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POWERING INNOVATION

Metering and the Smart Grid: Last Mile and Home Area Networking

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Agenda

- **What is the Smart Grid**
- **Meter connectivity**
  - Last Mile
  - HAN
- **Freescale solutions**
- **Summary**

Key Terms

- **HAN** – Home Area Network
- **NAN** – Neighborhood Area Network
- **PLC** – Power Line Communication
- **PLM** – Power Line Modem
- **Modulation**
  - **DSSS** – Direct-Sequence Spread Spectrum
  - **FSK** – Frequency Shift Keying
  - **SFSK** – Spread Frequency Shift Keying
  - **OFDM** – Orthogonal Frequency Division Multiplexing
  - **OQPSK** – Offset Quadrature Phase Shift Keying
- **Standard and Alliances**
  - **802.15.4g –** RF spec for the Smart Utility Network driven by IEEE
  - **G3** – Power line modem specification driven by the G3 alliance
  - **G.hnem** – Power line modem specification driven by ITU
  - **P1901.2** – Power line modem specification driven by IEEE
  - **PRIME** – Power line modem specification driven by the PRIME alliance

Smart Grid

- **Smart Grid includes generation to consumption**

- Reduce power consumption through intelligent monitoring and control
- Increase power availability through optimized distribution
- Improve power reliability and quality
- Expand consumer choices for electrical energy
- Improves the resiliency of the electric power grid
- Enables easier use of renewable energy and distributed generation

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Smart Grid

- **But, if the Smart Grid includes generation to consumption then why is all the focus on:**

- Reduce power consumption through intelligent monitoring and control
- Increase power availability through optimized distribution
- Improve power reliability and quality
- Expand consumer choices for electrical energy
- Improves the resiliency of the electric power grid
- Enables easier use of renewable energy and distributed generation

The Home and the Meter

- **Impacts many of the requirements of the Smart Grid**
- **Is one of the quickest and easiest to address**
- **Can be tied to a quicker return on investment**

- Reduce power consumption through intelligent monitoring and control
- Increase power availability through optimized distribution
- Improve power reliability and quality
- Expand consumer choices for electrical energy
- Improves the resiliency of the electric power grid
- Enables easier use of renewable energy and distributed generation

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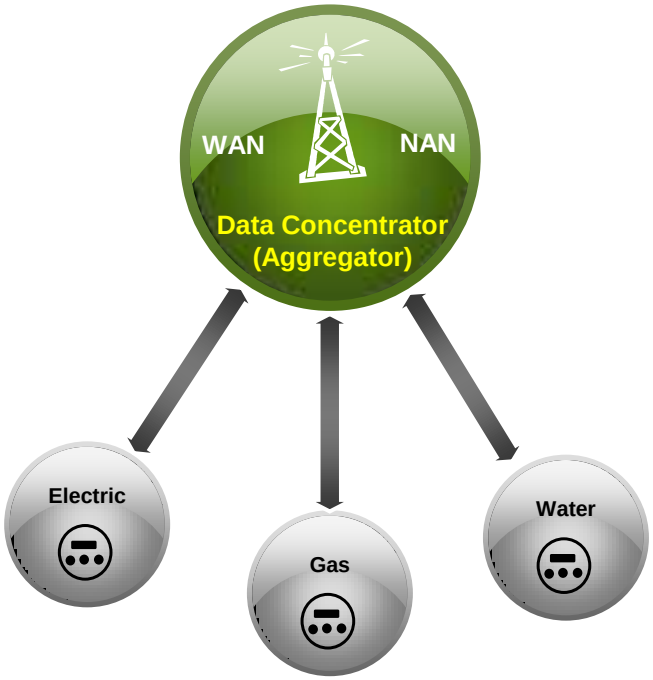
Where Does the NAN Fit in the Smart Grid

- **Neighborhood Area Network (NAN)**
  - Commonly known as last mile
  - Communication from meter to a data concentrator
  - Traditionally used for AMR (Automated Meter Reading)
  - Expanded to AMI (Automated Metering Infrastructure)
    - 2-Way
  - Multiple technologies and standards
    - Sub-GHz
      - Proprietary, W-MBUS, 802.15.4g
    - PLC
      - S-FSK, OFDM (PRIME, G3, P1901.2)
    - Cellular
      - GPRS, WiMax

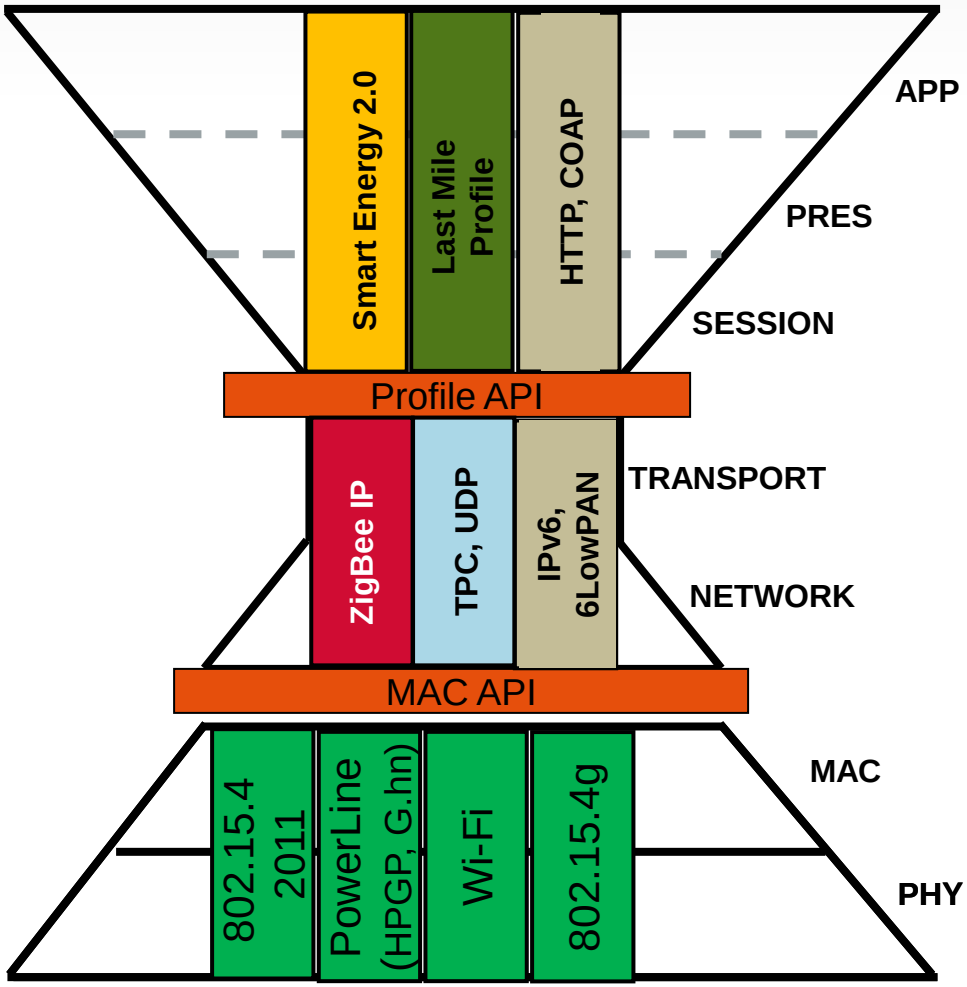
Migration to Standards are Still Complex

- **802.15.4g**
  - Defines alternate PHYs for the Smart metering Utility Network (SUN)
  - Adds support for multiple physical layers
    - 2FSK, 4FSK, OFDM, O-QPSK
    - Data rates from 4.8 Kbps to 800 Kbps
  - Regional differences
    - 470-510 MHz for China
    - 779-787 MHz for China
    - 863-970 MHz for Europe
    - 902-928 MHz for North America
    - 917-923 MHz for Korea
    - 950-958 MHz for Japan
    - 2400-2483.5 MHz Global



Internet Protocol

- IP is a key technology for convergence
  - Open standards
  - Supports multiple Physical layers
- 6LowPAN and IPv6
  - Has moved IP into the embedded space
  - IP everywhere



