NRPCAN : A NOVEL ROUTING PROTOCOL FOR COGNITIVE AD-HOC NETWORKS

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Received: 16 March 2020 Revised and Accepted: 17 June 2020

ABSTRACT: The cognitive radio networks (CRNs) enhance spectrum usage by imparting an authorized spectrum with CR gadgets. In CRANs, the routing protocol will be a very problematic task because of modifications interrupted connectivity & frequency spectrum caused by the activity of the primary user (PU). In this manuscript, a “Novel Routing Protocol for Cognitive Ad-hoc Networks(NRPCAN)” is introduced. The convention uses channel accessibility & makes various node disjoint routes among “source & destination nodes”. The suggested convention will be contrasted with FTCRP& SEARCH conventions. The presentation assessment is conducted through scientific examination and utilizing OPNET simulation. The execution of suggested protocol accomplishes an expansion in throughput of the network; other than it diminishes the route failure probability because of PU activity & mobility of node. We have discovered that NRPCAN method outcomes in 35% to 80% enhancement in throughput of the network, with sensible extra routing overhead & average packet delay. Because of the successful decrease of impact among PUs & cognitive users, the NRPCAN method outcomes in diminishing the path failure rate by 52% to 88%. Keywords: Cognitive radio networks (CRNs), cognitive radio ad hoc networks (CRAHNs), Primary users (PUs), frequency channel (FC), channel activity table (CAT)
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I. INTRODUCTION

The developing field of CRNs will be geared to address expanding “congestion in unlicensed band” by utilizing an empty spectrum, like public service, frequencies licensed for transmission, among others [1]. Though there are impressive research exertions in devising proficient “spectrum sensing & sharing methods” at the level of the node, it will be significant to consistently incorporate these plans in executions of end-to-end network conventions. Furthermore, when PU is recognized, routing protocol should make an important choice of either (i) exchanging channel in an influenced bit of route, or (ii) going through totally various areas together, therefore expanding latency. The often changing PU movement & CR user’s mobility make the issue of maintaining “optimal routes in ad-hoc CR networks challenging”. In this manuscript, we introduce NRPCAN. This convention depends on “geographic routing”, that adjusts to dynamic spectrum accessibility& mobility of node, whereas attempting to handle end-to-end connectivity.

The CRAHN topology often modifies because of intermittent PU activities & mobility of node, prompting to route failures. This creates the task of routing is much challenging.

The routing in CRNs is earlier surveyed to offer reliable ways for effective spectrum sharing specified the frequent modifications of “wireless network topology”. The routing in CRNs has correspondences with ad-hoc networks in terms of routing in multichannel, multi-route. They show diverse problems with respect to the dynamic conduct of Pus & their impacts on modifying the accessible spectrum bands to utilize. The primary difficulties of “routing protocols in CRAHNs” incorporate the accompanying [1]:

(1) The consciousness of the spectrum will be needed to take very exact choices, as in [2].
(2) The “traditional route quality measures” must be combined with new dimensions on spectrum accessibility& path stability [2].
(3) The unpredictable &“frequent route failure” requires efficient maintenance of the route to re-establish "broken" ways with the least impact on apparent quality [3].

The current works in “CRAHN routing protocols” might be characterized dependent on their help for the accompanying [4]:

(i) The routing with choice of the spectrum, which is a joint spectrum choice with the decision of subsequent hop sending node.

(ii) The routing with the awareness of PU &joint spectrum choice, whereas CUs have capable to recognize the areas of PUs & route [5].
(iii) The routing with reconfigurability & joint spectrum choice, whereas route, might be adjusted with local spectrum modifications of sending nodes together.

In this, an article suggests a "novel disjoint multipath activity based routing protocol for CRAHN". The strategy enhanced will be capable to create at least 2 node disjoint routes among "source & destination nodes", with least "PUs activity value". In this situation, route failure outcomes because of node mobility are handled over other routes to discover other node increments, the association failure probability diminishes. Furthermore, at any rate, 2 channels with various frequencies were made over every route to secure the route from failure because of PU activity. Throughout information transmission, if the association will be interrupted because of PU activity over 1 of 2 frequency channels, thus the FC will be currently inaccessible. Then there will at least another accessible FC per route utilized to recuperate a novel FC if conceivable.

