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Research Article

Impact of Various Network Attacks on Time Synchronization in Cognitive Radio

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Abstract

Time synchronization in CRNs is a demanding task due to the dynamic and cooperative nature of these networks. DCR-Sync, a novel time synchronization protocol for CRNs is proposed. DCR-Sync is fully distributed and resilient towards failure of root nodes, i.e., the nodes which play the role of master on the synchronization process. We present DCR-Sync in two versions. The first version is static in nature, and the second version can adapt dynamically to network changes. This protocol aims to be distributed and reliable even in root node failure. DCR-Sync following two versions, called DCRSync1 and DCR-Sync2. The former deals mainly with static networks in nature, and it is more suitable for physical time synchronization. The latter considers dynamic face of synchronization root node failures. It is more suitable for logical time synchronization. Both versions offer easy adaptation to changes in network topology, a feature not supported by other existing protocols. Hence, this proposal is better congruous to the needs of networks with mobile topologies. The various classes of attacks and its impact on time synchronization and other parameters is mentioned along with the ways to mitigate the attacks.

Keywords: *Cognitive Radio Networks, Distributed Cognitive Radio (DCR-1, DCR-2), Impact of network attacks*

1. Introduction

Cognitive radio systems are radios with the ability to exploit their environment to increase spectral efficiency and capacity. As spectral resources become more limited the FCC1 has recommended that significantly greater spectral efficiency could be realized by deploying wireless devices that can coexist with primary users, generating minimal interference while somehow taking advantage of the available resources. Such devices, known as cognitive radios, would have the ability to sense their communication environment and adapt the parameters of their communication scheme to maximize rate, while minimizing the interference to the primary users. Thus the two most popular research areas when it comes to cognitive radios are spectrum sensing and interference management and resource Allocation. Spectrum sensing is the ability to detect the presence of licensed users and available frequencies/ timeslots to transmit in. The problem is then that the algorithms need to have as little delay as possible so that once channels are available one can transmit immediately. And of course one would want as few false detections and false no-detections as possible. Research in the area of interference management and resource allocation consists of how to allocate power in channels to maximize capacity while minimizing interference to other users. One way is of course to transmit when no one else is using that frequency/timeslot, but given a scenario where there are multiple cognitive users in the same environment this may not be possible and certainly not the way to maximize capacity. Cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time, with two primary objectives in mind:

- Highly reliable communications whenever and wherever needed;
- Efficient utilization of the radio spectrum.

2. Features

- An intelligent wireless communications system
- Based on SDR technology
- Reconfigurable
- Agile Functionality
- Aware of its environment
- RF spectrum occupancy
- Network traffic
- Transmission quality
- Learns from its environment and adapts to new scenarios based on previous experiences.

The term Cognitive Radio was firstly described by Joseph Mitola. From his description Cognitive Radio is defined as

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a radio capable of analyzing the environment (as channels and users), learning and predicting the most suitable and efficient way of using the available spectrum and adapting all of its operation parameters (J. Mitola and G. Q. Maguire, Aug.1999), (Jari Nieminen, Riku Jantti, Lijun Qian, 2009). The main reason for introducing the cognitive radio is the inefficient use of the radio resources and particularly the spectrum.

Software Defined Radio (SDR)

As mentioned before, Cognitive Radio is not expected to be fully implemented until 2030 (Yasir Saleem, Adnan Bashir, Ejaz Ahmed, Junaid Qadir, Adeel Baig, 2012) until the complete Software Defined Radio (SDR) hardware become available in a suitable size. The term SDR was introduced in the late 1990s by some manufacturers who created radio terminals capable of using more than one communication technique (e.g., GSM and CDMA); that is the terminals can alter their operation mode or technique by means of software. Thus this technique is known as Software Defined Radio (SDR).
The desired cognitive radio system should have the ability to freely switch between the techniques. Thus, an SDR with all the latest communication techniques is the core of cognitive radio.

