恩智浦无线连接及网关产品解决方案：低功耗蓝牙/ZigBee/Thread

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NXP | CONNECTS

内容纲要

- **物**联网行业标准与技术趋势

- **智能家居无**线互联方案

- NXP 产品和软件解决方案
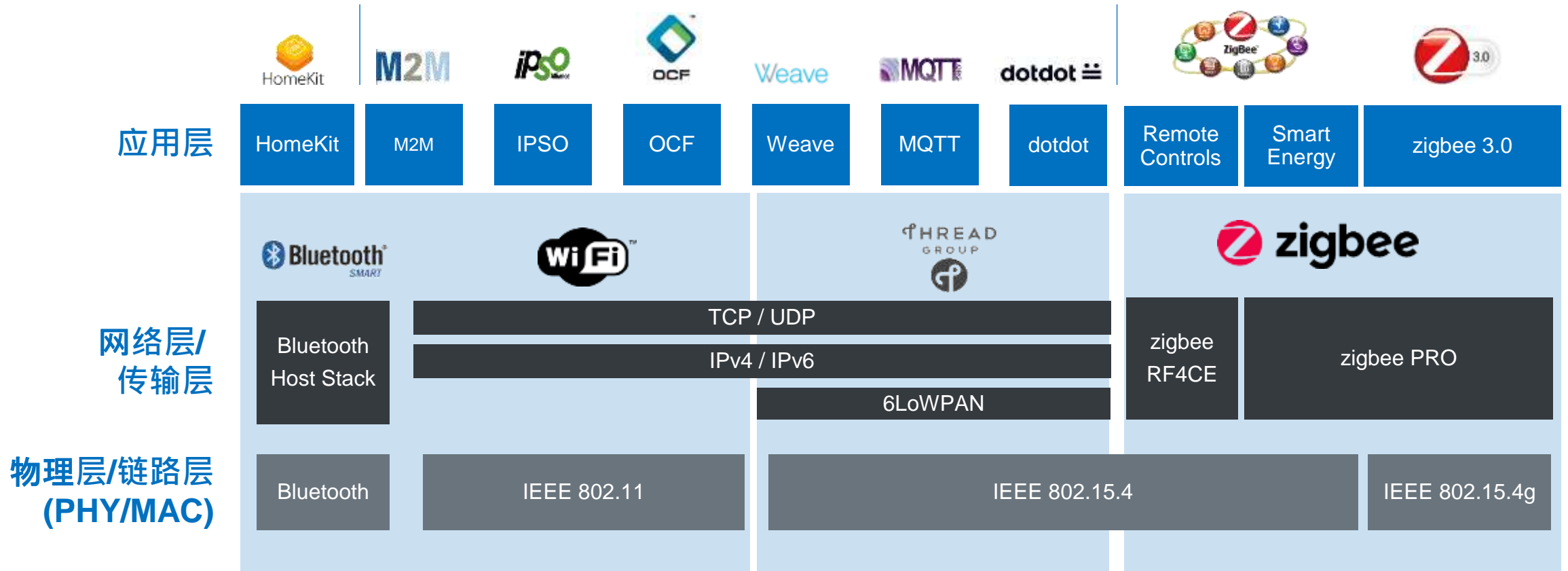
  - Zigbee

  - Thread

  - BLE（**低功耗**蓝牙）

- 应用案例

物联网行业标准与技术趋势

恩智浦致力于无线互联

文档

软件

芯片

参考设计

THREAD   zigbee   Bluetooth SMART   NFC

物联网行业标准

应用层	HomeKit	M2M	IPSO	OCF	Weave	MQTT	dotdot	Remote Controls	Smart Energy	zigbee 3.0

Bluetooth SMART   **WiFi**   ᵠHREAD GROUP   **zigbee**

网络层/ 传输层	Bluetooth Host Stack	TCP / UDP			zigbee RF4CE	zigbee PRO
		IPv4 / IPv6				
			6LoWPAN			

物理层/链路层 (PHY/MAC)	Bluetooth	IEEE 802.11	IEEE 802.15.4	IEEE 802.15.4g

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大中华地区无线微控制器市场份额与技术趋势
(Zigbee/Thread/BLE)

协议	Zigbee			Thread	BLE						Zigbee/Thread + BLE
	智能家庭	照明	工业数据采集	智能家庭	消费类	健康和医疗	电子支付	信标	汽车电子	网关
应用											
市场容量 (百万片/年)	30Mpcs/y	10Mpcs/y	10Mpcs/y	潜在市场	100Mpcs/y	20Mpcs/y	20Mpcs/y*	5Mpcs/y	潜在市场	10Mpcs/y

Low power **Mesh** **Security**

**Market size is estimated by customer group.

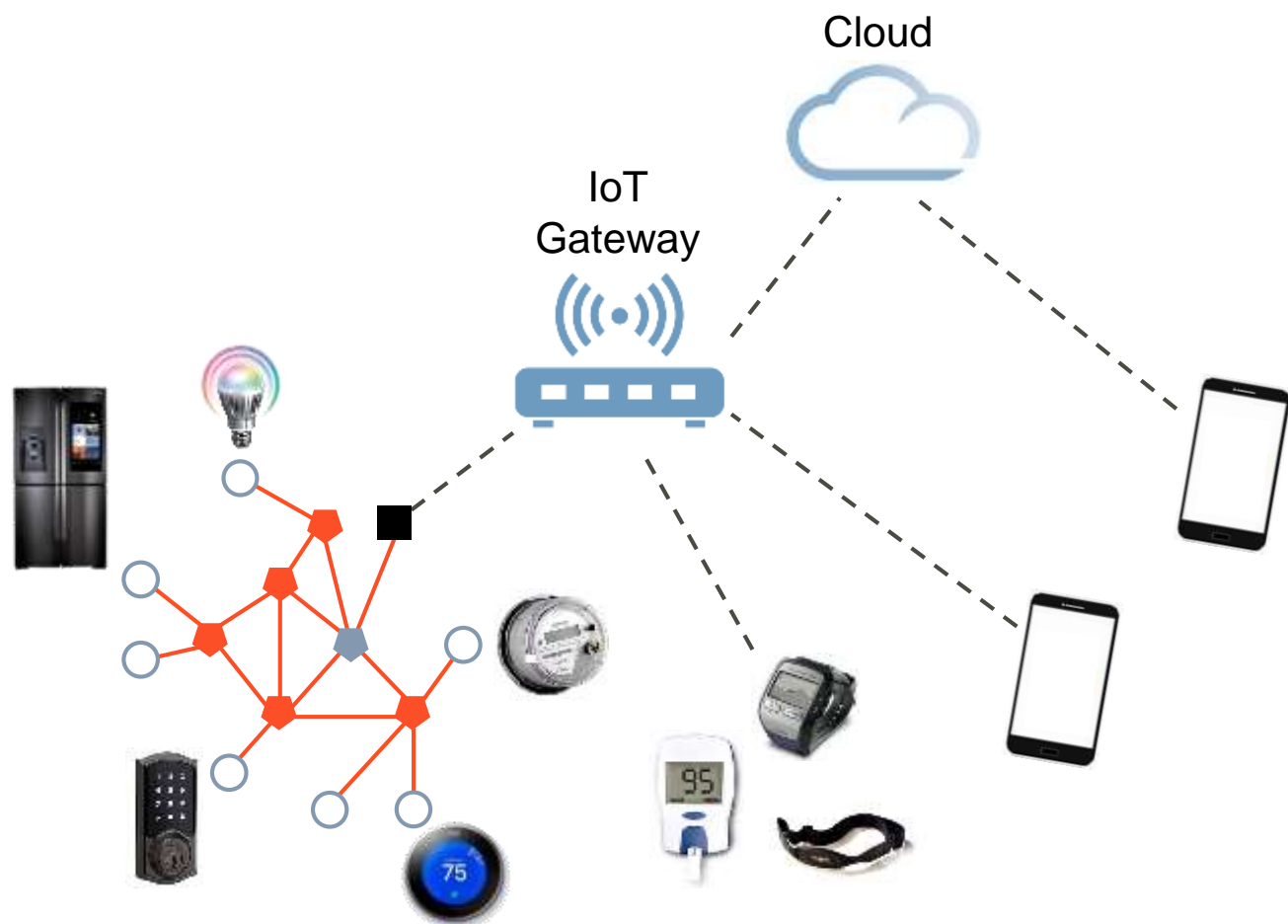**20Mpcs/y includes Classic/BLE dual-mode chip, but BLE single mode can replace it in future.
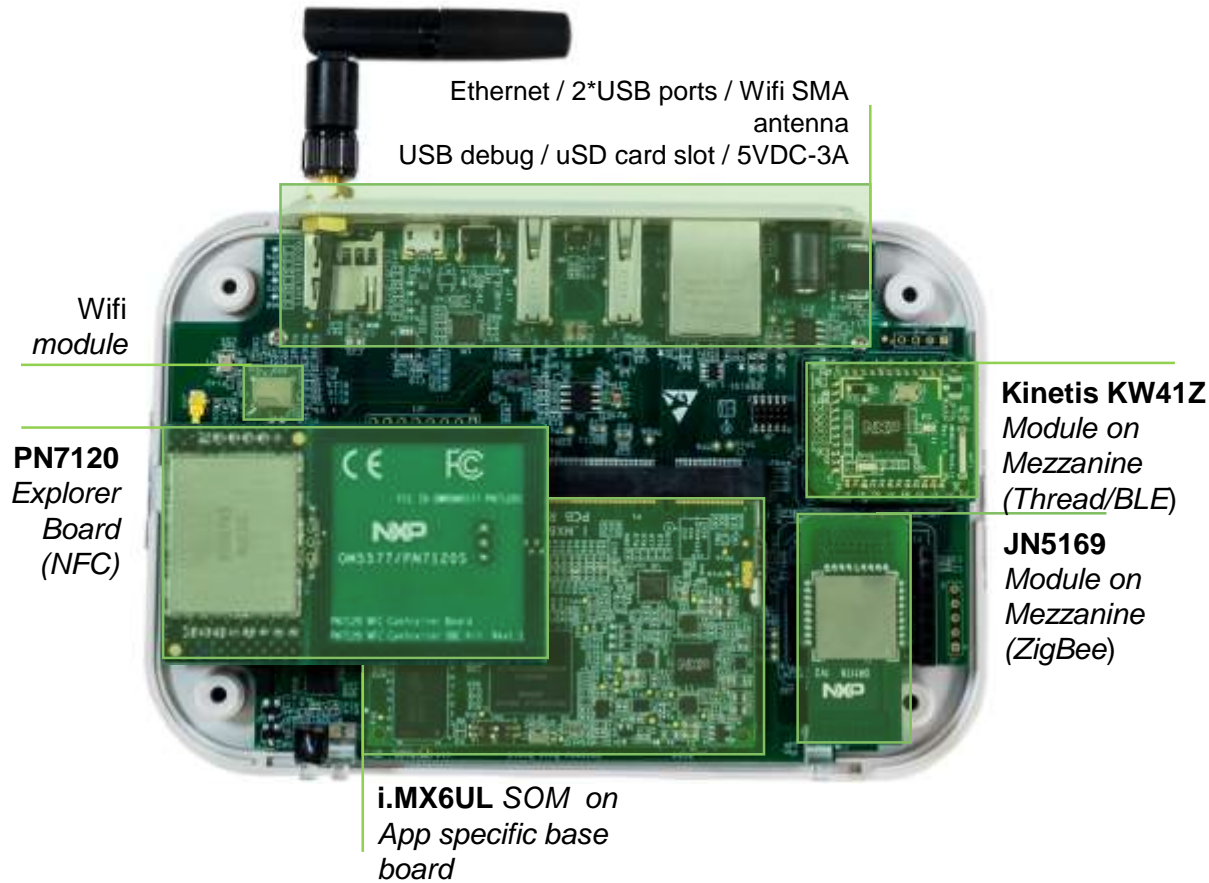
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无线SoC微控制器集
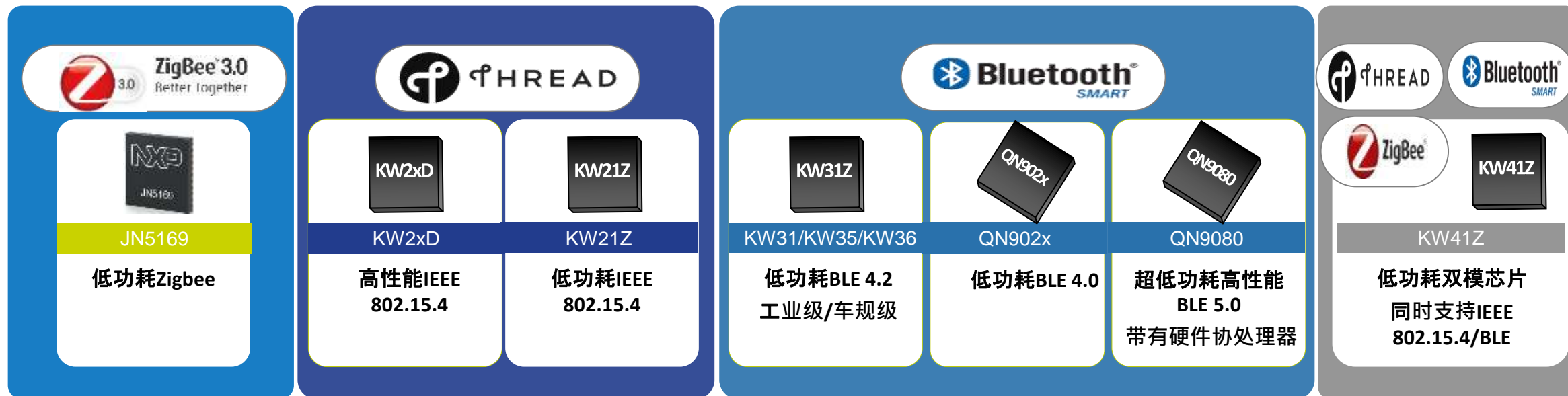
持续演进与更新中