Comparing Wireless Technologies

Technology	W-MBus/KNX Proprietary	ZigBee® 15.4	802.15.4g	Wi-Fi a,b,g,n
Operating Frequency	100MHz-1GHz	868 MHz 900-928 MHz 2.4 GHz	868 MHz 900-928 MHz 2.4 GHz	2.4GHz 5GHz
Data Throughput	1Kb/s-500Kb/s	250Kb/s	5Kb/s-800Kb/s	54-300Mb/s
Modulation	FSK	DSSS	FSK, OFDM, O-QPSK	DSSS, OFDM
Topology	Point-to-Point	Star, Mesh	Point-to-Point Star, Mesh	Point to Hub Ad-hoc (direct)
Power	Very Low- Low	Low	Low-Med	Med-High
Range	Long	Medium	Long	Short
Cost Adder	$$	$$	$$$	$$$$
HW SW Complexity	Low	Medium	Medium-High	Very High
Typical applications	Industrial control and monitoring, sensor networks, building auto home control and automation	Industrial control and monitoring, sensor networks, building auto home control and automation	Smart Utility Network	Wireless LAN connectivity, broadband Internet access

Where Does the HAN Fit in the Smart Grid

- **Home Area Network (HAN)**
  - Communication from meter into the home
  - Key component to provide load control, demand response and time of use pricing
  - Standards are still being worked out
    - NIST, CEN/CLC/ETSI, IEC, IEC PC118
    - ZigBee SE appears to have the most traction
      - SE 2.0 supports multiple PHY technologies
        - ZigBee, Wi-Fi, HomePlug

Growing Market for ZigBee® Smart Energy and Home Automation

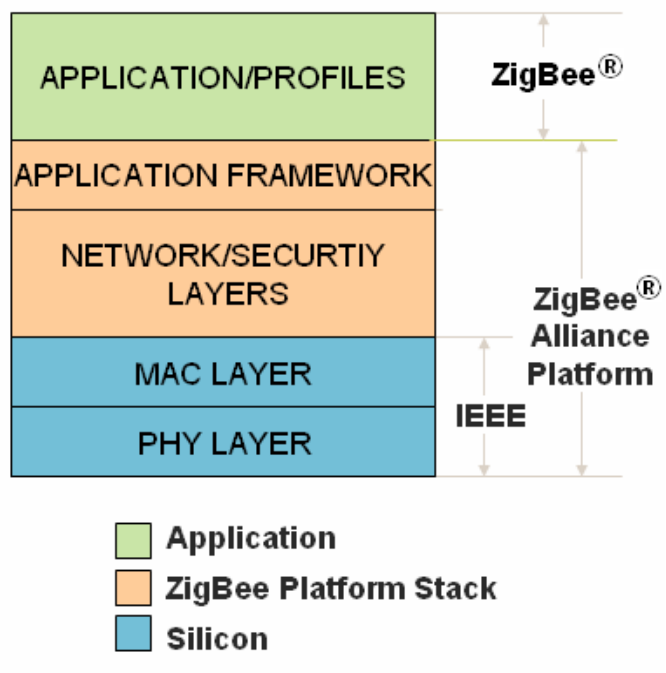
- **Energy management and efficiency solutions can bridge the gap between the power grid today and the Smart Grid of tomorrow**
  - Households with digital tools controlling temperature and price preferences saved on average 10% on utility bills
- **Market is starting with large scale rollouts**
  - Technology is available today, deployment are happening now
    - Over 10 million ZigBee® enabled meters deployed through 2010
- **Major companies launching products**
  - GE, and LG have launched ZigBee® enabled appliances
  - Cisco, Intel and Control4 have launched Home Energy Management systems

Growing Market for ZigBee® Smart Energy and Home Automation (Cont.)

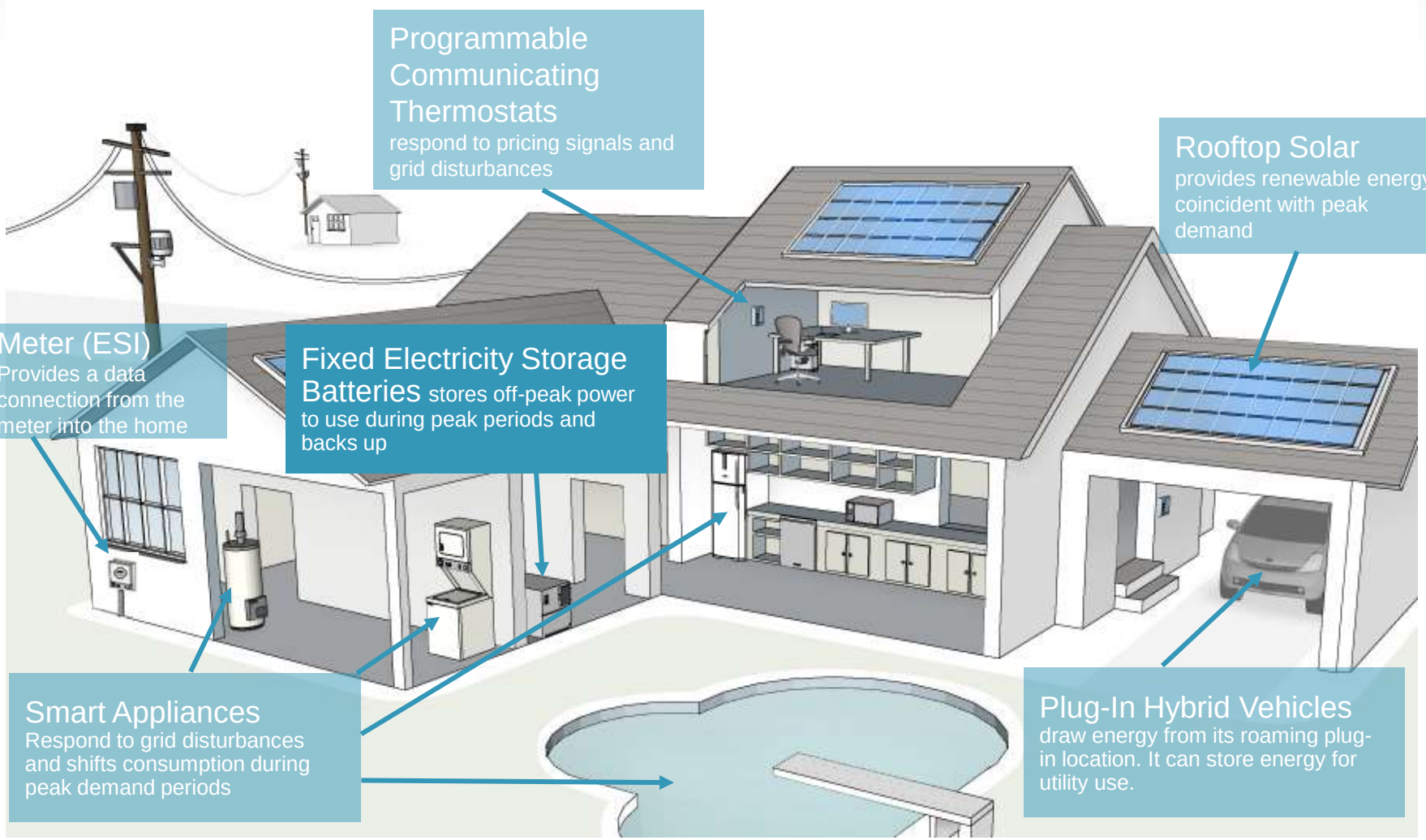
- **Government mandates and stimulus funds are driving early adoption**
  - **3.4 billion in stimulus funds awarded for the Smart Grid in the US**
  - **EU Plan 20% reduction of Energy consumption by 2020**
  - **China**
    - $9.7B investment to deploy AMR/AMI
    - State Grid will deploy 180M Smart Meters in 3-5years.
  - **India**
    - Over 20Mu AMR meters will be deployed annually in the coming few years
    - Government will invest $10M for 8 pilot projects in 2012
  - **South Korea**
    - Korea Electric Power Corporation had Smart Grid pilot project in Jeju Island of South Korea. 6000 households involved.
    - Planned to replace all 18M in South Korea with smart meters from 2010 to 2020
  - **Australia**
    - Victoria State will replace all 2.7M# power meters in 2013 with Smart Meters.
    - NSW State will replace all 2.3M# power meters in 2017.
    - Other States have started pilot projects.

