# Low Power Wireless Technologies


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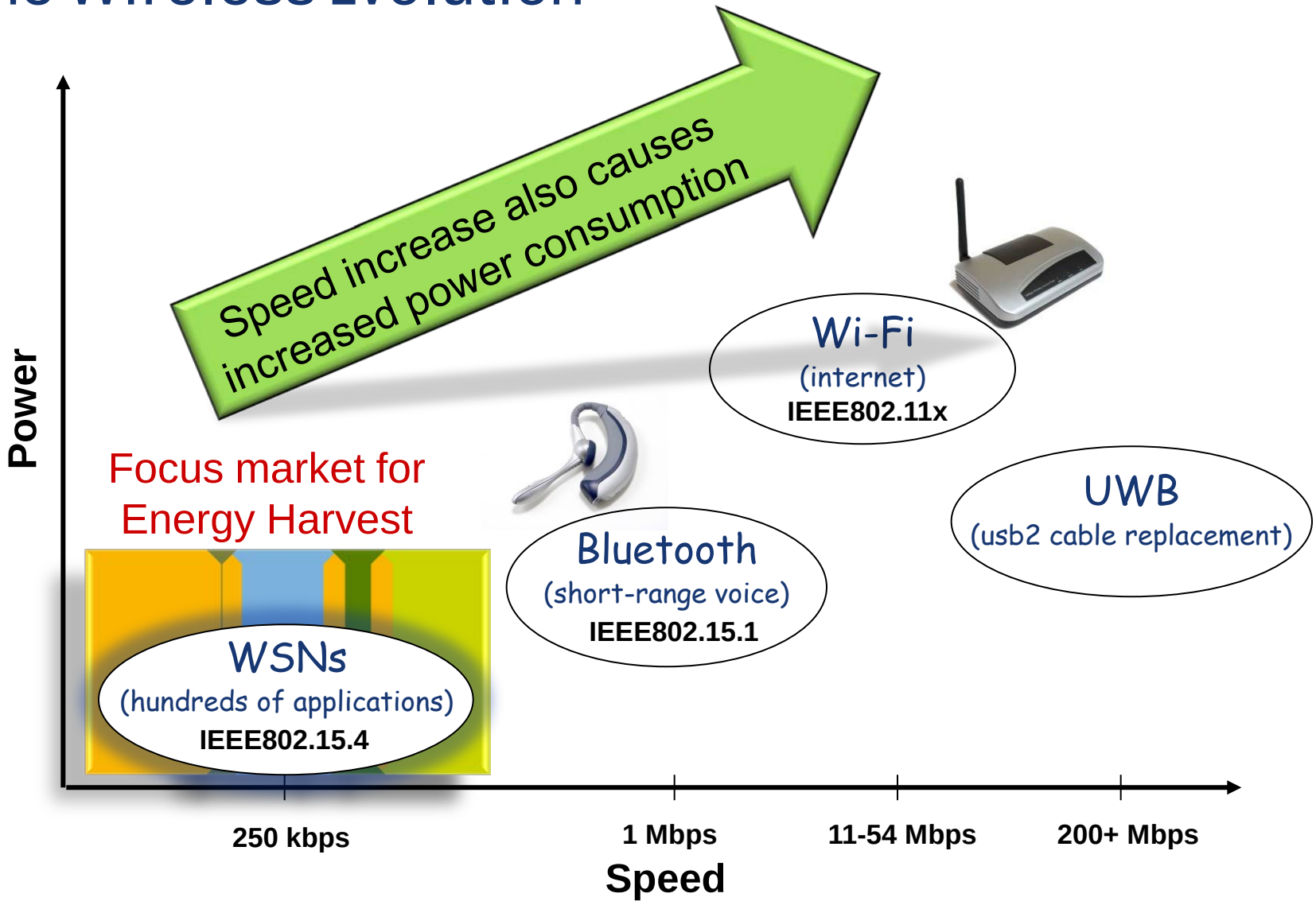
## APEC 2013 EH Forum Industry Session

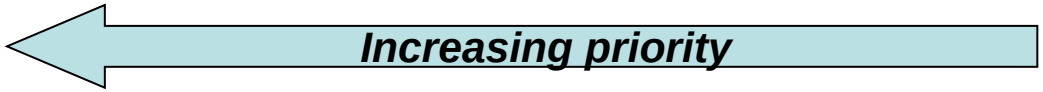
# Low Power Wireless Session Overview

- Review industry standards and wireless evolution with a focus on IEEE 802.15.4 radios
- Wireless compatibility with energy harvesting power supplies
- Wireless power profiles and design techniques
- Energy harvesting-based wireless demo to highlight key concepts

# The Wireless Evolution



# RF Comparison Usage and Scenarios



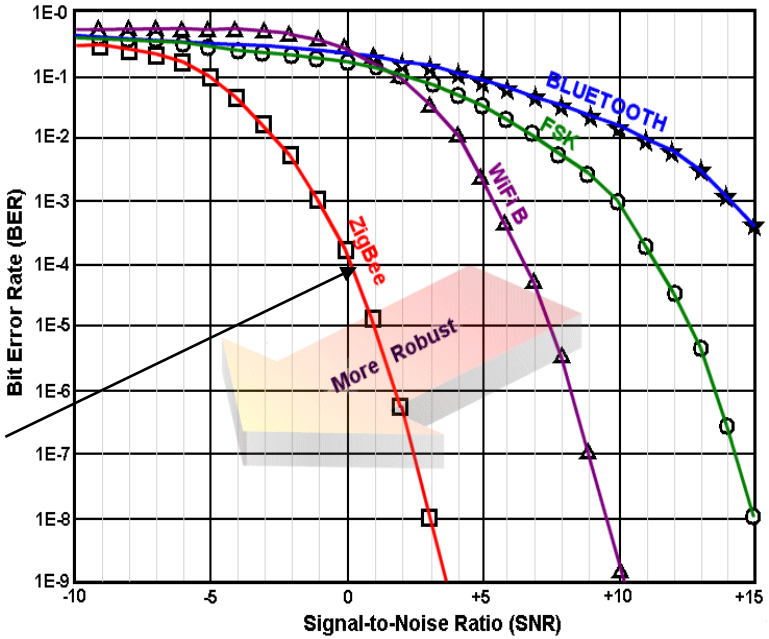

| | Implementation Price | Power | Co-existance with other networks | Large-scale Networking stack | Small-scale Networking stack | Wireless Microcontroller design route | Interoperability | Encryption | Datarate |
|---|---|---|---|---|---|---|---|---|---|
| **Bluetooth** | Low | High | Poor | No | Yes | No | Yes | Fair | High |
| **BT LE** | Low | Low | Poor | No | Yes | No | Yes | Fair | High |
| **Proprietary** | Low | Low | No | No | No | Yes | No | No | Low |
| 802.15.4 | Low | Low | Good | Yes | Yes | Yes | Yes | Good | Low |
| **WiFi** | High | High | Good | Yes | Yes | No | Yes | Good | High |

- **IEEE802.15.4 offers optimal solution**
  - Designed to operate in large networks of devices
  - Lowest cost. Flexible design solution for many different applications
    - » No ‘application-profiles’ ensures design flexibility
  - Lowest power with prospect of interoperability
  - Co-existence with other wireless networks (e.g. Wi-Fi)

What about range?

