



Low Power Wireless Solutions for Industrial IoT

STEVEN LIN/林仕文 | SR. FAE, TAIWAN



Silicon Labs

A leading provider of silicon, software and solutions for a smarter, more connected world

- Core competencies in mixed-signal and RF integration
- A track record of multiple industry firsts, transforming and disrupting large markets
- Focus on high-quality, diversified markets positioning us well for sustainable growth
- Scalable, fabless manufacturing model



FOUNDED IN 1996



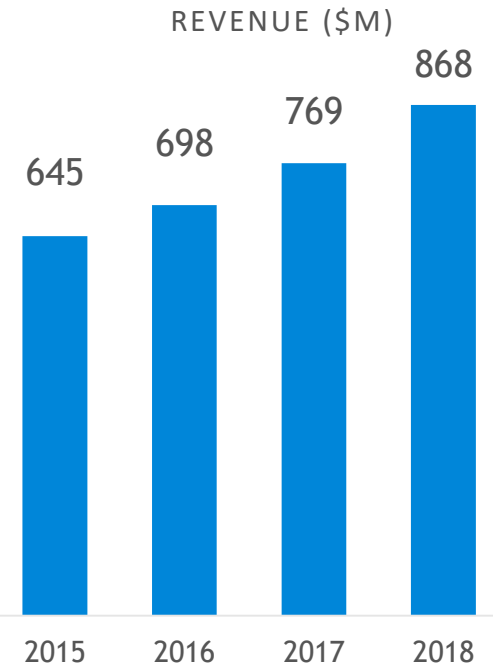
LISTED SLAB



~35,000 CUSTOMERS



>1,700 PATENTS



2015, 2016, 2017, 2018 and 2019 MOST RESPECTED SEMICONDUCTOR COMPANY

We are the Leader in IoT Wireless Connectivity

Innovation

- Enabling wireless adoption and time-to-market

Longevity

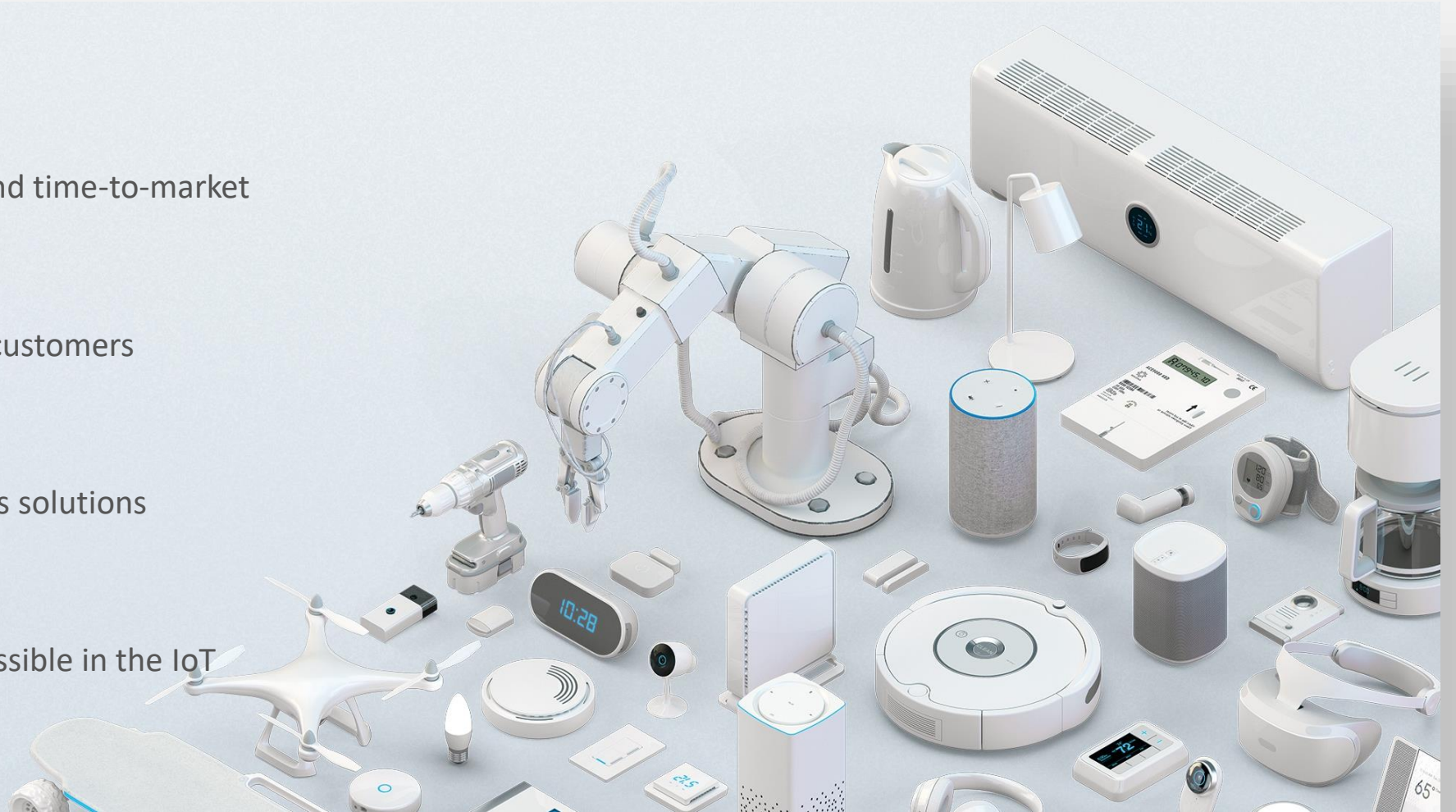
- Commitment to IoT and our customers

Platform

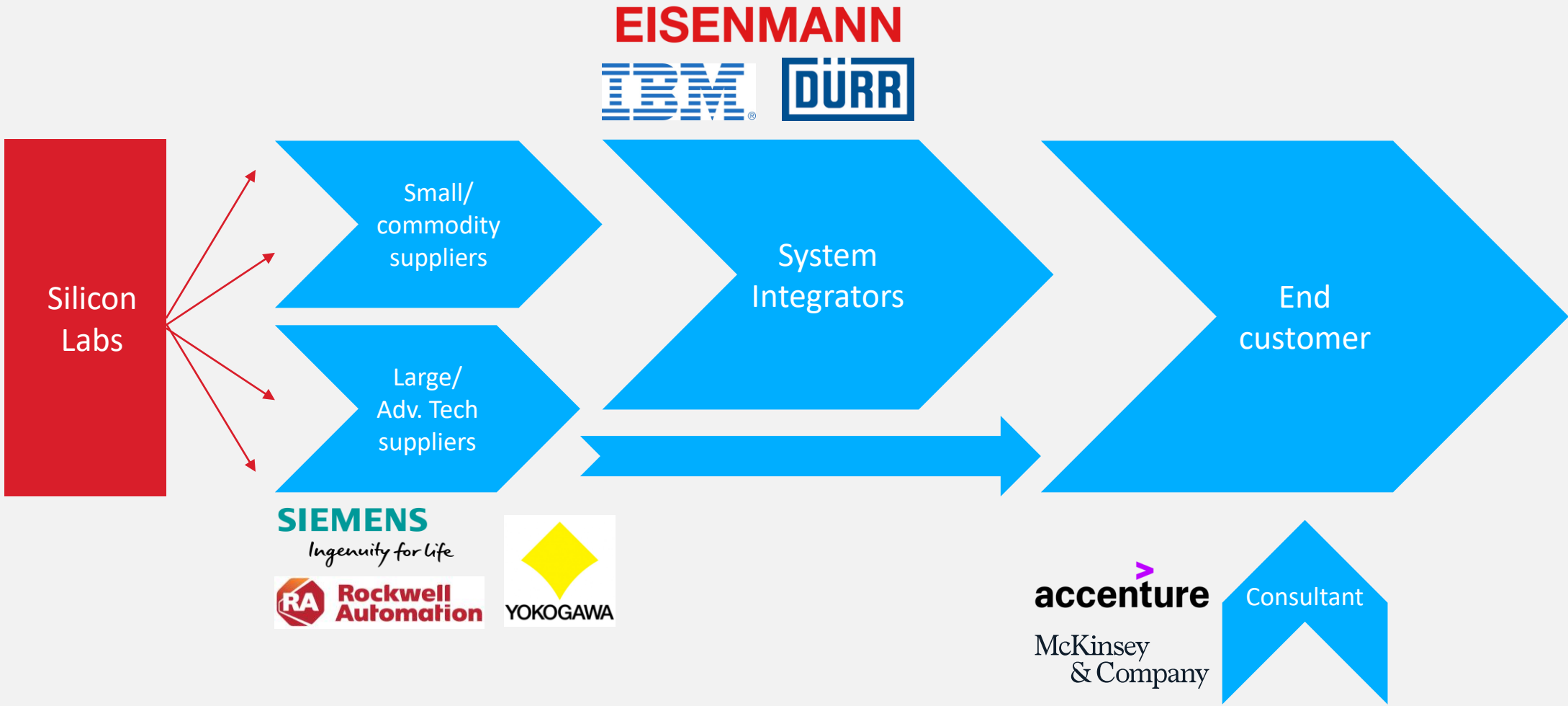
- Breadth and depth of wireless solutions

