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Frequency Agility in a ZigBee Network for Smart Grid Application

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Agenda

- Motivation
- Objective
- Performance of ZigBee and WiFi Coexistence
- Interference Avoidance Scheme—Frequency Agility
- Test Result and Performance Evaluation
- Conclusion
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Motivation

Smart Grid is an intelligent power generation, distribution and control system which seeks to maximize energy efficiency and foster greater adoption of renewable energy sources.

IIT Perfect Power Project, a five-year project sponsored by DoE, aims to develop, demonstrate, promote, and commercialize a Perfect Power system that cannot fail to meet the electric needs of the individual end-user.

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Motivation

ZigBee is the most suitable wireless technology to monitor, collect, and analyze data on energy usage in real time for smart grid application.

- Low cost
- Low power Consumption
- Flexible and extendable
- Easy and inexpensive to deploy
- Global with use of unlicensed radio bands

Problem: IEEE 802.11 Wireless Local Area Networks (WLAN) shares the same license-free 2.4GHz Industrial, Scientific and Medical (ISM) frequency band with ZigBee.

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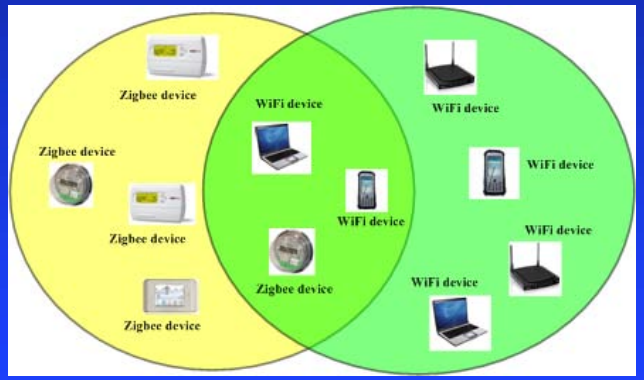
Objective

- Design an efficient interference avoidance scheme which is simple and practicable to ensure the performance of ZigBee with WiFi present
  - require minimal adjustments to the existing IEEE 802.15.4 standard
  - avoid a performance penalty
  - Minimum the usage of system resources.



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Performance of ZigBee and WiFi Coexistence

- Bit Error Rate (BER) and Packet Error Rate (PER)
- Assume signal transmission in an Additive White Gaussian Noise (AWGN) channel, with blind transmissions for both IEEE 802.15.4 and IEEE 802.11b
- $$L_p(d) = \begin{cases} 20\log_{10}(\frac{4\pi d}{\lambda}) & , \quad d \le d_0 \\ 20\log_{10}(\frac{4\pi d}{\lambda}) + 10n\log_{10}\frac{d}{d_0}, & \quad d > d_0 \end{cases}$$

where path loss exponent n equals to 3.3 and d_0 is 8 meter

$$BER = Q(\sqrt{2SINR})$$

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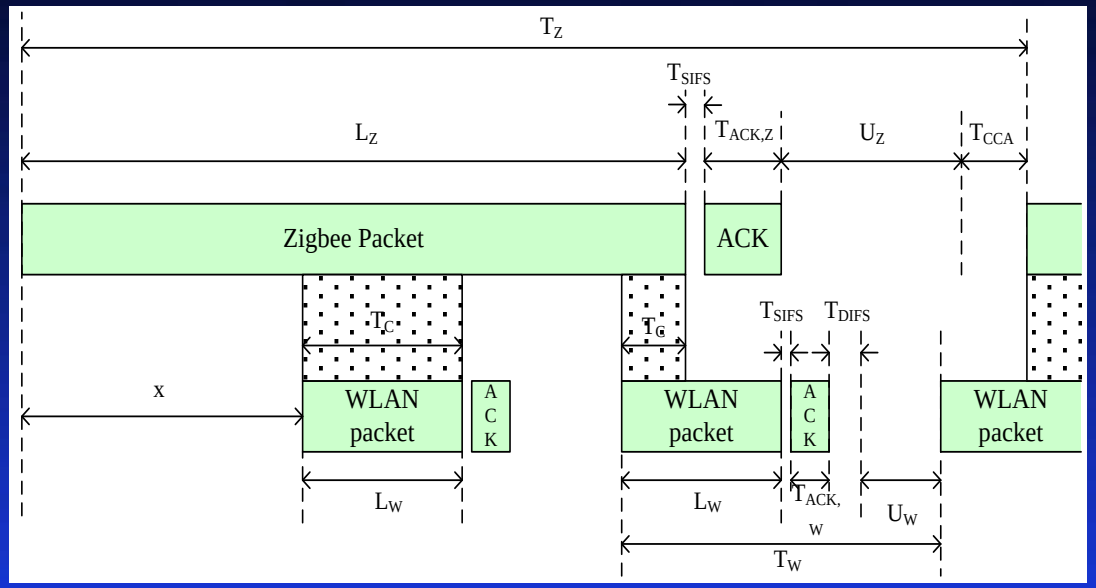