# IEEE 802.15.4 Radio Characteristics

ZigBee is based upon IEEE 802.15.4 which has a much lower BER for a given SNR




- **IEEE802.15.4 offers an optimal solution**
  - Designed to operate in large networks of devices
  - Lowest cost. Flexible design solution for many different applications
  - Lowest power with prospect of interoperability
  - Co-existence with other wireless networks (e.g. Wi-Fi)
  - Offset Phase Shift Keying is superior to Bluetooth and WiFi modulation in high noise environments

# ISM Band

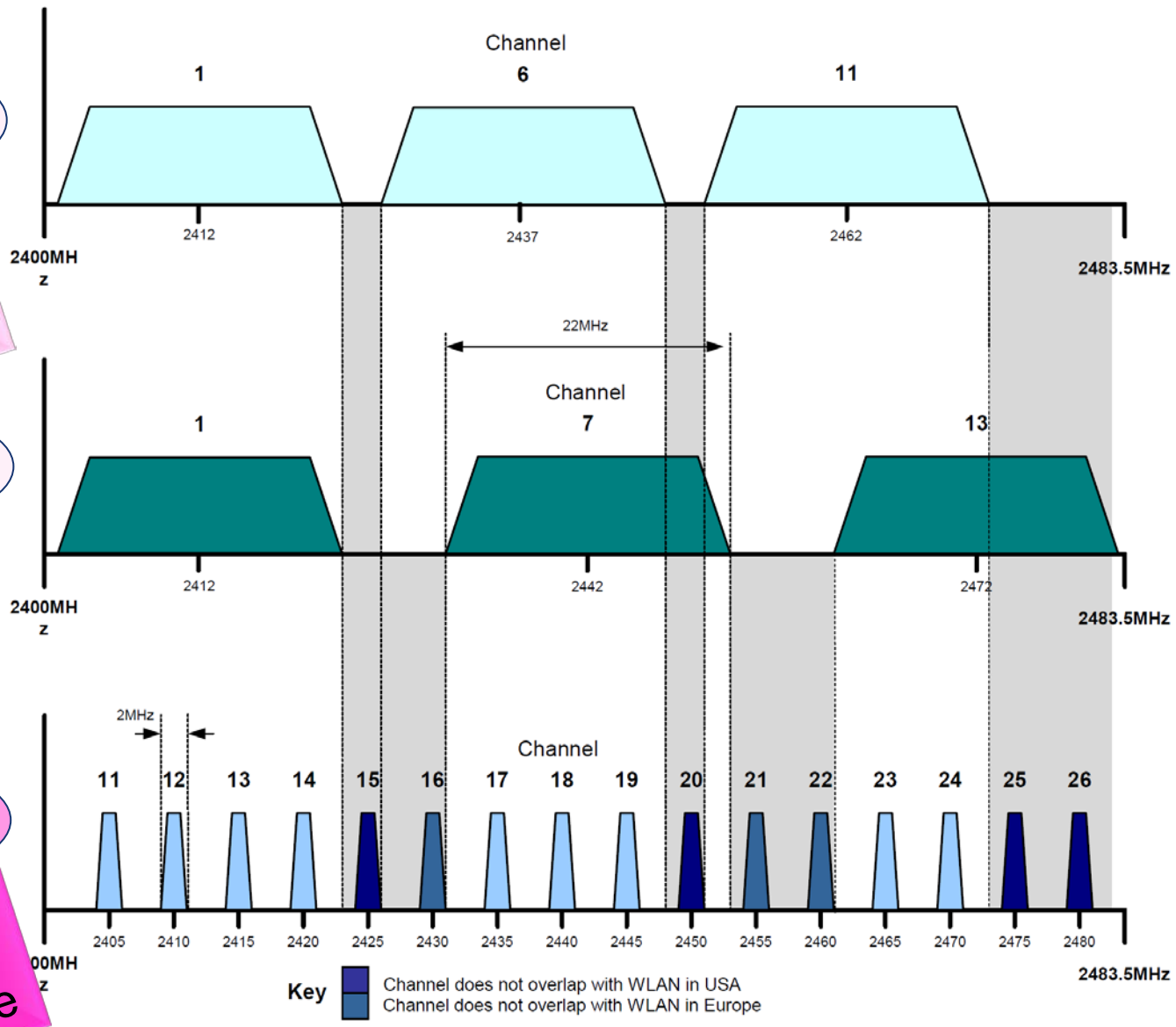
US WLAN
(IEEE 802.11b)
non-overlapping

WiFi is **not** world wide on all channels

European WLAN
(IEEE 802.11b)
non-overlapping

IEEE 802.15.4
2400 MHz PHY

802.15.4 All countries accept all channels world wide








Graphic courtesy of JN-AN-1059 & JN-AN-1079

# Is WiFi found everywhere?

WiFi is **not** world wide on all channels

| Channel | AFRICA | ASIA | AUSTR | CANADA | EUROPE | FRANCE | ISRAEL | JAPAN | MEXICO | SOUTH AMERICA | USA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | XXX | XXX | XXX | XXX | XXX | | | XXX | | XXX | XXX |
| 2 | XXX | XXX | XXX | XXX | XXX | | | XXX | | XXX | XXX |
| 3 | XXX | XXX | XXX | XXX | XXX | | | XXX | | XXX | XXX |
| 4 | XXX | XXX | XXX | XXX | XXX | | | XXX | | XXX | XXX |
| 5 | XXX | XXX | XXX | XXX | XXX | | XXX | XXX | | XXX | XXX |
| 6 | XXX | XXX | XXX | XXX | XXX | | XXX | XXX | | XXX | XXX |
| 7 | XXX | XXX | XXX | XXX | XXX | | XXX | XXX | | XXX | XXX |
| 8 | XXX | XXX | XXX | XXX | XXX | | | XXX | | XXX | XXX |
| 9 | XXX | XXX | XXX | XXX | XXX | | | XXX | | XXX | XXX |
| 10 | XXX | XXX | XXX | XXX | XXX | XXX | | XXX | | XXX | XXX |
| 11 | XXX | XXX | XXX | XXX | XXX | XXX | | XXX | XXX | XXX | XXX |
| 12 | XXX | XXX | XXX | | XXX | XXX | | XXX | | XXX | |
| 13 | XXX | XXX | XXX | | | | | XXX | | XXX | |
| 14 | | | | | | | | XXX | | | |





