

Low Power Wireless Technologies

Roman Budek - NXP

APEC 2014 EH Forum Industry Session



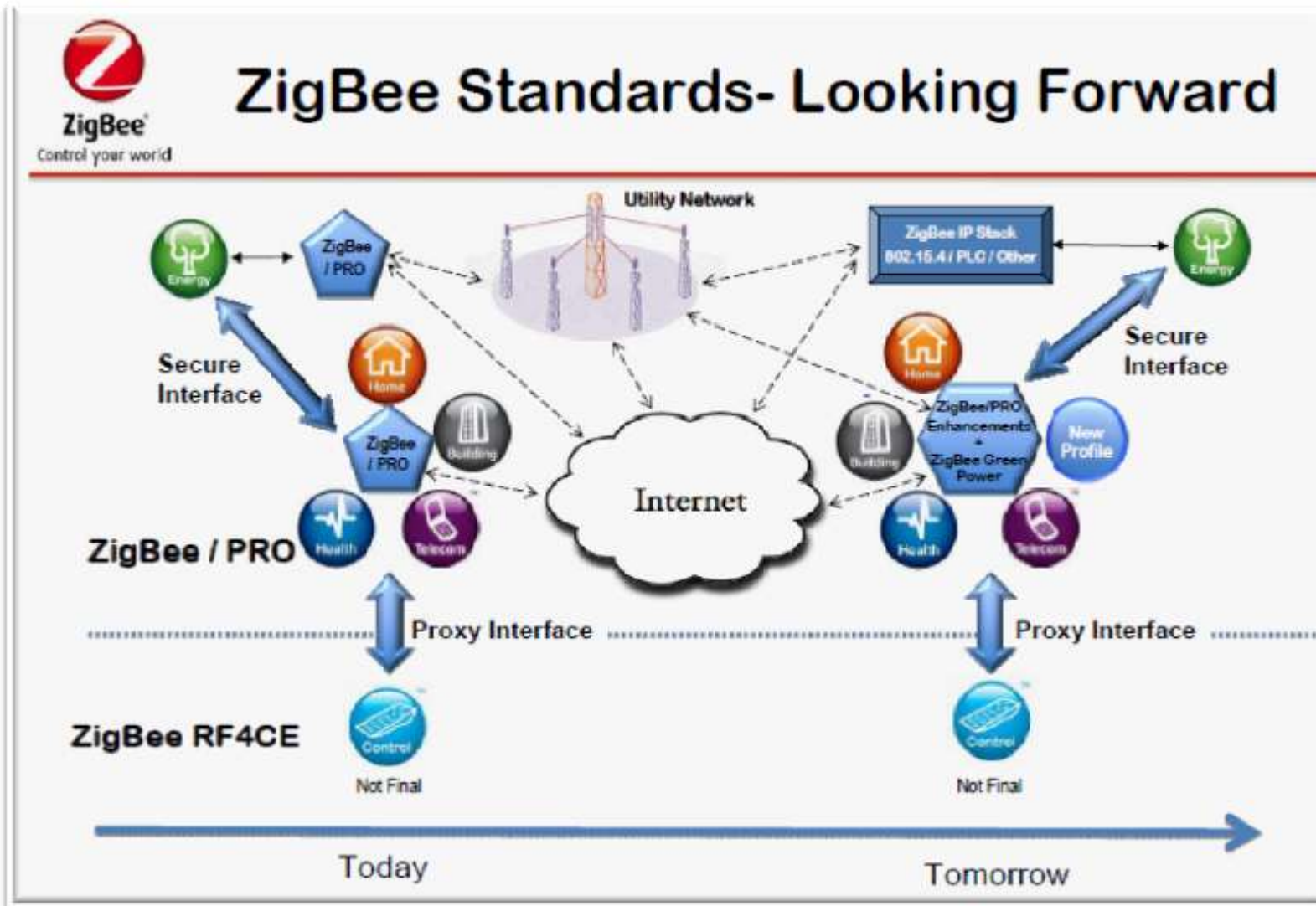
Low Power Wireless Session Overview

- 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

Wireless Networking Standards Comparison

	JenNet-IP	ZigBee SL	ZigBee HA	Wi-Fi	ZigBee-IP
Routing Topology	"Mesh Under" Tree w/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 fees & product cert. fees, potential 3 rd party IP costs	ZB Alliance fees & product cert. fees, potential 3 rd party IP costs	Wi-Fi Alliance membership & product cert. fees.	ZB Alliance fees & product cert. fees, potential 3 rd 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