Every route comprises at least 2 FCs having least activity elements. The suggested convention partitions every FC into various time slots to permit different CUs to utilize them at the same time. In view of this case, the suggested method evades utilize of channels with high PUs action in routes, subsequent in lessening the probability of path failure &blocking, and enhancing the complete execution of throughput for network.

The remainder of this manuscript will be composed as follows. Segment 2 sums up the review of the literature. Section 3 about the operation of suggested protocol & network method. Section 4 presents the performance evaluation & experimental outcomes. At last, section 5 presents the conclusion of this manuscript.

II. RELATED WORK

The routing will be a well-surveyed region in "classical ad-hoc networks with protocols" intended for different mobility contemplations, hardware assumptions. The SEARCH protocol will be intended for CR networks &varies from a common class of "protocols for ad-hoc networks" in its deliberation of (i) Areas influenced by activity of PU, (ii) consciousness of "dynamically changing channel condition". In this segment, we explicitly concentration on present distributed &"centralized routing protocols" for CR systems. We additionally examine methods dependent on the rule of geographic routing that will be a vital part of SEARCH.

The incorporated system introduced in [6] characterizes "link disruption probability" to simulate the activity of PU. It will be accepted that this probability will be recognized before network activity through a few assessment procedures. The routing issue will be planned as an optimization aim, which limits total average delay that will be described by: (i) the information volume is should be sent, (ii) the path mean ability as link & spectrum disruption probability functions, (iii) propagation delay of channel. Centralized methodology [7] represents flow fairness in the total information of flows among any 2 nodes that will be recognized. Here, a network-wide optimization issue will be resolved &consistent factor approximation to optimal result is given. In [8], a graph-theoretic method is suggested, where "time slots &non-overlapping channels" over 2 hop ranges have appointed through the formation of autonomous sets, whether the whole graph of the network has recognized. The 2 routing algorithms, which need network topology at every node have given in [9] to enhance the path latency & some channel switches, separately.

In [10], a layered chart is built that has accessible channels in a vertical layer, &classical network chart demonstrating the hub adjacencies along with every layer. The nodes in the correspondence range on the provided layer have a "horizontal edge" among them. Complete channels are operational at the provided node are associated with "vertical edge". The expenses of edge traversal are suitably set contingent upon time charge of exchanging a vertical edge as against sending of the packet on a horizontal edge. The routing issue might now be stated as discovering the smallest path in this changed graph. Though, in mobile networks, gathering the whole "network topology" will be infeasible. This methodology helps as "optimal centralized result for routing methods with static topologies".

The formation of the route in "SEARCH protocol is based on geographic routing". This standard is utilized in GPSR, which attempts "greedy forwarding" under typical situations &goes into edge mode when a void is experienced [12]. To avoid this void, it needs the structure of the planar chart of the network at every node at total times [13]. But, this establishes an overhead as only some chosen nodes require participating in "perimeter forwarding mode". The standard GPSR is changed for specific application situations like mobile vehicular networks in GPSRJ++ [15] & GPCR [14]. Despite the fact that these efforts feature enhanced route maintenance capability under mobility presumptions &defeat the requirement to handle planar diagrams, they require street-level information of junctions & roads, in this manner limiting their application.

In [16], [17], the mobility deliberations have addressed local single-hop data. By assessing the velocity-dependent on location updates by signal messages, a node might calculate when the subsequent hop goes out of extending in [17]. Also, the creator's guarantee that huge packet loss happens at the penultimate hub in the path, whether the destination is moved from the original area, however, is as yet present inside its transmission go. By basically trying for goal hub at each bounce, before avariciously sending the bundle, some strength to goal-related versatility is accomplished in [17]. But, this neither gives a result to "large scale destination mobility nor re-evaluates the optimality cases" of the present path intermittently, dissimilar to our suggested NRPCAN convention. In overview, conventions dependent on "geographic forwarding" have presently devised for "single-channel networks"& no help for CR particular problems.