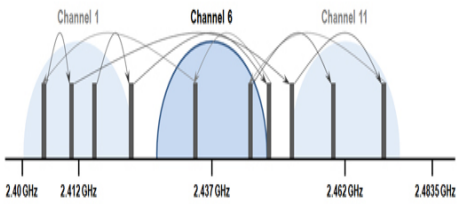
Chart courtesy NeatGear Setup Screen

# Bluetooth versus 802.15.4

## When to use Bluetooth

Stereo Audio

Cell phone already has BT




No WiFi interference or use AFH

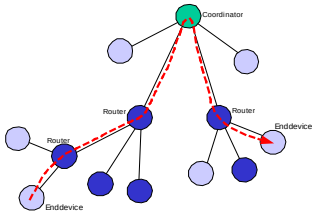
## Problems with Bluetooth


Spec changes every 18 months

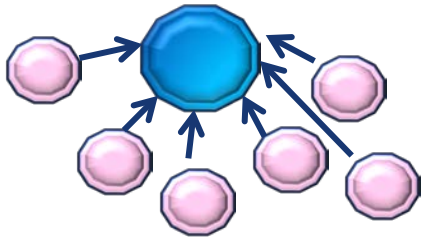
Channel hopping will cause interference

## Benefits of 802.15.4

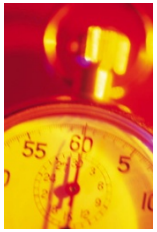
Multiple channels



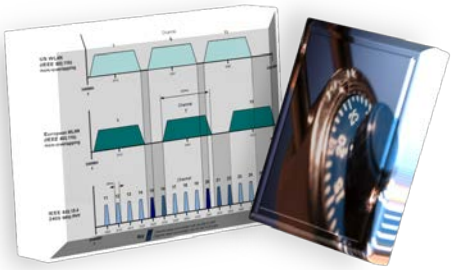

Network of devices



Large number of connections



Fast connect times of 6mS

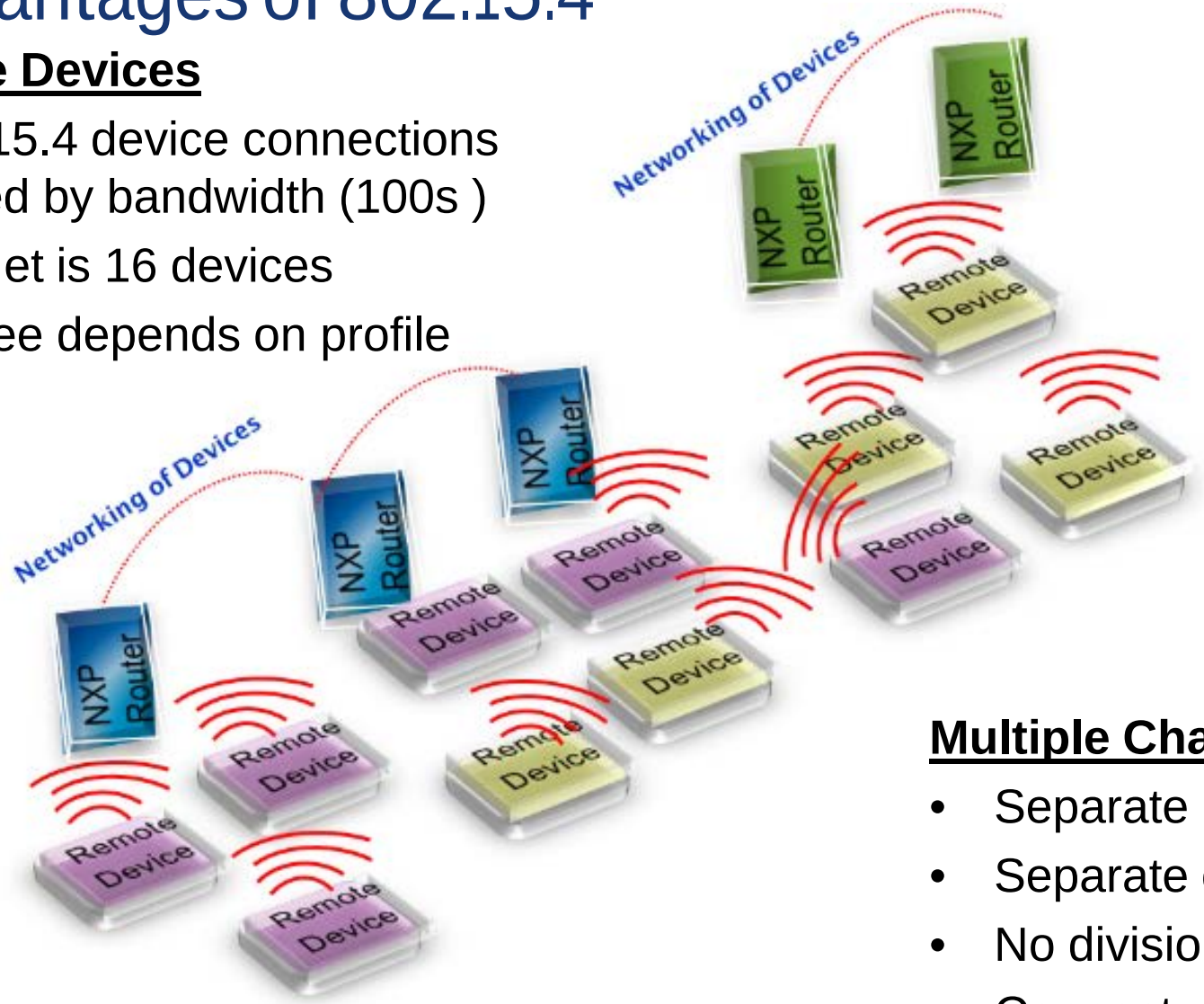


Coexist by locking onto a clear channel

# Advantages of 802.15.4

## Multiple Devices

- 802.15.4 device connections limited by bandwidth (100s )
- JenNet is 16 devices
- ZigBee depends on profile




## Multiple Channels

- Separate PAN id
- Separate channels
- No division of bandwidth
- Connects to its router

# IEEE802.11 vs IEEE802.15.4 Module Solutions

| |  |  |  |
|---|---|---|---|
| **Part Number** | **RF Monolithics WSN802G** | **NXP JN5148-001-M00** | **NXP JN5148-001-M04** |
| **Technology** | IEEE 802.11 b/g | IEEE 802.15.4 | IEEE 802.15.4 |
| **Frequency** | 2.4GHz | 2.4GHz | 2.4GHz |
| **World Wide Acceptance for All Channels** | No. Country specific | Yes | Yes |
| **Active Power** | 200mA | 17mA | 110mA / 23mA |
| **Sleep Current** | 8uA | 2.8uA | 2.8uA |
| **Data Rate** | 11Mbps / 54Mbps | 250 Kbps | 250 Kbps |
| **Distance** | 250m / 820ft line of sight | 400m / 1,300ft line of sight | 6Km / 19.685ft line of sight |
| **Dimensions** | 25.4mm x 26.7mm | 18mm x 32mm | 18mm x 41mm |
| **Pricing at 1pc / 10K pcs** | Roughly 3X of standard power 802.15.4 module | $X | 20 percent more than std power |



