2023 tech talks
WEBINAR SERIES

Welcome

Designing Low Power Applications with Wi-Fi 6

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WI-FI SERIES

SILICON LABS

Agenda

- Introduction
- Low Power Requirements for IoT Wi-Fi Devices
- Pre Wi-Fi 6 (Legacy) Power Saving Features
- Wi-Fi 6 Power Saving Features
- Additional Silicon Labs Power Saving

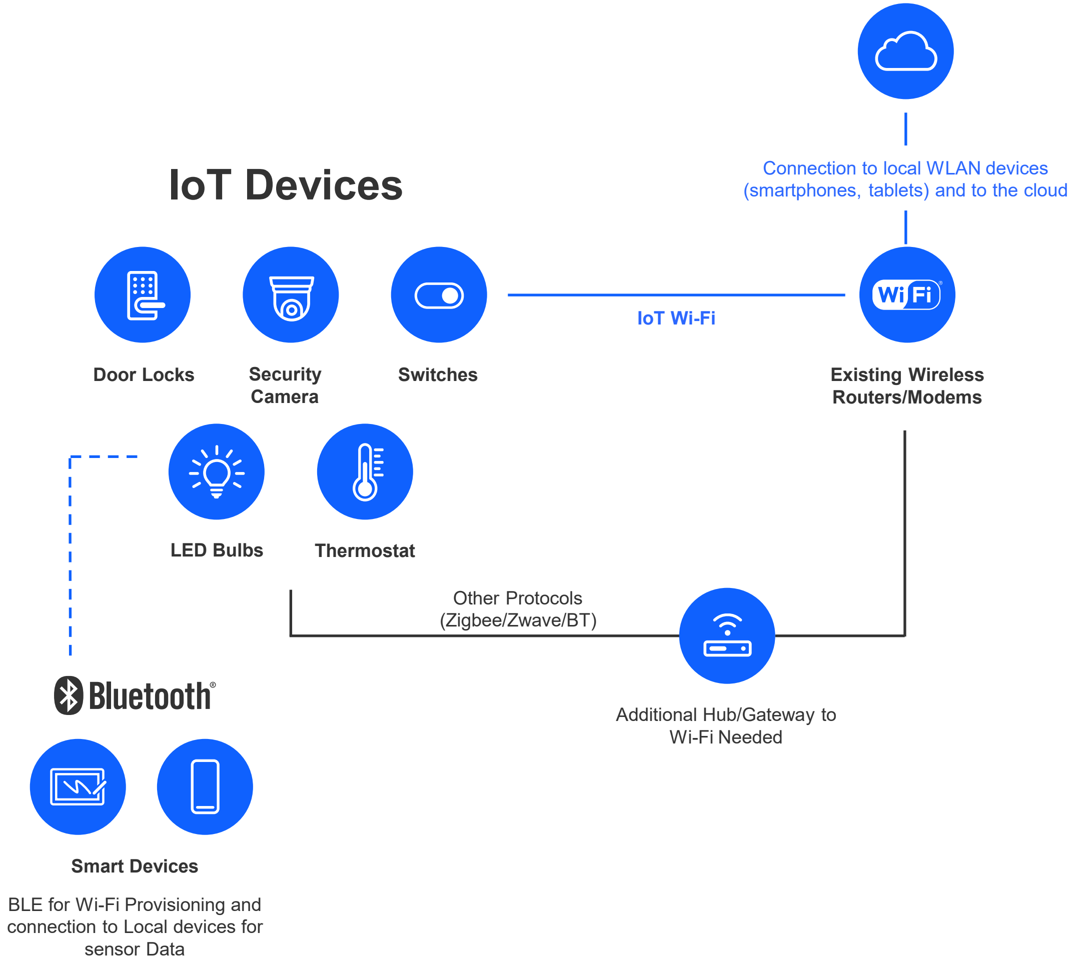
Evolution of Wi-Fi

New features in a version

IEEE Protocol	802.11b	802.11a	802.11g	802.11n	802.11ac	802.11ax
WFA Naming	N/A	N/A	N/A	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6, Wi-Fi 6E
Year Introduced	1999	1999	2003	2009	2013	2019, 2021 for 6E
Band(s) (GHz)	2.4	5	2.4	2.4, 5 (SB or DB)	5	2.4, 5, 6 (SB, DB, TB)
Channel Bandwidth (MHz)	20	20	20	20, 40	20, 40, 80, 160	20, 40, 80, 160
Allowable Streams	1	1	1	4	8 (only 4 implemented)	8
Max Data Rates (Mbps)	11	54	54	600 (150 Mbps per stream)	433 (80MHz, 1SS) 866 (160MHz, 1 SS) 3467 (160MHz, 4 SS)	143 (20MHz, 1 SS) 600 (80MHz, 1 SS) 9607 (160MHz, 8 SS)
MIMO	N/A	N/A	N/A	Single User (SU-MIMO)	Downlink Multiuser (DL MU-MIMO)	Multiuser (Uplink and Downlink MU-MIMO) – 8 Users
Subcarrier Spacing (KHz)	N/A	312.5	312.5	312.5	312.5	78.125
Symbol Duration (us)	N/A	3.2	3.2	3.2	3.2	12.8
Guard Interval (us)	N/A	0.8	0.8	0.4, 0.8	0.4, 0.8	0.8, 1.6, 3.2
PHY Modulation	DSSS	OFDM	DSSS, OFDM	DSSS, OFDM, HT-OFDM	DSSS, OFDM, HT-OFDM, VHT-OFDM	DSSS, OFDM, HT-OFDM, VHT-OFDM, OFDMA
Multi-user Operation	No	No	No	No	(DL MU-MIMO)	Uplink and Downlink OFDMA
Highest Order Modulation	CCK	64-QAM	64-QAM	64-QAM	256-QAM	1024-QAM
Power Saving Mechanisms	PS-POLL	PS-POLL	PS-POLL	PS-POLL	PS-POLL	Target Wake Time
Spatial Reuse Mechanisms	No	No	No	No	No	BSS Coloring

Wi-Fi 6 is the largest upgrade to Wi-Fi and expect Wi-Fi 6 deployments to grow significantly, yet backward compatible

Wi-Fi Usage in IoT Applications



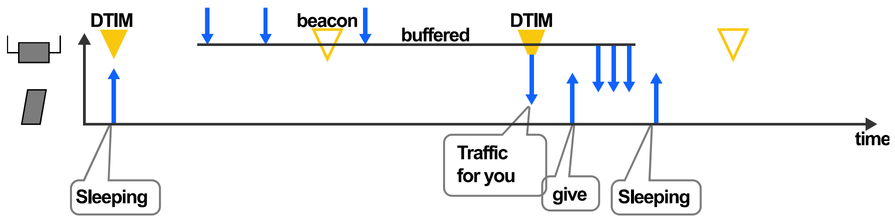
- **Simplified installations and cost reductions:**
  - Use existing Wi-Fi router/modem
  - Native IP protocol for internet communication
  - No additional Hub/Gateway required
- **Extended range, battery life, throughput**
  - Energy efficient and longer range 2.4GHz single-band
  - Power saving capabilities
  - Higher data rate support
- **Improve user experience and interoperability with**
  - The new Matter protocol
  - Ecosystem cloud integration and connectivity
  - Local area network connectivity
- **Bluetooth Low Energy usage with Wi-Fi**
  - Simplified provisioning
  - Proximity detection
  - Sensor connectivity

Low Power Requirements for IoT Wi-Fi Devices

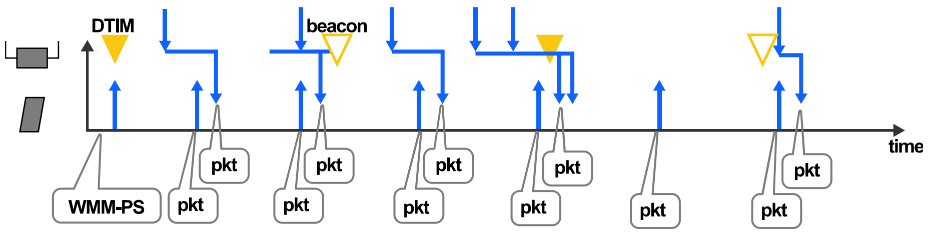
- **Why Low Power?**
  - IoT devices are different from traditional Wi-Fi devices such as laptops, tablets and cell phones
    - Limited resources (MCU, memory, etc.)
    - Lower requirements (lower throughput)
  - Like laptops, tablets and cell phones, they tend to be battery powered
  - Their batteries are expected to last long periods of time (months or years) before being replaced.
- **What are the main requirements?**
  - Low power consumption to ensure long battery lifetime
  - Wireless and networking stack integration
  - Cloud connectivity
  - Cost and size constraints
  - (Newer / future) AI/ML integration

Pre-Wi-Fi 6 (Legacy) Power Saving Features

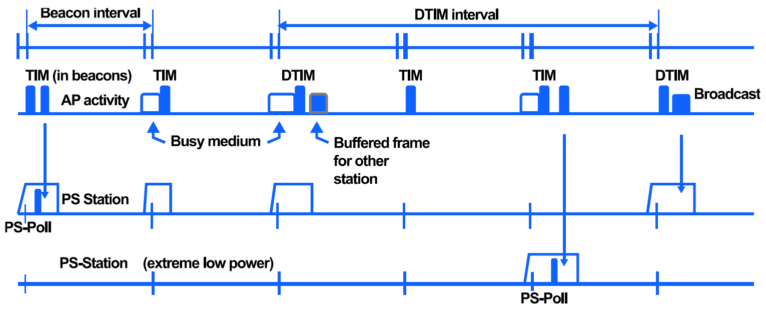
Traditional Power Save



WMM Power Save

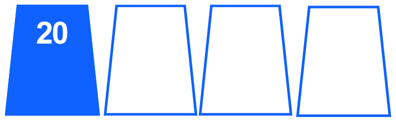


DTIM Intervals



Example: DTIM every 3 beacon intervals

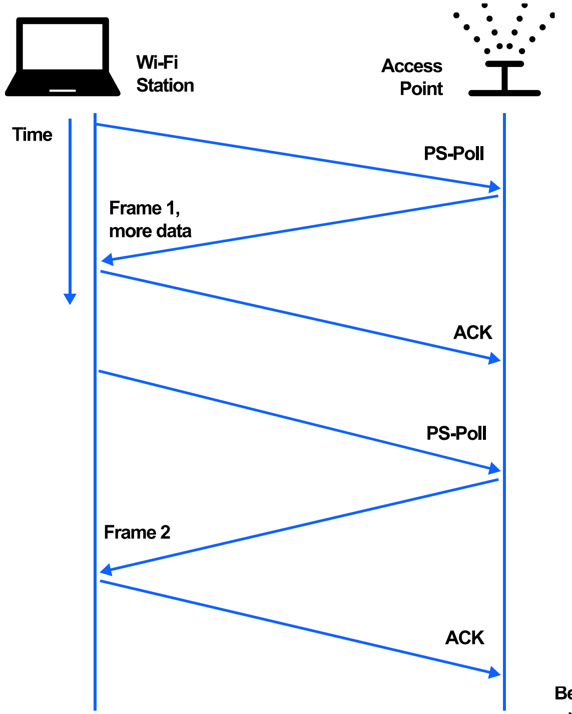
20 MHz Channel Usage

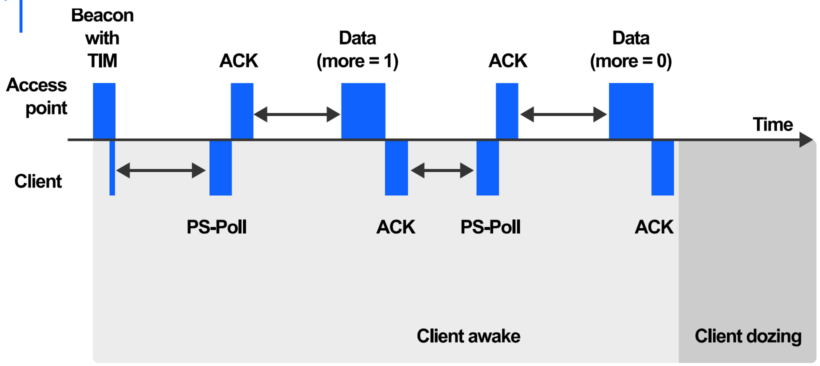


- **Pre-Wi-Fi 6 Power saving features**
  - Traditional Power Save
  - WMM Power Save
  - DTIM Intervals
  - 20 MHz Channel Usage

DTIM: Delivery Traffic Indication Message
WMM: Wireless Multimedia

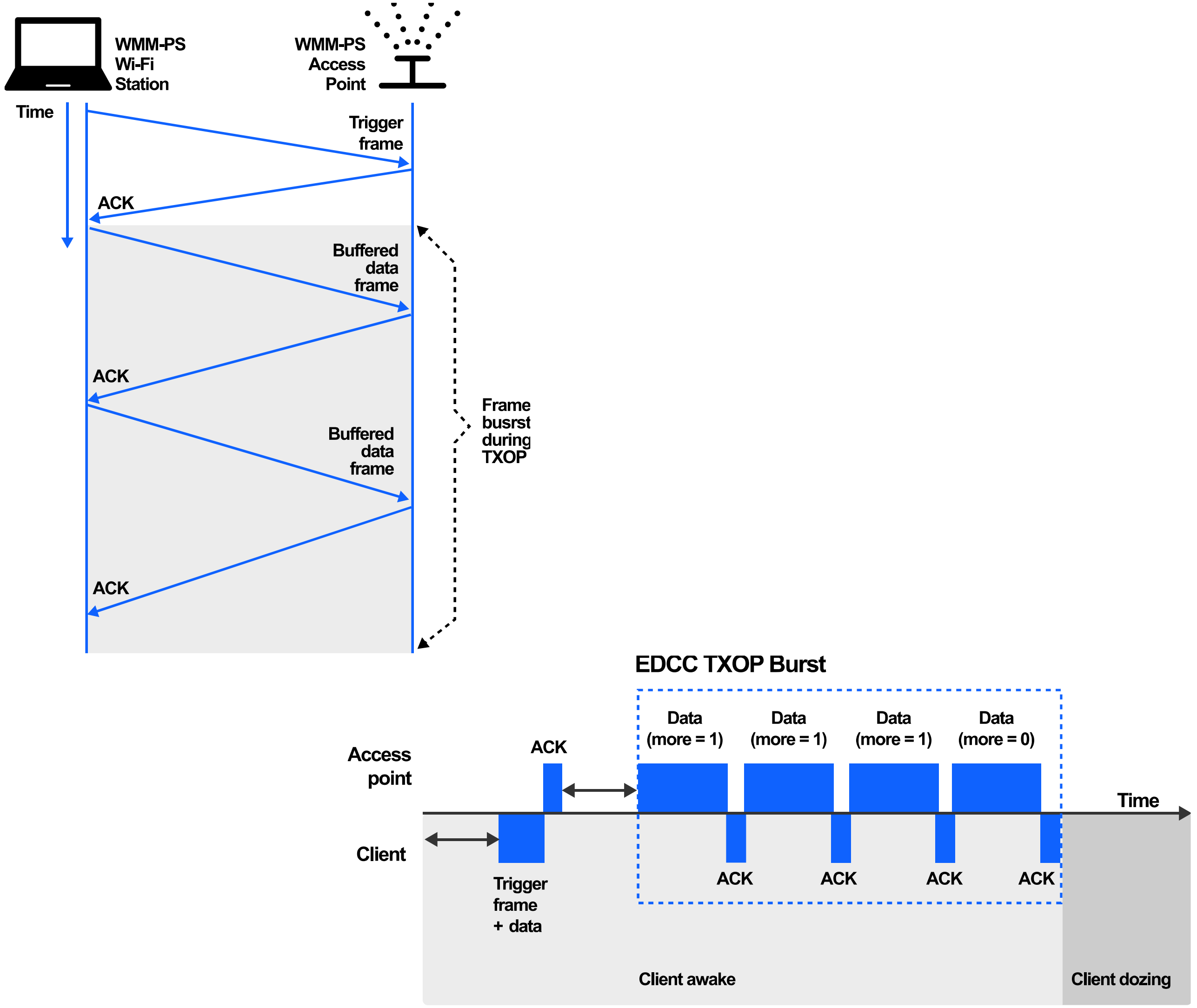
Traditional Power Save





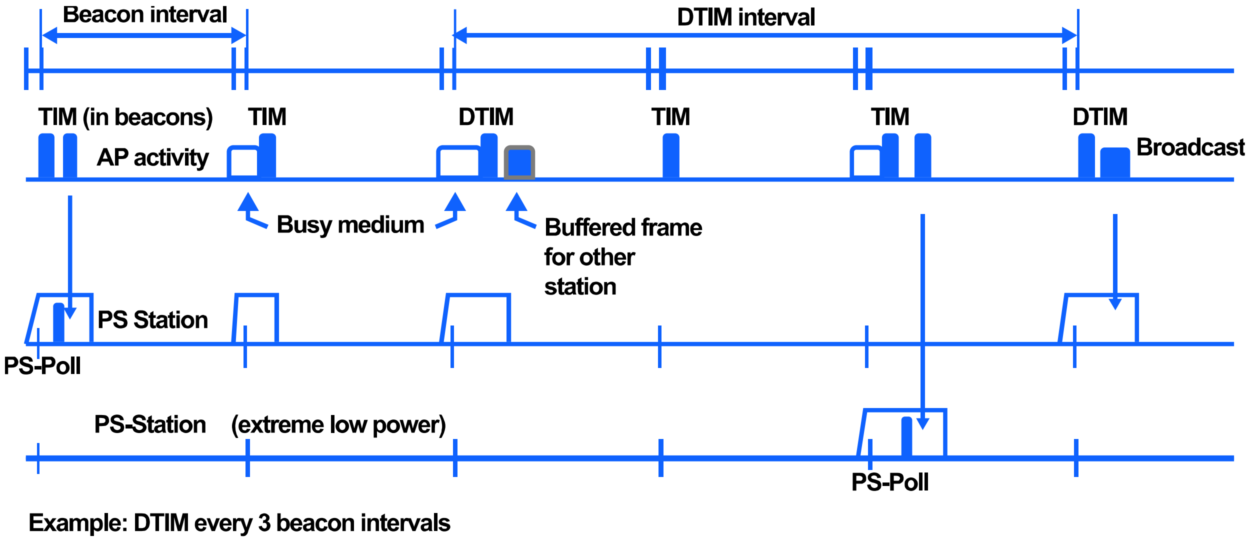
- **Traditional Power Save**
  - Wi-Fi stations go to sleep and wake up to listen to beacons transmitted by the Access Point (AP)
  - On AP beacons they find out when frames are buffered for them at the AP
  - Wi-Fi Stations then use PS-Poll frames to request frames buffered at AP for them
  - This method is inefficient:
    - Wakeup times depend on beacon periodicity
    - Beacons are typically transmitted every 100 mSec
    - PS-Poll frames need to be sent for each buffered frame
  - For each buffered frame the following needs to be done:
    - Station (STA) sends PS-Poll
    - AP sends buffered frame
    - STA sends ACK to acknowledge receipt of buffered frame