As the activity of PU differs in space & frequency domains, diversity of methods might present an effective path to address this issue. In [18], routing protocol in route finding procedure gives multipath multi-channel routes, subsequent hop routing will be is adopted as routing metric. This method enhances the overhead & complexity of the procedure of "route discovery". Definitely, it needs the RREQ broadcast packet back to the source that needs a much resource consumption &bigger routing table.

In [19], the authors suggested "Cognitive Ad hoc On-demand Distance Vector (CAODV) routing method" that enhance the presentations by exploiting the benefit of accessibility of numerous channels & execute a joint path & selection of channel & evade PU activity areas without need that any "dedicated control channel" evaluates the value of any accessible channel to limit route charges.

In [20], this manuscript concentrates mostly on presenting a "reactive routing protocol" by evading interfaces with PUs, through information sending & formation of the route. The suggested method gives models to adopt "dynamic spectrum accessibility" during information communications to enhance the complete presentation of CUs. Nonetheless, this protocol is problematic since it needs the accessibility of an idle channel. It exploits the accessibility of numerous channels to enhance the exhibition of CUs, yet the impacts of PUs activities might still destroy the presentation.

Recent work suggested named "joint path & spectrum diversity in CRAHNs (D2CARP)" [21]. The researchers suggested "joint exploitation of spectrum & path diversity" for efficient utilization of spectrum in CRAHNs. By mutually abusing both diversities, CUs might move powerfully to various ways and "Spectrum bands" for corresponding with every other in the existence of PU activity.

In [22], "Fault-Tolerant Cognitive Ad hoc Routing Protocol (FTCARP)" is presented as a quick & effective route recovery in the existence of path failures while information delivery in CRAHNs. In FTCARP, a backup path will be promptly used path failure happens over an essential transmission route without affecting a serious assistance interruption. The suggested protocol utilized a diverse route recovery method to control diverse reasons for "path failure". Over simulation, it was demonstrated that protocol accomplished the best presentation of the network regarding normal "throughput and end-to-end delay" as contrasted with past D2CARP protocol.

In [23], the "Spectrum Aware Routing for Cognitive Ad-hoc Networks (SEARCH) protocol" dependent on geographic routing is suggested that adjusts to the mobility of node & dynamic spectrum accessibility, whereas attempting to handle end-to-end connectivity.

III. PROPOSED NRPCAN PROTOCOL

This segment portrays vision to limit the impedance among PUs & CUs in CRAHN &expand the usage of spectrum. The suggested protocol will be a "reactive multipath routing protocol" dependent on "Ad hoc on-demand Multipath Distance Vector (AOMDV) routing protocol" [11]. The primary objectives of suggested "multipath routing protocol" is to (1) decrease interference PUs to diminish route failure probability, (2) decrease route break because of PUs activity & CUs node mobility, (3) increment spectrum usage by expanding the quantity of CUs utilizing the accessible spectrum, &(4) increment the general network throughput.

The NRPCAN convention accomplishes these objectives by utilizing various components, expressed as follows.

(1) Low Activity Node-Disjoint Routes: For every association demand, the suggested convention finds a few “node disjoint routes”, at least 2 “node disjoint routes”, & reserves at least 2 diverse FCs for every route with least “probability of PUs activity”. Thus, there are at least 4 diverse paths per association. This method is diminishing the “route failure probability” because of PU activity or node mobility.
(2) FC Sharing: Every FC will be separated into various time slots & shared between various CUs; & every CU holds a 1time slot per FC. This expands various CUs utilizing the accessible spectrum.
(3) Local Route-Decision: Every node decides the much “probable idle channel” dependent on its data of PUs activity. Thus, as per the location of PU &its “transmission range”, the most “probable idle FC” will be diverse between diverse CUs nodes. Thus, there is no need for similar FC accessibility in the entire area crossed by the route. Here, every “intermediate neighbor node” is utilizing its local most “probable idle FC” to shape the course.

