Wireless and Connected Home of the Future

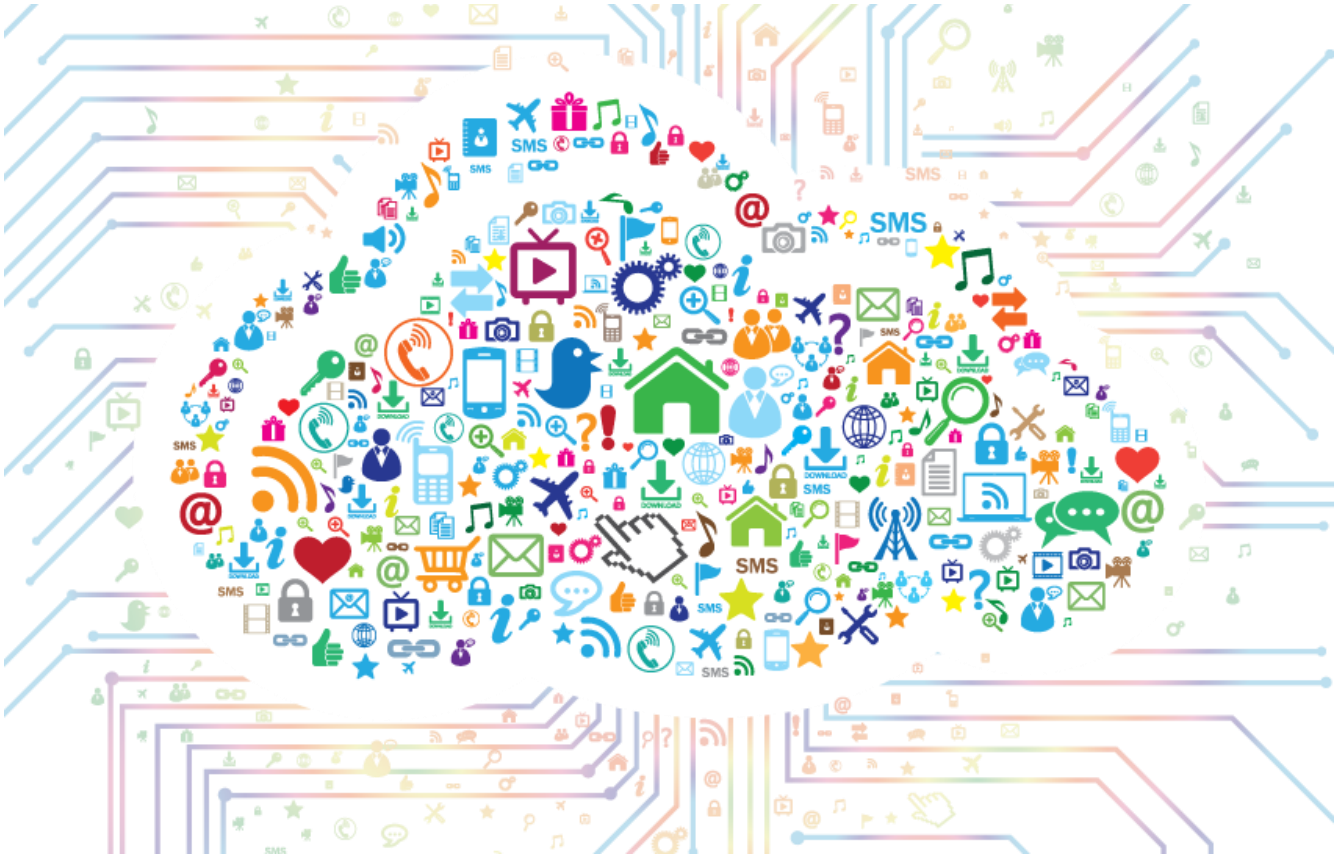
EUF-IND-T1462

Antonio Concio | FAE Wireless Connectivity EMEA

M A Y . 2 0 1 5

External Use

The Internet of Things



M2M. Connectivity. Context.

FREESCALE CONNECTED INTELLIGENCE:

BRINGING THE INTERNET OF THINGS TO LIFE

SMART HOME

While you're in rush hour traffic on the way home, your car advises your home hub to turn up the thermostat, turn on the lights, heat the oven – and make sure there's plenty of hot water for your shower.

CLOUD

Your vehicle deactivates the house alarm as you pull into the driveway

Session Introduction

This session will:

- Provide an overview on commonly used wireless technologies and standards for Home Automation
- Show how Freescale microcontroller families offer easy to use solutions for connectivity requirements and challenges
- Introduce to Freescale development environment for wireless connectivity technologies
- Thread Technology basic concepts

Agenda

- Home Automation Trends and Standards
- Freescale Development Options for Smart Home Connectivity
- Freescale Connectivity Software Positioning
- Thread Technology basic concepts

Home Automation
Trends and Standards

Home Automation as IoT Forefront

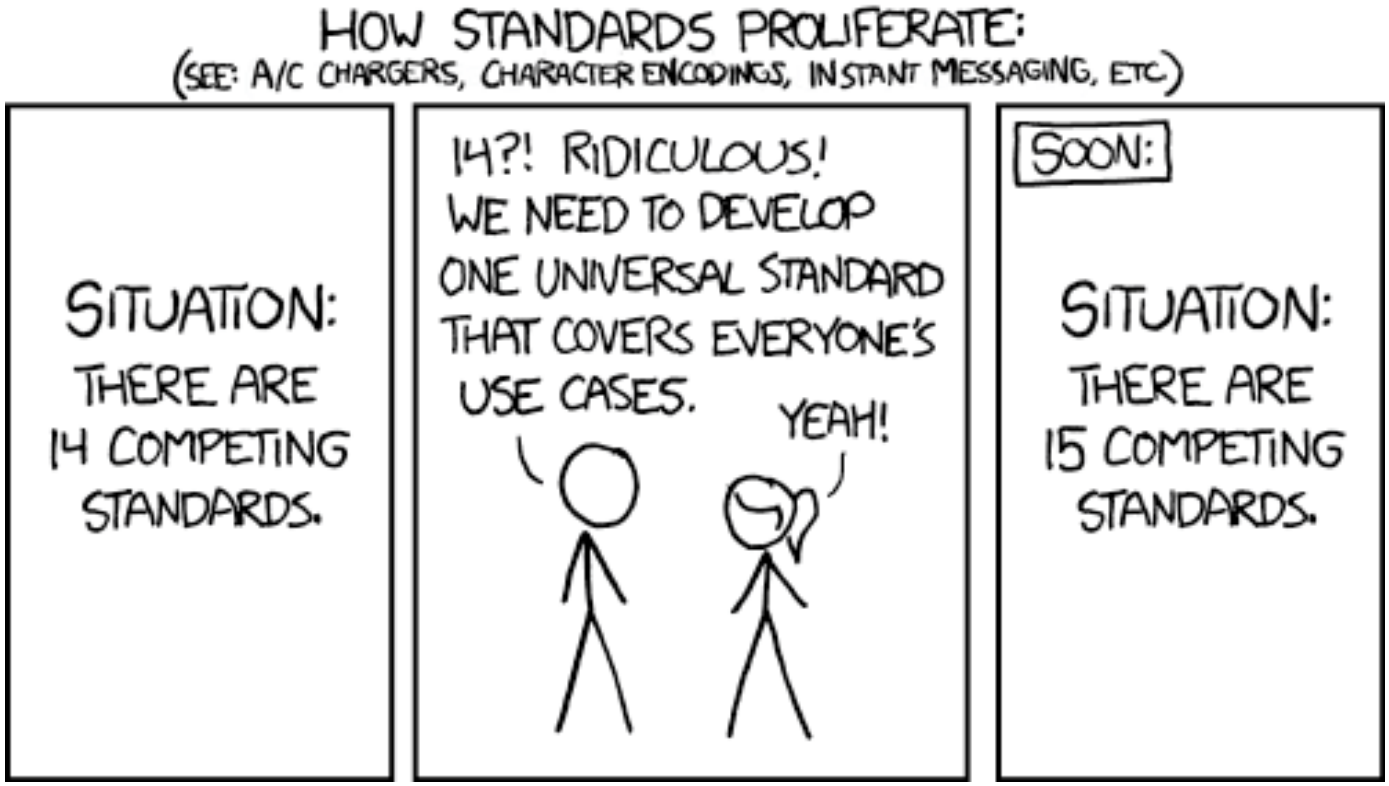
The business of home automation is enabling the internet of things.