智能家居无线互联方案

恩智浦智能家居无线互联方案

Cloud

IoT
Gateway

75

95

模块化物联网网关实物图

Ethernet / 2*USB ports / Wifi SMA antenna
USB debug / uSD card slot / 5VDC-3A

Wifi
module

PN7120
Explorer Board (NFC)

Kinetis KW41Z
Module on Mezzanine (Thread/BLE)

JN5169
Module on Mezzanine (ZigBee)

i.MX6UL *SOM on App specific base board*

Hardware Modules

Radio Modules

JN5169
Zigbee

KW2xD
Thread

KW41Z
Thread/BLE

Processor Module

i.MX6UL SOM

NFC Module

PN7120

NXP 产品和软件解决方案

Zigbee

- 广泛应用
- 低功耗
- 安全
- 网格网络 (Mesh)
- 互操作性

NXP 开发 Zigbee 3.0 协议栈

- Zigbee 3.0 是一个针对无线互联市场而推出的标准，该协议使得消费者可以通过低功耗无线组网的方式控制设备。
- Zigbee 3.0 和 Zigbee 之前的 Home Automation/ZLL 协议兼容
- 例如彩色灯光控制和遥控器
- "簇"是引入的一个概念，表示一组控制指令的集合，例如对于一个彩色灯而言，需要两个"簇"，开/关和色彩控制。
- 每一类设备都有一个或多个"簇"的要求，用来通过设备认证

Zigbee ———————————————————— *Years*

Others* ———— *Weeks/Months*

* Others: Wi-Fi, Bluetooth, Sub-G, … …

Zigbee 3.0 安全概述

在安全性和易用性中得到完美的平衡

设备唯一认证码用于入网

动态秘钥更新

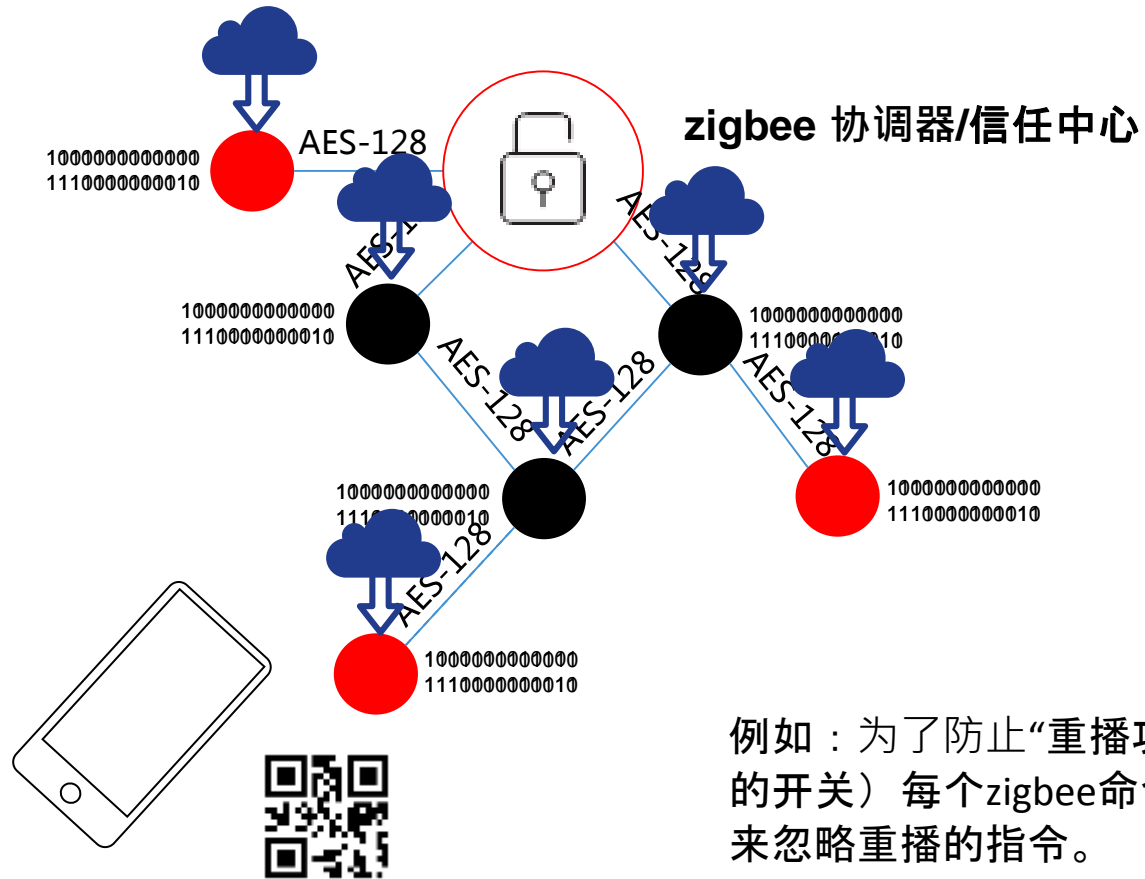安全空中固件升级 Over-The-Air (OTA)

逻辑链路层加密

zigbee

技术
守护超过10亿设备安全工作

全球范围内，上亿台电表设备
基于Zigbee安全技术而未被攻破

安全

NXP

Zigbee 3.0 安全特性

集中式的安全管理机制

zigbee 协调器/信任中心

AES-128

1000000000000
1110000000010

1000000000000
1110000000010

1000000000000
1110000000010

AES-128

1000000000000
1110000000010

1000000000000
1110000000010

例如：为了防止"**重播攻**击"（**攻**击者通过记录并重播空中无线指令来控制灯的开关）每个zigbee命令都包含一个帧计数器。接收端通过通过检查帧计数器来忽略重播的指令。

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NXP Zigbee 3.0 SOC Stack Overview

