of nodes [23]. Inspired by the work in [23] with regard to four kinds of node deployment scenarios (i.e., protocol model of primary interference, protocol model of n interferences, physical model, and per-node based model), we study essential elements (i.e., power control and radio resource allocation) for networking in a large-scale CRAHN and then examine one-hop forwarding capability of CR relay via stochastic geometry analysis as follows:

1) Power Control Procedures: It is used to achieve an underlay paradigm within large-scale CRAHNs, power control procedures are used in CRs' transmissions by with two steps as follows:

- The maximum power that CR-Tx can apply is examined from the reciprocal inference.
- CR-Rx's signal-to-interference-plus-noise ratio (SINR) is characterized by the spectrum map.

Consider these procedures for four different deployment scenarios within a fixed region. Furthermore, the physical model deals with the receiver SINR, which accumulates the effects from all interferers by physical-layer information (i.e., location). The avoidance region is not fixed anymore and might depend on node density. The per-node based model proposes the effective distance extracted from the given map and does not need location information anymore. It provides each specific transmitter with dedicated power control in a distributed manner, certifying its practicability. Link Service Rate from Radio Resource Allocation: Regarding various traffic patterns (i.e., DS, VS, DU, and VU) between CRs' and PSs', consider radio resource allocation for the service process of opportunistic links after power control procedures. For theoretical modeling, the outage probability is qT , and the equivalent service rate of opportunistic link with capacity C for CR's packet is $\tilde{\mu}_T = qTBC$, where B stands for packet per bit and depends on packet size. For engineering modeling, qP is used for the geometric service rate in deterministic packet size, and the equivalent service rate becomes $\tilde{\mu}_P = BW\log_2(1 + SINR)$ from the Shannon formula. For unslotted systems, different from the cases in regular CRAHNs that adopt available probability to characterize the opportunistic nature, actual PS's arrival traffic is precisely concerned in large-scale CRAHNs. That is, CR's link transmission can be interrupted by PS's traffic anytime (i.e., CR should avoid transmission whenever PS has its own traffic to transmit). For such kind of link transmissions, non-preemptive priority queue [24] is adopted, while PS's traffic is Poisson arrival with rate λ_{PS}, and its service rate is q_{PS} for deterministic packet size and μ_{PS} for variable one. With the crucial elements of CRs' opportunistic links, are ready for the link transmission delay that exhibits one-hop forwarding capability of CR relay over large-scale CRAHNs in the following.

Protocol Model of n Interferences: There are n interferers for 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 steps to decide the qT for a CR's transmitter–receiver pair.

Per-Node-Based Model: The observed spectrum map is reconstructed based on the "effective distance" for the geographic area instead of the Euclidean distance, due to signal propagation in fading channels. With the power level of transmitter PTx, the power at receiver PRx, and the interferences from other transmitters being neglected (i.e., far away from the target receiver) in the spectrum map, the effective distance is

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

Transferring the original map into an effective distance between the transmitter–receiver pair, easily get the essential location information and exploit the power control in the per-node-based model. With regard to different node deployments, the above investigations provide the one-hop forwarding capability of CR relay in terms of required forwarding time (i.e., delay), facilitating the relay section for networking in large-scale CRAHNs. Develop Hybrid Artificial Bee Colony based Spectrum Opportunistic Routing (HABC-SOR) suitable for previous considerations. Specifically, these algorithms need to be aware of PSs' spectrum usages to avoid interference. Furthermore, getting inspiration from cooperative diversity of CR relay, it is beneficial to exploit cooperative communications in CRAHN's multihop transportation.

