Spectrum-Aware and Cognitive Sensor Networks for Smart Grid Applications

Agenda

- Wireless Sensor Networks
- Challenges in applying WSNs in Smart Grid
- Spectrum-Aware and Cognitive Sensor Networks
- Advantages of SCSN
- Potential applications of SCSN in Smart Grid
- SCSN Communication Protocol Suite
- Case Study
- Conclusion

Wireless Sensor Networks(WSN)

- WSNs have been widely recognized as a promising technology that can enhance various aspects of electric power systems, including, generation, transmission, utilization etc
- They form a vital component of next generation electric power systems, the SMART GRID
- How do they work?

Challenges to Apply WSNs in Smart Grid

- Harsh environmental conditions
- Reliability and latency requirements
- Packet errors and variable link capacity
- Resource constrains

Spectrum Aware and Cognitive Sensor Networks(SCSNs)

- SCSNs overcome the spatio-temporally varying spectrum characteristics and harsh environmental conditions for WSN-based smart grid applications
- The goal of this paper is to envision potentials of SCSNs for reliable and low cost remote monitoring solutions for smart grid

Advantages of SCSNs

- Minimization of environmental effects
- Access to licensed and unused spectrum bands
- Adaptation to different spectrum utilization patterns
- Overlay deployment of multiple sensor networks

Potential applications of SCSN in Smart Grid

- Remote monitoring for electric power generation systems
- Remote monitoring for electricity T&D Network
- Remote monitoring for consumer facilities

Spectrum Management Requirement and Challenges

- **Spectrum Sensing**
  - Consider a large scale smart grid system with large number of nodes with low cost requirement
  - You cannot have sophisticated spectrum algorithm or equip sensor nodes with multiple radios
  - Have one radio per node
- Challenges
  - Address tradeoff between energy consumption and sensing accuracy

- **Spectrum Decision**
- Ability to change operating spectrum bands
- Parameter selection is an important aspect. Parameters include transmission power, energy efficiency, error rate etc
- Coordination among different sensor nodes is very important

- **Spectrum Sharing**
  - Transmission in smart grid environment should be coordinated by spectrum sharing functionalities to avoid packet collision
  - Implemented in MAC layer
- Challenges
  - Time Synchronization
  - Distributed Power Allocation & Spectrum Utilization
  - Topology Discovery

- **Spectrum Mobility**
  - In presence of interference, ongoing communication can be carried on a different channel
  - Decision is made by spectrum decision algorithm
- Challenges
  - Mobility may disturb ongoing communication
  - Heterogeneity

SCSN Communication Protocol Suite

- **Physical layer**
  - SCSN node's physical layer must be configurable in terms of operating frequency, modulation, channel coding, transmission power, spectrum sensing duration
  - Configuration should be based on spectrum sensing and decision results
  - Provide statistical information about channel conditions to upper layers

- **Data Link Layer**
- Efficient MAC and error control mechanisms
- Adaptive FEC or hybrid automatic repeat request(ARQ) for error correction instead of FEC
- Repetitive ARQ can block packet forwarding and cause congestion due to excessive incoming packets. This needs to be addressed
- Cost vs. benefit analysis of employing FEC, ARQ, hybrid and co operative schemes should be well investigated

- **Routing Layer**
  - Offers route selection through sink node to minimize interference
  - Spectrum decision must be performed after investigating tradeoffs between spectrum handoff and adaptation of routing layer to the concurrent operating channel
  - Multipath routing to benefit from path diversity
  - Cooperative routing schemes to increase energy efficiency on packet forwarding

- **Transport Layer**
- Reliability and congestion control become an extremely challenging task with integration of cognitive radio and sensor networks
- In SCSNs the congestion control algorithm must be aware of the cognitive cycle and perform load balancing in a distributed manner
- Real time requirements of time critical applications should be considered
- Real time transport protocols must maximize reliability and minimize delay

Case Study

- **Energy Harvesting in SCSN**
- Sensor nodes deployed in high voltage smart grid environment will need appropriate power sources
- While communicating a sensor node's power consumption is in the order of few milliwatts and it reduces to few microwatts in sleeping mode
- Energy harvesting can enhance the performance of SCSN with self charging or self healing capability
- Unattended energy in the environment, such as solar, mechanical, thermal etc can be scavenged to energize sensor nodes
- Possible energy harvesting techniques: Magnetic Induction, Modulated Backscattering

Conclusion

- Recent field test show that reliable communication in smart grid is a challenging task for WSN based smart grid applications due to electromagnetic interference, noise, dynamic topology changes, and fading. In this article, spectrum-aware cognitive sensor networks are introduced to provide reliable and efficient communication for remote monitoring applications in smart grid
- Challenges and requirements of spectrum management facilities as well as communication protocol suite was discussed