Sending Data from Energy Harvesting Node

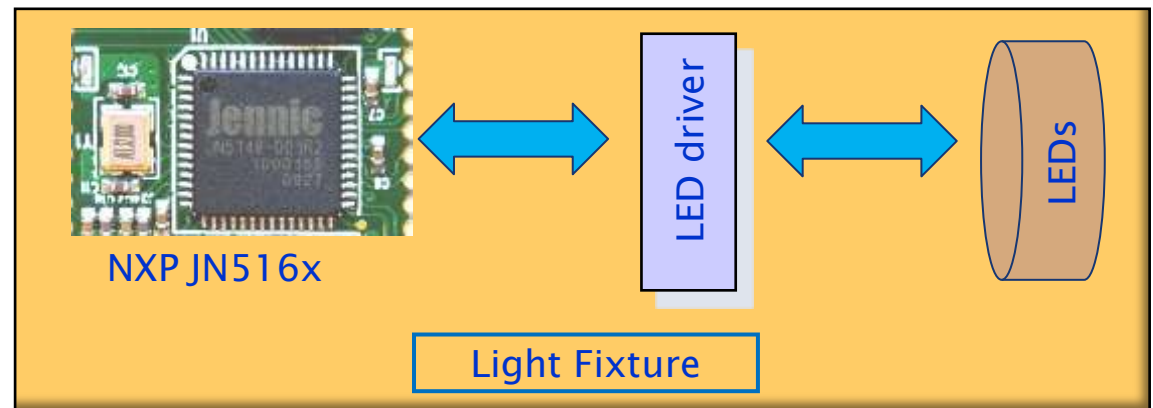
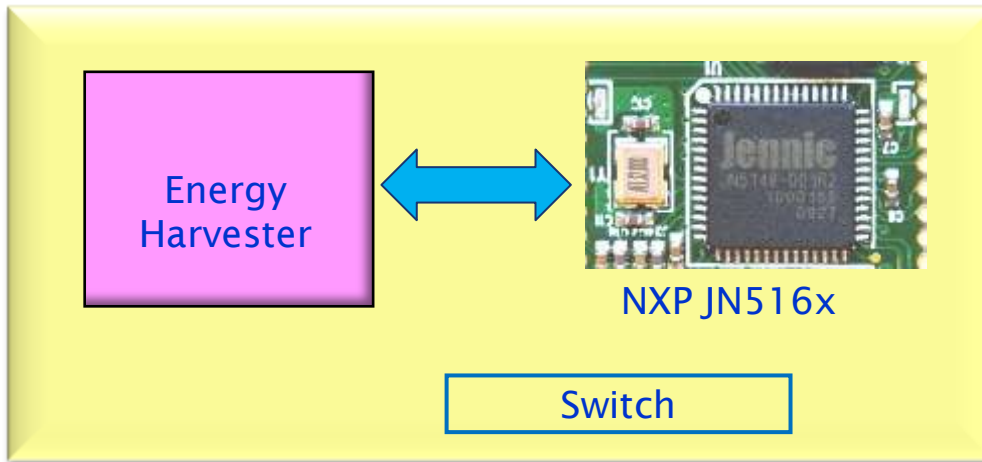
- Energy harvester generates an energy pulse
 - From the physical action of pressing the switch, light, etc
 - ZigBee Green Power requires 200uJ of energy
 - No stored energy available between switch presses
- Receiver
 - Requires battery or AC voltage
 - Receiver always on to receive packet
- Sending 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

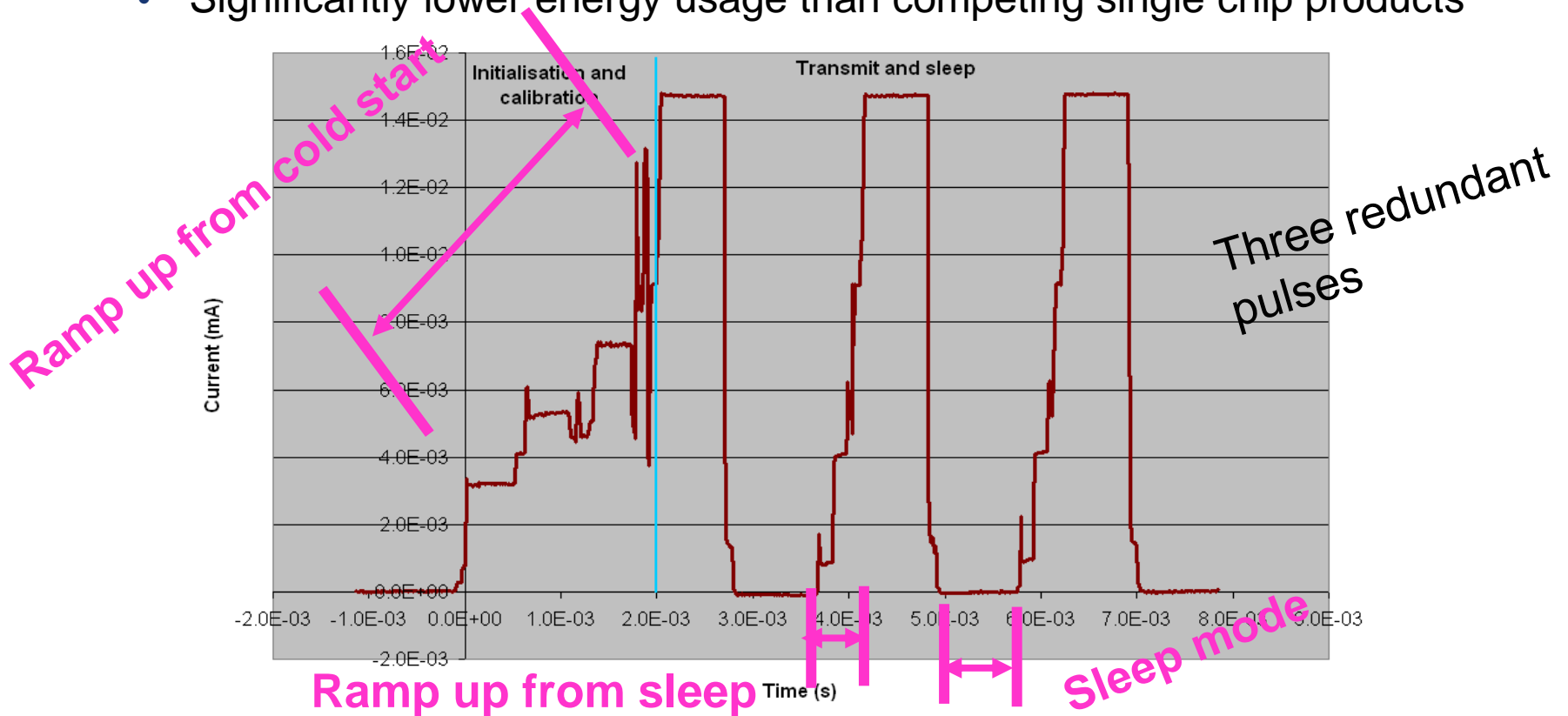
- Low power operation
 - Wake, load program code, calibrate radio
 - Transmit 3 packets at full output power (2.5dBm) using just 15.5mA
 - Sleep with RAM held between transmissions
- 19byte total transmitted packet (13 bytes MAC frame plus 6 byte header)
 - Standard IEEE802.15.4 frame
 - Sequence number 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)