The zigbee 3.0 is a standard designed fulfil the needs for the wireless lighting market. It allows consumers to wirelessly control their lights.
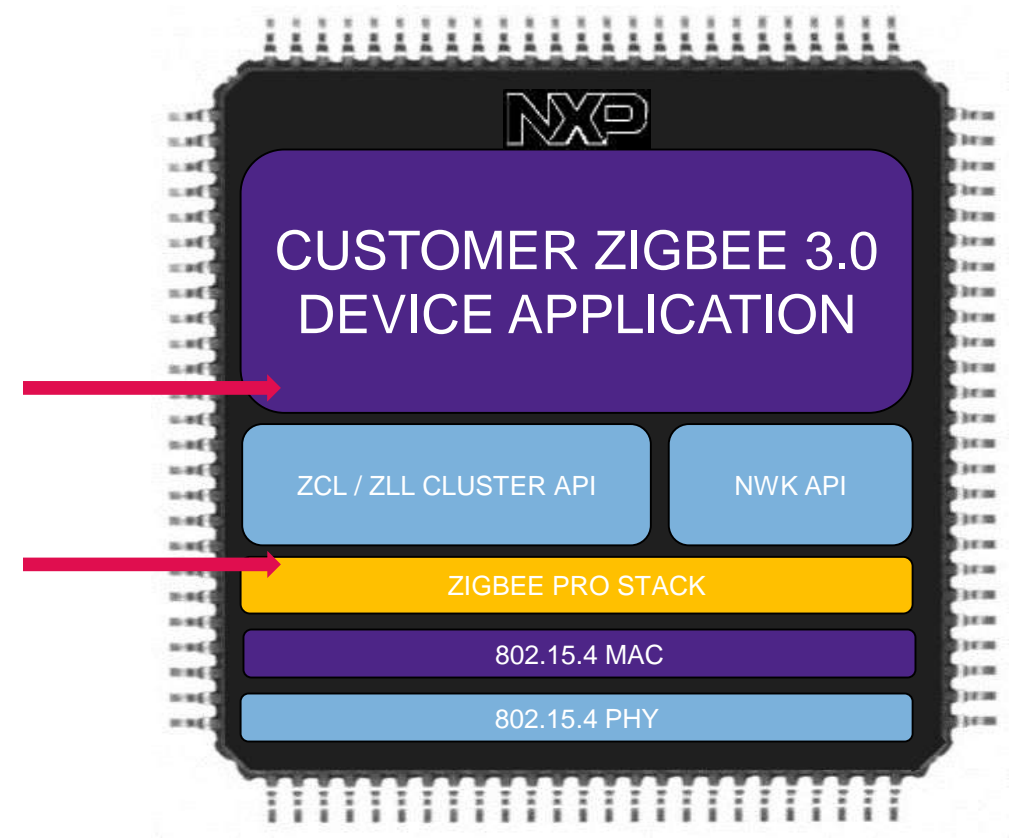
Within zigbee 3.0 there are devices and clusters which compatible with Home Automation/ZLL

- Example devices are a Colour light or Remote Control.

- A cluster is a group of commands and attributes that make up a device for example, a Colour Light will implement the On/Off cluster and Colour Control Cluster.

- Each device has a mandatory set of clusters it must implement to pass certification.
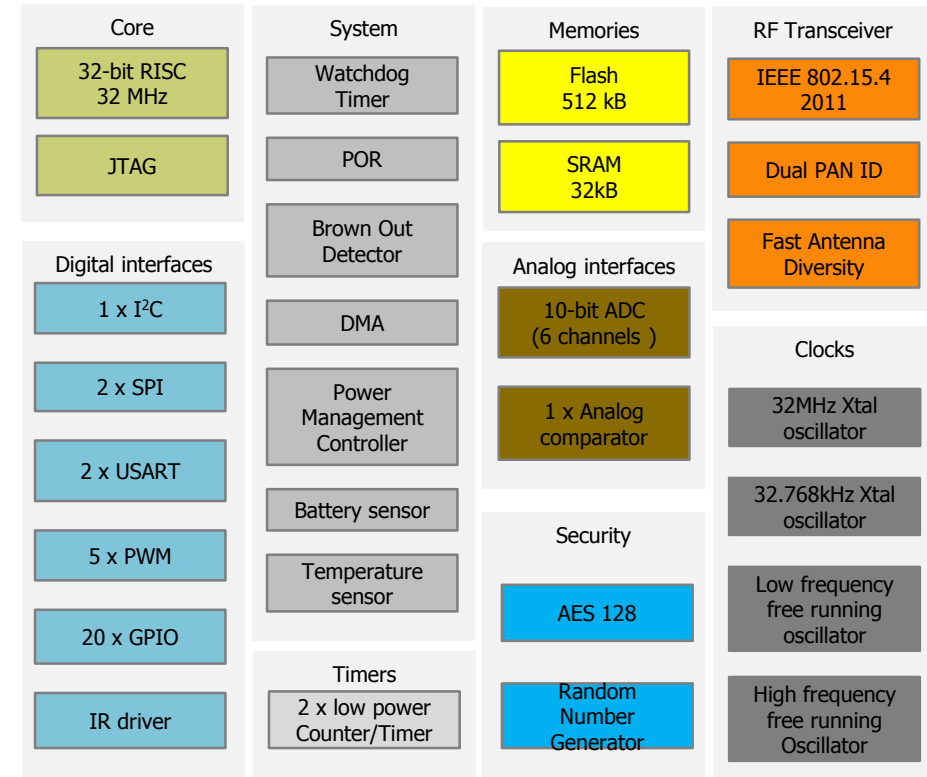
Collateral

zigbee 3.0 Landing Page

- JN-UG-3115-zigbee Cluster Library User Guide

- JN-UG-3113-zigbee 3.0 Stack User Guide

- KW21/41 zigbee 3.0 stack

CUSTOMER ZIGBEE 3.0 DEVICE APPLICATION

ZCL / ZLL CLUSTER API | NWK API

ZIGBEE PRO STACK

802.15.4 MAC

802.15.4 PHY

JN5169 Block Diagram

32-bit RISC, 512 kB Flash / 32 kB RAM, integrated PA

- **CPU**
  - 32 MHz, 32-bit RISC CPU core
  - 512 kB Flash & 32kB RAM & 4KB EEPROM
- **2.4 GHz radio transceiver**
  - IEEE-802.15.4 compliant
  - Antenna diversity
  - +10 dBm power amplifier
  - -96 dBm RX sensitivity
  - Peak typical current:
    - 23.3mA TX @ +10dBm, 14mA @ +3dBm
    - 14.7mA RX
- **Security**
  - Crypto engine: AES 128, RNG
- **System**
  - USART, SPI, I2C, PWM, IR
  - 10-bit ADC, Analog Comparator
  - Battery operating range: 2.0V to 3.6V,
  - Ambient temperature : -40°C to +125°C
  - HVQFN40 6x6mm

Core	System	Memories	RF Transceiver
32-bit RISC 32 MHz	Watchdog Timer	Flash 512 kB	IEEE 802.15.4 2011
JTAG	POR	SRAM 32kB	Dual PAN ID
	Brown Out Detector		Fast Antenna Diversity

Digital interfaces		Analog interfaces	Clocks
1 x I²C	DMA	10-bit ADC (6 channels)	32MHz Xtal oscillator
2 x SPI	Power Management Controller	1 x Analog comparator	32.768kHz Xtal oscillator
2 x USART	Battery sensor		Low frequency free running oscillator
5 x PWM	Temperature sensor	Security	
20 x GPIO		AES 128	High frequency free running Oscillator
IR driver	Timers	Random Number Generator	
	2 x low power Counter/Timer		

ZigBee 3.0 Better Together

IP6

Thread
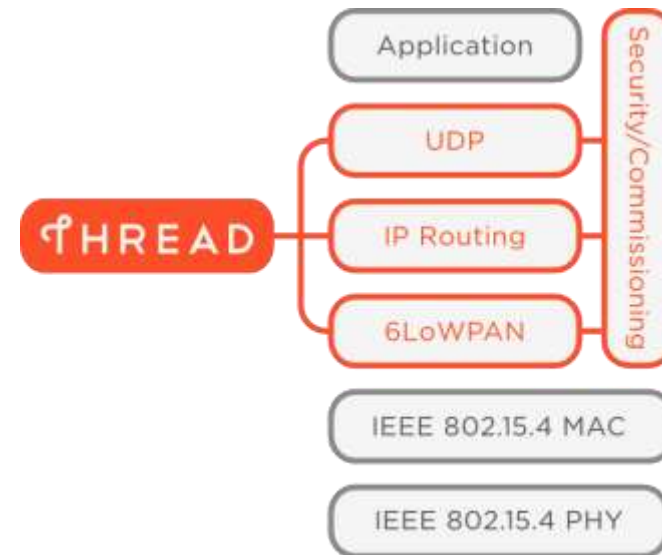
- 低功耗

- 安全

- 鲁棒性

- 网格网络(Mesh)

