Presentation on

An Overview of Medium Access Control Protocols for Cognitive Radio Sensor Networks

Prepared By:

Jemish V Maisuria

E. & C. Department, Uka Tarsadia University, Surat, Gujarat, India

Dr. Saurabh N Mehta

E. & C. Department, Vidhyalankar Institute of Technology, Mumbai, India

Outlines

- Motivation
- Introduction
- CR-WSN Application
- Literature Survey
- Reference

Motivation

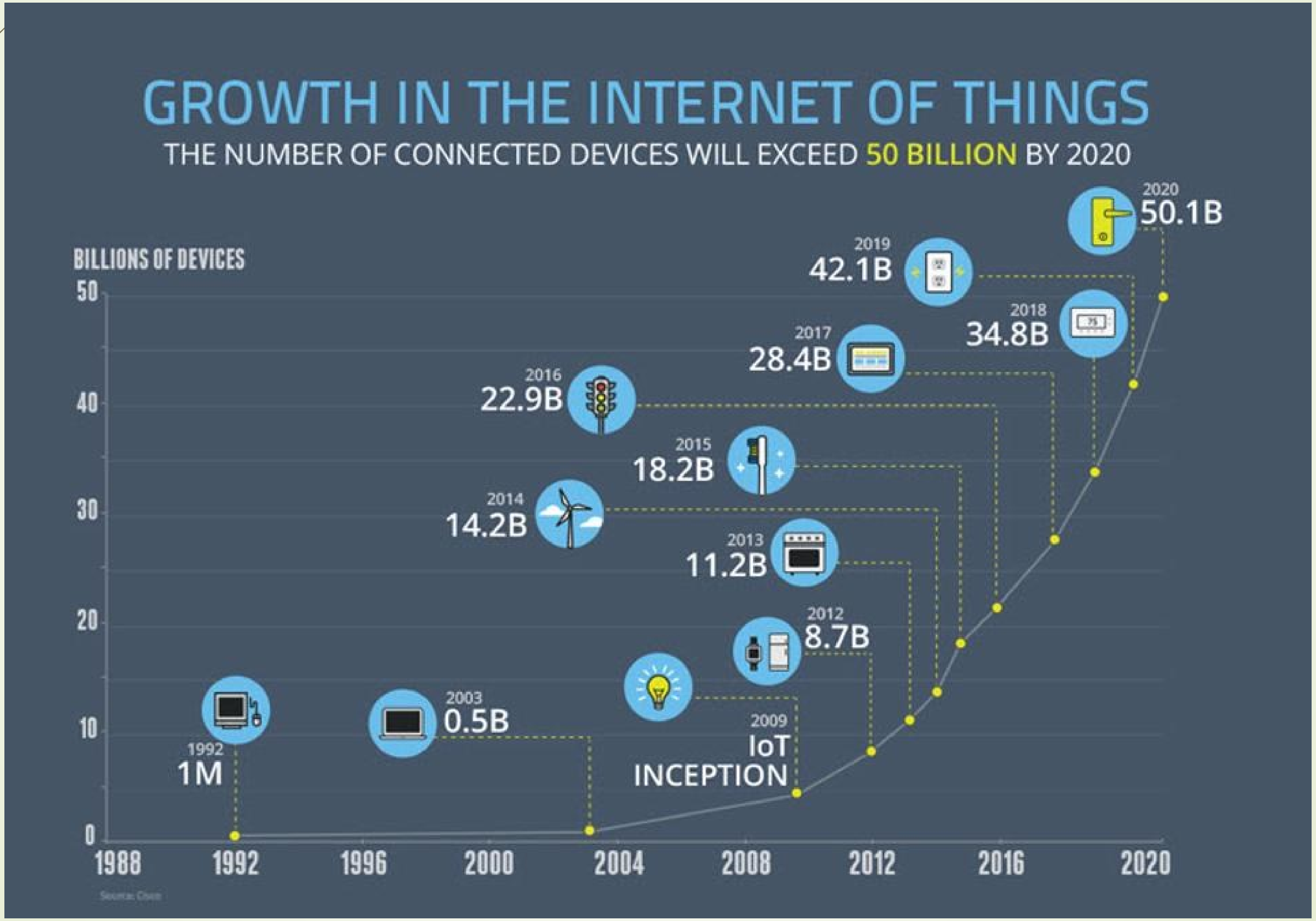

Figure 1: Growth of IoT [2]

Motivation

- Shortage of radio spectrum (Spectrum scarcity)
- Underutilization of the existing Fixed licensed spectrum policy
- Need for efficient spectrum allocation
- Performance degradation due to interface from co-existing wireless system
- Number of applications due to which unlicensed band is over crowded
- Multimedia application where high bandwidth required

Motivation

- Report published by FCC in US

" In many bands, spectrum access is a more significant problem than physical scarcity of spectrum, in large part due to legacy command-and-control regulation that limits the ability of potential spectrum users to obtain such access " [1]

- Due to static spectrum allocation policy

Introduction

- IoT is the third revolution in wireless Network due to advancement in MEMS and Wireless Sensor Network
- Definition of WSN
  - Highly distributed networks of small, lightweight wireless nodes,
  - Deployed in large numbers,
  - Monitors the environment or system by measuring physical parameters such as temperature, pressure, humidity.
- Node
  - sensing + processing + communication
  - Possible due to advancement in MEMS

Wireless Sensor Network

- Applications of WSNs
  - Constant monitoring & detection of specific events
  - Military, battlefield surveillance
  - Forest fire & flood detection
  - Habitat exploration of animals
  - Patient monitoring
  - Home appliances
  - WBANs

Wireless Sensor Network

- WSN Design Objective and Challenges
  - Resource limitations: memory, power, processing, transmission range
  - Small Node size
  - Low Node cost
  - Low Power Consumption – due to limited energy
  - Self-Configurability – due to random deployment
  - Scalability, Adaptability and Reliability
  - Fault Tolerance
  - QoS support

Wireless Sensor Network

- WSN operates on low power communication standard

  Such as IEEE 802.15.4
- Operates on unlicensed spectrum
- Saturated due to the coexistence of various emerging networking standards and technology

  Such as IEEE 802.11, Bluetooth, WLAN, WPAN, RFID, Wi-Fi, ZigBee and WSN etc.
- Performance degradation due coexistence