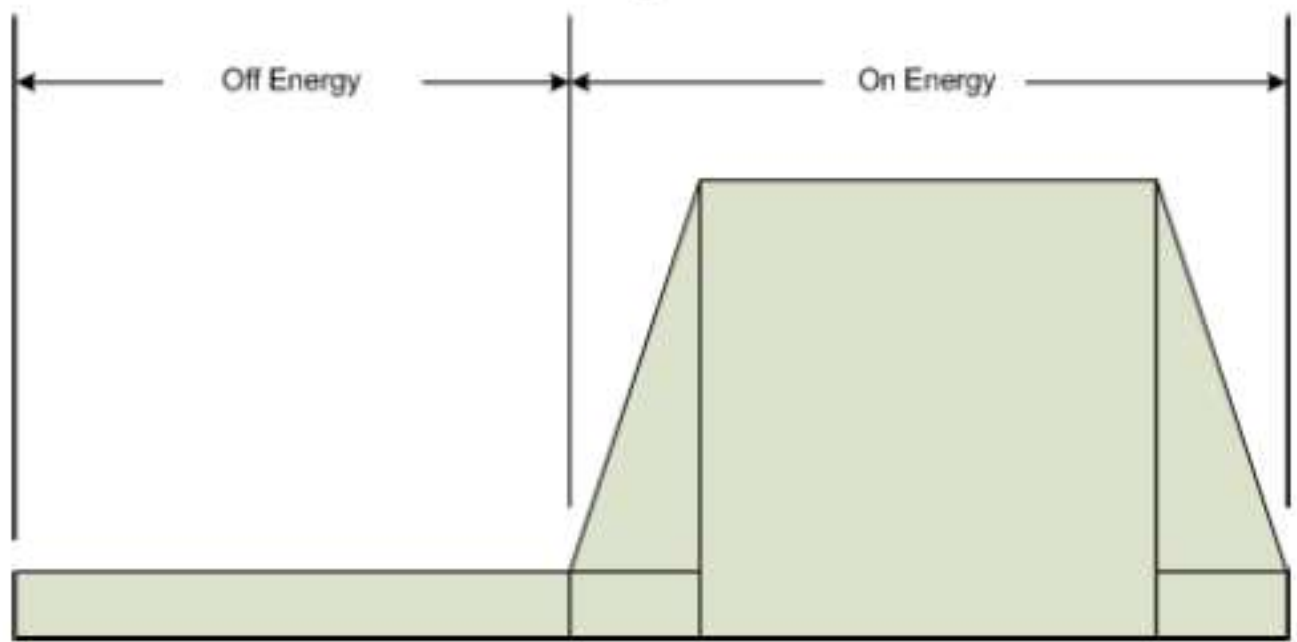
- Very low overall energy consumption due to very low TX current
- Significantly lower energy usage than competing single chip products