WMM Power Save



- **WMM Power Save**
  - Provides current consumption improvement over traditional power save
  - Unscheduled Automatic Power Save Delivery (U-APSD) is common method method used for power save
  - Its goal is to be more power efficient than legacy PS-Poll method
  - Does this by replacing PS-Poll frames with trigger frames
  - Trigger frames can be ANY data frame
  - AP sees station being awake through receipt of trigger frame
  - At this point, AP can send multiple buffered frames as part of a TXOP burst
  - With this, station does not need to send a PS-Poll for each outstanding frame, thus saving energy

DTIM Intervals

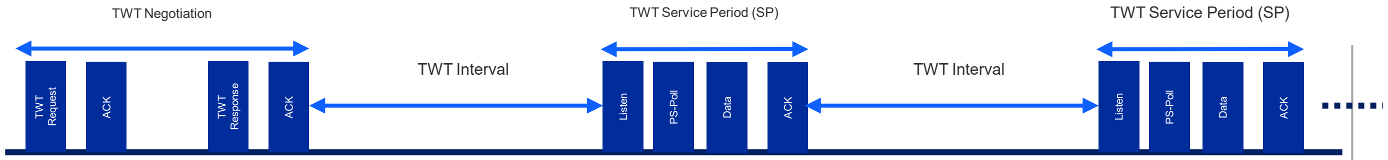


- **DTIM Intervals**
  - Wi-Fi APs set a DTIM (Delivery Traffic Indication map) period
  - DTIM period specifies frequency (in number of beacons) with which it will transmit multicast frames
  - Multicast frames are used for a number of things
    - DHCP
    - ARP
    - IGMP
    - IPv6 discovery
    - MDNS
  - The longer the DTIM period, the longer stations can sleep
  - DTIM period is set by AP and fixed for ALL stations associated to AP

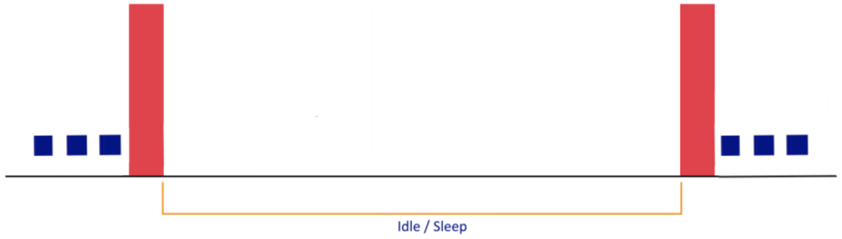
20 MHz Channel Usage

- **20 MHz Channel Usage**
  - Wi-Fi allows for the transmission of frames using either 20, 40, 80 or 160 MHz channels to enable higher throughput
  - Higher current consumption for wider bandwidths
  - For low throughput IoT stations, wider bandwidths are not typically needed
  - Using 20 MHz to transmit data helps such stations:
    - Reduces current consumption
    - Still meets throughput requirements

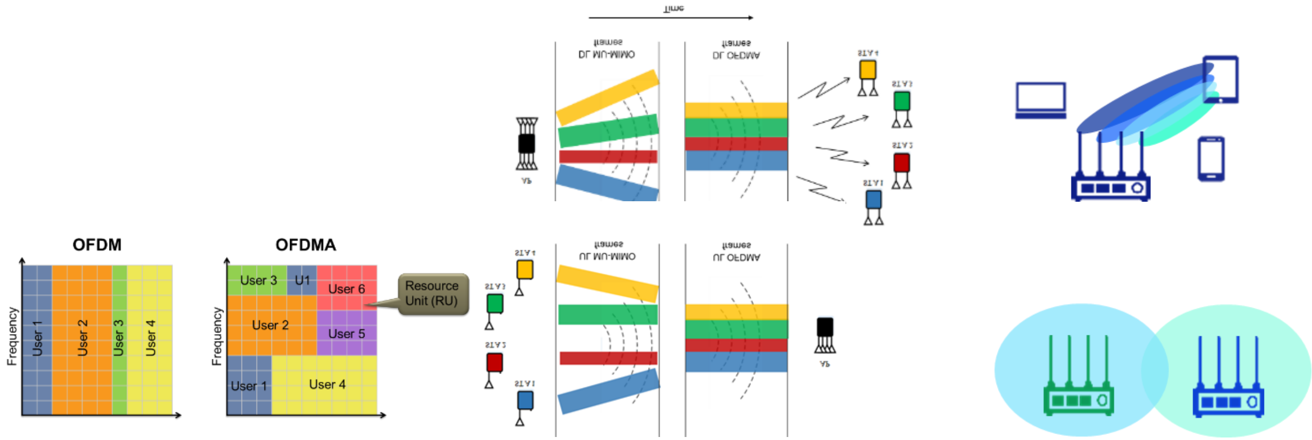
Wi-Fi 6 Power Saving Features



Target Wake Time



BSS Max Idle

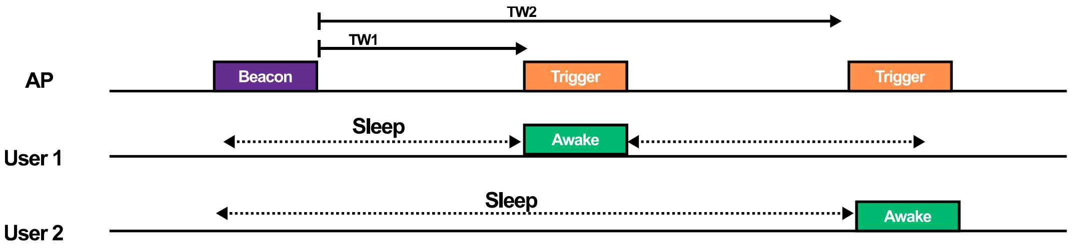


Other Wi-Fi 6 features

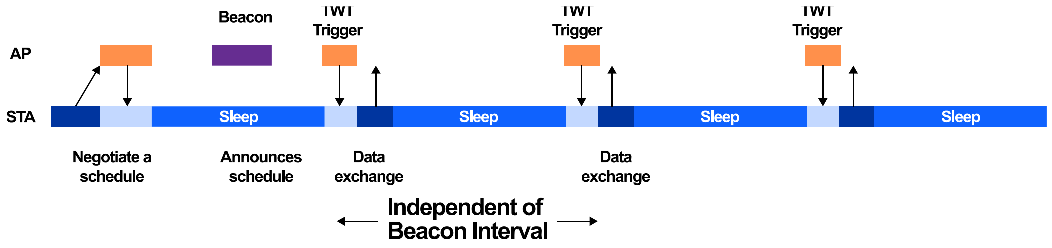
- **Wi-Fi 6 is meant to support battery-powered devices**
  - Wi-Fi 4 provided power saving mechanisms sufficient to support traditional mobile devices (cell phones, tablets)
  - The battery lifetimes of those devices are in hours or days in the best case
  - Wi-Fi 6 was designed to support IoT and other low power devices with battery lifetimes of months or years
- **Wi-Fi 6 Power saving features**
  - Target Wake Time (TWT)
  - BSS Max Idle
- **Other Wi-Fi 6 features that help current consumption**
  - OFDMA (Orthogonal Frequency Division Multiple Access)
  - Beamforming
  - Multi User MIMO (MU-MIMO)
  - BSS Coloring

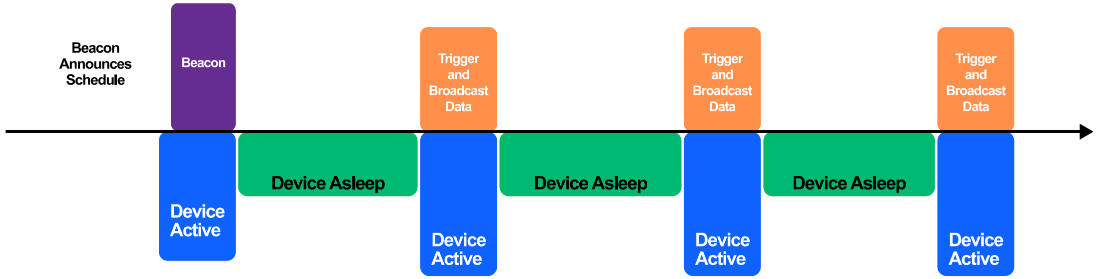
BSS: Basic Service Set

Target Wake Time (TWT)



Individual TWT





Broadcast TWT

- **TWT enables wireless AP and devices to negotiate and define specific times to access the medium.**
  - Enables devices to determine when and how frequently they will wake up to send or receive data (independent of Beacon)
- **TWT has two methods available**
  - Individual TWT: each device can negotiate sleep period with AP
  - Broadcast TWT: AP provides sleep period for a group of devices
- **Individual TWT is ideal for battery operated IoT devices**
  - Further reduces power consumption for devices on battery
  - Eliminates interop issues due to client long sleep durations
  - Optimize spectral efficiency by reducing contention
  - Combined with other Wi-Fi 6 features helps significantly reduce power consumption in congested environments compared to previous generation Wi-Fi
- **TWT provides three major benefits**
  - Allows Wi-Fi stations to increase their sleep times
  - Reduces contention between stations by scheduling air usage times.
  - Helps collect information from devices on the network through channel sounding

Wi-Fi 6 TWT further reduces power consumption for devices on battery, enabling longer battery life

TWT Allows for Increased Sleep Times

	Request Type	Target Wake Time	TWT Group Assignment	Nominal Minimum TWT Wake Duration	TWT Wake Interval Mantissa	TWT Channel	NDP Paging (optional)
Octets:	2	0 or 8	0, 3, or 9	1	2	1	0 or 4

TWT Parameter Set field format

TWT Wake Interval Mantissa is a 2 byte (16 bit) field

	B0	B1 B3	B4	B5	B6	B7 B9	B10 B14	B15
	TWT Request	TWT Setup Command	~~Reserved~~ Trigger	Implicit	Flow Type	TWT Flow Identifier	TWT Wake Interval Exponent	TWT Protection
Bits:	1	3	1	1	1	3	5	1

TWT Request Type field format

TWT Wake Interval Exponent is a 5 bit field

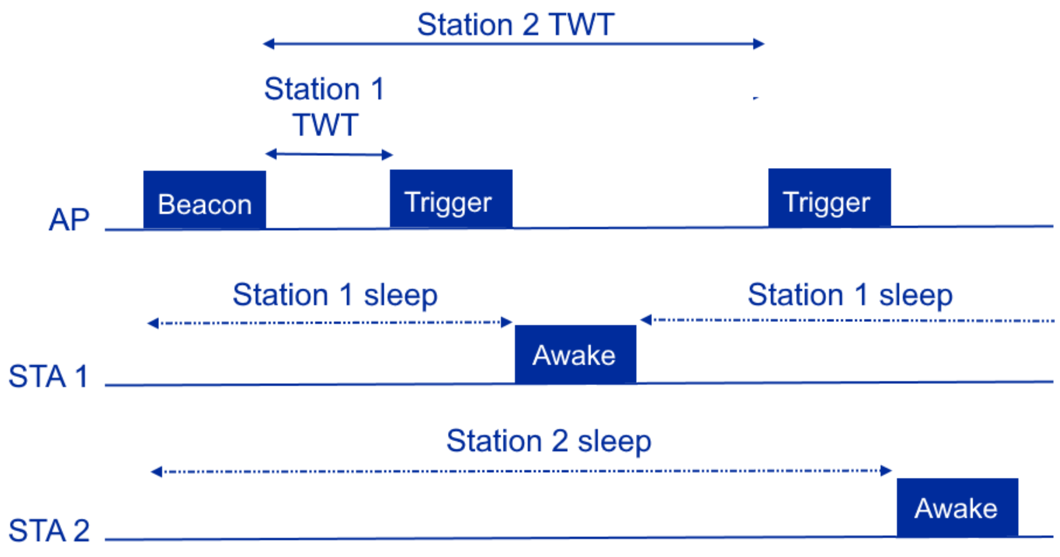
- **How does TWT allow for increased sleep times?**
  - As legacy power save modes (legacy and WMM) are tied to beacons they are limited in the time stations can remain asleep
  - From the 802.11ax standard:

$$\text{TWT wake interval} = (\text{TWT Wake Interval Mantissa}) \times 2^{(\text{TWT Wake Interval Exponent})} \text{ (in microseconds)}$$

  - As the TWT Wake Interval Mantissa is a 2-byte field, its maximum value is 65,535
  - As the TWT Wake Interval Exponent is a 5-bit field, its maximum value is 31
  - This yields a maximum TWT Wake Interval as follows:
  - Maximum TWT Wake Interval = 65,535 x [2^31] uSec
  - Or 4 years, 5 months, 16 days, 13 hours, 37 minutes, 39.49 seconds

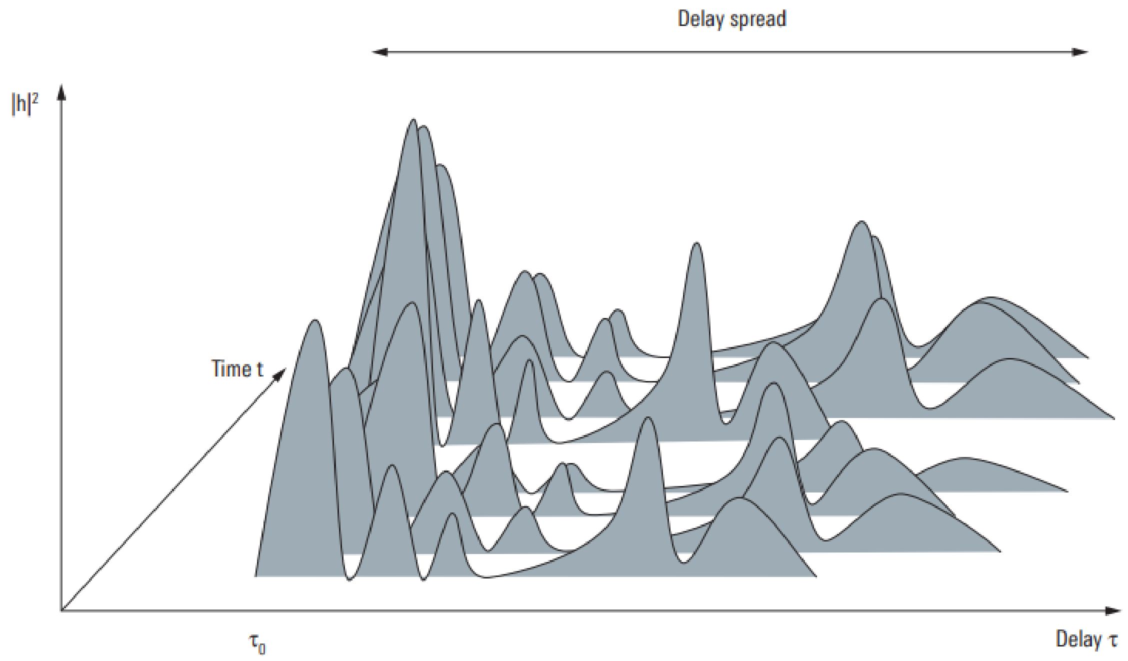
- **Considerations to take when selecting sleep times**
  - While TWT enables the use of VERY long sleep times, there are other considerations that should be carefully taken when selecting the durations of sleep periods for your IoT devices. Some of them are the following:
    - Application layer timeouts (for example, TCP server timeouts)
    - Cloud server timeouts (Amazon, Google, etc.)
    - Group Key Exchanges

