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RANDOM LINEAR NETWORK CODING IN COGNITIVE RADIO NETWORKS

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Abstract:
Introduction: In the present day, governments mostly manage wireless networks according to a set spectrum allotment scheme.
Aim of the study: the main aim of the study is Random Linear Network Coding In Cognitive Radio Networks
Material and method: When the signalling process between the two mobile phones is complete, a call can be made. Private Branch Exchange (PBX) is used for the signalling.
Conclusion: The findings from the simulation will be summed up here. Time and energy efficiency are two of the most common ways in which RLNC and floods are compared to one another.

I.INTRODUCTION

1.1 ROUTING IN COGNITIVE RADIO NETWORKS: CHALLENGES AND SOLUTIONS

In the present day, governments mostly manage wireless networks according to a set spectrum allotment scheme. Long-term usage of several, typically narrow, frequency bands over large areas is made possible by licencing agreements. The exponential growth in demand for spectrum allotment in recent years may be traced back to the widespread use of wireless applications. Concurrently, the ISM band has become overcrowded due to the widespread adoption of wireless technologies that do not require a licence. The utilisation of licenced spectrum exhibits significant variability and is susceptible to the wireless technologies utilised, the degree of market adoption of such technologies, and the financial performance of the operators granted access to said frequencies. On average, the utilisation of these spectrum bands ranges from 15% to 85%.

The DSA framework facilitates the unlicensed utilisation of licenced spectrum bands in a non-interfering and opportunistic manner. The feasibility of this proposition is attributable to the advancements in software-defined radios (SDRs) that have taken place in recent times. The transceivers that emerge from this process are commonly referred to as Cognitive Radio (CR) devices. These devices exhibit adaptability to their spectral environment by means of modifying their operational spectrum, modulation, transmission power, and communication methodology. Cognitive Radio Networks (CRNs) are established through the interconnection of devices that possess cognitive capabilities. In cognitive radio networks, it is generally understood that Primary Users (PUs), who hold a licence for a particular frequency band, are granted priority in spectrum utilisation.

1.1.1 Routing challenges in multi-hop CRNs

Secondary devices in the standard network architecture described in Fig. 1 share separate spectrum operating parameters (SOPs) from prime users. Due to the intrinsic localization of the spectrum sensing process, the SUs may have various perspectives of the accessible spectrum bands (1..., M) and their respective capacities C1, C2, CM. The PUs is often thought to be stationary, but the SUs' locations may shift somewhat before, after, or even during a gearbox. This poses a significant challenge in terms of routing. However, it presents an additional challenge of managing the transmissions of multiple primary users (PUs) simultaneously, which may impact the accessibility of secondary opportunistic protocols (SOPs). Within this region, there exist three plausible results.

1.1.2 Routing schemes based on full spectrum knowledge

This is to be achieved through the implementation of centrally managed spectrum databases that reflect the availability of channels across time and space. Prior to transmitting or receiving any data, cognitive opportunistic devices must first verify the availability of open transmission and reception paths by consulting these databases. The present configuration enables the spectrum evaluation modules, namely sensing and sharing, to operate autonomously from the routing policies and decisions, thereby facilitating their optimisation at the periphery of the network. This section provides feedback on routing strategies that presuppose complete knowledge of spectrum occupancy and suggests analytical methods to optimize/steer the routing choices.

