Sensors Expo Chicago 2005

Building Low Power into Wireless Sensor Networks Using ZigBee Technology

Jon Adams
Director, Radio Technology and Strategy

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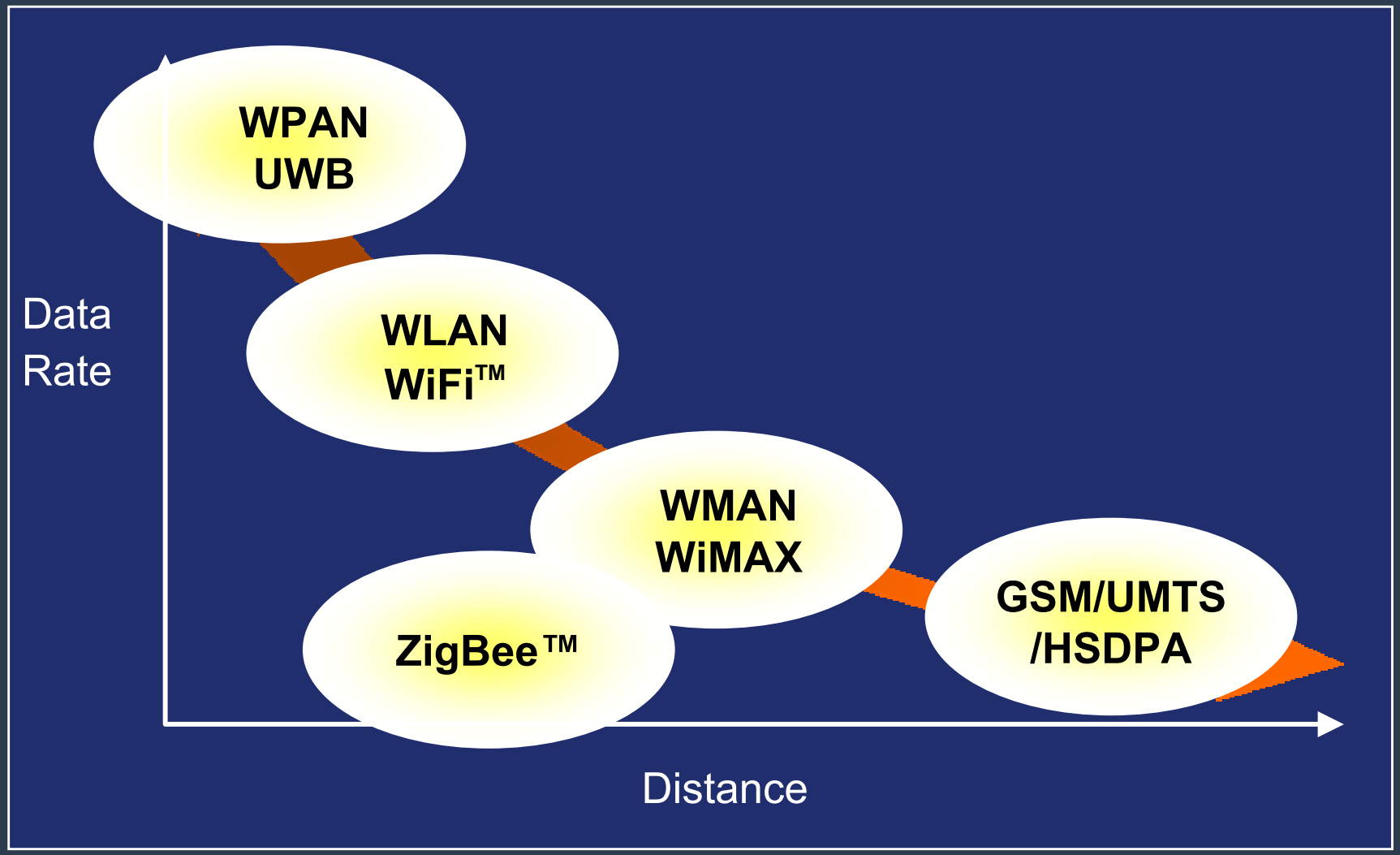
Agend

- **Introduction**
  - Director of Radio Technology and Strategy
    - > Freescale Wireless and Mobile Systems Group, Tempe, AZ
  - Past Chair, ZigBee Alliance Qualification Group
  - President, UWB Forum
  - Voting Member, IEEE 802.11, 802.15 and 802.16 Working Groups
- **IEEE® STD 802.15.4**
  - The “Chassis and Wheels” for ZigBee Technology
- **Taking Best Advantage of ZigBee Technology**
  - Networking – Self-Forming and Self-Healing - How it works
  - Wireless Pressure, Temperature, Humidity, Light, Disturbance, and yes, even Image Sensors

How Does ZigBee Fit In the World of Wireless



IEEE 802.15.4 Overview

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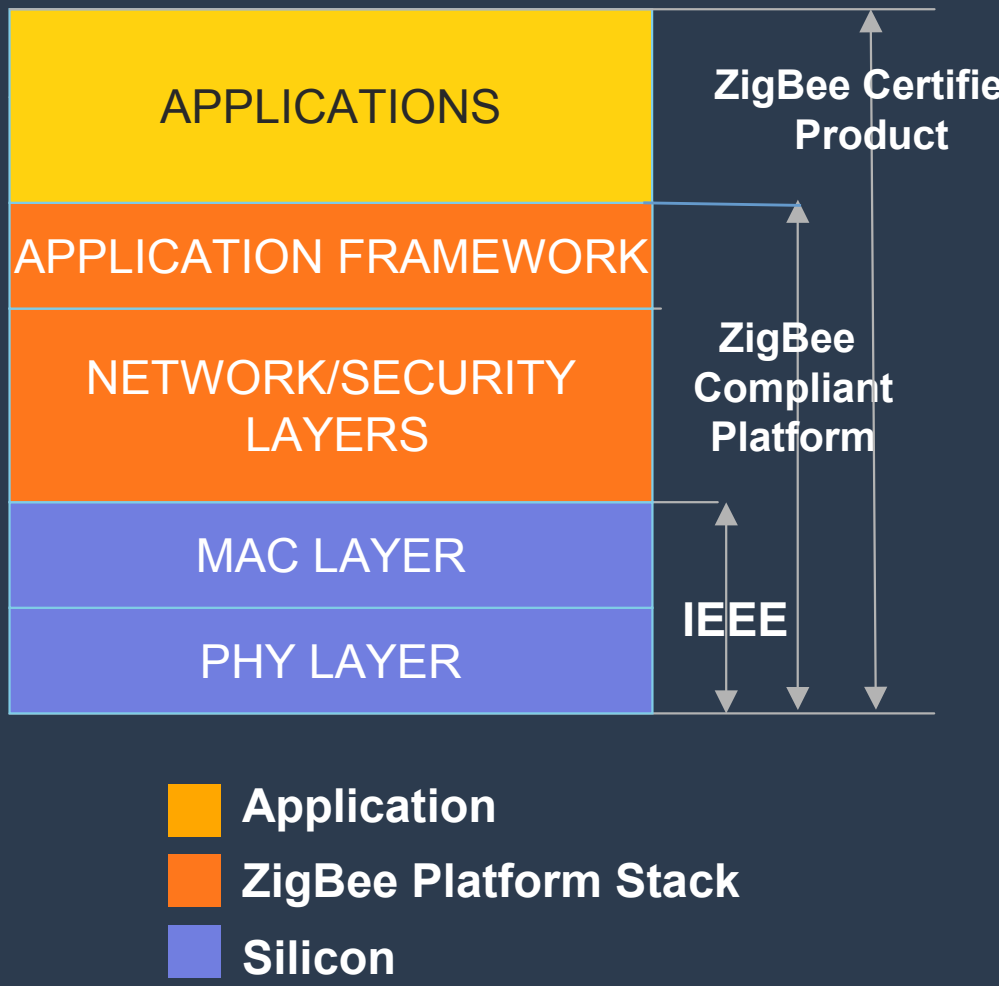
Protocol Stack Feature