Series 2

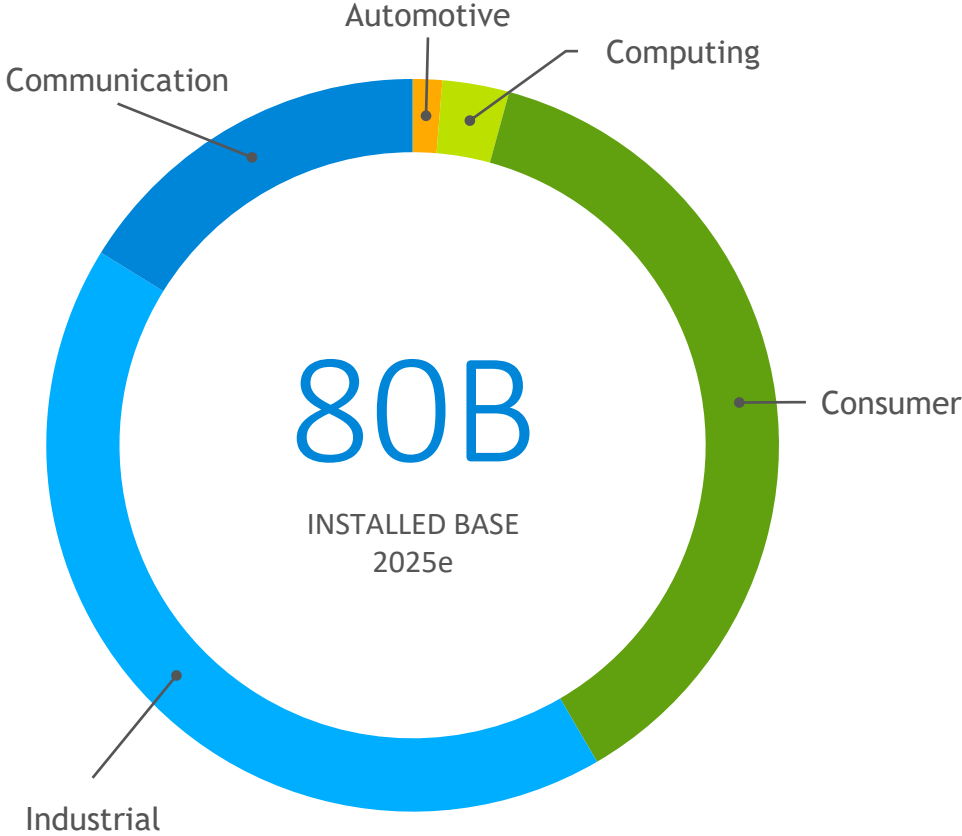
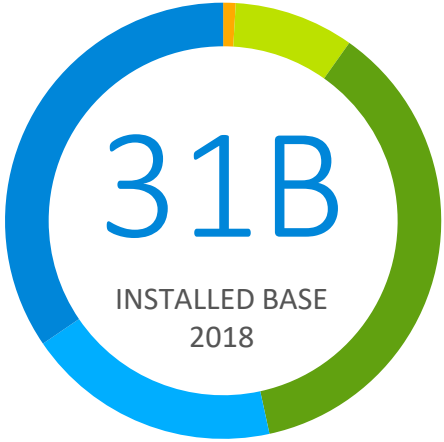
- Further advancing what is possible in the IoT



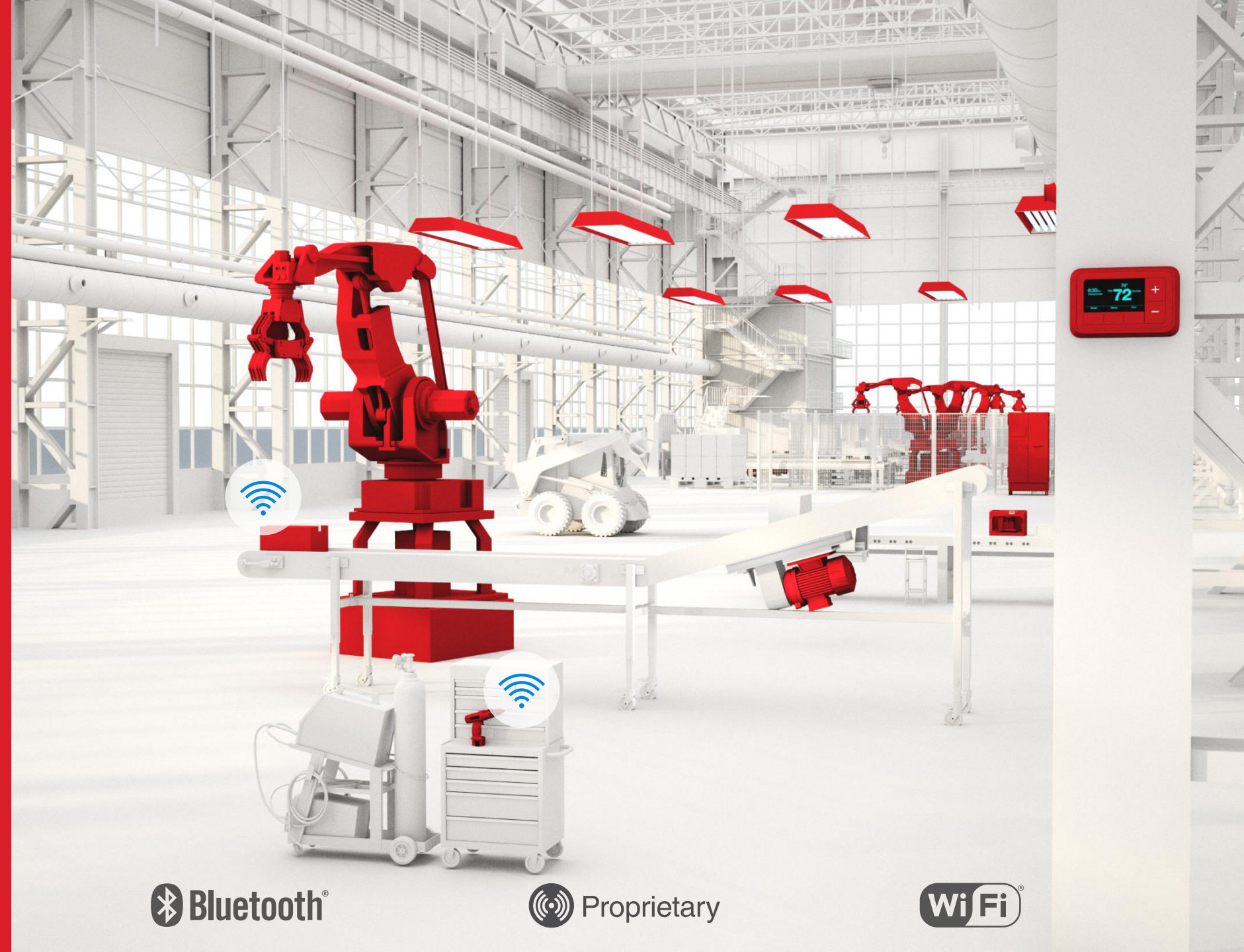
The industrial automation value chain



The Industrial IoT Opportunity



Source: IHSMarkit IoT Tracker 2018 Q3, WSTS Autumn 2018 and Silicon Labs' estimates.



