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Enhanced Spectrum Handoff Security Mechanism in Cognitive Radio Network

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Abstract: In this work we introduce a novel cognitive user emulation attack (CUEA) in a cognitive radio network (CRN), which can be exploited by intruders during spectrum handoff. Then, we propose a secure handoff mechanism that can successfully counter such an attack by introducing a coordinating cognitive user that computes the level of trust of each cognitive user based on its behavioral characteristics. Malicious users can be effectively identified by the coordinating cognitive user by looking up the trust values. The performance of the proposed mechanism is validated using MATLAB simulations. The simulation results show that the utility of the proposed mechanism in terms of its probability in correctly identifying false authentication, detection rate, throughput rate, and transmission delay.
Keywords: Cognitive Radio Network, Spectrum Handoff Security, Fuzzy Logic, Data Delivery Ratio and Liveness.

I. INTRODUCTION

Cognitive radio (CR) is an advanced technology with the aim of utilizing the spectrum bands which are unused in an opportunistic and dynamic way. The segments of spectrum bands which are not used, are called “spectrum holes” or “white spaces”. CR technology allows users to determine the unused bands in spectrum, choose the suitable one and use them in the best way possible. In CRN there are four stages for spectrum utilization which are spectrum sensing, spectrum assignment, spectrum mobility and spectrum sharing.

A. Spectrum Sensing

In CR network only an unused part of the spectrum may be allocated to a CR device. The CR use, therefore, should sense the spectrum bands, store that data, and identify the white spaces. Spectrum sensing techniques can generally be categorized into three main category:

1) Primary Transmitter Detection

In this technique the basic idea is to identify primary transmitter’s signal though the signal is very weak. It is achieved through local observation. The schemes that are used for detecting the transmitter are:

a) Matched Filter Detection: When the primary user signal information is known to the CR user, Matched filter, is an efficient detector for stationary Gaussian noise. Any signal which might be lost in interference and noise, can be identified using matched filter because of the spectral correlation properties of the signals are usually distinctive

b) Energy Detection: When the primary signal information is uncertain, energy detection is a better alternative. The energy obtained on a primary band during an observation period is determined by an energy detector, which confirms a spectrum hole, if the analyzed energy is lesser than a pre-defined threshold. Due to their inability to distinguish between signal types, energy detectors often produce false alarms caused by unknown signals. An analysis for threshold optimization and reduced probability of error is explained in [6].

c) Feature Detection: Usually, built-in periodicity or cyclostationarity characterizes any signal which is modulated. A spectral correlation function can be used to distinguish this attribute [10]. The key benefit of feature detection is its resistance to noise power instability. However, it is computationally complex and needs comparatively longer observation times.

2) Primary Receiver Detection

The primary receiver detection goal is to locate Primary Users that are receiving information within a CR user's contact range. The primary receiver detection method detects the presence of the primary receiver by using low leakage power. It will require additional hardware, for example a supporting sensor network for primary receivers in that region. While it is the most effective tool for locating spectrum gaps, it is currently only applicable to the detection of TV receivers.

3) Interference Based Detection

The FCC has developed interference temperature model for interference measurement. The radio station's signal is built to function in a range where the incoming power reaches the noise floor is depicted in this model. The noise floor rises as other interfering signals emerge at different points in the service area. The interference temperature model controls interference measured at the receiver by setting an interference temperature threshold, which is the maximum quantity of interference that the receiver can withstand. Since cognitive users cannot differentiate between signals received from PU and interference, the challenge of this model is calculating the interference temperature perfectly.

II. RELATED WORK

JianhuiHuang,(2016) [10] In D2D communications, random contacts can be utilized to exchange data among nodes without the support from infrastructures or central control units. Because of the huge quantity and high mobility of the nodes, the scarcity of the available spectrum severely limits the data delivery capacity in D2D communications. CR technology gives D2D the ability to use idle licensed radio spectra from licensed networks to improve data delivery capacity.

Jiang Zhu(2017) [11] Wireless sensor networks are utilized in medical area to gather multimedia information from multiple sources, such as video streams, images, voice, heartbeat and blood pressure data, which call for higher bandwidth and more available spectrum. Whereas, today's radio spectrum is very crowded for rapid increasing popularities of various wireless applications. Hence, wireless sensor networks utilizing the advantages of cognitive radio technology, namely cognitive wireless sensor network (CWSN), is a promising solution for spectrum scarcity problem.

ArsanyGuirguis, (2018) [12] In the scope of cognitive radio networks, typical routing protocols avoid areas that are highly congested with primary users, leaving only a small fragment of available links for secondary route construction. In addition, wireless links are prone to channel impairments such as multipath fading which renders the quality of the available links highly actuating. In this paper, we propose Undercover: a multi-hop routing protocol for cognitive radio networks in which we integrate the collaborative beamforming technique with layer 3 routing.