- **ZigBee Technology**
  - Provides network, security management, applications profiles, interoperability and certification testing
- **IEEE STD 802.15.4**
  - Designed to supply the radio and protocol, allowing the designer to concentrate on the application and their customers' needs

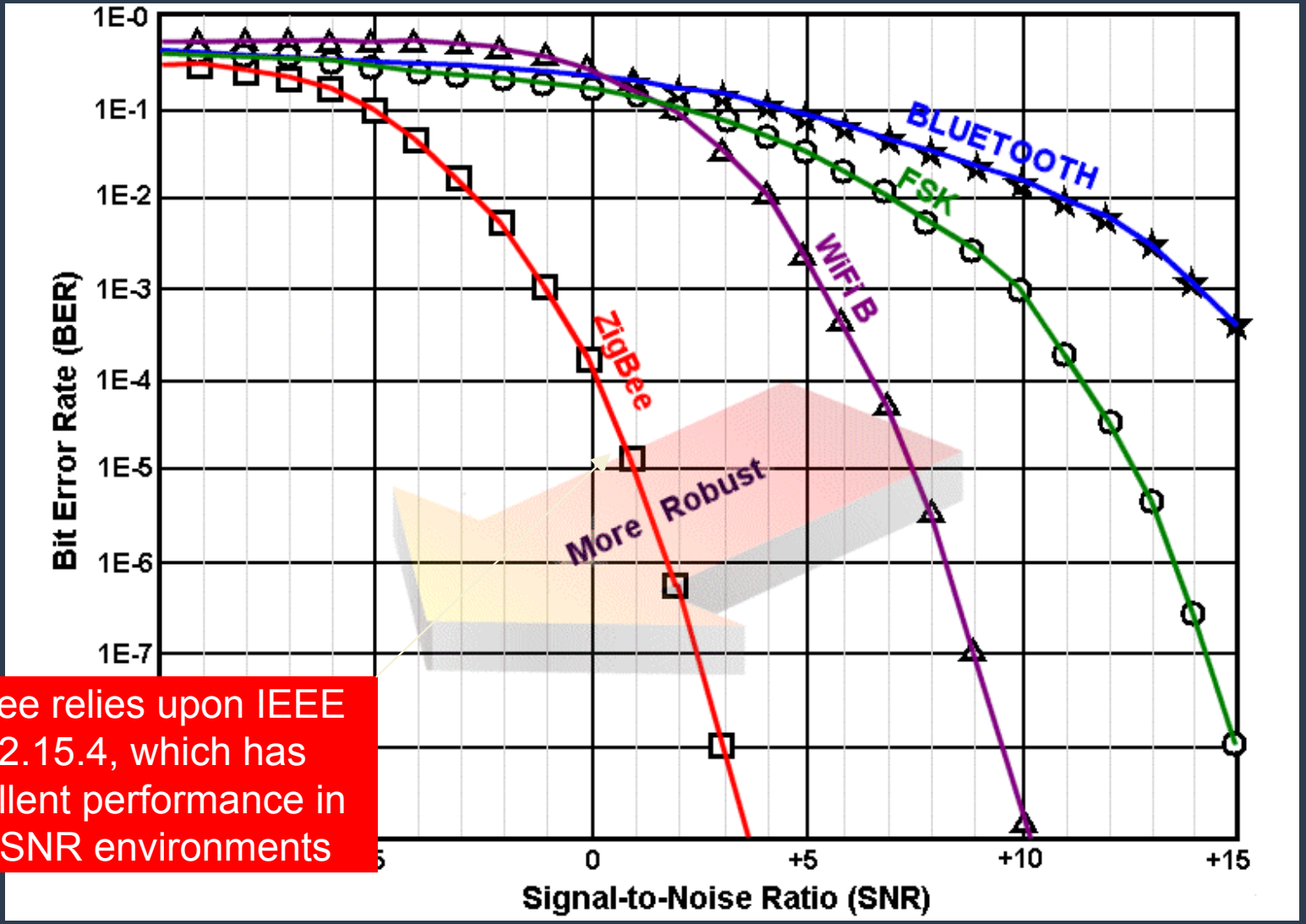


IEEE 802.15.4 Basics

- **Simple packet data protocol for lightweight wireless networks**
  - Released in May 2003
  - Primary channel access is via Carrier Sense Multiple Access with collision avoidance
  - Message acknowledgement and an optional beacon structure
  - Multi-level security
  - Works well for
    - > Long battery life, selectable latency for controllers, sensors, remote monitoring and portable electronics
  - Configured for maximum battery life, has the potential to last as long as the shelf life of most batteries

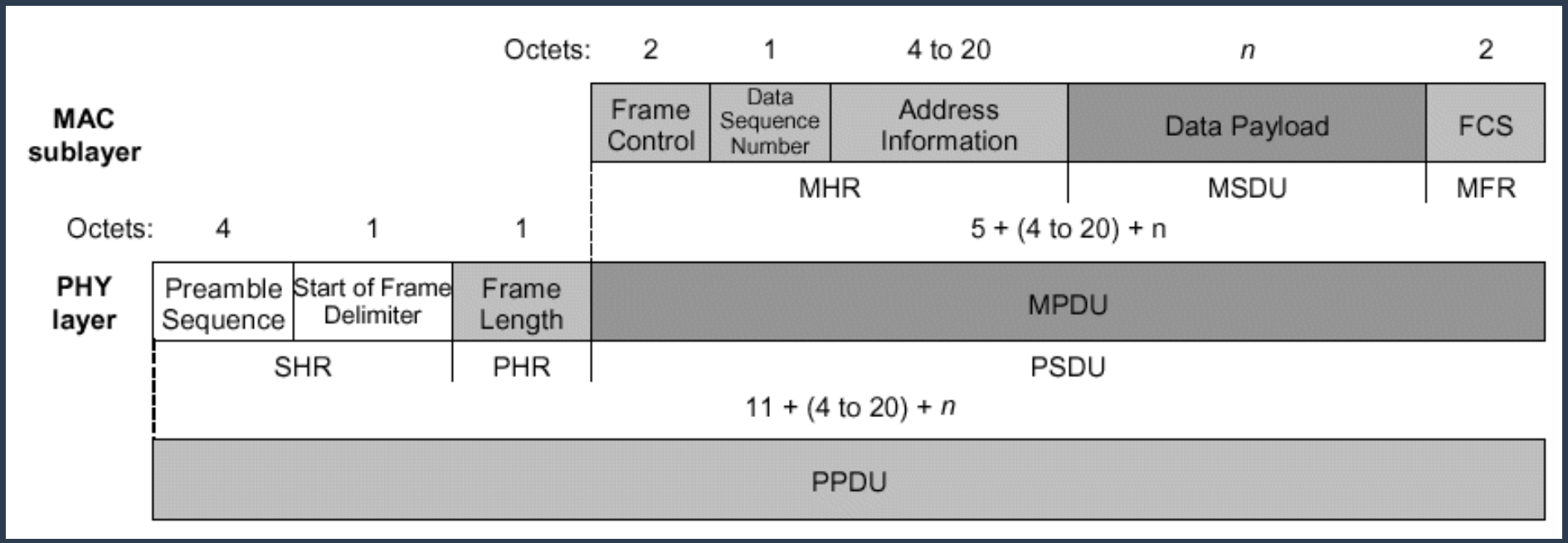
Frequency Band	License Required?	Geographic Region	Data Rate	Channel Number(s)
868.3 MHz	No	Europe	20kbps	0
902-928 MHz	No	Americas	40kbps	1-10
2405-2480 MHz	No	Worldwide	250kbps	11-26