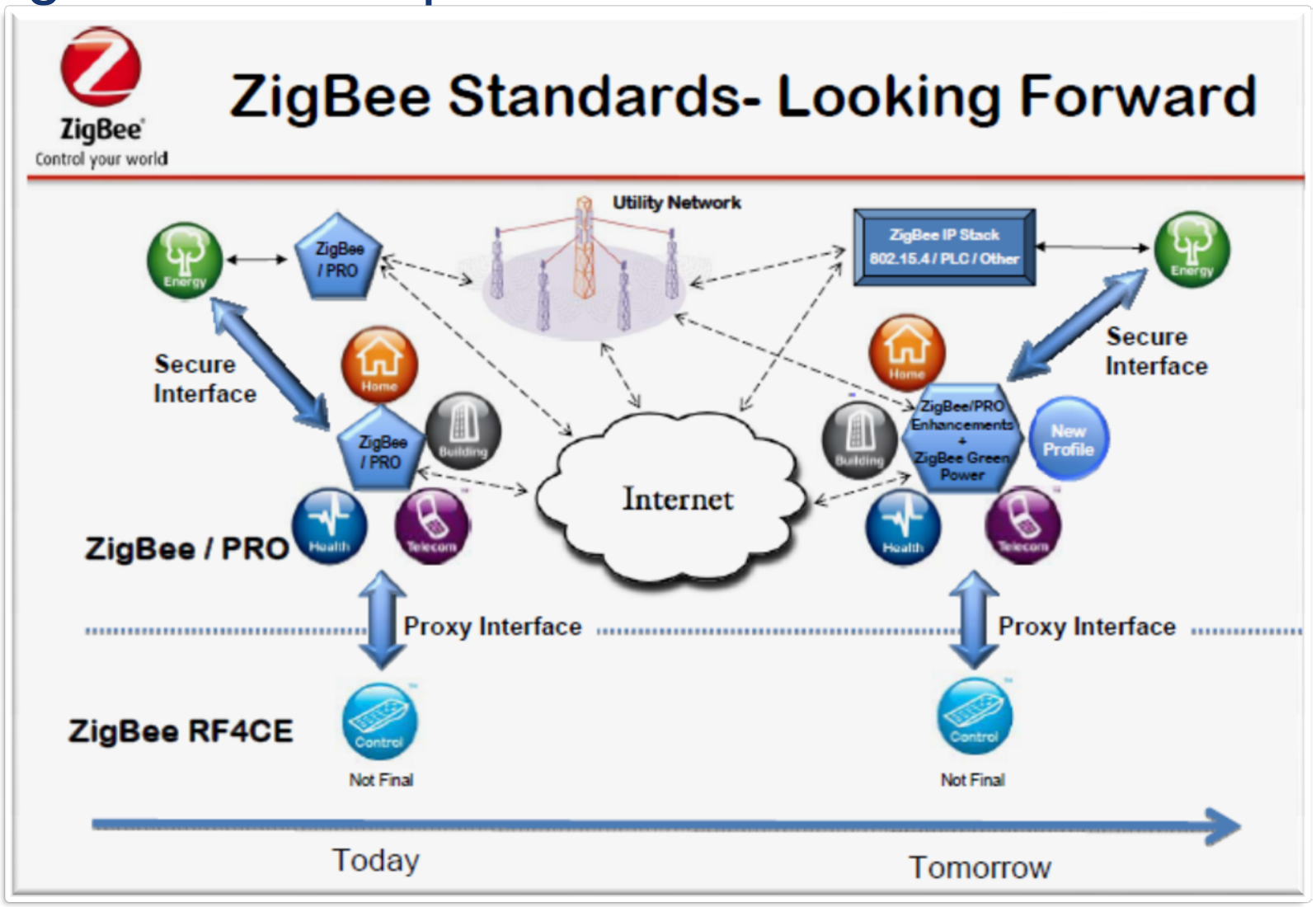


△ Data rate is one advantage for WiFi

# Wireless Networking Standards Comparison

| | JenNet-IP | ZigBee SL | ZigBee HA | Wi-Fi | ZigBee-IP |
|---|---|---|---|---|---|
| **Routing Topology** | "Mesh Under" Tree with self healing | Mesh | Mesh | Star | "Mesh Over" Mesh |
| **Max. Nodes** | 500 | TBD | 500 | 254 | 50 |
| **Availability** | Now | Q1/2012 | Now | Now | 2012 |
| **IP Based** | Yes (6LoWPAN) | No | No | Yes | Yes |
| **Stack Size (excl. application)** | <85KB | ~128KB | ~96kB | >256KB | <200kB |
| **Cost** | $ | $$ | $$ | $$$ | $$$ |
| **Frequency** | 2.4GHz | 2.4GHz | 2.4GHz | 2.4-5GHz | 2.4GHz |
| **Standby power** | Medium <150mW | medium <150mW | medium <150mW | high | Medium <150mW |
| **Operating Power** | Low | Low | Low | High | Low |
| **Optimized commissioning** | Yes | Yes | Yes, but no simple commissioning | No | Designed for Smart Energy apps |
| **Licensing Cost** | Free | ZB Alliance membership & product cert. fees, potential 3rd party IP costs | ZB Alliance membership & product cert. fees, potential 3rd party IP costs | Wi-Fi Alliance membership & product cert. fees. | ZB Alliance membership & product cert. fees, potential 3rd party IP costs |
| **Interoperability** | IPv4 and IPv6 | ZSL only | ZHA Only | any IP Device | ZB SE 2.0 and IPv6 |
| **Development Complexity** | Low | High | High | High | High |

# ZigBee Roadmaps

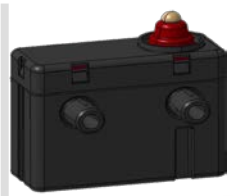





Courtesy ZigBee Alliance

# Sending Data from Energy Harvesting Node

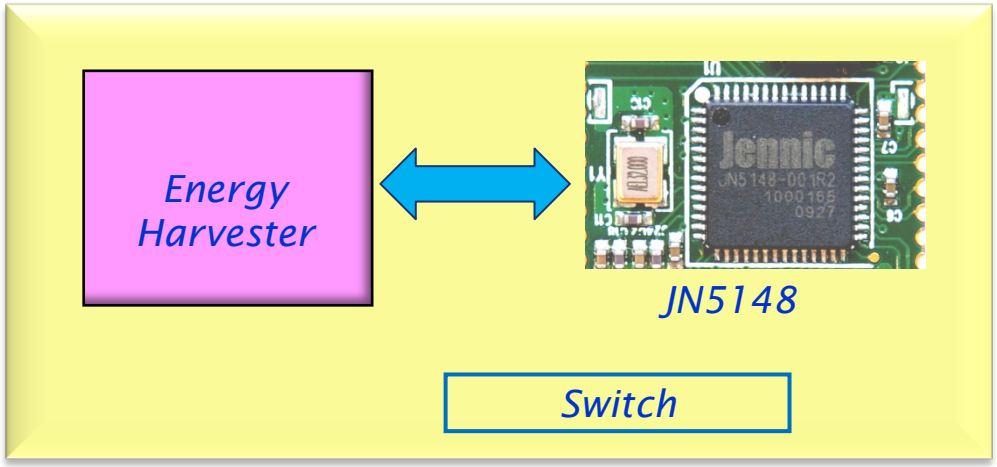
- Energy harvester generates an energy pulse
  - From the physical action of pressing the switch, light, etc
  - ZigBee Green Power requires 200uJ of energy
  - No stored energy available between switch presses
- Receiver
  - Requires battery or AC voltage
  - Receiver always on to receive packet
- Sending a packet
  - Not enough time to send a fully acknowledged packet
  - Not enough energy to join the network
- Transmitting with minimal amount of energy
  - Send stream of data with three packets
  - Redundancy assures that one of the three packets gets through
  - Acceptable for most applications, such as lighting
- Where should it ***not*** be used
  - Life critical applications, such as emergency door exit
  - Any application which requires acknowledgement of data