Fig. 2. IEEE 802.11b and IEEE 802.15.4 Interference Model [2]

$$PER = 1 - [(1 - P_b)^{N_z - \lceil T_c/b \rceil} \times (1 - P_b^I)^{\lceil T_c/b \rceil}]$$

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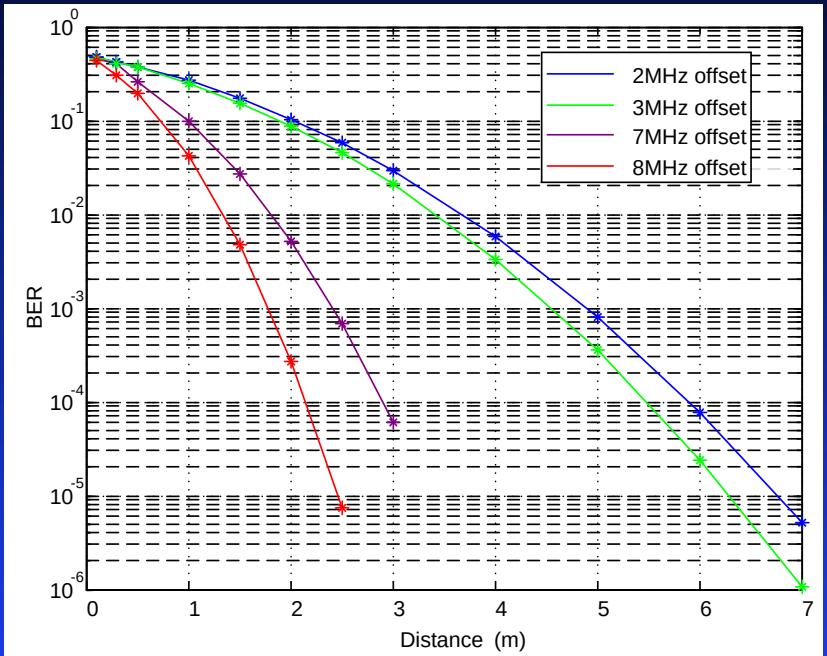

- Main interference power concentrate in the WiFi central frequency which create heavy interference.
- Distance is other important factor which can impact BER.