TWT Reduces Congestion



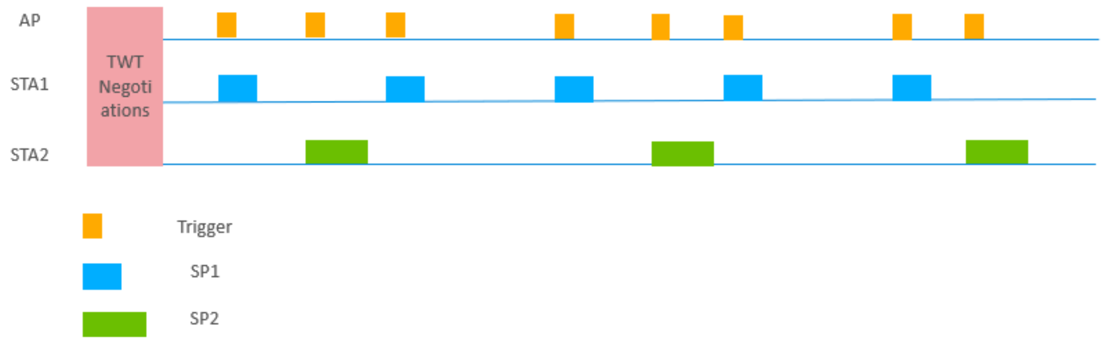
- **How does TWT reduce congestion?**
  - In legacy Wi-Fi networks, stations that go to sleep can wake up at random times and attempt to transmit packets once they are awake
  - Stations have no knowledge of the wake-up times of other stations
  - This can cause packet collisions
  - In Wi-Fi 6, as APs negotiate wake up times for stations, they can ensure that they do not wake up at the same time, thus avoiding packet collisions
  - Packet collisions in legacy Wi-Fi cause retransmissions which significantly increase station current consumption

TWT can help collect channel information



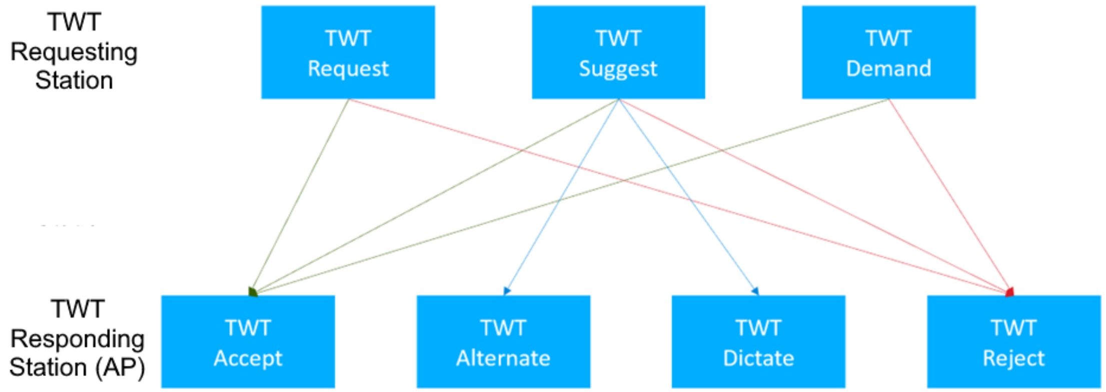
- **How can TWT help collect channel information?**
  - TWT allows APs to schedule the stations that are associated to it
  - This scheduling allows stations to be spaced in time
  - The time spacing of stations can then be taken advantage to use methods such as channel sounding to collect the state of the channel over time
  - The channel state can then be used at the AP to train its steering matrix (beamforming weights) to optimize the network's channel usage providing the following advantages
    - Increasing overall throughput
    - Improving range
    - Reducing station current consumption

TWT Key Concepts



- **TWT Service Period (TWT SP)**
  - It is the time period over which a station wakes up to receive or send data
- **TWT Wake Interval**
  - It is the average time that the TWT-requesting STA expects to lapse between successive TWT SP start times
- **TWT Channel**
  - It is the channel a station can use temporarily as its primary channel
- **TWT Agreement**
  - It is the final agreement between the AP and the station that is reached after negotiation.

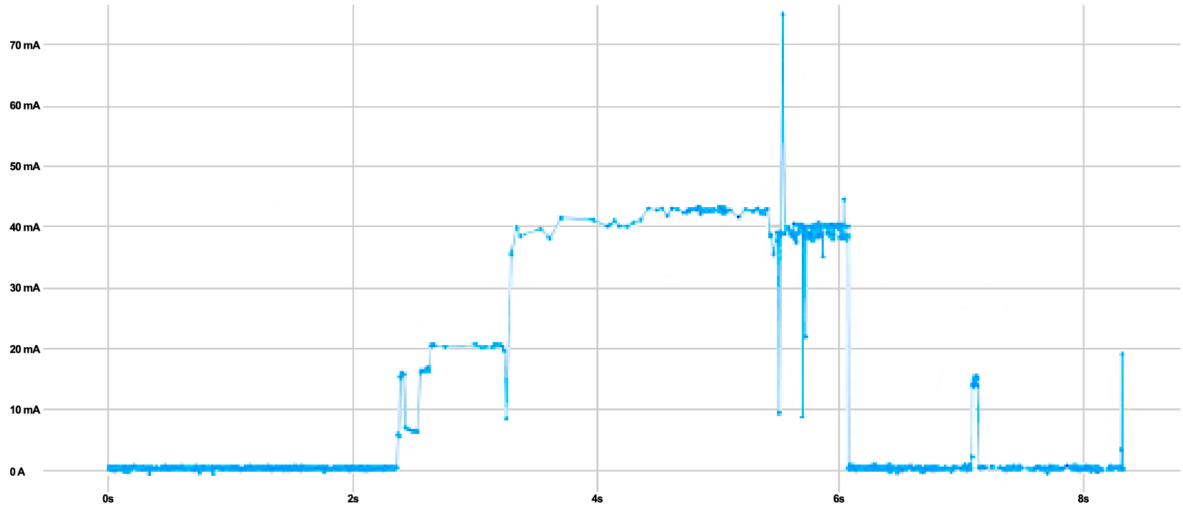
How does a station create a TWT session?



- **TWT Request messages can be:**
  - **Suggest:** Requesting STA suggest parameters for TWT session but will consider accepting an alternative set.
  - **Request:** Requesting STA lets replying STA specify TWT parameters
  - **Demand:** Requesting STA demands TWT parameters and will not accept a different set of parameters
- **TWT Response messages can be:**
  - **Accept:** Responding STA accepts parameters
  - **Alternate:** Responding STA proposes alternate parameters
  - **Dictate:** Responding STA demands other parameters with no possibility for further negotiation.
  - **Reject:** Responding STA rejects TWT session

BSS Max Idle

BSS Max Idle Sleep



WPA2 association current consumption

- **BSS Max Idle**
  - In typical Wi-Fi networks, stations associated to an AP must transmit frames within timeouts defined by the AP to avoid being disassociated
  - Typically APs set those timeouts to be one or a couple of minutes long, thus limiting how long clients can sleep
  - BSS Max Idle feature allows clients to request a longer sleep period from AP
  - Allows clients to remain associated for up to 18 hours
  - Avoids the need for reassociation, which is highly costly energy-wise
  - Enables higher energy savings

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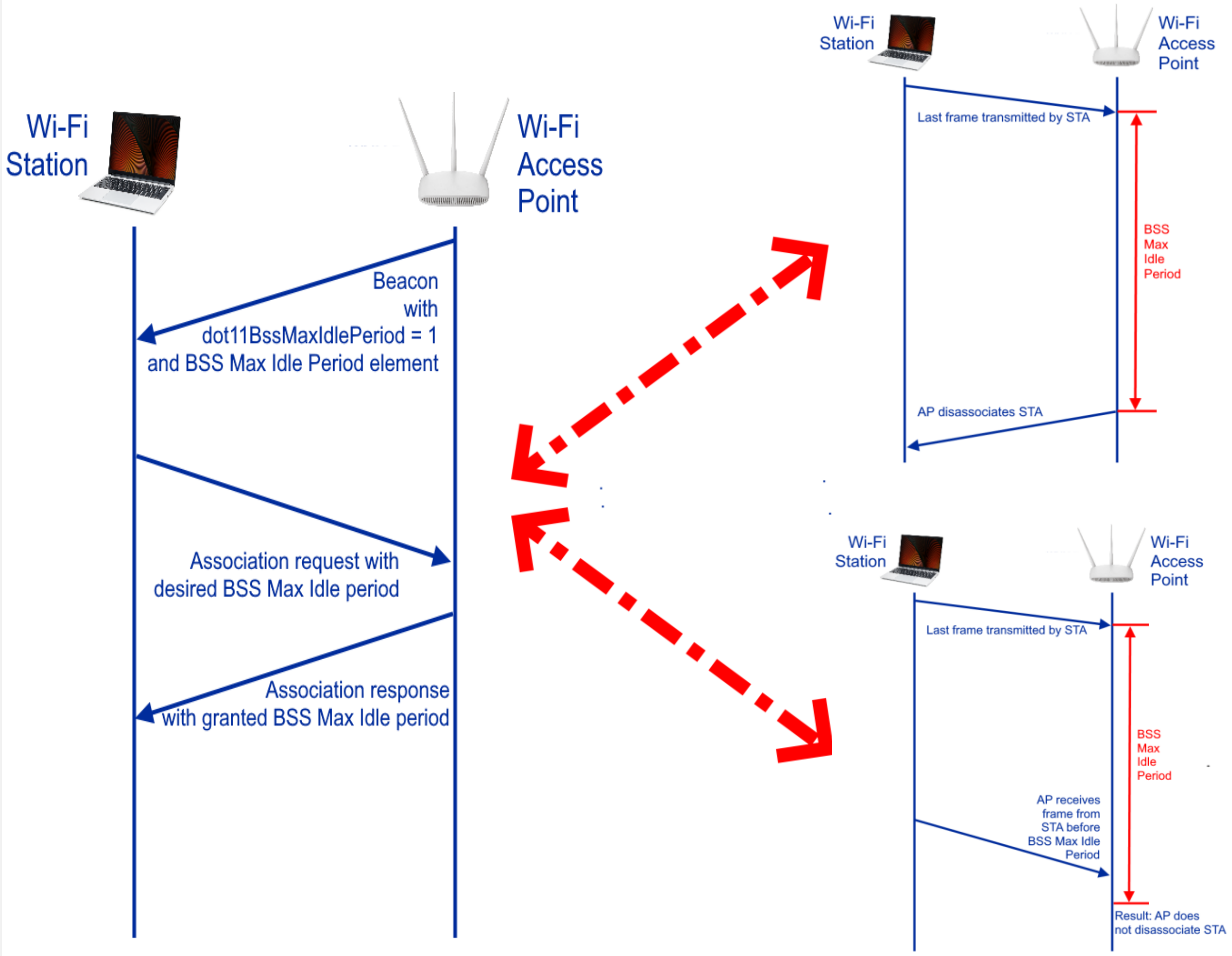
BSS Max Idle Period Negotiation



- **BSS Max Idle Period Negotiation**
  - AP Indicates BSS Max Idle support through the following elements in beacons:
    - dot11BssMaxIdlePeriod = 1
    - BSS Max Idle Period Element
  - Seeing the above, Stations request desired BSS Max Idle period in (re)association request frames
  - APs reply with granted BSS Max Idle period in (re)association response frames
  - Once BSS Max Idle period is agreed, as long as station transmits at least one frame within BSS Max Idle Period it will not be disassociated by AP

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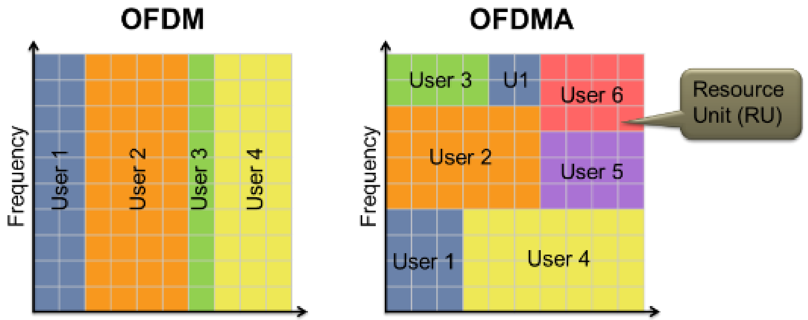
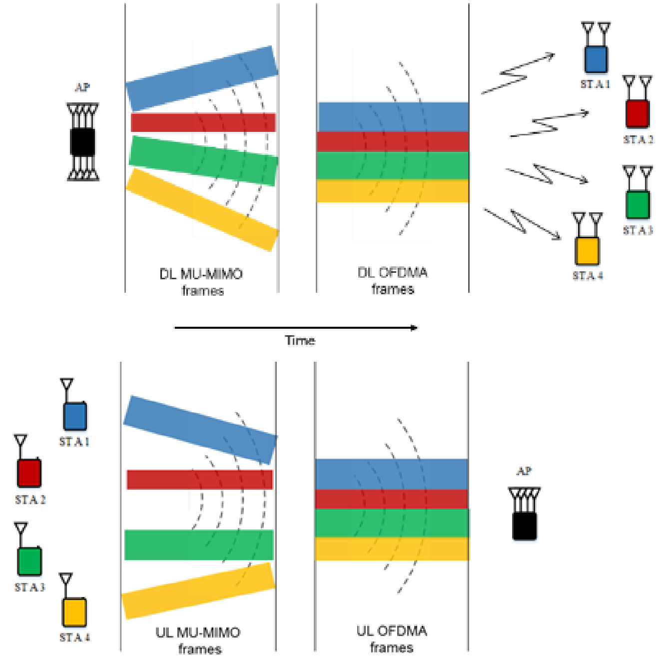
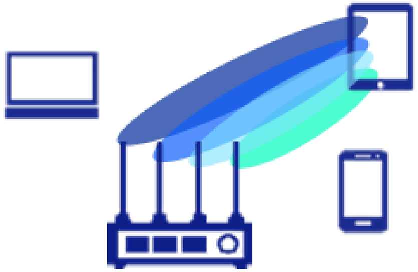
Other Wi-Fi 6 features that help current consumption



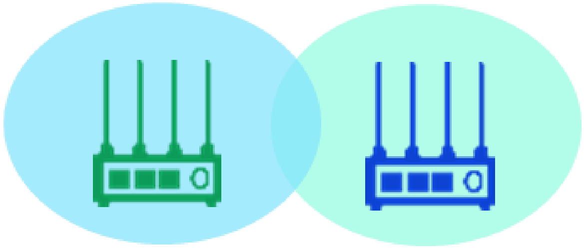
OFDMA



MU-MIMO



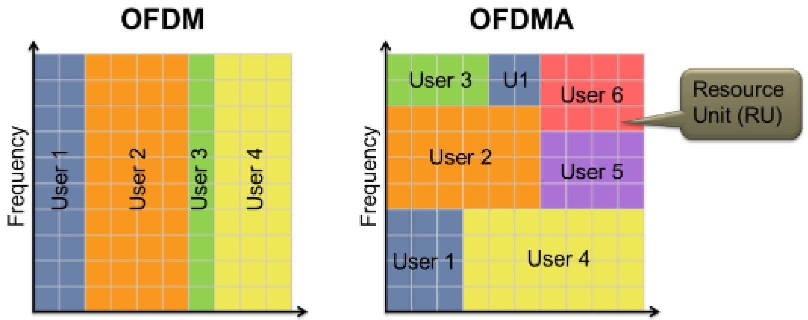
Beamforming



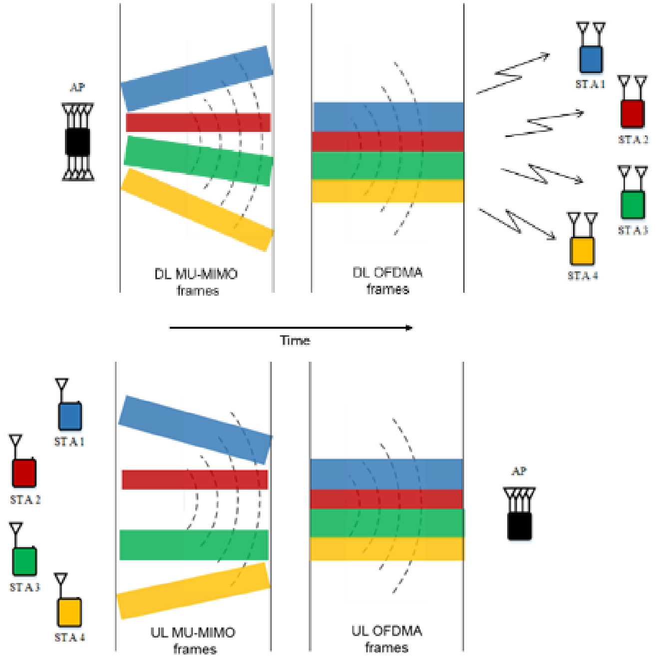
BSS Coloring

- **Wi-Fi 6 has multiple features that help alleviate congestion**
  - OFDMA
  - Beamforming and MU-MIMO
  - BSS Coloring
- **OFDMA**
  - Allows for spectral reuse through frequency multiplexing
- **Beamforming and MU-MIMO**
  - Allow for spectral reuse through spatial multiplexing
- **BSS Coloring**
  - Allow devices (APs and stations) to differentiate packets transmitted by its network from packets transmitted by other networks in the same channel
- **By alleviating congestion these features allow devices to stay on the air smaller amounts of time and thus, reduce current consumption**

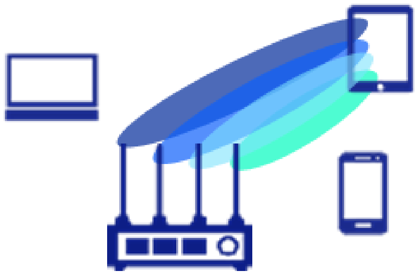
How do these features help current consumption?