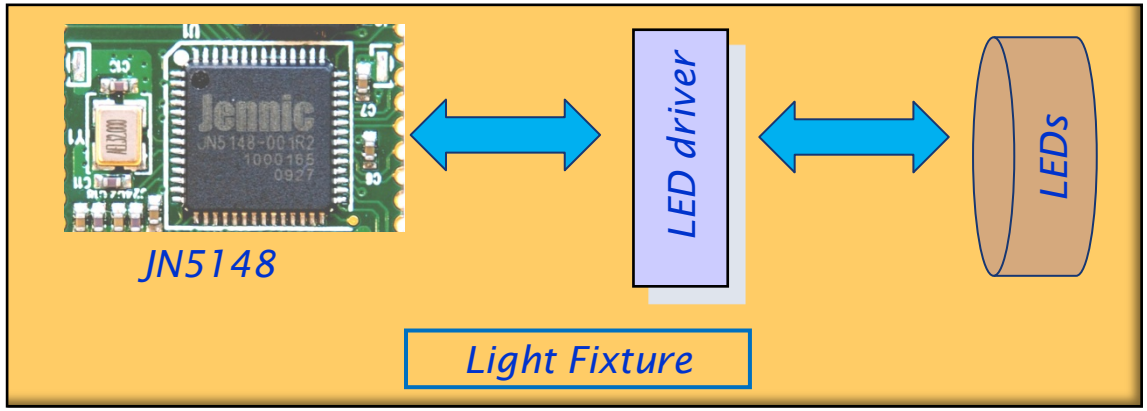
# Packet Format

- Low power operation
  - Wake, load program code, calibrate radio
  - Transmit 3 packets at full output power (2.5dBm) using just 15.5mA
  - Sleep with RAM held between transmissions
- 19byte total transmitted packet (13 bytes MAC frame plus 6 byte header)
  - Standard IEEE802.15.4 frame
  - Sequence number stored in external EEPROM when packet is sent
    - » Ensures each packet has unique sequence number
- Must be fixed channel
- Boot code size just 1kbyte
  - Fast boot-up
  - Conserves battery life

# Block Diagrams

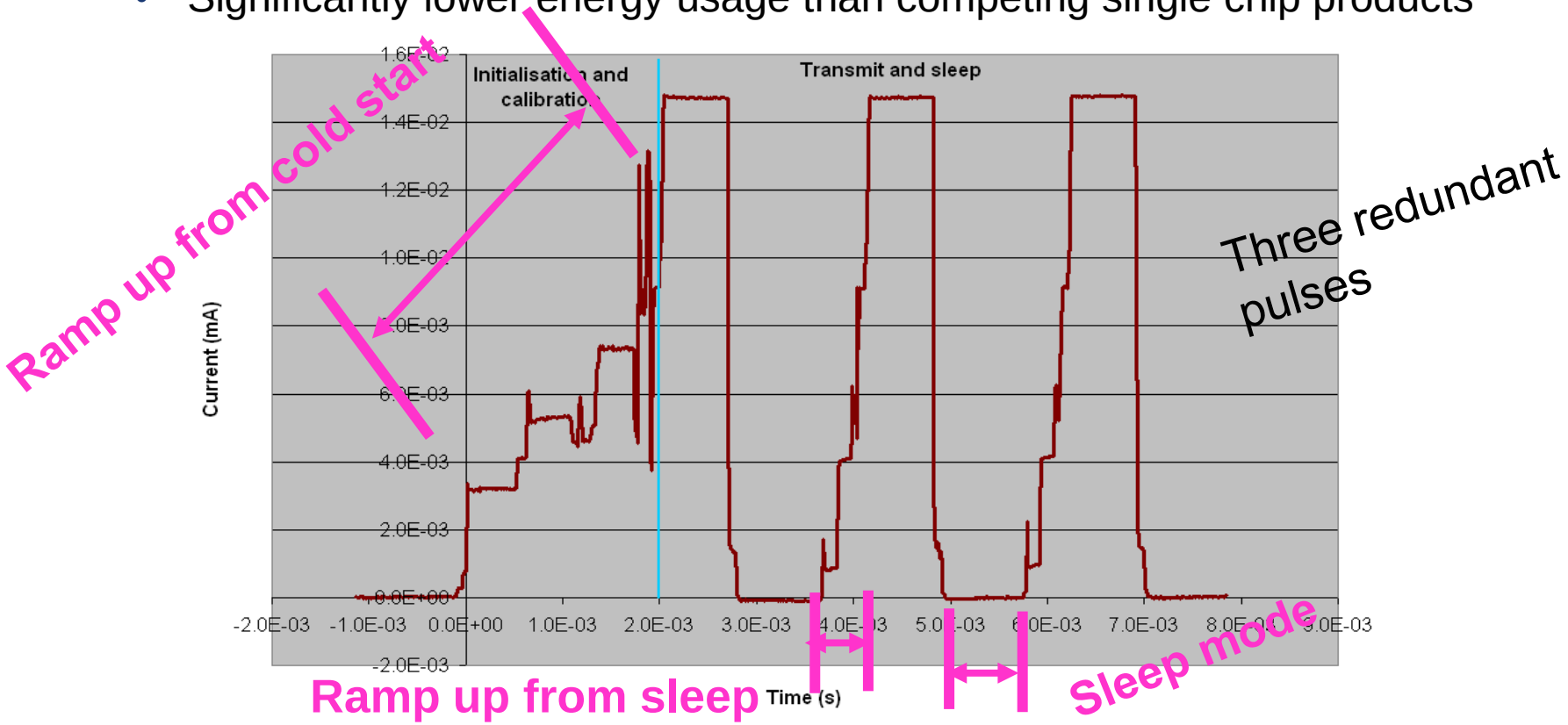






# 802.15.4 Current Profile (Minimum Required)

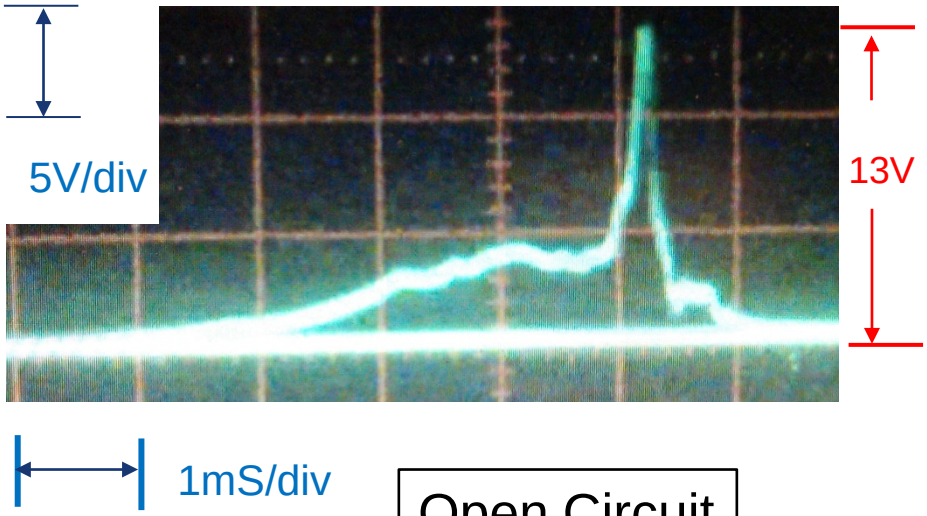
- Very low overall energy consumption due to very low TX current
- Significantly lower energy usage than competing single chip products