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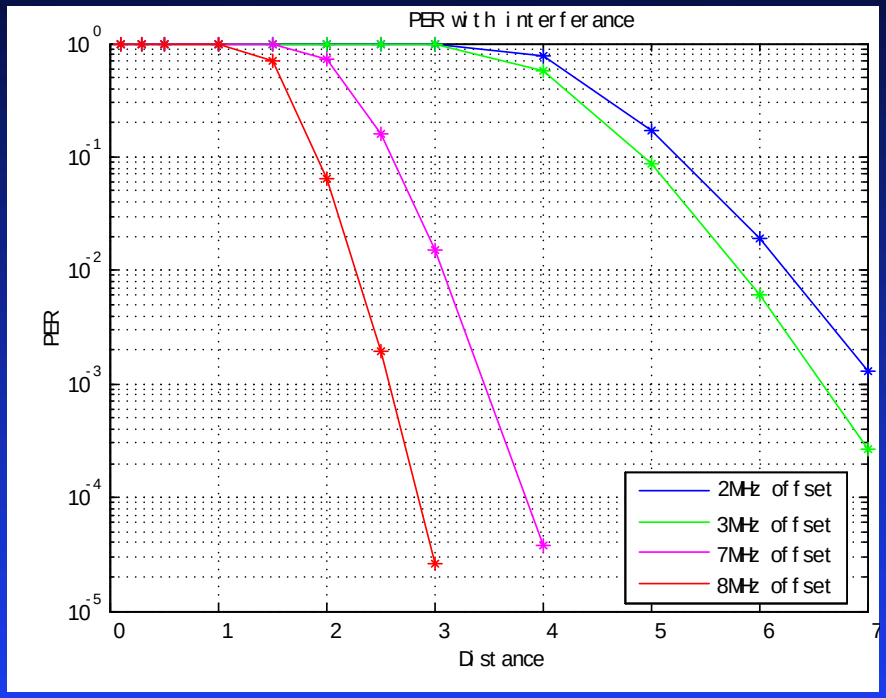

- Offset frequency is 2MHz, the PER is highest and the distance between the Zigbee and WIFi access point must be at least 7 meters.
- Offset frequency is 8MHz , the interference from WiFi is negligible.

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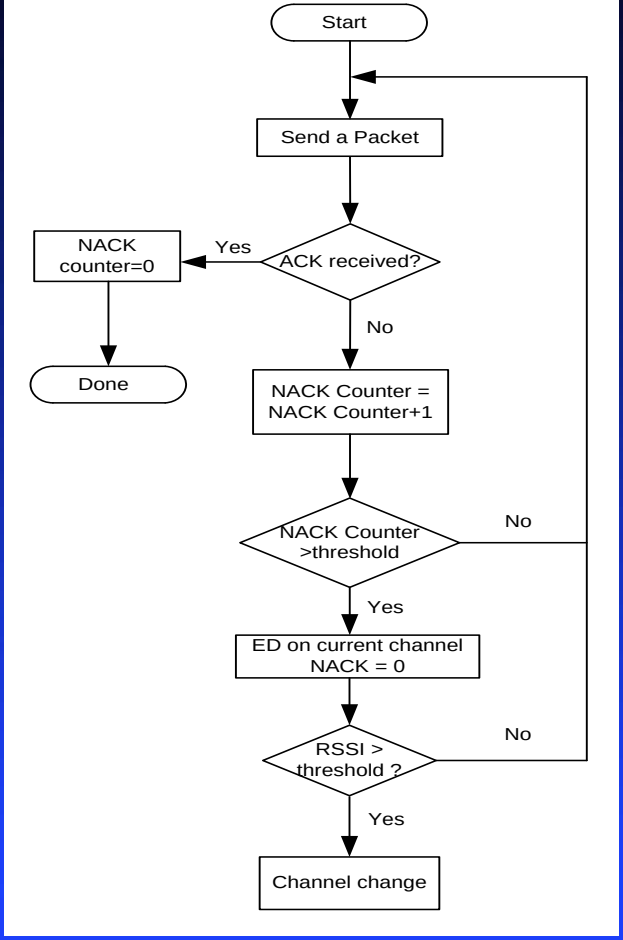
Interference Avoidance Scheme Frequency Agility

