WI-FI SERIES

Presentation Will Begin Shortly

tech talks UPCOMING SESSIONS

FEB 2nd	|	Wi-Fi 6 Benefits for IoT Applications
MAR 2ND	|	Designing Low-Power Applications with Wi-Fi 6
MAR 30TH	|	Fast Track Your Wi-Fi 6 Device Certification
APR 27TH	|	Design with our New Multiprotocol Wi-Fi Module
MAY 25TH	|	Building Smart Home Devices with Always-On Wi-Fi 6
JUN 22ND	|	Developing Wi-Fi 6 Sensors Using SiWx917 and Matter

We will begin in: 0:00

2023 tech talks WEBINAR SERIES

Welcome

Designing Low Power Applications with Wi-Fi 6

Alfredo Pérez Grovas

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
- Silicon Labs' Wi-Fi Portfolio

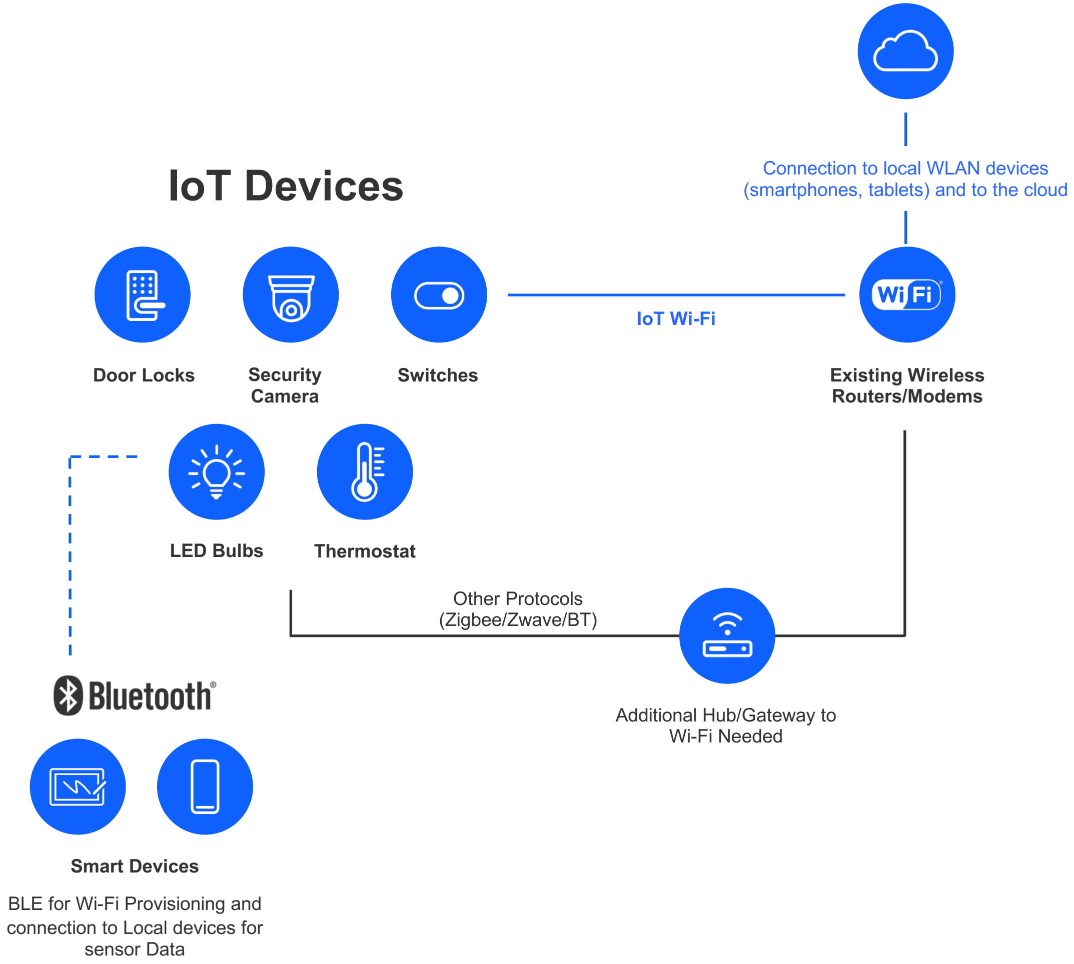
Evolution of Wi-Fi

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



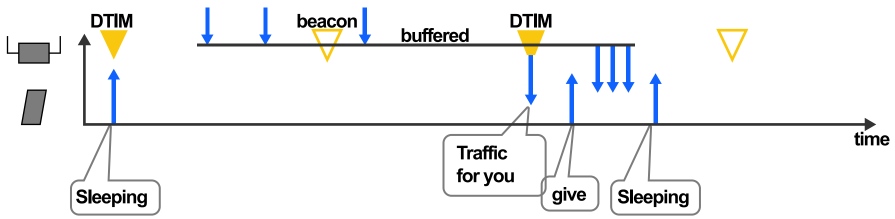
- **Simplified installations and cost reductions:**
  - Use existing Wi-Fi router/modem
  - Native IP protocol for internet communication
  - No additional Hub/Gateway required
- **Extended range, battery life, throughput**
  - Energy efficient and longer range 2.4GHz single-band
  - Power saving capabilities
  - 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

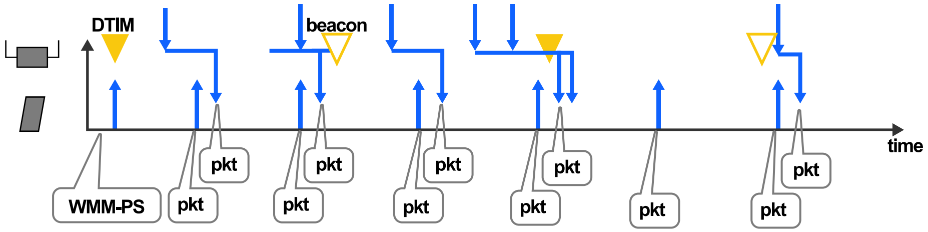
- **Why Low Power?**
  - IoT devices are different from traditional Wi-Fi devices such as laptops, tablets and cell phones
    - Limited resources (MCU, memory, etc.)
    - Lower requirements (lower throughput)
  - Like laptops, tablets and cell phones, they tend to be battery powered
  - Their batteries 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