- IPv6

Thread简介

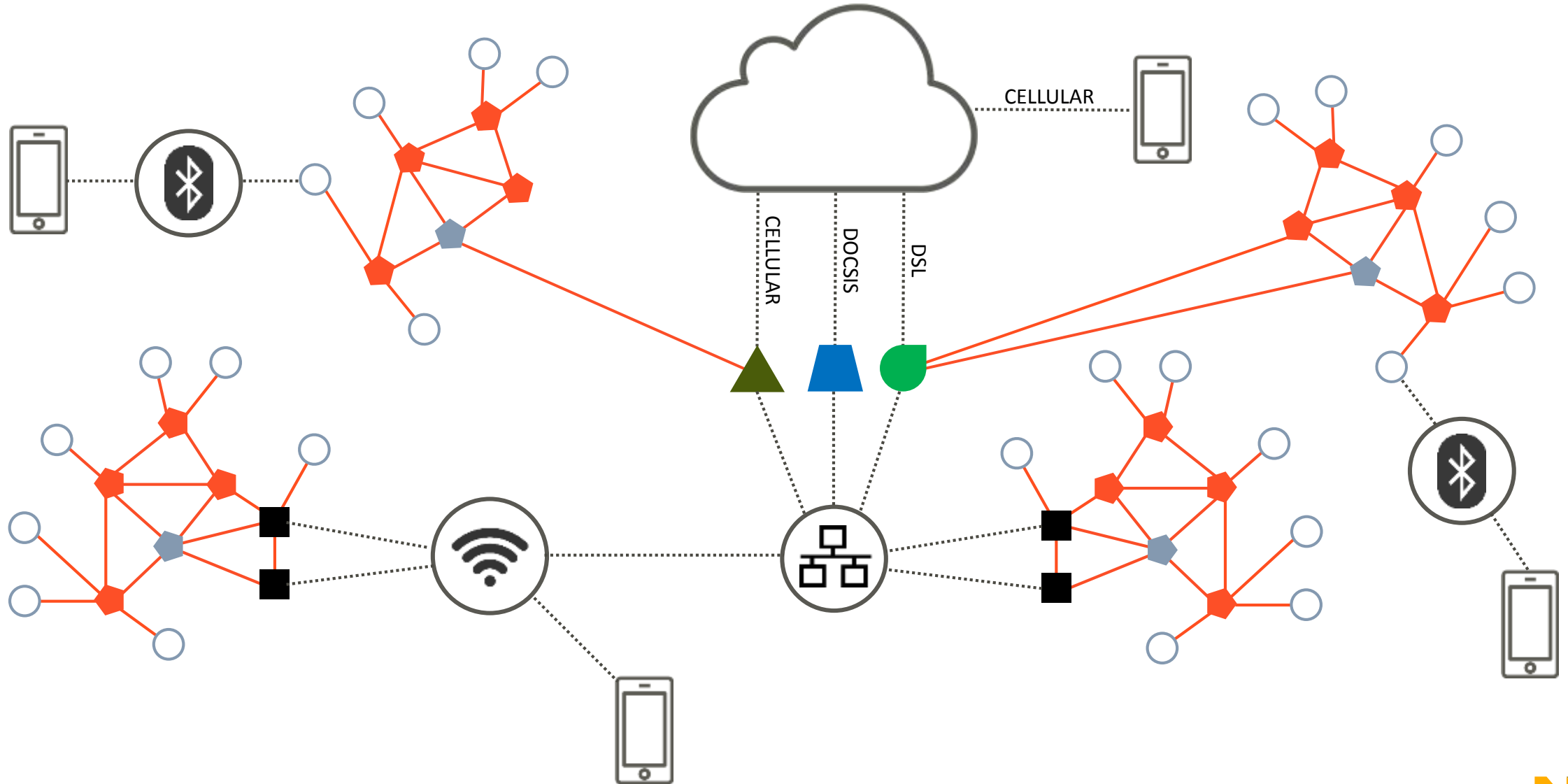7 创始成员, **目前成**长成为12个Sponsor成员, 超过230个会员

- 针对智能家居的安全的无线网格网络(mesh)
- **基于广泛**认证的现有的技术
  - 运行在IEEE 802.15.4 标准硬件上
  - 使用 6LoWPAN，基于IPv6 地址
  - UDP 传输
- **包含强制的安全架构**
  - 简单且安全的添加或删除设备
- 单个网络内可扩展至超过**250个**节点
- 针对低功耗操作而进行特别的优化
- 针对关键设备的可靠性设计

Can support many popular
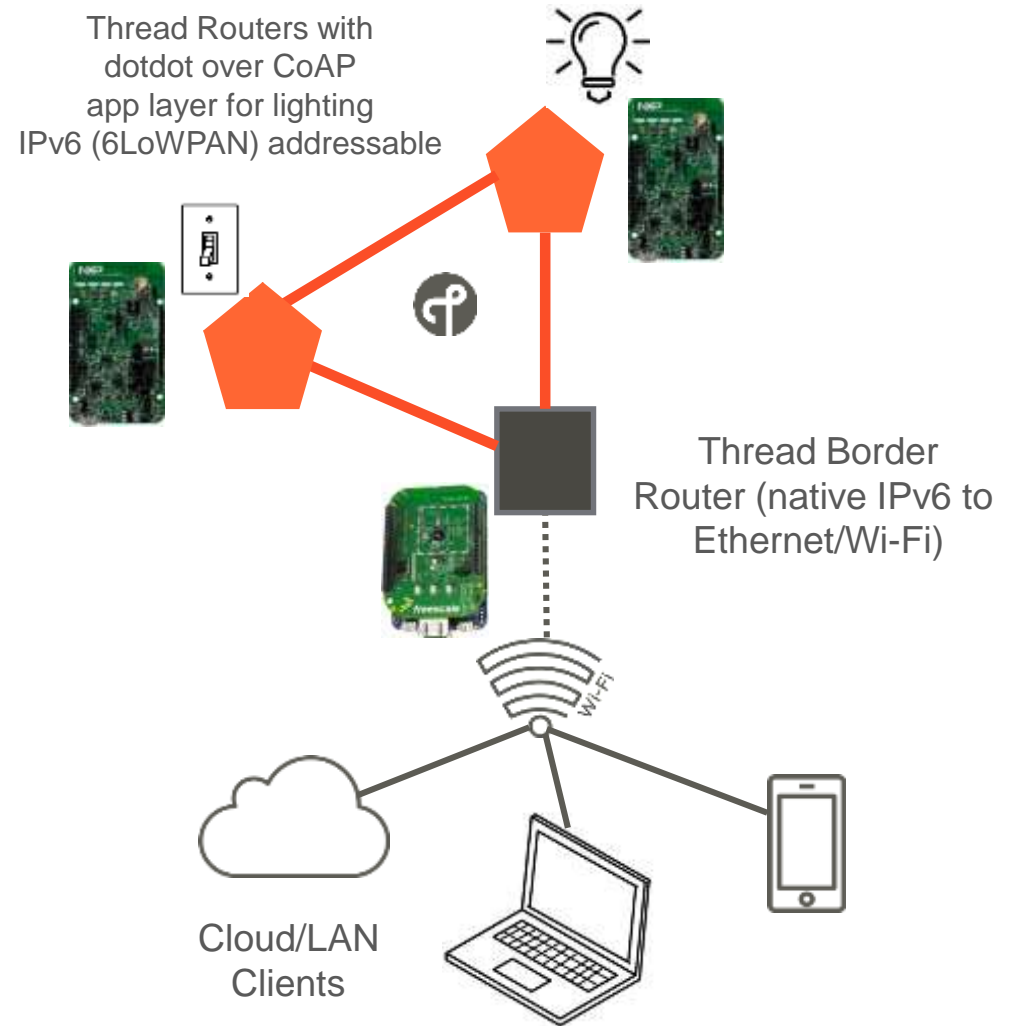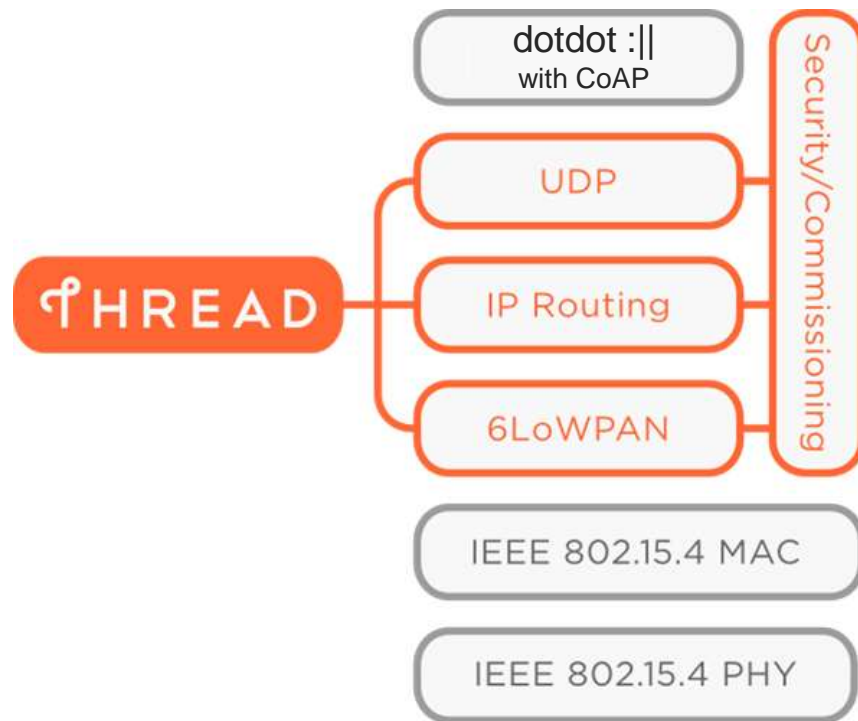application layer protocols and platforms

A software upgrade can add Thread to
currently shipping 802.15.4 products

Thread 灵活的组网方式

NXP 开发 DotDot 用于 Thread 和 Zigbee 互通

Thread Routers with dotdot over CoAP app layer for lighting IPv6 (6LoWPAN) addressable

Thread Border Router (native IPv6 to Ethernet/Wi-Fi)

Cloud/LAN Clients

dotdot :|| with CoAP

UDP

IP Routing

6LoWPAN

Security/Commissioning

IEEE 802.15.4 MAC

IEEE 802.15.4 PHY

Kinetis KW41Z/31Z/21Z

Core/System
- Cortex-M0+ running up to 48 MHz
- Four independently programmable DMA controller channels

Memory
- Up to 512kB Flash
- Up to 128 kB SRAM

Radio
- Support for BLE v4.2, 802.15.4, Generic FSK
- -95 dBm in BLE mode, -100 dBm in 802.15.4 mode
- -30 to +3.5 dBm programmable output power
- 6.8 mA Rx & 6.1 mA Tx (0dBm) current target (DC-DC enabled)
- On-chip balun with single ended bidirectional RF port

Communications/HMI/Timers
- 2xSPI, 2xI2C, LP-UART, GPIO with IRQ capability (KBI)
- Carrier Modulated Timer (CMT) for infrared transmissions
- Hardware Capacitive Touch Sensing Interface (TSI)
- 3xFlexTimer (TPM) with PWM & quadrature decode support
- Low Power (LPTMR), Programmable Interrupt (PIT) and RTC timers