- Interference Detection Scheme



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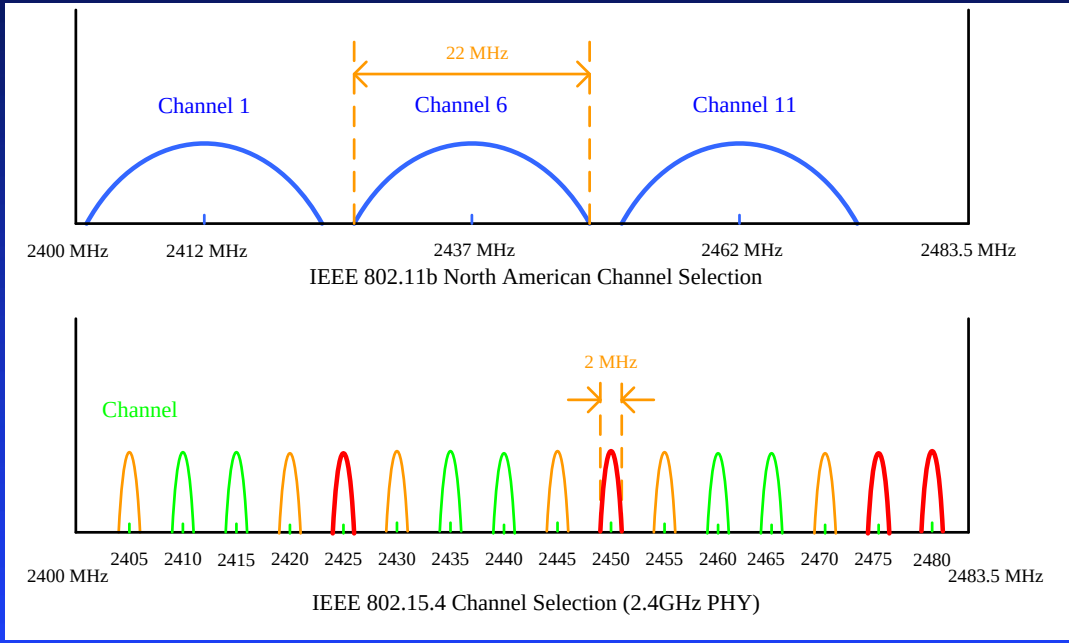
Interference Avoidance Scheme Frequency Agility

- Interference avoidance



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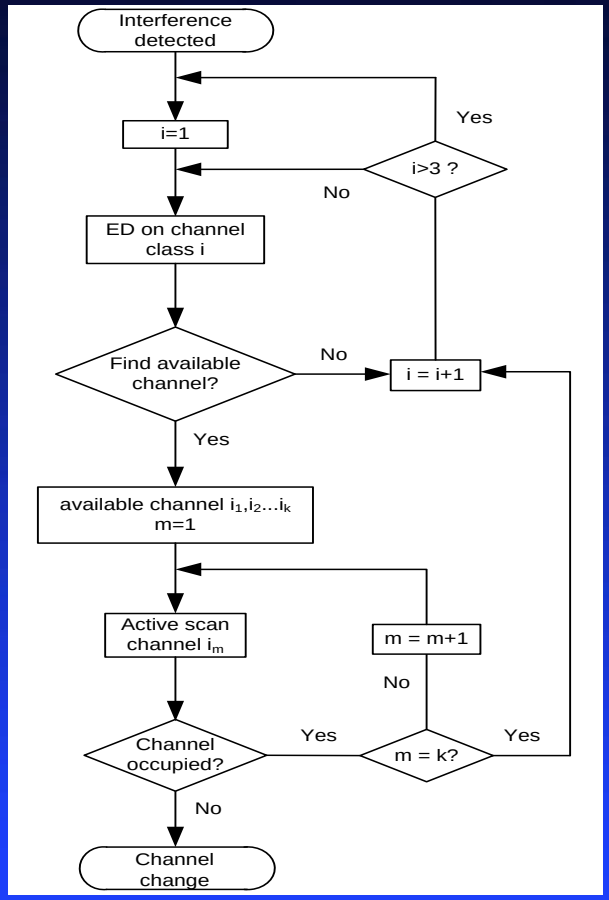
Interference Avoidance Scheme Frequency Agility

- Interference avoidance



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Test Result and Performance Evaluation