PHY Performance



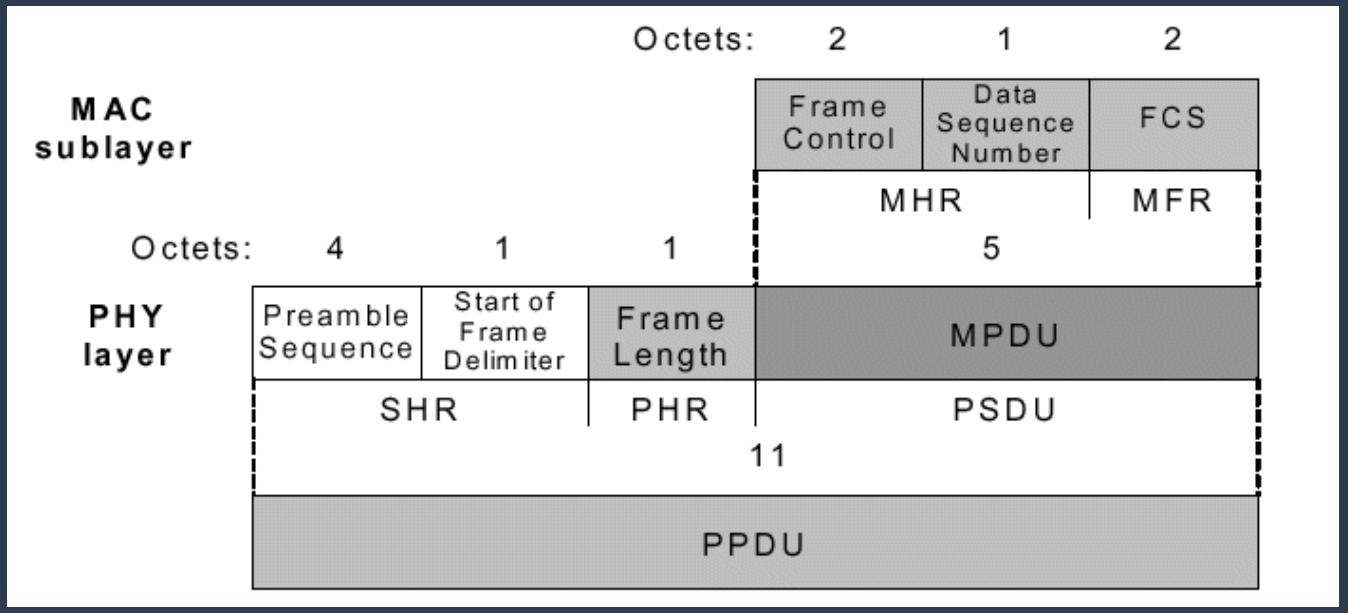
ZigBee relies upon IEEE 802.15.4, which has excellent performance in low SNR environments

IEEE 802.15.4 Data Fram



- One of two most basic and important structures in IEEE 802.15.4
- Provides up to 104 byte data payload capacity
- Data sequence numbering to ensure that packets are tracked
- Robust structure improves reception in difficult conditions
- Frame Check Sequence (FCS) validates error-free data

IEEE 802.15.4 Acknowledgement Fram



- The other most important structure
- Provides active feedback from receiver to sender that packet was received without error
- Short packet that takes advantage of standards-specified “quiet time” immediately after data packet transmission

ZigBee Networking

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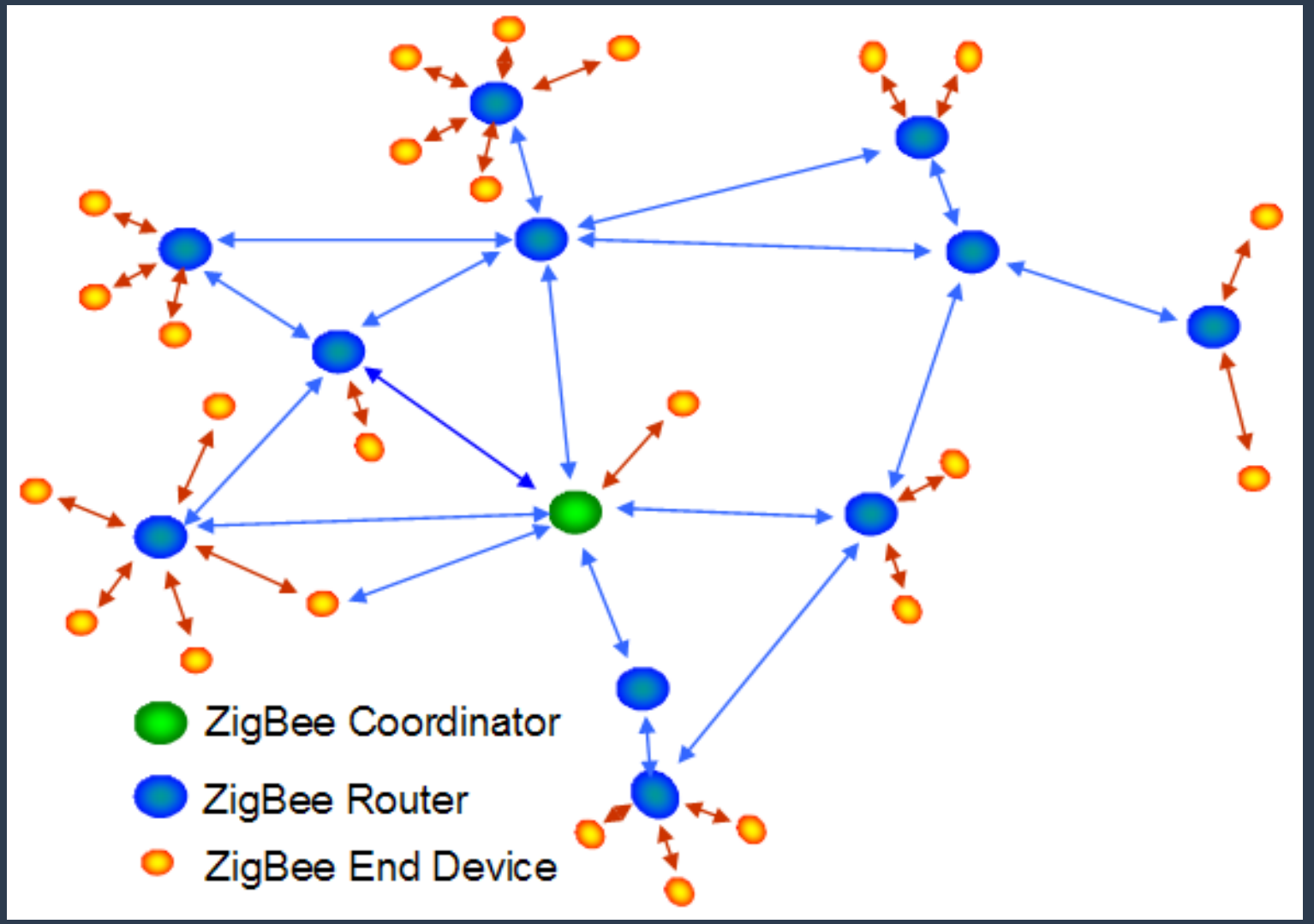
Mesh Networks Overcome Barriers to Wireless Adoptio

