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A CRN Based Radio Resource Optimization using Machine Learning

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Abstract: Cognitive radio networks (CRNs) have been widely used in various applications for the effective radio spectrum utilization in recent years. It is essential for fend off the growing demand for this finite natural resource for next-generation communications. In CRNs, detecting the activity of primary user requires opportunistic spectrum sensing of efficient usage in available radio spectrum, which is an limited for exquisite resource. Thus, CRNs key component in solving the spectrum scarcity issue in presence of primary user bands through secondary users. Cognitive radio Ad-Hoc networks (CRAHNs) are unique kind of CRNs where infrastructures less cognitive radio (CR) nodes are furnished. In CRAHN, the CR-MAC protocol works slightly different to the traditional wireless network MAC protocols. This proposed method such as high traffic scenario under contention-based IEEE 802.11 DCF MAC protocol. Accordingly it can be observed that both throughput and delay increase as the CW size and packet length of the 802.11 (DCF) MAC protocol for CRAHN varies. The experimental result of proposed framework for CRAHN with FIS shows that altering contention window increases throughput by 70% to 75% and reduces the delay by 25% to 30% compared to the IEEE802.11 (DCF) protocol for CRAHNs without FIS. Moreover, it is also revealed that the throughput is increased by 75% and the delay is reduced by 25% due to altering the packet length.
***Keywords**: Cognitive radio Ad-Hoc networks (CRAHNs), MAC protocol, 802.11 (DCF), Radio Resource optimization Model, Throughput, Latency, Packet loss ratio.*

I. INTRODUCTION

The CRN architecture is an framework that specifics the physical components of the networks along with operational principles and procedures. In a network-centric architecture, CRN can only communicate with Base Stations (BS). On the other hand, ad-hoc architecture communication between two neighboring cognitive nodes can happen. when these two nodes are tuned to be same channel. Since the cognitive radio ad-hoc network, an each node has its own accessible channel set, two neighboring nodes need to have at least one common channel in their accessible channel sets to make communication.

The infrastructure-based CRN is a network-centric architecture, where the key components for the architecture are cognitive terminal (CT)/cognitive radio (CR) and the BS.

An infrastructure-based architecture, CTs can only communicate with the BS. Thus, the two CTs want to be communicate with each other, BS needs to be used as the intermediate node and mesh networks, the cognitive radio mesh architecture is the combination of the infrastructure and ad-hoc architectures. Such that the architecture communication between the BS to BS or BS to CTs can be single-hop or multi-hop through the spectrum holes. CR improves spectrum efficiency by opportunistic spectrum access when the PU does not occupy the licensed spectrum.

Wireless CRN needs to vacate from channel upon the detection of the PU's in presence of protect PU from harmful interference. To achieve the fundamental CR functions, the CRs usually coordinate with each other by using an common medium for the control message exchange.

Control message exchanging is classified into two types, they are using the common control channel (CCC) technique and another one is using channel-hopping technique(CHT).

Cognitive Radio Networks (CRNs) are an advanced wireless communication technology designed to improve spectrum utilization and efficiency of CRNs introduce dynamic spectrum access, allowing unlicensed (secondary) users to use licensed spectrum without interfering with the primary users.

Therefore, designing an routing protocol in cognitive radio ad-hoc network is more challenging. Similar to any other ad-hoc networks, single-hop and multi-hop are the types of communication that can take place also in cognitive radio ad-hoc networks.

It Can dynamically select the best frequency band for communication, ensuring low latency, high speed, and stable connectivity. Prioritizes critical applications by adjusting spectrum allocation in real time.

II. ARCHITECTURE OF COGNITIVE RADIO NETWORK

The CRN architectures can be classified into infrastructure-based CRN, cognitive radio ad-hoc network and cognitive radio mesh network.