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

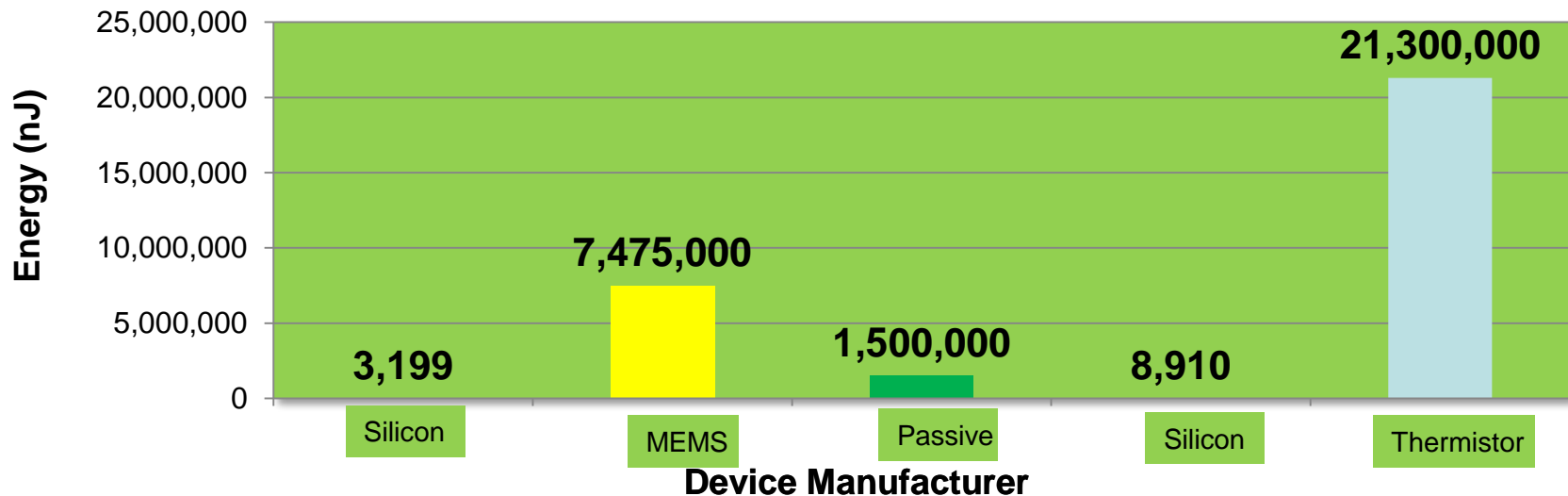
Detailed Power Analysis by Component Type

$$E = \int P dt$$



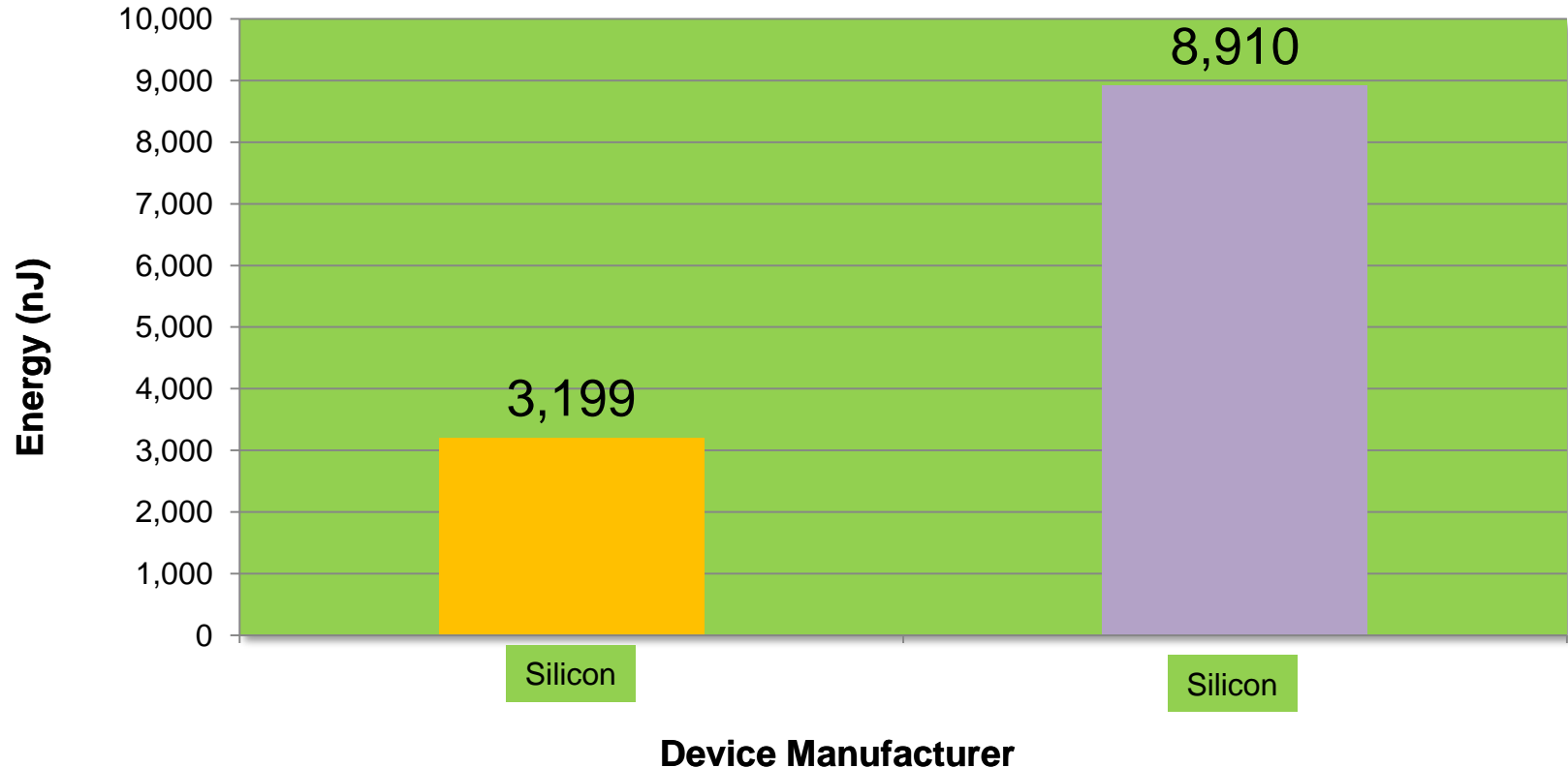
Energy Consumption – Temperature Reading