Cognitive Radio

- Dynamic spectrum access
  - Spectrum Sensing
  - Frequency agility (handoff)
- *"A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets." by Joseph Mitola*[3]

Cognitive Radio

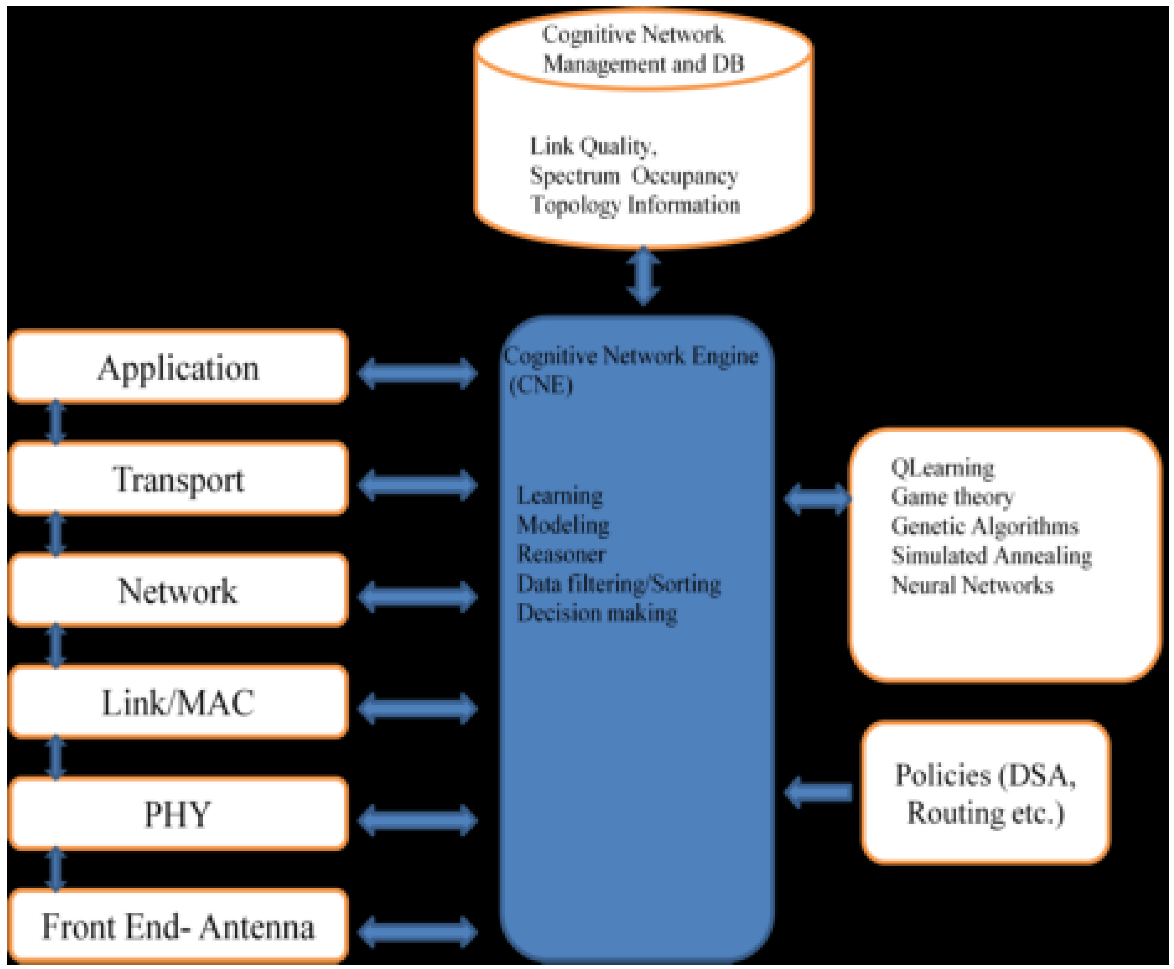

Figure 4: Concept of Cognitive Network [4]

Cognitive Radio

- Concepts of a spectrum hole and opportunistic spectrum sharing

- Spectrum gap, spectrum hole, white space
- Primary user (PU)
- Secondary user (SU)

Spectral opportunity for secondary access: a spectrum hole

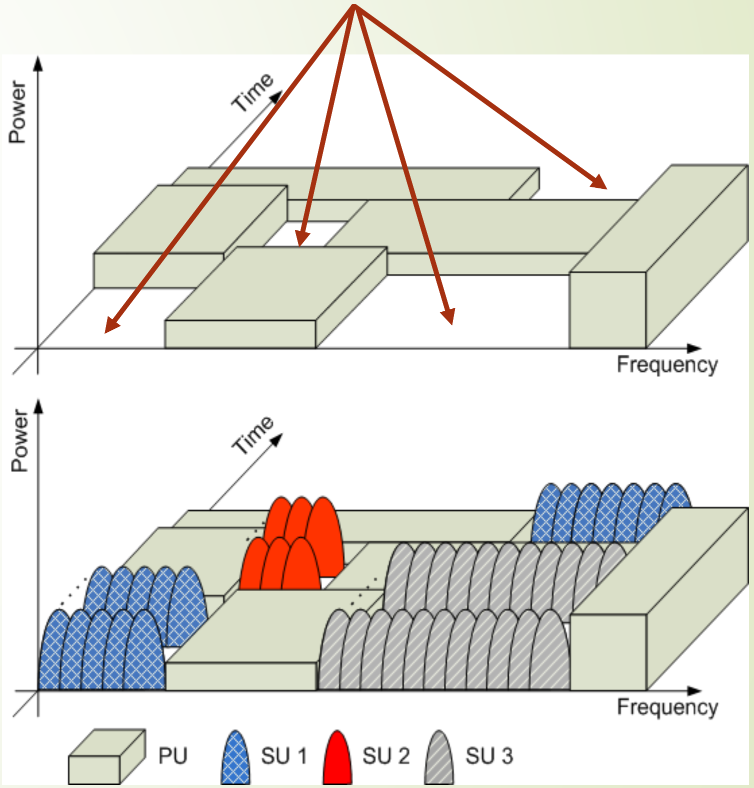

Figure 5: Concept of Cognitive radio [5]