II.LITERATURE REVIEW

Siddiqui, Muhammad & Khan (2019) The next generation of wireless technology is called Fifth Generation (5G), and it will make use of Cognitive Radio (CR). As more and more smart devices are added to a network, the most recent 4G technology for allocating bandwidth to many smart devices may become obsolete. Next-generation mobile technology is necessary to address the demanding requirement for fast and efficient data transmission across such devices. It is hoped that 5G technology would provide satisfactory answers to similar problems in the written word. While 5G has the potential to significantly increase data transfer speeds, it will be difficult to implement soon. The most effective way to accomplish this difficult task is to make full use of the spectrum's available capacity. CR is an adaptable, smart radio with built-in learning capabilities. It operates on the idea of dynamic frequency allocation, which allows it to reuse the frequency when the principal user is not present. Nodes can analyse and manage unused licenced channels with the help of CR, making it a crucial enabling technology for 5G networks. CR-based 5G cellular networks now have advantages, such as the capacity to adapt to a dynamic network environment, to cope with the spectrum shortage problem, and to function in a diverse setting. It also offers smart solutions and self-governing capacities to support essential 5G features, such as smart beamforming. In this article, we discuss the many advantages of 5G technology, the technologies that make it possible, the problems it faces, and the answers we have come up with. Spectrum sensing methods and CR are also addressed at length. Finally, CR based 5G technology is studied with the goal of exploring both technologies together and presenting a thorough overview that will encourage future research efforts in this fascinating area.

Sahota, Sukh (2018) The conventional wireless network must contend with both excessive SU use and insufficient PU use of licenced frequency. To address this issue, a new concept or piece of equipment called "Cognitive radio," which employs a "dynamic spectrum access policy," has been created. Cognitive radio networks, often regarded as the most reliable technology in wireless communication, are the subject of this study because of the vital part they play in the cross layer. The network channel poses unique challenges for this technology. Problems with cognitive radio are identified, and potential answers are provided.

Islam, Noman & Sheikh, Ghazala & Islam (2018) Humanity has struggled with disaster management for a long time. In recent years, technology has been used to try to fix this issue. Spectrum shortages and congestion concerns that emerge during disasters are resolved, and it can be installed quickly even in the absence of infrastructure. This study offers a fresh approach to crisis management. It offers a WSN-based disaster detection technique based on multi-layer perceptron (MLP) models. An MLP-based spectrum management plan has been presented as a possible solution to the spectrum shortage issue. An innovative service discovery mechanism is developed to facilitate cooperation among disaster relief personnel. It has been suggested that XML be used for all communication to maintain compatibility. There has been talk of using a real-time GUI to provide rescue personnel a more complete picture of the situation and help them make more informed decisions. The NS-2 simulator now incorporates the recommended method. The results demonstrate reliable early warning of disasters, effective use of spectrum, and cooperative working amongst nodes with little delay.

Bany Salameh, Haythem & Khatib, Rawan (2018) The NP-hardness of the optimisation problem can be demonstrated due to its association with a binary linear programming (BLP) problem. The present study proposes a solution that is nearly optimal, utilising a sequential fixing procedure. The binary variables are determined iteratively through the resolution of a sequence of relaxed programmes. In order to achieve this objective, a distinctive routing approach is developed, which selects the most efficient route and channel allocation to enhance capacity. The results of the simulation indicate that a carefully planned routing and channel assignment strategy could potentially provide significant advantages for FD CRNs.

Guirguis, Arsany & Digham (2018) Conversely, global routing techniques involve the cost of inundating the network with data packets during the process of identifying the optimal route to the destination. The present study proposes a k-hop routing approach, wherein k represents the discovery radius, that accords priority to the primary user. This is evidenced by evaluations conducted on NS2, which included a comparative analysis with conventional CRNs protocols.

III.METHODOLOGY

PBX: When the signalling process between the two mobile phones is complete, a call can be made. Private Branch Exchange (PBX) is used for the signalling. Signalling is handled using Session Initiation Protocol (SIP) with an open-source Asterisk PBX that treats mobile phones as SIP clients via OpenBTS. It functions as a server-client system and stores information about all connected mobile devices. Connectivity to the PSTN or the Internet may be provided via the Asterisk server, which also handles call routing and monitoring for all SIP users on the network. Its configuration may take place on a dedicated computer or on the BTS itself.

SIP authentication server: It is a crucial part of OpenBTS since it offers registrations with SIP authentication services.

SMQueue server: The messaging services for mobile phones are hosted on the SMQueue server.