A decentralized and self-configured network is considered as the ad-hoc network, where the network is does not depend upon pre-existing infrastructures. The decentralized feature of the wireless ad-hoc networks allows the network to be more scalable. Moreover, the swift deployment and minimal configuration to make wireless ad-hoc networks suitable for emergency situations like natural calamities or military conflicts. Thus, cognitive radio ad-hoc network is an ad-hoc network that needs to consider the spatial and temporal variance of spectrum and to protect the PU transmission.

These criterions primarily differentiate cognitive radio ad-hoc network from other traditional ad-hoc networks. In cognitive radio ad-hoc network, each CR observes different channel availability according to the primary user's activity.

However, traditional ad-hoc network (such as MANET or WSN) usually operates on predefined channel, which remains unchanged with time. In other word, cognitive radio ad-hoc network needs to consider the PU transmission to avoid any interference with the licensed user, which are entirely missing in traditional ad-hoc networks. These kinds of consideration are not required in QoS calculation of traditional ad-hoc networks.

Single-hop communication refers the source and destination within the communication range of each other where source can directly communicate with the destination.

However, the destination node is not within the communication range of the source. Thus the architecture of CRN can be shown in the figure 2.1

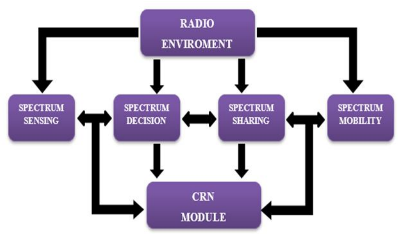

Fig. No: 2.1 Architecture of CRN in Spectrum Module

III. PROPOSED WORK

Cognitive Radio Networks (CRNs) play a vital role in radio resource optimization algorithms within wireless networks. The Radio resource optimization algorithms aim to enhance the efficient utilization of limited spectrum resources while ensuring minimal interference and maintaining Quality of Service (QoS) for users.

An ad-hoc network that comprises the self-organized CRs is considered as the CRs have sensing ability to utilize the free spectrums in a distributed manner. Both PUs and SUs co-exist in the network of the SUs transmission is sensed. It also assumed that there exists a global common control channel in the network. In the proposed protocol, a simple interference avoidance model are assumed to avoid interference between PUs and SUs. It is also assumed that every CR is equipped with two transceivers, such that one transceiver is used for control and the other one is used for data transmission. The transmission range for all of the radios is considered to be equal to the location aware.

Each CR has been computational capability to calculate the CHDF and also aware of CHDF values of the neighbors. In the network the radio spectrum is distributed into non-overlapping orthogonal channels within distinctive channel ID for each channel. SUs have only utilize PUs' licensed spectrum once PUs' transmission is absent. Depending on the physical position, channel availability varies from node to node.

In CRAHN, SU observes a local radio environment to identify the presence of PU's transmission and accordingly recognizes the current spectrum availability. It is assumed that the CRs use energy detector based spectrum sensing method to identify the spectrum availability. This is because, implementation of energy detector (non-coherent detector) is simple. Energy detector is also considered to be an optimal detector of unknown signal where noise power is known. Thus, efficiency of energy detector depends on the strength of the received signal, noise characteristics of the receiver and sensing duration.

The clustering mechanism proposed in this article are independent of any precise PU activity model. The Semi-Markov ON-OFF model is considered to be offer an analytical performance evaluation of the proposed clustering scheme, where the Semi-Markov ON-OFF process is modeled on any channel for the PU traffic.

Busy (ON) or idle (OFF) are the two states that have been considered for any channel. The length of the busy or idle period is anticipated to be an autonomous random variable. These hypothesis is anticipated to be proper as the dynamically based on user mobility , network load and service.

In the proposed protocol, every cluster consists of a leader node called Cluster-Head (CH), where the CH coordinates both are intra-cluster and inter-cluster communications.