HABC-SOR:

The foraging behavior of bee colonies is simulated, by Artificial Bee Colony (ABC) algorithm, which is a swarm intelligence-based optimization algorithm for numerical function optimization [25]. There are three kinds of bees in ABC algorithm that are employed bees, onlooker bees and scout bees. The colony is equally divided by employed bees and onlooker bees. In this work the number of nodes in the CRAHN is considered as the input and considered as bees. The employed bees that are nodes in the CRAHN explore the power range with effective distance and send the information of nodes from source to destination of the power range with effective distance to the onlooker bees. Depend on the information of nodes shared by the employed bees the onlooker bees choose a power range based on effective distance to exploit. The scout bee, which is one of the employed bees whose food source is abandoned, finds a new power range based on effective distance selected randomly. The power range position with effective distance is a possible solution to the routing. The power range with effective distance number is denoted as SN, the ith power range position with effective distance as x_i ($i = 1,..,SN$). In ABC algorithm, the ith fitness value fit_i for a routing is defined as:

$$fit_i = \begin{cases} \frac{1}{1+f_i} & f_i \geq 0 \\ 1+abs(f_i) & f_i < 0 \end{cases} \quad (16)$$

where f_i is the cost value of the ith solution. With the power level of transmitter PTx, the power at receiver PRx, and the interferences from other transmitters being neglected (i.e., far away from the target receiver) in the spectrum map, the effective distance is considered as the cost value of the ith solution. The selected food source probability of a onlooker bee is given by:

$$p_i = \frac{fit_i}{\sum_{i=1}^{SN} fit_i} \quad (17)$$

A old one can generate candidate solution that is given by:

$$v_{ij} = pr_{ij} + \phi_{ij}(pr_{ij} - pr_{kj}) \quad (18)$$

where $\in \{1,2,..,SN\}$, $k \neq i$ and $j \in \{1,2,,D\}$ are randomly selected indices, $\phi_{ij} \in [\,1,1]$ is a uniformly distributed random number. The candidate node solution is compared with the old one, and the better one should be remained. If the abandoned effective distance is d_{eff} , the scout bee uses a new effective distance according to where pr_{ij}^{max} and $pr_{ij}^{min}$are the upper and lower bounds of the jth dimension of the problem's search space.

Chaotic initialization: Chaos is a deterministic random-like process and found in non-linear dynamical systems, the characteristics of chaos are random, unpredictable, regularity, and sensitive dependence upon the initial condition and parameters. Mathematically, chaotic maps may be considered as source of randomness. Because of these randomness and sensitivity dependence on the initial conditions of chaotic maps, it has been considered as an initialization method for the heuristic algorithms to improve the global convergence by escaping from local optima [26]. Chaotic map is a discrete time dynamic system running in chaotic state, which is: $x_{k+1} f(x_k) = ,0\ 1\ k < x <, k = 1,2,\cdots$. According to the definition of f(x) , the chaotic maps include several types, such as logistic map, circle map, gauss map , sinusoidal iterator, and so on. Here, the sinusoidal iterator is employed as a chaotic map in colony initialization. The initial equation is defined as follows:

$$v_{ij} = pr_{ij}^{min} + ch_{kj}(pr_{ij}^{max} - pr_{ij}^{min}) \quad (19)$$

where $ch_{k,j} = \sin(\pi.ch_{k-1,j}), ch_{k-1,j} \in (0,1), k = 1,..K,$ is the chaotic sequence.

Inter-cell initialization: In the population initialization step, the initial population can be divided uniformly over solution space uniformly without any missing of

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space. For this, the inter-cell initialization can be employed: the feasible solution space is divided into SN subspace and a solution is randomly selected in each one of these subspaces. Here, SN is the population size.

Algorithm 1 (HABC-SOR)

1) Traffic is partitioned by source into batches of packets for transmissions.

2) At each available time slot of sources, Source collects link information (i.e., $\delta_{i,j}$ and $\nu_{i,j}, \in \{CR_S, n, CR_D\}$) from the map to prioritize forwarders into the candidate list regarding node metric mi, i ∈ n, randomly mixes packets in a batch via HABC ( ) , 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, collect 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.

HABC ( )

Initialize the effective distance sources by using one of the initialization methods, and evaluate the population, traili $= 0, (i = 1, 2, \ldots, SN)$
Cycle =1, Repeat
Step 1: Search the new effective distance food source for employed bee according to (18) and evaluate its quality.
Step 2: Apply a greedy selection process and select the better solution between the new effective distance food source and the old one.
Step 3: If solution does not improve $trail_i = trail_i + 0$ otherwise $trail_i = 0$
Step 4: Calculate the probability according to (17) and apply roulette wheel selection scheme to choose an effective distance as food source for onlooker bees.
Step 5: Search the new effective distance as food source for onlooker bees according to (19) and evaluate its quality.
Step 6: Apply a greedy selection process and select the better effective distance solution between the new food source and the old one.
Step 7: If solution does not improve $trail_i = trail_i + 0$ otherwise $trail_i = 0$
Step 8: If $\max(trail_i)$ limit i trail >, replace this food source with a new effective distance as food source produced by the initialization methods
Step 9: Memorize the best solution achieved so far Cycle = Cycle +1 Until (Cycle = Maximum Cycle Number).