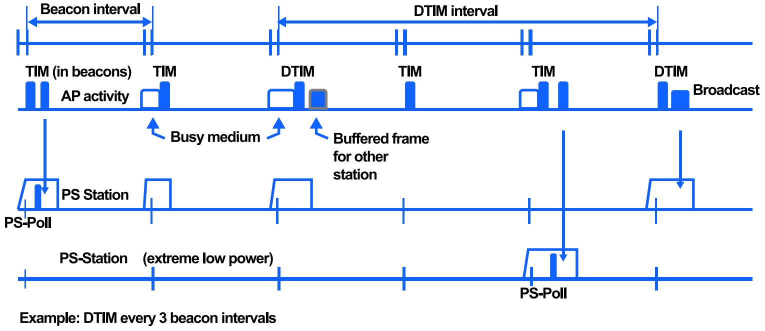
Traditional Power Save



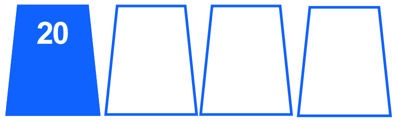
WMM Power Save



DTIM Intervals



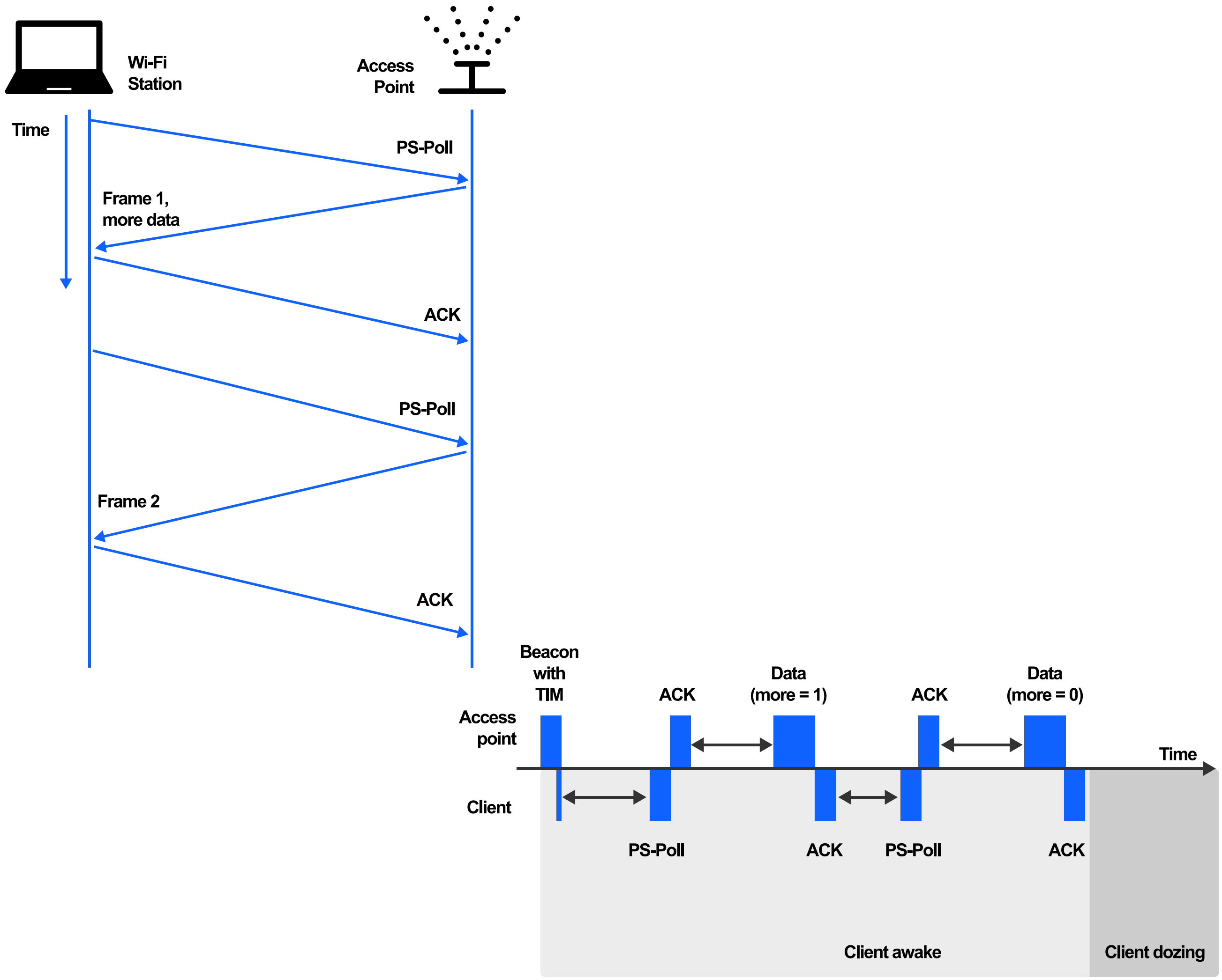