- **Barrier #1: Reliability**
  - People can move when wireless reception is poor; machines typically cannot
  - Humans tolerate garbled communication; machines do not
- **Barrier #2: Wireless Expertise**
  - Customers (and some installers) do not want to become wireless experts
  - Want “wireless control that simply works”

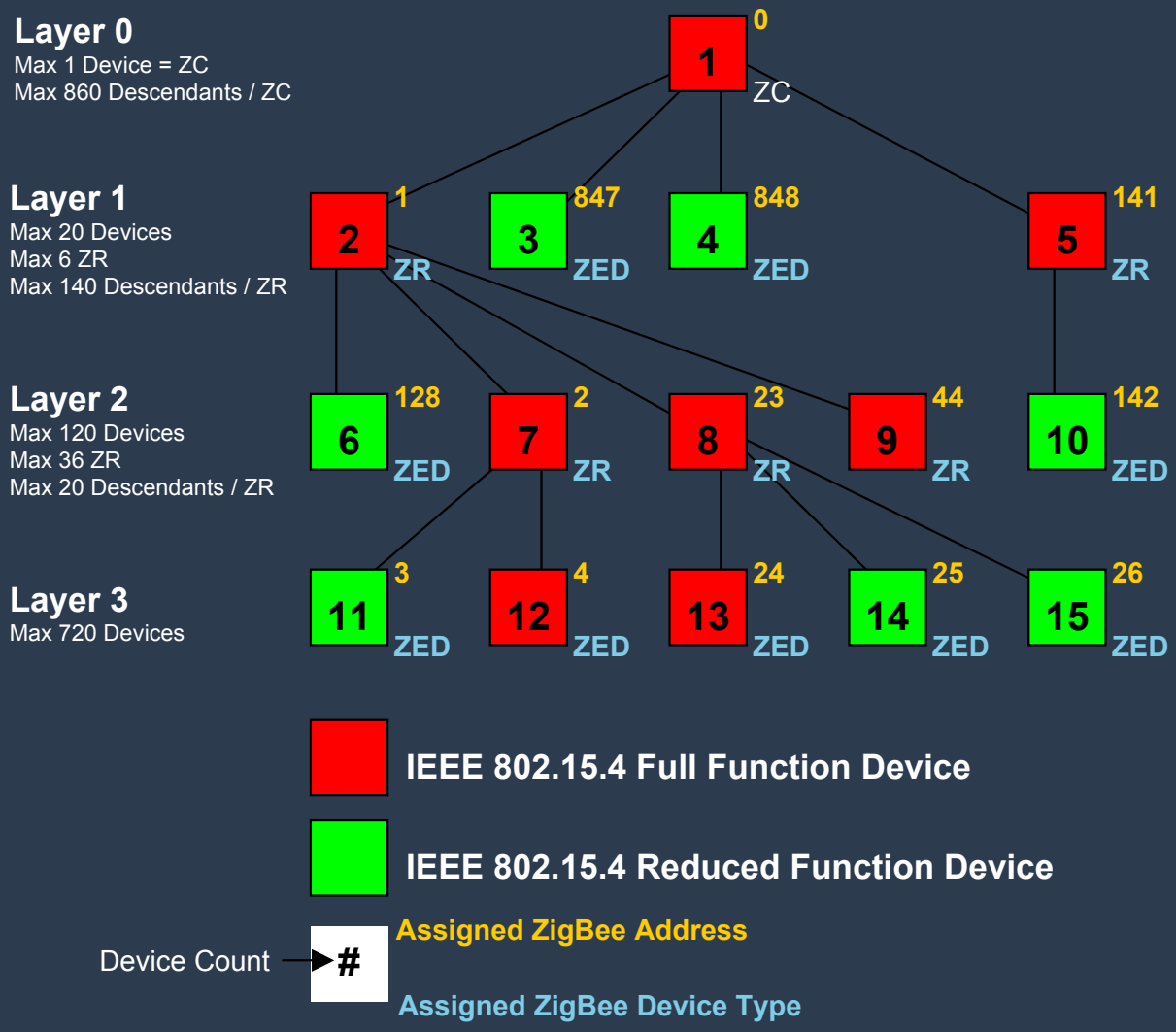
ZigBee is Native Mesh Networkin



Layers, Children and Routers – The ZigBee Network Ke

- **Layers (Lmax)**
  - Specifies the maximum “radius” that any ZigBee network may have
  - For an Lmax=3 network as depicted before, this means that no node may be more than three physical RF hops from the Coordinator
  - From the “family” concept, Device 11 is the “great-grandchild” of device 1
- **Children (Cmax)**
  - Defines the total number of nodes in Layer n that may be directly connected to a parent Router in Layer n-1
  - Node 2, a Router, may have a total of 20 children, but in the previous diagram has only 4, including 3 Routers and 1 End Device
  - According to the address assignment procedure, node 2 holds in reserve sufficient addresses in case more children join
- **Routers (Rmax)**
  - Maximum number of children that may also function as Routers
  - Previous example of 20 children per parent, 6 of those children may also act as parents to their own children, while the remaining 14 (Cmax-Rmax) may not be parents
  - For any procreating Parent, the first R address blocks are reserved for Router children, while the remaining Cmax-Rmax addresses are reserved for End Device children.

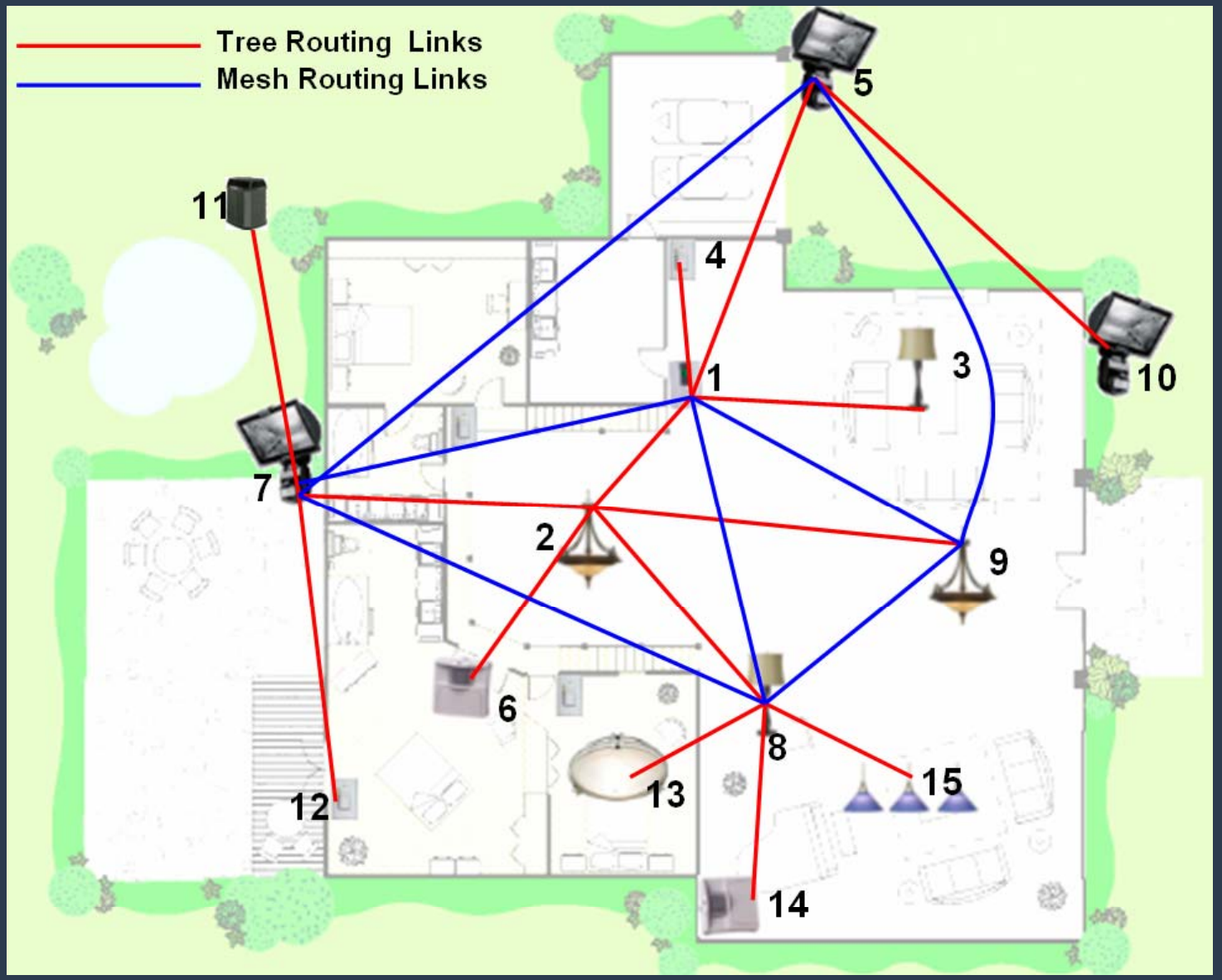
ZigBee Sparse Network Initial Address Assignme