Analog
- 16-bit ADC with integrated temperature sensor and battery monitor
- 12-bit DAC and 6-bit High-speed Comparator

Security
- AES-128 Accelerator and True Random Number Generator
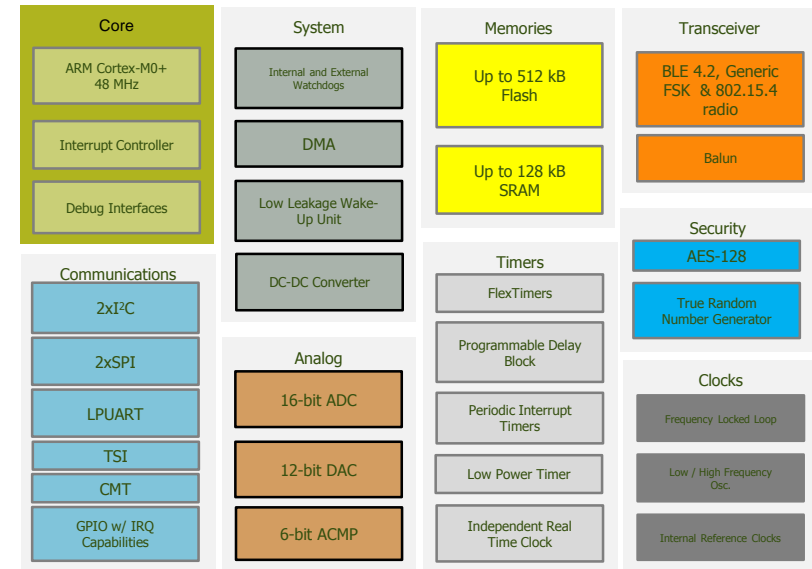- Advanced flash security

Integrated DC/DC Converter
- Normal: 1.71V to 3.6V
- Buck : 2.1V to 4.2V for coin cell operation
- Boost : 0.9V to 1.795V for single alkaline battery operation

Unique Identifiers
- 80-bit unique device ID programmed at factory
- 40-bit unique media access control (MAC) subaddress can be used for Bluetooth Low Energy or IEEE 802.15.4 MAC Address

-40ºC to +105ºC

Device	Memory (Flash/RAM)	Protocol	Package
MKW21Z512VHT4 MKW21Z256VHT4	512 kB / 128 KB 256 kB / 64 KB	802.15.4	7x7 48-pin Laminate QFN
MKW31Z512VHT4 MKW31Z256VHT4	512 kB / 128 KB 256 kB / 64 KB	BLE v4.2 / Generic FSK	7x7 48-pin Laminate QFN
MKW41Z512VHT4 MKW41Z256VHT4	512 KB / 128 KB 256 KB / 64 KB	BLE v4.2 / Generic FSK / 802.15.4 (Supports concurrent operation)	7x7 48-pin Laminate QFN

Features	Description
Software and Protocol Stacks	Bluetooth Smart Host Stack & Profiles Generic FSK (250 kbps, 500 kbps, 1Mbps) Thread Stack, IEEE 802.15.4 MAC, SMAC Thread + BLE Multi-Protocol Stack KSDK, RTOSes, IAR & KDS Support

Kinetis KW41Z/31Z/21Z: Key Differentiators

Multi-Protocol Radio – High performance radio supporting Bluetooth Smart/Bluetooth Low Energy (BLE) v4.2, Generic FSK and IEEE 802.15.4 (Thread) based standards

Large Memory – Enough memory to adequately contain desired networking stack(s) with ample room remaining for custom applications

Low Power – Low transmit, receive and standby currents that maximizes battery life, including standard coin-cells

Complete Enablement – Fully compliant, certified Bluetooth Low Energy, Thread and 802.15.4 MAC/PHY. Support for Generic FSK, BLE Mesh, SMAC, multiple RTOSes, KSDK 2.0, KDS and IAR IDEs.
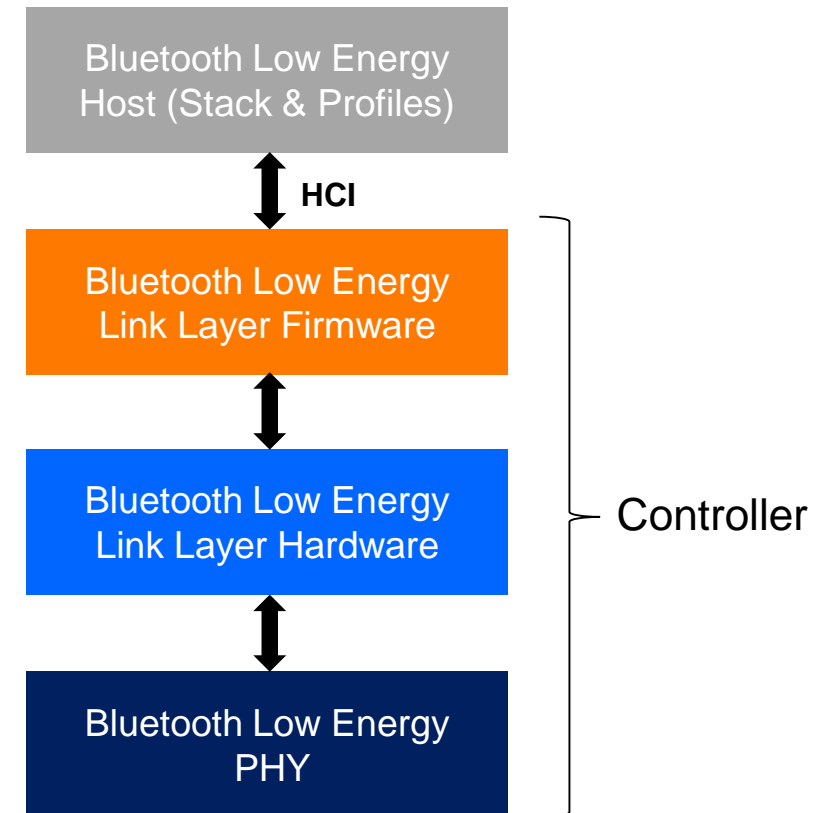
低功耗蓝牙 （BLE）

- 低功耗

- 安全

- 广泛使用

- 标准的 GATT 特性

- BLE 4.2 & BLE 5.0

NXP 开发低功耗蓝牙协议栈 Bluetooth Low Energy (BLE) Stack

- Present on KW41Z / KW31Z / QN908x

- Controller consists of Link Layer (LL) and PHY Layer

  - BLE Link Layer (Hardware and Firmware)
    - Data management
    - Link Control
    - Handle IRQ from the hardware

  - BLE Physical Layer (Hardware)
    - Setup and sustain BLE link
    - Perform low latency functions
   - Advertising, Scanning, etc
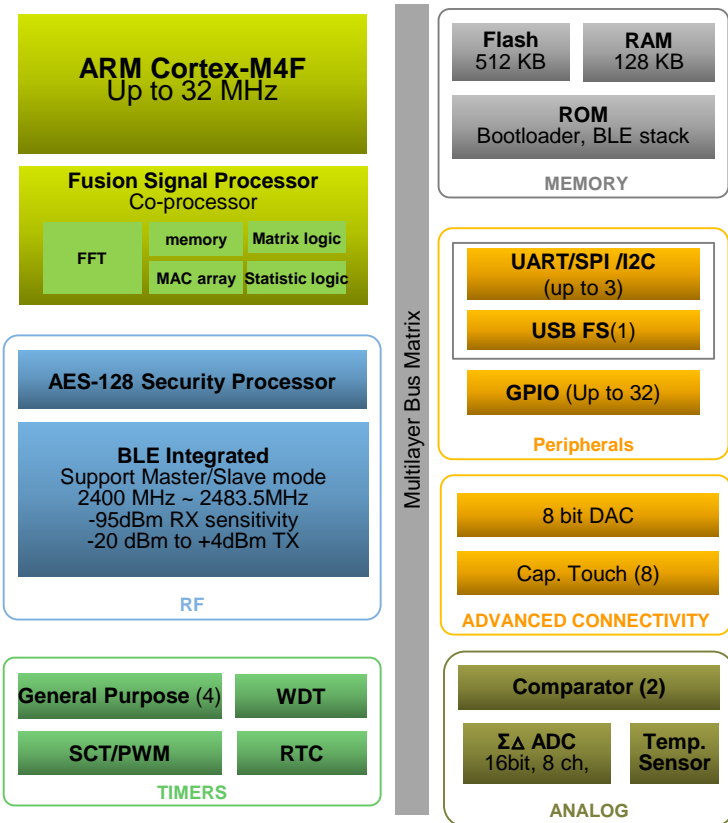   - Packet management
    - Encryption

Bluetooth Low Energy Host (Stack & Profiles)

HCI

Bluetooth Low Energy Link Layer Firmware

Bluetooth Low Energy Link Layer Hardware

Bluetooth Low Energy PHY

Controller

BLE协议栈对比 - 4.2 & 5.0

Version of Standard	Features	Description	Category	
BT 4.2	Errata	Core spec Errata of 4.1	Mandatory	✅
	LE Secure Connections	ECDH key generation, add Numeric Comparison pairing	Optional	✅
	Link Layer Privacy	Link layer resolve RPA	Optional	✅
	LE Data Packet Length Extension	Payload increase to 255 bytes	Optional	✅
BT 5.0	Errata	Core spec Errata of 4.2	Mandatory	✅
	CSA 5 features	TX power up to 20dBm	Optional	
	2Mbps PHY for LE	Higher data rate	Optional	✅
	LE Long Range	Longer range, data rate support 125/500kbps	Optional	
	LE advertising extensions	Enable longer advertising packet, more advertising channels, and more advertising type	Optional	
	High Duty Cycle Non-connectable Advertising	Reduced the minimum advertising interval for non-connectable advertising, enable high duty cycle beacon	Optional	
	LE Channel Selection Algorithm #2	Enable channel selection in sub-event	Optional	