3. Literature Survey

In this paper, we propose DCR-Sync, a novel time synchronization protocol for CRNs. Differently from existing proposals, DCR-Sync is fully distributed and resilient towards failure of root nodes, i.e., the nodes which play the role of master on the synchronization process. DCR-Sync is presented in two versions. The first version is static in nature, and the second version can adapt dynamically to network changes. Through extensive simulations, it is shown that both versions outperform the performance of existing synchronization protocols. Precisely, both versions of DCR-Sync are simulated using NS2 simulator and are compared to the TPSN protocol. Simulation results show the improvements obtained by DCR-Sync in terms of network overhead and convergence time. **(**Srishti Shaw, Yacine Ghamri-Doudane,Aldri Santos and Michele Nogueira, 2012)

In this paper, a novel synchronization protocol is proposed especially for Cognitive Radio (CR) networks called CR-Sync. The proposed CR-Sync achieves network-wide time synchronization in a fully distributed manner, i.e., each node performs synchronization individually using CR-Sync. Contrary to many existing synchronization protocols that do not exploit CR attributes, the proposed protocol takes advantage of the potential multiple spectrum holes that are discovered by CR and distributes the synchronization of different pairs of nodes to distinct channels and thus reduces the synchronization time significantly. Detailed analyses of synchronization error and convergence time are provided. Results show that the proposed CR-Sync out-performs other protocols such as TPSN in CR networks. **(**Jari Nieminen, Riku Jantti, Lijun Qian, 2009)

In this paper, a selfish attack detection technique, known as COOPON, is used which proves the reliability and efficiency of the proposed work. Here ad-hoc network advantages such as autonomous and cooperative characteristics for better detection reliabilities. **(**Minho Jo, Longzhe Han, Dahoon Kim, and Hoh Peter In, 2013)

In this paper A distributed spectrum-aware dynamic channel assignment (SA-DCA) scheme for CRN’s is proposed. It aims at maximum connectivity and minimum interference. (Yasir Saleem, Adnan Bashir, Ejaz Ahmed, Junaid Qadir, Adeel Baig, 2012)

4. Problem Definition

DCR-Sync is a novel protocol for time synchronization in Cognitive Radio Networks (CRNs) presented in two versions. Both of them are distributed and resilient against root node failure but the impact of various network attacks on time synchronization is not studied. I will try to endeavour a solution to these problems.

5. Objective

To provide time synchronization protocol for cognitive radio networks along with sharing wireless channels with licensed user holders.

A survey on MAC protocols for cognitive radio networks

In cognitive radio (CR) networks, identifying the available spectrum resource through spectrum sensing, deciding on the optimal sensing and transmission times, and coordinating with the other users for spectrum access are the important functions of the medium access control (MAC) protocols. In this survey, the characteristic features, advantages, and the limiting factors of the existing CR MAC protocols are thoroughly investigated for both infrastructure- based and ad hoc networks.

First, an overview of the spectrum sensing is given, as it ensures that the channel access does not result in interference to the licensed users of the spectrum. Next, a detailed classification of the MAC protocols is presented while considering the infrastructure support, integration of spectrum sensing functionalities, the need for time synchronization, and the number of radio transceivers. The main challenges and future research directions are presented, while highlighting the close coupling of the MAC protocol design with the other layers of the protocol stack.

The DCR-Sync1 Protocol

DCR-Sync version 1 (DCR-Sync1) is a kind of master-slave protocol where all the nodes are synchronized to the predefined root nodes, i.e., those nodes equipped with a GPS receiver. The synchronization protocol has two phases: level discovery phase and the synchronization phase.

The DCR-Sync2 Protocol

The DCR-Sync, version 2, (DCR-Sync2) is also a kind of master-slave time synchronization protocol aiming to mitigate delay effects on large distributed CR ad hoc networks. DCRSync2 consists of the two phases: Hierarchical-cum-Leader Discovery phase (HLD) and synchronization phase. The HLD phase is used to create synchronization hierarchy, keep the hierarchy up to date and dynamically determine new leaders (pseudo-root nodes) to initiate and regulate HLD.

6. Various Classes of Attacks

1. Dynamic Spectrum Access Attacks (PUE Attacks) **:** It can be effective in DSA environments. PU owns a frequency band and can use whenever they wish. An attacker creates a waveform similar to PU.