gigaom.com, Dec 2013

The Internet of Things

Connectivity Standards Used for Home Automation

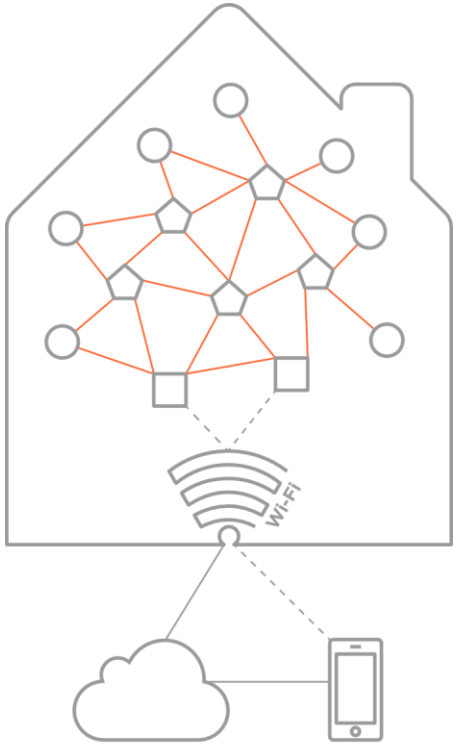
No Single Standard

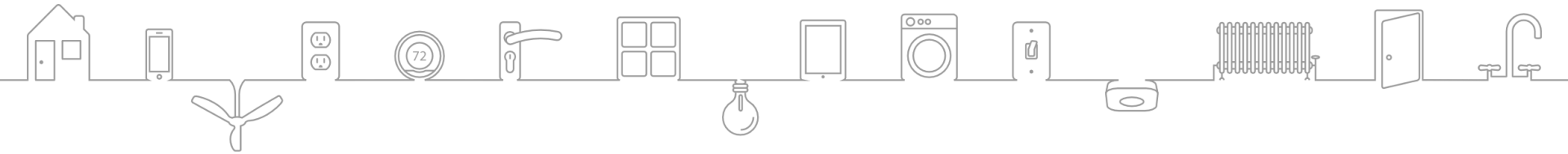


https://xkcd.com/927/

The New Standard for the Smart Connected Home

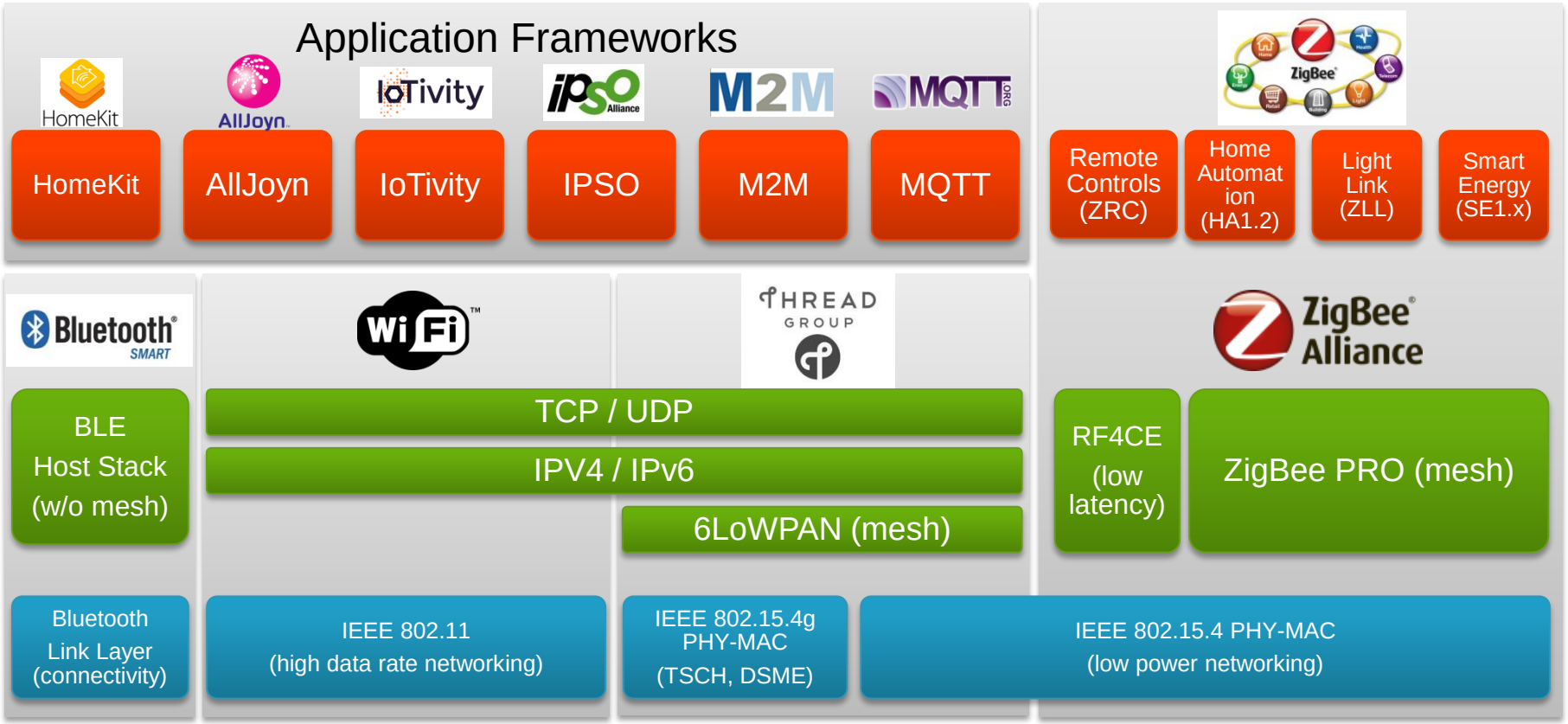
THREAD





Connectivity Software Options

Freescale Connectivity Positioning



Wearables

Content Sharing
Gateways
Border Routers

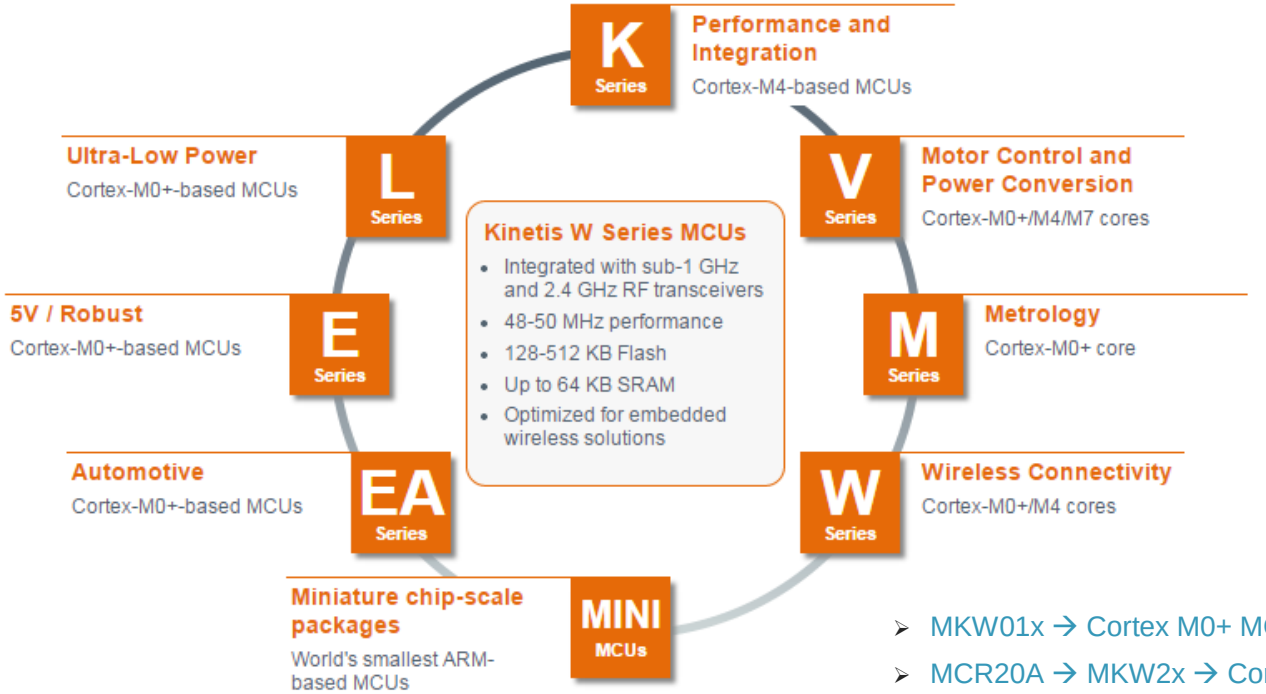
<1 GHz Industrial
Wireless

2.4 GHz Low Power Home Sense &
Control Networks

Freescale Development Options for Smart Home Connectivity

What is KW Series?

Extension of Kinetis line to include wireless connectivity technologies

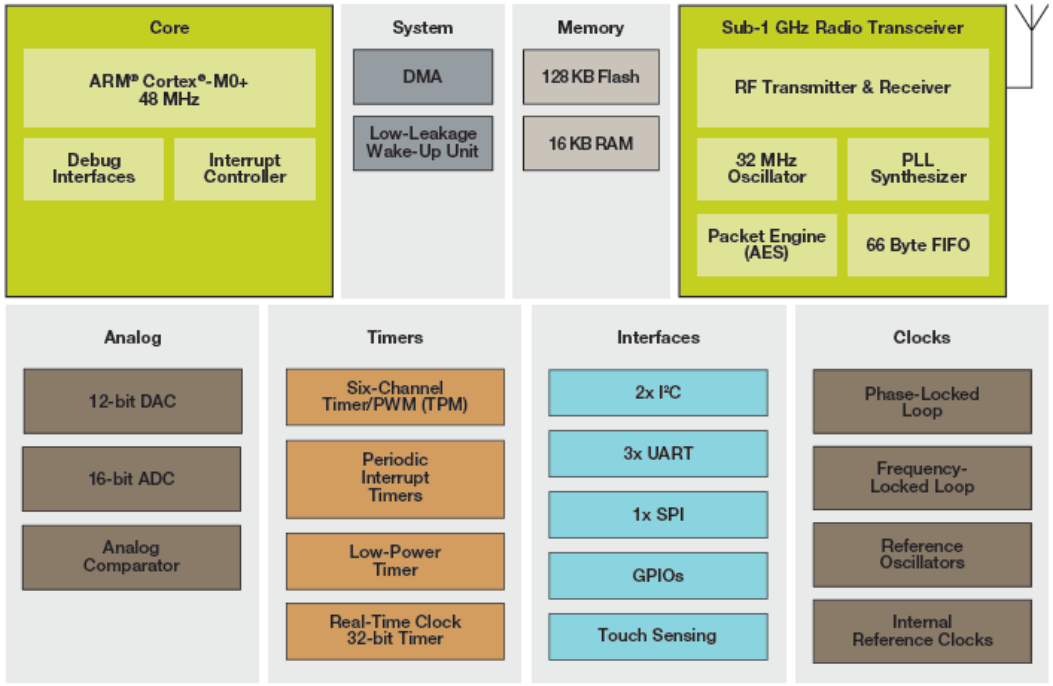


- MKW01x → Cortex M0+ MCU + Flexible Sub-1GHz radio.
- MCR20A → MKW2x → Cortex M4 MCU + IEEE-802.15.4 2.4GHz radio

More information available in the following link: http://www.freescale.com/wireless

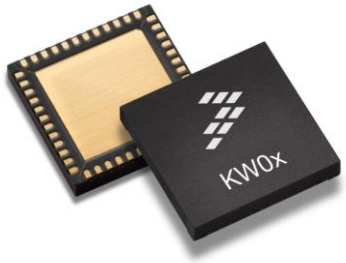
Sub 1-GHz Smart Radio Solutions from Freescale

Kinetis KW01 Wireless MCU (Sub 1-GHz)



Orderable Part

Part Number	Description
MKW01Z128CHN	• 290–1020 MHz smart radio • 128 KB flash/16 KB RAM • 60 MAPLGA 8 mm x 8 mm • Bulk tray



Cortex

IP

CPU

- 32-bit ARM® Cortex®-M0+ 48 MHz Core
- 128 KB Flash and 16 KB SRAM

Radio Transceiver, Sub 1-GHz

- Supports 290-340MHz, 424-510 MHz, and 862-1020 MHz frequency bands
- FSK, GFSK, MSK, GMSK and OOK modulations up to 600kbps
- Up to -120dBm RX sensitivity @ 1.2 kbps
- -18 to +17 dBm TX output power in steps of 1 dBm

Ultra Low Power for Battery Operated Devices

- Typical consumption
  - 1.25 µA standby
  - <130 µA/MHz CPU system run mode
  - 16 mA RX peak
  - 20 mA TX peak at 0 dBm, 33 mA at +10 dBm

Software

- SMAC (Simple-MAC), user modifiable for proprietary protocols
- IEEE 802.15.4g/e MACPHY, FlexIP, WM-Bus

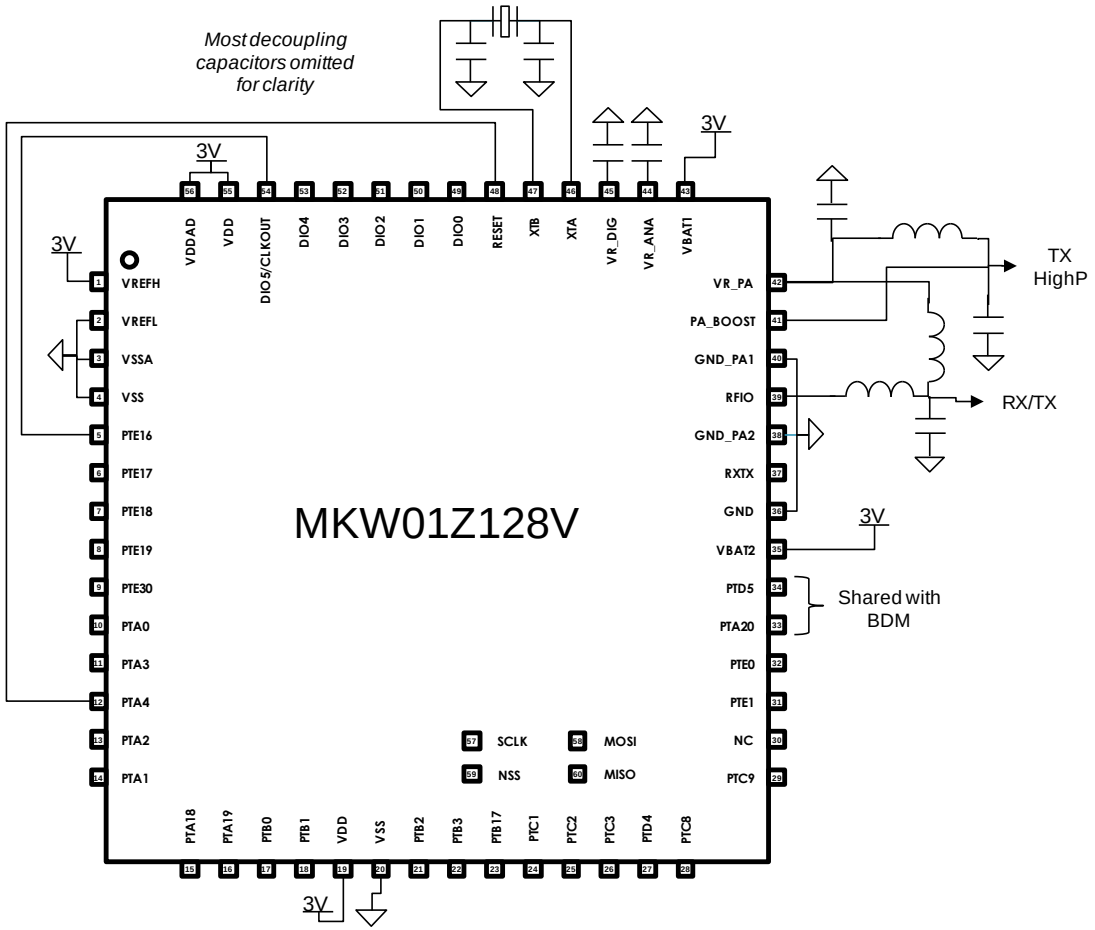
System

- 16-bit ADC, Capacitive Touch Sensing, I2C, UART, SPI, Timers
- Operating Range: 1.8 V to 3.6 V, -40C to +85C

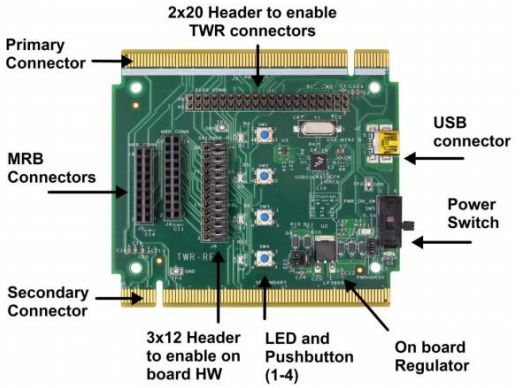
KW01 High Integration: Minimum Bill of Material

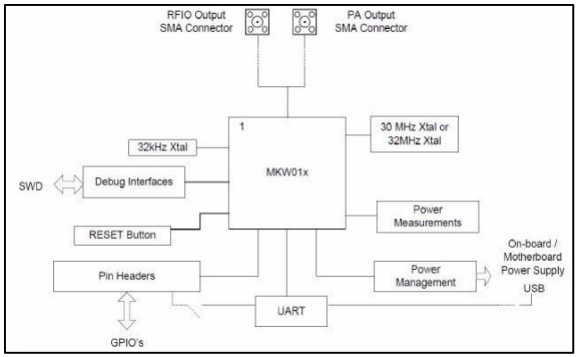
Minimum requirements (RF+MCU) :

- A **32 MHz** crystal for RF operation
- A **matching network** to filter harmonics and match antenna (PCB, power and load dependent)

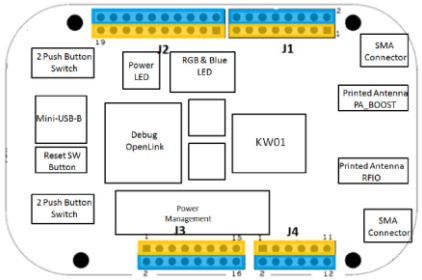


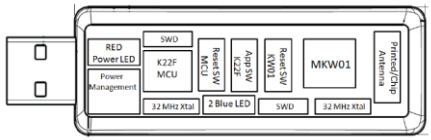
MKW01x Evaluation Boards





http://www.freescale.com/MRB-KW0x

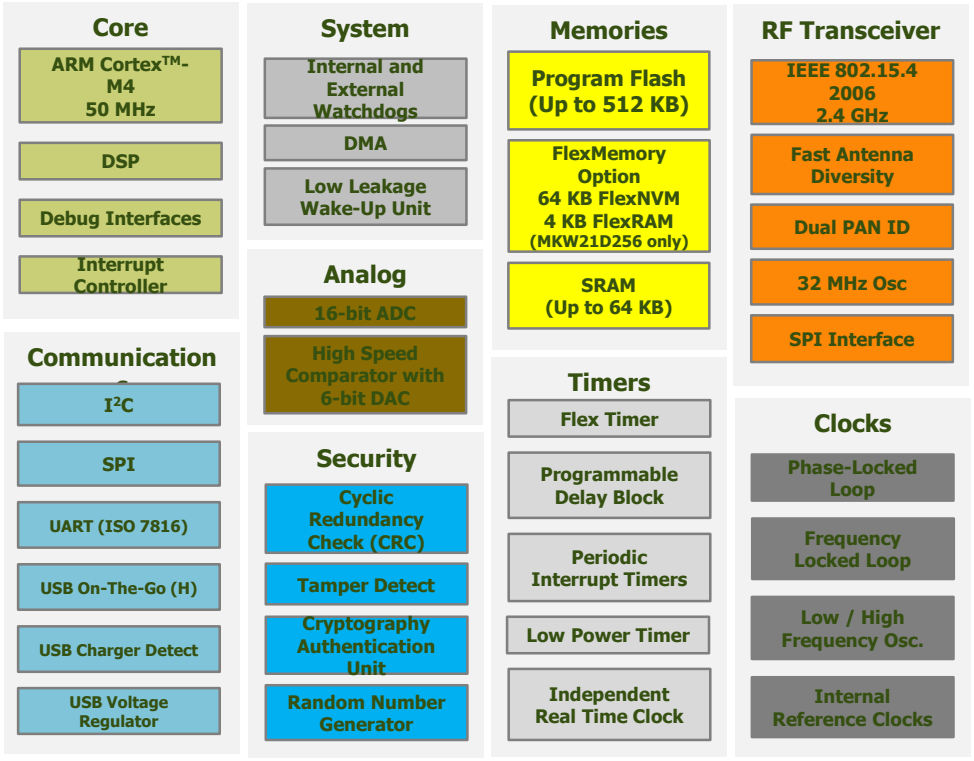




Coming soon

802.15.4 (2.4 GHz) Home Automation Solutions from Freescale

Kinetis KW2x Wireless MCU



Device	Flash	RAM	Feature	Package
MKW21D256VHA5	256 KB	32 KB	No USB	8x8 63-pin LGA
MKW21D512VHA5	512 KB	64 KB	No USB	8x8 63-pin LGA
MKW22D512VHA5	512 KB	64 KB	USB	8x8 63-pin LGA
MKW24D512VHA5	512 KB	64 KB	USB and Smart Energy 2.0	8x8 63-pin LGA