Asset Tracking

- Protect your workforce, equipment and inventory across large areas with advanced, reliable wireless devices that power real-time location systems (RTLS)

How It Works

- Asset tags broadcast Bluetooth beacons in manufacturing facilities
- Bluetooth mesh or Sub-GHz nodes receive beacons and passes location data to a gateway
- Gateway sends relevant asset location information to a cloud application





Connected Lighting

Reduce energy consumption, customize settings by work area, and control lighting from remote locations

How It Works

- Large scale mesh network connects lights, luminaires, controls and switches
- Bluetooth mesh, Sub-GHz, Thread or Zigbee technologies are ideal for mesh networking
- Multiprotocol connectivity enables a multi-function IoT wireless backbone



Smart Energy Management

Generate electricity and heat water with a wireless smart energy system that provides factory operators the ability to reduce costs and better manage energy usage

How It Works

- Industrial-grade LPWAN provides connectivity to solar panels, smart meters, thermostats, HVAC and environmental sensors throughout the facility
- Multiprotocol Sub-GHz and Bluetooth IoT wireless network provides simultaneous long-range device-to-device communications and direct smartphone connectivity
- Direct smartphone control simplifies device set-up, monitoring, and maintenance





Process Automation

Connect machines, devices, sensors and people to a system that automates factory tasks including production, maintenance, quality control, and reporting

How It Works

- LPWAN or mesh networks provide the wireless reach to factory automation sensors located throughout the premises
- Bluetooth mesh, Sub-GHz, Thread or Zigbee all meet the needs of low-power sensor applications
- IoT gateways provide cloud connectivity and enable remote management



Industrial automation segmentation

MONITORING	INTERFACING	NETWORKING
		
 BT Mesh		
 Proprietary		 Proprietary
 BLE		 Wi-Fi
 802.15.4 Mesh		 802.15.4 Mesh
<p style="text-align: center;">Security</p>		

Why is security important in industrial automation?

CONFIDENTIALITY



Ensures the data is only readable by the proposed destination

AUTHENTICATION



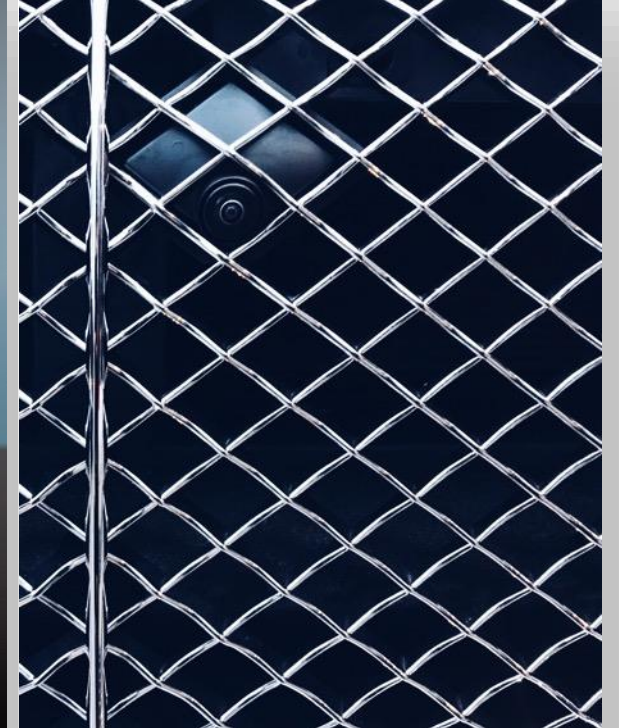
Ensures the supposed sender is the real sender

INTEGRITY



Ensures the information contained in the original message is kept intact

PRIVACY



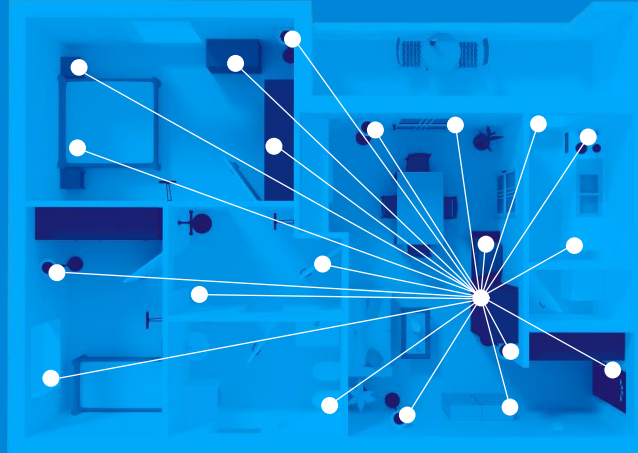
Ensures only the desired end devices and gateways are part of the network