2. Objective Function Attacks: Whenever higher level security is attempted, the system's objective function decreases & higher security level is never used. Eg : Radio's 3 goals – low power, high rate & secure communication.

3. Malicious Behavior Attacks: When it finds PU idle, it attacks on it. This attacker can decrease the throughput.

4. Wormhole Attacks: The nodes turn malicious and send corrupted data.

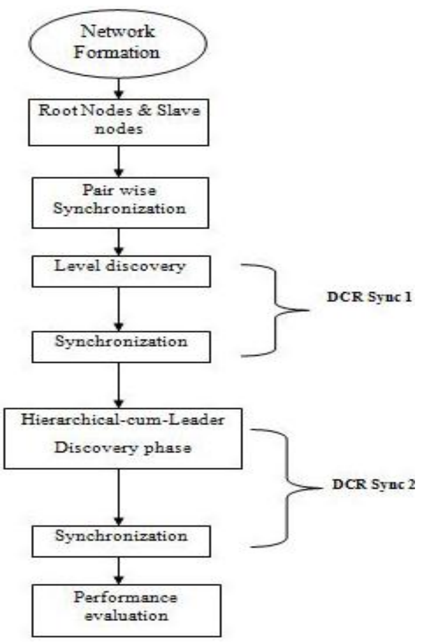
7. Attack Mitigation

*1. Robust Sensory Input***:** Improving sensor inputs can reduce attacks. For example- If radios can differentiate between interference and noise, natural and man-made.

2. Mitigation in Individual Radios: Need to instill common sense in radio system. A better sensing algorithm may be able to distinguish the PU from enemy.

3. Mitigation in Networks: It applies PSO (Particle Swarm Optimization). Each CR in a network represents a particle, each with its own hypothesis about the best behavior in a particular situation. PSO takes average of all hypothesis behaviour. Weighted majority will be taken.

Flow Diagram



8. Simulation Set Up

Table 1

Parameters	Values
No. of mobile nodes	10
Number of channels per	3
Frequency	2.4 Ghz
Area Covered	40 m
Bandwidth	28.8 Kbps
Antenna type	Omni directional
Simulation Time	50 msec

9. Simulation Results

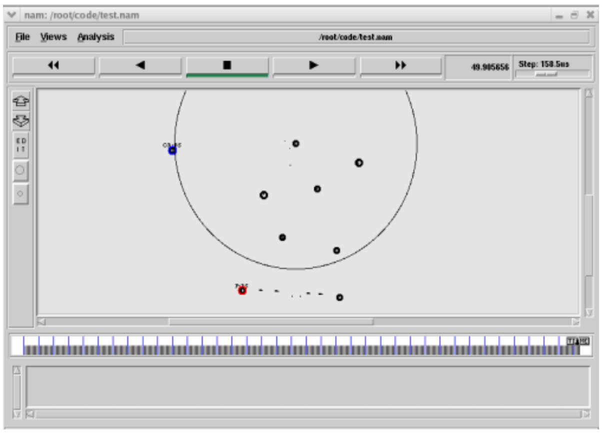


Fig.1 CRN nodes (10) before wormhole attack)

Table 2

Parameters	Values / Specifications
Simulator	NS-2
No. of nodes	100
Area	1000m*1000m
Packet Size	1000 Bytes
MAC Protocol	IEEE 802.11
Max. Transmission range	1.5 m
Antenna Type	Omni Directional
Routing Protocol	DSR
Simulation time	10 sec
Traffic Source	CBR