YihangDu,(2019) [13] Transmission latency minimization and energy efficiency improvement are two main challenges in multi-hop Cognitive Radio Networks (CRN), where the knowledge of topology and spectrum statistics are hard to obtain. For this reason, a cross-layer routing protocol based on quasi-cooperative multi-agent learning is proposed in this study. Firstly, to jointly consider the end-to-end delay and power efficiency, a comprehensive utility function is designed to form a reasonable tradeoff between the two measures.

Dingde Jiang, (2016) [14] The collaboration of nodes in cognitive wireless networks is a large challenge. This paper studies the collaborative multi-hop routing in cognitive networks. We propose a new algorithm to construct the collaborative routing in multi-hop cognitive networks. Our algorithm takes into account the interference among nodes including primary and secondary users.

III. METHODOLOGY

"In almost every case you can build the same product without fuzzy logic, but fuzzy is faster and cheaper . " [16]. It is seen that fuzzy logic has been considered as the superset of conventional logic or classical logic. This fuzzy logic has been used to take into account the concept of partial truth, wherein truth values lies between completely false and completely true. Fuzzy logic is discussed in detail in [8][9]. Fuzzy logic concerns the relative importance of precision. How important is it to be exactly correct when a rough answer will do? Fuzzy logic balances significance and precision (see Figure 1), something that humans have been managing for a very long time.

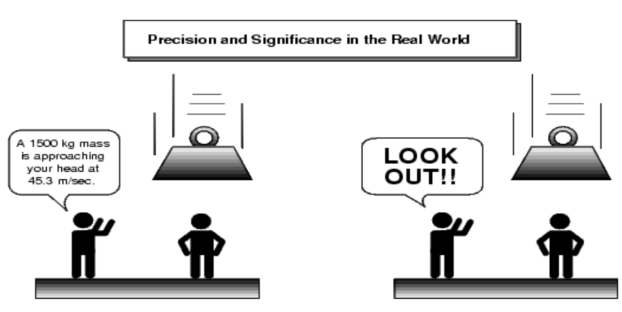

Figure 1: Precision versus significance (Source Matlab, 2013)

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Fuzzy logic has been considered as an easy way of input–output mapping, leading to the capture of the expert knowledge. For example, a user states how good the service was at a restaurant, and fuzzy logic tells the user what the tip should be. Graphical representation of input and output mapping is depicted in Figure 2.

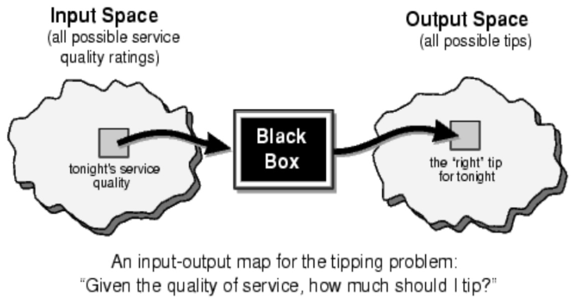

Figure 2: Mapping of input and output (Source Matlab, 2013)

A. Secure Handoff Mechanism

The identification and security of each CU during the handoff mechanism is provided by a CCU that analyzes and regulates activities of CUs, by identifying and computing their TVs based on their communication behavior. The detection and elimination of handoff threats depend upon the liveliness of the CU in the network, data delivery ratio of intermediate nodes, and the number of nodes present in the network. The proposed security mechanism is presented for two different cases: 1) when the NU is detected as PU, and2) when the NU is recognized as CU or HCU. The spectrum handoff is initiated whenever a CU desires to switch its ongoing transmission to another accessible channel with the arrival of the PU through the packet transmission by recalling the previous key functions (i.e., spectrum sensing, spectrum decision, and spectrum sharing).During the spectrum handoff, the CU can be compromised by MUs that can introduce various malicious attacks in the CRNC environment. The MU exploits the delay needed to vacate the present channel and occupy anew unused channel during the spectrum handoff to behave as a legitimate PU or CU [16].