The principle thought of our suggested method is to productively utilize channel accessibility relying upon CUs detecting history &present “sensing decision of specific mobile PUs activity”. Hence, the utilization of various FCs per “single path &sharing least activity channels” between diverse CUs will expand reuse of frequency & decrease the interference to PU that expands the spectrum usage & the capability of the network. Lastly, by diminishing route failure probability & expanding the numerous CUs & usage of spectrum, the whole network throughput will increment.

1.1 Network Model

In this work, it will be accepted that CRAHN comprises of various CUs assembled with various PUs in a limited 2-D space. Additionally, “bidirectional correspondence symmetry” on each connection among nodes is expected. The CUs have accepted to openly move &PUs, arbitrarily circulated, is thought to be fixed.

The PUs transmission standards & the location has assumed to be unknown the CUs. The spectrum band will be separated into non-overlapping channels & every channel will be utilized by 1 PU. The CUs might communicate by diverse channels through utilizing the accessibility of the free primary spectrum.

The accessible spectrum will be composed of 2 diverse kinds of channels. A typical control channel chose as in [15–17] is utilized by whole CUs for replacing the “control packets for route management”&synchronization determinations. It comprises data about available time slots are every FC utilized for information transmission through CUs. A “data channel (DC)” will be utilized communication of data & it will be thought to be isolated into various “time slots with optimum value 12-time slots” as established through experimentation in Sec 5.

Every time slot comprises of data transmission for every CU. The CUs initially sense spectrum band to check for PUs activity intermittently & upgrade ideality factor as appeared in Figure 1.

Toward the beginning of every data, the frame will be also header field that comprises “source IP address, destination IP address, ID, & packet size”.

Figure 1. Time slot frame

1.2 Proposed Protocol Pre-processing

Dependent on the suggested protocol, the PUs’ activity on every FC will be measured intermittently and signified by diverse numbers that designate the “channels’ ideality factor degree”. This procedure will be proficient while CUs have a sensing spectrum.

The “ideality factor for channel" is estimated as follows:
-----(1)
Here, ( ) be channel accessibility at a specific time,$i($ $-1)$ be channel accessibility history (last time), and $bfi($ $)$ be channel accessibility in current time:

-----(2)
And$a$be forgetting element to handle the impact of earlier sensing history$0 \leq a \leq 1$. Each CU in the "CRAHN network" estimates ideality element for every "channel in the spectrum during sensing period". Then, every CU builds a CAT comprising all sensed channels organized in a descendent sequence of their ideality elements. The CAT also comprises "free time slots" on every channel as represented in Figure 2.
Lastly, every CU might estimate average link costs among node $n$and node $n + 1$ utilizing data discover in its CAT as follows:
-----(3)
Here, $C(\ )$ be the FC cost:
-----(4)
z be the complete amount of FC accessible, and Tube amount of "busy time slots", Tsbe whole amount of time slots, and ratio Tu/Tsbe utilized for load balancing.

1.3 Protocol Operation

The suggested protocol will be an "on-demand multipath routing protocol" & will depend on AOMDV with a small change to create a low action hub disjoints ways among "source & destination nodes". The protocol operates in 3 stages: route discovery stage, information sending stage, & route maintenance stage.

1.4 Route Discovery Phase

The source node (SN) starts a "route discovery procedure through broadcasting a route request (RREQ) packet" to every neighbor CU, through basic control channel with information, whether there are general routes among SN& its neighbors. At that point, SN waits for "route reply (RREP)". The RREQ packet comprises CAT of SN, & path cost field with zero.

1.5 Data Forwarding Phase

In the data forwarding stage, the SN segments the information flow &sends it on accessible paths by hopping on distinctive FCs produced during the coordinating procedure.