	#1 NXP SEN200	#2 MEMS	#3 Cap	#4 Silicon	#5 Thermistor (2.1Kohm -> 700ohm)
Voltage	3.3	2.3	5.0	3.0	3.0
Meas Current (uA)	139	650	500	330	1,420
Meas time (ms)	7	5,000	600	9	5,000
Energy (nJ)	3,199	7,475,000	1,500,000	8,910	21,300,000



Energy Consumption – Temperature Reading

- Look only at top 2 from previous chart

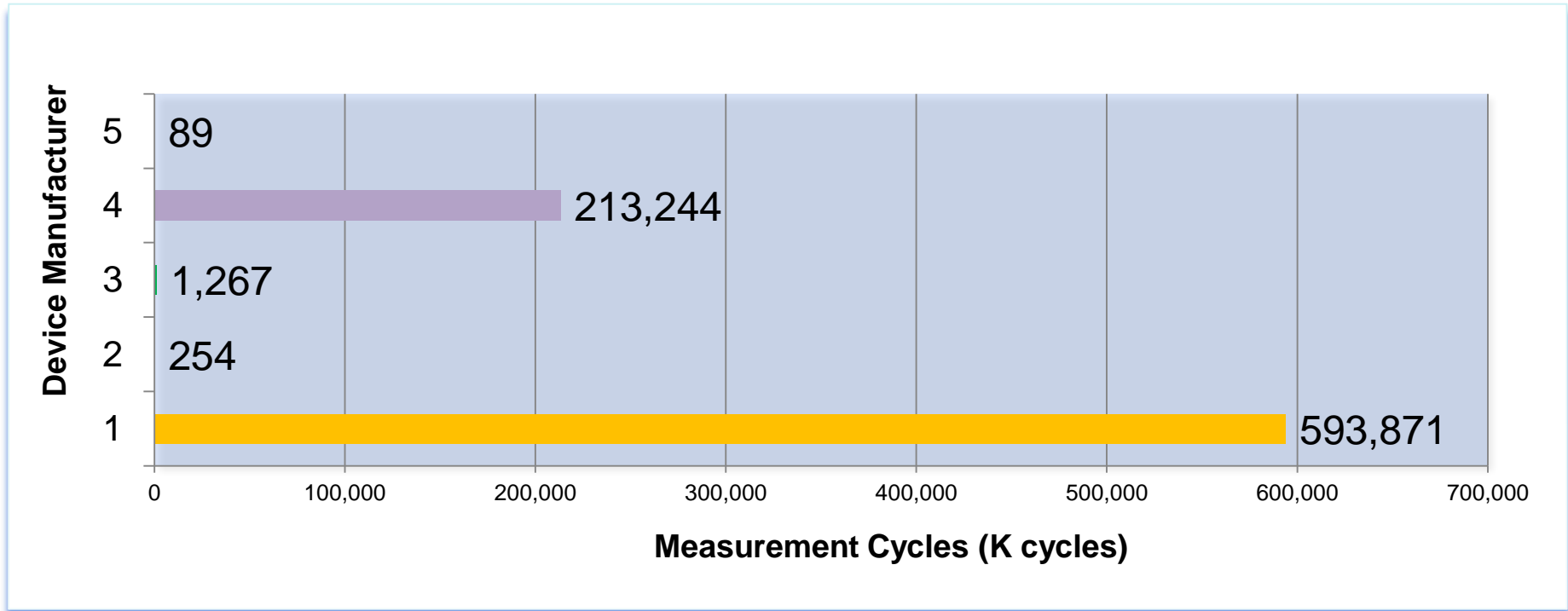


Energy Consumption – Temperature Reading

- Measurement Cycles with two AA batteries (2 x 9,500J)