Cognitive Radio

- Spectrum sensing
  - Cooperative sensing
  - Occupancy sensing
    - ‘white’ spaces or spectra
    - ‘grey’ spaces
    - ‘black’ spaces
  - Methods
    - Matched filtering
    - Energy-based detection
    - Feature-based detection

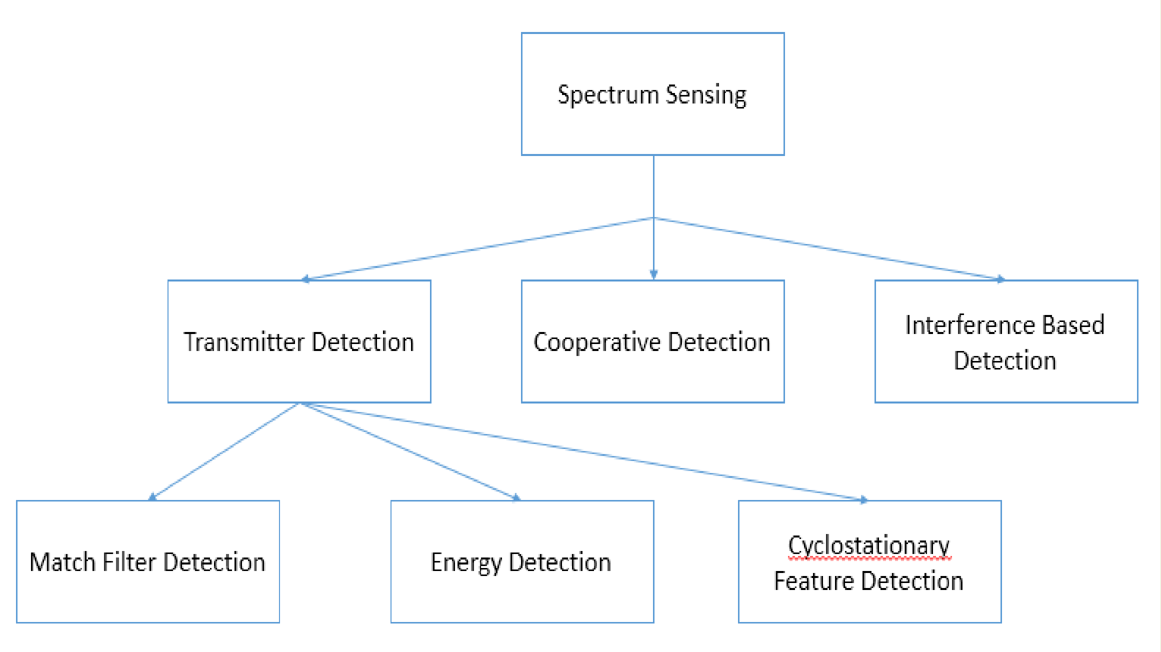

Figure 6: Spectrum Sensing Detection Methods[5]

Cognitive Radio

- Spectrum management
  - Spectrum management is a task to predict how long the spectrum holes are remain available for use to the unlicensed users (secondary users or SUs)
- Spectrum sharing
  - Spectrum sharing is a task to equally distribute the white space between all the secondary users considering usage cost
- Spectrum mobility
  - Spectrum mobility is a task to maintain seamless communication requirements during the transition to better spectrum.

Cognitive Radio Sensor Network

- Sensor nodes
  - energy constrained
  - self configurable
  - cognitive capable
- Sink
- Base station
- Primary user
- Increase spectrum utilization, network life time, efficiency

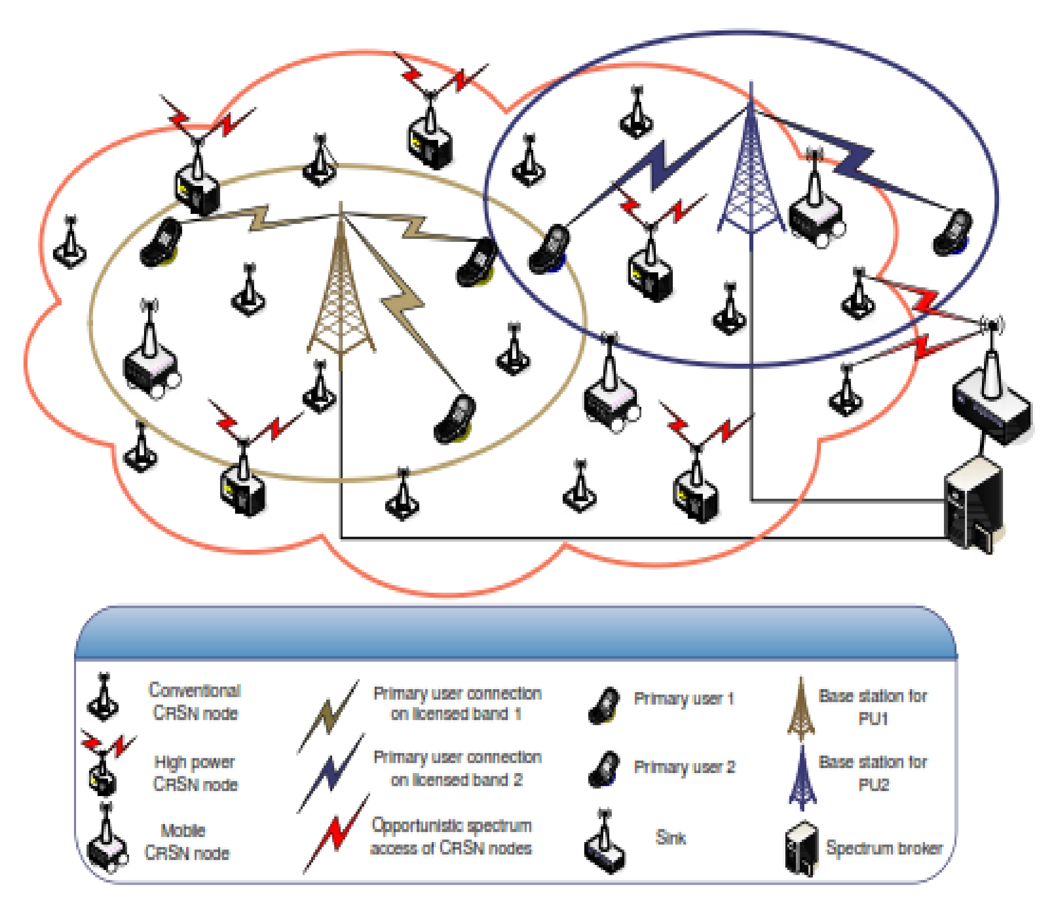

Figure 7: A typical communication model of CR-WSN[3]