Once the network is clustered, then each cluster has its own control channel and Moreover, a node that is situated at the border of two neighboring clusters is termed as FN. Since any FN can hear beacons from both clusters, CH uses FN for inter-cluster communication. However, due to a sudden appearance of PU, the common channel of a cluster can become inaccessible.

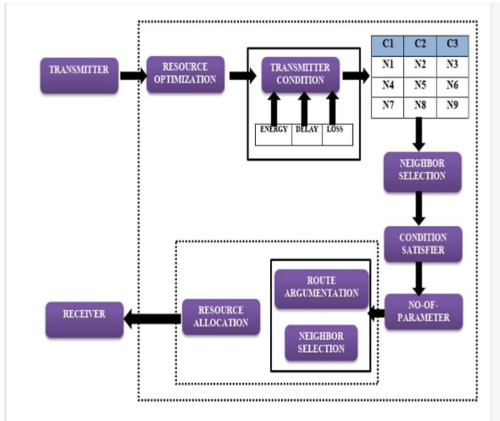

Fig. No: 3.1 Block diagram radio resource optimization algorithm

In network communications, particularly wireless and cellular networks, a Radio Resource Optimization (RRO) algorithm is a method or set of procedures.

Hence, SU only operates on the free available channels and SU has to vacate channels wherever PU's have a designed to efficiently allocate, manage, and adjust radio resources (like frequency channels, time slots, transmission power, and bandwidth) to maximize network performance on user mobility, network load, and service requirements (e.g., voice, video, or data). Therefore, RRO algorithms typically include functions like Load balancing (distributing users across different cells or frequencies)

- Power control channel (adjusting transmission power to reduce interference)
- Hand-over management (ensuring smooth transitions between cells)
- Scheduling and resource allocation (deciding which users get what resources and when)
- Interference co-ordination (managing cross-cell and in-band interference)

Some Examples of Radio Resource Optimization techniques as follows

- Dynamic Spectrum Access
- Proportional Fair Scheduling
- Cognitive Radio techniques
- Self-Organizing Networks (SON) mechanisms
- Beamforming and MIMO optimization in 5G networks

The total delay of link T can be expressed by δT_L where δT_s is the switching delay, δT_B is the back-off delay and δT_Q is the queuing delay of link T.

The goal is to enhance key metrics such as throughput, coverage, capacity, energy efficiency, and quality of service (QoS) while minimizing interference and resource wastage. Radio resources are finite, and demand can vary the node of it.

The main objective of the proposed clustering scheme in the protocol is to allocate the maximum number of idle channels for intra-cluster communication with a reduced number of clusters.

To carry out this objective, a parameter called Cluster Head Determining Factor (*CHDF*) is introduced. *CHDF* concentrates on two parameters; number of neighboring nodes and number of common channels, where values of these two parameters are obtained from the maximum edge biclique graph. Every cognitive node in the network computes *CHDF* based on Equation 3.1, which is shown below

$$CHDF_i = \sqrt[ci]{c^\wedge Ni} \quad \text{--------------} \quad 3.1$$

Topology management in Cognitive Radio Networks (CRNs) refers to the process of organizing and maintaining the network structure to optimize communication, resource utilization, and energy efficiency. It involves dynamically adapting the network topology based on spectrum availability, node mobility, and environmental conditions. This ensures efficient operation, reduced interference, and enhanced fault tolerance in wireless networks.

Hence, path that ensures lesser delay is selected by the proposed routing protocol to deliver the message. It is expected that the proposed clustering scheme identifies stable nodes as CHs and FNs. Moreover, In the intermediate nodes or the relaying nodes of a route are also the CHs and the FNs. In the protocol, delay is considered as the routing metric where three types of delay are considered, namely switching delay, back-off delay and queuing delay.

Hence, the total Link Delay (δTL) is defined as the arithmetic sum of these delays, which is expressed as the equation 3.2

$$\delta_T^L = \delta_T^S + \delta_T^B + \delta_T^Q \quad \text{---------------} \quad 3.2$$

where, T is an intermediate link, which is positioned on the path from the sender node CRs to the destination node C_{Rd}.