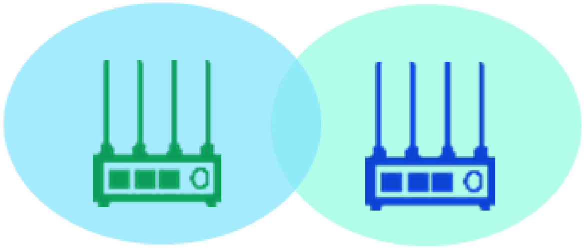
OFDMA



MU-MIMO



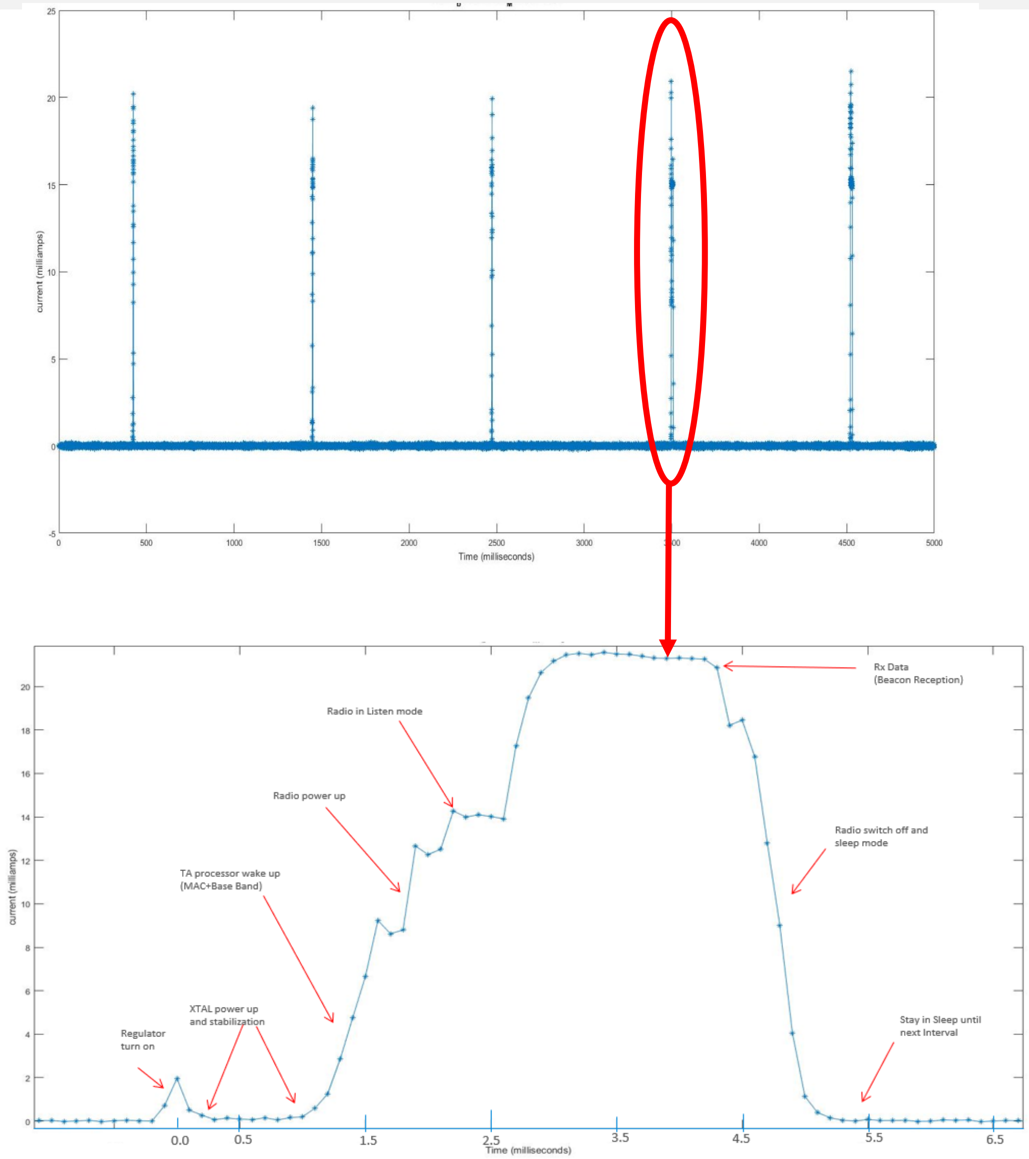
Beamforming



BSS Coloring

- **OFDMA**
  - Allows for the subdivision of the Wi-Fi spectrum into subbands that can be used by multiple clients simultaneously
  - Allowing multiple clients to transmit at the same time, low throughput devices such as IoT can reduce the amount of time spent with their radio on, thus reducing their current draw
- **Beamforming and MU-MIMO**
  - Transmit of data to/from multiple devices through multiple spatial beams.
  - Allow to increase number of devices served at any given time and CiNR of their received signals
  - Allows devices to stay shorter time in the air, reducing their current draw
- **BSS Coloring**
  - Wi-Fi uses CSMA-CA to reuse the same channel between several networks
  - Legacy Wi-Fi devices demodulate packets to look at the MAC header to determine if those packets are transmitted by their network. This takes time and consumes energy
  - BSS Coloring includes "Color Value" on the HE PHY header
  - Wi-Fi devices can check it to see if the packet is transmitted by their network w/out needing to demodulate and decode complete MAC header
  - This allows clients to reduce time with radio on, reducing current draw
  - APs can quickly detect if another network is using the same color as theirs and quickly change to a different color
  - Switching to a different color minimizes interference, reduces transmission retries and reduces current consumption

Additional Power Saving Enabled by Silabs Wi-Fi SoCs

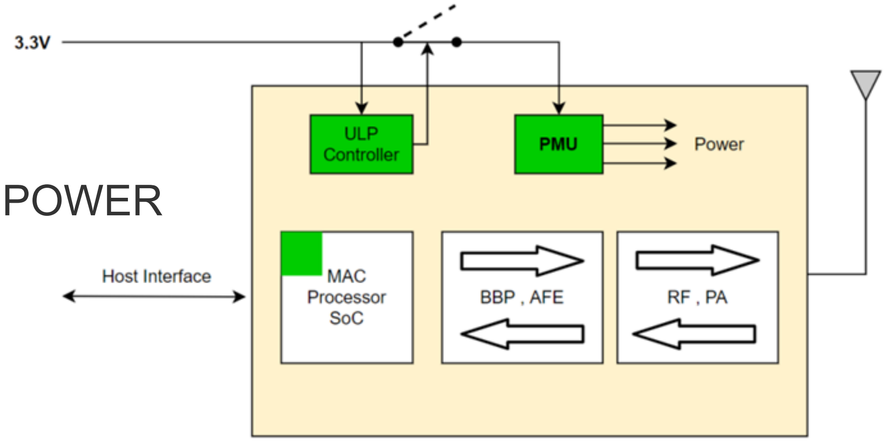


- **Multiple Low Power Modes and embedded stack enable ultra low system power consumption**
- **Wi-Fi Standby associated with automatic periodic wake-up**
  - DTIM, listen interval or TWT based
  - Device remains associated to AP
- **Low power optimized at each device wake-up**

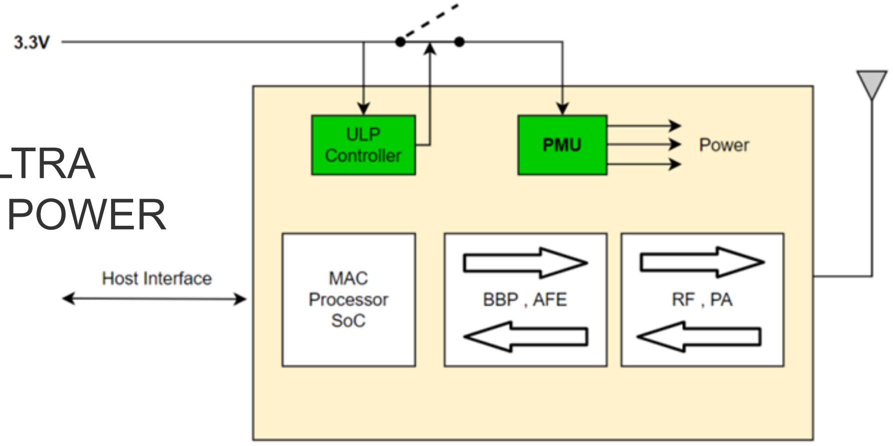
Description	Comments
Sleep Time Between Wakeups	Micro-amp drain
Fast Boot Up times	WLAN still asleep
Wake up Wireless to listen for Beacons using low power receiver	Reduced radio power consumption
Transmit only if needed	Lower average current

Silicon Labs Wi-Fi – Power Save Sleep Options

LOW POWER



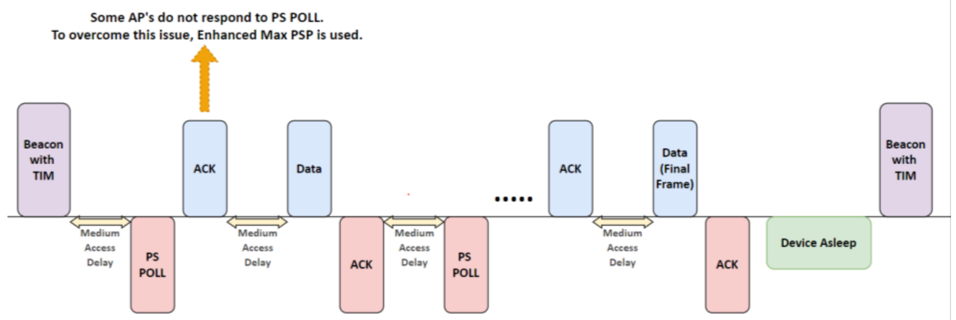
ULTRA LOW POWER



- **Supports various power modes to reduce system current consumption**
  - Low Power Mode (Sleep)
  - Ultra Low Power Mode (Deep Sleep)
- **Low Power Mode**
  - Radio and Modem is turned off but rest of SoC is on in low power state
  - System maintains state, Host interface is active and can respond to packets from Host
  - Recommended for line-powered or rechargeable battery designs that want low power consumption
- **Ultra Low Power Mode**
  - Except of ULP sub-system, rest of device is shutdown
  - Two options are available,
    - With RAM Retention (system state is saved)
    - Without RAM retention (system state is lost)
  - Host interface is not active, device is woken up using ULP sub-system (ULP-GPIOs)
  - Recommended for lowest power consumption and longest life for battery based designs

Silicon Labs profiles supported with Wi-Fi power save

- **Max PSP**



Application	Requirement	Recommended Settings
Streaming device	Always On, High Throughput	No Power Save is used
Smart Locks or Smart Sensors	Low power consumption, Battery powered Small data transmissions	Max PSP or Enhanced Max PSP Listen Interval based power save (1s listen interval)
Wi-Fi Video Doorbell	Event based power on; Battery Powered; higher throughput during video	Enhanced Max PSP or UAPSD DTIM based power save

- **Based on Application usage, the following power save profiles can be used to optimize battery life**
  - MAX Power Save and Enhanced Max Power Save Profile (PSP)
  - FAST Power Save Profile
  - UAPSD Power Save Profile

- **Max PSP**
  - Recommend using this profile for maximizing power save
  - Data is retrieved using PS-POLL mechanism using either DTIM or Listen Interval
  - If AP response is delayed, device switches to FAST PSP (this is referred to as Enhanced Max PS)

- **FAST PSP**
  - Recommend using this profile if throughput is a priority;
  - Offers good trade-off for latency and power consumption

- **UAPSD PSP**
  - Application based priority - Recommended when doing Wi-Fi Multimedia (WMM)
  - Designed for VoIP where real-time Wi-Fi traffic is a requirement
  - Traffic is categorized into voice, video, Best Effort, Background
  - Requires support on AP side (most newer AP's have this support)

2023 tech talks
WEBINAR SERIES

Welcome

Building Smart Home Devices with Always On Wi-Fi 6

Slides by Scott Farester
Presented by Alfredo Pérez Grovas

WI-FI SERIES

SILICON LABS

Agenda

- Introduction
- Always On Wi-Fi 6 – what does it mean
- End Device Architecture for Always On
- Always On Key Performance Specs

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What is a Smart Home Device?

- **A product that can be automatically controlled remotely from anywhere with an internet connection using a mobile or other networked device.**
- **Allows you to control functions - turn on / off, adjust or monitor the status and performance through your smartphone or voice assistant**
- **Includes automation through pre-set triggers or timed events to change setting or status of the device**
- **Full-scale home automation through interconnectivity between devices based on rules, scenes and schedules**

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Wi-Fi – Key Enabler in the evolution of the Smart Home

- Global Standard – interoperable technology
- Proven security
- User provided infrastructure – no specialized gateway required
- Local Network and Cloud Support
- Reliable
- Matter compatible

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Requirements of Wi-Fi in Smart Home Devices

- **Traditional Wi-Fi is better for PC/smartphone/Multimedia**
  - Meant for infrastructure, high bandwidth, or mains-powered devices
  - Used with highly resourced hardware (CPU, memory) running Linux/Android/iOS/Windows
- **Wi-Fi for Smart Home Devices is different**
  - Limited device resources (MCU, memory etc.)
  - Wireless, networking stack integration
  - Cost and size-constrained devices
  - Low power consumption
  - Challenges from crowded RF spectrum
  - Cloud connectivity to multiple cloud providers
  - Security from online and physical attacks
  - Coexistence and Interoperability
  - Limited user interface options
  - Longer product time use cases

Wi-Fi 6 Addresses Smart Home IoT Device Requirements

BETTER IN DENSE ENVIRONMENTS
Improve average throughput per user in dense or congested environments

FASTER THROUGHPUT
Deliver higher peak data rates for a single client device

INCREASE NETWORK EFFICIENCY
Support large number of devices

EXTEND BATTERY LIFE
Of client devices

Users demand more efficient, reliable, and secure connectivity

The time is NOW to utilize Wi-Fi 6 for Best Performance and User Satisfaction

What is Always On Wi-Fi?

- What is Always On Wi-Fi
  - Smart Home Device maintains connection to the AP and does not have to re-establish connectivity to send and receive data

- Why Is Always On Wi-Fi Important
  - Smart Home Devices are “reachable”
  - Minimize the delay to receive or send packets
  - Increases performance

- Traditionally a feature for Line Powered Devices Wi-Fi-6 and Silicon Labs enable battery powered devices with Always On Wi-Fi mode

