Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Initial proposal of Resilient Relay with Rate adaptation for reliable LECIM PHY]

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Re: [[802.15-GENERAL-LIST] IEEE 802 TG4k issues a call for proposals (CFP)]

Abstract: [For required reliability of LECIM, the resilient relay with rate adaptation is considered.]

Purpose: [To contribute the initial process of PHY standardization for reliable LECIM system.]

Viable CapEx & OpEx with Reliable LECIM

- Reliable Link with appropriate coverage justifying CapEx

  (Frequency & Regulation, Modulation/Coding, Diversity)

  - **Select appropriate frequency bands : Sub 1GHz**
    (due to better propagation & interference)
  - **Modulation/Coding based on Channel Model : 5dB ~ 7dB Eb/No with FEC**
    (@~BER 10^{-3})
  - **Diversity : Frequency, Time, Space (Antenna) as well as Path.**
    (regardless of short packet (block) length)

- Battery Power Life with necessary data transmission frequency

  - **Battery Life affects directly in OpEx : ~ 10 years @ 10 packets / 1 hour**

- Channel Diversity and Path Resiliency (spatial, temporal and frequency)

  - **Contingency Cost on OpEx : Resiliency against Single point of failure.**

LECIM PHY

Critical Infrastructure requires the enhanced reliability.

Hypothetical Global Commonality of 900MHz

Sub 1GHz "Golden Bands" could be available in each WW regions.

915-928MHz
in Japan,

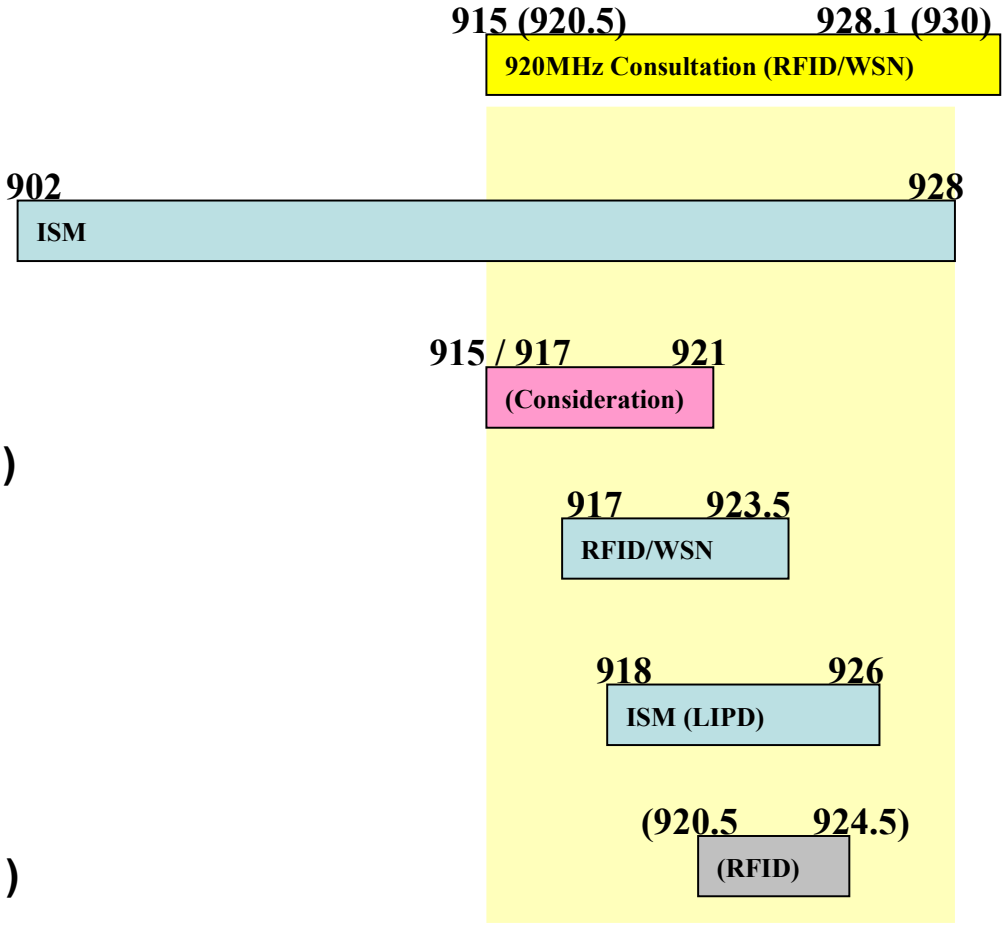
902-928MHz
in US,

870-874MHz / 915-921MHz
in EU, (under consideration)

917-923.5MHz
in Korea,

918-926MHz
in Australia & New Zealand,

(920.5-924.5MHz in China ?)