CPU

- 50 MHz Cortex-M4 CPU core
- Up to 512 KB Flash & up to 64 KB SRAM
- Optional (MKW21D256): 64 KB FlexNVM & 4 KB FlexRAM
- Typical current: 250 uA/MHz run, 1.7uA RTC standby

Radio Transceiver, 2.4GHz

- IEEE-802.15.4 compliant
- -102 dBm RX sensitivity and +8 dBm TX output power
- Peak typical current: 17mA TX and 19mA RX
- Dual Personal Area Network (PAN) support in hardware
  - Run two RF networks simultaneously
- Antenna diversity with automatic antenna selection

Security

- Active and passive tamper detection with RTC timestamp
- Crypto engine: DES, 3DES, AES 128-256, SHA-1, SHA-256, MD5, RNG

Software

- 812.15.4 2006 MAC
- Thread
- Freescale IPv6 Stack
- ZigBee PRO: ZHA, ZLL
- MQX RTOS

System

- UART, SPI, I2C, optional USB 2.0 FS/LS H/D/OTG
- 16-bit ADC
- Operating range: 1.8 V to 3.6 V, -40C to +105C

Cortex THREAD IPv6 ZigBee Control your world

freescale™

MCR20A High-Performance 802.15.4 Transceiver

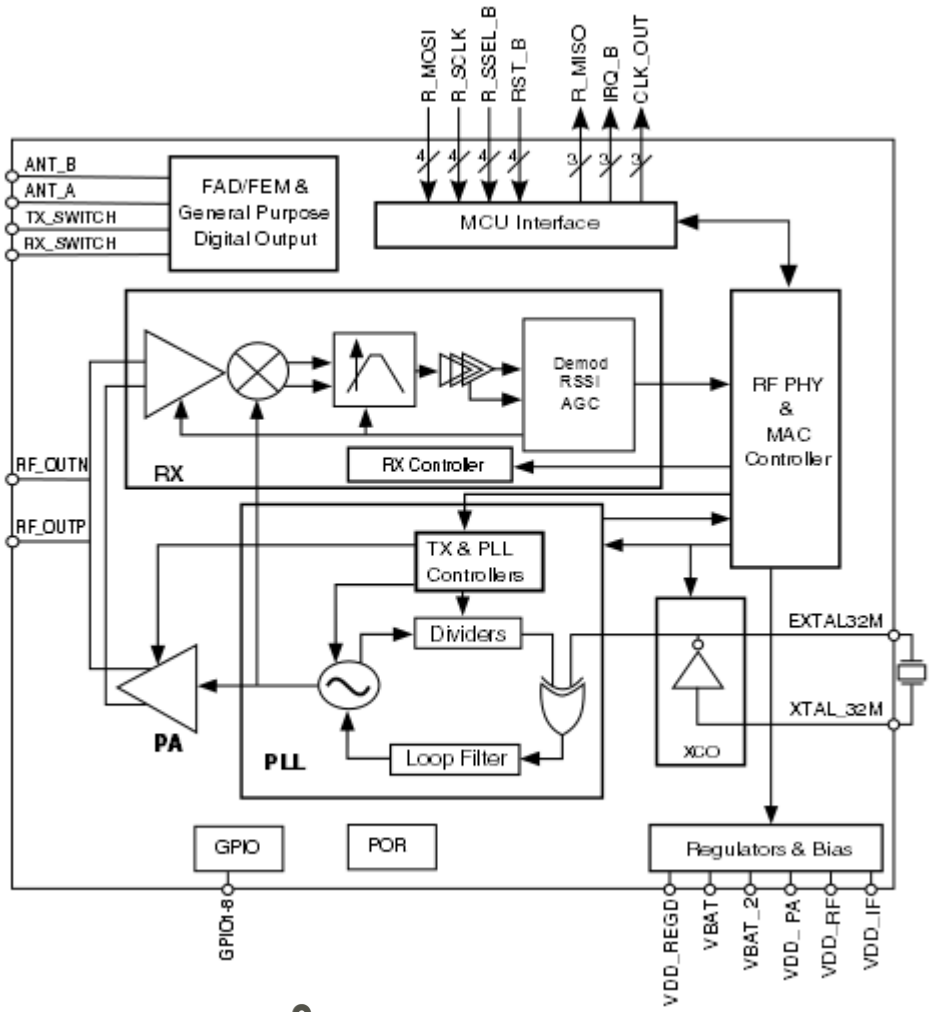
RF Features

- Same transceiver in KW2x family
- Support for MBAN frequencies (2.36-2.48GHz)
- Packet processor for hardware acceleration
- Differential RF input/output port
- Supports Fast Antenna Diversity (FAD)
- Support for external PA/LNA (FEM)
- Dual-PAN support
- -102 dBm receiver sensitivity
- -35dBm to + 8dBm prog. output power
- Rx 15nmA LPPS mode, 19.5mA full Rx
- Tx 18 mA @ 0d Bm
- AES Hardware encryption/decryption
- True Random Number Generator
- SPI Interface
- 8 GPIOs (+4 outputs via FAD manual control)

- Part Number – MCR20AVHM

System Features

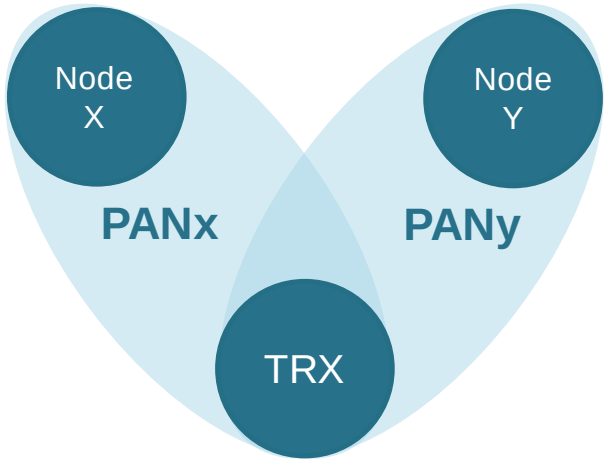
- -40 °C to 105°C
- 1.8 to 3.6 V
- 5x5 32-pin LGA



Dual-PAN

- Allows a single 802.15.4 radio to participate in 2 different PANs simultaneously with 2 different stacks as well

- Maintains 2 sets of network parameters for each PAN :
  - ChannelX
  - MacPanIDX
  - MacShortAddrsX
  - MacLongAddrsX
  - PANCORDNTRX



- The transition from one PAN to the other one can be manual (under software control) or automatic

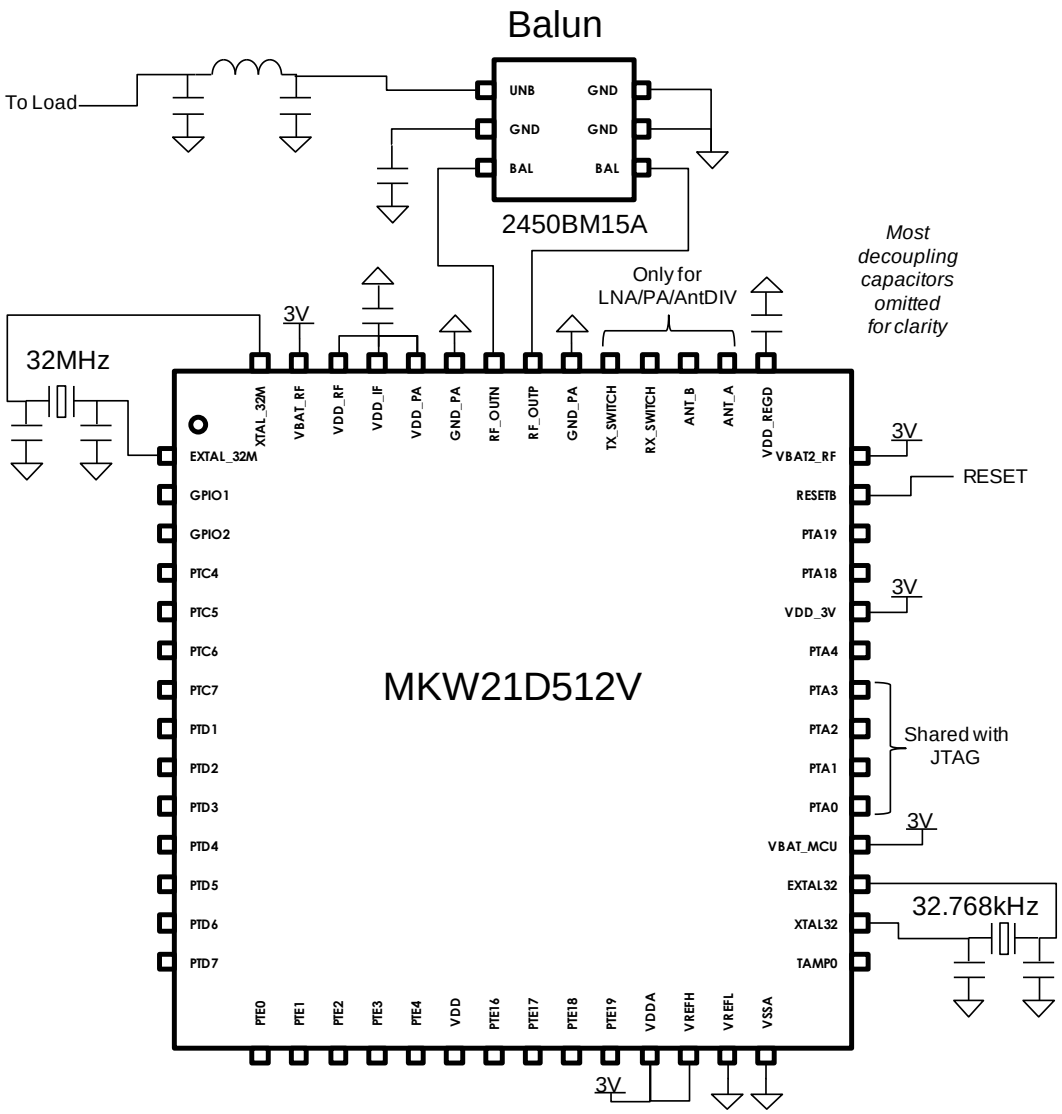
- Automatic transition is done using a programmable timer with a PAN Dwell Time from 0.5ms to 3.2s

- If both PAN are defined on the same channel, TRX is able to process both PAN simultaneously (no PAN Dwell Time to define)

KW2x High Integration: Minimum Bill of Material

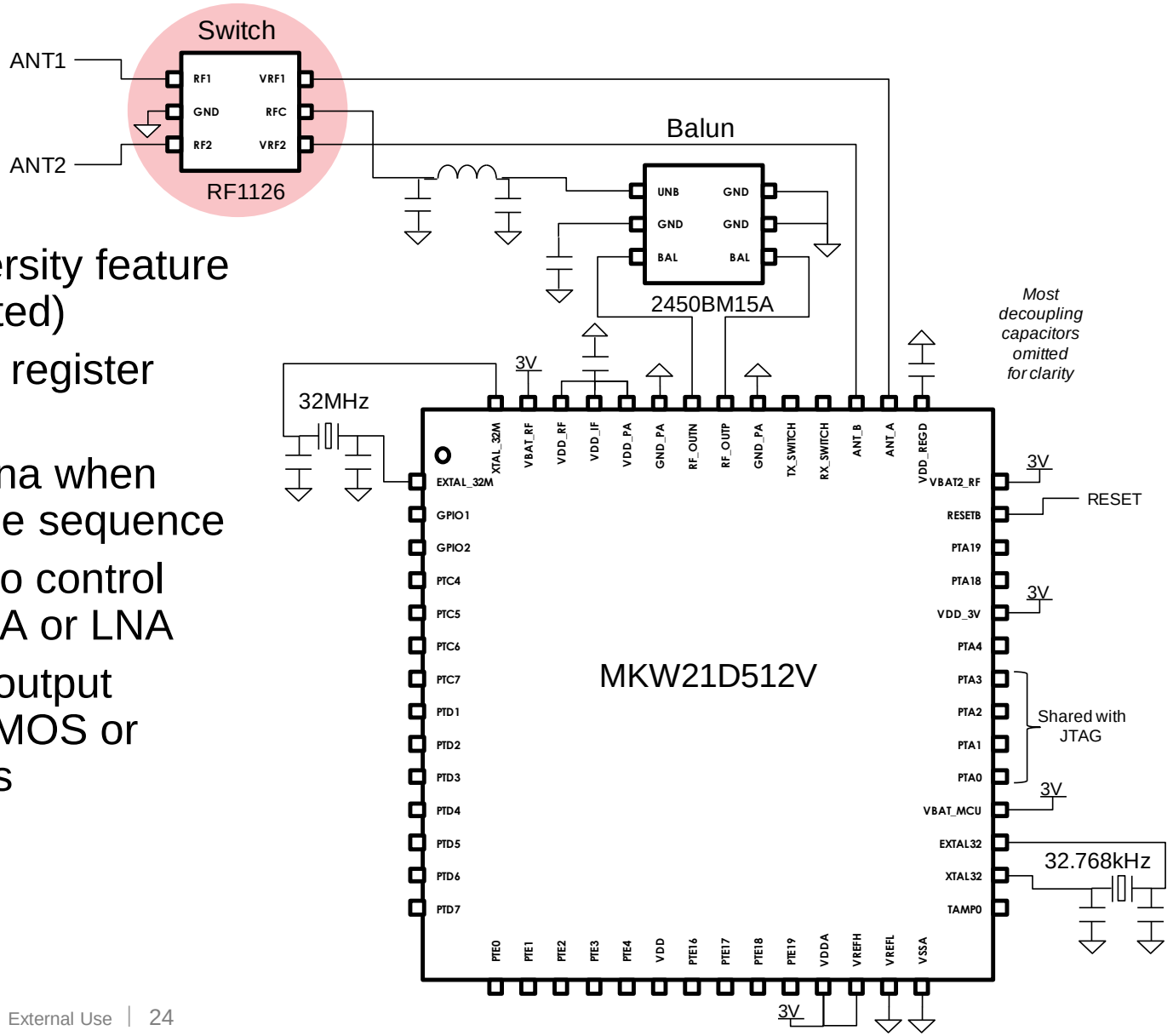
Minimum requirements (RF+MCU) :

- A **32 MHz** crystal for RF operation – the MCU is internally clocked by the transceiver (**48 MHz** core/peripheral bus)
- A **32.768 kHz** crystal for MCU low-power operation / RTC operation
- A **balun** to make balanced/unbalanced transformation
- A **matching network** to filter harmonics and match antenna (PCB, power and load dependant)