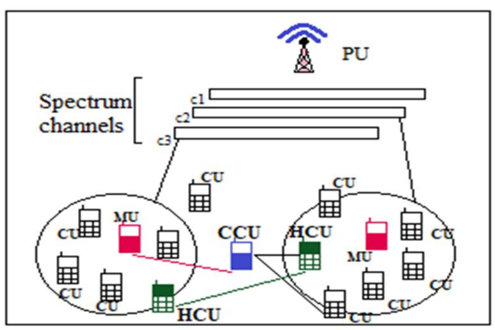

Figure 3: A typical CU handoff mechanism for CRNC

The proposed security mechanism aims to detect and resolve the newly exposed security threat in the CRN, called CUEA, by using a CCU to compute the TF/TV of all the CUs. The system model of the proposed mechanism is depicted in Figure 3.10. It comprises of a centralized CR environment, including an HCU, CCU, PU, and n number of CUs. The HCU requests for another channel from the CCU uponarrival of a PU and contains n number of CUs which utilize the idle channels of the PU for communication. Figure 3.11 presents the flowchart of the proposed framework where among n number of CUs, some are selected as PU, MU, and HCU. Initially, the CCU analyzes the type of users (PU, HCUor CU) by identifying their communication characteristics and terminates all communication upon identification of thePU. Further, if the user is CU then CCU allows initial transmissions to analyze its trust value (behavior) by storing every transaction into its database. After a predefined number of transmissions, CCU confirms the legitimacy of CU as either 1 or 0, if TV is identified as 0, the user isMU and would be blocked by CCU permanently. Similarly, when the user is HCU, there may be a possibility of MUintrusion where the legitimate address of HCU is forged. The CCU verifies the HCU's authenticity by identifying itsST from the lookup table. If the trust value of HCU and ST of legitimate CU is greater than the malicious user, the useris allowed to undertake further communications; otherwise, the user is deemed malicious.

IV. RESULT AND DISCUSSION

In this work a cognitive radio network is developed having two different area with some primary users PU and multiple cognitive users. In figure 4 it can be observed that the proposed CRN has 25 nodes having random initial positions and they are moving in different direction and displacements. And simulation parameters are shown in table 1.

Table 1: Simulation Parameters

Parameters	Size
Network Area	400 m×400 m
Number of Users	25
MAC Protocol	IEEE 802.22
Routing Protocol	AODV
Simulation Round	500
Traffic Source	CBR
Packet Size	512 bytes
Antenna	Omni-Directional

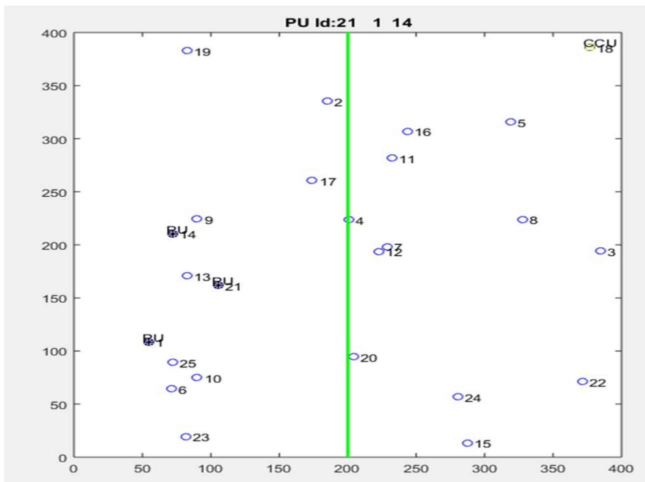

Figure 4: Distribution of nodes in CRN

Table 2: Initial position of nodes

Node Id	X coordinate	Y coordinates
1	58.9231	128.2515
2	193.2828	315.4887
3	383.7329	190.9195
4	202.5865	232.48
5	302.8266	313.0737
6	89.5164	63.0016
7	234.4993	207.6172
8	339.0788	223.1827
9	102.5929	209.5139
10	101.844	56.2221
11	11.967	276.5509
12	229.0163	211.8337

13	77.7849	181.2686
14	83.7736	190.9216
15	289.8133	15.5479
16	251.3725	315.4863
17	387.0993	5.2095
18	362.3857	369.7269
19	99.7087	386.5547
20	207.4924	96.3356
21	89.1704	181.2625
22	388.1204	51.8266
23	64.4627	3.4827
24	265.2205	58.6867
25	80.2153	109.2552

Table 1 shows the initial coordinates of all the nodes distrusted randomly in Area 1 and 2. The position of nodes is changing with uneven displacements. The nodes which lie at the boundary of Area1 and 2 are taken as passing through the handoff process.

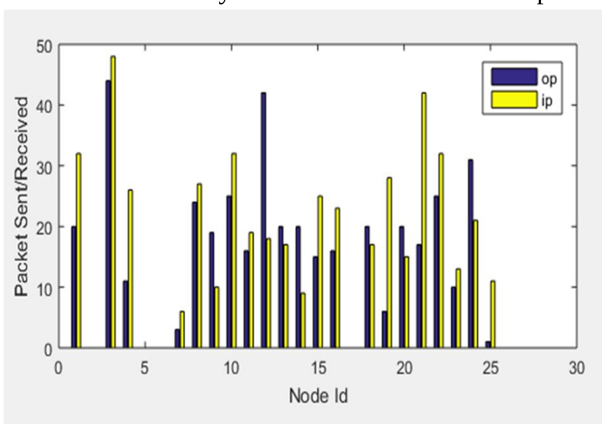

Figure 5: Packet sent and received by different nodes

Figure 5 shows the value of data input and output at each node respectively at a specific round. The blue bar shows the plot of data sent by each node and yellow bar represent data received by each node. In this case total 25 nodes are only considered.