Robust Modulation Scheme & Coding

- **Robust (Low Rate) Modulation Scheme within Existing IEEE802.15.4**
  - 15.4b : DS-DBPSK 20kbps/40kbps without FEC
  - 15.4d : DS-DBPSK 20kbps without FEC
  - 15.4g : MR-OFDM-BPSK 50kbps (possible 25kbps or lower) with FEC
  - may deserve to be utilized for LECIM, **combining with 15.4e freq. agility, e.g. TSMP.**
- **Required Link Budget (~120dB) of LECIM suggests ;**
  - (B)PSK over FSK : 3 ~ 6dB advantage
- **FEC should be preferable ;**
  - Hopefully, FEC combined with time, frequency, space or path diversity.

Resilience for LECIM

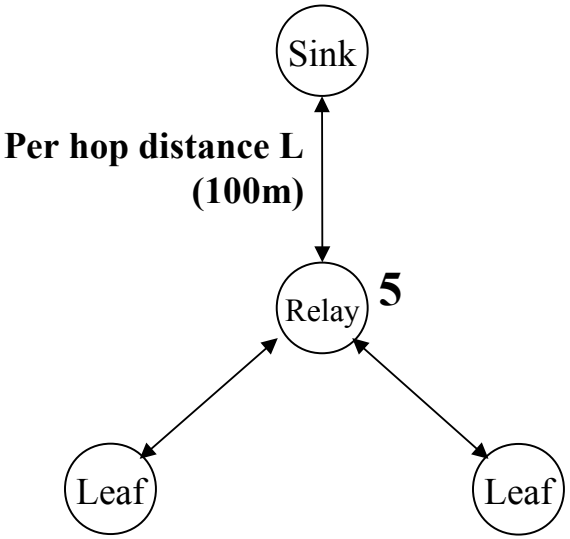
Critical Infrastructure requires the enhanced reliability.

Consuming power with and without hopping (1)

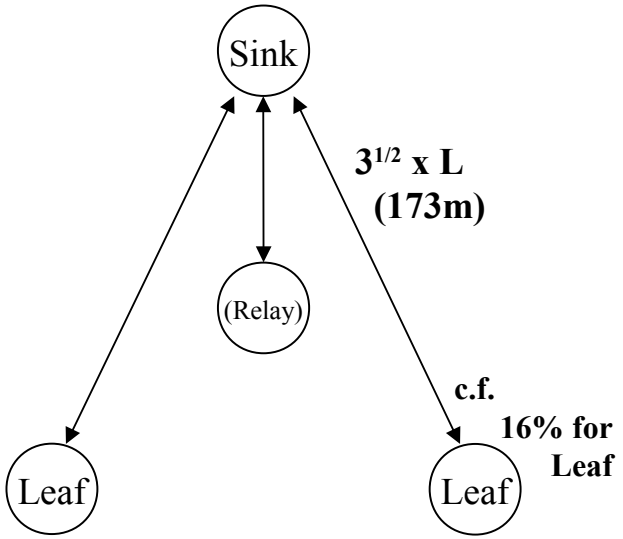
< Assuming constant Tx Power, same frequency band & Eb/No >

Data Rate K (250kbps) ⟷ K/6.25 (40kbps)

6.25 times
Per Bit Energy



$(6.25)^{1/2}$=2.5 times farther reach @ free space



Relay node carries 5 times traffic

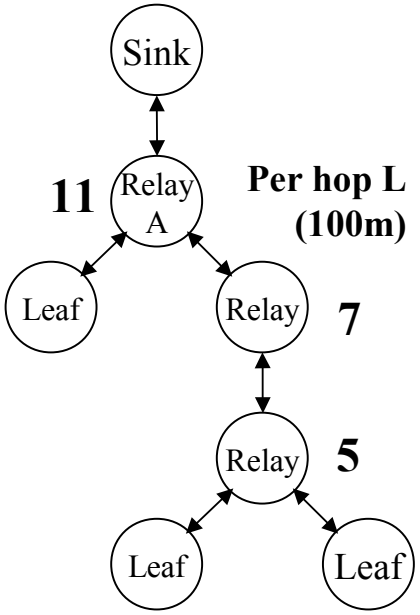
80% (5/6.25) Battery life for Relay node

Consuming power with and without hopping (2)