Cognitive Radio Sensor Network

- Opportunistic channel usage for bursty traffic
- Dynamic spectrum access
- Using adaptability to reduce power consumption
- Overlaid deployment of multiple concurrent WSN
- Access to multiple channels to conform to different spectrum regulations

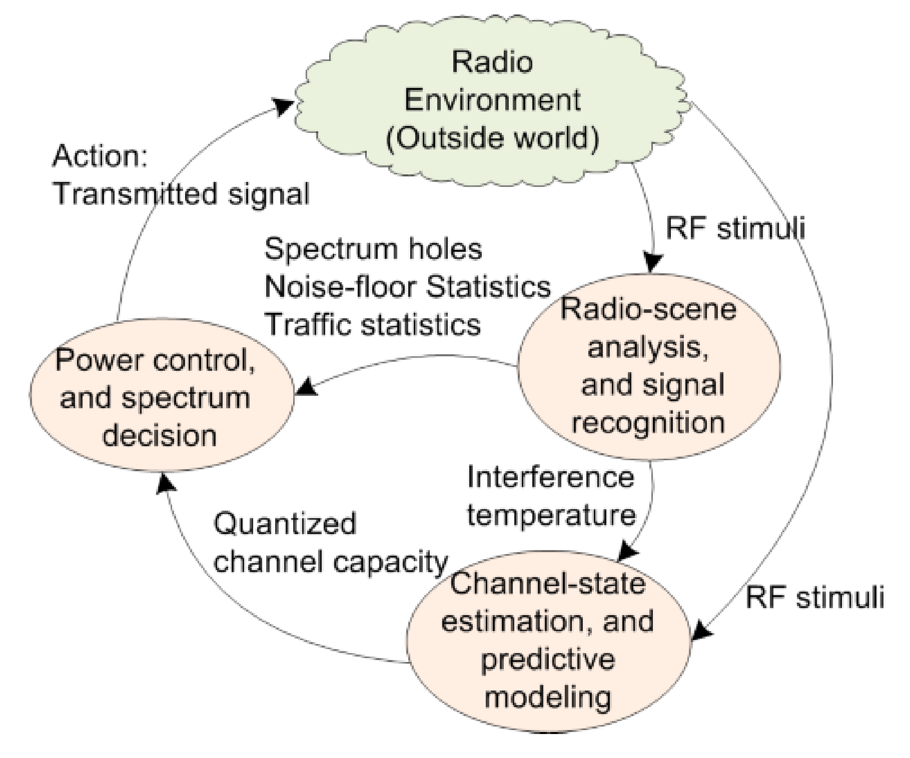

Figure 6: Basic cognitive cycle of CR-WSN [7]

Cognitive Radio Sensor Network

- WSN vs CR-WSN
  - ISM - Licensed spectrum bands (Data channels) Licensed or ISM band (control channel)
  - Intelligent, cognition capabilities, small, moderate processing capacity, moderate memory capacity
  - Bandwidth deficient – Sometimes
  - Seamless operation – Not concerned with PUs
  - Failure rate – High - Moderate (*expected)
  - CCC requirement - Not really - Mostly Required (except some exceptions)

Cognitive Radio Sensor Network

- Applications
  - Military and Public Security Application
    - Jamming signal problem
  - Health Care
  - Home Appliances and Indoor Applications
    - ISM bands are extremely crowded
  - Bandwidth-Intensive Applications
    - Multimedia application
    - Huge bandwidth requirement
  - Real-Time Surveillance Applications
    - Minimum channel access delay

Cognitive Radio Sensor Network

- Challenges and issues
  - Detection, False Alarm, and Miss-Detection Probability
  - Frequent topology changes
  - Fault Tolerance
  - Manufacturing Costs
  - Channel Selection
  - Power Consumption
    - Energy efficiency in sensing
    - Clustering for energy efficiency
    - Energy efficient Modulation Technology
    - Energy Efficient MAC design

Cognitive Radio Sensor Network

- Energy-Efficient Design
  - Efficient and low cost physical layer design to support extra CR capabilities
  - Efficient Data link layer Design
    - Efficient error control mechanism
    - MAC sub layer to fair access of medium
  - Efficient Network layer Design to support CR based routing

Medium Access Control Protocol

- Responsible for the sharing of a common communication medium fairly amongst multiple users
- Addressing of destination and source stations
- Provide transparent service to Logical Link Layer
- Protection against errors by dividing in frame and frame sequences
- To provide Cognitive capabilities redefinition of protocol stack required
- Which provide efficient utilization of spectrum and protect PU rights

Medium Access Control Protocol

- Issues with MAC
  - Spectrum sensing error as a miss detection and false alarm
  - Selection of common control channel for control signalling
  - Spectrum sensing delay in each phase
  - Energy Consumption in sensing.
  - Interference with PUs which violate the rights of PUs
  - Synchronization of SUs nodes

Medium Access Control Protocol

- Classified in three categories
  - Split Phase based – two sub phase control phase and data transmission phase
  - Dedicated control channel based - two transceivers one tuned with CCC
  - Frequency hopping based – hop between the channels
- Environment sensing
- Channel negotiation
- Data transmission

Literature Survey

- Paper 1: Energy Efficient Channel Management Scheme for CRSN [11]
  - Authors : Jeong Ae Han, W. S. Jeon and D. G. Jeong
  - IEEE Transaction on Vehicular Network 2011
- According to authors, CRSN required extra more energy to support CR capability like channel sensing and switching
- Select operating parameters according to channel sensing and energy uses
- Practically Observable Markov Decision process
- Discontinue transmission during frequency agility if PU appears
- Trade-off between long and short sensing to reduce energy consumption and protect PU's rights

Literature Survey

- POMDP framework depends on
  - Data Communication
  - Channel sensing for operating channel
  - Channel sensing for backup channel
  - Changing of Operating channel
  - Changing of Backup channel