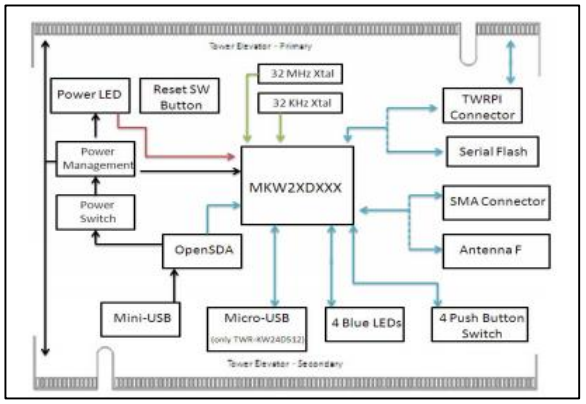


Antenna Diversity Support

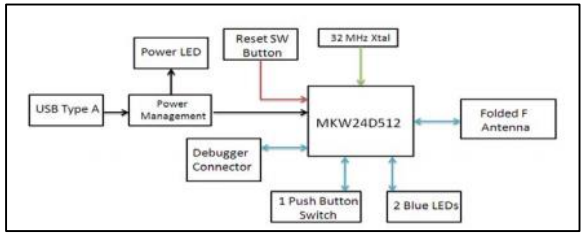
- Fast antenna diversity feature integrated (Patented)
- No MCU use, just register programming
- Select best antenna when receiving preamble sequence
- 4 dedicated pins to control external switch, PA or LNA
- Low/high current output programming for MOS or diode pin switches



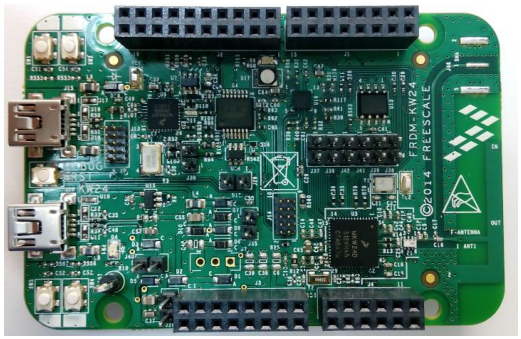
MKW2x Evaluation Boards

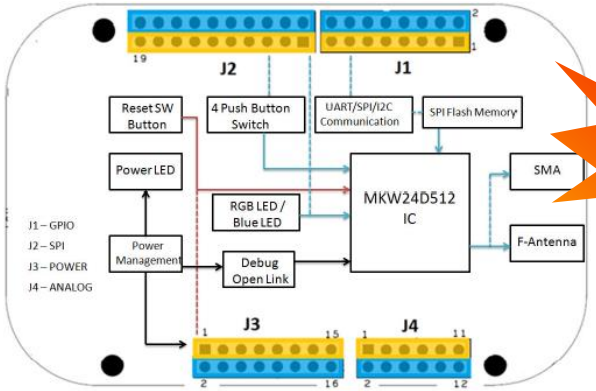


http://www.freescale.com/twr-kw2x



http://www.freescale.com/usb-kw24d512



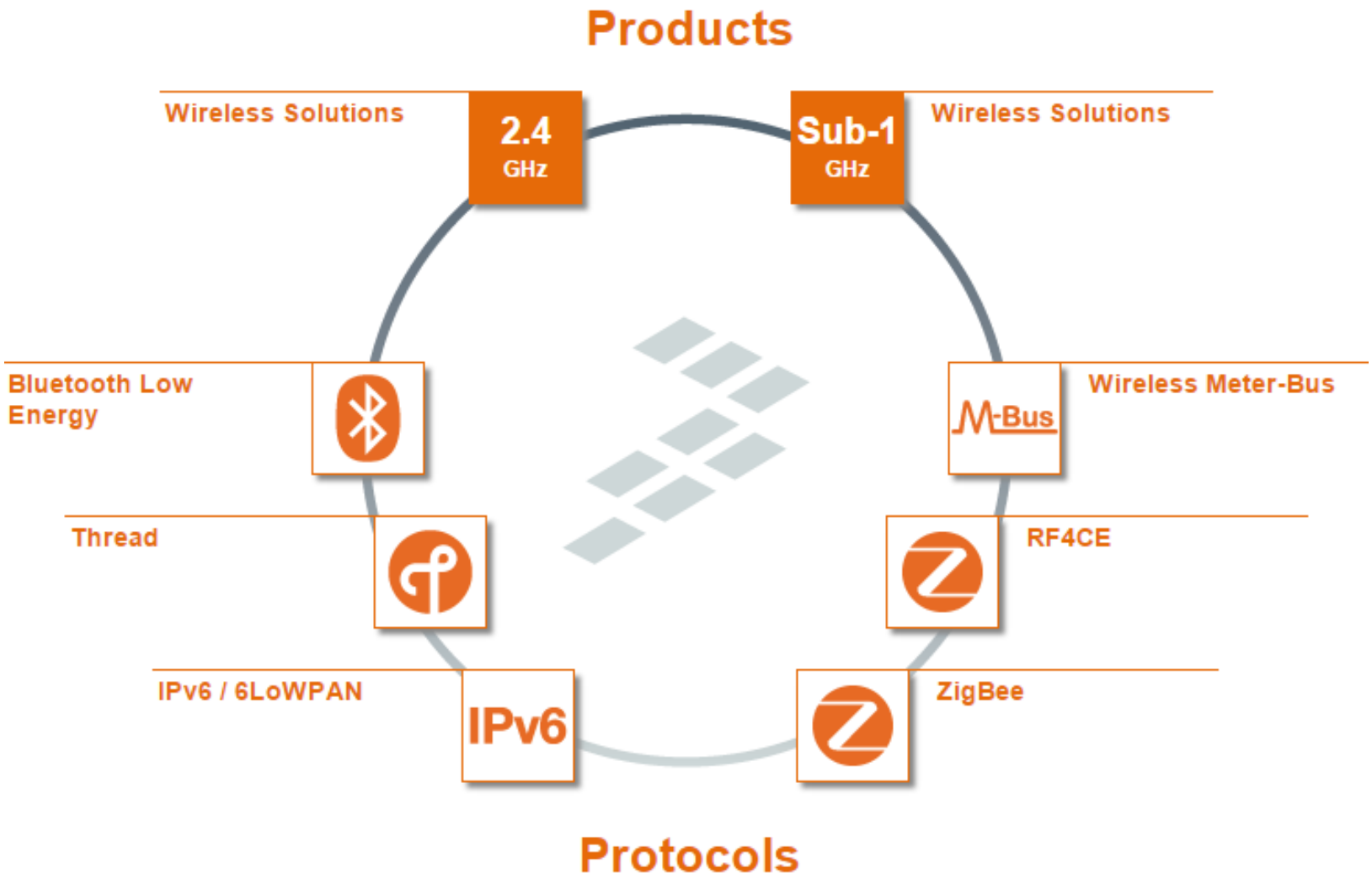


Coming soon

Software Strategy for Connectivity Stacks moving forward

- Port all the software stacks to Kinetis SDK drivers and ecosystem
- Adding support for MQX™ and FreeRTOS via Kinetis SDK OS Abstraction
- Provide initial support for IAR Embedded Workbench and later add support for Kinetis Design Studio with GCC compiler

Freescale Wireless Connectivity



Connectivity Software Offering

- **BeeKit**
  - Bare metal solution for Kinetis KW2x series
  - SMAC
  - 802.15.4 – 2006 PHY-MAC
  - ZigBeePRO Stack with
    - Home Automation 1.2
    - Smart Energy 1.1
    - Healthcare Profiles
  - Test Tool 12

Available Now

ZigBee Certified product

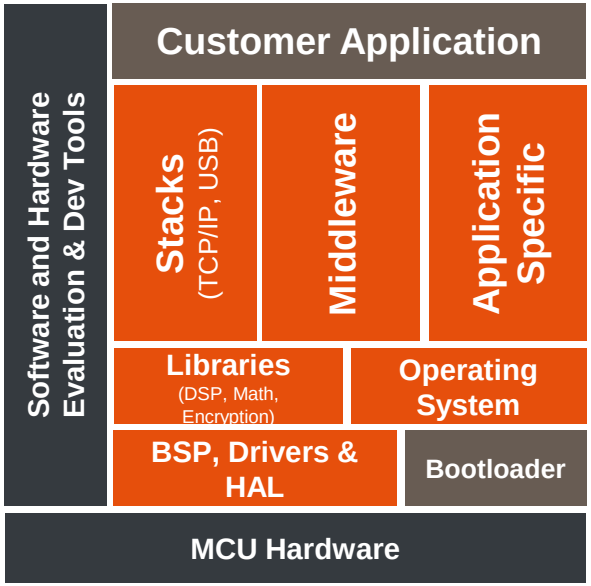
- **Kinetis SDK based stacks**
  - RTOS based solution for Kinetis KW01, KW2x, K64F+MCR20, KL46+MCR20
  - SMAC
  - 802.15.4 PHY-MAC
  - Thread Stack
  - BLE Host Stack and BLE Profiles
  - ZigBee PRO stack with HA1.2 and ZigBee Light Link profiles

Coming soon

Kinetis Software Development Kit (SDK)

A software framework for application development across all Kinetis MCUs

Hardware abstraction, peripheral drivers, stacks, RTOS's, utilities, and usage examples; delivered in C source



Open Source Initiative

CMSIS COMPLIANT ARM® Cortex™ Microcontroller Software Interface Standard

CERTIFIED USB

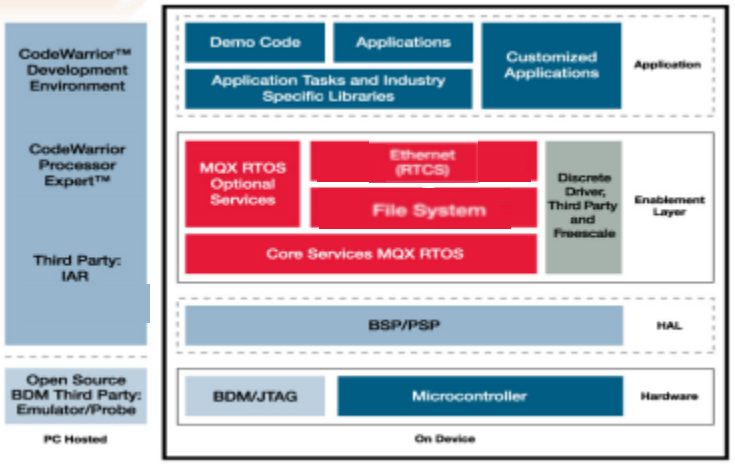
Product Features

- Open source hardware abstraction layer (HAL) provides APIs for all Kinetis hardware resources
- BSD-licensed set of peripheral drivers with easy-to-use C-language APIs
- Comprehensive HAL and driver usage examples and sample applications for RTOS and bare-metal
- GUI configurable projects and peripheral drivers using Processor Expert
- CMSIS-CORE compatible startup plus CMSIS-DSP library and examples
- RTOS Abstraction Layer (OSA) with support for Freescale MQX, FreeRTOS, Micrium uC/OS, and bare-metal
- Integrates new Freescale unified USB stack, open source TCP/IP stack (lwIP), open source FAT file system, encryption math/DSP libraries, and more and
- Support for multiple toolchains: GNU GCC, IAR, Keil, Atollic, and Kinetis Design Studio

Freescale Bundled MQX RTOS

- ***Free* Scalable, fully-featured and proven RTOS with 32-bit MCUs**
  - **Full-featured and powerful**
    - BSPs incorporate tightly integrated RTOS, Middleware (USB, TCP/IP stacks), file system, and I/O drivers
    - Designed for speed and size efficiency
  - **Market proven**
    - Available on Freescale processors for > 15 years
    - Used in millions of products including Medical and Heavy Industrial applications
  - **Simple and scalable**
    - As small as ~10KB for smallest implementation, or scale up to support sophisticated networking and threading
    - Intuitive API & modular architecture enables straight-forward fine-tuning of features
    - Production source code provided
  - **Similar to other "pay-for" software OS**

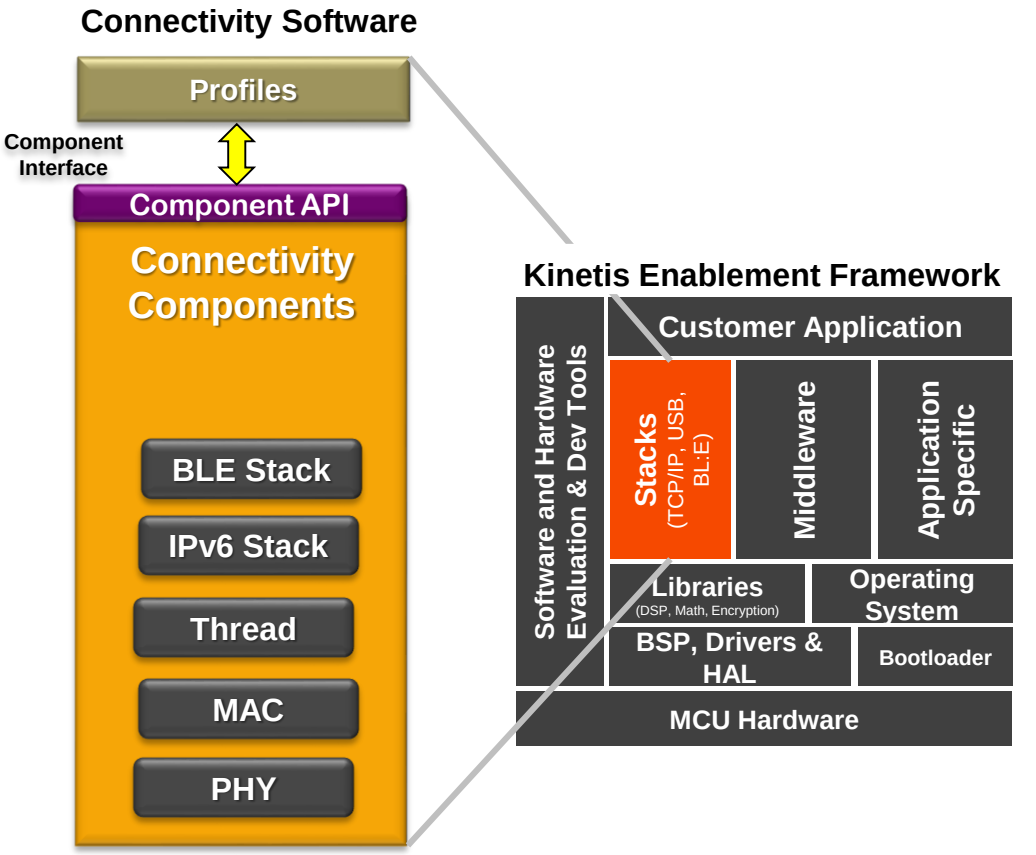
Software integration headache



✓Stable
✓Upgradable
✓Easy to maintain

Wireless Connectivity Enablement Overview

Bringing our solutions closer to the customer

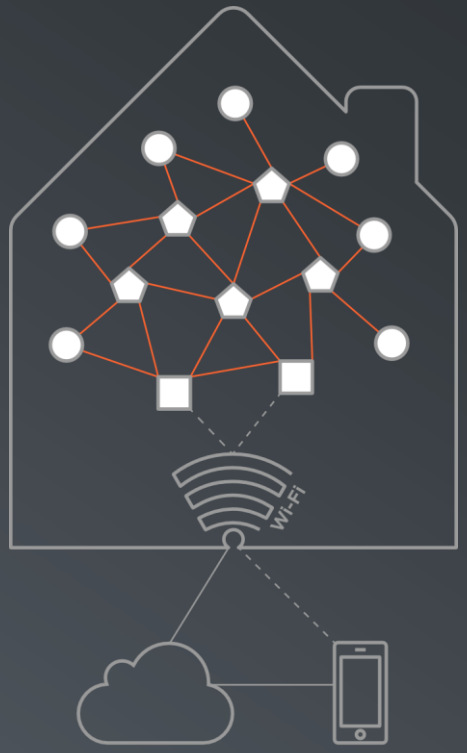


Development Hardware

- Freedom Board
  - compatible with the overall Kinetis HW
  - easy solution proof of concept.
- USB dongle
  - Small form factor,
  - end nodes demonstration,
  - sniffer for easy of debugging)