Smart Home Market Product Segmentation

Smart Home Devices and Home Network performance improves with Wi-Fi 6

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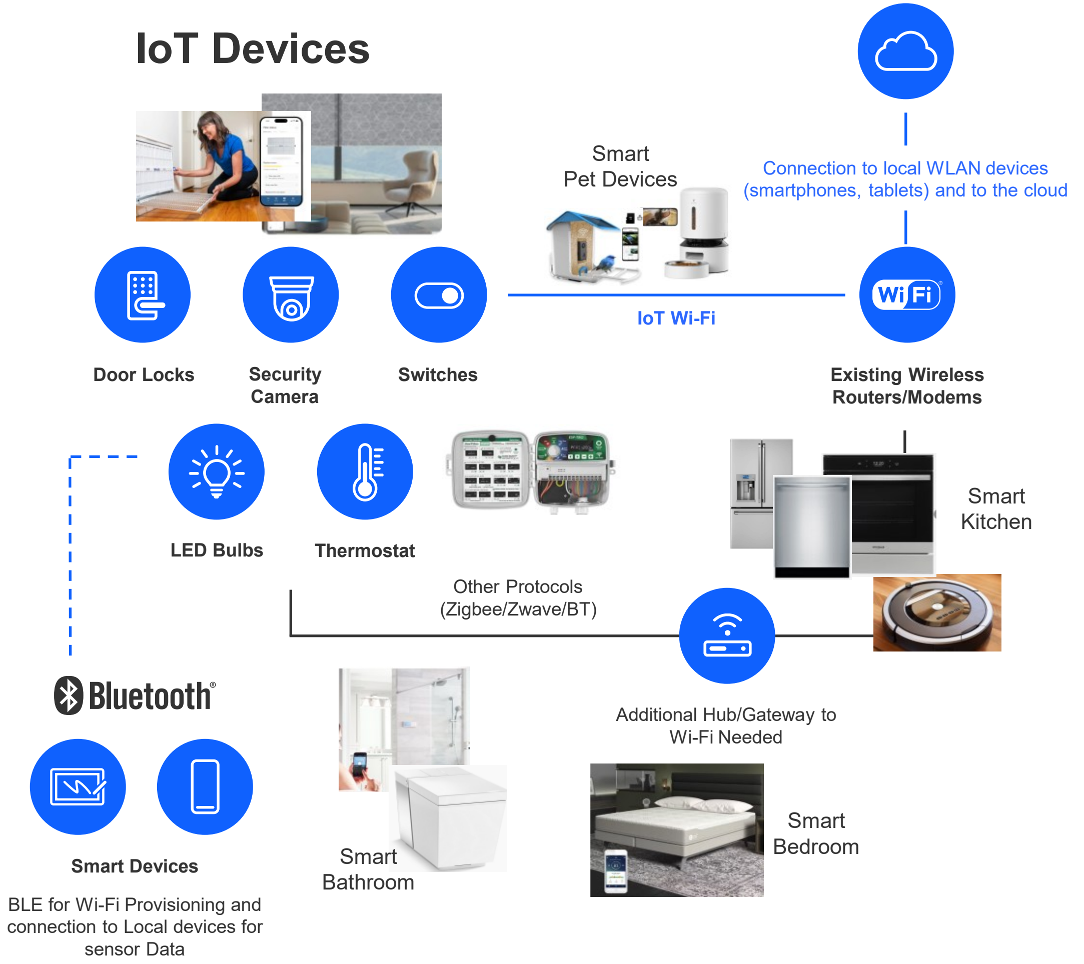
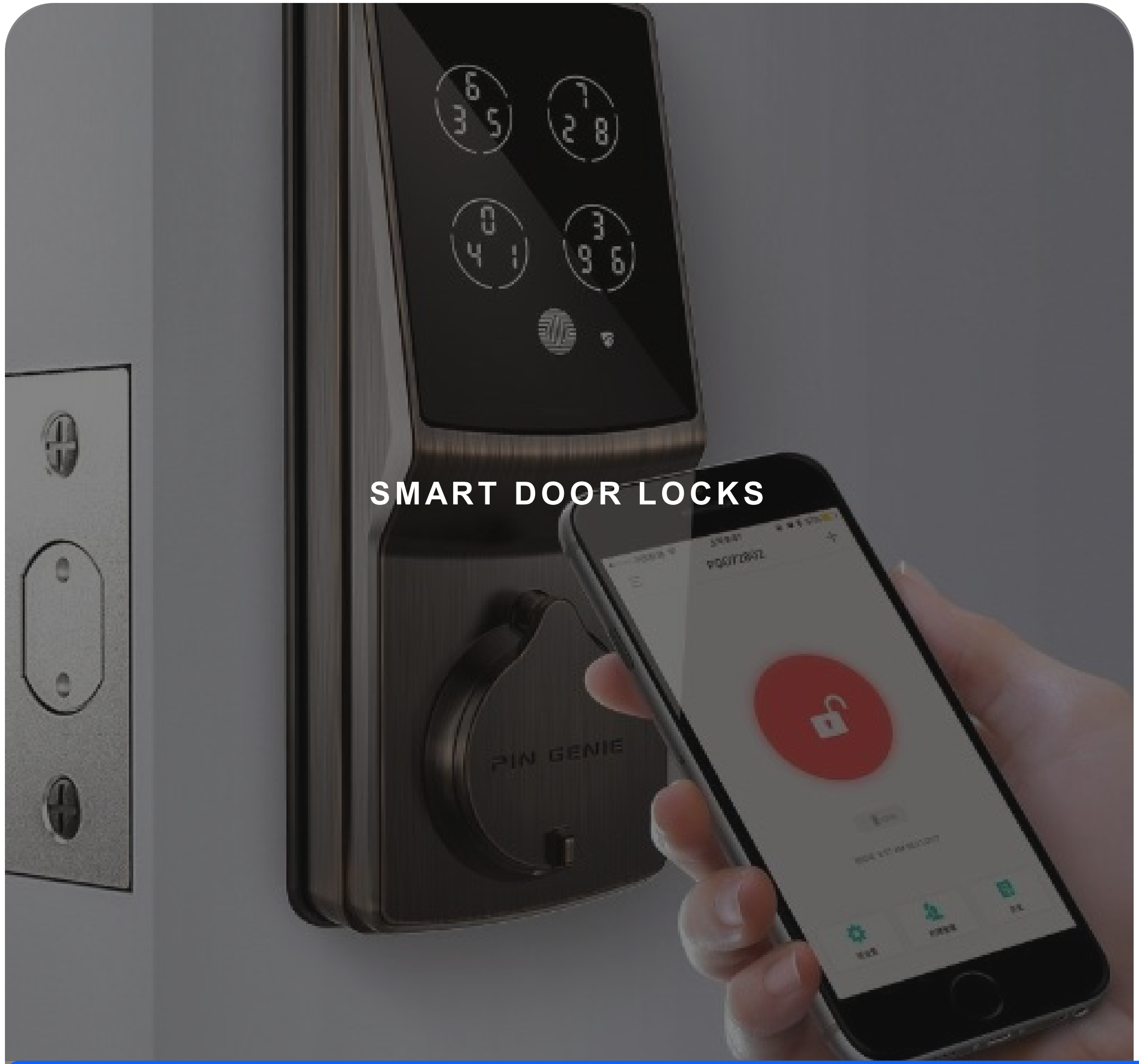
Wi-Fi Usage in Smart Home Applications



- **Simplified installations and cost reductions:**
  - Use existing Wi-Fi router/modem
  - Native IP protocol for internet communication
  - No additional Hub/Gateway required
- **Extended range, battery life, throughput**
  - Energy efficient and longer range 2.4GHz single-band
  - Power saving capabilities
  - Higher data rate support
- **Improve user experience and interoperability with**
  - The new Matter protocol
  - Ecosystem cloud integration and connectivity
  - Local area network connectivity
- **Bluetooth Low Energy usage with Wi-Fi**
  - Simplified provisioning
  - Proximity detection
  - Sensor connectivity

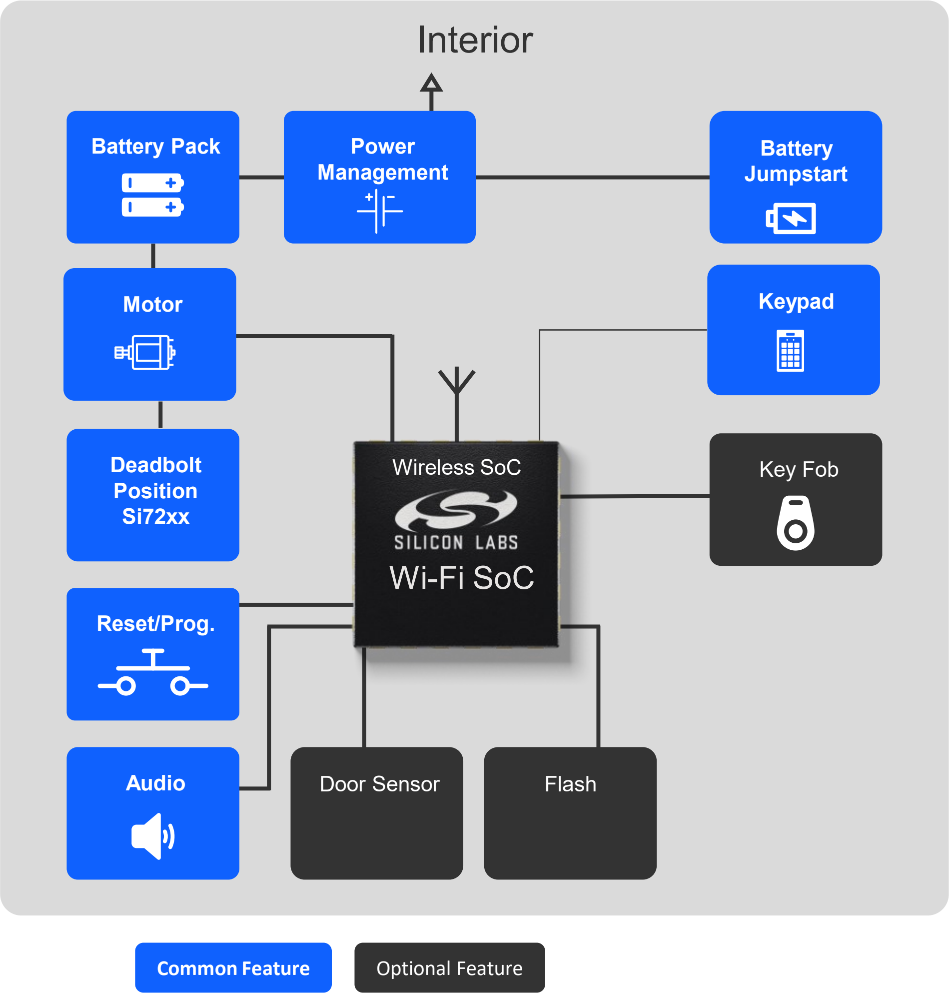
Prior to Wi-Fi-6, Smart Home Devices face a challenging and congested Wi-Fi environment

Battery Powered Smart Home Products benefit from Wi-Fi-6



Congestion and Interference have a major impact on the user experience

Building Smart Home Devices with Always On Wi-Fi 6 – Smart Door Lock



Network Efficiency

- OFDMA – High Density Network performance Improvement
- MU-MIMO
- BSS Coloring

Power Efficiency

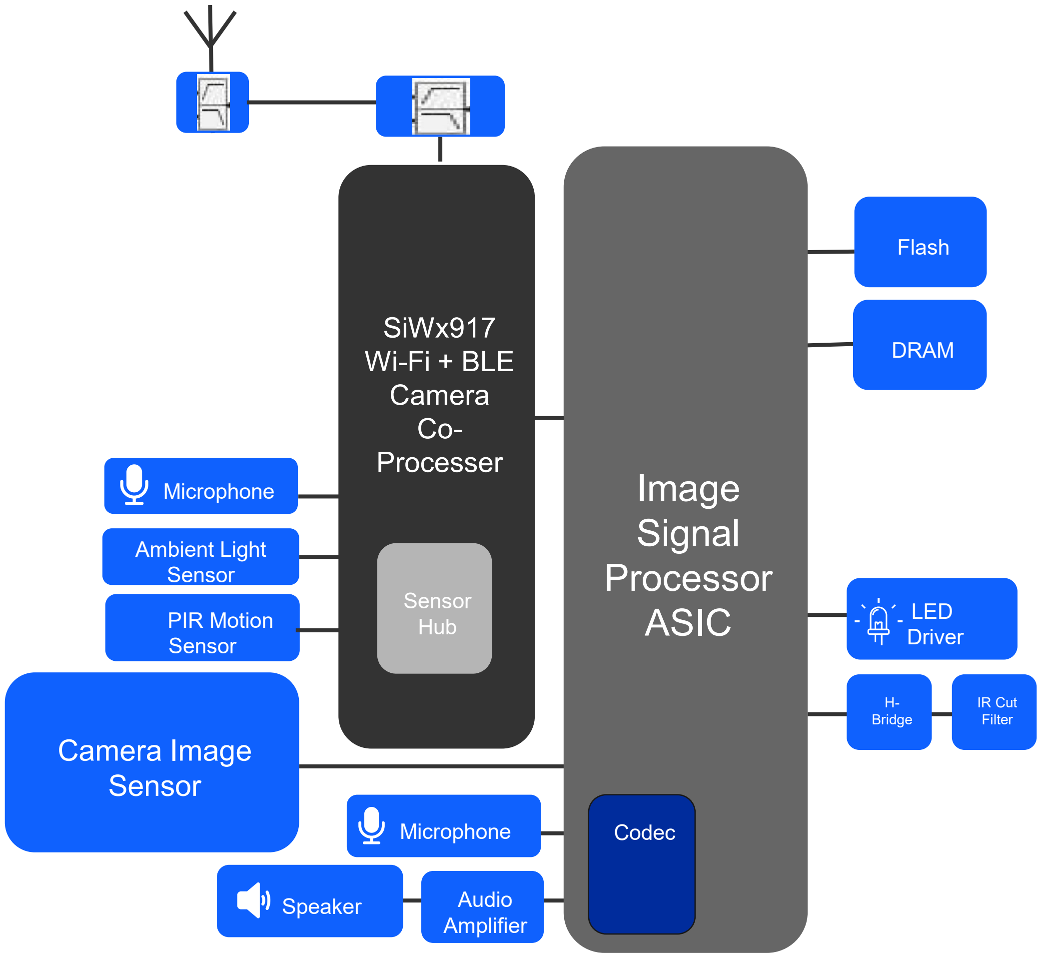
- Target Wake Time (TWT)
  - Reduce Product Size
  - Improve Battery life
- BSS Max Idle

Improve Range and Throughput

- TWT - training AP's steering matrix (beamforming weights) to optimize channel usage

Wi-Fi 6 Smart Home devices contribute to better home network operation

Building Smart Home Devices Always On Wi-Fi 6 – Battery Security Camera



Network Efficiency

- 2.4Ghz advantageous due to distance and environmental factors
  - OFDMA
  - MU-MIMO
  - BSS Coloring

Power Efficiency

- Target Wake Time (TWT)
  - Reduce Product Size
  - Improve Battery life
- BSS Max Idle

Improve Range and Through put

- TWT - training AP's steering matrix (beamforming weights) to optimize channel usage
- Guard Interval Duration

Wi-Fi Connected IoT Devices require fast demand response

Optimizing Power for Always On Wi-Fi 6

- Optimized Instruction Set w/ single cycle
- Optimal power vs performance trade off capabilities
- Wi-Fi Standby Associated mode current
- Wi-Fi listen current
- Low MCU Sub-system active current – (LP mode and HP mode)
- Deep sleep mode
- WLAN Rx sensitivity

Ultra Low Power – more than a marketing tag line

Calculating your Smart Home Device Power Consumption

1. Time spent Sensing
2. Time spent in Wi-Fi
3. Time spent in deep sleep

Power Calculator Parameters

1. ~~Deep Sleep current~~ Standby Associated (Deep Sleep + Beacon Listen)
2. Initialization time and current
3. Rx at start
4. Tx
5. Interpacket gap
6. Return to sleep

Configurable/Variable Parameters

1. Data Size (Number of packets)
2. Wake-up interval (Send / Receive)
3. Computations / Sensing

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SiWx917 Wi-Fi 6 + Bluetooth LE SoC

- **Ultra-Low Power Wi-Fi 6 + Bluetooth LE**
  - Multiprotocol combo with Matter support
  - Integrated applications MCU, SRAM, FLASH, AI/ML Accelerator
  - PSA L2 certifiable security engine and power management subsystem
- **Supports Wi-Fi 6 IoT Expansion**
  - Higher bandwidth, better coverage
  - Robust interoperability, security and longer battery life
  - Bluetooth LE multiprotocol for easy provisioning
  - Matter support for coexistence with multiple ecosystems and protocols
- **Single-chip solution to simplify design, reduce cost and speed up time to market**
  - Integrated with Simplicity Studio

Wi-Fi Standby Associated mode current: 50uA @ 1-sec beacon listen interval

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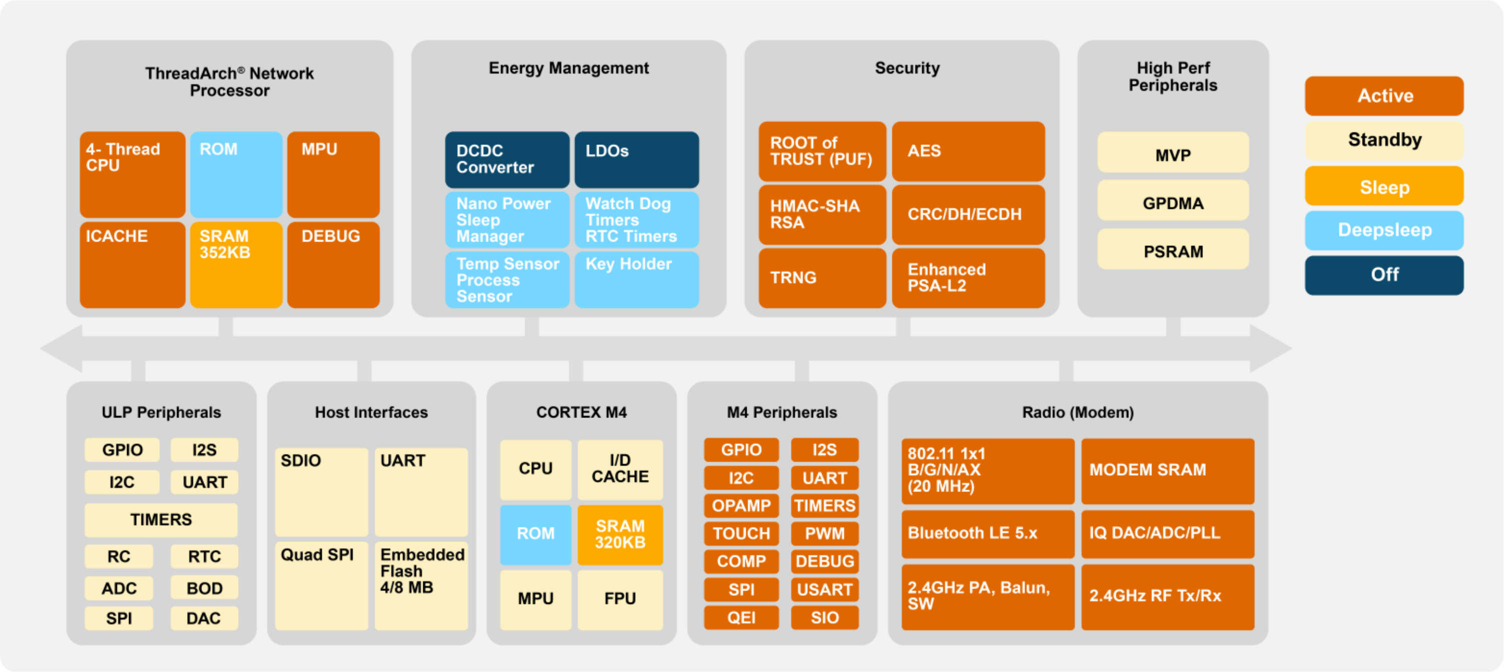
In addition to Wi-Fi 6 - SiWx917 Power Save Capabilities