1.6 Route Maintenance Phase

Through data transmission, a route break might be affected by mobility of node.
(1) Node Mobility: When intermediate hub distinguishes a connection failure because of "node mobility", it produces a "RERR packet"& unicast it to SN over the route with failed connection, the SN, & all "intermediate nodes" about triggers & route failure SN to start "novel route discovery process".
(2) PU Activity: When, an intermediate node nk recognizes a PU activity over FC fi, it produces a specific REER packet named a "Locally REER (LREER) packet" &sends it to the neighbour hub nk+1 imparting this FC to it over other normal FC utilized. At the point when the neighbor hub nk+1 get "LREER packet", it upgrades its CAT& unicasts it to hub nk utilizing a "channel-request (Ch-req) packet". Node nk scans for match & sends "channel-replay (Chirp) packet" comprising nominated novel FC to hold and fix the broken route.

1.7 Frequency LockedMechanism (NRPCAN + F)

Through route discovery stage of NRPCAN protocol & after coordinating procedure at intermediate nodes, every node holds coordinated channels $(fi, Tfi) \cdot (fj, Tfj)$ without updating "upstream neighbor node" about this booking. In this way, through the RREP packet going up from "destination to the source node, intermediate nodenk+1" will request from upstream neighbor node nk to hold time slots, it held to frame the sending. Because of time delay among RREQ &its comparing RREP packets going through this node, the mentioned resources by hub nk+1 might be utilized by node nk for another association, so route discovery procedure will fail that increment blocking probability.

To adapt to this problem, we adjust the "route discovery stage" as represent in Figure 3. Throughout the "route discovery stage", while any "intermediate node F" gets an RREQ and executes coordinating, it sends an "Immediate Response (IR) packet to upstream neighbor node C" that sent RREQ. This IR packet comprises the outcomes of coordinating procedure (fi, Tfi). At the point when node "C" gets IR packet, it incidentally chooses the requested resource with timeout until the RREP packet will be received. At that point, node "C" sends "ACK packet to node F" if chose (fi, Tfi) will be yet appropriate.

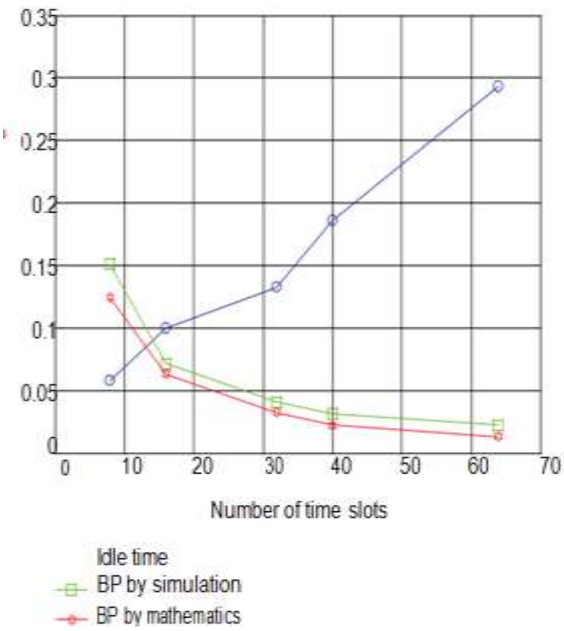
Nevertheless, if (fi, Tfi) discover in IR packet are busy, node "*C*" sends a "NACK packet" comprising its CAT to node "*F*" to find for the extra match. This procedure will be repeated until 2 nodes lock on minimally 2-time slots at 2 diverse FCs. This "frequency locked mechanism" is capable to decrease "route discovery failure" that increments whole network throughput.

The disadvantage of this method will be additional "control packets" utilized during "route discovery phase".

III. SIMULATION RESULTS

In this segment, we have selected OPNET [23], meanwhile, it is complete, in graphical modeling, the industry's leading network, & a simulation platform to execute the presentation of NRPCAN protocol. Throughout the simulation, the network node will be in 100×100m2 areas with "60 moveable CUs". Every node's transmission range is 25m with irregular "path point mobility". The nodes have corresponded with one another by utilizing the IEEE 802.11n MAC layer protocol. Therefore, the CUs might utilize 12 frequency channels partitioned into 128 msslots. In the application layer, nodes communicate utilizing 12 frequency constant "Bit Rate generators (CBR)". Every generator generates "information packet 512 bytes at 10 packets" per each second. The execution time will be fixing to 300 seconds. Every reproduction is repeated 4 times & then "average values" of their outcomes have taken to guarantee integrity.