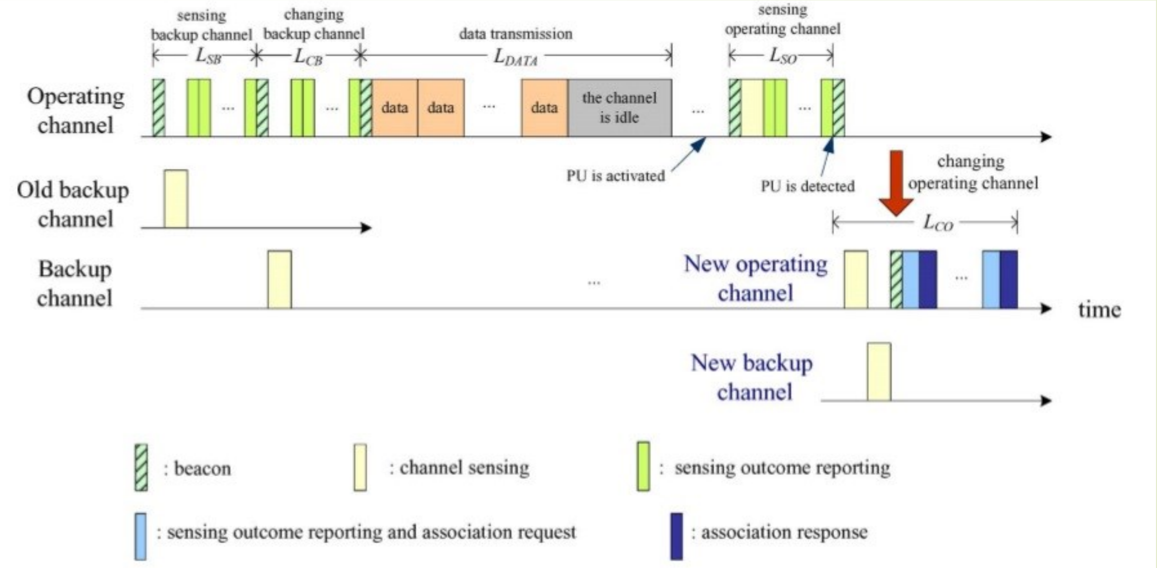

Figure 7: Operation of CRSN according to [11]

Literature Survey

- Paper 2: Performance analysis of CSMA-based opportunistic MAC protocol in CRSN [14]
  - Authors : G. A. Shah and O. B. Akan
  - Ad Hoc Networks Journal, Elsevier 2014
- According to authors, PUs are more privileged users of spectrum
- Dedicated common control channels (CCC) for SUs
- Channel co-ordination using CCC

Literature Survey

- Node want to send data start first a spectrum sensing at medium
- Search for the channel - low noise & maximum vacancy
- Come again to ccc and ask for contention
- Send sensed channel information in Cognitive RTS
- At receiver side when it receive C-RTS search for channel
- If suggested channel is free send C-CTS or send with free channel list
- At transmitter side when receive C-CTS and found same suggested channel start transmission otherwise start spectrum sensing for free channel suggested by Rx

Literature Survey

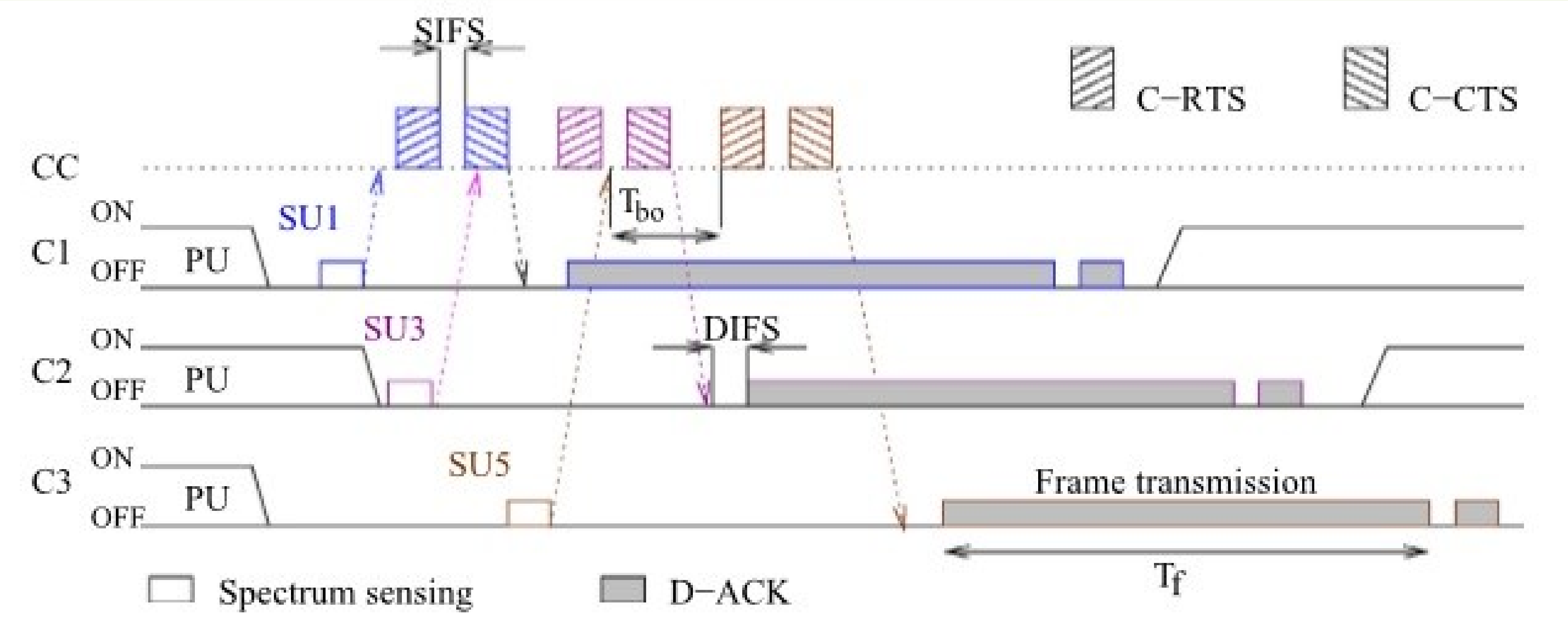

Figure 8: Dynamic spectrum access of SUs driven by CCC [14]