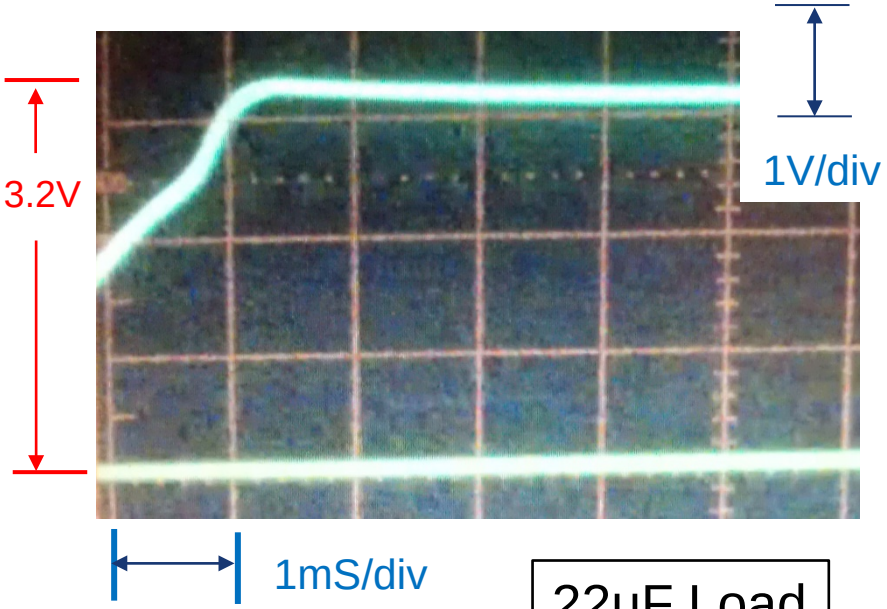



Full solution is achieved using just 50uC of charge (100uJ at 2v)

# Current Profile (Supplied by Energy Harvester)

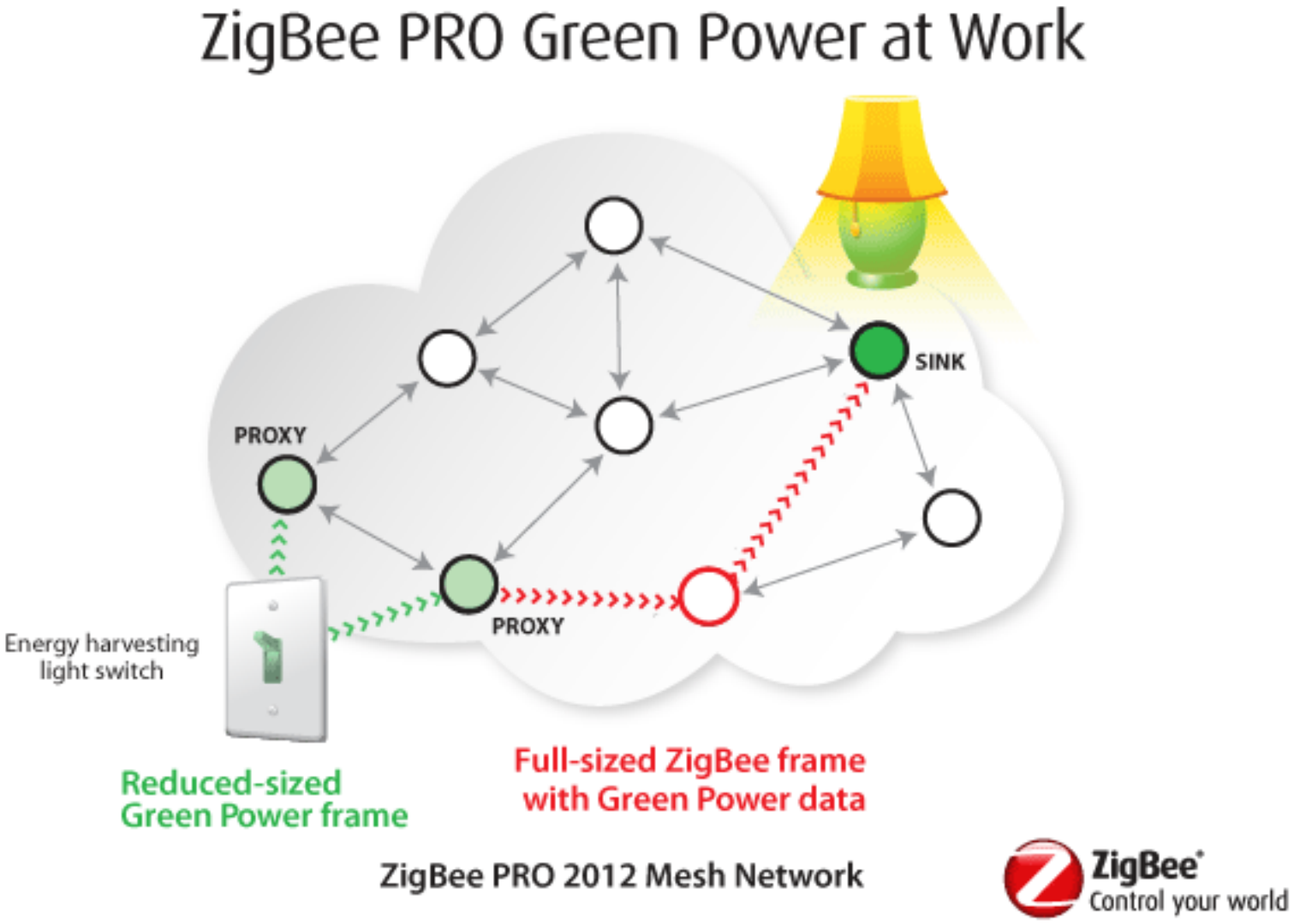
- More than enough current is supplied
- Might be capable of transmit and receive operations