Completely Seamless Solution delivered by Freescale

Freescale's Thread Implementation



THREAD GROUP

7 companies founded the Thread Group

Not another standards body

A market education group offering product certification

Promoting Thread's use in connected products for the home

Thread will offer rigorous product certification to ensure security and interoperability

Board of Directors

President: Chris Boross - Nest Labs

VP of Marketing: Sujata Neidig - Freescale

VP of Technology: Skip Ashton - Silicon Labs

Secretary: Bill Curtis - ARM

Treasurer: Kevin Kraus - Yale Security

Director: Landon Borders - Big Ass Fans

Director: Benny Getz - Samsung Electronics

THREAD GROUP Organization Status

100+

Member companies

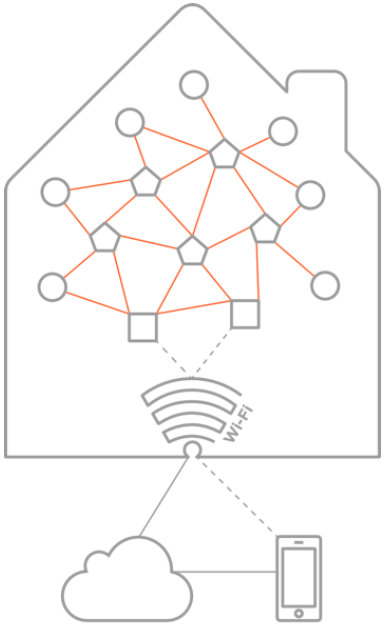
800+

membership interest signups in 90 days

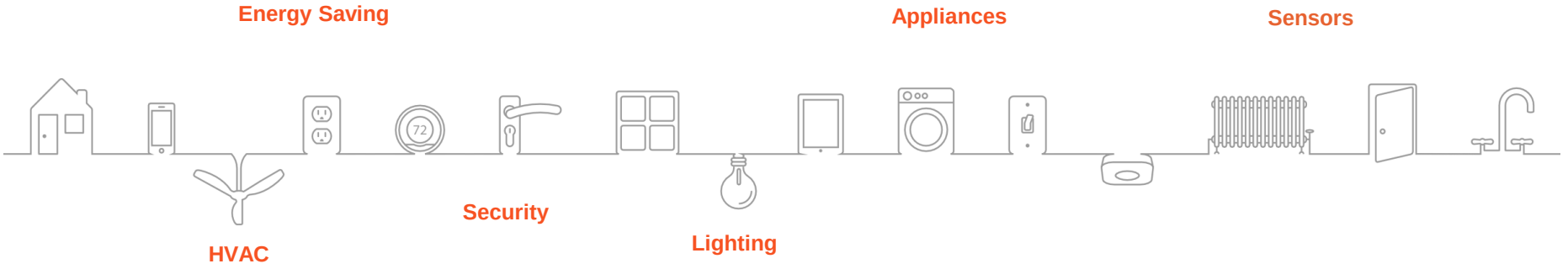
What is Thread?

The Thread stack is an open standard for reliable, cost-effective, low power, wireless device-to-device communication.

It is designed specifically for Connected Home applications where IP based networking is desired and a variety of application layers can be used on the stack



Connected home requirements



Normally Powered

Gateway
Lighting
Appliances
Smart Meter
Garage door opener
HVAC equipment
Smart Plugs
Fans

Powered or battery

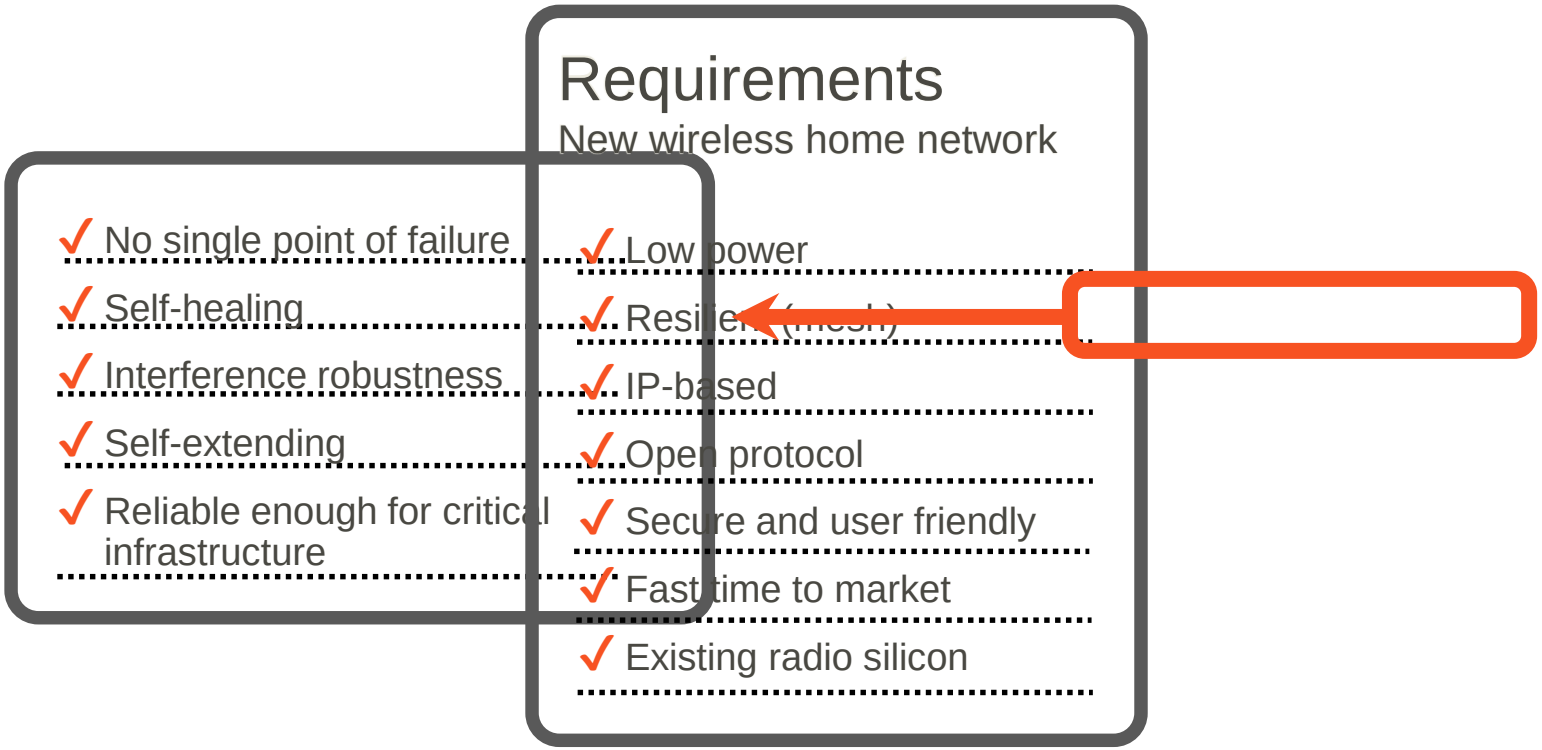
Thermostat
Light switches
Smoke Detectors
CO detectors
In home display
Shade or blinds control
Door bell
Glass break sensors
Robots/cleaners

Normally Battery

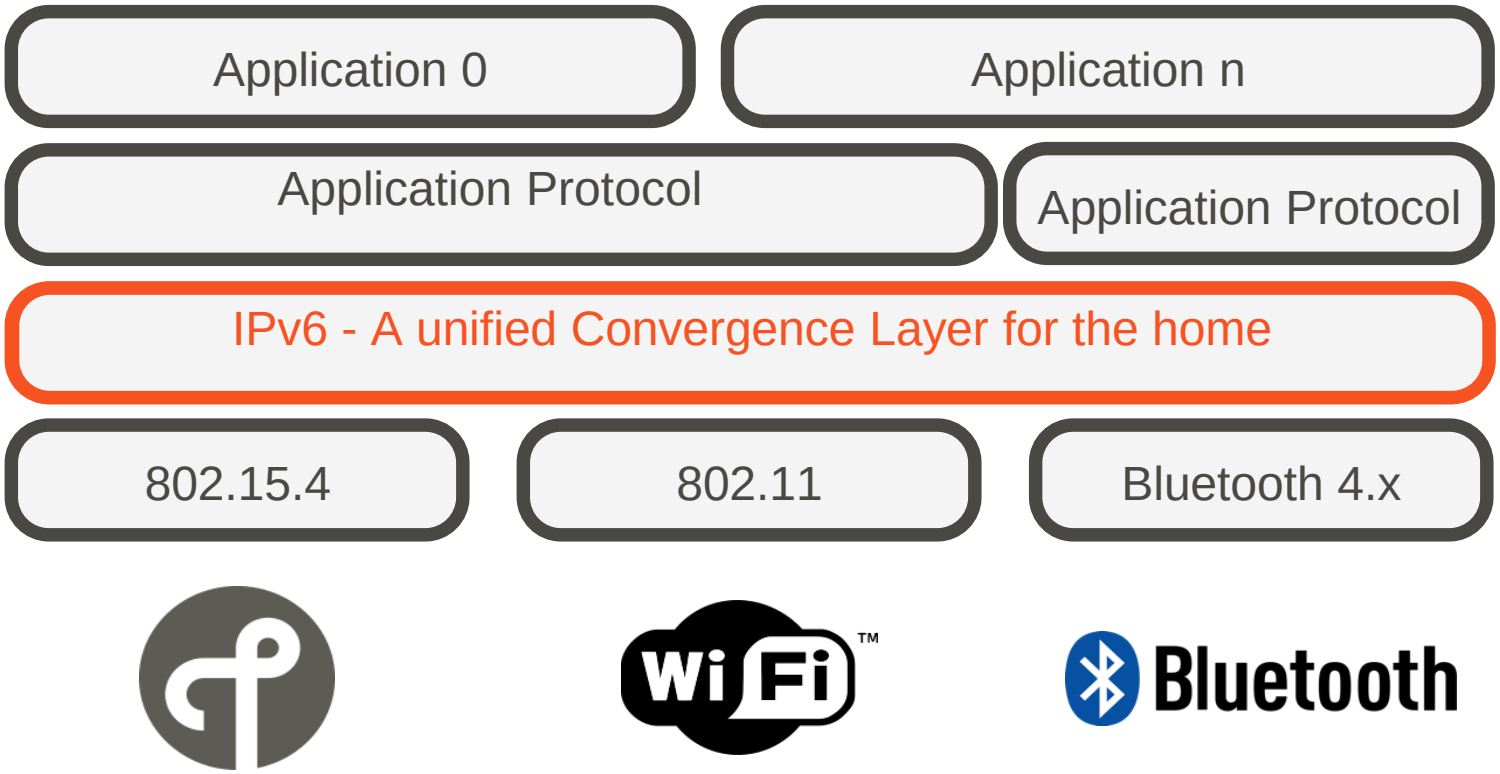
Door sensors
Window sensors
Motion sensors
Door locks
Radiator valves
Body sensors (health care)

Consideration for devices that rely on energy harvesting is also a requirement

The need for a new wireless network



IPv6 to converge with conventional IP networks



Thread | Basic Concepts

Thread Protocol Stack

A secure wireless mesh network for your home and its connected products

Built on well-proven, existing technologies

Uses 6LoWPAN and carries IPv6 natively

Runs on existing 802.15.4 silicon

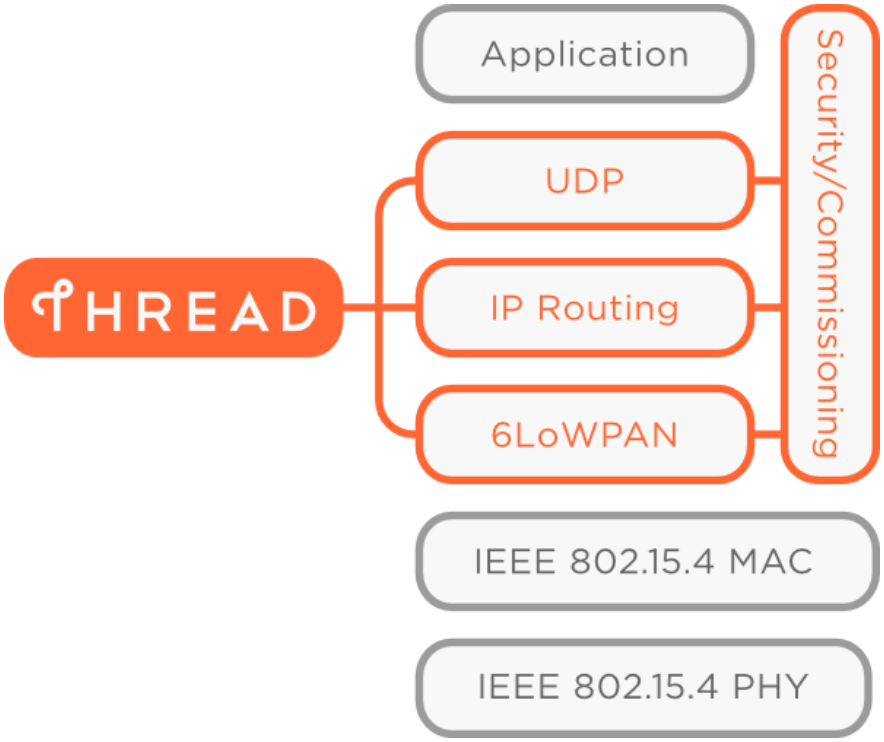
250+ products per network

Designed for very low power operation

Reliable for critical infrastructure

Security at network and application layers

Can support many popular application layer protocols and platforms



A software upgrade can add Thread to currently shipping 802.15.4 products

IPv6 based

Lightweight and low latency

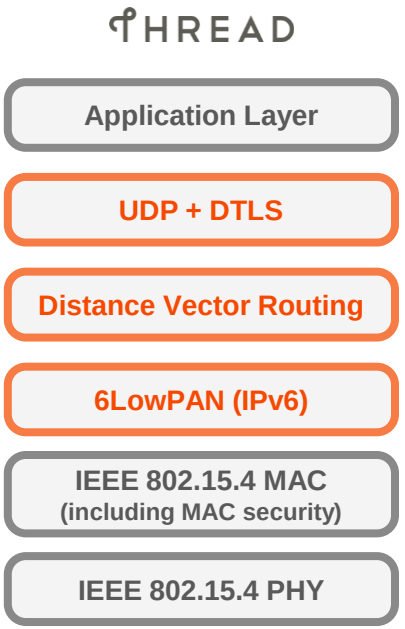
Not a whole new standard

Collection of existing IEEE and IETF standards

Runs on existing 802.15.4 based products

250+ devices on a PAN

- Direct Addressability of devices
- Flexible network with full point to point connectivity of all devices
- No single point of failure
- Enable low cost bridging to other IP networks
- Simple security and commissioning
- Low Power support for sleeping devices