ZigBee Overview

- **A global protocol developed and supported by companies around the globe**
  - Based on 802.15.4
  - Creates specifications for wireless sensing and control
    - ZigBee 2007 (HA, SE 1.x, BA, HC)
    - ZigBee RF4CE (RC, HID)
    - ZigBee IP (SE 2.x)
  - Defines certification and compliance testing
  - Provides branding, market development and user education



Where does ZigBee Fit Into the Smart Grid



Source: wsj.com

ZigBee Energy Management Solutions

- **Multiple options being rolled out to meet the needs of energy management**
- **SE 1.x**
  - Based on ZigBee Pro
  - Early rollout in US, Europe and Australia and India (AMR)
- **HA 1.x**
  - Based on ZigBee Pro
  - Choice for Energy at Home
    - Lower cost and easier commissioning
  - HA 1.2 provides interoperability with SE 1.2
- **SE 2.0**
  - Based on Internet Protocol
  - Provides end to end IP support

Seamless Integration via Home Energy Gateway

Home Energy Gateway

Residential Gateway

Internet

Utility Companies

Energy Saving Services

Monitor and Alert

Consumer

Remote Control and

Monitor

No single comms protocol is an outright winner

Key feature / Protocol	Distance in ideal conditions (Free air in case of RF)	Data rate	Cost of end node	Cost of infrastructure /installation
Ethernet Wire	100m	>100Mb/s	Medium	High
RS485 Wire	1200m	100kb/s	Low	High
WiMax/GPRS/3G RF	10km	2-12Mb/s	High	High
ZigBee® RF 2.4GHz	100m (building influence)	Up to 250kb/s	Low/medium	Medium
802.15.4/KNX/WM-Bus Sub 1GHz RF	200m	4.8kb/s to 100kb/s	Low/medium	Low
Homeplug GreenPhy OFDM PLM	300m	14Mb/s	High	High
Cenelec A,B,C NB OFDM PLC (e.g. G3)	1km	38 to125kb/s	Medium	Medium
Cenelec A, B, C S-FSK PLC	1km	2400b/s	Low	Low

2.4GHz ZigBee® and Sub-1GHz WM-BUS offer a combined solution

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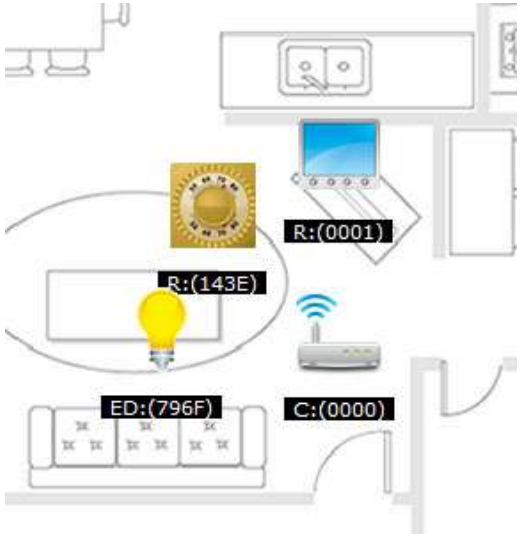
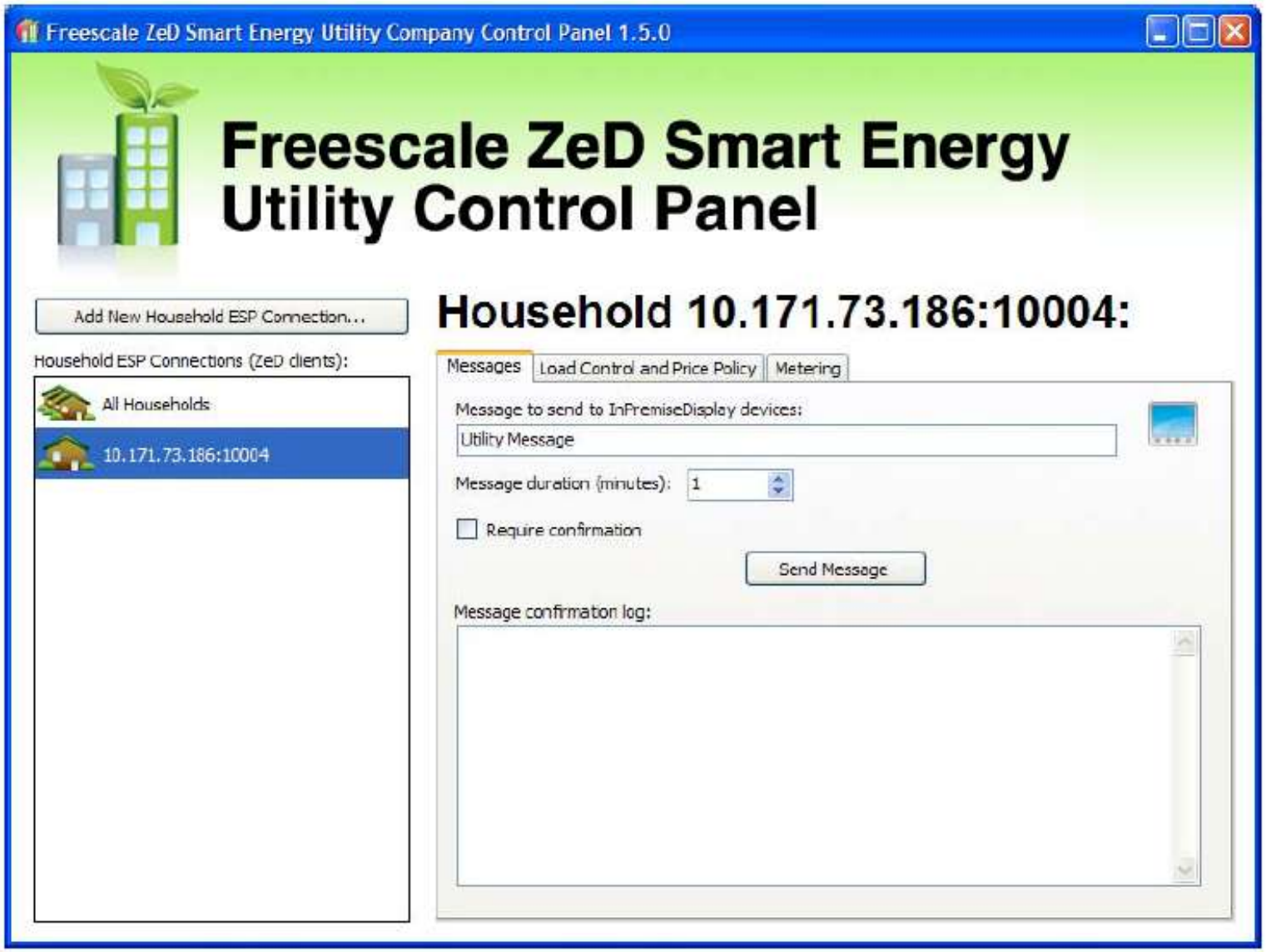
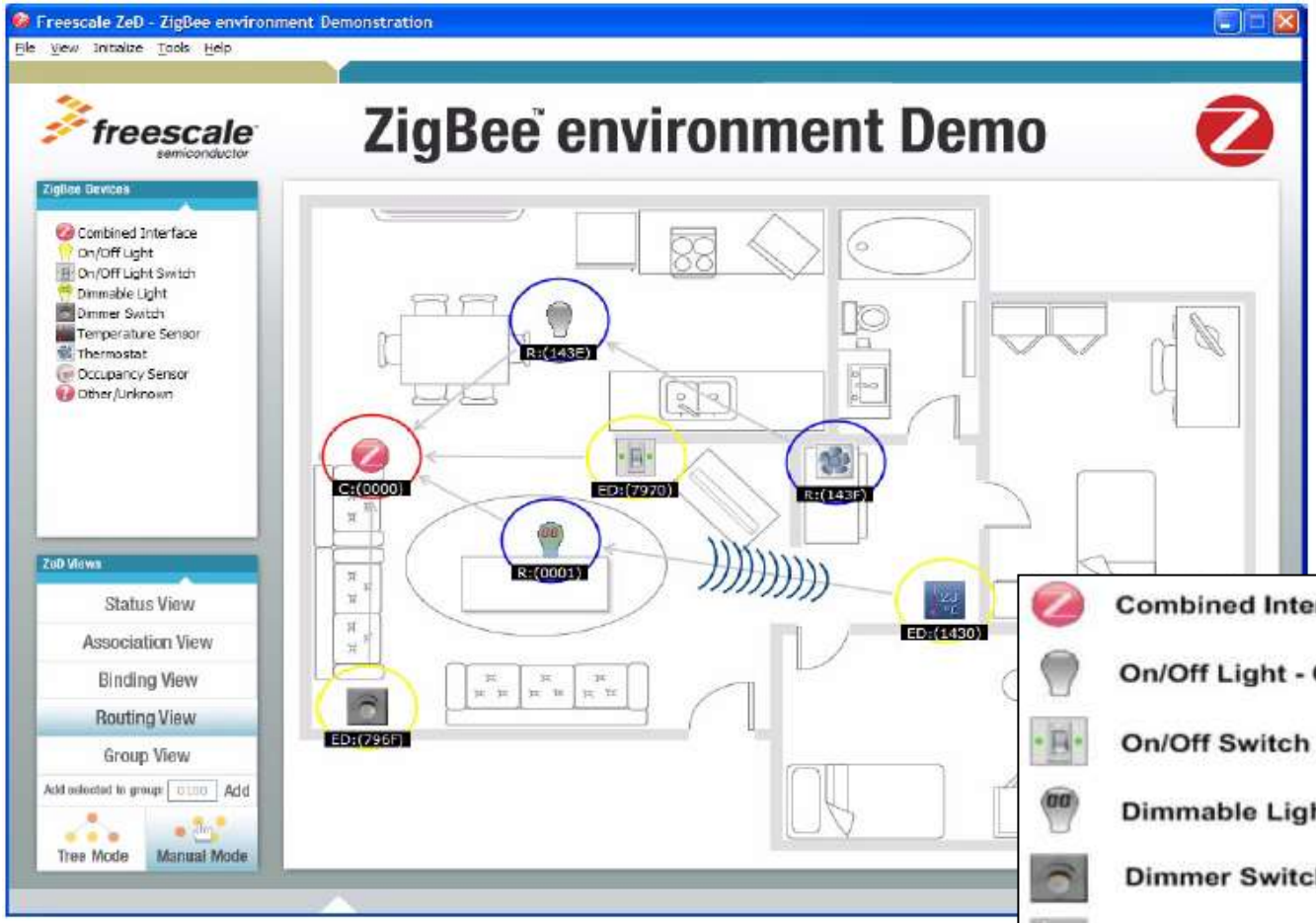
Smart Energy Demo