恩智浦低功耗蓝牙选型表
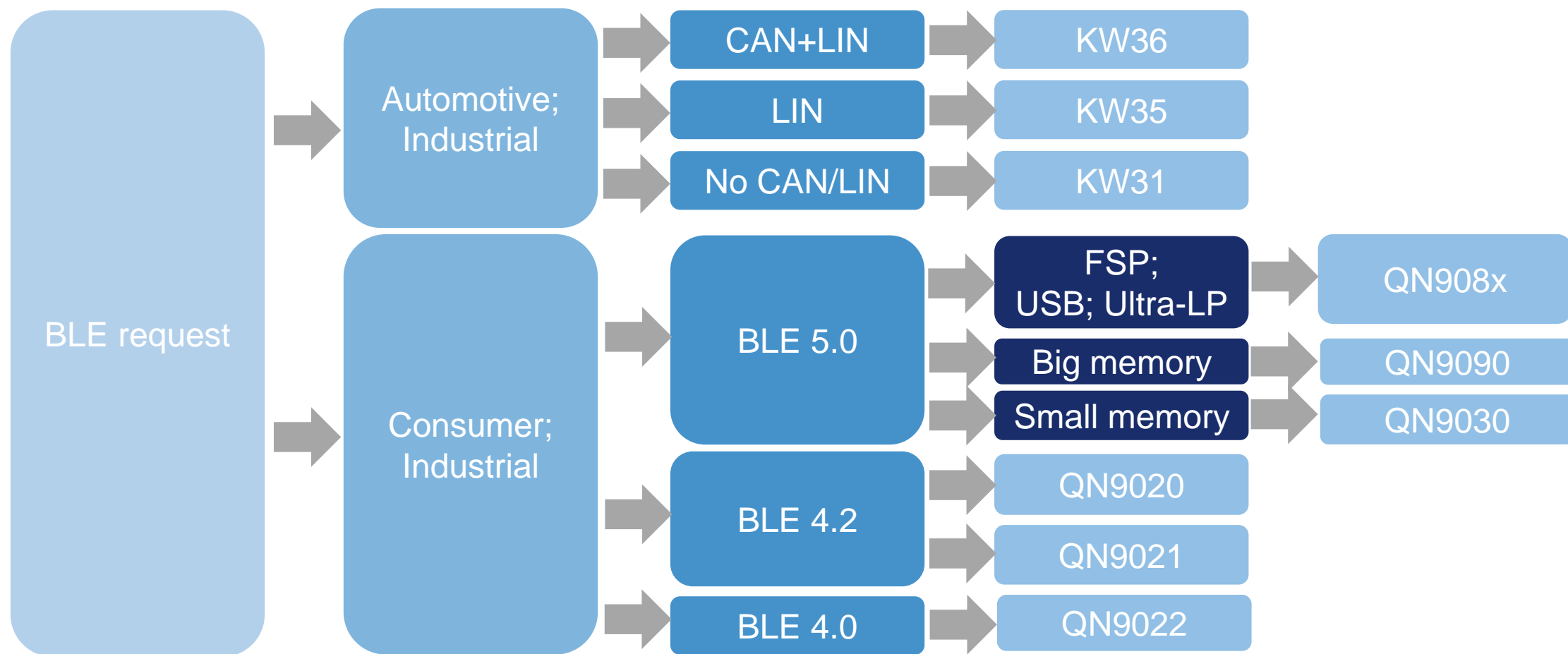
QN908x: 32MHz Cortex-M4F + FSP with 512 KB Flash Block Diagram and Key Features

Block Diagram

ARM Cortex-M4F — Up to 32 MHz

Fusion Signal Processor — Co-processor
- FFT
- memory
- Matrix logic
- MAC array
- Statistic logic

AES-128 Security Processor

BLE Integrated
Support Master/Slave mode
2400 MHz ~ 2483.5MHz
-95dBm RX sensitivity
-20 dBm to +4dBm TX

RF

TIMERS
- General Purpose (4)
- WDT
- SCT/PWM
- RTC

Multilayer Bus Matrix

MEMORY
- Flash 512 KB
- RAM 128 KB
- ROM — Bootloader, BLE stack

Peripherals
- UART/SPI /I2C (up to 3)
- USB FS (1)
- GPIO (Up to 32)

ADVANCED CONNECTIVITY
- 8 bit DAC
- Cap. Touch (8)

ANALOG
- Comparator (2)
- $\Sigma\Delta$ ADC 16bit, 8 ch,
- Temp. Sensor

CPU
- 32MHz Cortex-M4F
- Fusion signal co-processor

Memory
- 512 KB Flash, 128 KB RAM
- BLE 5.0 (LE 2M PHY)

Interfaces for connectivity & sensors
- UART/SPI/I2C up to 3
- 1 USB FS
- 8 Ch 16-bit $\Sigma\Delta$ADC,
  - 16 ENOB at 128Hz
  - 2 Ch 14 bit at 16KHz for dual Mic application
- 8 bit DAC with 1Msps
- 2 ultra low power Comparator
- SCT/PWM
- Temp. sensor
- 8 Ch Cap. Touch
- Quad-SPI for XIP

Availability
QN908x – Now

Target Applications
- Sports and fitness
- Consumer / Wearable / Personal Health Mgmt
- Gaming / Entertainment
- Home / Building Automation & Control

Packages
HVQFN48 (6 x 6 mm)
WLCSP

Other
Operating voltage: 1.62 to 3.6V
Temperature range: -40 to 85 °C

Clocks & timers
4 x general purpose timer
32K sleep timer
Watchdog timer
RTC with calibration

Basic Type	M4F+FSP	BLE Stack	Freq. (MHz)	Flash (KB)	RAM (KB)	$\Sigma\Delta$ADC	UART/SPI /I2C	USB	Cap. Touch
QN9080A (HVQNF48)	Y	ROM	32	512	128	8Ch x 16b	3	1	8
QN9083A (WLCSP)	Y	ROM	32	512	128	8Ch x 16b	3	1	8

QN908x Fusion Sensor Co-processor (FSP)

- HW accelerator for frequently used math and signal processing computations
  - Compared to Cortex-M4 FPU, primarily better with matrix inverse and 256 point FFTs
- Software APIs designed to match ARM CMSIS-DSP library
- Interrupt once calculation is complete
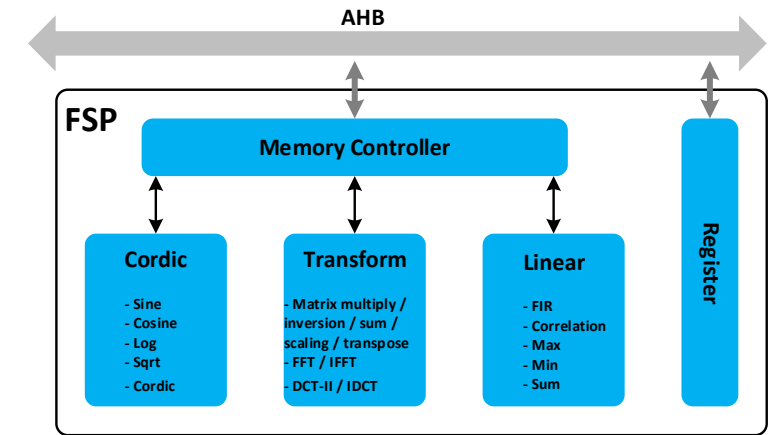
Matrix	Statistic	Transform	Linear Filter	Triangle	Nonlinear
Matrix vector multiplication	Accumulation	FFT	FIR	Sine	log
Matrix multiplication	Power Accumulation	IFFT	Xcorr	Cosine	Square root
Inverse	Max	DCT/IDCT			
Transpose	Min				
Scale					
Addition					

	FSP clock cycles	Cortex-M4F clock cycles
256-point FFT	2043	20970
Matrix multiplication (9*9 matrix)	912	8500
Matrix Inverse (9*9 matrix)	888	20972

符合车规级要求（AEC-Q100）的低功耗蓝牙芯片 Kinetis KW35/36A

Production – Sept 2018

Core/Memory/System
- Cortex-M0+ running up to 48 MHz
- KW35: 512kB (2x256kB, swappable) Program Flash with ECC; *OR*
- KW36: 256kB Program Flash + 256kB FlexNVM both with ECC;
- 64 kB SRAM
- KW36: 8 KB of user-segment defined byte write/erase EEPROM
  - Allocation of FlexNVM (minimum 32KB) to EEPROM emulation will determine effective endurance
- Four independently programmable DMA controller channels

Radio
- Support for BLE v4.2, will be upgraded to BLE 5 in Q1'2018
- Rx Sensitivity, -95 dBm BLE ,
- -25 to +3.5 dBm programmable output power
- Increased coexistence performance; Radio I/O for Wi-Fi coexistence
- 6.8 mA Rx & 6.1mA Tx (0dBm) current target (DC-DC enabled)
- Integrated balun (~9% board area savings)
- Support for 8 concurrent connections

Communications/HMI/Timers
- 2xSPI, LP-UART with LIN, 2xI2C, CMT, GPIO with IRQ capability (KBI)
- KW36: CAN-FD and 2nd UART with LIN
- 3x FlexTimer (TPM) with PWM & quadrature decode support
- Low Power (LPTMR), Programmable Interrupt (PIT) and RTC timers

Analog
- 16-bit ADC with integrated temperature sensor and battery monitor
- 6-bit High-speed Analog Comparator

Security
- AES Accelerator and True Random Number Generator
- Advanced flash security