Initially, the optimum amount of time slots for each FCs to diminish the "connection request blocking probability" should be discovered & then increases flow time usage. From Figure 2, it might be noticed that the optimum amount of time slots for FC will be 12-time slots. The fundamental focal point of simulations will be to assess our suggested protocols contrasted with FTCARP & SEARCH protocols.



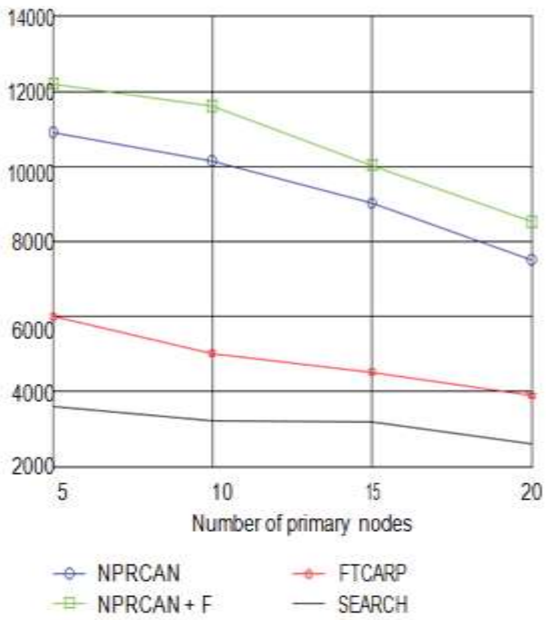
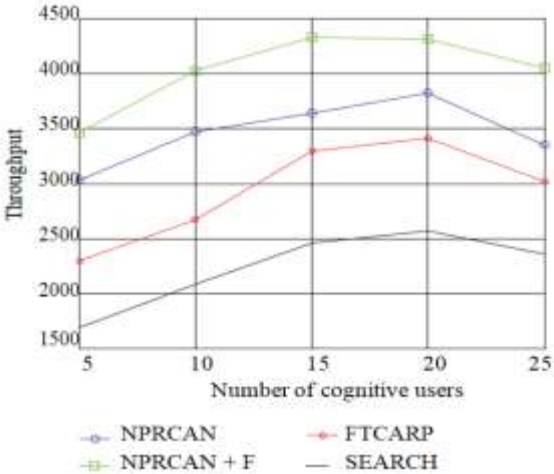


Figure 2: Per flow time usage vs number of time slots. **Figure 3: Throughput vs number of primary users.**



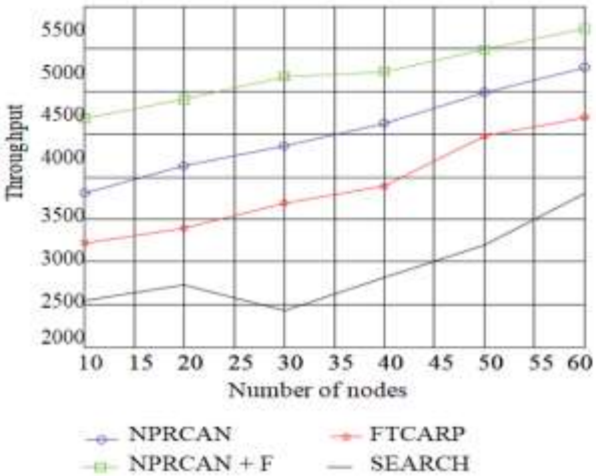


Figure 4: Throughput versus number of cognitive users. Figure 5: Throughput vs number of network nodes

In OPNET, throughput will be distinct as total "number of successfully transmitted data packets per simulation time".

$$\text{Throughput} = \frac{\sum \text{actual successfully transmitted data packets}}{\text{Total sent number of data packets}}$$

From Figure 3, it might be observed throughput diminishes as amount of PUs increments. This is because of existence of PUs that diminish amount of accessible "frequency channels for Sus", thus amount of data packets are diminish. Moreover, it might be observed NRPCAN protocols increment network throughput to 87% above SEARCH and 91% above FTCARP protocols. This is because of sharing of less active (PUs activity) channels among CUs &utilization of multiple paths.