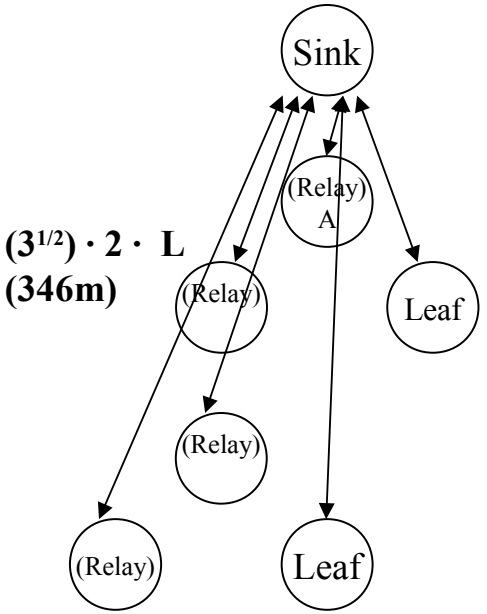
< Assuming constant Tx Power, same frequency band & Eb/No >

Data Rate K (250kbps) ⟷ K/6.25 (40kbps)

6.25 times
Per Bit Energy



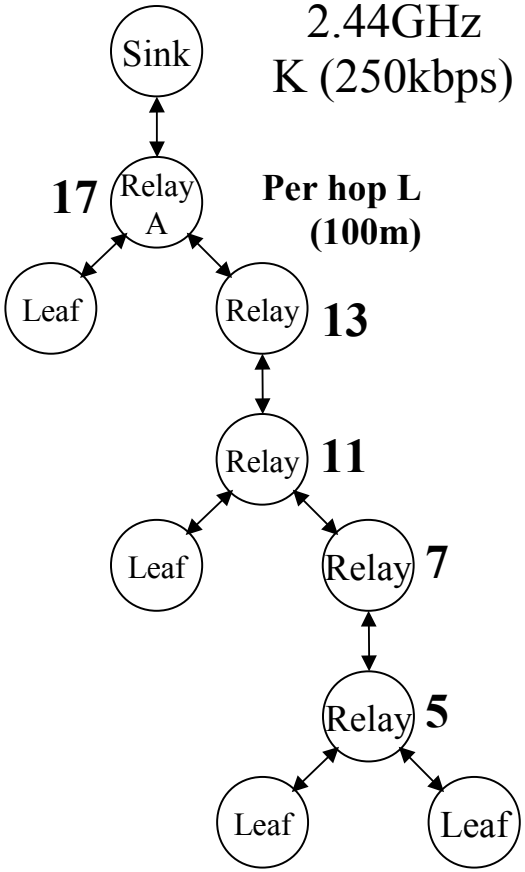
$(6.25)^{1/2}$=2.5 times
i.e.
2.5 times farther reach
@ free space



Relay A node carries 11 times traffic **176% (11/6.25) Battery life for Relay A node**

Consuming power with and without hopping (3)

< Assuming constant Tx Power, same Eb/No and different frequency >



2.44GHz
K (250kbps)

Per hop L (100m)

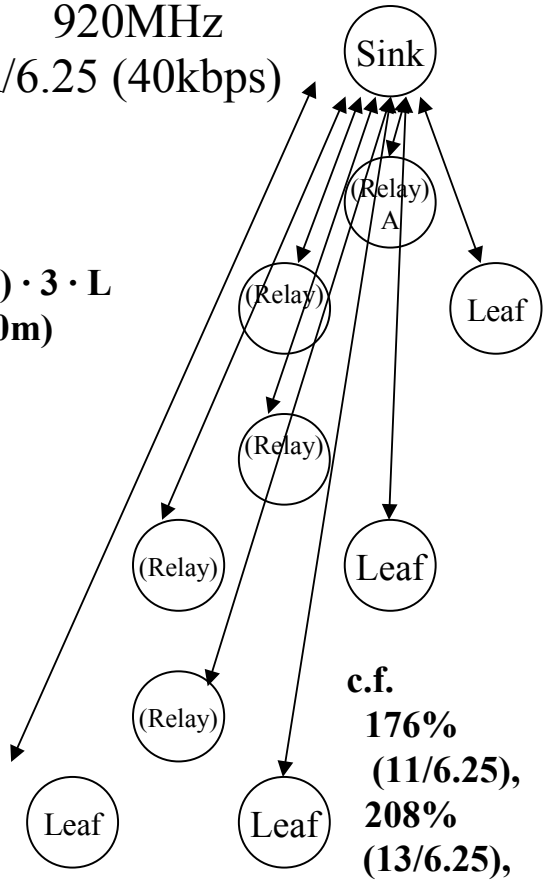
x 2.65 times

6.25 times
Per Bit Energy

$(6.25)^{1/2}$=2.5 times
and
2.65[2.44/0.92] times
i.e.
6.6 times farther reach
***@* free space**