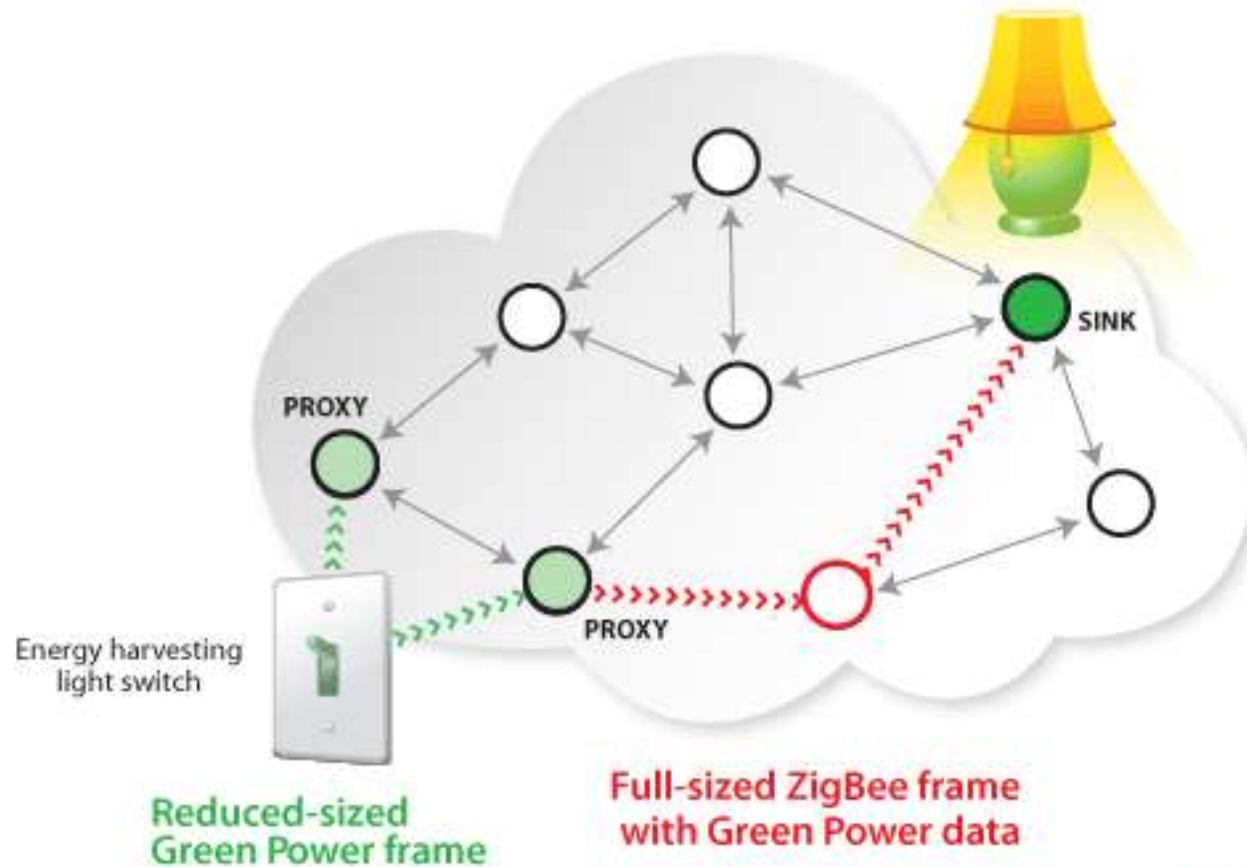


	#1 NXP SEN200	#2 MEMS	#3 Cap	#4 Silicon	#5 Thermistor (2.1Kohm -> 700ohm)
Battery (AA x 2) (J)	19,000	19,000	19,000	19,000	19,000
Energy (NJ)	3,199	7,475,000	1,500,000	8,910	21,300,000
Measure Cycles (K)	593,871	254	1,267	213,244	89