Every Mother is Someone's Daughte

- **ZigBee networks strongly use the concept of generations of family**
  - Device 5
    - > Child of Device 1
    - > Parent of Device 10
  - Device 2
    - > Total of 9 descendants (4 Children, 5 grandChildren)
    - > Note that only IEEE802.15.4 Full-Function devices may "procreate", and at Layer Lmax no device may procreate
    - > ZigBee devices that may procreate are considered ZigBee Routers (ZR), those that may not or can not procreate are ZigBee End Devices (ZED)
    - > Layer 0 shall contain only the ZigBee Coordinator (ZC)

Initial Tree Addressing with Subsequent Mesh Route



Wireless Sensors Make Your Environment Work Better

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ZigBee Home Contr

Entertainment

Safety

Lifestyle

Comfort

Energy Savings

Security

ZigBee Commercial Contr

- **Wireless lighting controls**
  - Dimmable intelligent ballasts
  - Light switches/sensors anywhere
  - Customizable lighting schemes
  - Quantifiable Energy savings
  - Opportunities in residential, light commercial and commercial
  - Lighting network can be integrated with and/or be used by other building control solutions
- **Hotel energy management**
  - Centralized HVAC management allow hotel operator to make sure empty rooms are not cooled
  - Easy to Retrofit
  - Battery operated thermostats, occupancy detectors, humidistats can be placed for convenience
  - Personalized room settings at check-in

Developing Wireless Sensors

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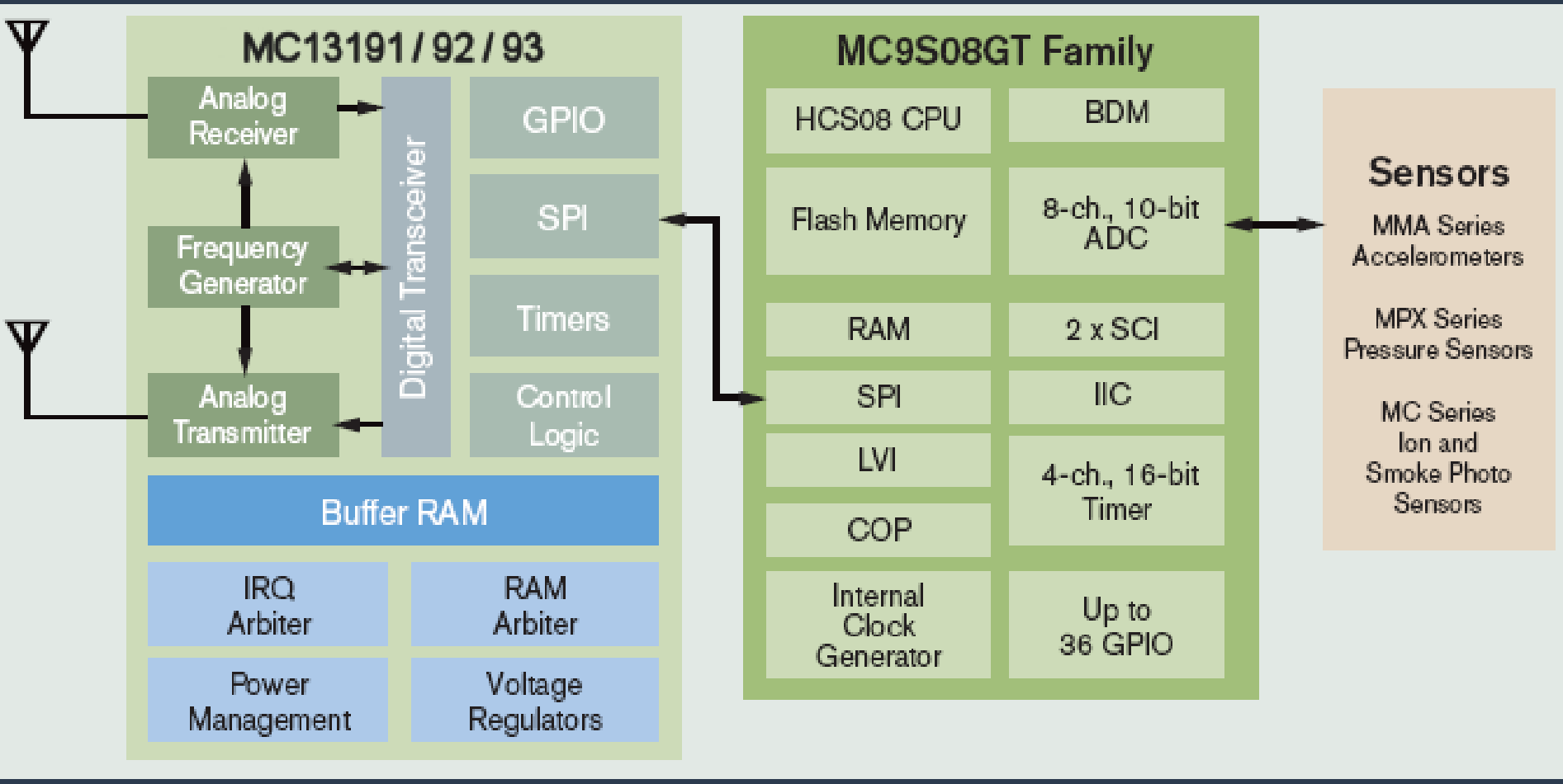
IEEE802.15.4 and ZigBee Compliant Platform

- **Features**
  - MC13191, MC13192 and MC13193 RF Data Modems
  - 350+ meter Range demonstrated by outside Test House
  - Power supply 2.0-3.4 V w/ on-chip regulator, logic interface 1.7 to 3.3
    - > Runs off a single Li or 2 alkaline cells, using ~100% of battery capacity
  - Complete RF transceiver data modem – antenna in, serial data out
  - Data and control interface via standard SPI at 4 MHz minimum
  - IEEE 802.15.4 compliant MAC supplied
  - Interoperates with Freescale HCS08 MCUs
  - Adapts easily to many of the Freescale sensors, DSPs, Coldfire processors
  - Strong roadmap to very high levels of integration