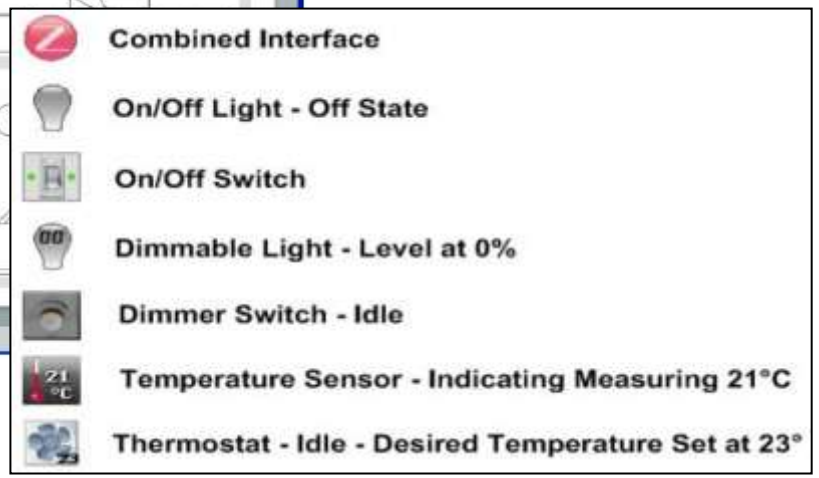


Smart Energy Demo (Cont')

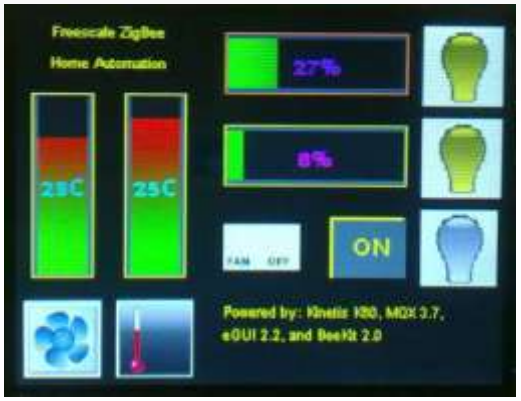


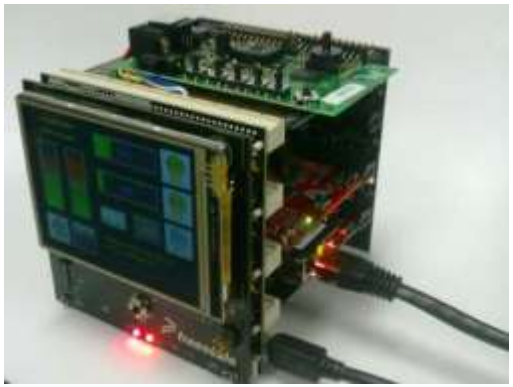
Home Automation Demo





ZigBee® Home Gateway with Kinetis K60





Optional SD Card (Web Page Storage)

WiFi

Display and Keypad (Tower LCD)

SDHC

SPI

FlexBus

To PC (for initial setup and firmware upgrade)