Thus, if a node requires channel switching to deliver the message to its next hop, time required for this switching purpose is considered to be a non-zero value

In this paper, the channel switching time is termed as Switching Delay (δ_S), where δ_S depends on the relative positions of the two channels in the channel set.

Thus, if any node CR_i forwards message to the next hop CR_j, where CR_i needs to switch from a-th channel of AC_{Li} to b-th channel, the switching delay can be expressed as the equation 3.3

$$\delta_{i.j}^S = k*|a-b| \quad \text{--------------} \quad 3.3$$

Here, k is considered to be a positive real number where k is determined by the tuning delay of two neighboring channels for a particular step size.

In the network, a CH waits for a random time before it broadcasts the beacon. CH uses the random back-off time to avoid collision when multiple neighboring cluster-heads intend to use the same channel.

Moreover, because of the back-off period for the beacon message, other mini-slots in the super-frame are also delayed. Thus, for Ni contending nodes on a given channel Ci with a contention window size of wrong channel occupancy (WCO) and PC be the probability of collision, δ_B for C_{Ri} can be determined by the following equation 3.4

$$\delta_i^B = \frac{1}{(1-p_c)\,(1-(1-p_c)^{Ni}-1)} wc_o \quad \text{-----------} \quad 3.4$$

Thus, if a node requires channel switching to deliver the message to its next hop, time required for this switching purpose is considered to be a non-zero value.

where the neighborhood density refers to the number of 1-hop neighbors of a node.

Let, Ni be the number of neighboring nodes of C_{Ri} where data rate of C_{Ri} is D_{Ri} and packet size is P.

Then, Queuing Delay of upcoming packets (δ_Q) for C_{Ri} can be determined by the following equation 3.5

$$\delta_i^Q = \frac{PN_i}{DR_i} \quad \text{---------------} \; 3.5$$

Therefore, based on Equation 3.5 and considering the results from above equation delay $\delta_i L_j$ of the link that connects C_{Ri} and C_{Rj} can be expressed as follows the following equation 3.6

$$\delta_{i.j}^L = \delta_{i.j}^S + \delta_{i.j}^B + \delta_{i.j}^Q \quad \text{----------} \; 3.6$$

The path delay or route delay is defined as the cumulative sum of link delays for all the links in the route. Thus, considering a route r from a sender CRs to the destination C_{Rd}, the path delay δ_{rP} can be expressed as the equation 3.7

$$\delta_r^P = \sum_{i.jPth\,s,d} \delta^L D_{i.j} \quad \text{----------} \quad 3.7$$

For the proposed route maintenance algorithm, two types of disruption are considered, namely link failure and destination failure. When a link in the routing path is broken, then predecessor node of the broken link sends the route error message to the sender node. Upon receiving the route error message, sender node first removes the current route entry from the Path array.

Afterwards, the sender node removes all the routes that contain the broken link from the Path array. Next, the path selection process starts where the sender node identifies a new routing path using the Route Selection Algorithm.

In the cluster-based network, data traffic flows through the intermediate CHs and FNs, where neighborhood density plays an important role in the traffic flow.

The message may require remaining in the queue for a longer period but the message passes through a dense area.

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Greater energy efficiency under different weighted ranges that ensures maximum clustering for preventing node failures. The time delay is confined for the varying nodes and clustering process both individually and collectively to increase the communication rate. The network stability is retained to achieve better communication between the devices such that the node movements and re-clustering processes are optimized and CMU Monarch projects and Sun Microsystems.