20 MHz Channel Usage



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

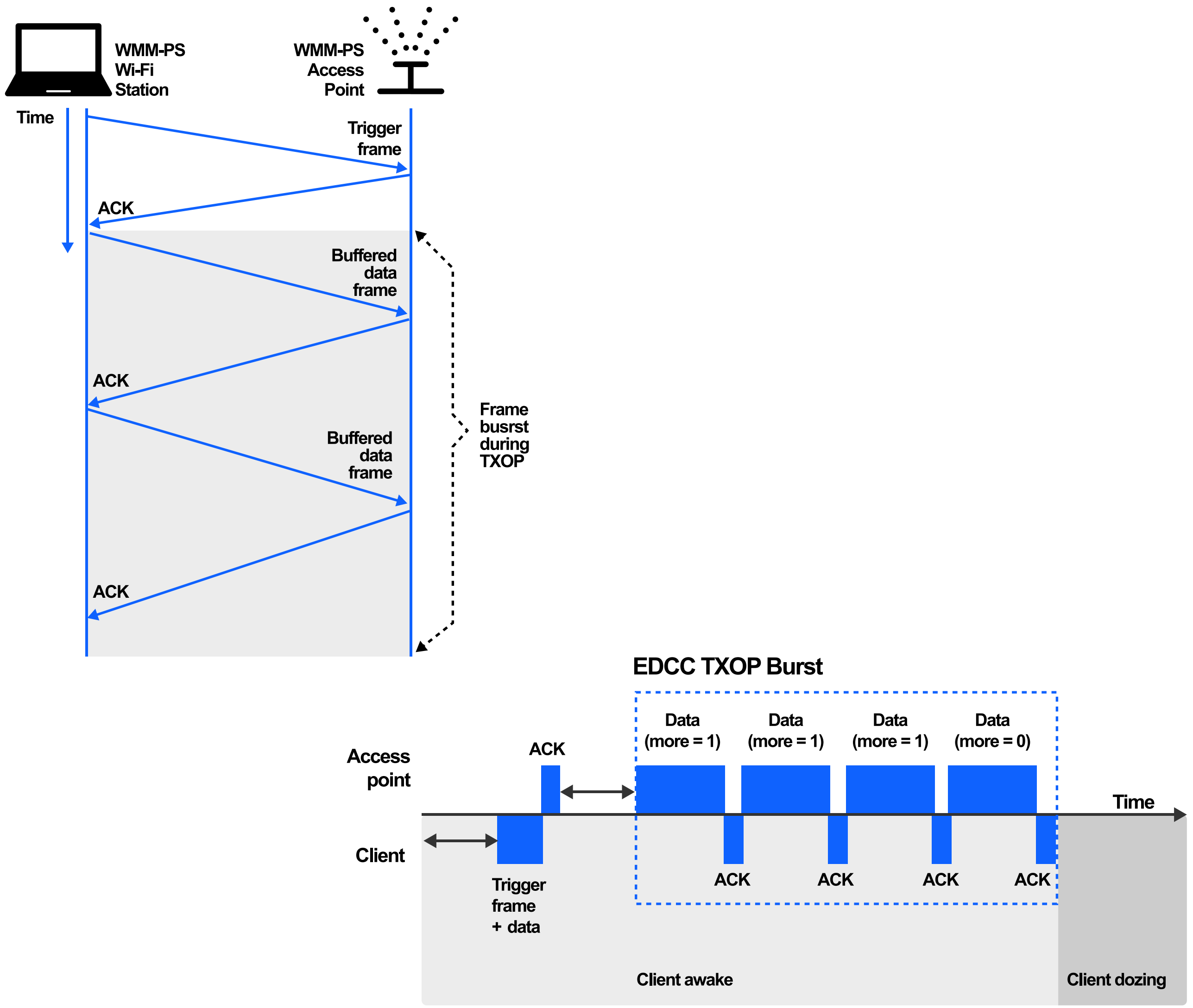
DTIM: Delivery Traffic Indication Message
WMM: Wireless Multimedia