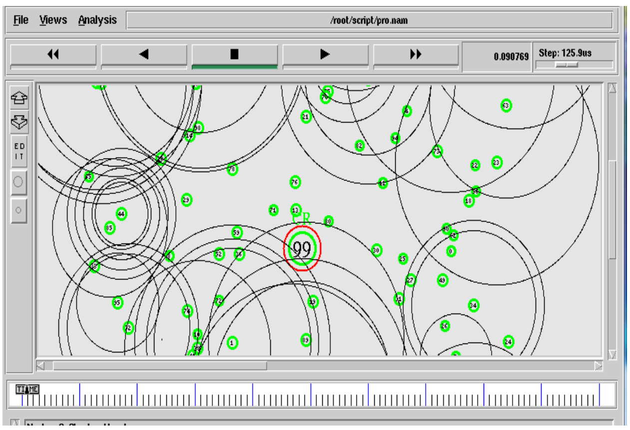


Fig.2 CRN nodes (100) before wormhole attack

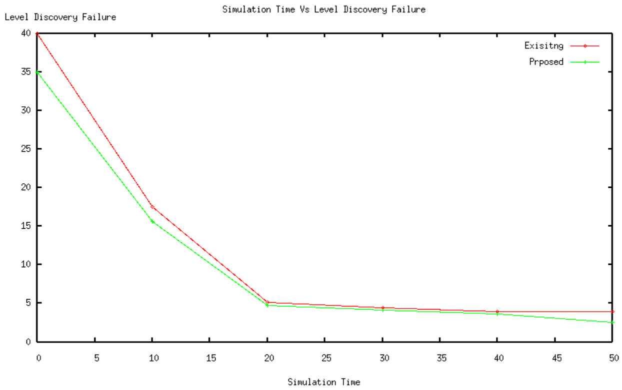


Fig.3 Simulation Time Vs Level Discovery Time

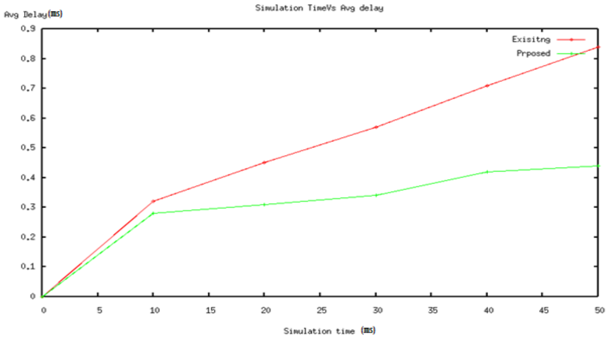


Fig.4 Simulation Time Vs Average Delay

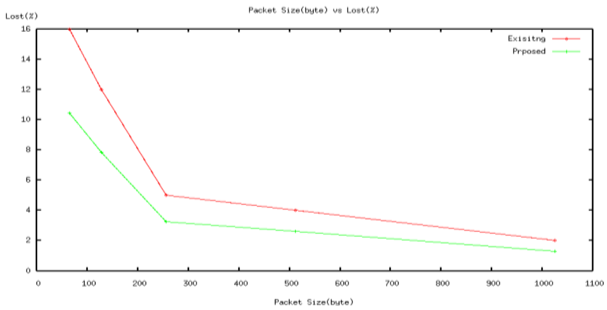


Fig.5 Packet Size Vs Lost

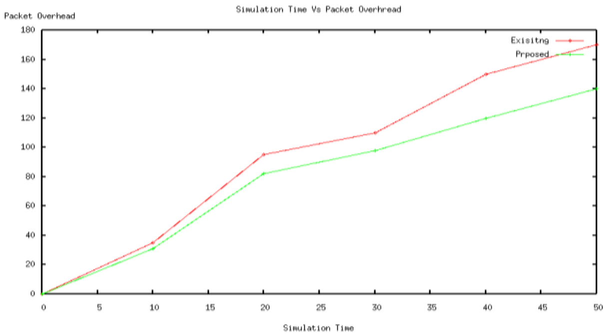


Fig.6 Simulation Time Vs Packet Overhead

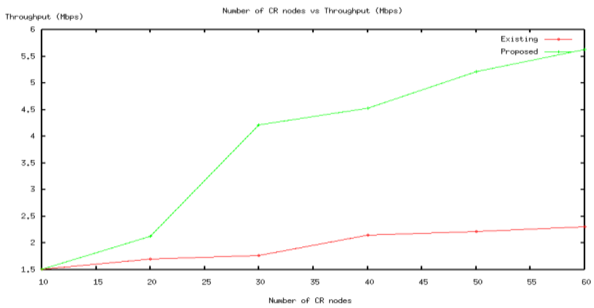


Fig.7 Number of CR Nodes Vs Throughput

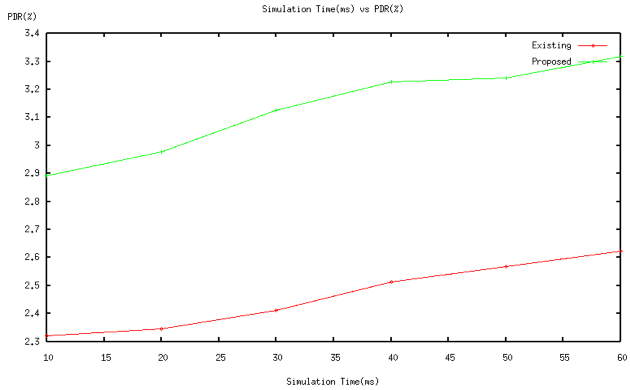