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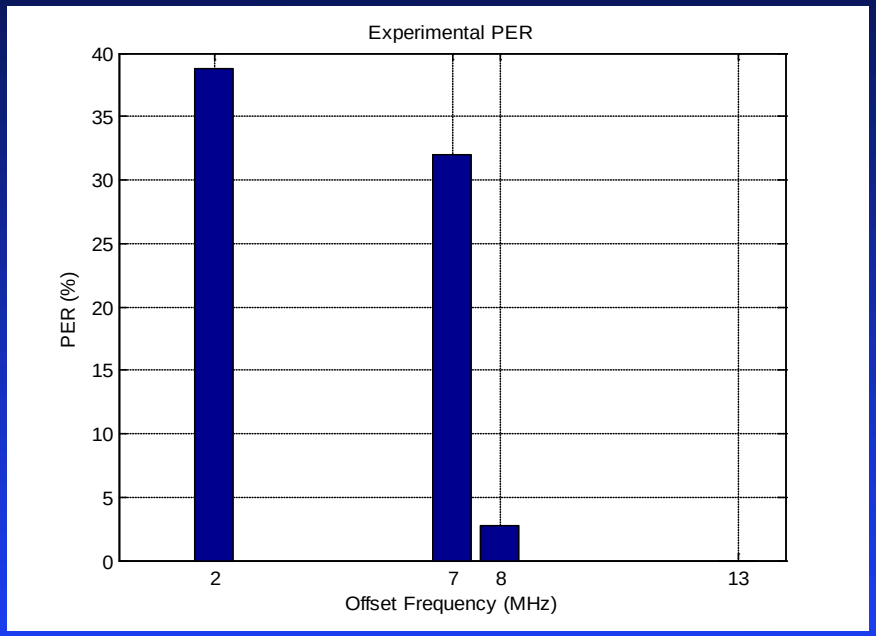
Test Result and Performance Evaluation

- PER = (Number of failed messages / Number of attempted measurements)*100



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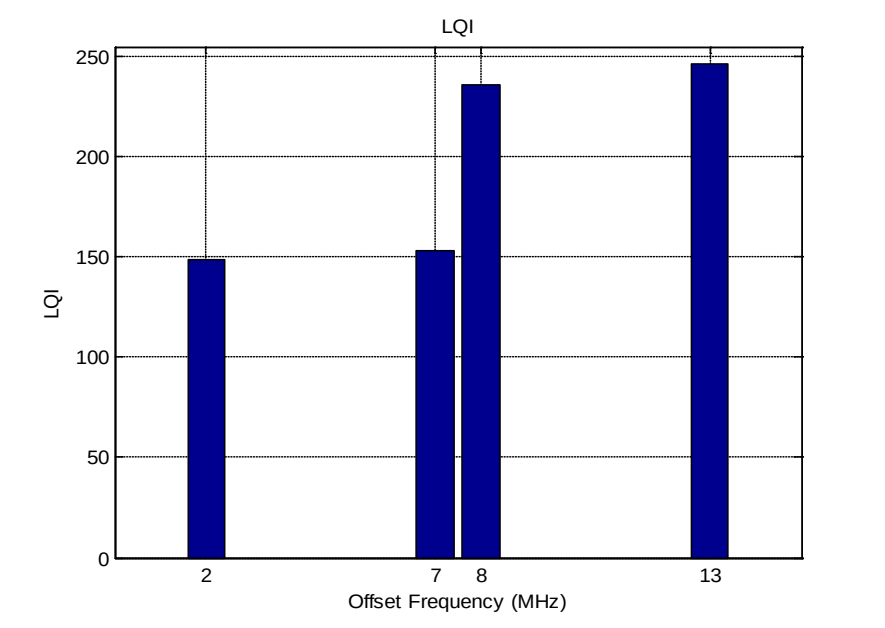
Test Result and Performance Evaluation

• Link Quality Indicator (LQI): indicate the strength or quality of received packet, PER decreases as LQI increases .



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Conclusion

- Frequency Agility Interference Avoidance algorithm:

1. NACK-based interference detection
2. Energy Detection as an energy saving and accurate interference detection scheme
3. Classified channels' energy detection in sequence
4. Active scan makes sure the channel is not occupied

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Future Work

•Interference avoidance algorithm will be implemented on real Zigbee board and performance will be measured in real work, especially in cluster-tree topology in the presence of interference from multiple WLAN APs.

•Design and develop self-forming and self-healing cluster-tree ZigBee systems

•Design and develop MAC Layer protocol to achieve energy-efficient access for cluster-tree networks

•Develop a plan to install ZigBee routers in Siegel Hall and design energy-efficient routing algorithm for communications among cluster heads and routers

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Thank You !