Figure 4displaysoutcomes of number of CUs versus network throughput. It might be observed the NRPCANprotocol is dominant &NRPCAN + *F* protocols are finest. This is because of utilization of paths with lesser "probability of PU activity"& because of frequency sharing between CUs. Figure 3also represents as amount of CUs increments (> 20) & diminishes throughput. This will be because of increment in number of CUs that increments collision probability.

Relation among amount of network nodes & throughput of network is presented in Figure 5. The detected presentation is reasonable by "high diversity of routes" attained with higher amount of CUs that diminishes "connection blocking probability" & increments whole "network throughput". It might be observed that "NRPCAN protocols" increment throughput of network on average by 35% above "FTCARP protocol" and 80% over SEARCH protocol.

4.2 Delay

Delay will be estimated as average delay encountered by transmitted packets.

$$\text{Delay} = \frac{\sum \text{delays encountered by every transmitted packet}}{\text{Sent number of packets}}$$

It will be observed that suggested method executes higher delays, particularly for NRPCAN + *F* scenario because of "ACK/NACK feedback messages & multi route discovery algorithm". Furthermore, delay is incrementing function in amount of PUs because of least probability of obtaining time slots & idle frequenciesto be employed by CUs.

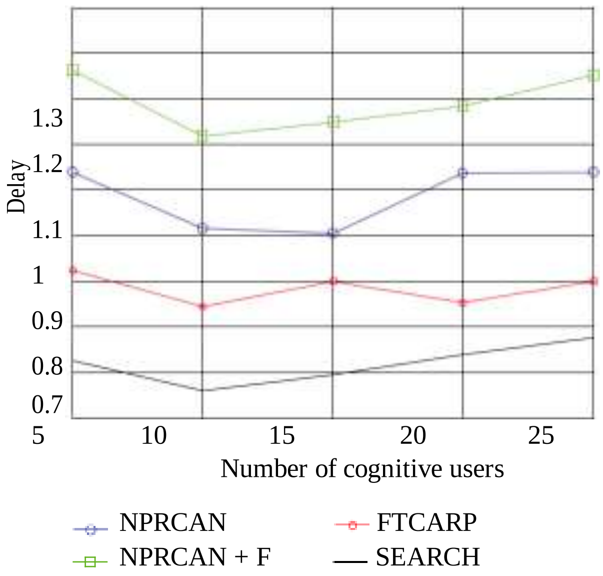


Figure 6: Delay vs number of cognitive users.

Figure 6 displays the outcomes of "average delay" encountered by the packet versus the number of CUs. It is noted that the suggested protocol pays a price in terms of increasing the packet delay.

IV. CONCLUSION

In this manuscript, NRPCAN protocol & its altered version NRPCAN + F have suggested for mobile CRAHNs. The execution of the suggested protocol with FTCARP & SEARCH routing protocols were analyzed. And furthermore, a systematic method & presentation assessment of "connection request blocking probability of NRPCAN multi-path routing protocol" is given &compared at single route SEARCH & FTCARP protocols.

The suggested protocol to diminishing the collision probability among PUs & CUs and enhances the throughput of the network. Likewise, it effectively diminished the "association blocking probability", particularly in a dense network, &decreased the amount of ailed paths because of the activity of PU & mobility of node, however, with increment in average overhead & packet delay.

Through experimentations, we demonstrated that suggested protocols expand the throughput of the network on average 35% above FTCARP convention and 80% over SEARCH protocol.
The suggested protocols diminished the amount of failed paths because of node mobility on average through 45% below "FTCARP protocol"& 60% below the SEARCH protocol. In this manner, NRPCAN prevailing with regards to discovering low "PU activity routes", sharing these routes between diverse CUs that diminishes various failed paths &blocking probability & enhances the throughput of network with little expansion of routing overhead &increment in "average packet delay".

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