The Sensors Application Reference Design (SARD) Boar

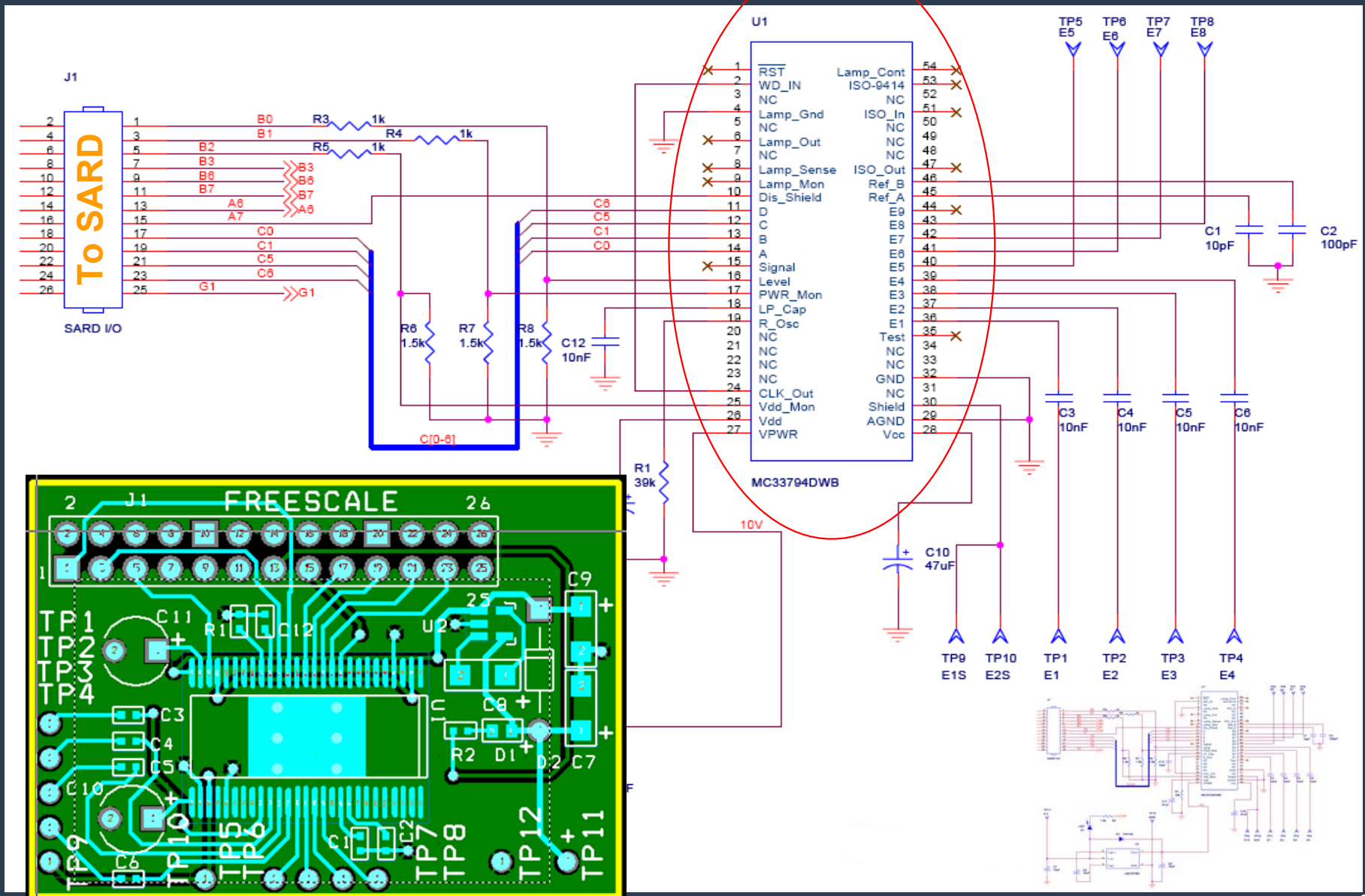
- **Easy way to get started on many different sensor applications**
  - Contains full radio, antenna, all passives
  - MCU for application
  - Built in three-axis accelerometer with apps software for immediate, out-of-the-box experience
  - Buttons, LEDs, RS232 serial port
  - 26-Pin Header brings out all connections to allow quick prototype and test of different sensor types
    - > Field disturbance
    - > Pressure (water, air, etc.)