The scheme exploits opportunistic relay selection regarding transmission qualities of cooperative links into packet delay. Specifically, it designs triggering ratios with counters and proposes node metrics and candidate lists in delay perspective.

4 PERFORMANCE EVALUATION

Listing all simulation parameters and values, evaluate HABC-SOR, SMOR-1 and SMOR-2 simultaneously. All of these algorithms depend upon the size (network models). When the network is small, 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 HABC-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 HABC-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.

In this work to measure the simulation results of various routing methods we use the topology shown in Fig.2, which is same like as [27] and [28]. 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.

Table I: Parameter Setting For Performance Evaluation over large-Scale CRAHNs

HABC-SOR with VS case in regular CRAHN	
Parameter	Value
$n + 1$	3

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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)
μ	200(pkt/sec) in CRAHN, 50 (Pkt/sec) in wireless network

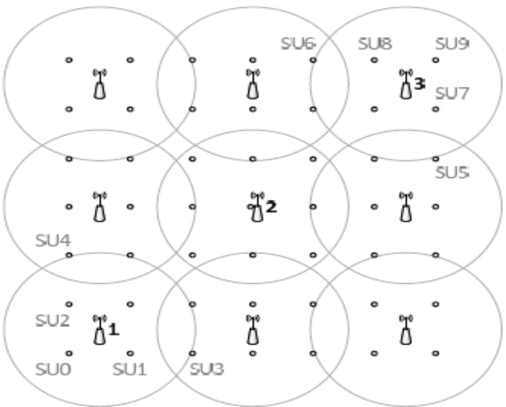


Fig.2. Simulation topology

Throughput comparison: In order to measure routing methods such as 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.

$$\text{Throughput} = \frac{\text{packet received}}{\text{amout of packet forwarded}} \qquad (20)$$

In Fig. 3, 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) respectively. Again, HABC-SOR outperforms when compare to other routing protocols. Since the research HABC-SOR algorithm might be to study the relationship among end-to-end delay and throughput.

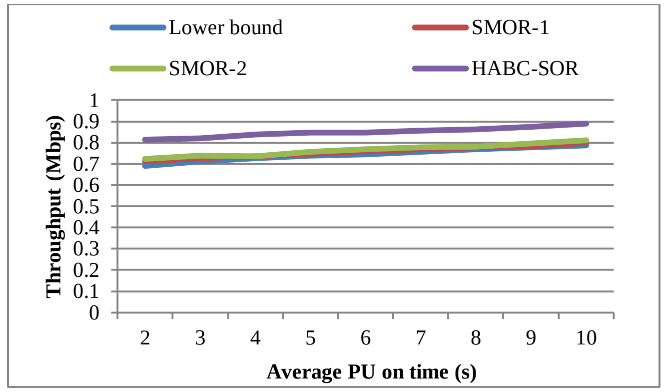
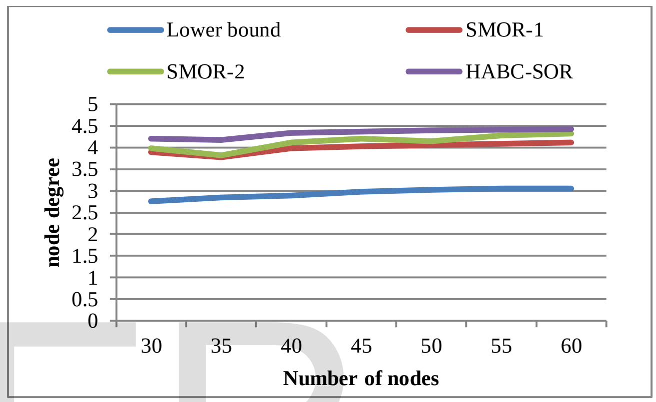
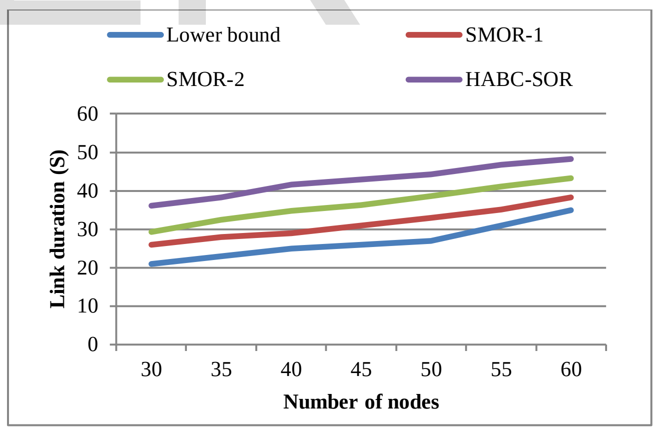