IV. SOFTWARE AND HARDWARE REQUIREMENTS

1) Software Requirements

Operating System: LINUX /UBUNDU//
Software Package: Network Simulation Version-2
Cross platform: VM Ware
Language: Front end - Tool Control language(TCL)
Back end - C++

2) Hardware Requirements:

Processor: Dual Core2.0
Hard Disk Space: Min 10Gb (Package and Library Extraction)
Physical Memory: 2-4 Gb
Input: Standard Pointing device and Keying device
Output: Standard display

A. Network Simulation (NS)

NS are the discrete event simulator targeted at networking research. NS provides substantial support for simulation of TCP, routing and multicast protocols over wired and wireless (local and satellite) networks.

NS Embarked as a variant of the REAL network simulator in 1989 and has evolved substantially over the past few years. In 1995 ns development was supported by DARPA through the VINT project at LBL, Xerox PARC, UCB, and USC/ISI.

Currently NS development is support for DARPA with SAMAN and through NSF with CONSER, both in collaboration with other researchers including ACIRI. NS have always included substantial contributions from the other researchers that including wireless code from the UCB Daedelus.

NS2 provide users with executable command NS which take on input argument, the name of a Tcl is simulation scripting file. Users are feeding the name of a Tcl simulation script (which sets up a simulation) as an input argument of an NS2 executable command NS. In most of the cases, a simulation trace file is created, and is used to plot graph and/or to create animation.

NS2 consists of two key languages: C++ and Object-oriented Tool Command Language (O-Tcl). While the C++ defines the internal mechanism (i.e., a backend) of a simulation objects, the O-Tcl sets up simulation to assembling and configuring the objects as well as scheduling discrete events (i.e., a frontend). The C++ and O-Tcl are linked together using Tcl. Mapped to a C++ object, variables in the O-Tcl domains are sometimes referred to as handles. Conceptually, a handle (e.g., n as a Node handle) just a string (e.g., _O10) in the O-Tcl domain, and does not contain any functionality.

For the documentation of recent changes, see the version 2 change log. NS was built in C++ and provides a simulation interface through OTcl, an object-oriented dialect of Tcl. The user describes a network topology by writing OTcl scripts, and then the main NS program simulates that topology with specified parameters.

Simulation is widely-used in system modeling for applications ranging from the engineering research, business analysis, manufacturing planning and biological science experimentation to name a few Compared to analytical modeling, simulation usually requires less abstraction in the model (i.e., fewer simplifying assumptions) since almost every possible detail of the specifications of the system can be put into the simulation model to best describe the actual system.

When the system is rather large and then complex, a straight forward mathematical formulation can not be feasible. In this case, the simulation approach is fully preferred to the analytical approach. In common with analytical modeling, simulation modeling may leave out some details, since too many details may result in an unmanageable simulation and substantial computation effort. It is important to carefully consider a measure under consideration and not to include irrelevant detail into the simulation. Note that the member procedures and variables in the O-Tcl domain are called instance procedures (instprocs) and instance variables (instvars), respectively. Before proceeding further, the readers are encouraged to learn C++ and O-Tcl languages. NS2 provides a large number of built-in C++objects and its algorithms.

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V. EXPIRIMENTAL RESULTS

A. Throughput Of Radio Resource Optimization

Throughput in wireless networks and communication services refers to actual rate which data is successfully transmitted to the sender and the receiver over a communication channel. It is typically measured in bits per second (bps), kilobits per second (kbps), megabits per second (Mbps), or gigabits per second (Gbps).

It shows the effective data rate and considering all real-world issues be like:

- Signal interference
- Network congestion
- Protocol overhead (headers and acknowledgements)
- Device limitations

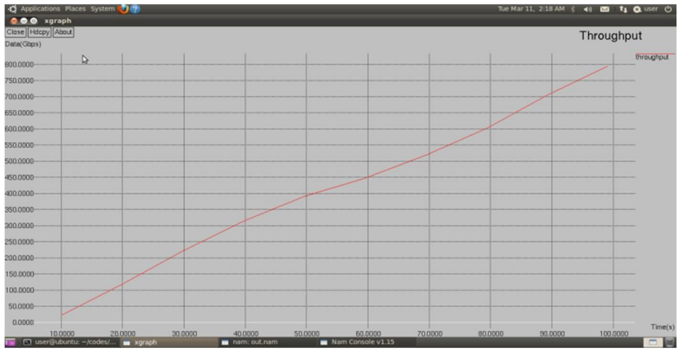

Fig No: 5.1 Throughput of CRN in radio resource optimization

B. Delay In Radio Resource Optimization

Delay is also known as **latency**. It has the **time that takes in a data packet to travel from the source of its destination** across by the network. It is measured by **milliseconds (ms)**.