Zig Bee Green Power

ZigBee PRO Green Power at Work

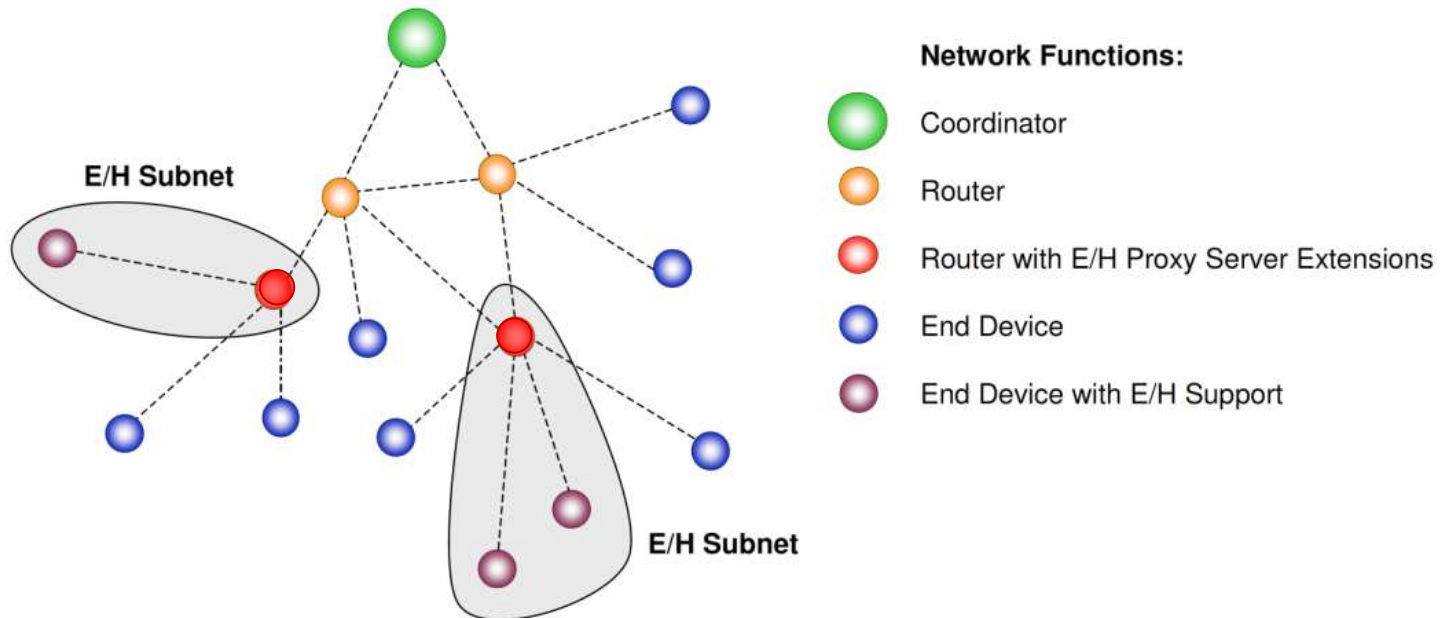


ZigBee PRO 2012 Mesh Network



Wireless Network Software

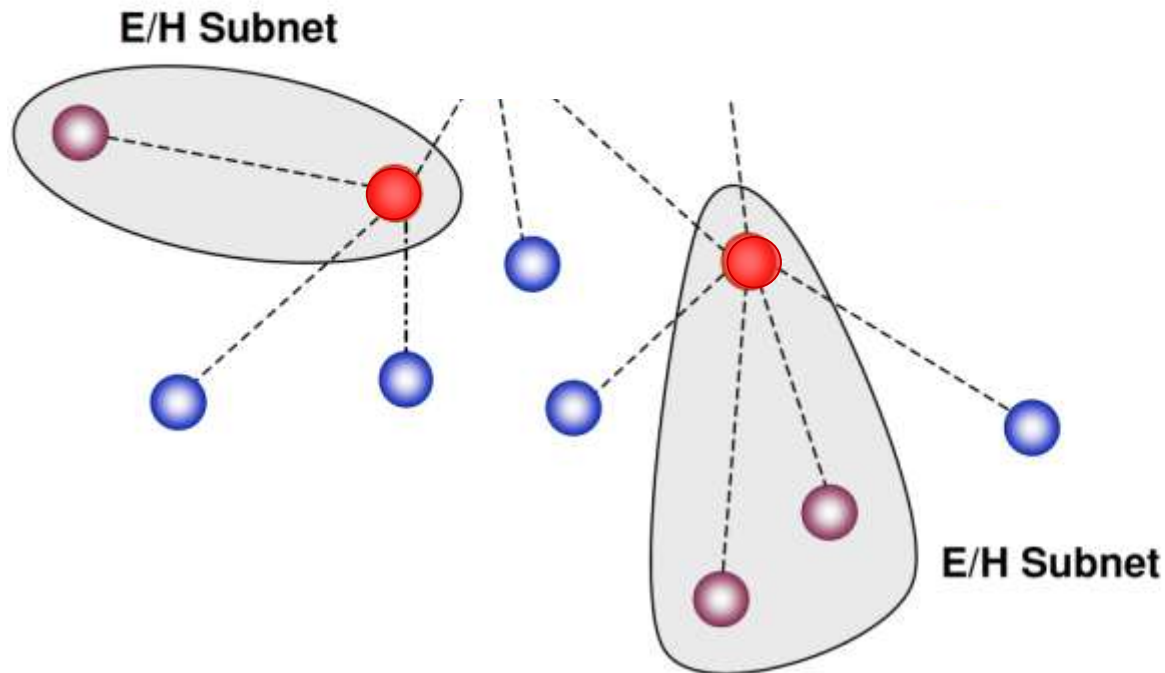
- Configured to support intermittent end device transmission
 - Ready to service requests when the end device needs
- Uses a Proxy Server
 - Powered Routers – always ready to receive from E/H end devices



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



LL (Light Link)



HA (Home Automation)