USB

Kinetis K60

UARTs

MC13233 ZigBee® HA

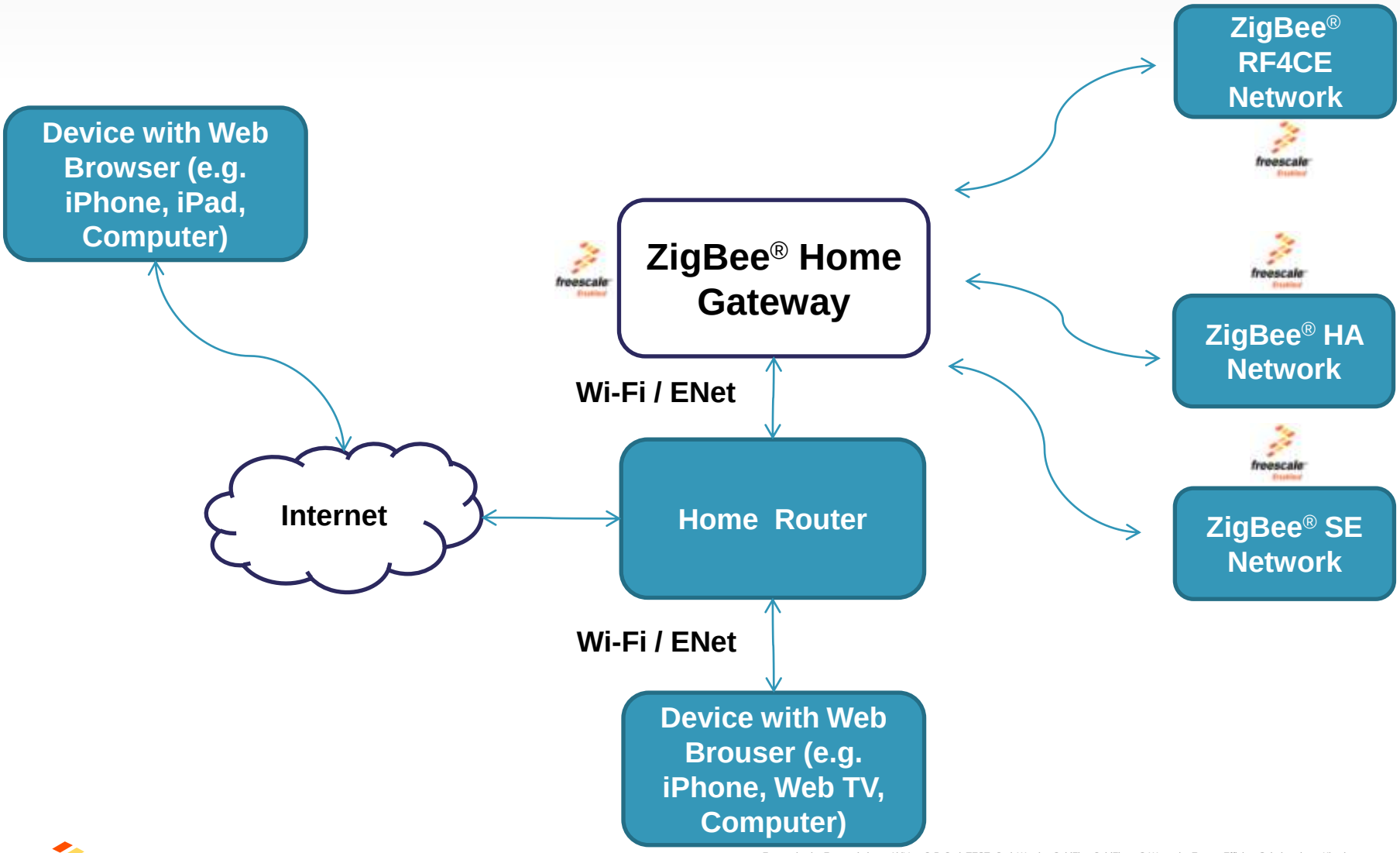
RMII

Ethernet PHY

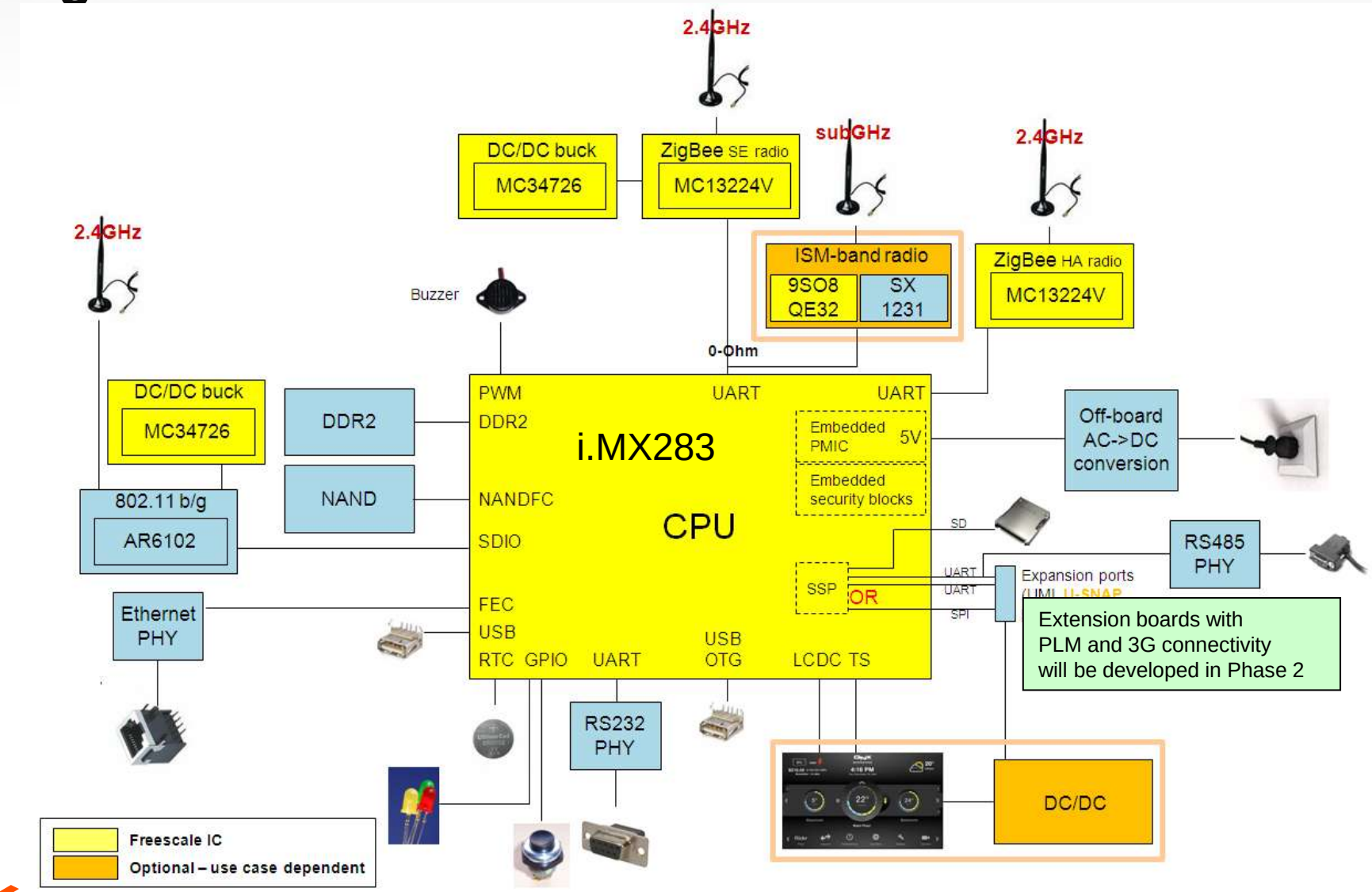
MC13226V ZigBee® SE

To Home Router

ZigBee® Home Gateway with Kinetis K60 : Usage Model



Home Energy Gateway with i.MX: Platform block diagram



Home Energy Gateway with i.MX283

IHD

Wi Fi

Smart Meter

Hardware specifications
MCU: Freescale MCF51EM256 coldfire
ZigBee SE1.0: MC13226V