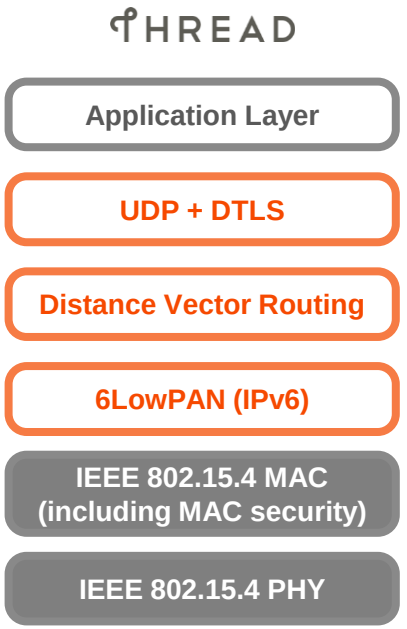


IEEE 802.15.4 is a standard used for Low-Rate Wireless Personal Are Networks.

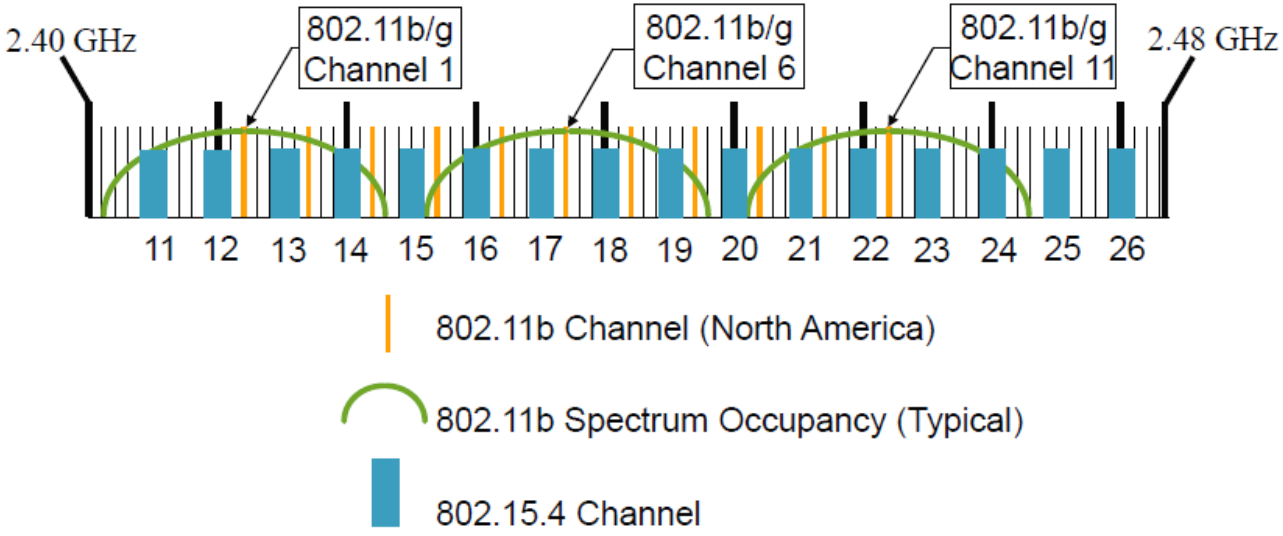
Main features:

- Low cost
- Low complexity
- Low power consumption
- Low data rate transmissions
- Generally used for WSN (Wireless Sensor Networks)

Higher-level layers and interoperability sublayers (Thread, Application Layer) are not defined in the 802.15.4 standard



IEEE 802.15.4 channel occupancy



THREAD

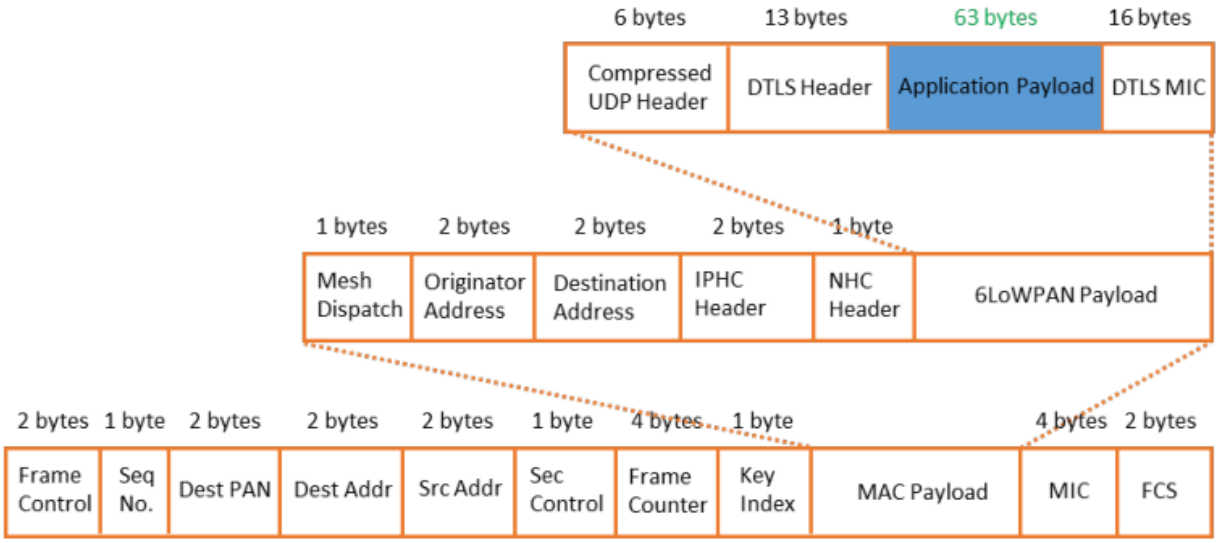
- Application Layer
- UDP + DTLS
- Distance Vector Routing
- 6LowPAN (IPv6)
- IEEE 802.15.4 MAC (including MAC security)
- IEEE 802.15.4 PHY

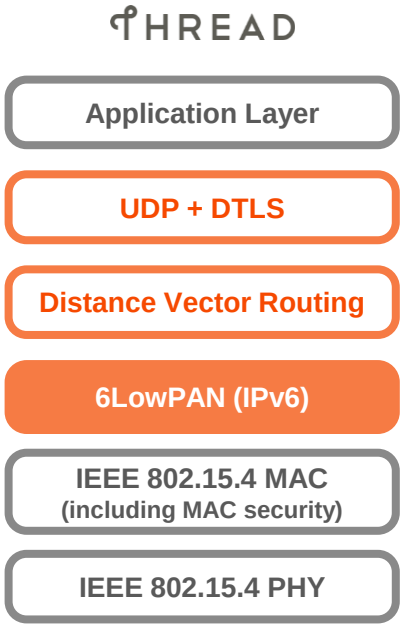
802.15.4 open channels when Wi-Fi fully utilized the band

- 15, 20, 25, 26.

Break down “big” IPv6 packets into “small” 802.15.4 packets

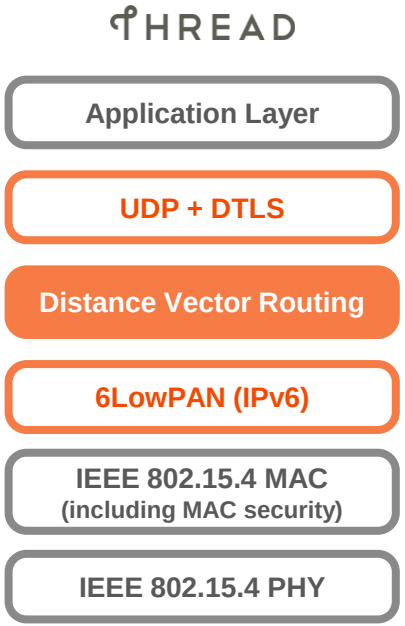
6LoWPAN offers interoperability with other wireless 802.15.4 devices as well as with devices on any other IP network link (e.g., Ethernet or Wi-Fi) with a simple bridge device.





Routing Information Protocol next generation (RIPng)

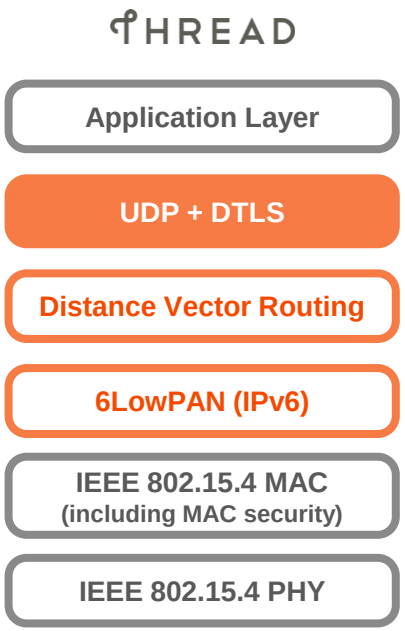
- Distance Vector routing protocol
- Prevents routing loops
- Router informs its neighbors of topology changes periodically



UDP – User Datagram Protocol
DTLS – Datagram Transport Layer Security

UDP
Connectionless protocol - One program can send a load of packets to another with no handshake establishment. Suitable for applications that need **fast**, efficient transmission.

DTLS provides communication privacy (integrity, authentication and confidentiality) and other security properties such as replay prevention for datagram protocols

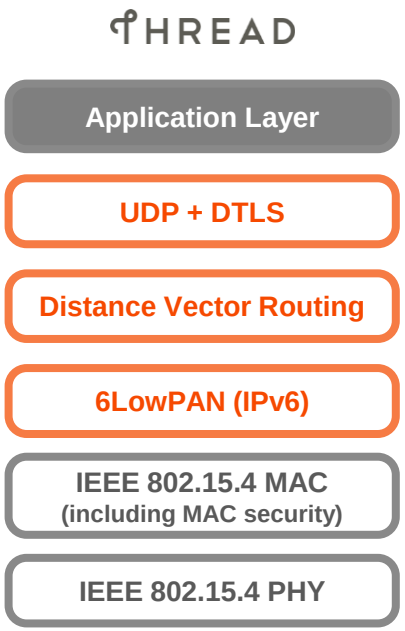


Thread provides basic services required for applications

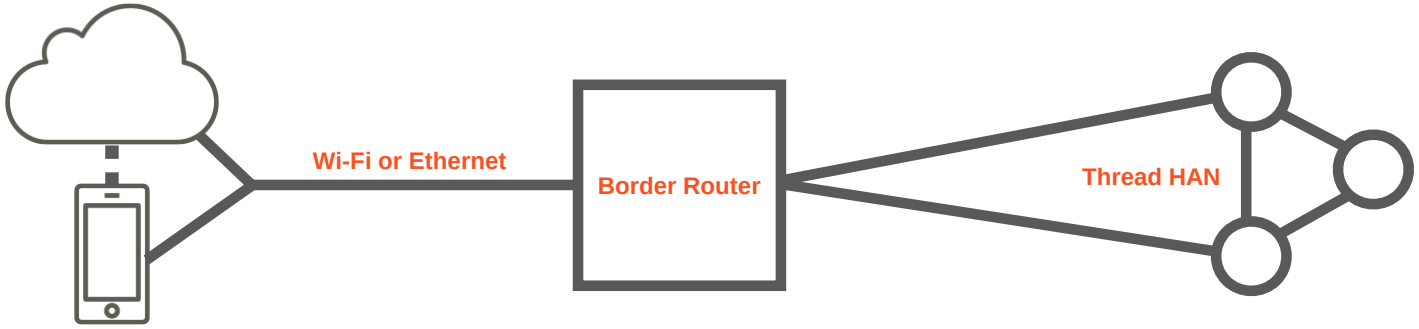
- UDP messaging and acknowledgement
- Multicast messaging

Thread allows use of many application layers using IP services

Those application layers not using IP services would need some adaptation



System Messaging Model



Cloud Connectivity

Cloud connectivity for control when not at home

When within the home, phone or tablet must go direct to gateway to eliminate latency
of going to the cloud