- Big Little Radio Design (listen/Beacon)
- Dynamic voltage scaling
- Clock Scaling
- High performance and ultra-low-power MCU peripherals and buses
- Hardware based wakeup from Standby/Sleep/Shutdown states
- Using low leakage cells
- Multiple voltage domains
- Fine grained power-gating including buses and pads
- Two integrated buck switching regulators
- Multiple Active states using “gear-shifting” approach based on processing requirements

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2023 tech talks WEBINAR SERIES

Welcome

Designing Connected Wi-Fi 6 Sensors Using SiWx917 and Matter

Slides by Abhilash Yarragolla
Presented by Alfredo Pérez Grovas

WI-FI SERIES

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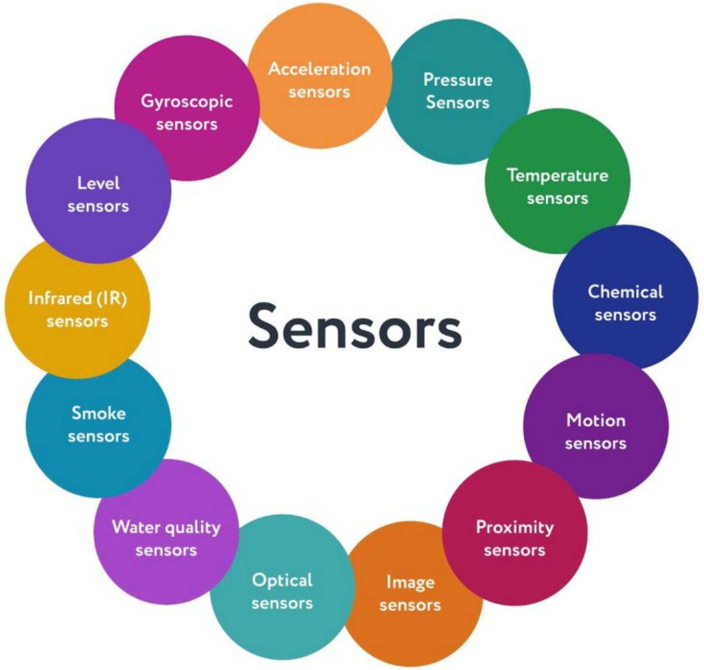
Agenda

- Introduction to sensors and key types
- Wi-Fi 6 key feature review for sensors
- Matter benefits for sensors
- SiWx917 ultra low power for battery-based sensors
- SiWx917 features for designing sensors(Sensor hub)
- AI/ML advantages for sensors
- Summary of Silicon labs portfolio
- Q&A

What is a Smart IoT Sensor Device?



SMART BUILDING

SMART HOME

COMMERCIAL

LIFE

INDUSTRIAL

HEALTH & FITNESS

- **Sensors are devices that detect and respond to physical or environmental stimuli, real-time, converting them into measurable signals**
- **These signals are processed allowing for detection of change anomalies or time critical events and used for various applications and notifications (locally or cloud)**
- **Sensors are widely used for automation, safety and security in industries, smart buildings, commercial, healthcare, Smart Homes, and many other fields**
- **They enable customizations, optimization of process and help improve productivity, energy and cost savings through automation**

Smart IoT Sensor Requirements

CONNECTIVITY AND RANGE

Wired or Wireless Connectivity

Cloud or local network

Long range – whole home or office

Interoperability

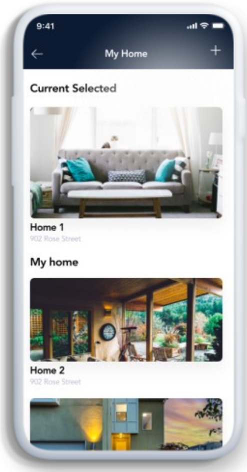
SIZE AND BATTERY LIFE

Small form-factor size designs

Long battery life (months or years)

Limited resources (MCU, memory, etc.)

Lower requirements (lower throughput)



EASE OF USE AND DEPLOYMENT

Easy commissioning of Wi-Fi

Bluetooth for Mobile Phone communication

Use of existing infrastructure

SECURITY AND EDGE COMPUTING

Protect data and user privacy

Edge processing for local decisions

Security from online and physical attacks

  NDA Required SILICON LABS

Wi-Fi – Key Enabler in the evolution of the Smart IoT Sensors

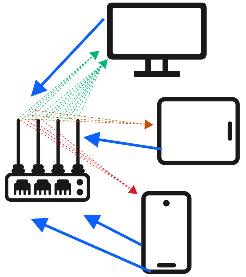
- **Global Standard – widely deployed interoperable technology**
- **Proven security**
- **Existing infrastructure – no specialized gateway required**
- **Low power capabilities**
- **Local Network and Cloud Support**
- **Reliable and long range**
- **Matter compatible**

Wi-Fi 6 Key Features and Benefits for Sensors

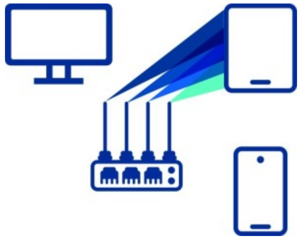
Wi-Fi 6 CERTIFIED

Better Performance/Connectivity

Full Duplex
Multi-User MIMO



Beamforming

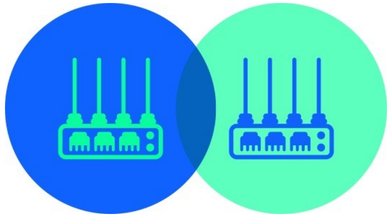


Higher Throughput, Reduced Overhead

Support Denser Environments

OFDMA

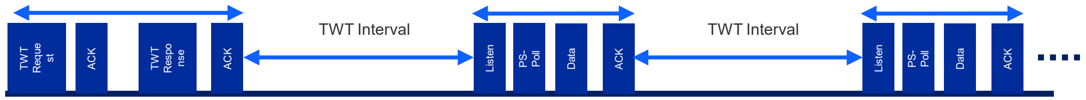
Spatial Reuse,
BSS Coloring



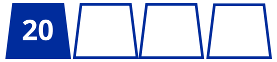
Network Efficiency

Longer Battery Life

Target Wake Time



2.4GHz, 20 MHz Channel



BSS Max Idle

Improved coverage/Longer Range

2.4GHz, 20 MHz Channel

Extended range packet structure

8µs	8µs	4µs	4µs	16µs	4µs					
L-STF	L-LTF	L-SIG	RL-SIG	HE-SIG-A	HE-STF	HE-LTF	...	HE-LTF	Data	PE

Enhanced delay spread protection- long guard interval

- 0.8us
- 1.6us 11ax
- 3.2us 11ax

The time is NOW to utilize Wi-Fi 6 for Best Performance and User Satisfaction

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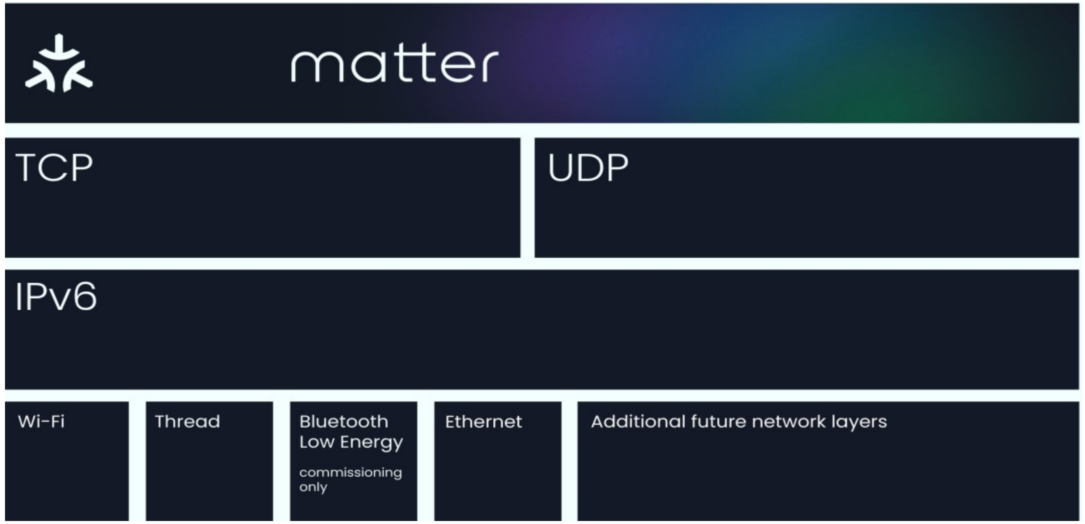
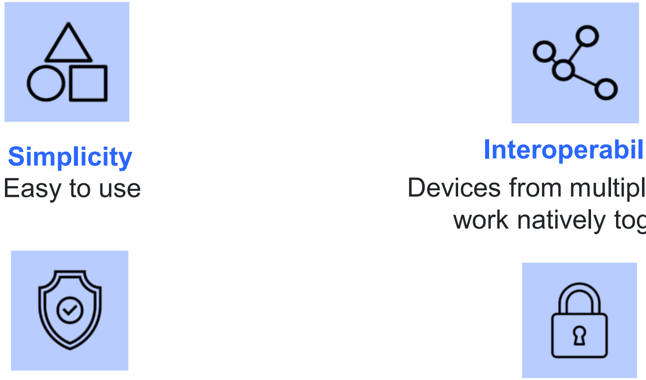
Matter and its benefits for Smart Sensors

- **What is Matter?**
  - Unified approach to IoT device development.
  - Matter is open-source connectivity standard
    - Smart home and IoT devices, which aims to improve their compatibility and security.
  - An application layer over existing protocols Wi-Fi and Thread
    - Not an entirely new protocol
  - Matter drives the convergence between the major IoT ecosystems
    - Create one easy, reliable, and secure wireless protocol to connect all IoT devices and networks
  - Matter works over Wi-Fi, ethernet, and Thread.
- **Benefits of Matter**
  - Interoperability - With multiple ecosystems like Google, Apple, Samsung, Amazon
  - Security – secure application layer for data protection
  - Simplicity - Ease of use through unified approach
  - Reliability – common and consistent connectivity standard





Simplicity
Easy to use

Interoperability
Devices from multiple brands work natively together

Reliability
Consistent and responsive local connectivity

Security
Robust and streamlined for developers and users

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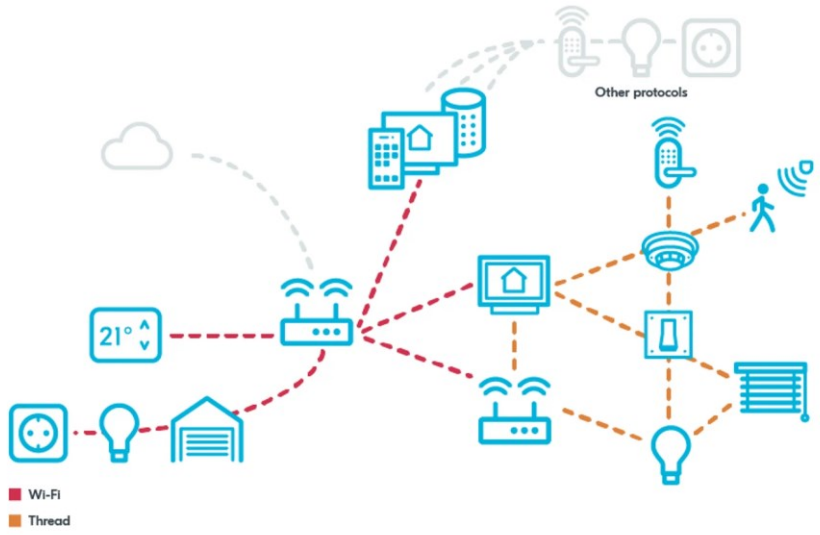
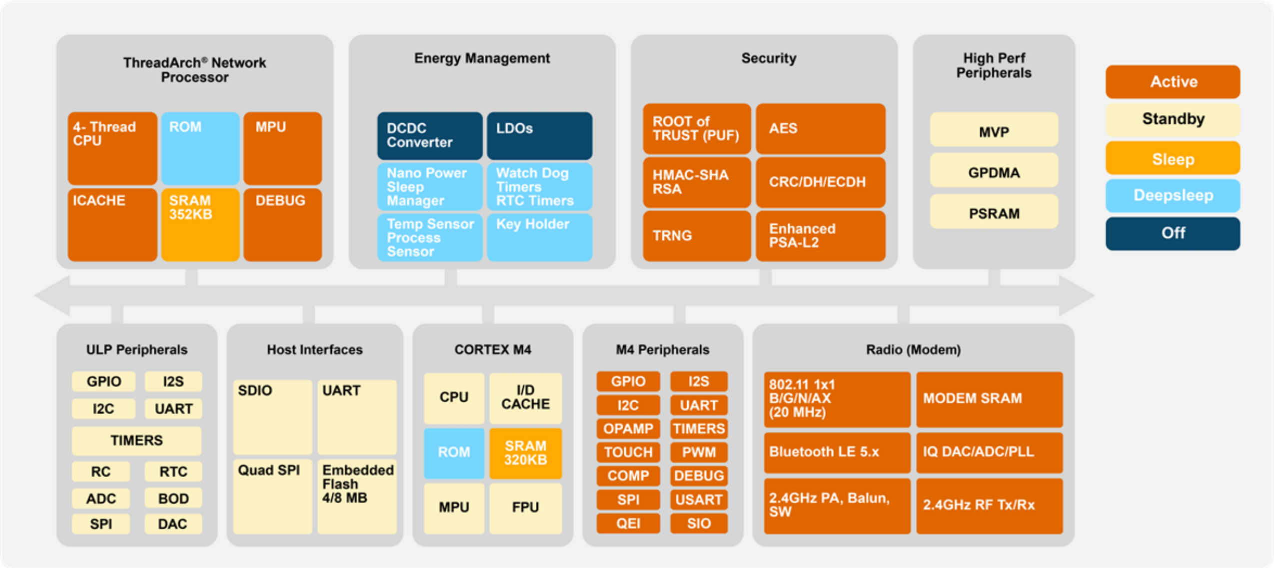
Silicon Labs Wi-Fi 6 IoT Optimized Sensor Solution - SiWx917



Ultra Low Power
Multi Protocol
Secure

- Multiprotocol support Wi-Fi 6 + Bluetooth LE 5.4
- Ultra low power Wi-Fi 6 for long battery life
- Integrated applications MCU, SRAM, FLASH for sensor apps
- Matter support for coexistence with multiple ecosystems
- AI/ML Accelerator for smart edge processing
- Best in class security for sensors via PSA-L2 certifiable security engine
- Robust Interoperability, better coverage and range with 2.4GHz
- Bluetooth LE multiprotocol for easy provisioning
- Single-chip solution to simplify design, reduce cost and speed up time to market

In addition to Wi-Fi 6 - SiWx917 Power Save Capabilities



- Big Little Radio Design (listen/Beacon)
- Dynamic voltage scaling
- Clock Scaling
- High performance and ultra-low-power MCU peripherals and buses
- Hardware based wakeup from Standby/Sleep/Shutdown states
- Using low leakage cells
- Multiple voltage domains
- Fine grained power-gating including buses and pads
- Two integrated buck switching regulators
- Multiple Active states using “gear-shifting” approach based on processing requirements

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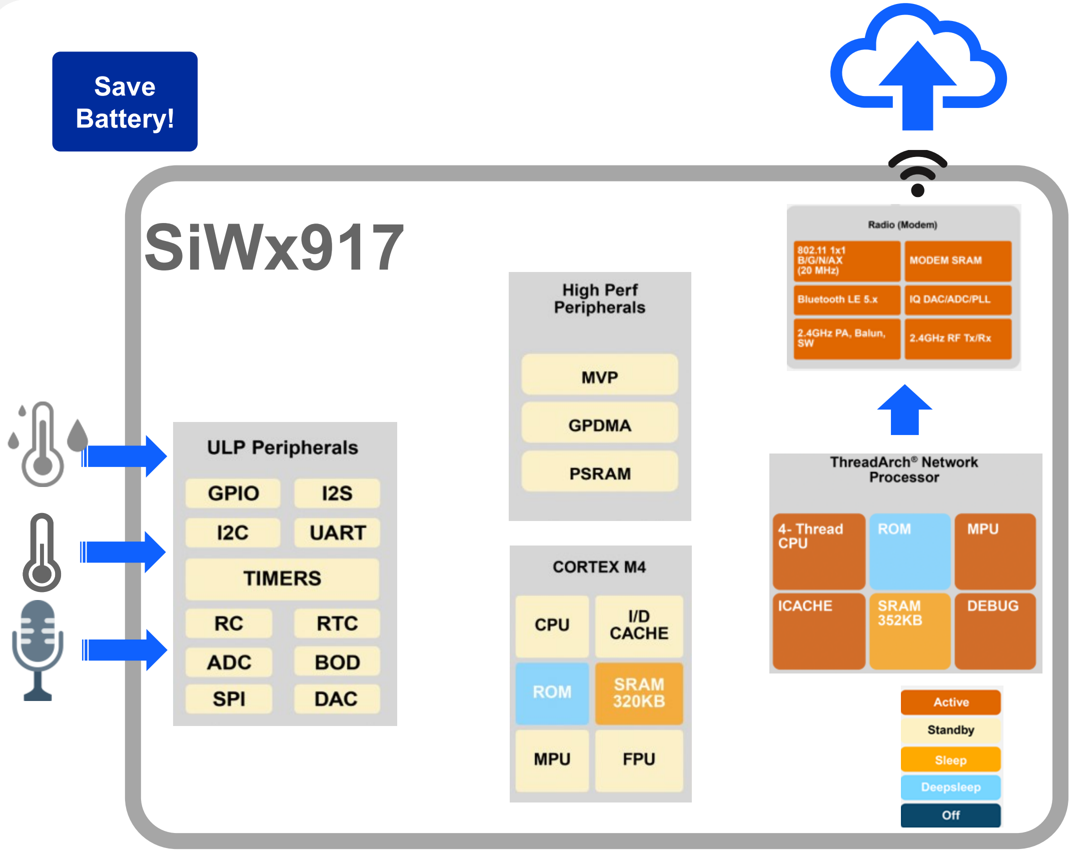
SiWx917 power save architecture with sensors



1 *Receive sensor data via ULP peripherals in ULP mode*

2 *Local decision in on MCU*

3 *Wake up radio only when a cloud connection needed.*

- Si917 has four major power save modes.