V. CONCLUSION

The demand for highly efficient spectrum utilization scheme is getting more pronounced in the recent increasingly digitalized application at high definition data. But, this has also introduced multiple type of new threats over the security. In this work, I have introduced a smart cognitive user based attack emulation scheme for the cognitive radio network (CRN), that helps to exploits the intruders attack during the process of the handoff of the spectrum. I have also proposed and developed a simulation model on MatLab software having a highly secure handoff process that helps to counter the attack successfully introduced by malicious user through the supervision of coordinating cognitive user that evaluates the trust value level using the fuzzy logic algebra for cognitive user going through the handoff process based on its behavioral characteristics.

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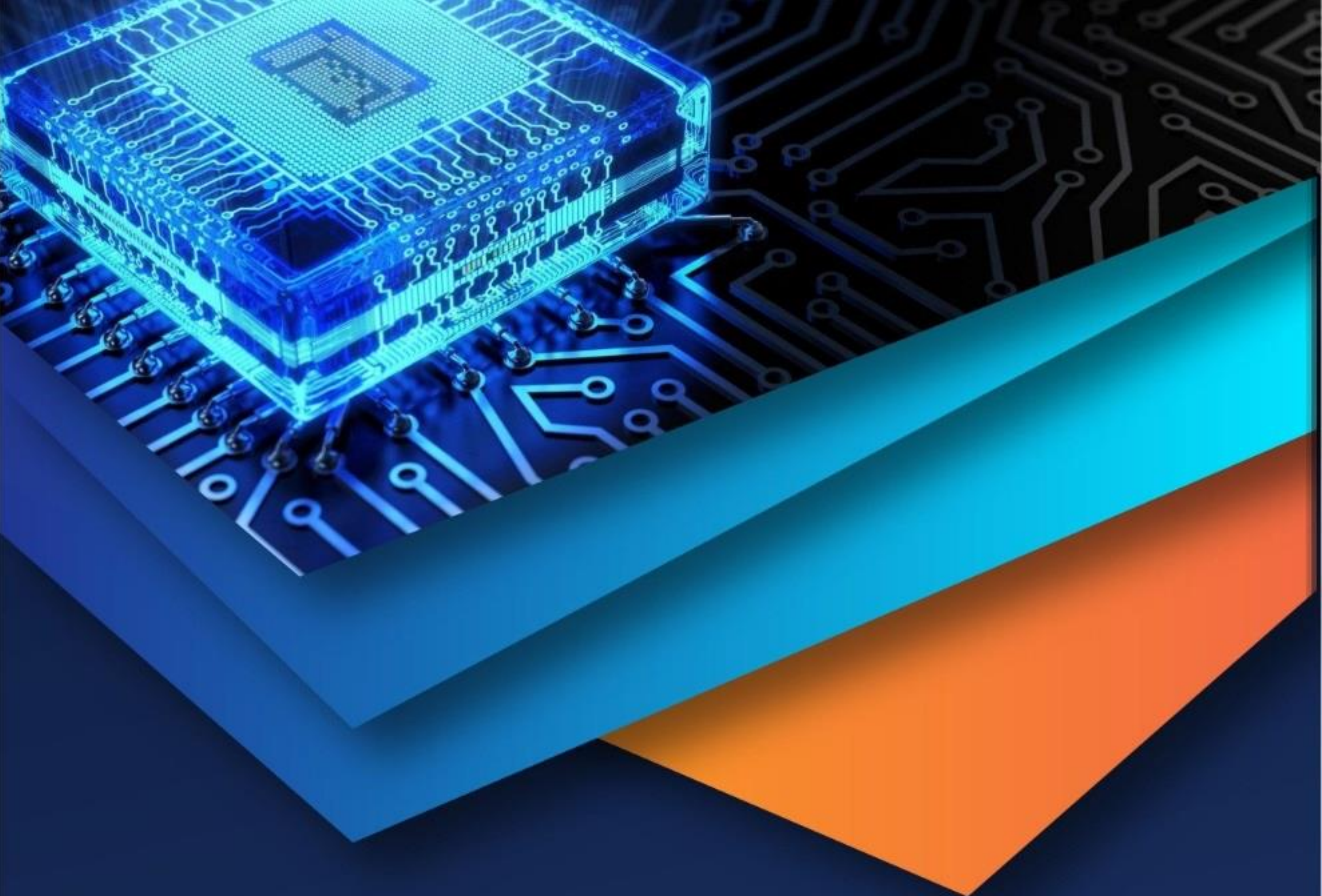

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