Integrated DC/DC Converter
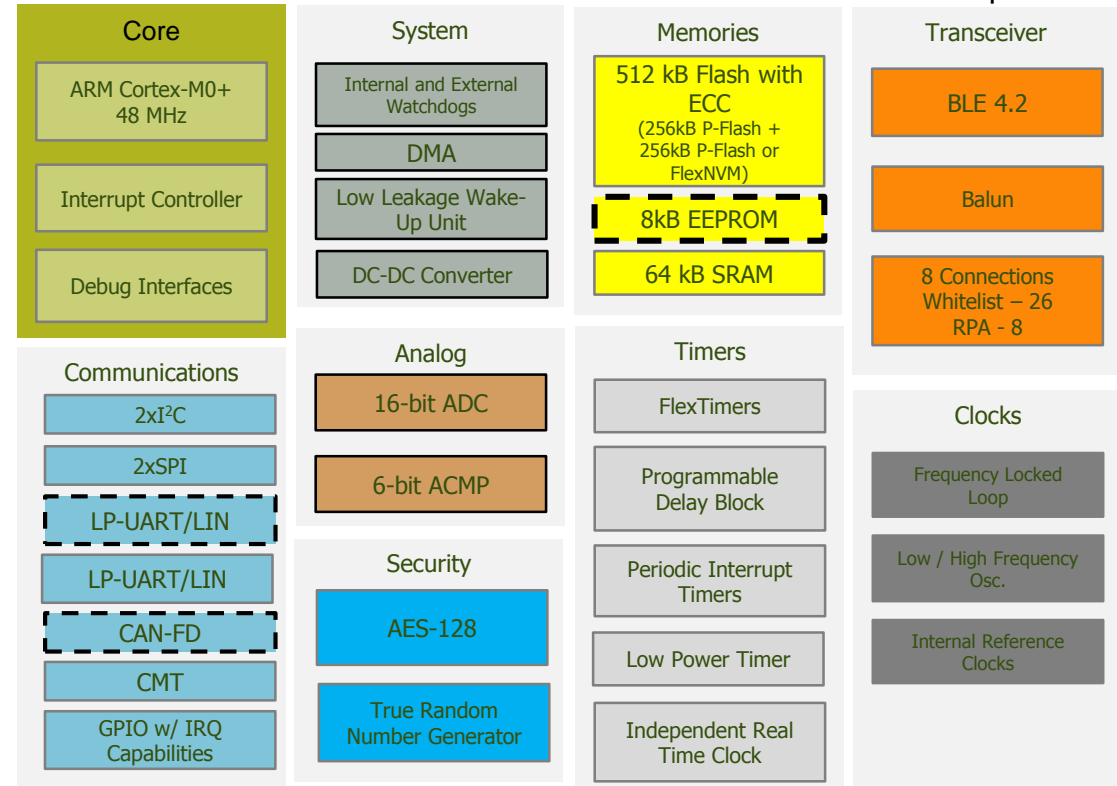- Normal: 1.71V to 3.6V
- Buck : 2.1V to 4.25V

Unique Identifiers
- 80-bit device ID programmed at factory
- 40-bit unique number can be used for Bluetooth Low Energy

AEC Q100 Grade 2
Operating Range (Ambient): -40ºC to +105ºC

Core
- ARM Cortex-M0+ 48 MHz
- Interrupt Controller
- Debug Interfaces

System
- Internal and External Watchdogs
- DMA
- Low Leakage Wake-Up Unit
- DC-DC Converter

Memories
- 512 kB Flash with ECC (256kB P-Flash + 256kB P-Flash or FlexNVM)
- 8kB EEPROM
- 64 kB SRAM

Transceiver
- BLE 4.2
- Balun
- 8 Connections Whitelist – 26 RPA - 8

Communications
- 2xI²C
- 2xSPI
- LP-UART/LIN
- LP-UART/LIN
- CAN-FD
- CMT
- GPIO w/ IRQ Capabilities

Analog
- 16-bit ADC
- 6-bit ACMP

Security
- AES-128
- True Random Number Generator

Timers
- FlexTimers
- Programmable Delay Block
- Periodic Interrupt Timers
- Low Power Timer
- Independent Real Time Clock

Clocks
- Frequency Locked Loop
- Low / High Frequency Osc.
- Internal Reference Clocks

Device	CAN FD	2nd UART with LIN	8kB EEPROM	Package
MKW36A512VFP4	Y	Y	Y	6X6 40-pin "Wettable" QFN
MKW35A512VFP4	N	N	N	
MKW36A512VHT4	Y	Y	Y	7X7 48-pin Laminate QFN

NXP

BLE MCU High-Level Comparison (Differences in Red)

	KW31Z (Industrial, Production in 2016)	KW35/36 (Automotive, Production in July 2018)
Core	48MHz Cortex-M0+	48MHz Cortex-M0+
Memory (Flash/RAM)	512kB / 128kB	512kB (ECC on Flash) / 64kB 8 kB FlexRAM EEPROM Emulation Option (KW36)
Radios	BLE 4.2	BLE 4.2 will be upgraded to BLE 5 in Q1'2018
Number of simultaneous BLE connections (HW)	2 (all types master/slave)	8 (all types master/slave) also Whitelist (26) and Resolvable Private Address (8) upgrades
Radio Tx Power / Sensitivity	+3.5 dBm at antenna connector / -95 dBm w/ balun	+3.5 dBm at antenna connector / -95 dBm w/ balun
Radio current consumption (Rx/Tx)	16.2 mA Rx & 14.7 mA Tx (0dBm) (no DC-DC) 6.8mA Rx & 6.1 mA Tx (0dBm, DC-DC)	16.2 mA Rx & 14.7 mA Tx (0dBm) (no DC-DC) 6.8mA Rx & 6.1 mA Tx (0dBm, DC-DC)
Connectivity Stacks/App layers	BLE 4.2, (KSDK, FreeRTOS, bare metal)	BLE 4.2, (KSDK, FreeRTOS, bare metal)
CAN FD	No	Yes- KW36
UARTs	LP-UART	LP-UART + 2nd UART with LIN (KW36)
Other	TSI, 12-bit DAC	removed
User Experience (IDE / OS) + Boards	KDS, IAR / FreeRTOS FRDM-KW41Z and USB-KW41Z boards	KDS, IAR / FreeRTOS FRDM-KW35Z
Package type	7x7 48 pin Laminate QFN 3.9x3.8 WLCSP (Mar'17)	7x7 48 pin Laminate QFN 6x6 40 pin QFN with wettable flanks
Qualification Tier	Industrial	Automotive (AEC Q100 Grade 2)

NXP

Use Case

BLE in Automotive – A Paradigm Shift
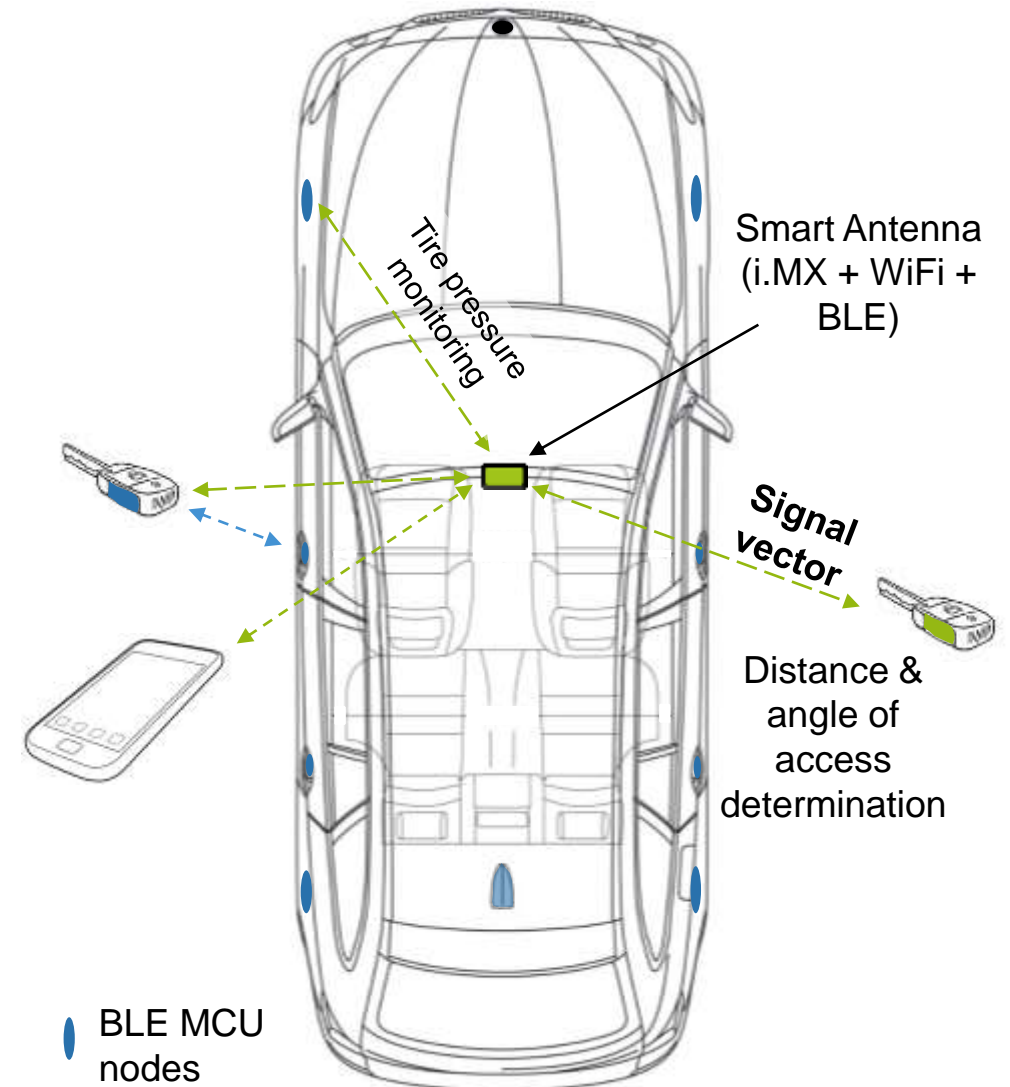
- ## Smart Mobile Devices as the Digital Key
  - Smart mobile devices communicate with the BLE MCU in the Smart Antenna using tailored BLE protocol tailored to work with the car's secure framework
    - Only authenticated smart devices (owners) are allowed access
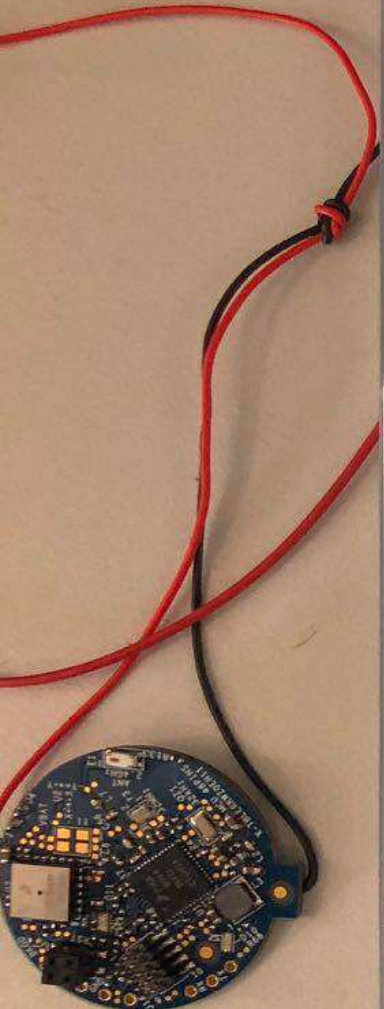   - MCU needs to support multiple concurrent connections