1. Active mode

- There are four power states within active mode PS4-PS1
- The difference between Power states (PS4/3/2/1) is based on CPU operating frequency, voltages and SRAM availability.

2. Standby mode

- There are three power save states PS4 – PS2 within the standby mode.
- In this mode and these states, CPU is clock gated and between the three states voltage differs.

3. Sleep mode

- Within sleep mode there are three power save states PS4 – PS2.
- In this mode and these states, CPU will be power gated & the amount of RAM can be retained varies.

4. Deep Sleep mode

- In deep sleep mode, CPU & RAM is power gated.

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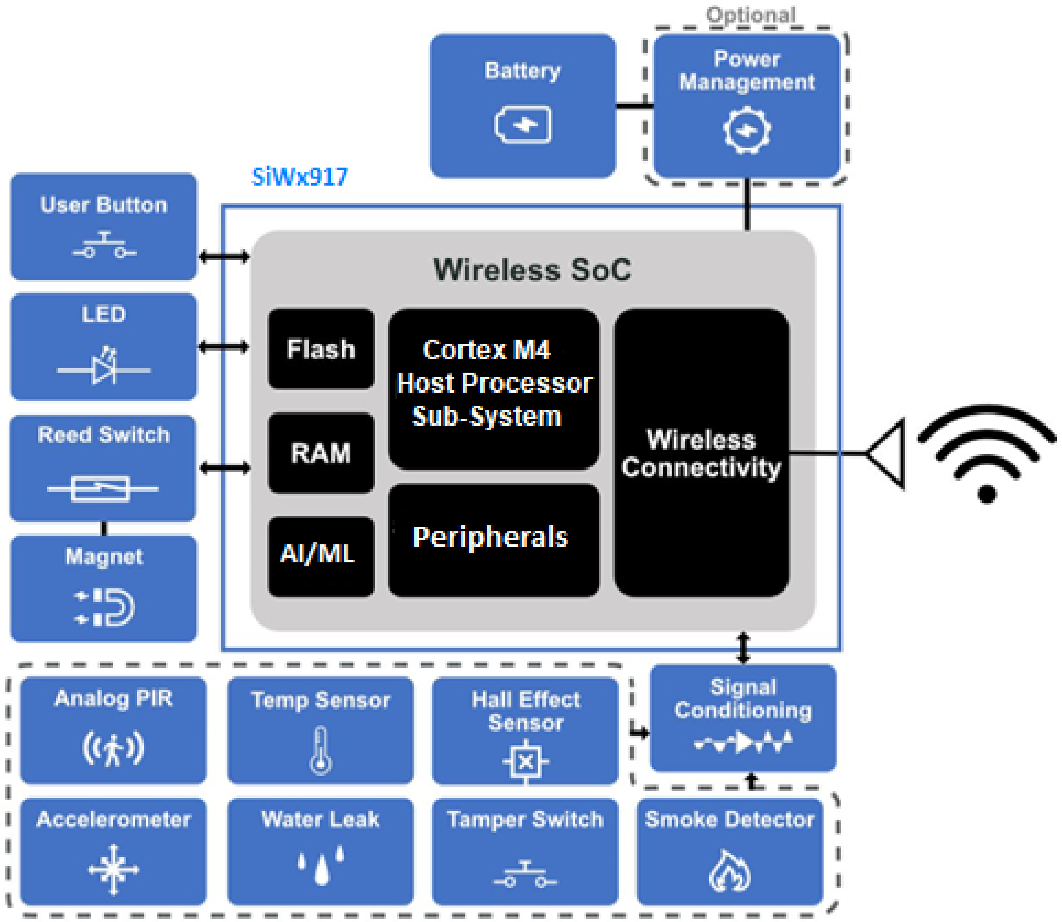
SiWx917 features for designing Sensors (Sensor hub)

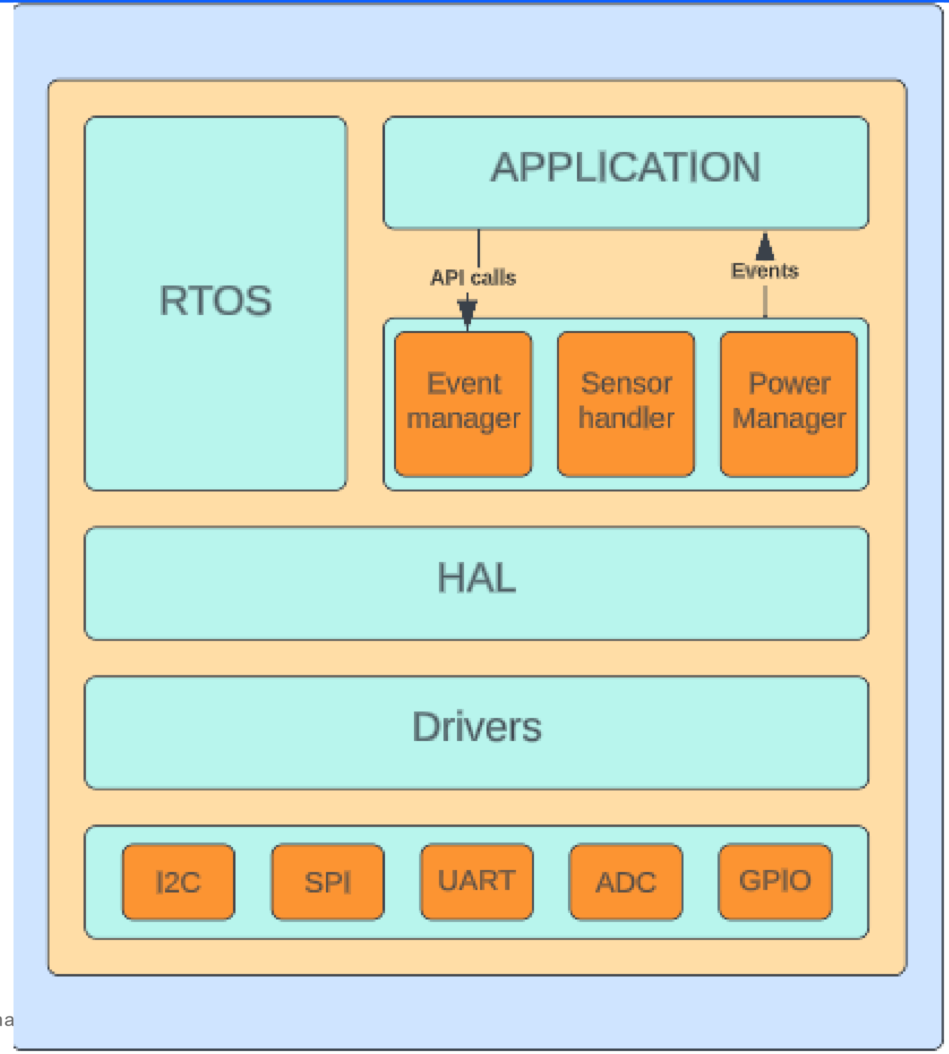


- Sensor Hub is a sensor management component
- Sensor hub aids in processing and integrating data from several sensors.
- It assists in off-loading various tasks from a product's primary core, reducing energy consumption and enhancing performance.

- The Sensor Hub addresses low power and high-performance sensor applications
- Decouples the software dependencies from peripheral drivers and sensor drivers.
- Reduce complex sensor implementations

SiWx917 Sensor framework Architecture

SENSOR FRAMEWORK ARCHITECTURE



Informa

Framework and API for efficient management and allocation of ULP memory

- Sensor Data RAM mapped to ULP memory
- API to confirm RAM is available

Sensor Implementation utilizes the HAL

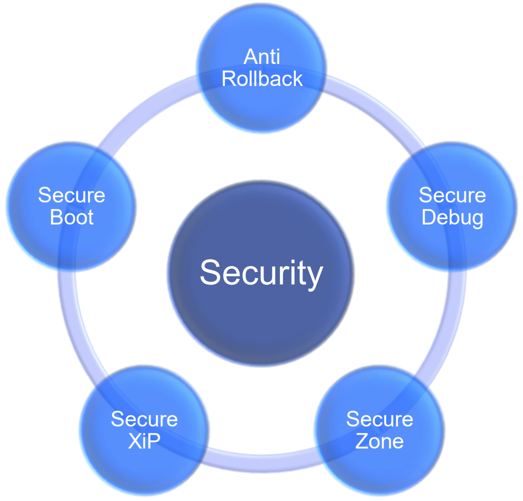
HAL interface for all developer defined sensors

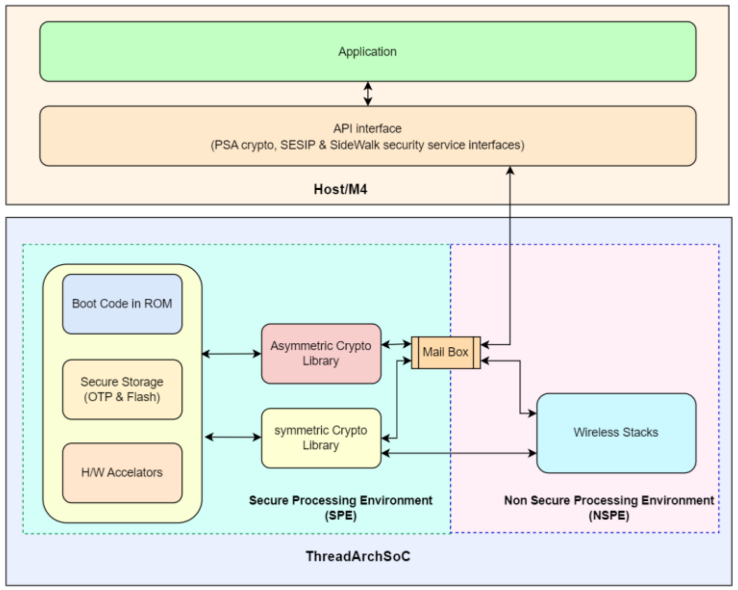
Sensor_Hal.c file stores the information of the HAL

- **Three Data Attributes (when the Sensor Hub should hand over the data to the application)**
  1. Based on user defined threshold for that specific sensor
  2. Time out
  3. Number of samples
- **Data Attributes created and maintained for each individual sensor**

SiWx917 Security Features for Sensors

- **Secure Boot**
  - Authenticate flash contents, Wireless and MCU firmware based on digital signature, MIC before booting based on device configurations.
  - Flash Image can be encrypted and authenticated using signatures.
- **Anti Rollback**
  - When enabled, downgrading of the firmware to a lower version will not be allowed.
- **Secure Debug**
  - Wireless and MCU debug ports are disabled by default in hardware
  - Debug ports can be enabled in software using host interface commands based on token exchange between an authorized host and bootloader
- **Secure Zone**
  - Logically idea is similar to Secure Vault implementation(barrier between secure and non-secure stuff)
  - **Access to memory and hardware registers to security processor is disabled from external devices including On Chip M4 processor.**
- **Secure XIP**
  - Images are saved in encrypted format and decrypted using PUF intrinsic keys specific to each device while executing.
  - Key holder holds PUF keys
  - In-line decryption based on-the-fly AES engine(based on PUF keys)
  - Supported modes: XTS & CTR





Why AI/ML for sensors at the Edge?

Low Latency Required

- Mission or safety-critical applications require real-time reactions
- Large data to process - typically at vision use cases - no time to upload to anywhere to process

Privacy and IP Protection, Security

- Data never leaves the sensing device, only inference result/metadata is transferred
- Less sensitive data to transmit, less chance to be hacked
- Protecting IP

Bandwidth and Power Constraints

- Long range, low power, and slow networks can't transfer all TimeSeries data to process somewhere else
- Overloading of mesh network is an issue
- Large data to chunk
- Process vs. transmit tradeoff in power cons.

Offline Mode Operation

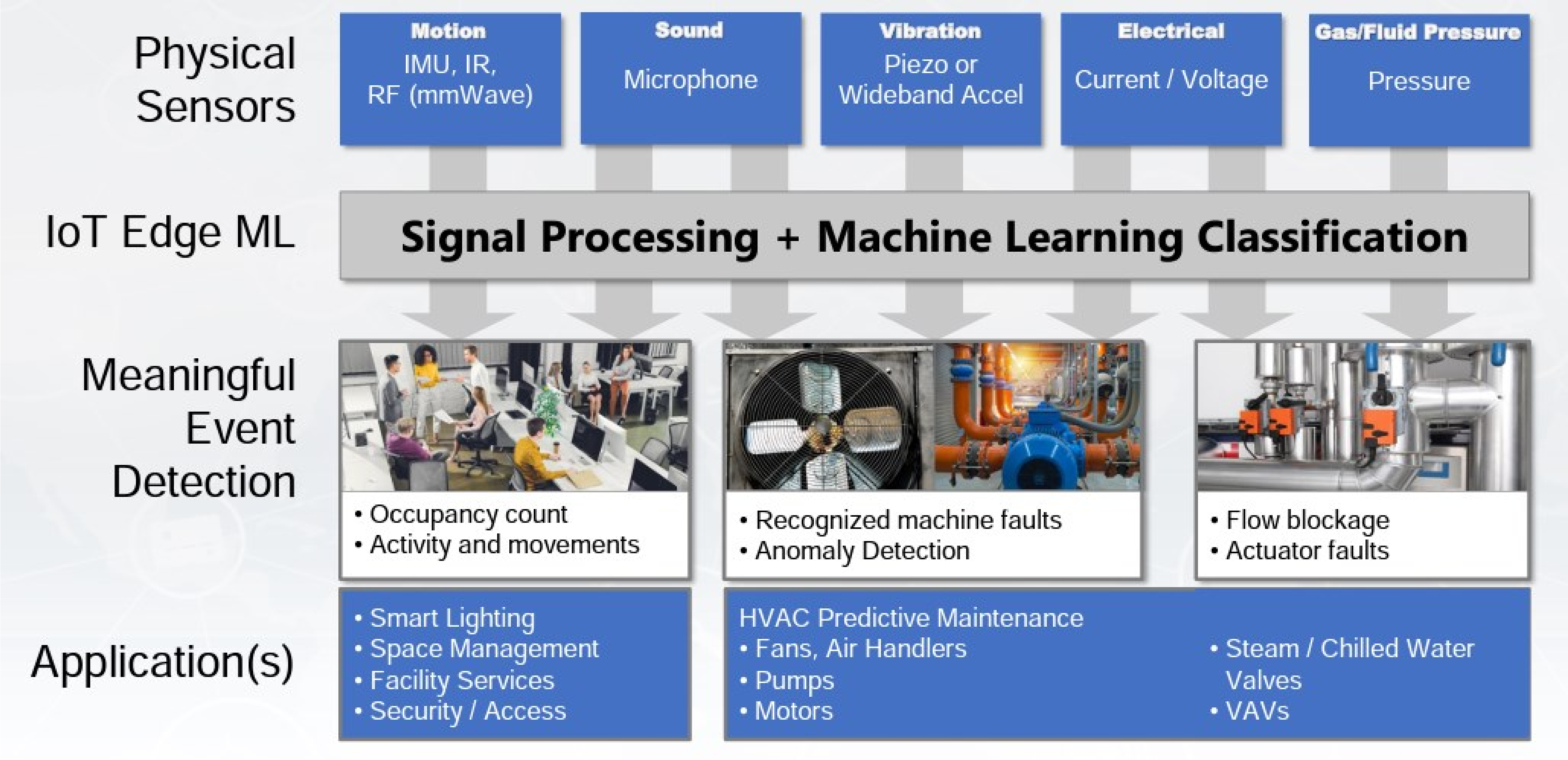
- Local system keeps operating standalone in case of any network issue
- Connectivity is occasional or blocked by admin

Cost Reduction

- Network and infrastructure costs
- Data ingestion costs
- Data storage costs
- Cloud services
- Ops, maintenance
- Compact edge with ML solutions integrated to wireless SoC

Data processing is more efficient with AI/ML at the Tiny Edge – various new use cases enabled

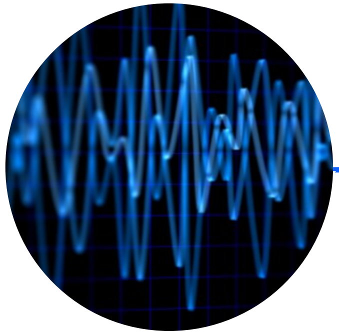
Use Cases for AI/ML on the Edge in Predictive Maintenance