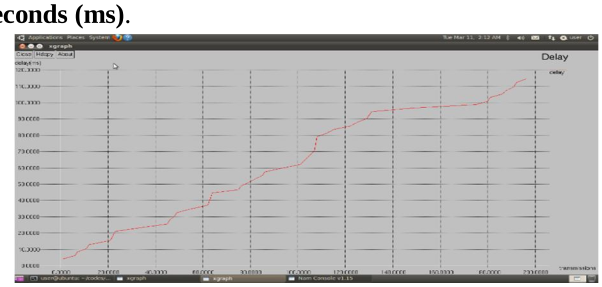

Fig. No: 5.2 Delay in packet loss

The packet is transmitted to transmission medium, that has to go through the medium to reach its destination. Hence the time taken by the last bit of the packet to reach the destination is called propagation delay.

Furthermore, the proposed scheme constructs an lessest number of clusters compared to the other approaches, as the highest number of neighboring nodes is one of the major considerations for the cluster head election in the proposed scheme.

C. Overhead In Proposed System

In a network communication system, overhead refers to an many extra information, processing or time that are needed to manage and support the actual transmission of data is not a actual user data itself.

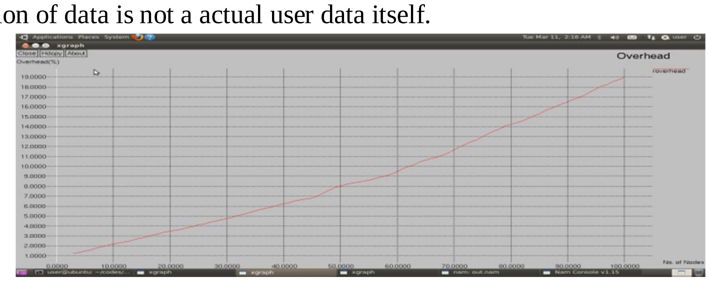

Fig. No: 5.3 Overhead in CRN

In other words, overhead is the cost of making sure data gets transmitted correctly, reliably and efficiently.

VI. CONCLUSION AND FUTURE SCOPE

In this article, a spectrum aware cross-layer MAC protocol for CRAHN is presented.

In the Radio resource method, the clusters are formed based on the parameter called CHDF and The protocol that attempts to maintain the number of clusters lesser while ensuring a stable and suitable number of common channels per cluster.

The suitable number of common channels makes the proposed clustering scheme more robust to varying spectrum availability.

The protocol also introduces secondary cluster head in each cluster, which reduces the re-clustering issue for mobile nodes Thus, less number of clusters leads the backbone to be smaller, which results in efficient and reliable communication. On the other hand, a delay aware routing protocol is presented, where delay is considered as the routing metric for the protocol. In the proposed protocol, link weight is calculated based switching delay, back-off delay and queuing delay

A. *Future Scope*

- In future, the CRN has no delay will be occurred , because of the Communication has growing in day by day. So that we will implement the Federated Learning.
- In network communication systems, a Federated Learning algorithm refers to a decentralized machine learning process where multiple networked devices (or nodes) collaboratively train a shared model without sending their raw data to a central server.
- Instead, they only exchange model updates (e.g., weights or gradients), which reduces privacy risks and communication costs. But the federated Algorithm is testing in ICOM LABS that was located in AUSTRALIA.

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