System Simplicity and Flexibili

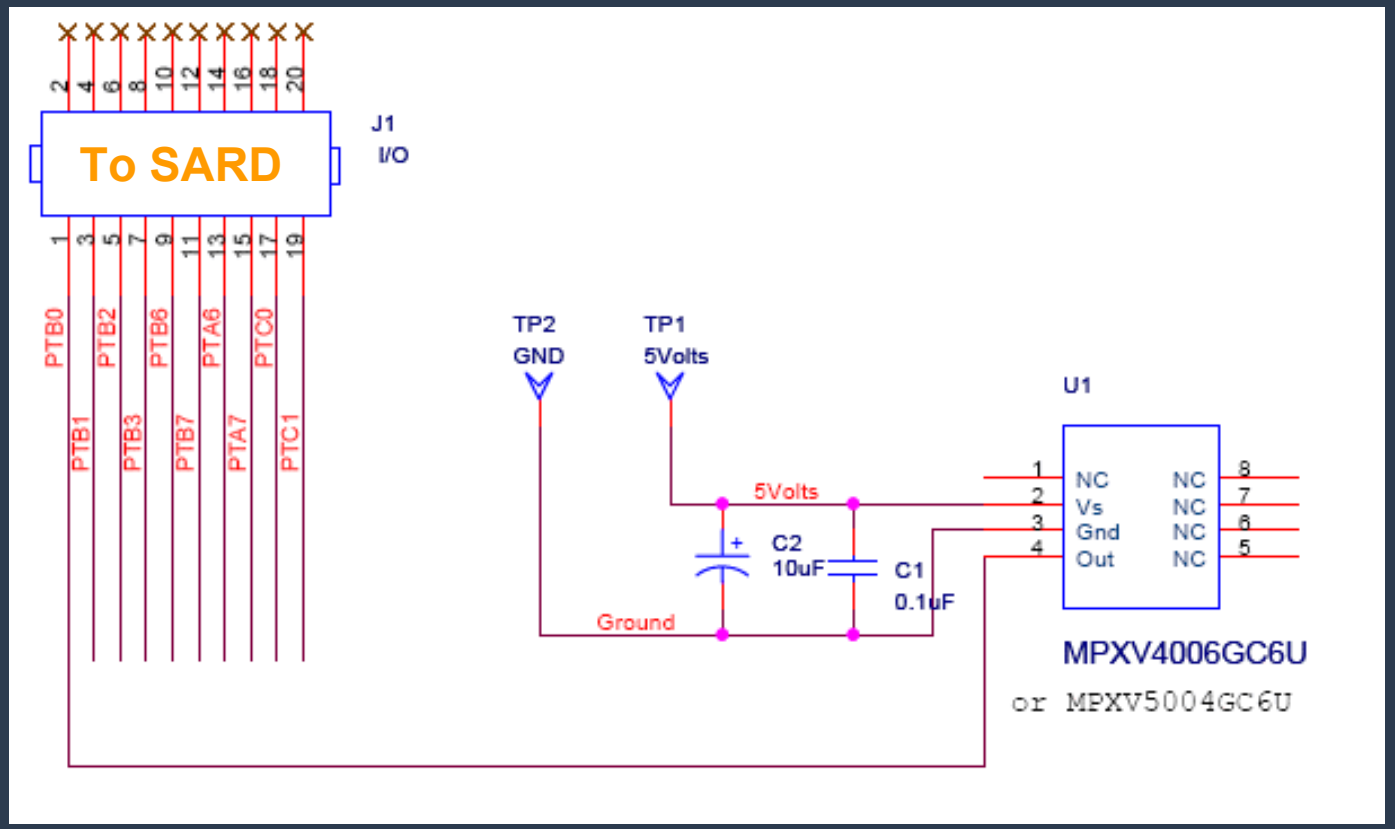


- See www.freescale.com/zigbee for detailed information

Freescale E-Field Disturbance Sens

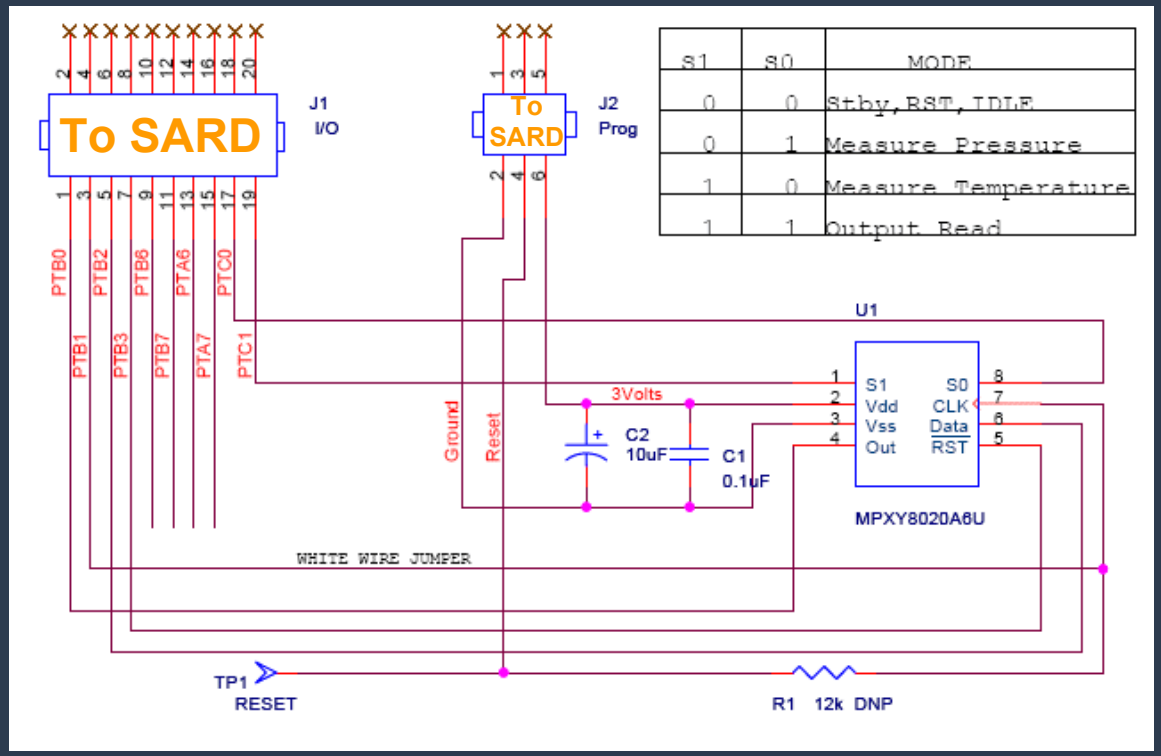


Freescale Low-Pressure Water/Liquid Sensor



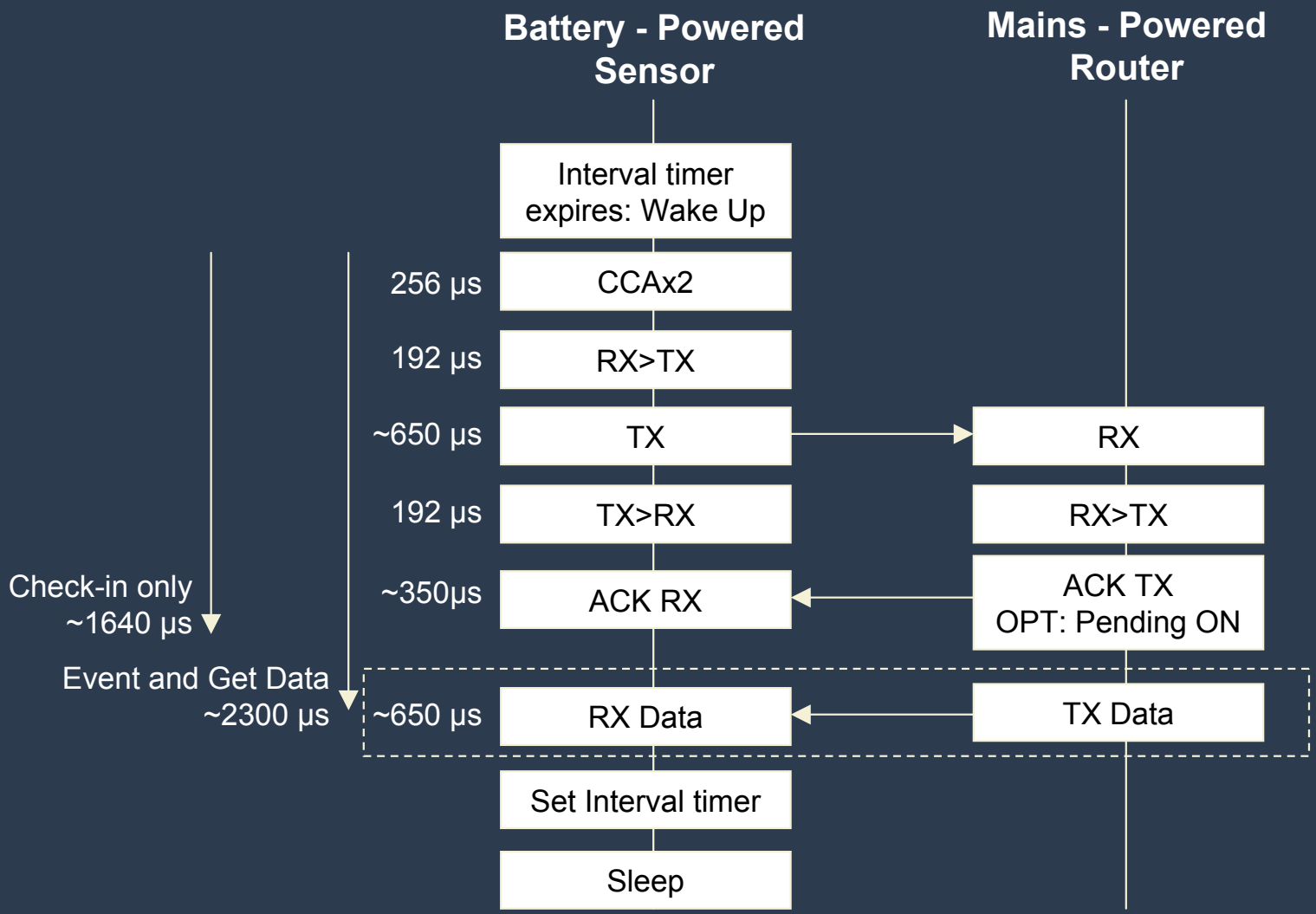
- Industrial, residential, agricultural, commercial applications
- Only three added parts