Fig.8 Simulation Time Vs Packet Delivery Ratio

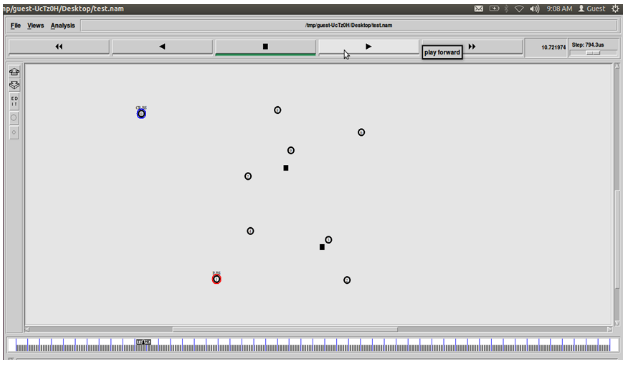


Fig.9 CRN after wormhole attack

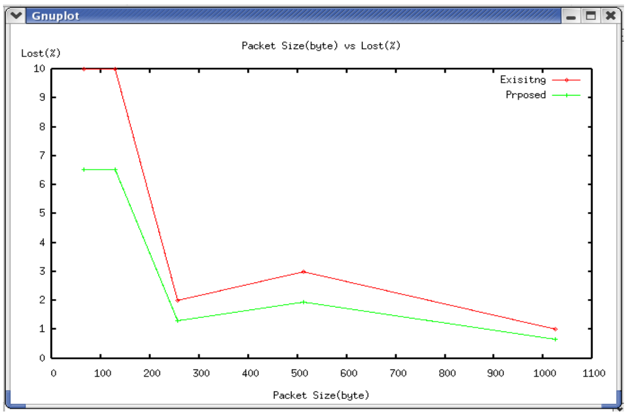


Fig.10 Packet Size Vs Lost

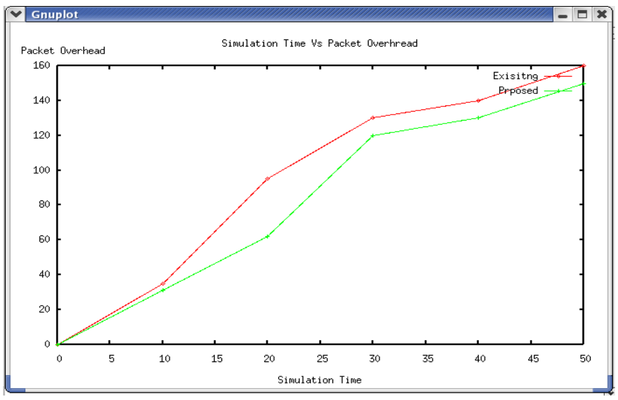


Fig.11 Simulation Time Vs Packet Overhead

Table 3

Sr. No.	Parameters	DCR-SYNC before wormhole attack	DCR-SYNC after wormhole attack
1.	Packet Losses	4 %	4.96 %
2.	Packet Overhead	75 ms	81.67 ms
3.	Packet Delivery Ratio	3.13 %	2.75 %
4.	Throughput	3.92 Mbps	1.75 Mbps