Has to be seamless to consumer using device

Border Router

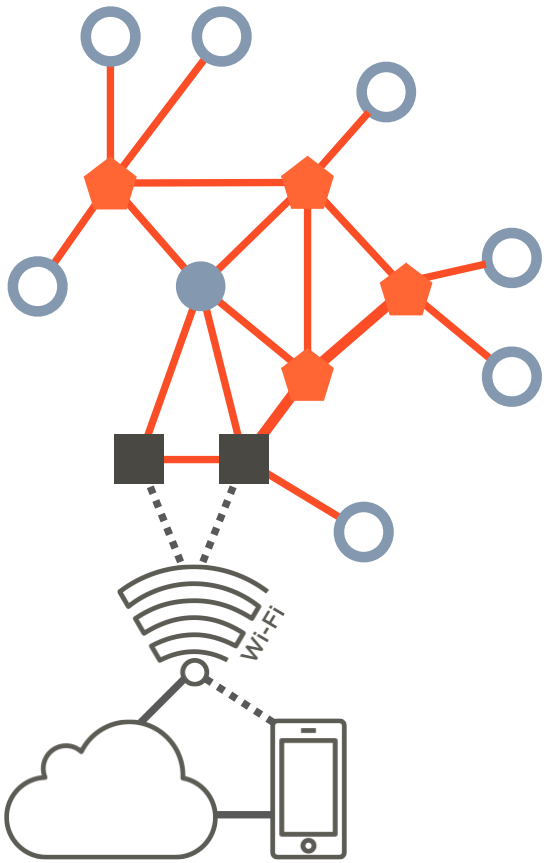
Border Router forwards data to cloud

Also provides Wifi connectivity to phone or tablet in the home

Device Communication

Expect device to device communication within HAN for operations in the home

Network Architecture



End Device Router Eligible

Thread Router

Leader

Border Router

Thread Link

Direct Addressability of devices

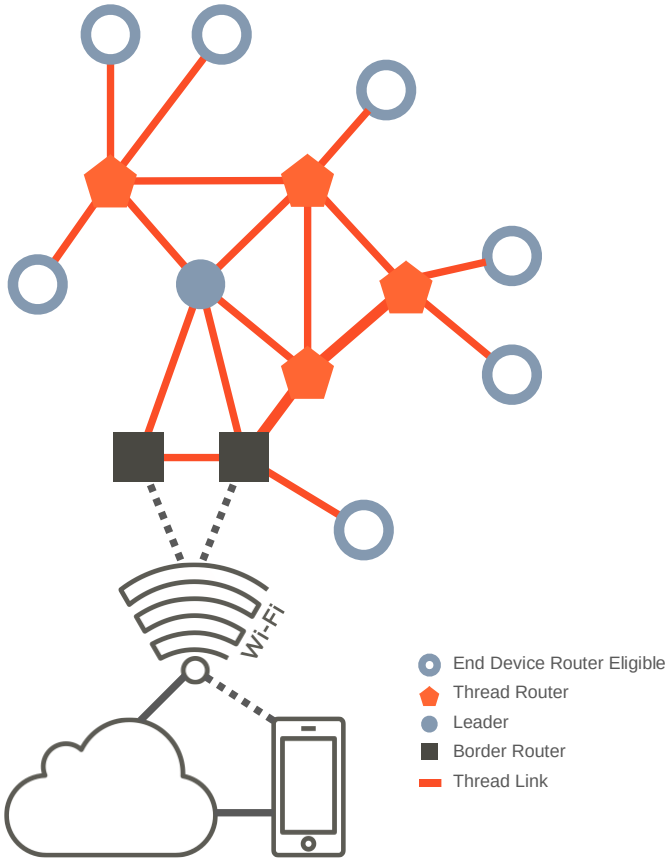
All devices have IPv6 addresses plus short address on HAN

DHCPv6 used for router address assignment

Home Network can directly address devices through Border Routers

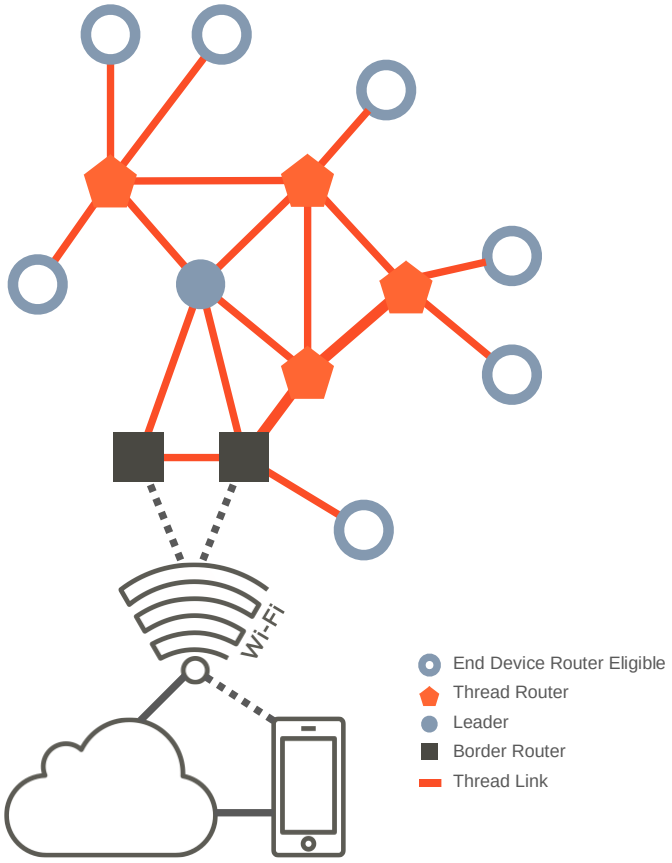
Cloud Services can address devices from the Internet

Devices can address local devices on HAN or off network devices using normal IP addressing



Flexible Network

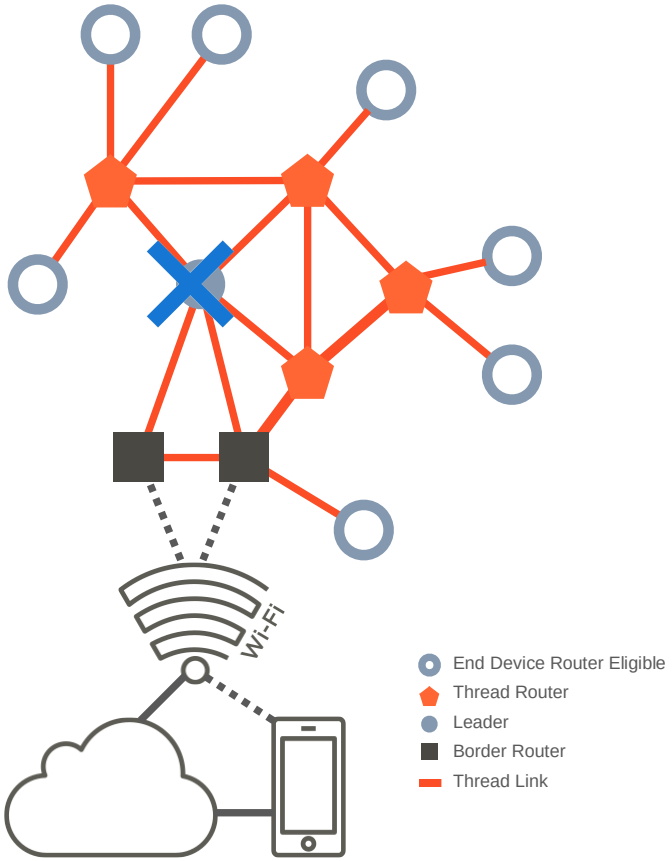
- Devices join as router eligible or end devices
- Router eligible can become routers if network agrees it is needed
- All routers maintain state to all other routers through trickle mechanism and MLE
- All routers maintain state of border routers through trickle mechanism and MLE
- Sleeping end devices route through parent router
- Router eligible devices can also maintain state
- Leader used to make decisions within network



No single point of failure

No need to recognize specialized devices within the network

Leader makes decisions but can fail and another router will become Leader

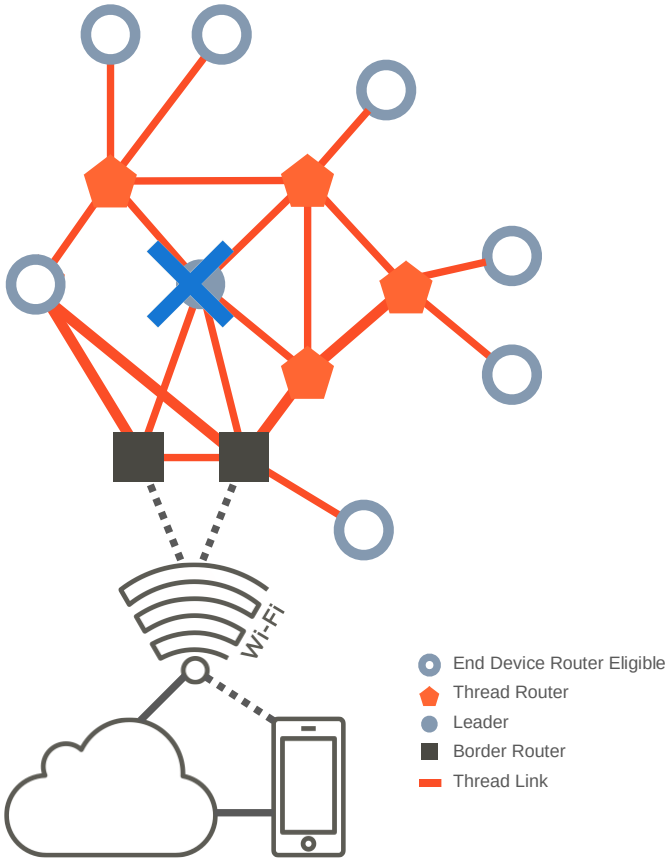


No single point of failure

No need to recognize specialized devices within the network

Leader makes decisions but can fail and another router will become Leader

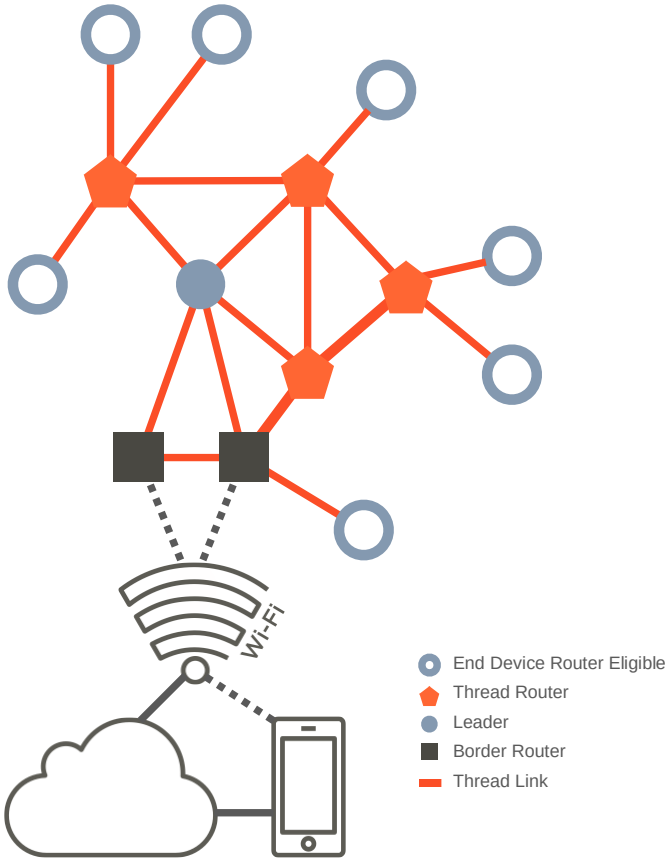
Network will add routers to improve connectivity when required



No single point of failure

Multiple border routers can be used for off network access

Devices operate without Border Router



Simple Commissioning

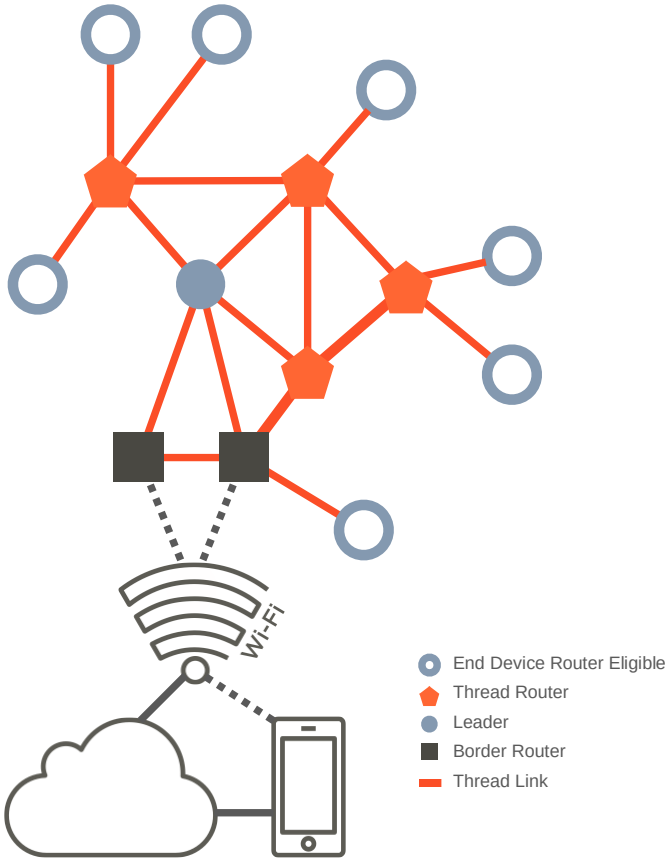
- User authorizes devices into the network using smart phone, computer
- GUI rich device within network can be used to authorize devices

Security session established between new device and commissioning device to authenticate and provide credentials

Once commissioning session is done – device attaches to network

MAC security used for all messages

Application level security used based on device requirements



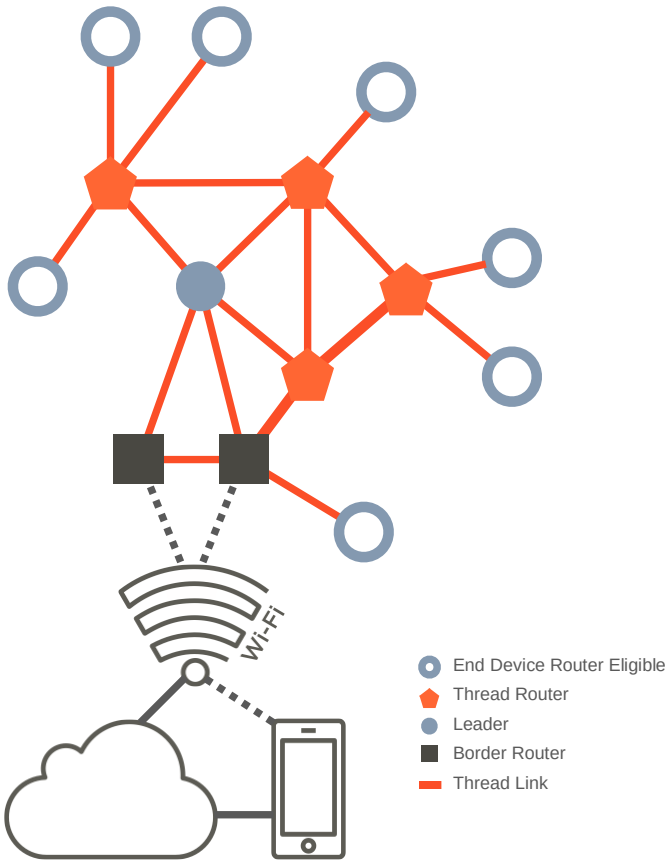
Low Power Operation

Sleeping devices poll parents for messages (or remote device if application configured)