Traditional Power Save



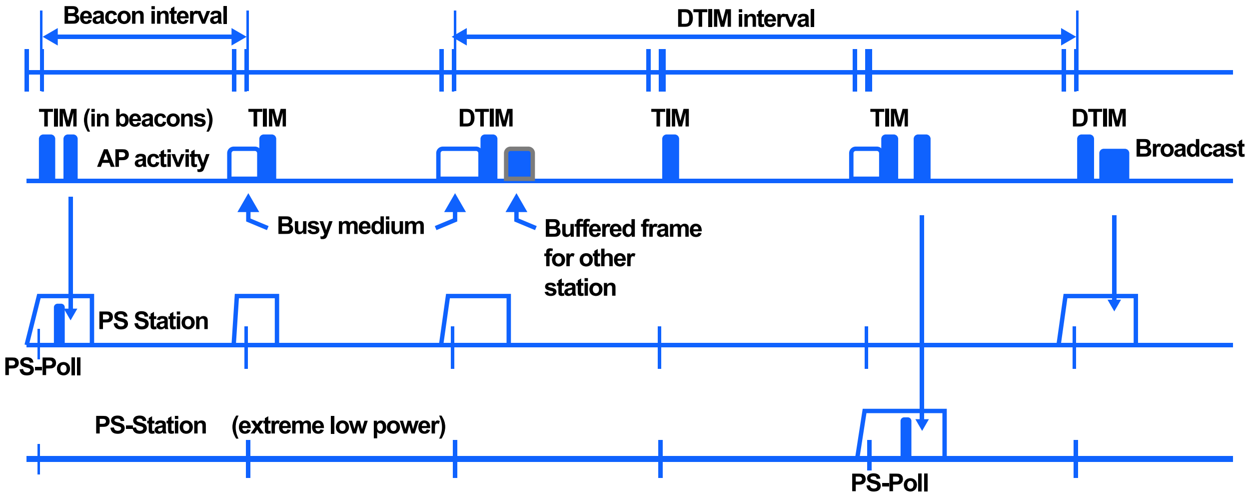
- **Traditional Power Save**
  - Wi-Fi stations go to sleep and wake up to listen to beacons transmitted by the Access Point (AP)
  - On AP beacons they find out when frames are buffered for them at the AP
  - Wi-Fi Stations then use PS-Poll frames to request frames buffered at AP for them
  - This method 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