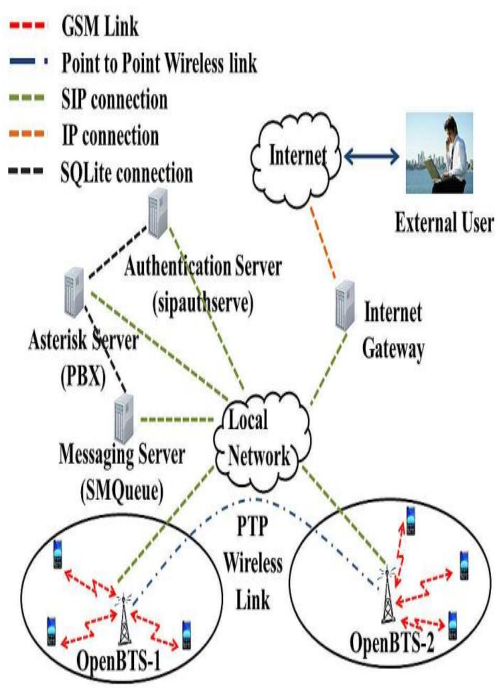

Figure 3.1 A general architecture of multiBTS prototype.

IV.RESULTS

4.1 CR BROADCASTING PROTOCOLS

4.1.1 Network Model

In this part, we will detail the infrastructure of the simulated networks and the primary methods used in these simulations. From the perspective of an SU node, signals from PU nodes will be seen as interference. This chapter examines how well the SU network broadcasts despite interference from the PU network. This chapter will attempt to address the crucial topic of how to increase broadcast efficiency in the face of interference. It's also worth noting that the simulations in this chapter treat PU and SU operation identically. The timing and mode of transmission are the primary determinants of whether a user is a PU or SU. To guarantee that the SINR at all PUs is within a predetermined limit, an SU may additionally use power control. A SU will thus attempt to decrease both band utilisation and transmit power in order to lower the SINR at PUs.

Topology

One such PU and SU case is seen in Figure 4.1. SUs, seen above as tiny squares, are in the inner circle. The central red square represents the source node in the SU network that will send out its packets to every other node in the network. Small triangles denote PUs, which are in the outer circle but are also possible inside the inner circle. Both the outside and inner circles have the same diameter of L. Simply said, it's a mathematical model that depicts how things are dispersed in a given space. Although there is a wide variety of PPs, the PPP has found widespread application in wireless network node placement, largely due to the simplicity with which it can be analysed. A random variable N in the PPP is assumed to have a Poisson distribution, with the probability of n given by Equation 2.1, if the region R has an area AR.

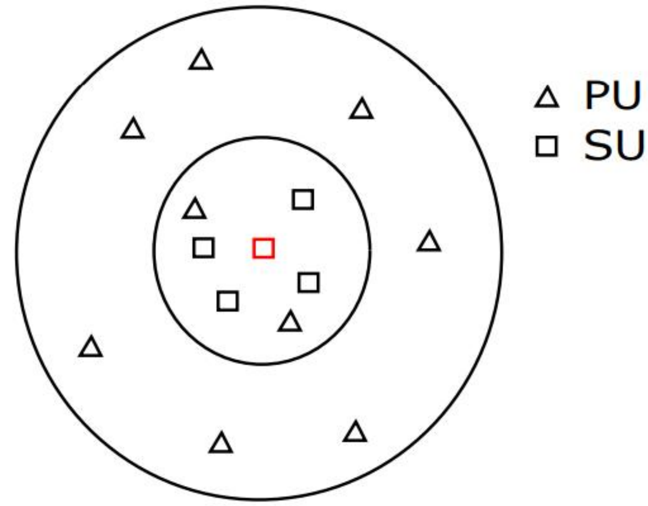

Figure 4.1 Network topology

$$P\{N=n\}=\frac{\lambda^{n}}{n!}e^{-\lambda} \qquad \lambda>0, n\geq 0$$

The user density is the term that will be used to describe this metric throughout the thesis. This parameter determines whether the point process is homogenous or stationary throughout time and space. The points also have the crucial attribute of being evenly spaced across all Cartesian coordinate axes.