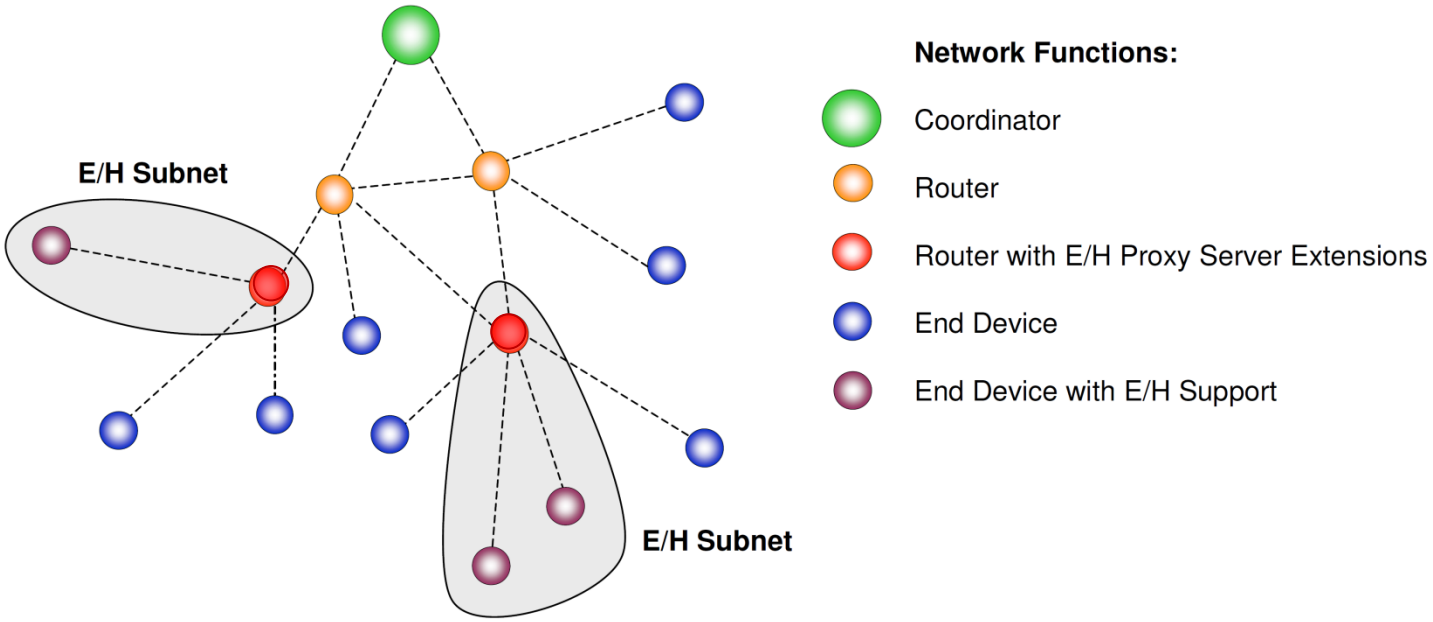

Single depression or release of switch

# ZigBee Green Power



# Wireless Network Software

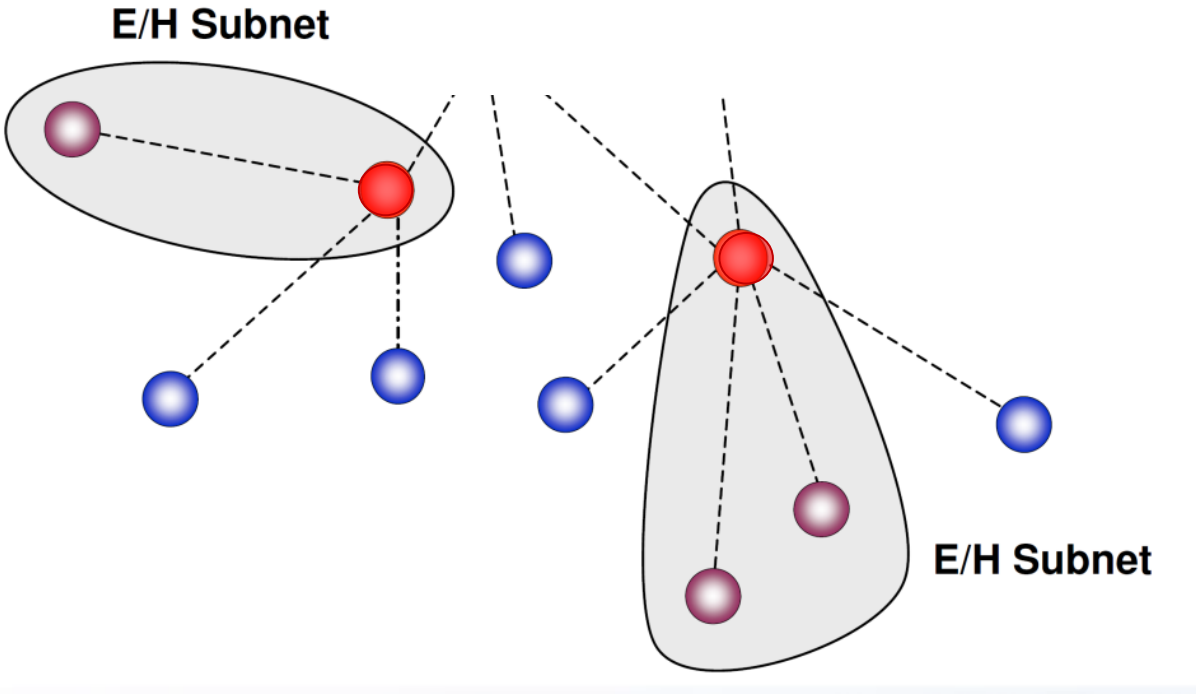
- Configured to support intermittent end device transmission
  - Ready to service requests when the end device needs
- Uses a Proxy Server
  - Powered Routers – always ready to receive from E/H end devices




Interoperate with ZigBee or IP (6LoWPAN) Nodes

# Wireless Proxy Server

- Differentiates from other Energy Harvesting technologies
- Receives E/H data and sends it along the network
- Remote device can be operated by E/H activity




Interoperate with ZigBee or JenNet IP (6LoWPAN) Nodes

# ZigBee Green Power

- Available in ZigBee PRO 2012 Specification
  - Available to all profiles running the stack
  - Support for the proxy server
- Profiles that are appropriate
  - Light Link
  - Home Automation
- Probably not acceptable
  - Smart Energy has a lot of security and encryption keys associated
  - Healthcare with patient security issues

ZigBee®
Control your world


Light — LL (Light Link)