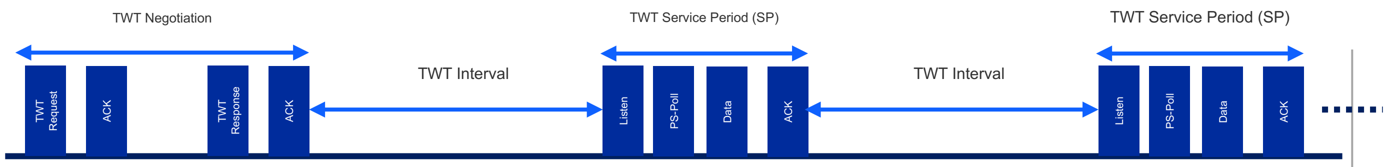
Example: DTIM every 3 beacon intervals

- **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

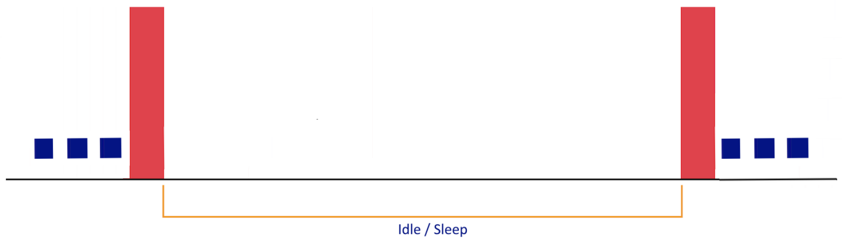
20 MHz Channel Usage

- **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

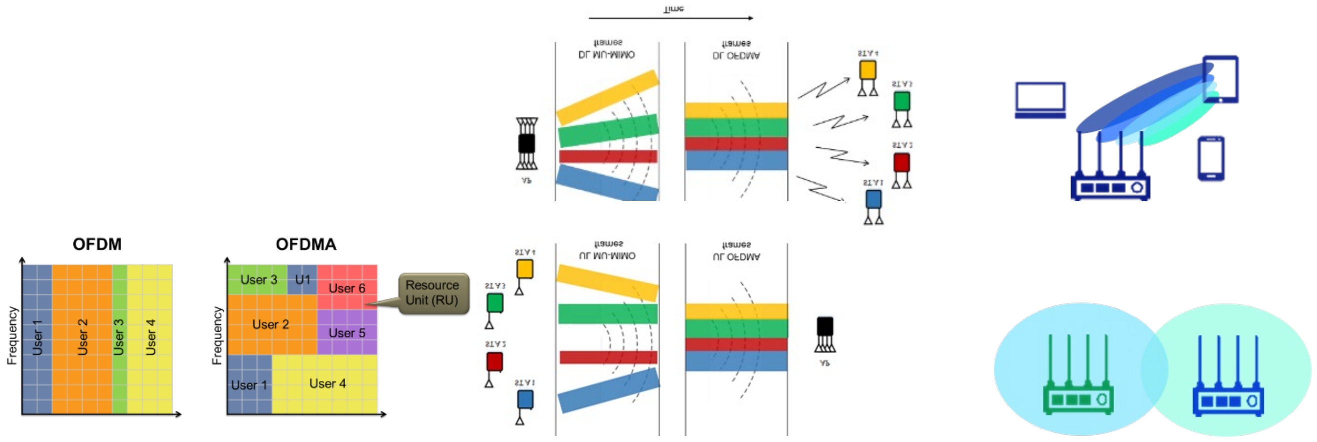
Wi-Fi 6 Power Saving Features



Target Wake Time



BSS Max Idle

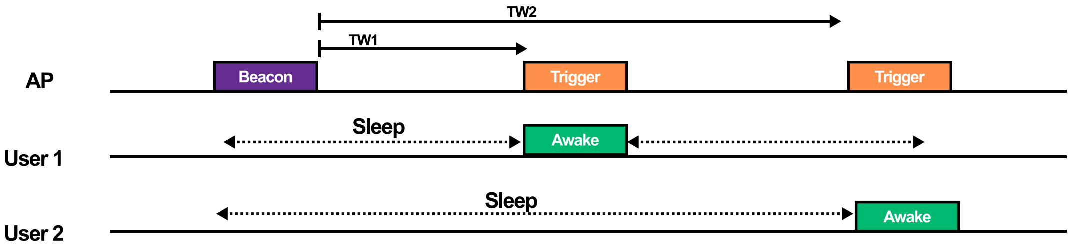


Other Wi-Fi 6 features

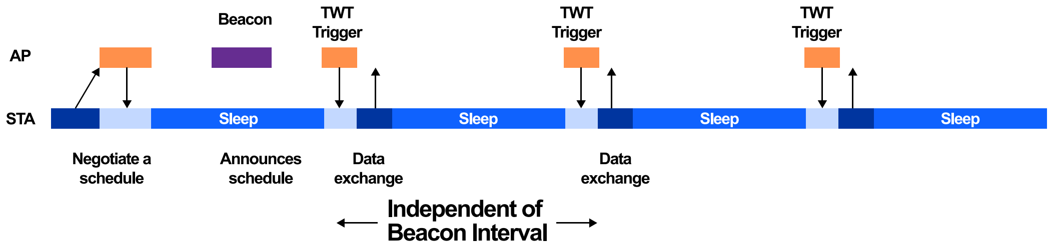