4.1.2 Physical Layer

The PHY layer and its related components, such as the wireless channel and packet reception, will be discussed in this section.

Packet Reception

The duration of the packet's transmission is guaranteed to be an integer multiple of time-slots. Time-slots are discrete intervals of time, Ts, and the amount of time it takes to transmit a packet, Tf, is always an integer multiple of Ts, hence Tf = sTs. In all simulations, the number of bits in a packet, Nb, will remain unchanged. Packet time (Tf = Nb/Rb) is a function of the data transfer rate (Rb).

Note that packets are evaluated rather than individual bits to determine whether or not they were successfully received.

The minimal frame error rate (FERmin) is expected to be known, and the minimum Bit Error Rate (BERmin) may be computed using Equation, both of which are used to determine the SINR threshold, Equation, where er f c is the complementary error function, is a good approximation for the relationship between BER and SINR when employing BPSK and assuming Gaussian interference. Equation may then be used to get the required SINR threshold, The estimated threshold here implies that a single bit mistake will occur if the instantaneous SINR goes below this value, leading to the packet being discarded.

$$\mathrm{FER}_{\min}=1-(1-\mathrm{BER}_{\min})^{N_b}$$

$$\text{BER} = \frac{1}{2} erfc(\sqrt{\text{SINR}})$$

$$\gamma = (erfc^{-1}(2\text{BER}_{\min}))^2$$

4.1.3 MAC Layer

P-persistent CSMA combines the benefits of 1-persistent and non-persistent CSMA by being less aggressive towards other nodes and so minimising collisions while still being more efficient than the latter. Since the work will primarily involve broadcast transmissions, it is important to note that neither automatic repeat request (ARQ) nor acknowledgement (ACK) packets will be sent after each transmission. Particularly popular in WiFi networks, p-persistent CSMA has also been proposed for use in SU networks.

4.1.4 Network Layer

In this part, we'll compare the two different broadcast protocols and talk about the metrics we utilised to do so.

Flooding

To "flood" is to broadcast a packet from one node to every other node in the network. Sending control packets to every node in a network is an example of a use for flooding. One such use case is the dissemination of routing data, such as a node's routing table or knowledge about its neighbouring nodes. In recent years, flooding has become a standard method of group chat.

Random Linear Network Coding (RLNC)

The original motivation for proposing NC was to boost network throughput. The goal of NC is to increase network throughput and efficiency, and it may also assist prevent hacking and eavesdropping. The term "NC" refers to a method of combining many packets into one. Many of these packets are received by the receiving node, and they are used to decode the original packets.

The means by which the packets are combined distinguishes NC methods from one another. Transmissions in Linear NC are made up of a linear combination of packets. Due to the difficulty of decoding non-linear NC, most NC protocols employ linear combination. The bits of many packets are combined into one using XOR in digital network coding (DNC). Prior to demodulation, analogue NC (ANC) combines packets by adding them as analogue signals. These two approaches can combine more than one packet, but decoding them requires access to the resulting mangled set of packets. This is why the typical range for packet mixing applications is 1-3.

The packets can be decoded by the recipient if it has access to the coefficients used in the combinations. Therefore, the coefficients employed in the combination process must be included as overhead in each transmitted combination packet.