Fig. 3. Baseline throughput comparison, the data points for methods , Avg. PU ON time = 6 sec



(a) Node degree



(b) Link duration

Fig.4. Baseline throughput comparison, the data points for methods

Fig. 4 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. 4(a) examines the resulting of various routing Lower Bounds, SMOR 1, SMOR-2 and HABC-SOR methods under average node without topology control. It observed that the results of HABC-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. 4(b). 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 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.

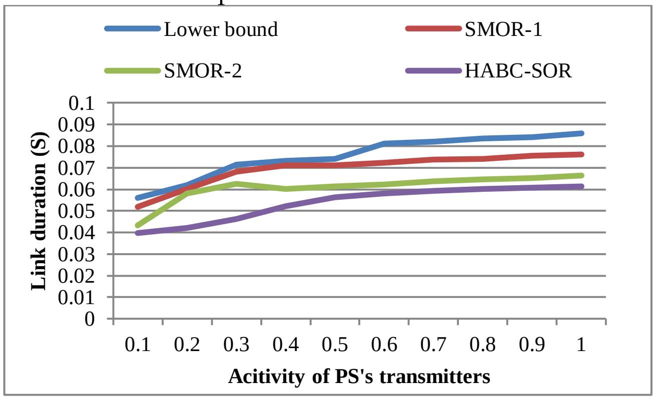


Fig.5. End-to-end delay with respect to PS-Txs' activities

Under different opportunistic routing algorithms in the network is characterized by activity of PS-Txs, Fig.5 shows the better performance of HABC-SOR from its cooperative variety gain through the aid of cooperative relays.

5 CONCLUSION AND FUTURE WORK

In Cognitive Radio Ad Hoc Networks (CRAHN), Cognitive radio technology will have significant impact on upper layer performance .This paper proposes an algorithm called Hybrid Artificial Bee Colony based Spectrum Opportunistic Routing (HABC-SOR) to provision cognition capability to the routing protocols in CRAHN, aware of information aggregation platform , interference , duration and end-to-end transportation for wireless fading channels. The spectrum map serves as an information aggregation platform to dynamically update all kinds of sensing and inference results. ABC initialization methods can affect the quality of the solutions and the convergence speed. Hence, the HABC-SOR algorithms are proposed to establish reliable end-to-end transportation and throughput. Proposed work is designed for regular CRAHNs, SMOR-1 is incorporated to HABC which need to satisfy orthogonal property among Primary System(s) (PSs') and Cognitive Radios (CRs') spectrum practice in the spatial domain. On the other hand, SMOR-2 is also incorporated to HABC which needs to satisfy spatial reuse in a specified geographic area by allowing CR simultaneous transmissions in CRAHNs. Proposed HABC-SOR evaluates the routing performance metrics such as end to end delay and throughput through computer simulation. In future work, extract the information of physical transmission qualities in spectrum map and experiment using practical testbed. In Future work, routing is also performed based on multimedia applications in Cognitive Radio Networks (CRN) with security and admission control issues in heterogeneous networks.

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