ZigBee SE 1.0

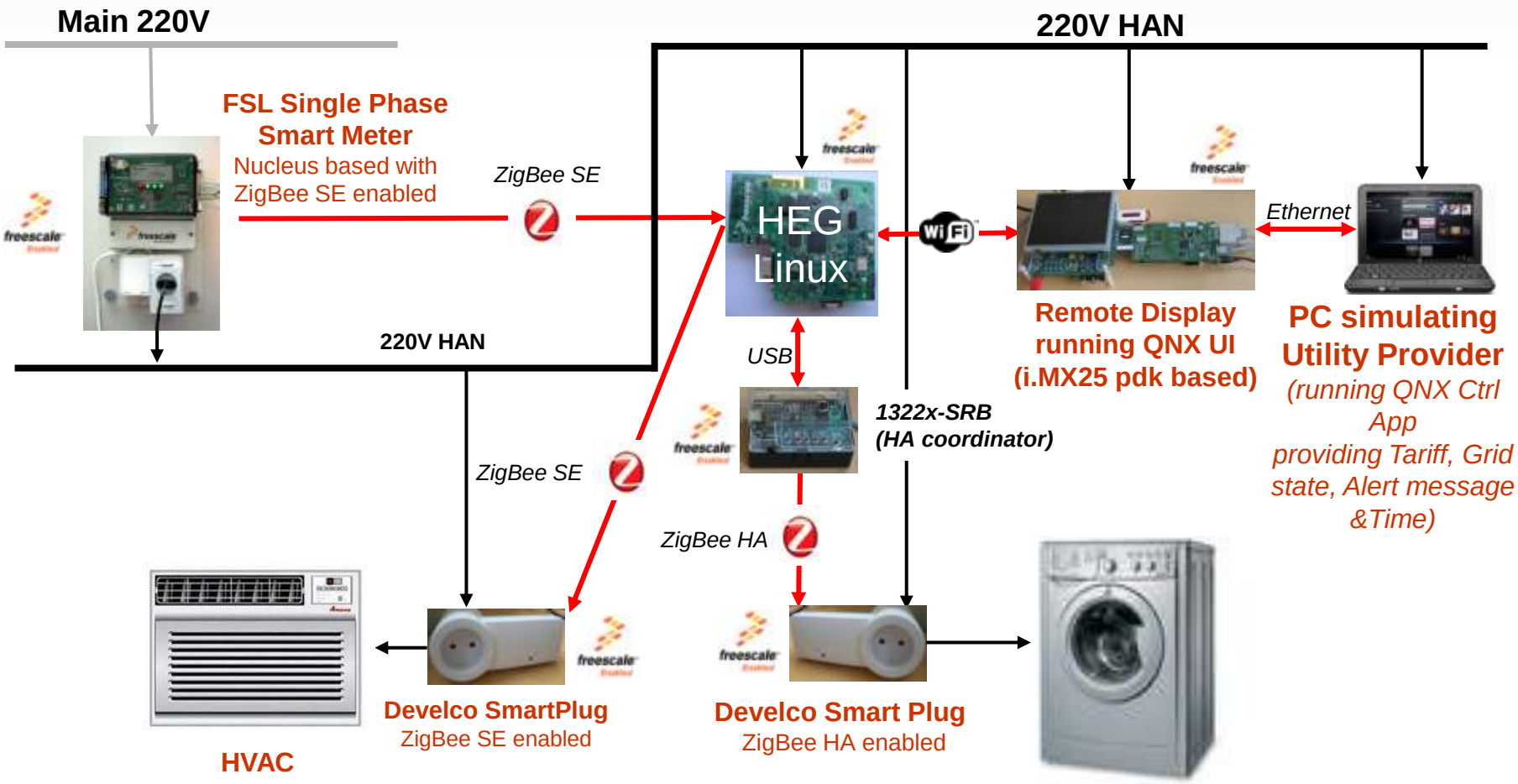
ZigBee HA

HEG

Supported Operating Systems
Linux 2.6.31
WinCE 7

Smart Appliances

Home Energy Gateway with i.MX283 : Reference Design



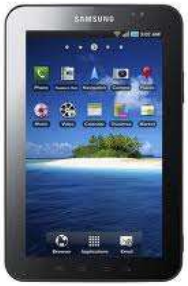
Smart Energy Network Gateway Demo with MPC830x

(Smart Energy Gateway SEG + Wireless Residential Media Gateway WMG)

Internet-enabled devices
For Remote monitoring
and Control of sensor devices
Energy – energy meters and appliances
Security – smoke/intrusion alarms, surveillance
Safety – remote health monitoring
e.g. connectivity to wearable medical monitors

ZigBee SE 1.0

ZigBee module



WiFi 802.11n

TCP/IP AP WLAN

110 / 220V

Smart Meter

Single phase MCF51EM256 DLMS Server implemented

ZigBee SE 1.0

PLC (planned)

3G

Energy Data Concentrator

MPC8308 DLMS Client

PLC / Wireless

cameras
WiFi 802.11n

Wireless Residential/Media Gateway (WMG)	Smart Energy Gateway (SEG)
MPC830x, P10xx AP WLAN with NAS and NVR, Video Surveillance HD movies, streaming mp3, mp4 etc and Bit-Torrent P2P, DLNA, uPnP, Web-server (remote monitoring & control)	HAN – Home Area Network MPC830x, P10xx DLMS Client, Web-GUI ZigBee Stack and AP WLAN, Web-server (remote monitoring & control of ZigBee WSN Wireless Sensor Network)

Smart Energy Network Gateway (SENG = SEG + WMG)

Smart Home (Smart, Secure, Safe)

NAN - Utility Link

830x, P10/20xx

- Utility collects usage from neighborhood meters
- Utility deliver real-time tariff rate

Freescale Home Energy Management Overview

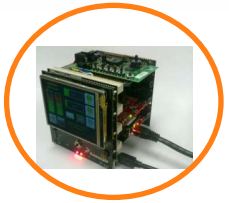
MPC8308 NSG
Networked Smart Gateway

Home Media Controller
HAN-enabled Wi-Fi Router
Security Console Controller

i.MX28 HEM
Home Energy Manager

Connected Thermostat
Security Panel
Stand Alone HEM

K60 Home Gateway



Home automation and Monitor
Stand Alone HEM

		NSG	HEM	HG
Home Area Networks:	ZigBee HA	X	X	X
	ZigBee SE	X	X	X
Connectivity & Control:	Integrated Display Capability		X	X
	Wi-Fi Connectivity	X	X	X
	Mobile Control	X	X	X
Value Added Services:	Router	X		
	Video Surveillance	X		
	DLNA Media Serving	X		
	VOIP	X		

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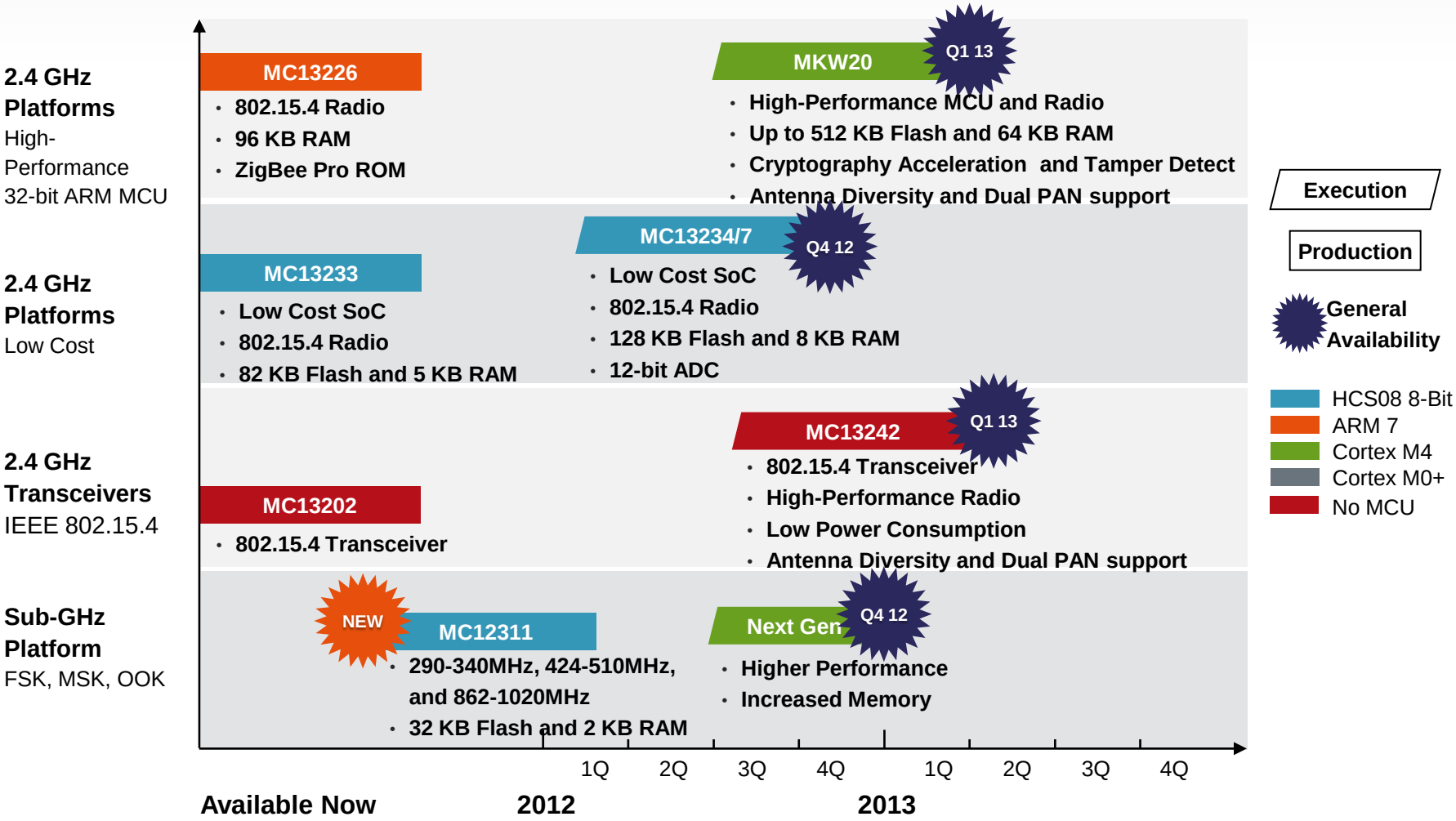
Freescale Hardware