Literature Survey

- Paper 3: Cognitive Adaptive Medium Access Control in Cognitive Radio Sensor Networks [10]
  - Authors : Ghalib A. Shah and Ozgur B. Akan
  - IEEE Transaction on Vehicular Technology 2015

- Spectrum sensing is an integral part of MAC in CR - an energy consuming
- Required to be minimized for CR-WSNs due to resource scarcity
- Energy conservation in CAMAC is achieved in three fronts:
  - On-demand spectrum sensing
  - Limiting the number of spectrum sensing nodes
  - Applying a duty cycle

Literature Survey

- Use dynamic and adaptive sensing period
  - fast sensing
  - fine sensing
- Slotted ALOHA for access of common control channel

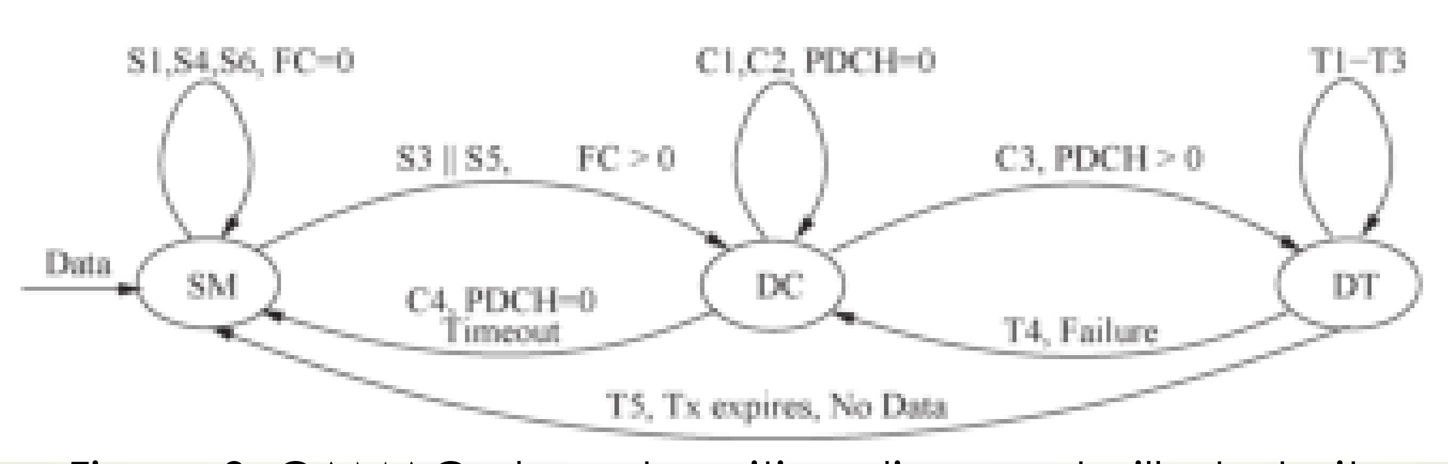

Figure 8: CAMAC phase transition diagram to illustrate its MAC operations [10]

Literature Survey

- Paper 4: Energy Efficient COGnitive MAC for Sensor Networks under WLAN Co-existence [8]
  - Authors : Ioannis Glaropoulos, Marcello Lagana, Viktoria Fodor and Chiara Petrioli
  - IEEE Transaction on Wireless Communication 2015
- Energy efficiency is a main parameter for design of communication protocol for battery constrained WSN
- Performance degrade due to interference from high power wireless system
- A novel cognitive MAC scheme is propose
- Minimize the energy cost by optimizing Packet length & single hop transmission distance

Literature Survey

- Scenario in which coexistence of WLANs IEEE 802.11 and WSN IEEE 802.15.4
- WSN – 5MHz channel in 2.4GHz ISM band – 0 to 3dBm
- WLAN – 22MHz channel which cover WSN channel – 15 to 20dBm
- Two Phase of COG-MAC
  - Estimation & Optimization
    - Listens to the channel
    - Select optimal packet size & transmission distance
  - Transmission with COG-MAC
    - actual network operation occurs
    - sensor transmits and receives data packets

Literature Survey

- Energy cost minimization is achieved by optimizing the WSN single hop transmission distance and packet length, based on the estimated parameters of the WLAN channel usage model
- In COG-MAC optimization of packet size and transmission distance and smart channel sensing are key mechanisms for increasing energy efficiency

Literature Survey

- Paper 5: Adaptive Window Size-Based Medium Access Control Protocol for Cognitive Radio Wireless Sensor Networks [9]
  - Authors : Gyanendra Prasad Joshi, Seung Yeob Nam, Sung Won Kim and Byung-Seo Kim
  - Journal of Sensors, Hindawi Publishing Corporation 2016

- Performance degrade due to fixed channel negotiation in CCC
- A new approach in MAC protocol is propose
- Adjusts the channel negotiation period based on network density

Literature Survey

- Incumbents have the first priority to utilize the licensed bands
- Protocol use a Common Control Channel (CCC) for data channel negotiation
- Protect rights and to mitigate the interference with the incumbents
- CCC-based protocols divide time
  - Beacon Intervals (BIs)
    - Channel Negotiation (CN) window
    - Data window
- CN window - nodes send control packets for channel negotiation and reservation
- Data window - nodes send actual data packets

Literature Survey

- Channel Utilization Limitation
- Bandwidth Waste in Channel Negotiation
- Long Channel Access Delay
- In proposed protocol network density estimation perform
- Accordingly CN window will adjust