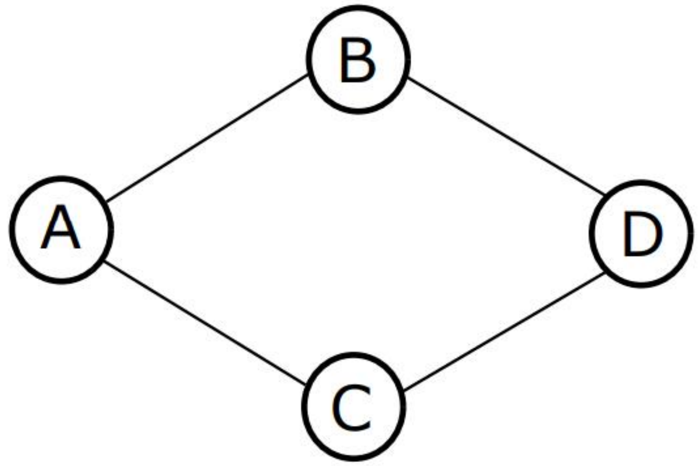

Figure 4.2 RLNC network example

To further illustrate how RLNC is implemented in the simulations, let us look at a basic example. The lines in Figure 4.2 illustrate a wireless link between the nodes in a basic network consisting of four nodes. Two packets, F1 and F2, are sent from node A to every other node in the network through a broadcast. There are q blocks in a packet of data with a total size of Nb bits. Each square represents a bit, a polynomial, or an integer that belongs to a 2q-element Galois field. Following are the equations that describe the transmission of two packets, YA1 and YA2, from node A:

$$Y_{A1}^T = g_1F_1^T + g_2F_2^T = \begin{bmatrix} F_1^T & F_2^T \end{bmatrix} \begin{bmatrix} g_1 \\ g_2 \end{bmatrix} = \begin{bmatrix} F_{11} & F_{21} \\ F_{12} & F_{22} \end{bmatrix} \begin{bmatrix} g_1 \\ g_2 \end{bmatrix} = \begin{bmatrix} F_{11}g_1 + F_{21}g_2 \\ F_{12}g_1 + F_{22}g_2 \end{bmatrix}$$

$$Y_{A2}^T = g_3F_1^T + g_4F_2^T = \begin{bmatrix} F_1^T & F_2^T \end{bmatrix} \begin{bmatrix} g_3 \\ g_4 \end{bmatrix} = \begin{bmatrix} F_{11} & F_{21} \\ F_{12} & F_{22} \end{bmatrix} \begin{bmatrix} g_3 \\ g_4 \end{bmatrix} = \begin{bmatrix} F_{11}g_3 + F_{21}g_4 \\ F_{12}g_3 + F_{22}g_4 \end{bmatrix}$$

Overhead information for the Galois field coefficients g1 and g2 are included in the first packet sent by node A, while g3 and g4 are included in the second. Both YA1 and YA2 are sent to nodes B and C, who then produce their own coefficients and send out two mixed packets, as seen in the following diagram.

$$Y_{B1}^T = g_5Y_{A1}^T + g_6Y_{A2}^T = (g_5g_1 + g_6g_3)F_1^T + (g_5g_2 + g_6g_4)F_2^T$$

$$Y_{B2}^T = g_7Y_{A1}^T + g_8Y_{A2}^T = (g_7g_1 + g_8g_3)F_1^T + (g_7g_2 + g_8g_4)F_2^T$$

$$Y_{C1}^T = g_9Y_{A1}^T + g_{10}Y_{A2}^T = (g_9g_1 + g_{10}g_3)F_1^T + (g_9g_2 + g_{10}g_4)F_2^T$$

$$Y_{C2}^T = g_{11}Y_{A1}^T + g_{12}Y_{A2}^T = (g_{11}g_1 + g_{12}g_3)F_1^T + (g_{11}g_2 + g_{12}g_4)F_2^T$$

The additional data is not wasted and will be useful if certain data packets get damaged. The power of RLNC is in its ability to use concurrent transmissions.

V.CONCLUSION

The findings from the simulation will be summed up here. Time and energy efficiency are two of the most common ways in which RLNC and floods are compared to one another. The following inferences may be made to save time:

1. First, regardless of the values of p, Tf, and λ, RLNC performs better than flooding.
2. Time efficiency increases with increasing p, while the benefit diminishes with increasing p.
3. Third, RLNC and floods are most effective at lower Tf (frame time).
4. As λ becomes larger, RLNC's timing efficiency improves but flooding's decreases.
5. Fifth, as rises, the RLNC efficiency ratio for time slots grows λ independently λ of other factors.

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