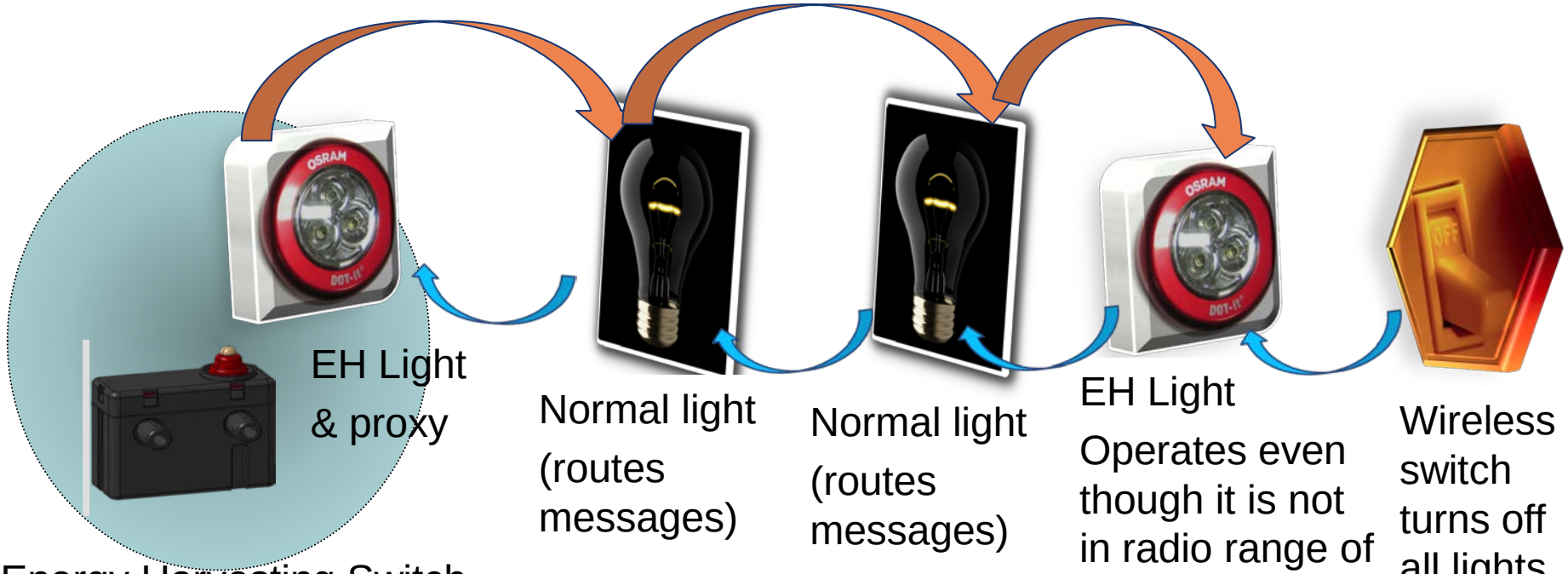
Home — HA (Home Automation)

Health — Healthcare

Energy — SE(Smart Energy)

# Networking stack important for Energy Harvesting

- Light can operate from energy harvesting switch or from network command
- At the end of the day, light switch can turn all lights off without having to activate all the energy harvesting switches individually
- Operational commands can be sent to lamps out of radio range



# Commissioning the Network

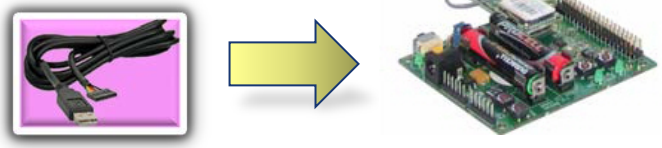
## How to setup the network is important

- Assign the right switch to the right lamps
- Assign channels
- Pick a PAN id

## Needs to be easy to do

- Limit the software required
- Better if flash programming is not required

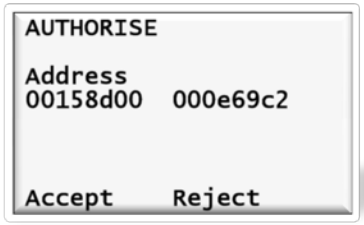
# Commissioning Methods



Flash programming


Serial port programming

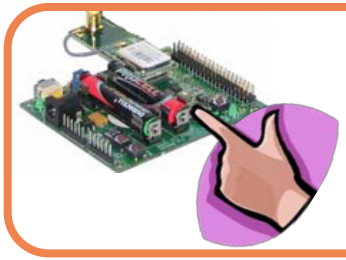

Open Window



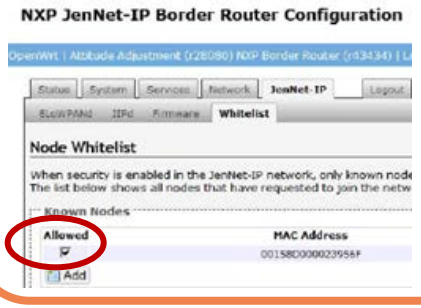

Verification at Coordinator

NFC RFID

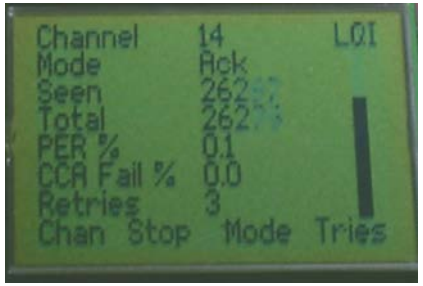

Receive PAN id at power up



Button Press




White List



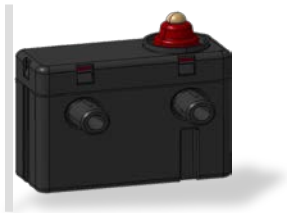

RF Signal Strength

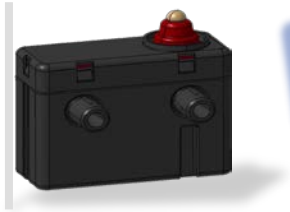
# One Method of Commissioning

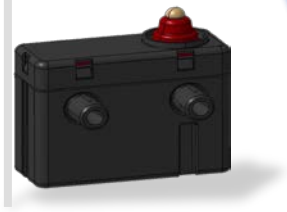
**Switch1** =
*SPSDemoTag_JLP_RANDOM_BF07.bin*

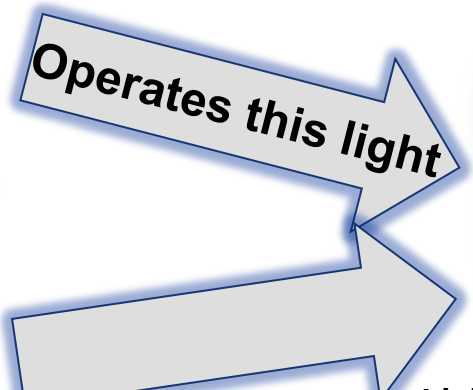
**Switch2** =
*SPSDemoTag_JLP_RANDOM_BF07.bin*

**Switch3** =
*SPSDemoTag_JLP_RANDOM_ECA0.bin*



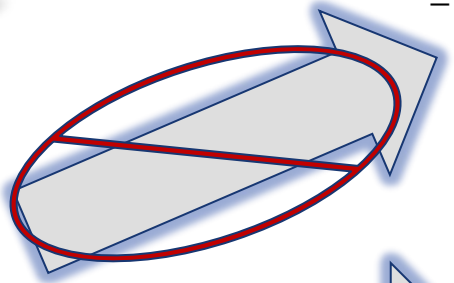


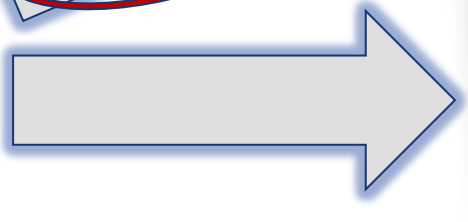






**Light #1** =
JN-AN-1146-EMPWS_JN5148_Light_ANY_ch15.bin






**Light #2** =
JN-AN-1146-EMPWS_JN5148_Light_ANY_ch15.bin

# Summary

- Energy harvesting technology is an important technology for powering wireless communications
- Wireless technology choices are determined by the amount of energy harvested and the tasks to be accomplished
- There are several ultra-low power wireless choices
- Optimizing the wireless network initialization, device registration process, and communication message duration is essential for proper network operation of Energy Harvesting powered wireless devices.

- Questions?