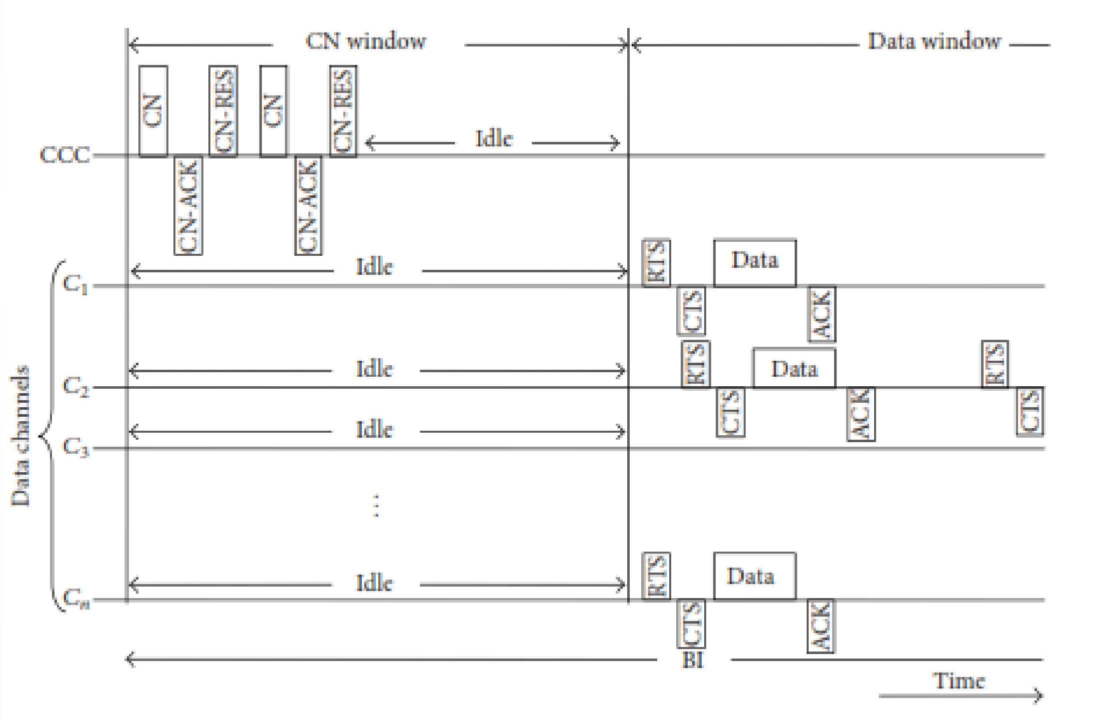

Figure 9: Bandwidth waste in existing approaches [9]

Literature Survey

- CN window divided in two phase
  - Nodes Estimation (NE)
  - Channel Negotiation (CN)

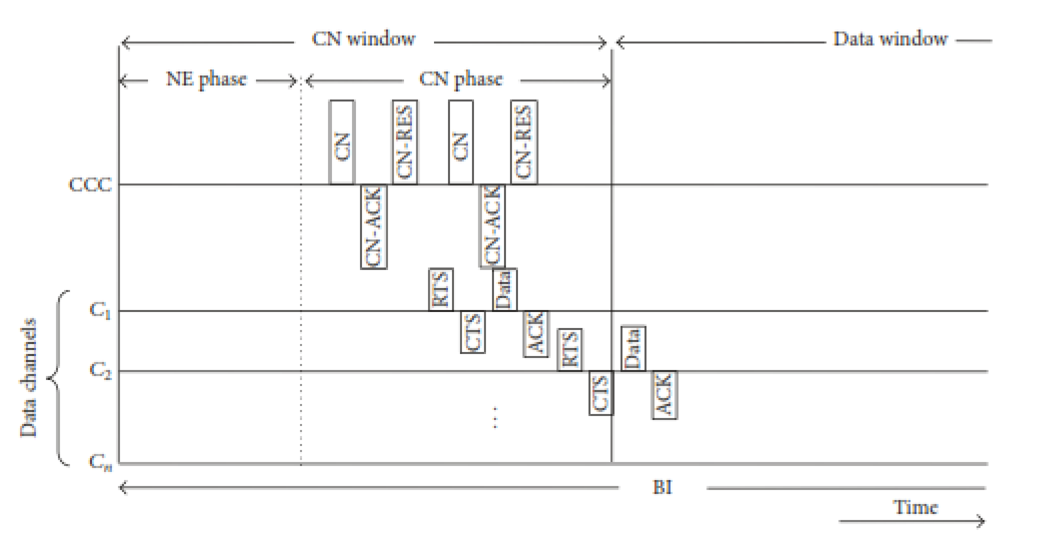

Figure 10: Efficient bandwidth utilization in proposed protocol [9]

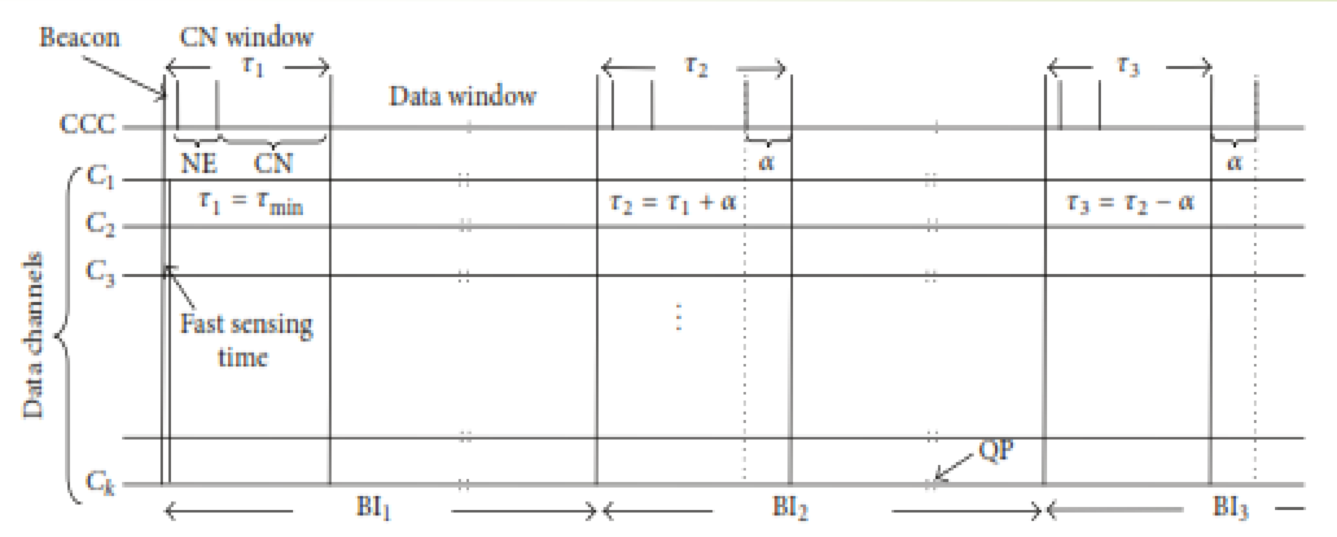

Figure 11: CN window adjustment [9]