The 4 Main Features of IoT Security

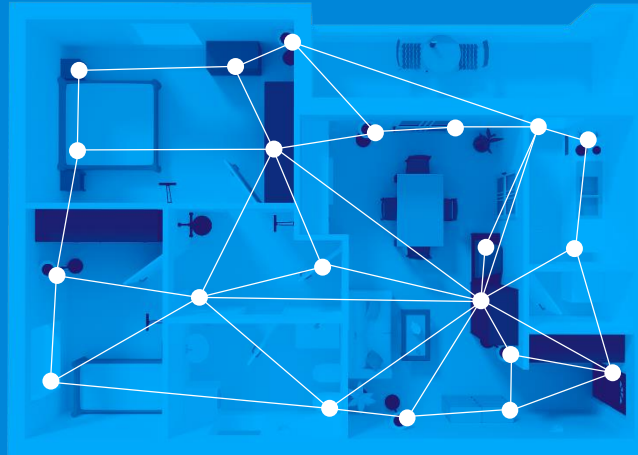
The Benefits of Mesh Networks



Star Network



Mesh Network



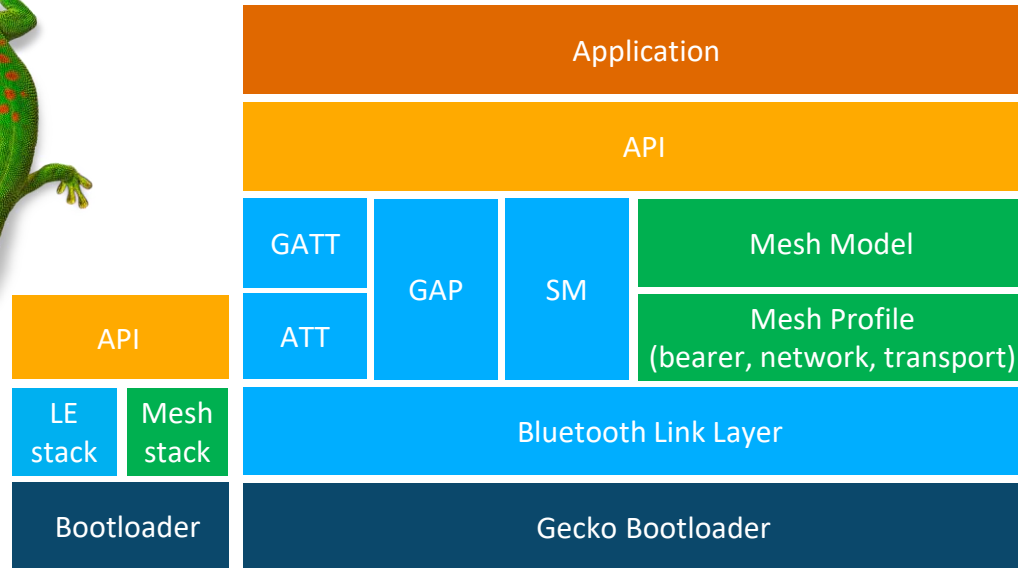
- **Extend the range** of connections from gateways or mobile devices with multi-hop communication
- **Reduce power consumption** in a system with shorter transmission distances between devices
- **Increase system scale** by supporting hundreds of devices in a single subnet
- **Improve system reliability** with self-healing networks that overcome node failures
- **Deliver optimal responsiveness** with device to device communication

Series 1 Gecko Wireless MCUs



	Z-WAVE	ZigBee	THREAD	Bluetooth	Proprietary wireless	
Zen Gecko	✓					256 – 512 kB Flash Up to 13 dBm Sub-GHz QFN32, LGA64
Mighty Gecko		✓	✓	✓	✓	256 – 1024 kB Flash Up to 19.5 dBm Sub-GHz + 2.4 GHz QFN32, QFN48, BGA125
Blue Gecko				✓	✓	128-1024 kB Flash Up to 19.5 dBm 2.4 GHz and Sub-GHz QFN32, QFN48, WLCSP43, BGA125
Flex Gecko					✓	32-1024 kB Flash Up to 19.5 dBm Sub-GHz + 2.4 GHz QFN32, QFN48, BGA125

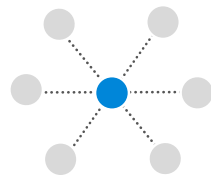
Silicon Labs Bluetooth Software: Bluetooth 5.1



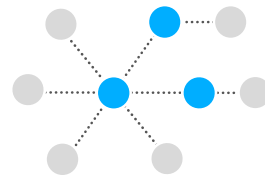
Beacon



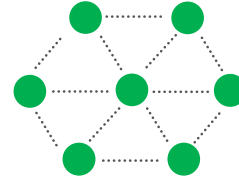
Point to Point



Star



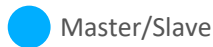
LE dual topology



Mesh



Master



Master/Slave



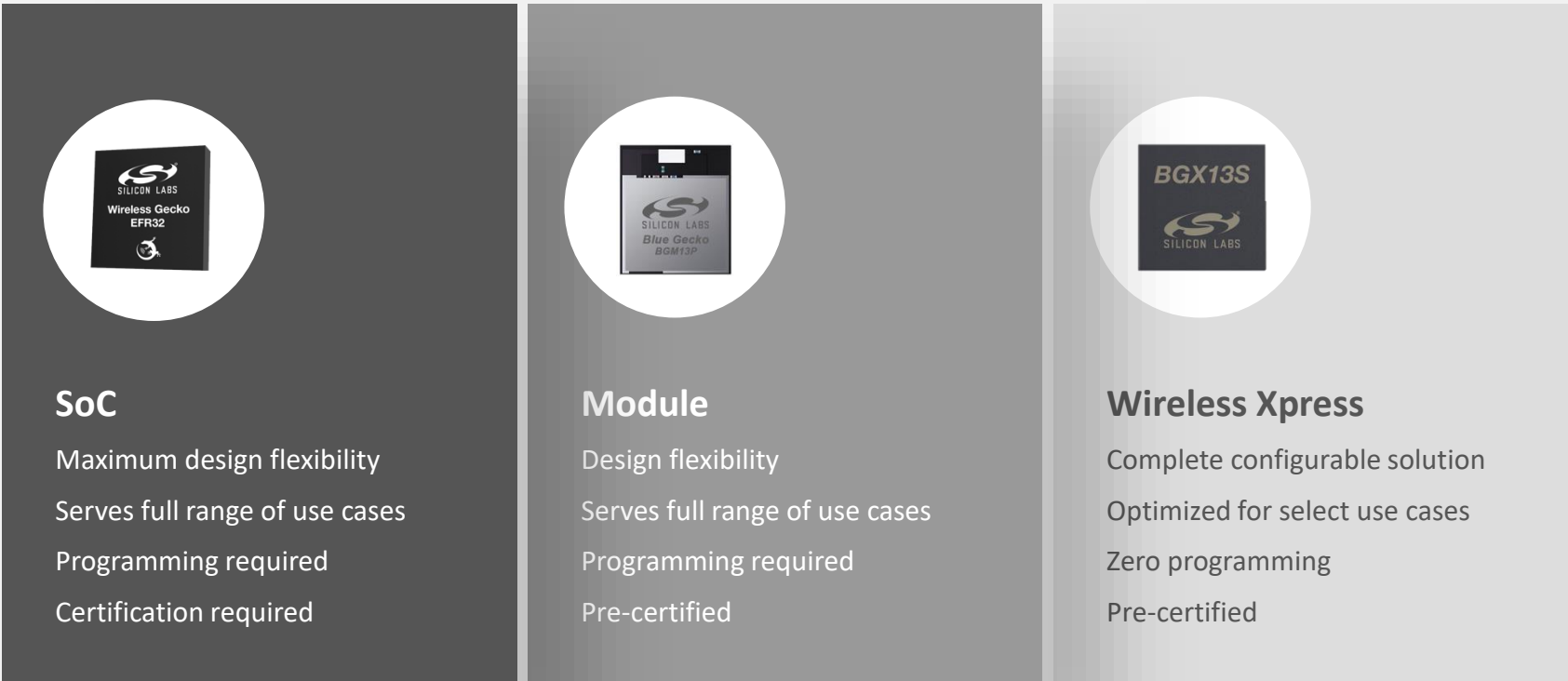
Slave



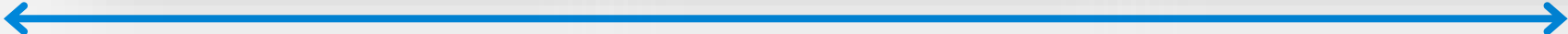
Mesh

- Bluetooth 5.1
 - AoA
 - GATT caching
- Bluetooth 5
 - 1M, 2M and LE Coded PHYs
 - Extended advertising: large packets and all channels and PHYs
 - Periodic advertising
 - Advertisement sets & scan event reporting
- Bluetooth 4.2 features
 - LE Secure Connections and LE Dual Topology
 - LE Data Length Extensions and LE Privacy 1.2 (slave) and whitelisting
- Central/Peripheral/Advertiser and Scanner
 - Up to 16 connections and 5 advertisement sets
 - Any combination of advertiser, scanner and LE connections or mesh
- Any GATT based service or profile
- Secure OTA over GATT

A Wireless Solution For Every Application



Design flexibility



Time-to-market

Bluetooth Xpress Modules



[BGX13P PCB module](#) | [BGX13S SiP Module](#)