920MHz
K/6.25 (40kbps)

$(3^{1/2}) \cdot 3 \cdot L$
(520m)



c.f.
176% (11/6.25),
208% (13/6.25),

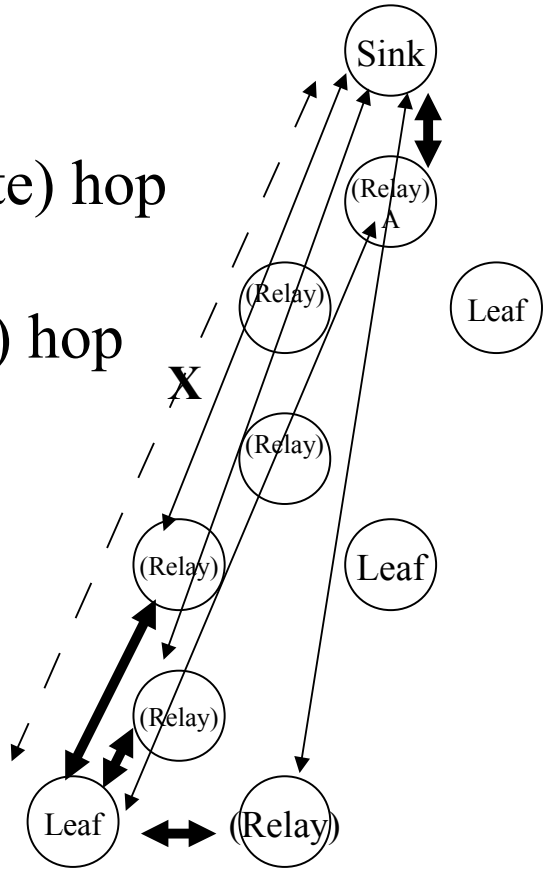
Relay A node carry 17 times traffic

272% (17/6.25) Battery life for Relay A node

LECIM needs resiliency by detouring hop

< Simultaneously, preserving Battery Power is crucial for OpEx >

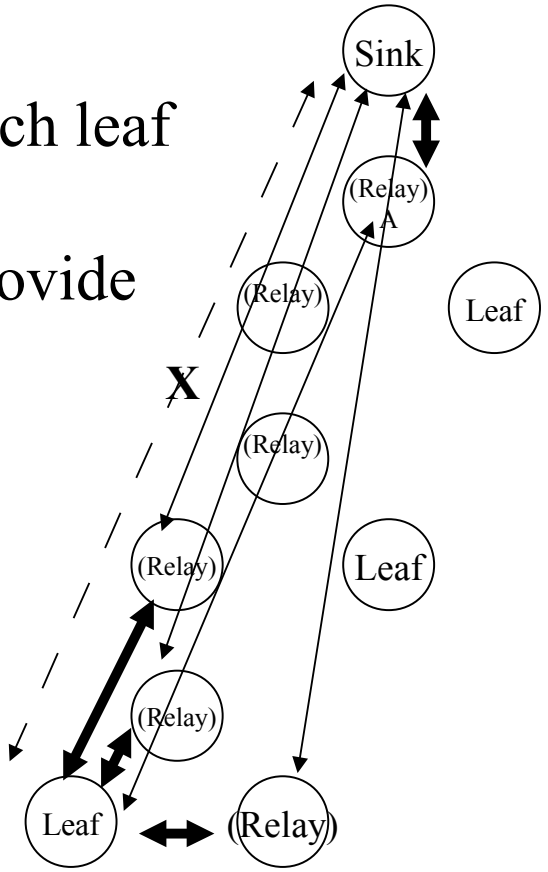
- Short distance QUICK (high data rate) hop
- Long distance SLOW (low data rate) hop
- Deconcentration of relaying traffic



Data Rate Adaptation & Leaf Sensor Cost

< Same PHY on Leaf and Relay >

- LECIM sink provides and helps
  - Long distance SLOW hopping
  - Managing one hop neighbor of each leaf
- Each LECIM leaf sensor needs to provide
  - Short distance QUICK hop
  - Rate Adaptation info
- Leaf Sensor Cost
  - Battery life is major in leaf OpEx
  - Less OpEx based on reliability
  - Not CapEx (major at Sink)



Conclusion

- **PHY**
  - Utilizing Sub 1GHz bands
  - Considering existing 15.4 PHY, with 15.4e MAC
  - Enhancing reliability using FEC and Reinforced diversity
- **Resiliency**
  - Data Rate Adaptation for detouring relay in order to preserve Battery Life
  - One hop neighbor management and Rate Adaptation info.

End