Sleeping device not required to check in allow lower power operation

Parents hold messages for sleeping devices

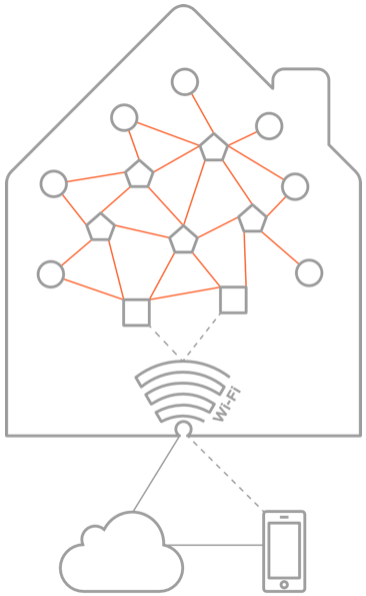
Sleeping device automatically switches parent if it loses connectivity



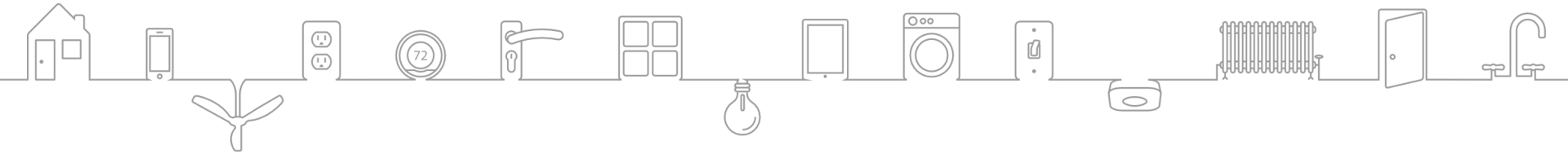
Target applications

Thread is designed for all sorts of products in the home

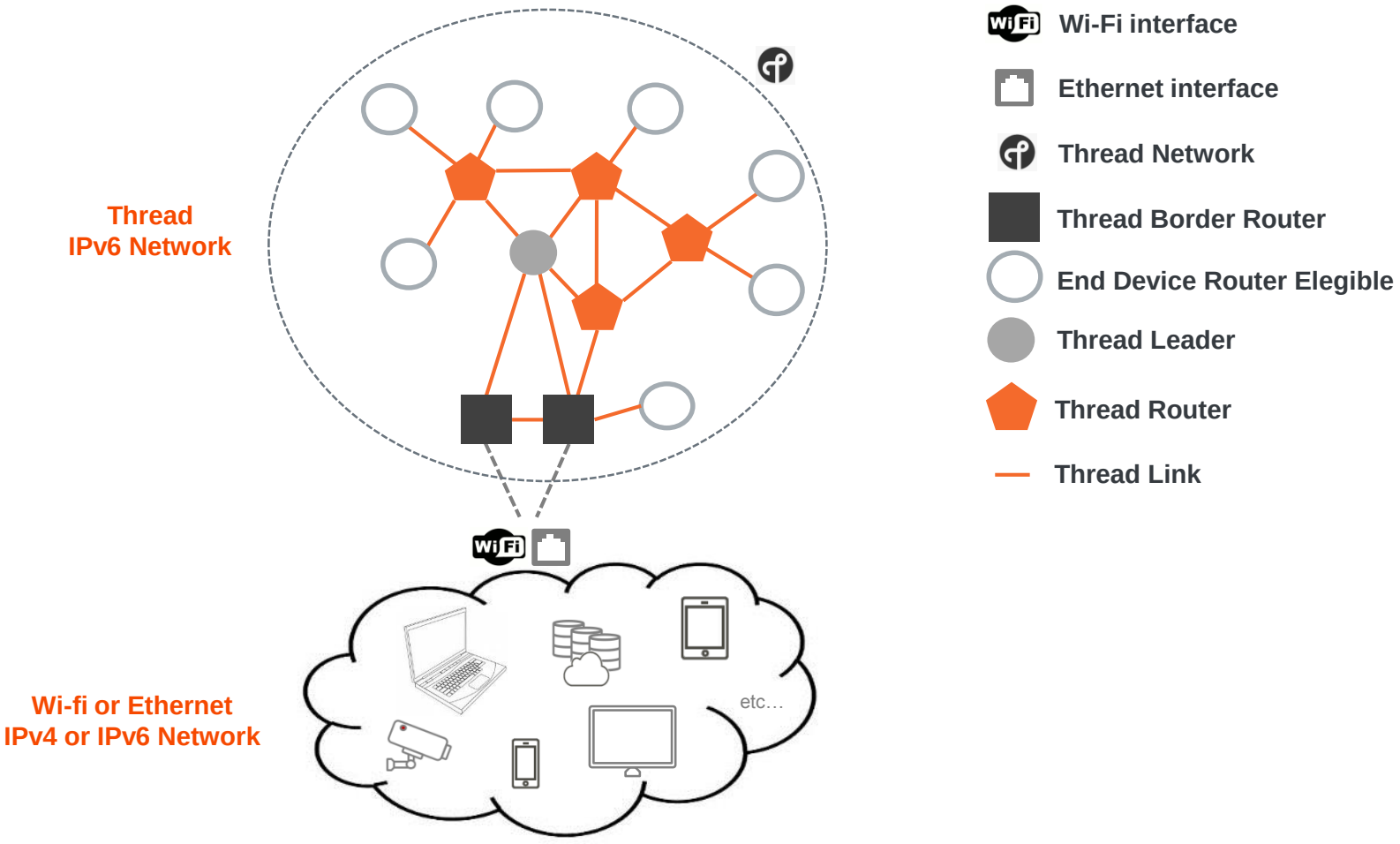
- Appliances
- Access control
- Climate control
- Energy management
- Lighting
- Safety
- Security



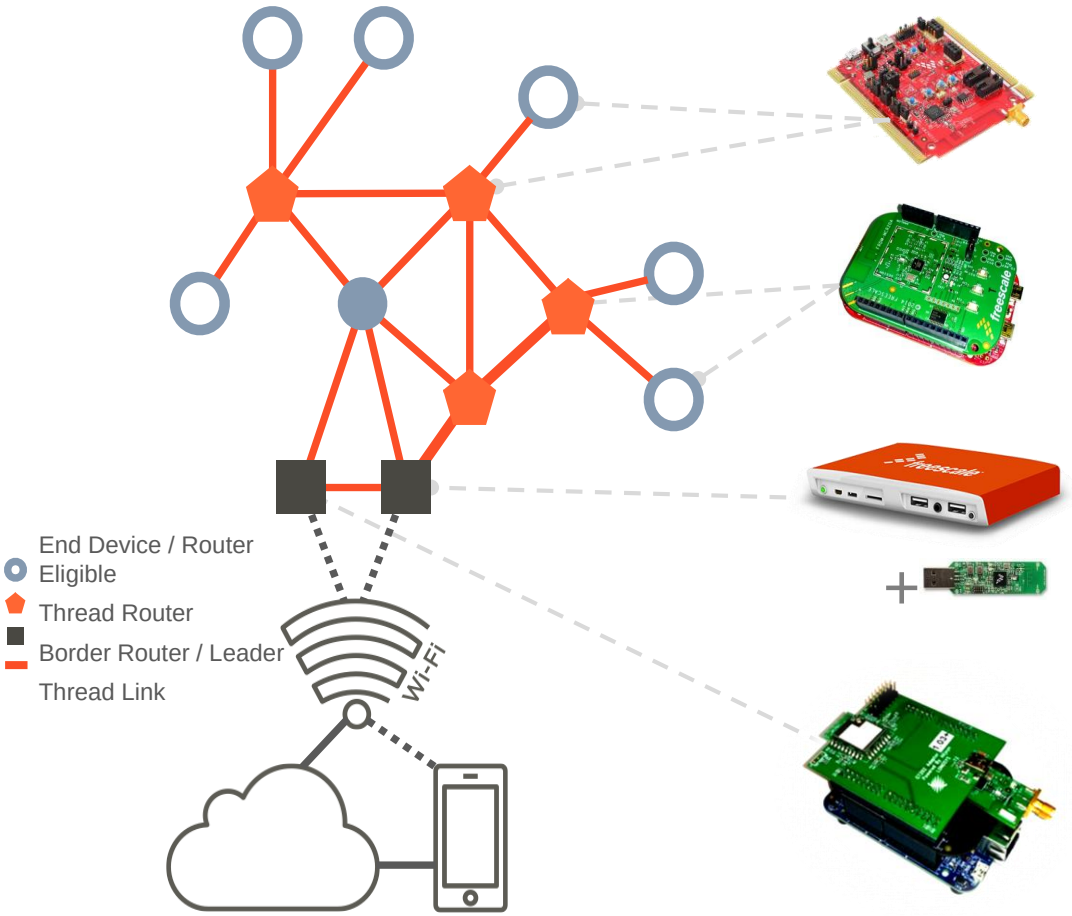
Devices working together to form a cohesive mesh network



Network architecture: Thread IPv6 Network + External IP Network



Freescale Thread Hardware Offering



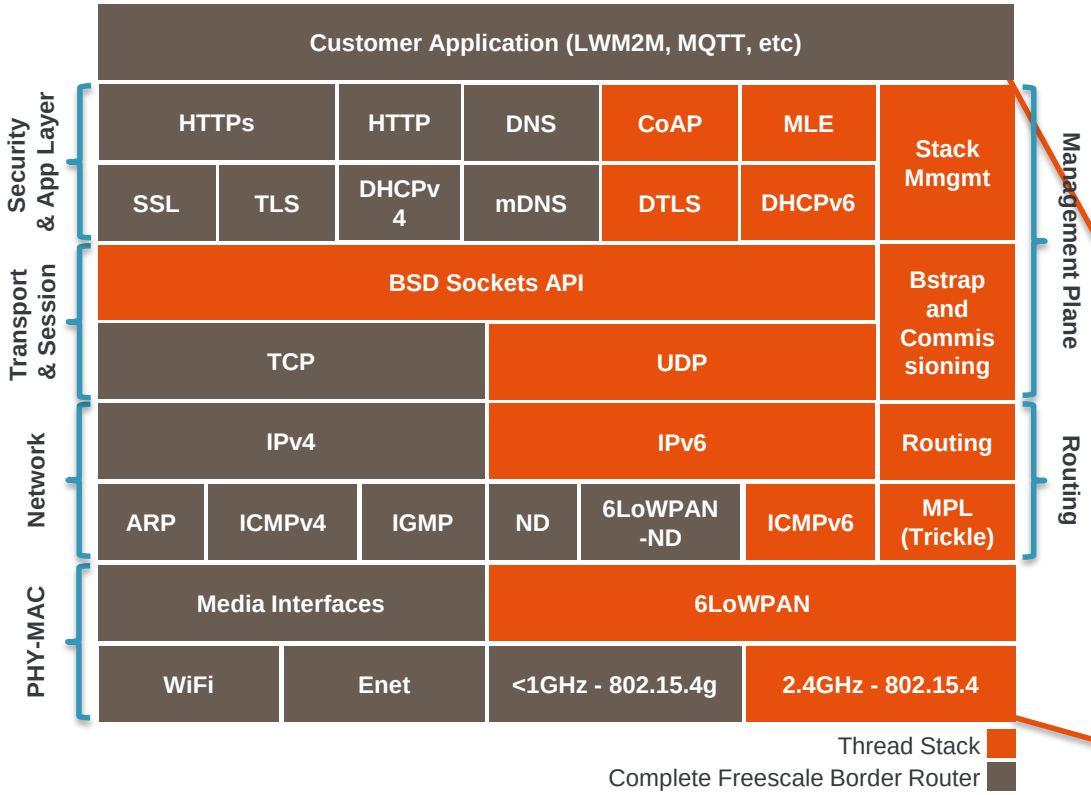
Freescale Kinetis KW2x MCU
Mesh Network Router / End Device
Thread and IEEE 802.15.4 compliant
Tower Board and Freedom Board coming up soon
Runs MQX for Kinetis SDK

Freescale Kinetis KL46 MCU+ MCR20A Transceiver
Mesh Network Router / End Device
Thread and IEEE 802.15.4 compliant
Freedom Board format
Runs MQX for Kinetis SDK

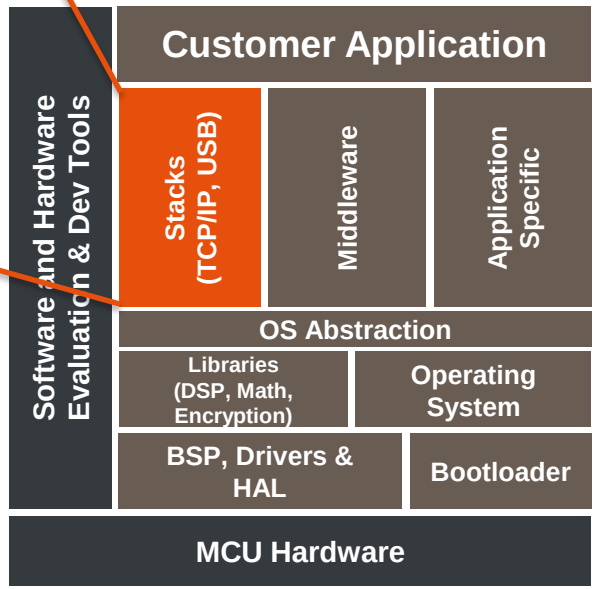
Freescale i.MX 6 applications processors IoT Gateway
Freescale Kinetis KW2x MCU USB
Border Router / Cloud gateway
Provides IP data routing and infrastructure integration
Runs Linux operating system

Freescale Kinetis K64F MCU+ MCR20A Transceiver + Wi-Fi
Border Router with Ethernet and Wi-Fi support
Thread and IEEE 802.15.4 compliant
Freedom Board format
Runs MQX for Kinetis SDK

Freescale Thread Stack Overview



- **Product Features:**
  - **Multiple OS support via Kinetis SDK OSA** running on MQX and possible to port to FreeRTOS, uCOS and even Bare Metal
  - **6LoWPAN and IPv6 stack successfully proven** interoperability with other vendors in various alliances.



- **Product Features:**
  - **Flexible, configurable and scalable** Dual Stack IPv4 & IPv6 for constrained resources devices
  - **Multiple interfaces support: 802.15.4 & 802.15.4g with 6LoWPAN**, Ethernet and WiFi
  - **Designed for Low Power**, Quick Wake-up Time and Low Memory footprint

Summary

Session Closing

After completing the session you are able to:

- Get a good perspective on how connectivity can enhance customer experience for Smart Home products
- Identify which Freescale microcontroller families are best suited for your connected appliance, sensor or hub product idea
- Understand how to use Freescale connectivity tools and software to implement effective wireless applications
- Understand the Thread Technology basic concepts

For Further Information

- Come to see the technology demonstrated in the Tech Lab
- For more information on the Freescale solutions introduced in this session:

Community:
IoT Center
Wireless Connectivity
Thread Technology

Web
Wireless Connectivity
Thread Networking Protocol
Bluetooth Low Energy
ZigBee
Kinetis Low Power 32-bit MCUs
i.MX

www.Freescale.com