- **Out-of-the-Box Bluetooth to UART cable replacement**
 - No firmware development needed
 - Built-in Xpress streaming service for data transfer
 - Streamlined framework for mobile app development
 - Xpress Configurator tools for graphical feature configuration
 - Built-in antenna and certifications for fastest time to market
- **Bluetooth features**
 - 1M and 2M PHYs
 - Up to 40kbps throughput
 - LE Secure connections and privacy
 - Custom Bluetooth service for data streaming
 - Operates in either central or peripheral role
 - Transmit at +8 dBm
- **Interfaces**
 - UART-to-Bluetooth data interface
 - Simple Xpress command API for configuration and control
 - Additional pins for connection state control
 - Configurable BLE throughput, GPIO and status LEDs

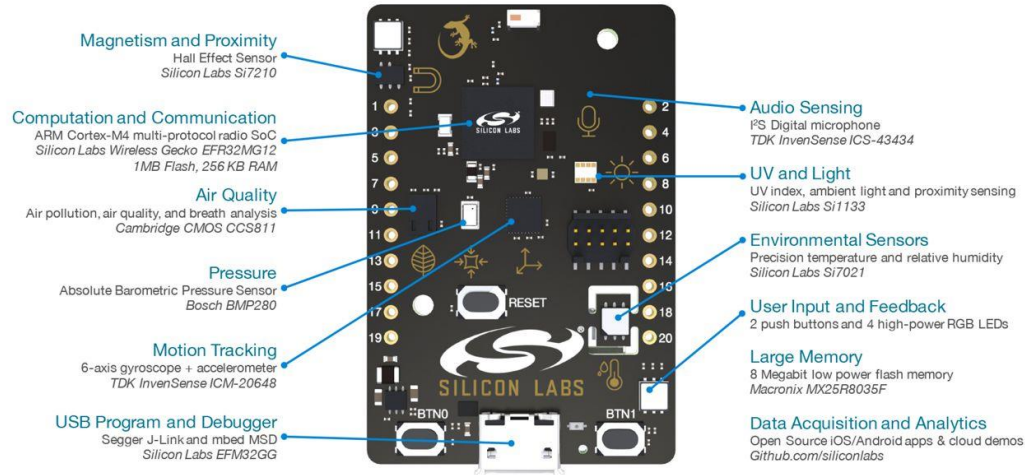


Getting started with Bluetooth Xpress

Getting started with Bluetooth Xpress

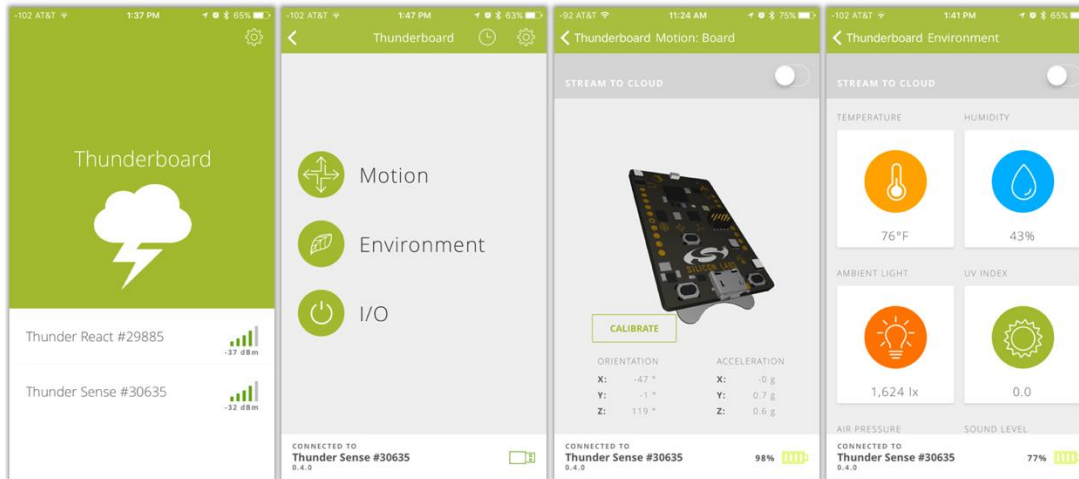
- https://www.youtube.com/watch?v=W7qs_NGS1bU

Thunderboard Sense 2 IoT Kit



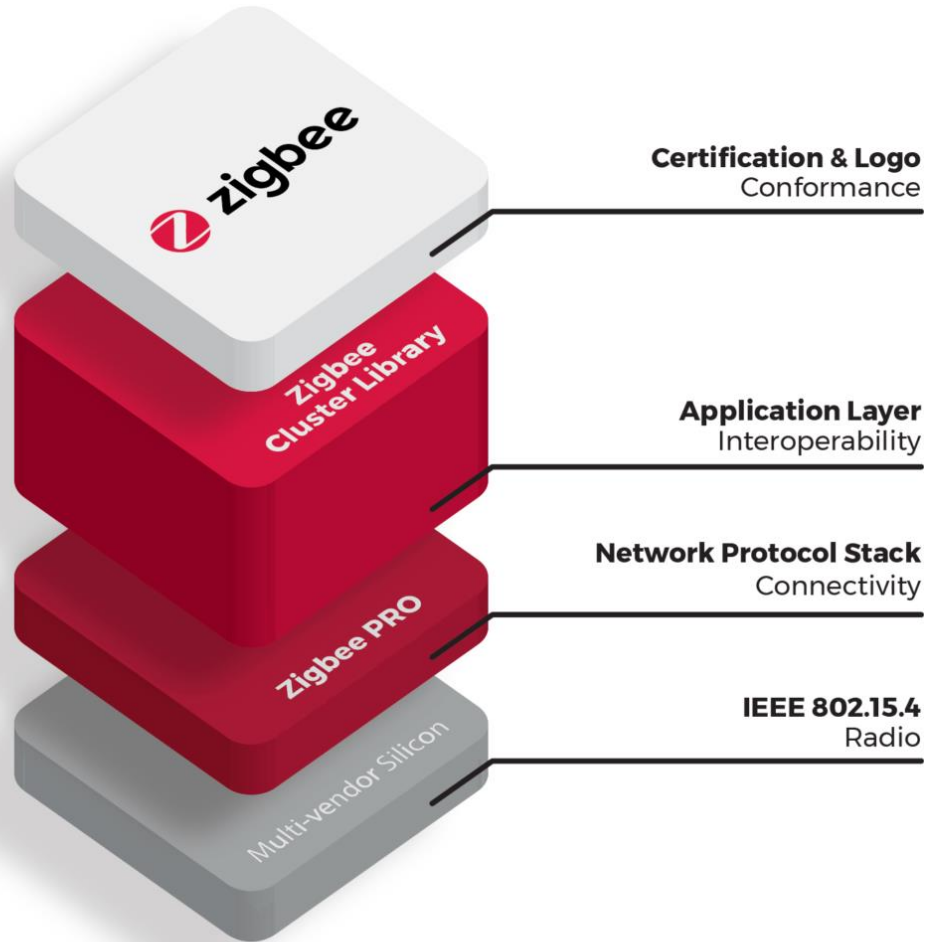
Thunderboard Sense 2

- Adds EFR32xG12 SoC with Bluetooth 5, 256kB RAM and 1M Flash
- Bluetooth 5 (2M and $\mathcal{A}\mathcal{E}$) and Bluetooth mesh capable
- Digital PDM microphone
- [Magnetic Hall effect sensor](#)