Table 4 Qualitative Comparison Table

Sr. No	Parameters	Protocols				
		CRSYNC [3]	COOPON[4]	SA -DCA [5]	TPSN [2]	DCR-SYNC [Proposed]
1	Time Synchronization	Reduces synchronization time	_	_	Not time Synchronized	Time Synchronized Protocol
2	Root Node Failure	Does not work	Does not work	_	Does not work in this situation	Distributed & Reliable even in RNF
3	Version	No	No	Dynamic	No	DCR 1 (Static – Physical) DCR 2 (Dynamic-logical)
4	Adaptation to changes in Network Topology	_	Adaptable	_	No	Easily Adaptable
5	Convergence Time & Resilience	High (b'coz root node located in center)	Low	High	Low	High
6	Level Discovery Failure	High	Low	Low	12.63	11.5
7	Average Delay	Low	Low	High	0.46 ms	0.29 ms
8	Losses	Medium	Medium	Medium	7.68%	4.96%
9	Packet Overhead	Less	_	_	91.67 ms	76.67 ms
10	Throughput	_	High	Medium	1.713 Mbps	3.725 Mbps
11	PDR (Packet Delivery Ratio)	Low	Medium	Hogh	2.46%	3.14%
12	Performance & Qos	Better than NTP & RBS but not better than DCR-SYNC	Good attack detection technique	Better than CCA & SB-CS but not better than DCR-SYNC	Low	High

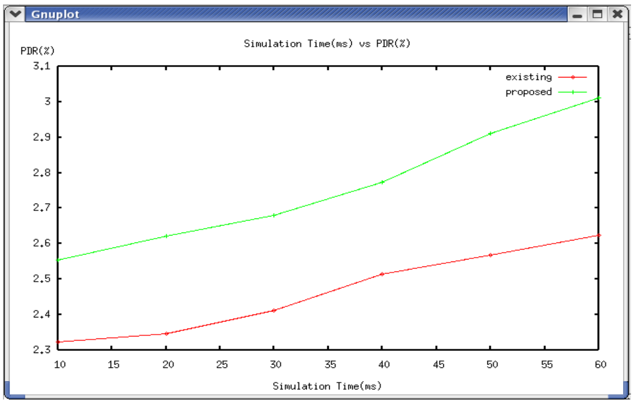


Fig.12 Simulation Time Vs Packet Delivery Ratio

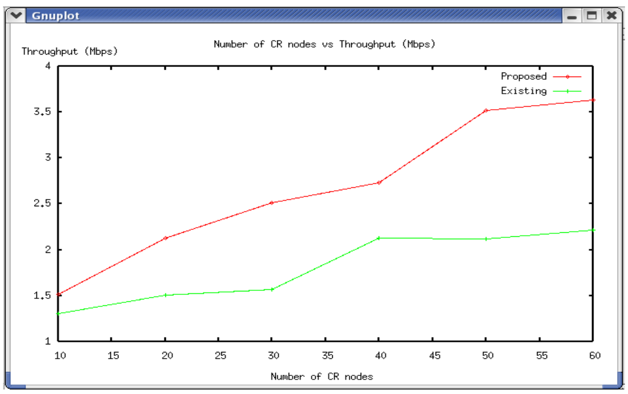


Fig.13 Number of CR nodes Vs Throughput

Conclusion

CR technology can solve the problem of spectrum utilization. DCR Sync offers a better precision for the time synchronization using multiple root nodes without compromising the network cost. DCR Sync presented better results than the existing time synchronization protocols for CR networks. This is proved by the qualitative comparison table in which various parameters are compared. From the graph of CR nodes Vs Throughput, it is proved that as no. of mobile nodes increases, the throughput also increases. Security is an important part - both recognizing threats to CRs and how cognition can improve security. The impact of various network attacks and its ways to mitigate is studied.

Future Work

Here the focus was PHYSICAL layer security. The emphasis is on PHYSICAL layer just because that is as far as basic research into cognitive radio. This security can be extended to the MAC, routing, transport or even application layers.

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