Freescale Pressure/Temperature Sens



- Quickly prototype sensors for industrial, agricultural, automotive and residential applications where temperature and pressure are valuable data
- Only four added components

Timing Is Everythin

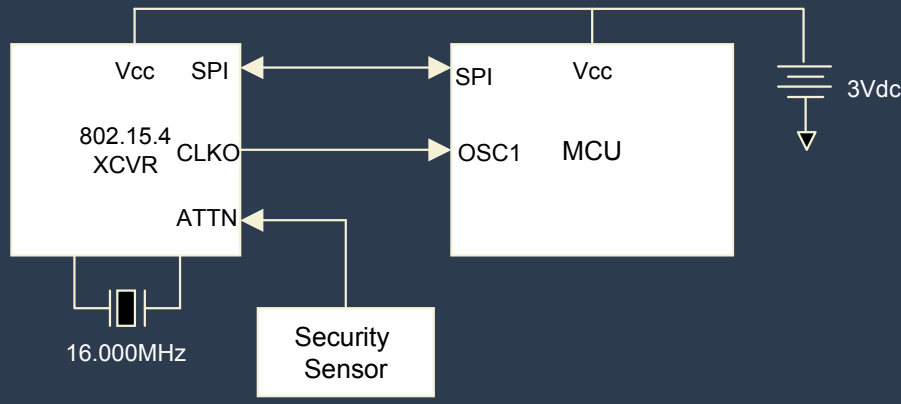


Intelligent Low-Power Sensor Desig

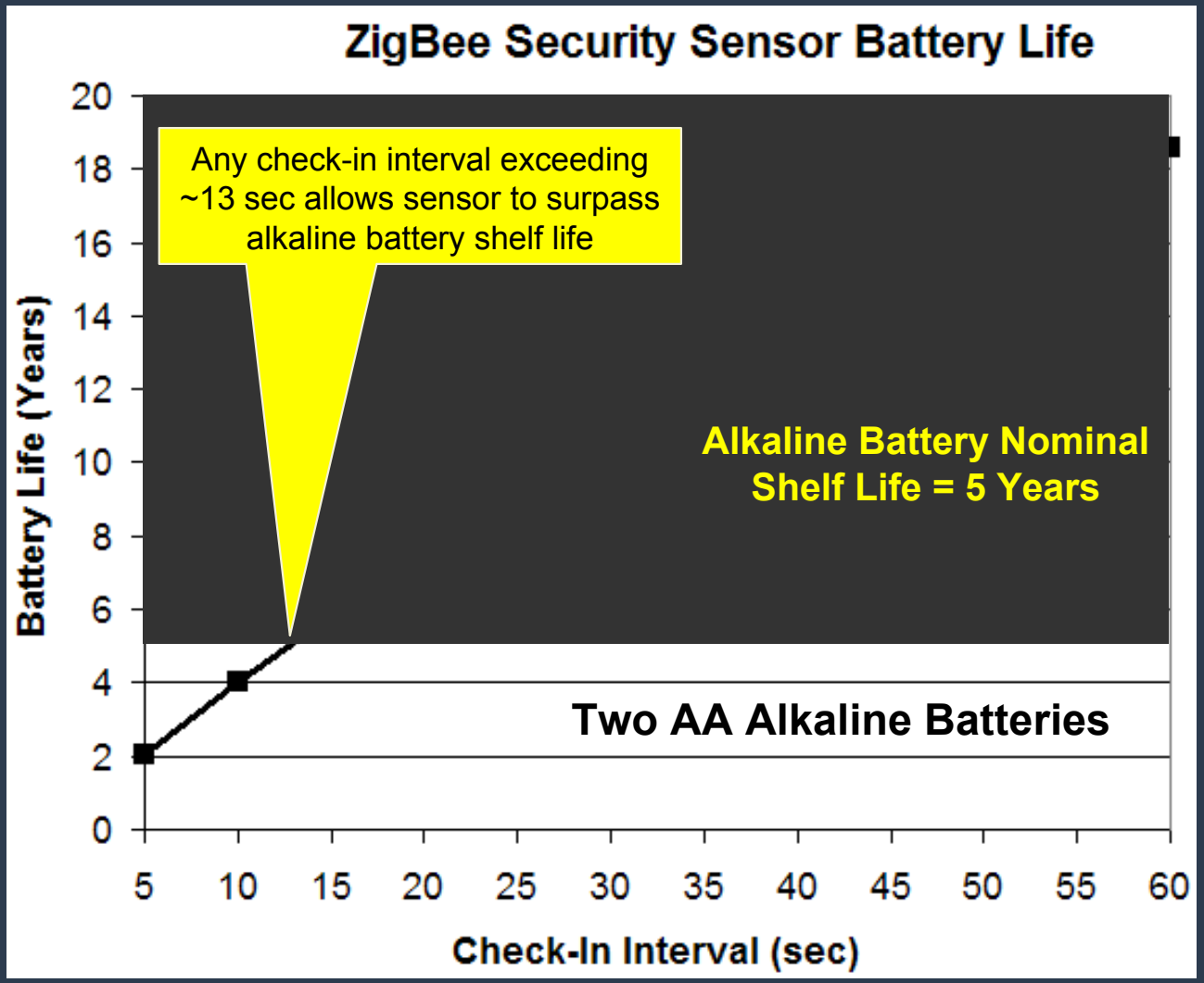
- **Long Battery Life means using fewer electrons to get the job done**
  - Simple steps but intelligent processing required – MCUs make your life easier
  - For sensors
    - > Reduce their duty cycle as practical – most sensors can manage this without contaminating the data
    - > At the same time, increase the sampling rate
    - > For applications involving human interaction (motion, occupancy, HID, etc.), sampling in the millisecond to tens of millisecond range is sufficient for nearly any application
    - > Sensor activity interval must be shortened to limit power consumption with increased sample rate – checking to see if the button has been pushed takes only few microseconds over tens of milliseconds
  - All this requires sensors that are microcontroller-based for ease of design and programming

Peel-n'-Stick Security Sensor

- **Battery Operation**
  - 2 AA Alkaline or 1 Li-AA cell
- **802.15.4 and ZigBee Mode**
  - Non-beacon network environment
- **Sensor process**
  - RC Oscillator wakes up MCU and doing network check-in at some interval
    - > Many security systems have between ~10 second and ~15 minute requirement
  - On a sensor event, device immediately awakens and reports in to network



Less Electrons Used Means Longer Battery Li



Freescale and our ZigBee Technology
are Ready – Let's Get Going!

Launched by Moto

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Summar

- **Freescale Semiconductor's ZigBee-Ready Platform**
  - One stop shop for the total solution
    - > Transceivers, MCUs, DSPs, Sensors, Application and 15.4/ZigBee stacks, antennas and reference designs
    - > Strong roadmap to high levels of integration, increased functionality and cost-effectiveness
- **IEEE 802.15.4 and ZigBee**
  - Allows Designer to concentrate on end application
    - > Silicon vendors and ZigBee Alliance take care of transceiver, RF channel and protocol, ZigBee "look and feel", interoperability, application certification
  - Reliable and robust communications
    - > PHY and MAC outperform all known non-standards-based products currently available
  - Flexible network architectures
  - Very long primary battery life (months to years to decades)
  - Low system complexity for the OEM
- **More Information**
  - Freescale: www.freescale.com/zigbee
  - ZigBee Alliance: www.zigbee.org


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