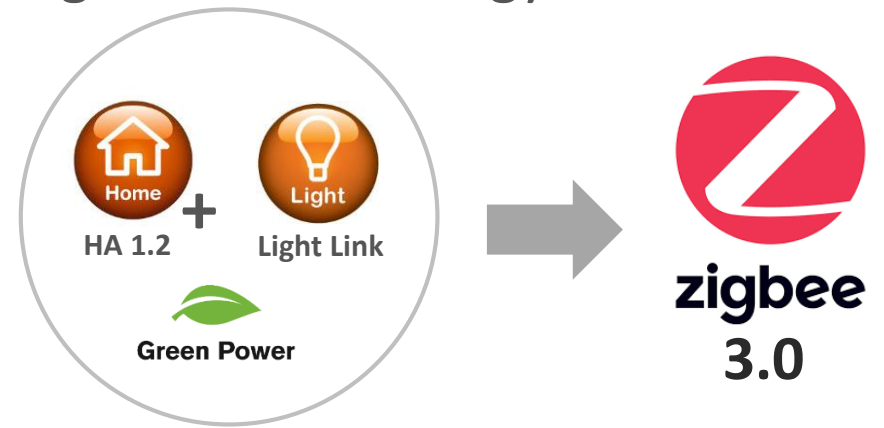


Kit OPN	Target Device	SRP	New SRP
SLWSTK6020B	EFR32BG13, BGM13, BG1	\$149	\$99
SLWSTK6023A	EFR32BG21, BGM21	N/A	\$99
SLEXP8027A	BGX13P	\$46	\$19.99
SLTB004A	Thunderboard Sense 2	\$36	\$19.99

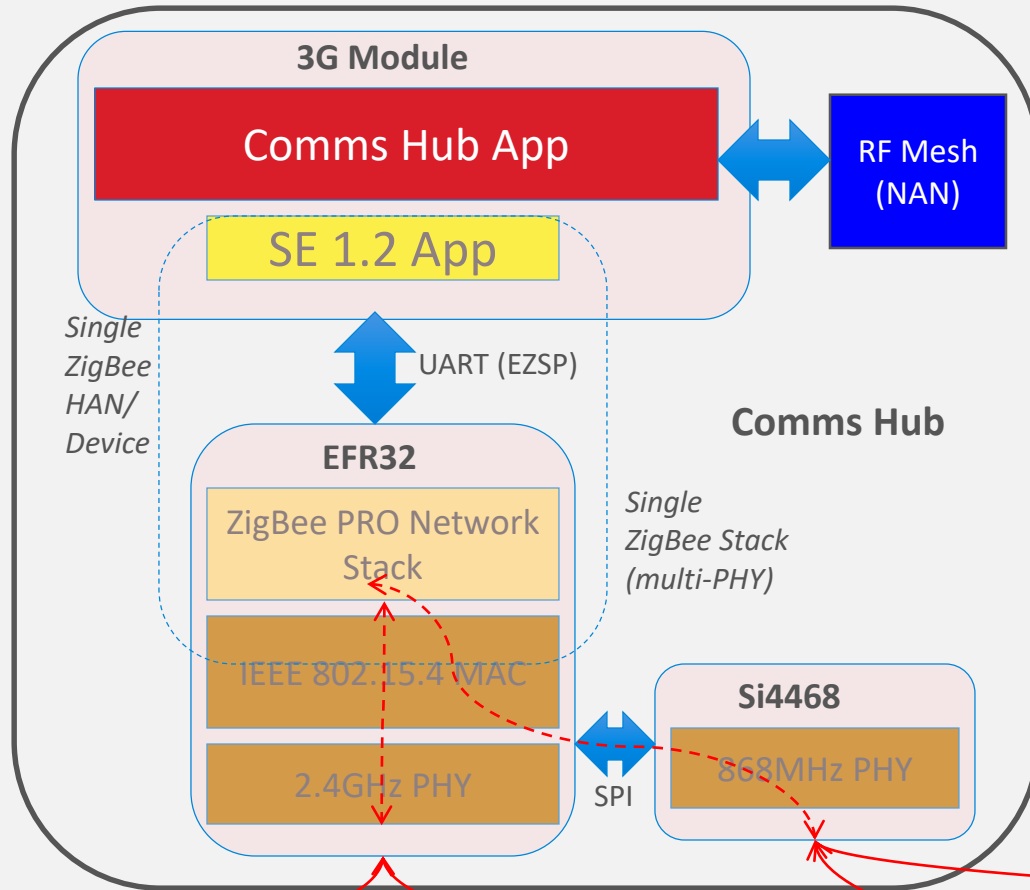
Zigbee Overview



- Zigbee 3.0
 - Unification of Zigbee profiles (except Smart Energy and RF4CE)
 - Enhanced networking and security
 - Backwards compatible
 - Mandated since May 2017
- Zigbee Smart Energy 1.4



SE1.4 – Communications Hub Architecture



- All devices appear on a single ZigBee Smart Energy 1.4 HAN
- Single ZigBee stack manages all ZigBee network traffic on both frequencies
- Both radios able to receive simultaneously
- Application does not know or care which frequency a device is on



Electric Meter (2.4GHz)



Display (2.4GHz)







Display (868MHz)



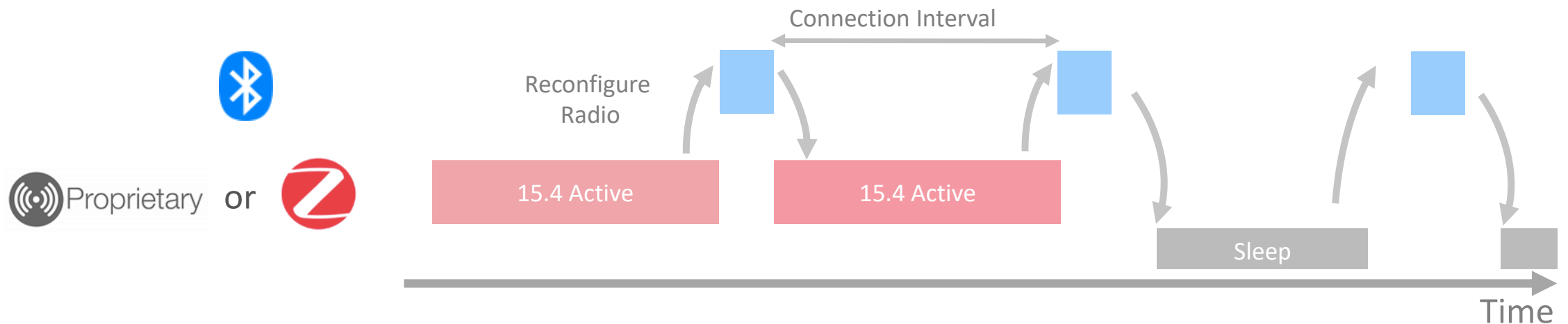
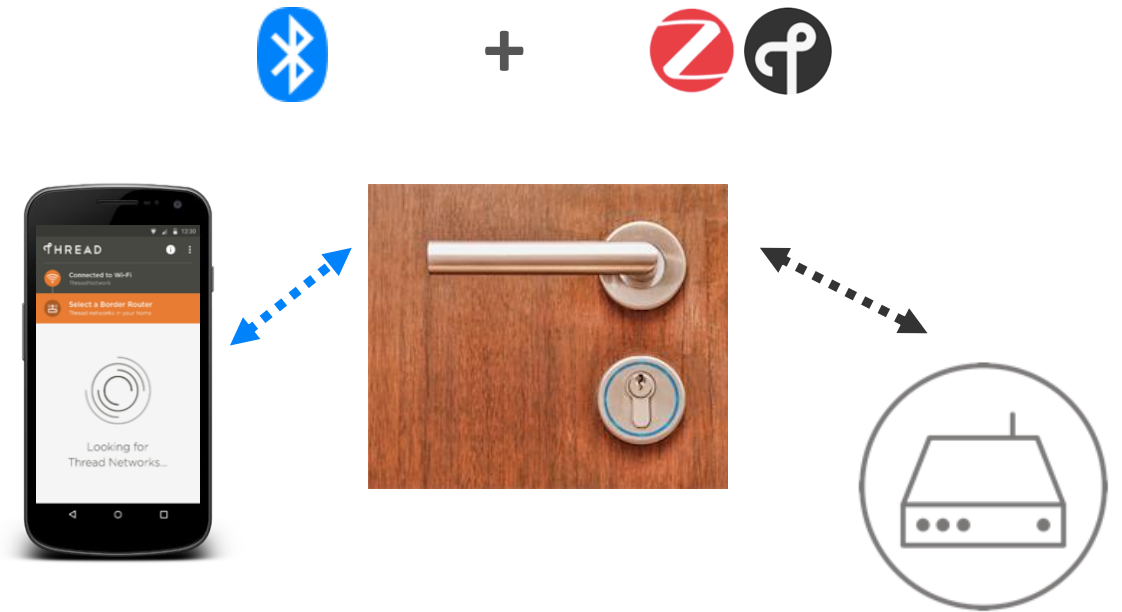
Gas Meter (868MHz)