Event Detection using Machine Learning

Sensors
- Acceleration, Temperature, Current/Voltage
- Time-series data on ADC or GPIO

ML methods based on Time-series Data
- Data anomaly detection
- Data pattern matching

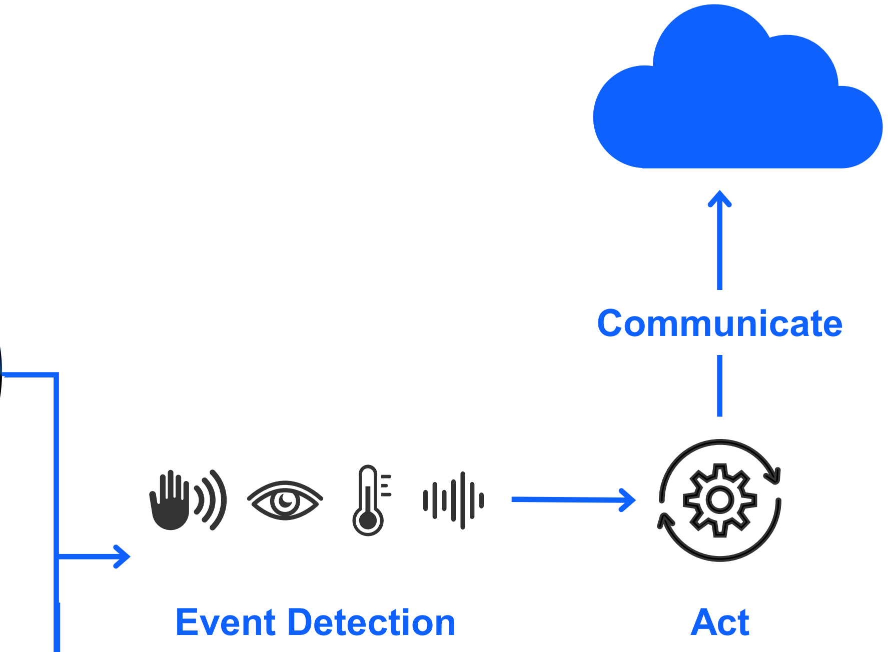


Microphones

Analog or Digital
- Audio mic array with beamforming
- Audio mic input with Audio Front End, DSP

ML methods based on Audio
- Audio pattern matching (ex. glass break)

ML methods based on Voice
- Wake word/command word detection



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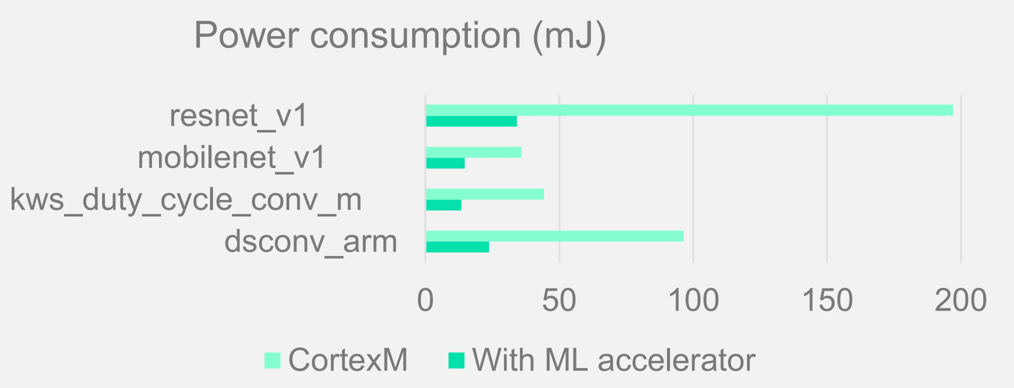
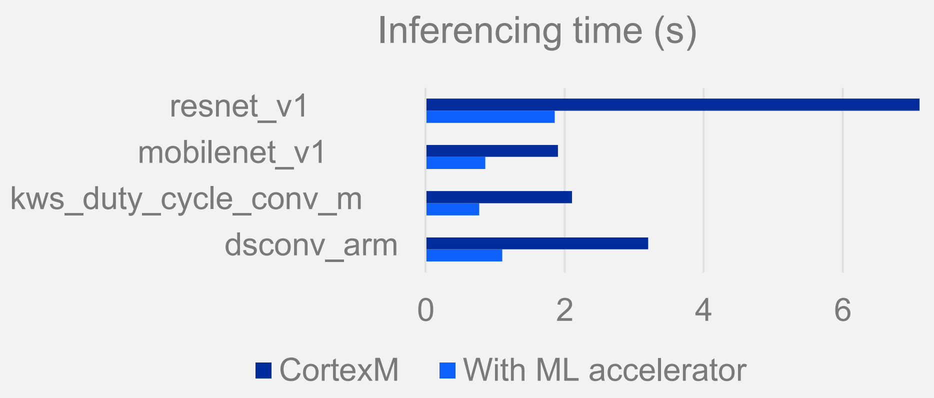
AI/ML Hardware Accelerator

- Dedicated **ML computing subsystem** next to the CPU
- Optimized Matrix Vector Processor (MVP) accelerates ML inferencing with a lot of processing power, **offloading the CPU**
- **Real and complex data**
- **2-8X faster** inferencing over Cortex-M
- Up to **6X lower power** for inferencing

- Benefits of processing AI/ML in device
- Lower power
- Save bandwidth
- Lower latency
- Ensure Privacy
- Higher Security
- Lower Cost

Inferencing with ML hardware accelerator vs. CortexM*





*Internal performance benchmarking with standard ML models. Results are for inferencing only (not for the complete application)

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Software and Tool Support for ML

ML Expert

Python scripts and tutorials

SILICON LABS Machine Learning Toolkit*

siliconlabs.github.io/mltk

TensorFlow

TFLite Flatbuffer

TFLite-micro Interpreter

CMSIS-NN Kernels | Silicon Labs HW-based Kernels

Cortex M | MVP (NPU)

ML Explorer

GUI Developer Tools

EDGE IMPULSE

edgeimpulse.com

SensiML™

sensiml.com

TFLite-micro Interpreter

CMSIS-NN Kernels | Silicon Labs HW-based Kernels

Cortex M | MVP (NPU)

ML Solutions

Solution Libraries

Wake Word / Voice Command — sensory

sensory.com

Anomaly Detection — Micro.ai

micro.ai

System Integrators

KLIKA·TECH GLOBAL IOT SOLUTIONS

AIZIP

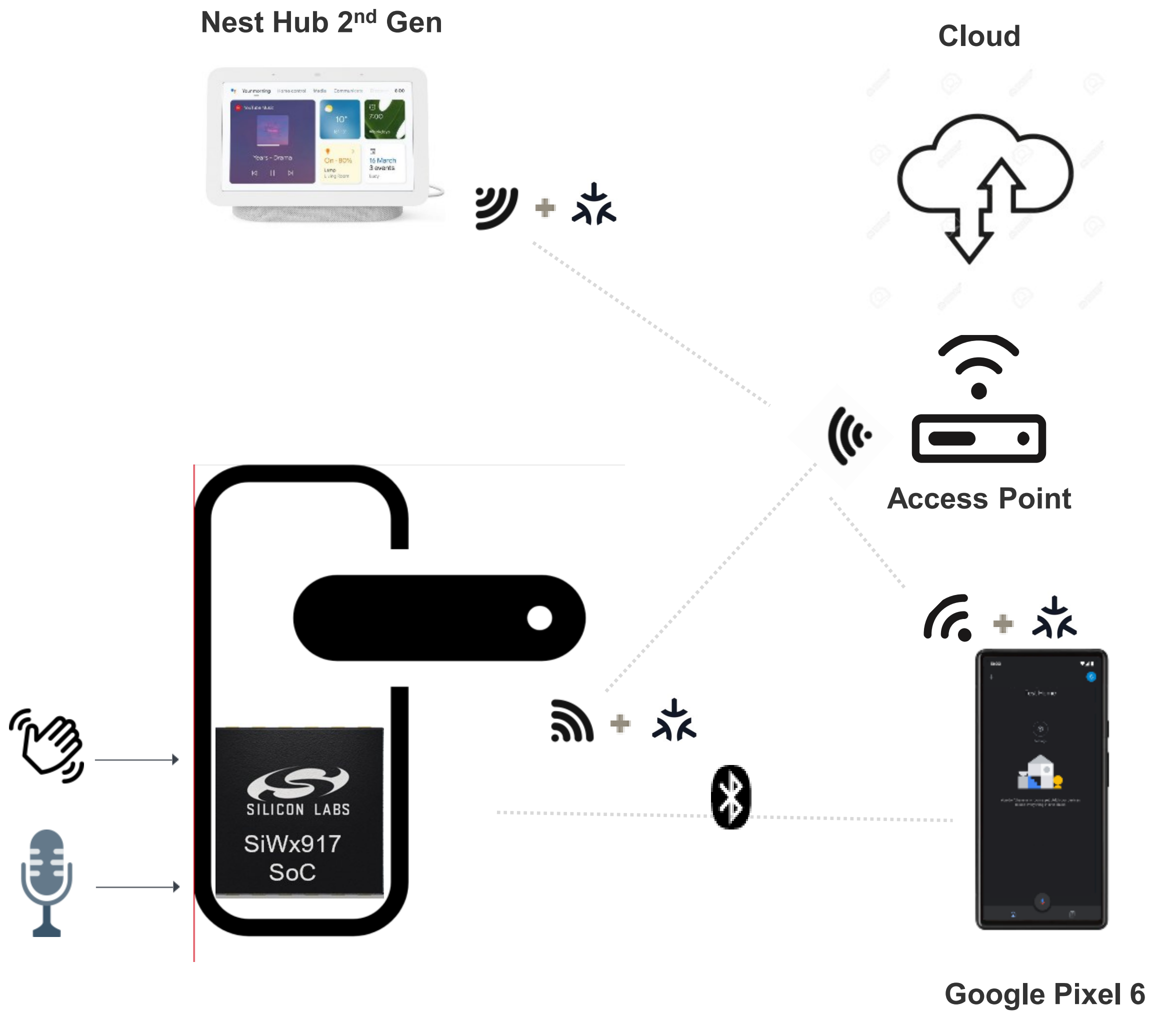
AITAD

Bellintegrator

Cortex M (& MVP)

*Machine Learning Toolkit is public but pre-alpha release

SiWx917 use case with sensors using Matter

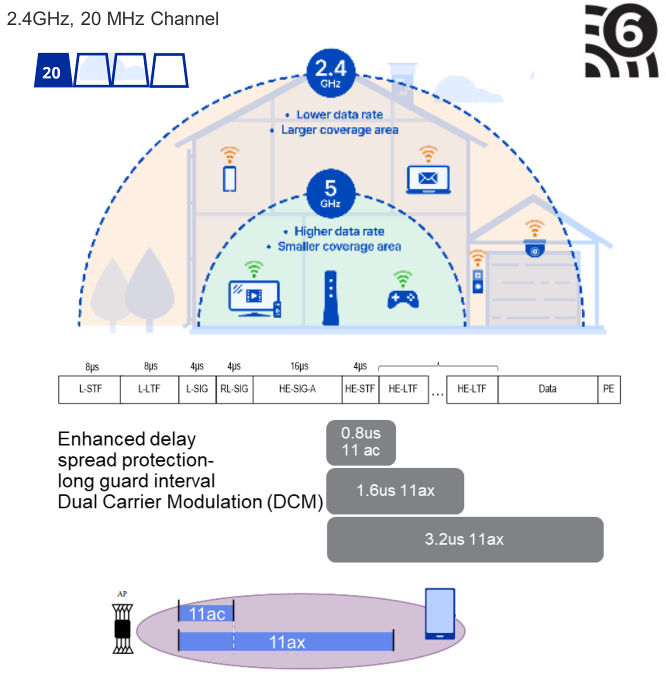


Sensor use case with SiWx917

- BLE commissioning to connect SiWx917 to AP connected to cloud.
- Integration of sensors for image, voice, object detection. The input from the sensors is processed in AI/ML Edge Hardware Accelerator to notify the user about the activity.
- Status of the Device is updated to the cloud over MQTT using Wi-Fi.
- Matter node (Si917) work reliably together with Google Home, Samsung SmartThings, Apple Home, or Amazon Alexa over Matter.

Optimal Wi-Fi 6 SoC solution for longest battery life secure cloud connected IoT sensors (devices)

SiWx917 Key benefits for IoT Sensor: Long Range & Battery Life

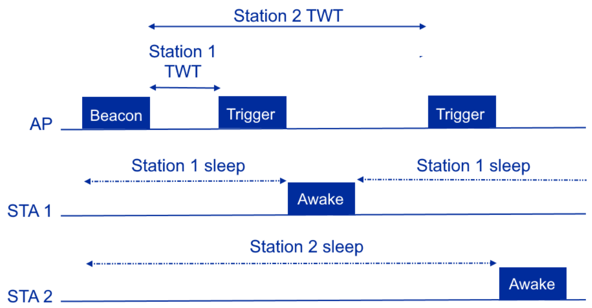


EXTENDED RANGE

Achieve whole home coverage including the yard

- 2.4GHz Long Range - better penetration through walls
- Longer guard interval to handle echoes from further away objects
- Extended range packet format - some fields are boosted by 3dB

TWT & SiWx917 power modes



LONG BATTERY LIFE

TWT helps Reduce unplanned replacing of batteries

- Allows devices to schedule their wake-up times and reduce unnecessary communication with AP
- Reduces power consumption and increases battery life significantly

SiWx917 power save enhancements helps to further lower current consumption.

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SiWx917 Benefits for IoT Sensor: Easy & Secure

EASE OF INSTALL

Optimal user experience

- Bluetooth Low Energy-based commissioning options.
- BLE used for sensor connectivity and easy provisioning of IoT devices in the home.
- Improve user experience and interoperability with the new Matter protocol

SECURITY AND EDGE COMPUTING

Protect user privacy

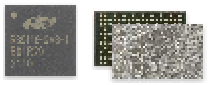
- Uses latest WPA3 for Wi-Fi security
- Secure boot with Root of Trust , Secure XIP, Secure zone.
- SiWx917 SoC supports best in class security (PSA Level 2 Certifiable)

Efficient Edge processing

- AI/ML hardware accelerator - MVP

  NDA Required SILICON LABS

Silicon Labs' Wi-Fi SoC Portfolio Summary

Features	WF200 	RS9116 	SiWx917 
Wi-Fi (2.4 GHz)	**Wi-Fi 4**	**Wi-Fi 4**	**Wi-Fi 6**
BT Low Energy (LE)		✓	✓
BT Classic (Audio)		✓	
Low Power Modes	**PS-POLL**	**PS-POLL, Listen Interval**	**PS-POLL, Listen Interval, TWT**
Wi-Fi Features	**OFDM**	**ODFM**	**OFDM, OFDMA, MU-MIMO**
Wi-Fi WPA3 Security	✓	✓	✓
ARM® Apps MCU (SoC Mode)			✓
ML Accelerator, PSRAM Interface, MCU Security (PSA-L2)			✓
Ultra Low Power		✓	✓
Matter	✓	✓	✓

Silicon Labs - Complete Solution for Enabling Wi-Fi Products

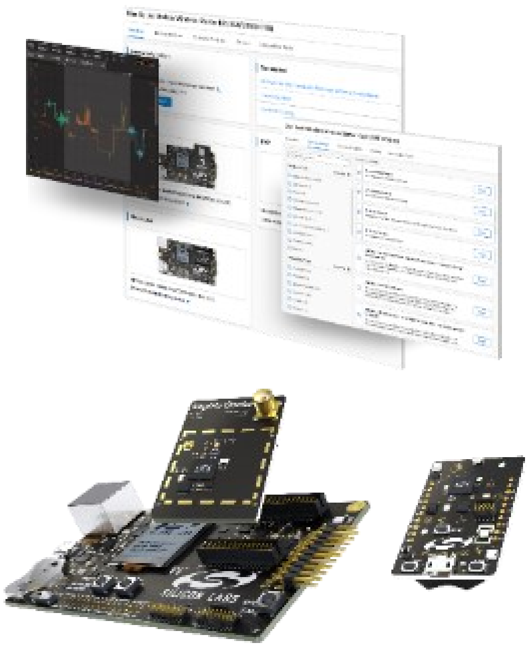
SoCS AND MODULES

Industry leading Ultra Low Power Wi-Fi 4 and Wi-Fi 6 SoCs and pre-certified modules

Application	
API	
TCP/IP	BT/BLE stack/profile
Wi-Fi and Bluetooth Link Layer	

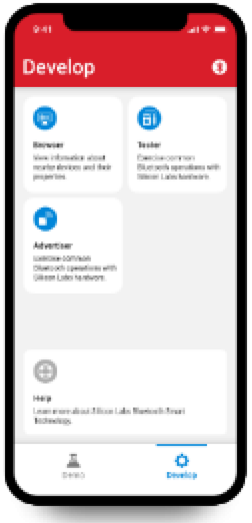
EMBEDDED SOFTWARE

Wi-Fi SDK with Integrated Wi-Fi, BT/BLE and IP networking stacks



DEVELOPMENT TOOLS

Evaluation Kit hardware and Studio software simplify development and speed time to market



MOBILE APPLICATIONS

EFR Connect for Wi-Fi Provisioning using BLE

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Q&A

WI-FI SERIES

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2023 tech talks WEBINAR SERIES

Thank You

WI-FI SERIES

Watch ON DEMAND