Freescale Smart Energy Differentiation

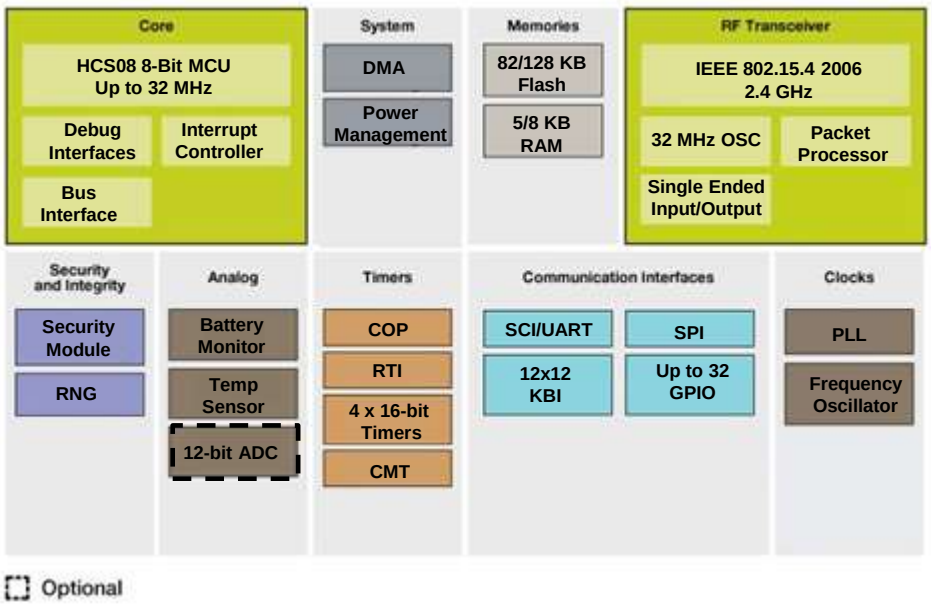
- **Variety of solutions to meet specific application needs**
  - Complete lineup of IC offerings
    - Kinetis Cortex M4 family
    - RF solutions
  - Robust software offering
    - Variety of protocol stacks
    - BeeKit™ Toolkit simplifies network development
  - Reference Designs and documentation
    - Provide extensive documentation and reference design
    - Hardware, software and application specific reference designs
  - Premiere Development Tools
    - Comprehensive and flexible development kit offerings

Freescale Wireless Roadmap



MC1323x System-on-Chip

- **Low cost 802.15.4 2006 solution**
  - Designed for low cost Consumer, Medical and Industrial applications
    - ZigBee PRO, ZigBee RF4CE, SynkroRF
- **Optimized for low cost applications**
  - Integrated 32-MHz HCS08 8-bit MCU
  - Up to 128 KB Flash and 8 KB RAM
  - RX sensitivity of -94 dBm
  - 34 mA Rx, 27 mA Tx, 23 mA PPD Rx
  - 12-bit ADC (237 only)
- **Low power**
  - <5mA at 32 MHz
  - 4 Low power modes (lowest <600 nA)
  - 1.8V to 3.6V for extended operating time on batteries

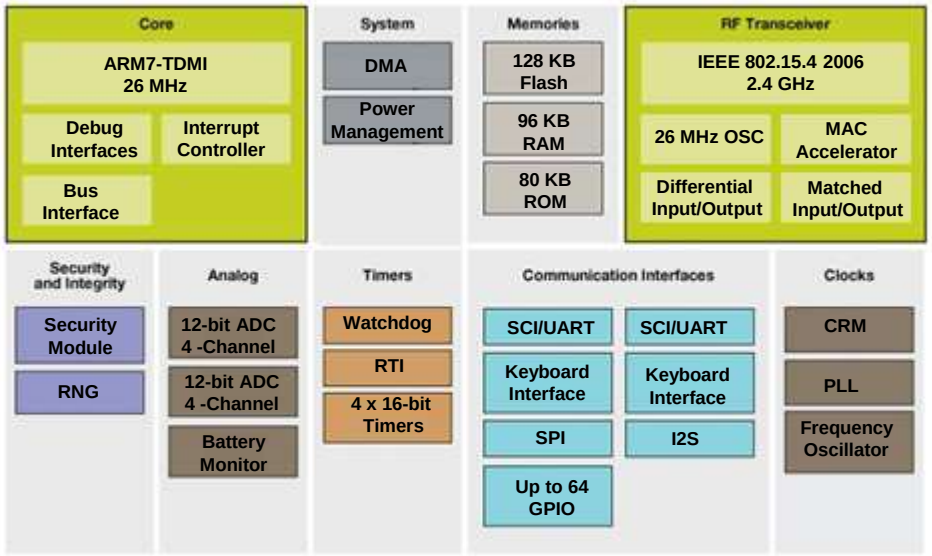


Device	Flash	RAM	Package
MC13233C	82 KB	5 KB	7x7 48-pin LGA
MC13234CHT	128 KB	8 KB	7x7 48-pin LGA
MC13237CHT	128KB	8KB	7x7 48-pin LGA

Features	Description
Software and Protocol Stacks	SMAC, 802.15.4 2006, SynkroRF, ZigBee (RF4CE, Pro)
2012 1K SRP	$2.69 (MC13233C)
Operating Temp	-40 to + 85

MC1322x Platform in a Package (PiP)

- **Integrated 2.4 GHz transceiver with 32-bit CPU**
  - 802.15.4 compliant transceiver
  - ARM7TDMI up to 26Mhz
- **Low power**
  - 1.8 to 3.6 operating voltage
  - 22 mA Rx & 29 mA Tx with radio and MCU
- **Improved RF performance**
  - -96 dBm sensitivity (DCD mode)
  - -100 dBm (NCD mode, +3-4 mA current)
  - +4 dBm power output
- **Hardware accelerator reduces MCU overhead**
  - MAC accelerator
  - AES 128-bit hardware encryption/decryption
- **Unique platform-in-package significantly reduces component count and system cost**
  - RF matching in package
  - Requires power, crystal and 50 Ohm antenna



Device	Flash	RAM	ROM	Package
MC13224V	128 KB	96 KB	80 KB	9.5x9.5 99-pin LGA
MC13226V	128 KB	96 KB	80 KB	9.5x9.5 99-pin LGA

Features	Description
Software and Protocol Stacks	SMAC, 802.15.4 2006, SynkroRF, ZigBee (RF4CE, Pro, IP*)
2012 1K SRP	$4.74
Operating Temp	-40 to + 105

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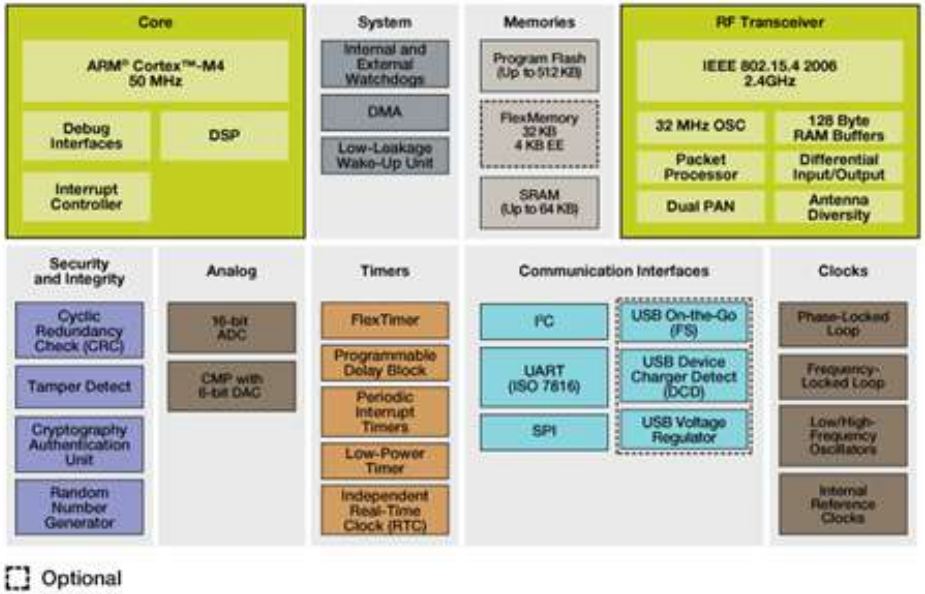
Kinetis MKW20 Wireless MCU

- **High-Performance RF and MCU**
  - 50 MHz Cortex M4 with up to 512 KB Flash
  - Best in class link budget
    - -102 sensitivity with +10dBM output power
  - Improved reliability with antenna Diversity
    - Automatic selection of antenna
- Low Power
  - Low RF power consumption
    - 15mA TX and RX
    - Low power receive mode
  - Multiple low power modes
    - Support Kinetis low power modes
- **Secure**
  - Increased security with tamper detect and hardware crypto engine
- **Flexible**
  - Dual Pan
    - Supports 2 networks simultaneously
  - Common software and tools with MC13242 + Kinetis
  - Industrial operating temp