Proprietary Solutions - The FLEX SDK

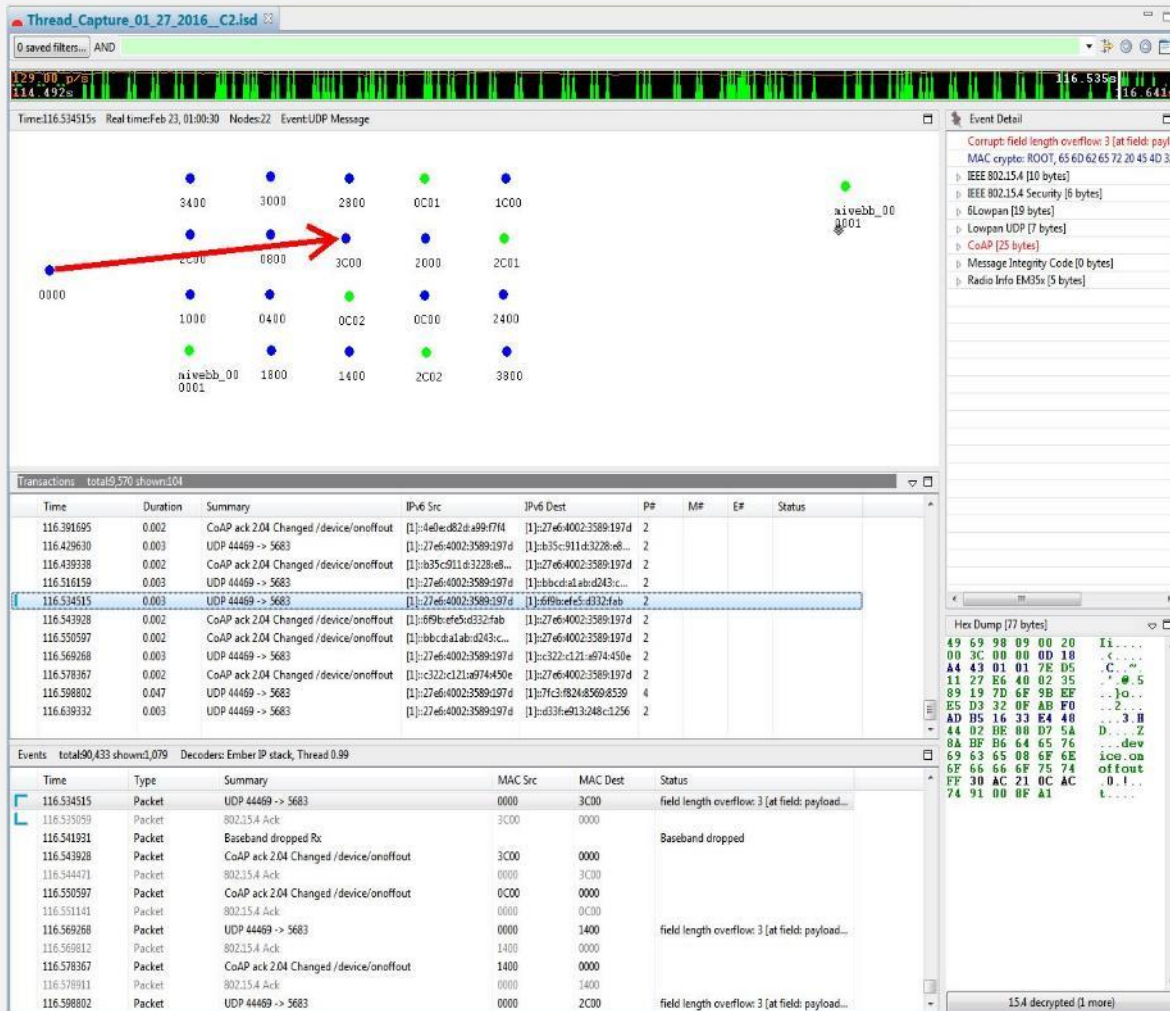
	 Bluetooth		 THREAD		 zigbee		FLEX SDK  Proprietary	
Application	Customer Application		Customer Application		Customer Application		Customer Application	
	GATT (profiles / services)	Mesh Models (e.g. lighting)	Application Layer (e.g. dotdot, CoAP)		Application Profile (e.g. HA1.2, ZLL, dotdot)			
Network / Transport	Bluetooth LE Core	Bluetooth Mesh Core	UDP		zigbee Core Stack		Connect Stack	Customer Proprietary Stack
			IPv6, Mesh Routing					
			6LoWPAN					
Link	Bluetooth Link Layer		IEEE 802.15.4 MAC		IEEE 802.15.4 MAC		IEEE 802.15.4 like MAC	
Physical	Bluetooth PHY (2.4 GHz)		IEEE 802.15.4 PHY (2.4 GHz)		IEEE 802.15.4 PHY (2.4 GHz)		Proprietary PHY (2.4 GHz or Sub-GHz)	
Platform	RAIL		RAIL		RAIL		RAIL	
	Common Bootloader		Common Bootloader		Common Bootloader		Common Bootloader	

Dynamic Multiprotocol (DMP)

- Time-sliced operation between 2 stacks running on Micrium RTOS
- Enables direct phone connectivity for local control and diagnostics
- Maintains critical Bluetooth connection interval timing
- Sleep mode support for low power



Network Analyzer



- Network-wide view of all packet activity
 - Correlates network traffic into events
 - Custom decoding and filtering options
 - Log files accelerate Silicon Labs support
- Uses unique Packet Trace Port (PTI) feature
 - 2-wire interface
 - Outputs every packet TX/RX with link quality
 - Can be used to output application debug statements



Advanced system-wide network debug and support

Network Analyzer

- Editor Panes

- Adapters
- Map
- Transactions
- Events
- Event Details
- Hex Dump
- Filters
- Tools

The screenshot shows the Network Analyzer interface with the following components:

