OPTIMAL SPECTRUM HOLE SELECTION & EXPLOITATION IN COGNITIVE RADIO NETWORKS

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Outline

- Introduction
- Cognitive Radio
- System Model
- Performance Evaluations
- Conclusion and Future Works
Introduction

- The mobile data traffic grew by 280% (during last two years)
- A huge increase in the machine-to-machine (M2M) wireless communications
- Radio spectrum needs to fulfill the above demands
Cognitive Radio

- A radio or system that senses, and is aware of, its operational environment and can dynamically and autonomously adjust its radio operating parameters accordingly [ITU].

- Cognitive Radio (CR) is defined as a radio that can change its transmitter parameters based on interaction with the environment in which it operates [Ofcom].
Cognitive Radio Capability

- Intelligent wireless system that possess rapidly reconfigurable radio functions.
  - Uses SDR technology (Technology that enables reconfigurable system for wireless networks.)
- Is Aware of its environment
  - Network Traffic.
  - RF spectrum occupancy
  - Transmission Quality.
- Can learn from its environment and adapts to new situations based on its previous experiences.
Dynamic Spectrum Access

Dynamic spectrum access and cognitive radio techniques

- Concepts of a spectrum hole and opportunistic spectrum sharing:

  Spectral opportunity for secondary access: a spectrum hole.

  Concept of opportunistic spectrum sharing: secondary utilization of the identified spectrum holes.
Dynamic spectrum access can drastically improve the performance of wireless networks struggling under increasing user demand.

Ofcom believe DSA technology could generate up to 6.5 bn for UK economy in next 20 years.

More efficient use of spectrum
- Minimize cost of changing channels
- Coordination
- who uses which channels when
- Synchronization
- overhead for coordination
System Model

- Multi-Licensed channels
- Secondary Users locate inside network
- Profoundly & frequently sensing
- Perfect adaptation phase (no delay)
Analysis Specifications

- Primary user channel utilization is Poisson process.
- OFF/ON channel model (identical independent random variable)
- $\mu_{off}$ and $\mu_{on}$: OFF and ON arrival rates
- OFF/ON period of times are exponential random variable

$$f(t, \mu_{off}) = \begin{cases} \mu_{off}e^{-\mu_{off}t}, & t \geq 0 \\ 0, & t < 0 \end{cases}$$

$$f(t, \mu_{on}) = \begin{cases} \mu_{on}e^{-\mu_{on}t}, & t \geq 0 \\ 0, & t < 0 \end{cases}$$

X, Y random variables

Secondary transmission cycle
Spectrum Hole Selection Schemes

- Minimum Collision Technique (MCT)
  - Based on the minimum evaluated probability of collision.
    \[ H_i(t) = \arg\min(i \mid P(Y^i \leq T_{Ri}^i) < \varepsilon) \in \mathbb{N}(t) \]

- Maximum Remain Lifetime Technique (MRLT)
  - Maximum remain lifetime of the idle channel at time instance \( t \).
    \[ H_i(t) = \arg\max(i \mid T_{Ri}^{idle} \in i \in \mathbb{N}(t) \]
Proposed Algorithm

- Channels mean OFF time values; 1, 5, 3, 6, 2, 1, 7, 1, 4, 3 seconds
- Channels mean ON times: 2 seconds
- Minimum period of secondary transmission: 3.2ms

Algorithm. Channel selection algorithm using (13) and (14)
1. Begin
2. Inputs $N, \mu_{off}, \mu_{on}, \epsilon, \delta, TthI$
3. For $i=1:N$
4. Sense channels
5. $Nt \leftarrow$ unoccupied channels
6. Evaluate (12)
7. end
8. If $Nt$ is empty
9. Stop Transmission
10. Else
11. $Hjt = \arg\min_i \pi(\forall t \leq \epsilon \leq \epsilon N(t))$
12. If $(j \neq 0)$
13. Transmission on channel $j$
14. Else
15. Stop Transmission
16. End (if)
17. $Hj1t = \arg\max_i \pi I_{idle}(\forall t \geq TthI \leq Nt)$
18. If $(j1 \neq 0)$
19. Transmission on channel $j1$
20. Else
21. Stop Transmission
22. End (if)
23. End
Average Channel Utilization

- Average channel utilization through MRLT and MCT schemes

\[ ACU = \frac{1}{T} \sum_{k=1}^{n} \left( 1 - \exp \left( -\frac{\mu_{\text{off}}T_k}{\mu_{\text{on}}} \right) \right) \times 100\% \]
Channels 4, 7 and 9 will be targeted because of channel OFF time.
Secondary Data Delivery

- Data delivery will be more through MRLT scheme during 100s.
Conclusion & Future works

- It can be seen that MRLT scheme improves spectrum utilization in comparison with MCT.
- Adaption delay and real sensing delay and sensing time need to be considered.
- Cooperative spectrum selection scenario in coexistence networks.
Thank you for your attention