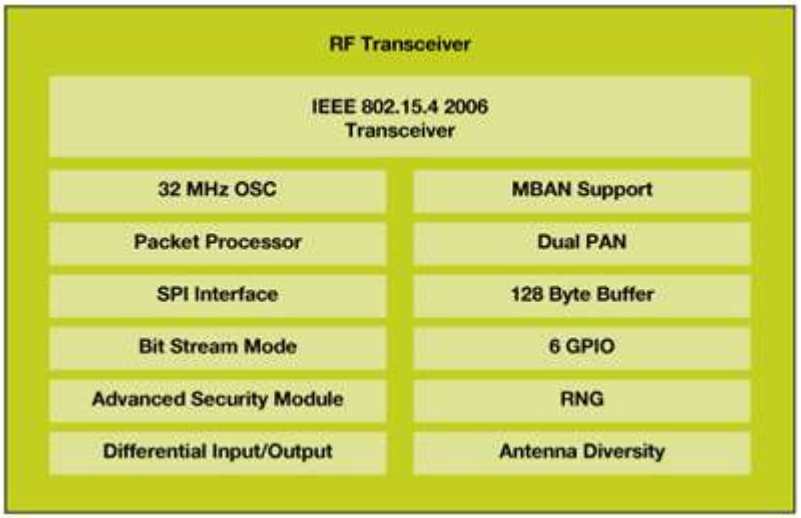


Device	Flash	RAM	Package
MKW21D256VHW5	256 KB	32 KB	8x8 56-pin LGA
MKW21D512VHW5	512 KB	64 KB	8x8 56-pin LGA
MKW22D512VHW5	512 KB	64 KB	8x8 56-pin LGA

Features	Description
Software and Protocol Stacks	SMAC, 802.15.4 2006, SynkroRF, ZigBee (RF4CE, Pro, IP)
2013 1K SRP	$4.49 (MKW21D256VHW5)
Availability	Samples - January 2013 Production – March 2013

MC13242 High-Performance 802.15.4 Transceiver

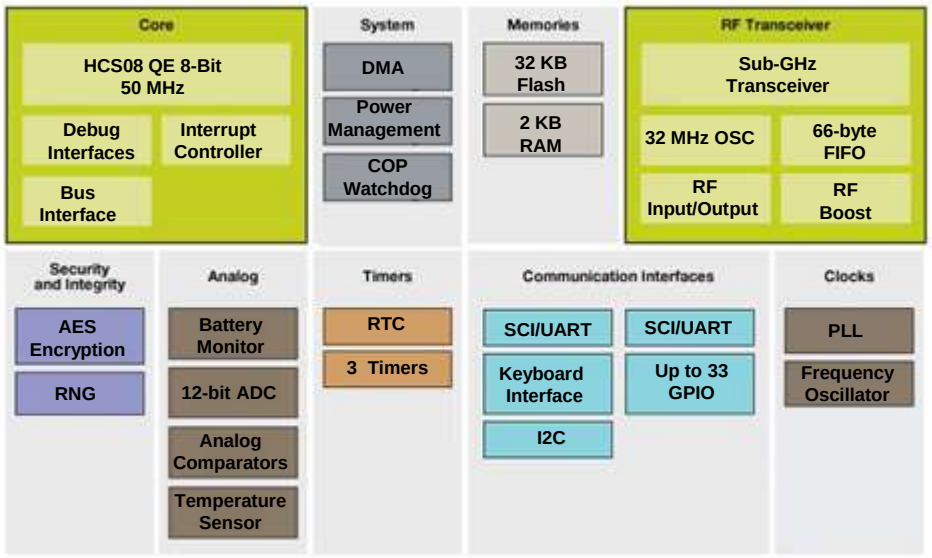
- **High performance 2.4 GHz IEEE 802.15.4 RF transceiver**
  - Packet processor for hardware acceleration
  - Supports single ended and diversity antenna options
  - Dual PAN support
    - Can participate in 2 ZigBee networks simultaneously
  - Best in class link budge
    - -102 dBm sensitivity
    - +10 output power
  - Low power consumption
    - TX 15mA @ 0dBm (CPU sleep)
    - RX 15mA (CPU sleep)
- **Advanced Security features**
  - AES encryption engine and random number generator
- **Compatible with K20W and Kinetis MCUs**
  - Software protocol stacks, tools and IDE are compatible with the Kinetis KW20 Wireless MCU



Device	Flash	RAM	Package
MC13242MHM	N/A	N/A	5x5 32-pin LGA
Features	**Description**		
Software and Protocol Stacks	SMAC, 802.15.4 2006, SynkroRF, ZigBee (RF4CE, Pro, IP)		
2013 1K SRP	$1.59		
Operating Temperature	-40 to +125		
Availability	Samples - January 2013 Production – March 2013		

MC12311 Smart Radio Overview

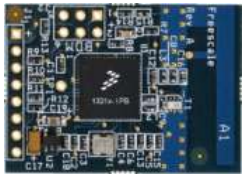
- **Sub-GHz radio with exceptional RF performance**
  - Link up to +137dB
  - Up to -120dBm sensitivity @ 1.2kbps, -105 dBm @38.4 Kbps
  - -18 to + 17dBm output in step of 1 dBm
- **Bullet-proof front end**
  - IIP3 = -18 dBm, IIP2 = +35 dBm, 80 dB Blocking Immunity
- **Very low power suitable for battery operated devices**
  - 1.8V to 3.6V
    - 6 mA Rx current
    - 20 mA Tx current at 0 dBm
    - 33 mA Tx current at +10 dBm
- **Flexibility and compliance with multiple standards**
  - Support of multiple modulation schemes (GFSK, MSK, GMSK, and OOK)
  - Supports 290-340MHz, 424-510MHz, and 862-1020MHz frequency bands



Device	Flash	RAM	Package
MC12311CHN	32 KB	2 KB	8x8 56-pin LGA
Features		**Description**	
Software and Protocol Stacks		GUI for RF evaluation SMAC, 802.15.4, Wireless M-Bus	
2012 1K SRP		$2.79	
Operating Temp		-40 to + 85	

Freescale 802.15.4 Reference Designs

- Development Board Reference Design
  - Based on development boards and include I/O, headers and additional functionality
  - FCC and CE certified
  - Provide
    - Schematic in OrCAD
    - Layout in Gerber
    - BOM
    - Direct support in BeeKit
- Form Factor Reference Designs
  - Form factor design with minimal I/O and headers
  - Focus is on RF design
    - Single Port Design
    - Chip or F Antenna
  - Basic Interfaces
    - UART, I2C
  - Provide
    - Reference Manual
    - Schematic in OrCAD
    - Layout in Gerber and Allegro
    - BOM
    - BeeKit Platform Editor Configuration File



- Dev Board Reference Design
  - 1319xEVB
  - 1320x-QE128DSK
  - 1320xRFC
  - 1321xNCB
  - 1321xSRB
  - 1322xLPB
  - 1322xNCB
  - 1322xSRB
  - 1322xUSB
- Form Factor Reference Design
  - 1320xQE128-IPB
  - 1321x-ICB
  - 1321x-IPB
  - 1321x-UCB
  - 1322x-IPB/ICB
  - 1322x-ERB

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IEEE 802.15.4/ZigBee® Modules

Extended Range Module

Freescale Reference Designs

Modules from Partners

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Summary

- **Smart Grid is more than just the meter**
- **Highly fragmented market and technology**
  - One technology will not win
- **NAN**
  - 802.15.4g is gaining traction in many markets for RF
- **HAN**
  - ZigBee SE has the early lead
  - SE 2.0 provides multiple PHY options
- **Flexible architecture is required**
  - Helps future proof the solution
- **Freescale provides communications solutions for the NAN and HAN**
  - Multiple offerings
  - Leverages Kinetis MCU family
  - Common software and tools across many platforms

Freescale on Kaixin
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Weibo?
Please use hashtag **#FTF2012#**

Session materials will be posted @ www.freescale.com/FTF

Learn More

- **Freescale Solutions**
  - Freescale Home Energy Management (Gateway) reference designs
    - http://www.freescale.com/webapp/sps/site/application.jsp?code=APLSEG
  - Freescale ZigBee Solutions
    - http://www.freescale.com/zigbee
  - Freescale Protocol Stacks
    - http://www.freescale.com/beekit


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