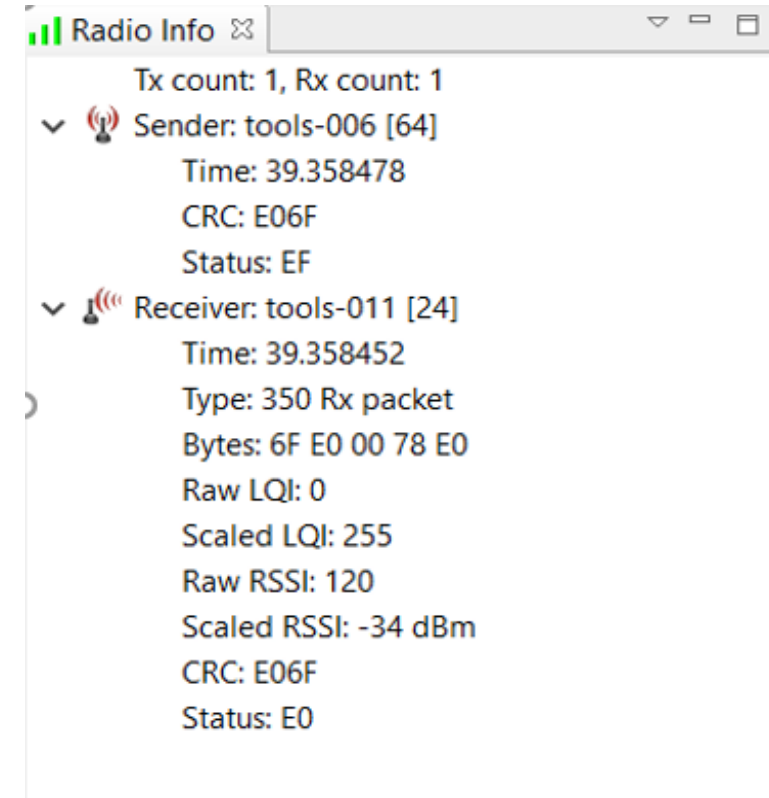
- Toolbar:** Located at the top, containing various icons for file operations, filters, and analysis tools.
- Debug Adapters:** A list on the left showing connected devices like 'J-Link Silicon Labs (440095438)' and 'PC01-ISA3 (10.6.54.99)'. A red box highlights this list.
- Map:** A central visualization showing a network topology with nodes and connections. A red box highlights the map area.
- Transactions Table:** A table listing network transactions with columns for Time, Duration, Summary, NWK Src, NWK Dest, P#, M#, E#, and Status. A red box highlights this table.
- Events Table:** A table listing events with columns for Time, Type, Summary, MAC Src, MAC Dest, and Status. A red box highlights this table.
- Event Detail:** A pane on the right showing details for a selected event, including protocol layers like IEEE 802.15.4 and ZigBee Network Security. A red box highlights this pane.
- Hex Dump:** A pane at the bottom right showing the raw hex data of the selected event. A red box highlights this pane.

Differences between using PTI and sniffer

- Advantages when capture packet trace using PTI directly
 - EZSP trace (super important to debug host/NCP issues)
 - API trace and debug prints(enable the debug extended library plugin)
 - Dropped/corrupted packets (could provide useful hints in debugging certain tricky problems)
 - Know what the radio sends/receives without extra work
 - Can capture from multiple nodes simultaneously

2.410207	Packet	Data Request
2.410763	Packet	802.15.4 Ack
2.411828	UART	slept for 955 ms
2.411865	UART	

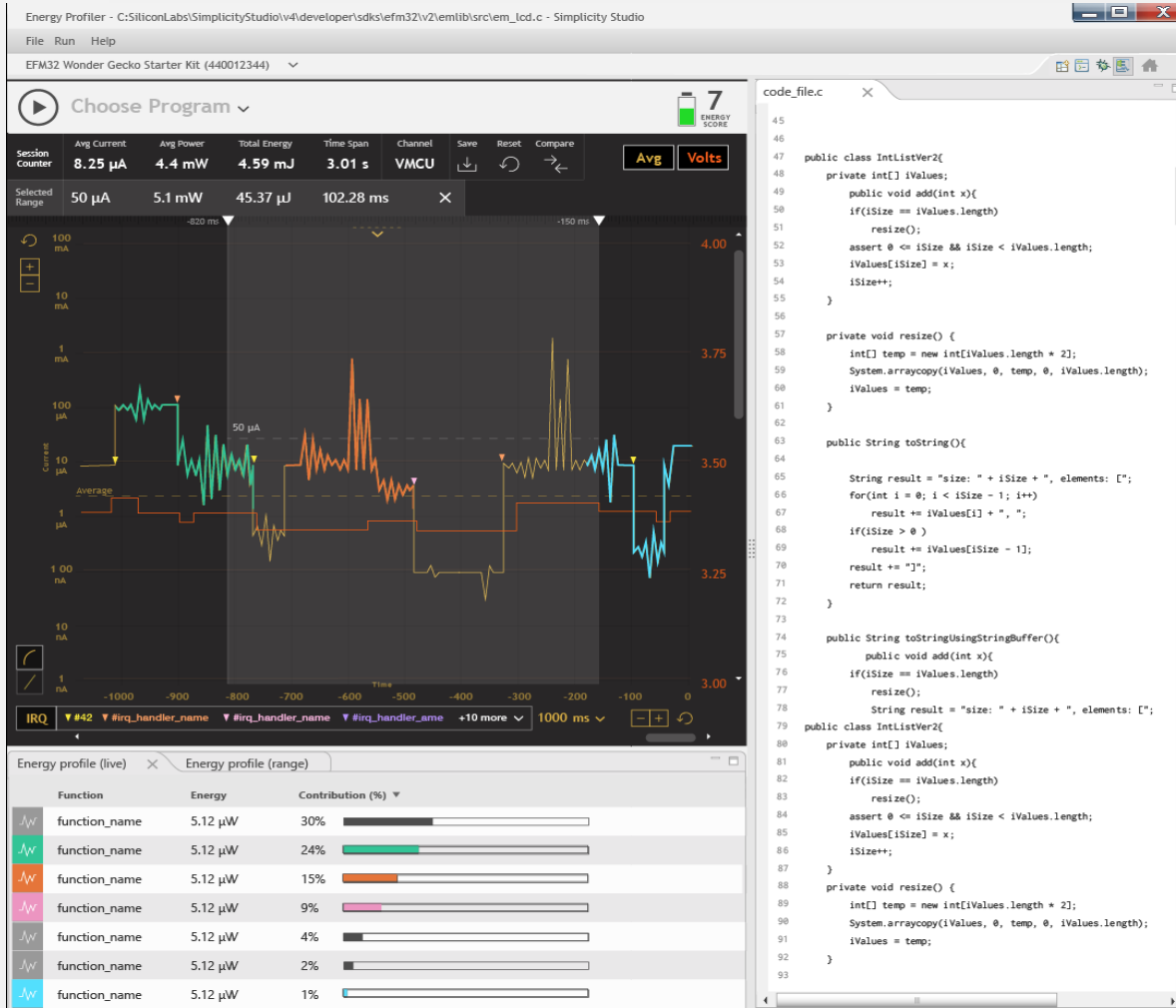
0.212627	Packet	ZCL: Toggle
0.214563	Packet	802.15.4 Ack
0.220005	APITrace	Message sent
0.220023	APITrace	Stack power down
1.215000	APITrace	Stack power up



The screenshot shows a 'Radio Info' window with the following details:

- Tx count: 1, Rx count: 1
- Sender: tools-006 [64]
 - Time: 39.358478
 - CRC: E06F
 - Status: EF
- Receiver: tools-011 [24]
 - Time: 39.358452
 - Type: 350 Rx packet
 - Bytes: 6F E0 00 78 E0
 - Raw LQI: 0
 - Scaled LQI: 255
 - Raw RSSI: 120
 - Scaled RSSI: -34 dBm
 - CRC: E06F
 - Status: E0

Energy Profiler



- Improve battery life
 - Simple energy optimization and debugging
 - Analyze real-time current consumption
 - Correlate energy consumption to code

Advanced real-time energy profiling tools for optimization and debugging

The First Series 2 SoCs : EFR32xG21



Enabling next-generation connected products

Wireless Gecko Series 2 100M range test



Wireless Gecko Series 2 100M range test

- <https://www.youtube.com/watch?v=Lzf6MBNLU9Y&t=4s>

Silicon Labs: Advancing what's possible in the IoT

- **Expertise:** 20+ years providing RF solutions with more than 750 million deployed wireless nodes worldwide
- **Security:** Providing enhanced security features that help developers increase consumer trust in connected products
- **Platform:** Simplifying IoT product design with highly-integrated devices, reusable software and advanced development tools





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