- ## Secure Key Fobs & Door Locks
  - Key fobs & door locks communicate directly using BLE tailored to work with the secure framework
    - BLE augments proprietary RF protocols

- ## Vehicle Condition & Status Monitoring
  - Leverage BLE in the car for monitoring & updating vehicle status to Driver Information System & smart phone
    - Tire Pressure Monitoring systems, customized seat settings, service reminders, trouble codes, etc.
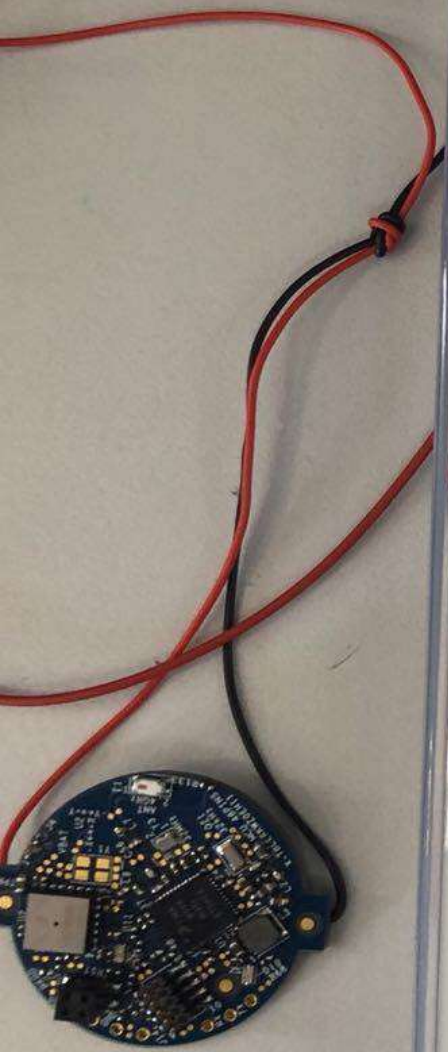
Tire pressure monitoring

Smart Antenna (i.MX + WiFi + BLE)

Signal vector

Distance & angle of access determination

BLE MCU nodes
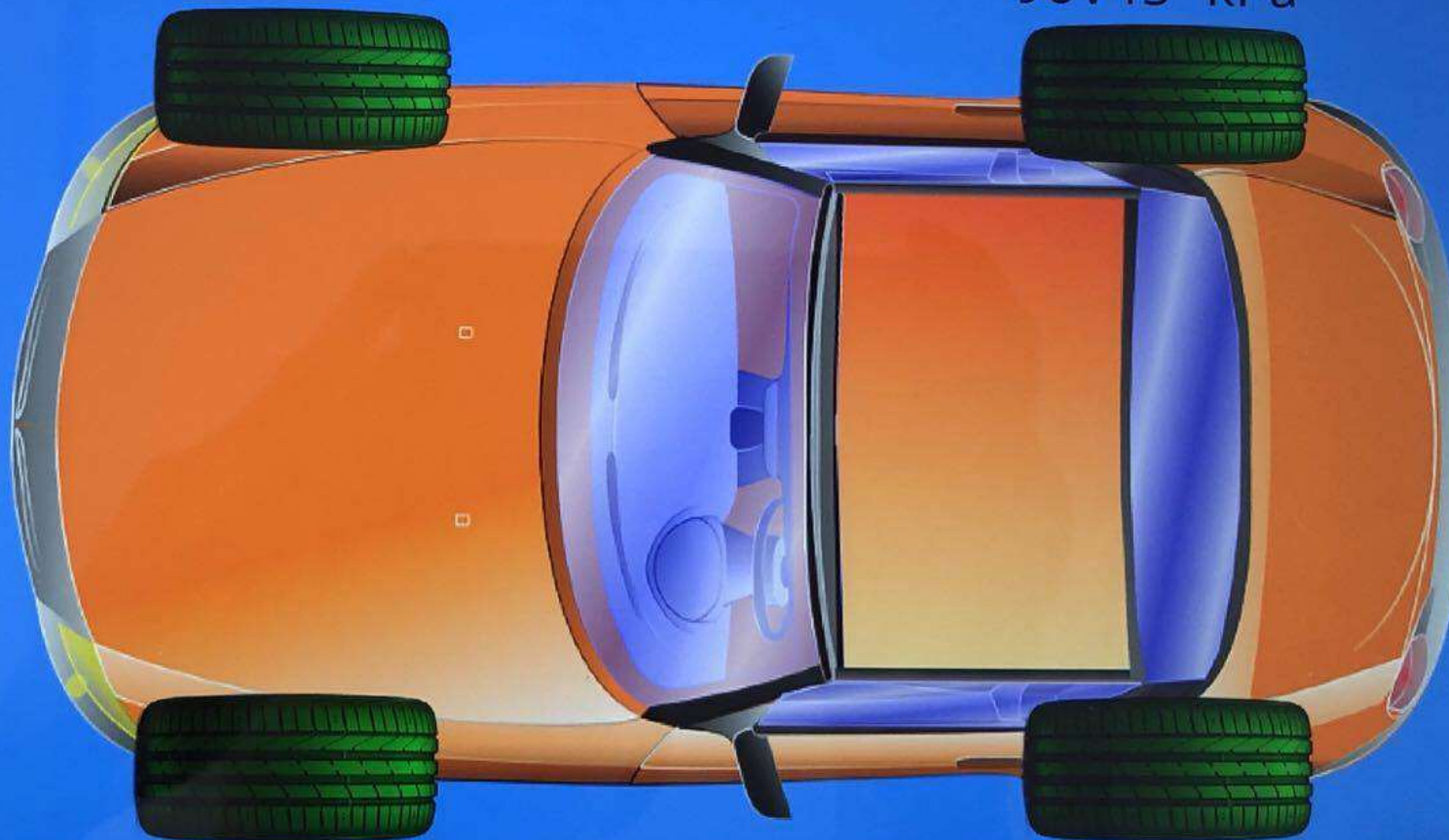
# NXP Multi-Protocol Application (Thread/Zigbee + BLE)

Door Lock using Thread/Zigbee and Bluetooth Low Energy

Smart Door Lock contains KW41Z Multi-Protocol Radio
- Bluetooth Low Energy
- Thread/Zigbee (802.15.4)

Direct and Network Controlled and Monitoring
- Out-of-band commissioning of device on Thread network using BLE
- Control directly from BLE enabled phone
- Control and monitoring using cloud connected Thread mesh network

Thread Network

Smart Door Lock

BLE Direct Communication

Wi-Fi
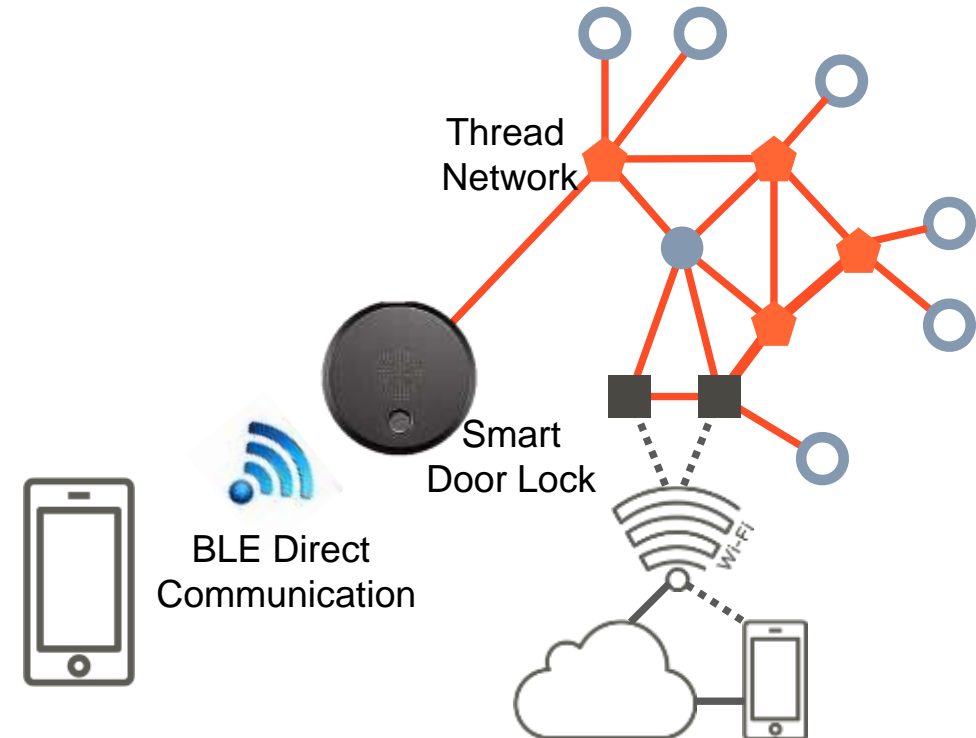
SECURE CONNECTIONS
FOR A SMARTER WORLD