Healthcare

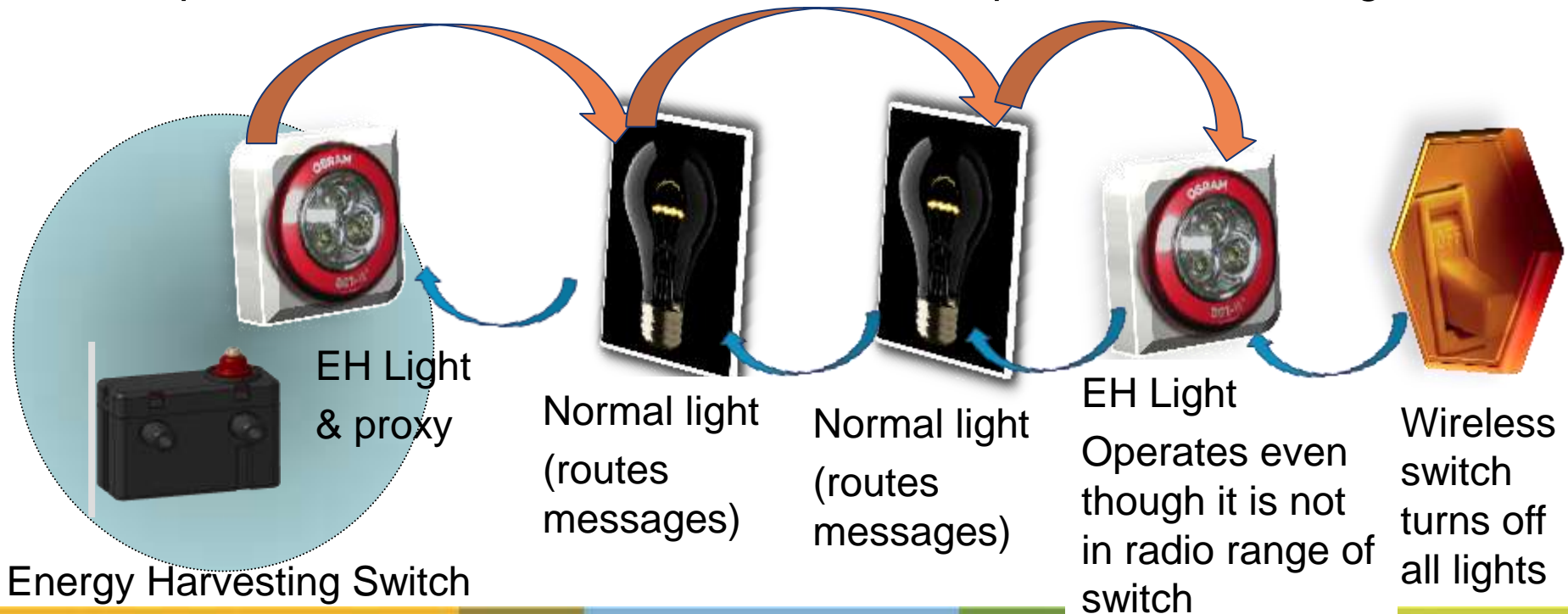


SE (Smart Energy)



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

Operates this light

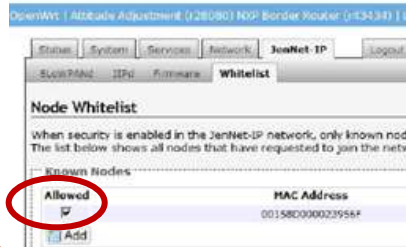


Receive PAN id at power up

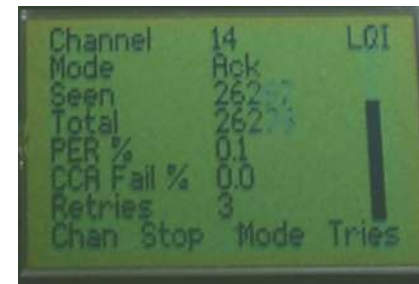


Button Press

NXP JenNet-IP Border Router Configuration



White List



RF Signal Strength

NFC with Energy Harvesting

Customize wireless parameters

- Tap switch to gateway
- Parameters are assigned



Identifies itself to network

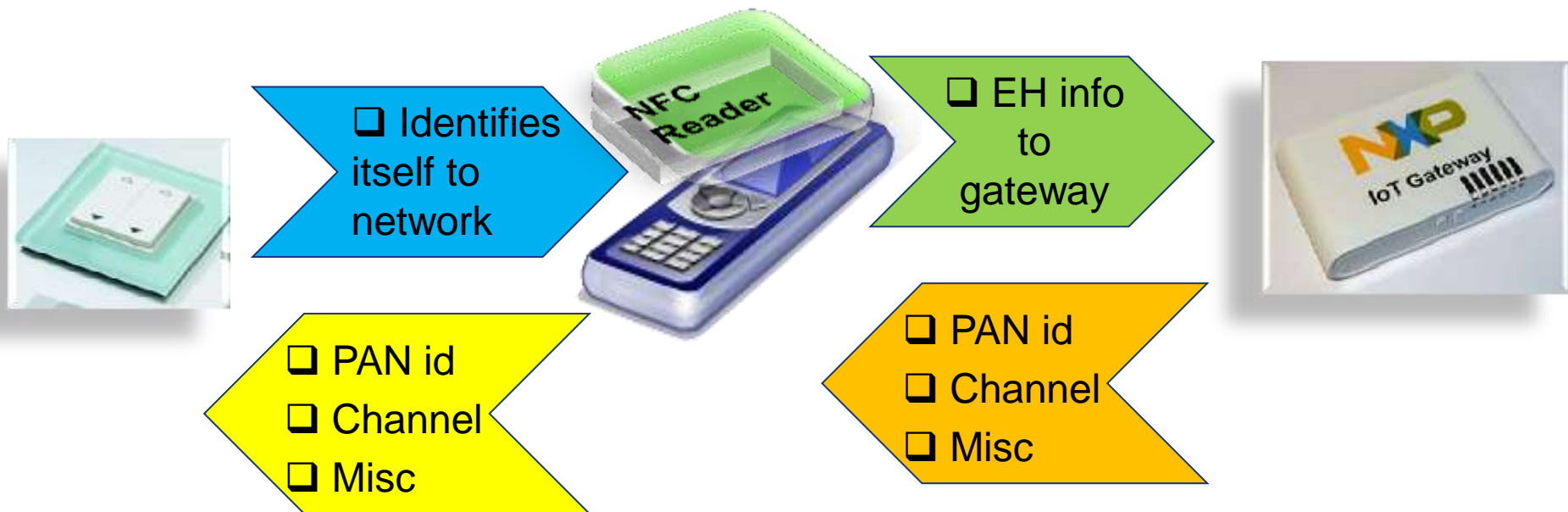
- PAN id
- Channel
- Misc



NFC with Energy Harvesting

Customize wireless parameters

- Tap switch to mobile phone
- Mobile phone communicates to gateway via WiFi
- Parameters are assigned from gateway



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?