Literature Survey

- Algorithm

if NE phase expired then

estimate n;

If $n < n_{\text{thresh}}$

and $\tau > \tau_{\text{min}}$ and $\tau \leq \tau_{\text{max}}$ then

$\tau - = \alpha$

else if

$n \geq n_{\text{thresh}}$ and $\tau_i < \tau_{\text{max}}$ then

$\tau + = \alpha$

else

remain unchanged

start contention for sending CN packet

Literature Survey

- In the dense network topology, a small CN window can be a bottleneck
- In the sparse network topology, a large CN window decreases network performance and increases delay
- The strategies used to turn off transceivers conserve energy
- It also protects licensed users by performing sensing in the middle of the data window and sending an ECM in case of signal detection of licensed users

Scope of Research

- Three ways to optimized energy consumption
  - Spectrum sensing
  - Capability to change transmission parameters
  - Ability to share network knowledge

Conclusion

- Cognitive radio technology is a potential technology for future wireless systems like the Internet of Things, WSNs, and M2M systems and provides benefit in co-existence of different wireless technology by improving spectrum utilization.
- Due to limitation of WSN and to support cognitive capabilities redefinition of protocol stack is required.
- The Cognitive MAC layer and its mechanisms provide a solution to these challenges and improving the secondary user's performance.
- We can conclude that the main tasks of cognitive MAC are environment sensing, channel negotiation, and data transmission.

Reference

1. Federal Communication Commission, “Spectrum Policy Task Force”,Rep.ET Docket no. 02-135, Nov-2002
2. J. Mankyika, M. Chui, P. Bisson, and J. Woetzel, “THE INTERNET OF THINGS : MAPPING THE VALUE BEYOND THE HYPE,” Report 2015.
3. O. B. Akan, M. T. Isik, and B. Baykal, “Wireless passive sensor networks,” IEEE Commun. Mag., vol. 47, no. 8, pp. 92–99, 2009.
4. S. Samoohi and C. Graff, "Challenges of using software defined radio platforms in validating Cognitive Network concepts," Wireless Information Technology and Systems (ICWITS), 2010 IEEE International Conference on, Honolulu, HI, 2010, pp. 1-4.
5. Jemish V Maisuria and Dr. Saurabh N Mehta, “Spectrum Sensing Techniques in Cognitive Radio Network: a comparative study” 11th International conference on Microwave, Antenna, Propagation and Remote Sensing (ICMARS 2015), 15-17 December 2015 Jodhpur – Rajasthan
6. A. Dalvi, P. K. Swamy and B. B. Meshram, "Cognitive radio: Emerging trend of next generation communication system," Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology (Wireless VITAE), 2011 2nd International Conference on, Chennai, 2011, pp. 1-5.
7. Jian-guang Jia, Zun-wen He, Jing-ming Kuang and Hui-fen Wang, “ Analysis of Key Tehnologies for Cognitive Radio Based Wireless Sensor Network”,IEEE ,2010.
8. Ioannis Glaropoulos, Marcello Lagana, Viktoria Fodor and Chiara Petrioli,”Energy Efficient COGnitive MAC for Sensor Networks under WLAN Co-existence.”, IEEE Transaction on Wireless Communications, TWC 2015.
9. Gyanendra Prasad Joshi, Seung Yeob Nam, Sung Won Kim and Byung-Seo Kim, “Adaptive Window Size-Based Mediam Access Control Protocol for Cognitive Radio Wireless Sensor Networks.”, Journal of Sensors, Hindawi, pp-9, Vol 2016.

Reference

10. Ghalib A. Shah and Ozgur B. Akan, " Cognitive Adaptive Medium Access Control in Cognitive Radio Sensor Network." ,IEEE Transactions on Vehicular Technology, Vol. 64, No. 2, Feb-2015.

11. Jeong Ae Han, W. S. Jeon, and D. G. Jeong, "Energy-Efficient Channel Management Scheme for Cognitive Radio Sensor Networks11 printed.pdf," IEEE Trans. Veh. Technol., vol. 60, no. 4, pp. 1905–1910, 2011.

12. Mubashir Husain Rehmani, St´ephane Lohier, and Abderrezak Rachedi. "A Survey of Channel Bonding for Wireless Networks and Guidelines of Channel Bonding for Futuristic Cognitive Radio Sensor Networks.", IEEE Communications Surveys & Tutorials · January 2015.

13. Tulika Mehta, Naresh Kumar and Surender S Saini, "Comparison of Spectrum Sensing Techniques in Cognitive Radio Networks" InternatIonal Journal of electronIcs & communIcatIon technology, Vol. 4 Issue 3, pp. 33-37, 2013.

14. G. A. Shah and O. B. Akan, "Ad Hoc Networks Performance analysis of CSMA-based opportunistic medium access protocol in cognitive radio sensor networks," Ad Hoc Networks, vol. 15, pp. 4–13, 2014.

15. Risheek Kumar, "Analysis of Spectrum Sensing Techniques in Cognitive Radio" International Journal of Information and Computation Technology, ISSN 0974-2239 Vol. 4, Issue 4, pp. 437-444, 2014.

16. Tevfik Yucek and Huseyin Arslan, "A Survey of Spectrum Sensing Algorithms for Cognitive Radio Applications", IEEE Communication Surveys & Tutorials, VOL. 11, NO. 1, pp: 116-130, 2009.

18. Gyanendra Prasad Joshi, Seung Yeob Nam and Sung Won Kim, "Cognitive Radio Wireless Sensor Networks: Applications, Challenges and Research Trends", Sensor, Vol. 13, pp-11196-11228, 2013.

19. A. Amanna and J. H. Reed, "Survey of cognitive radio architectures," IEEE SoutheastCon 2010 (SoutheastCon), Proceedings of the, Concord, NC, 2010, pp. 292-297.

Reference

20. G. Ganesan and Y. G. Li, “Cooperative spectrum sensing in cognitive radio-Part I: Two user networks” IEEE Trans. Wireless Commun., vol. 6, pp. 2204–2213, Jun. 2007.

21. G. Ganesan and Y. G. Li, “Cooperative spectrum sensing in cognitive radio-Part II: Multiuser networks,” IEEE Trans. Wireless Commun., vol. 6, pp. 2214–2222, Jun. 2007.

Thank You…