- **Wi-Fi 6 is meant to support battery-powered devices**
  - Wi-Fi 4 provided power saving mechanisms sufficient to support traditional mobile devices (cell phones, tablets)
  - The battery lifetimes of those devices are in hours or days in the best case
  - Wi-Fi 6 was designed to support IoT and other 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

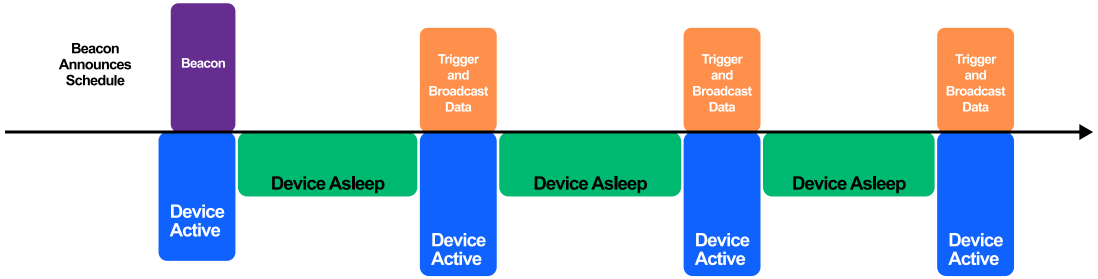
BSS: Basic Service Set

Target Wake Time (TWT)



Individual TWT



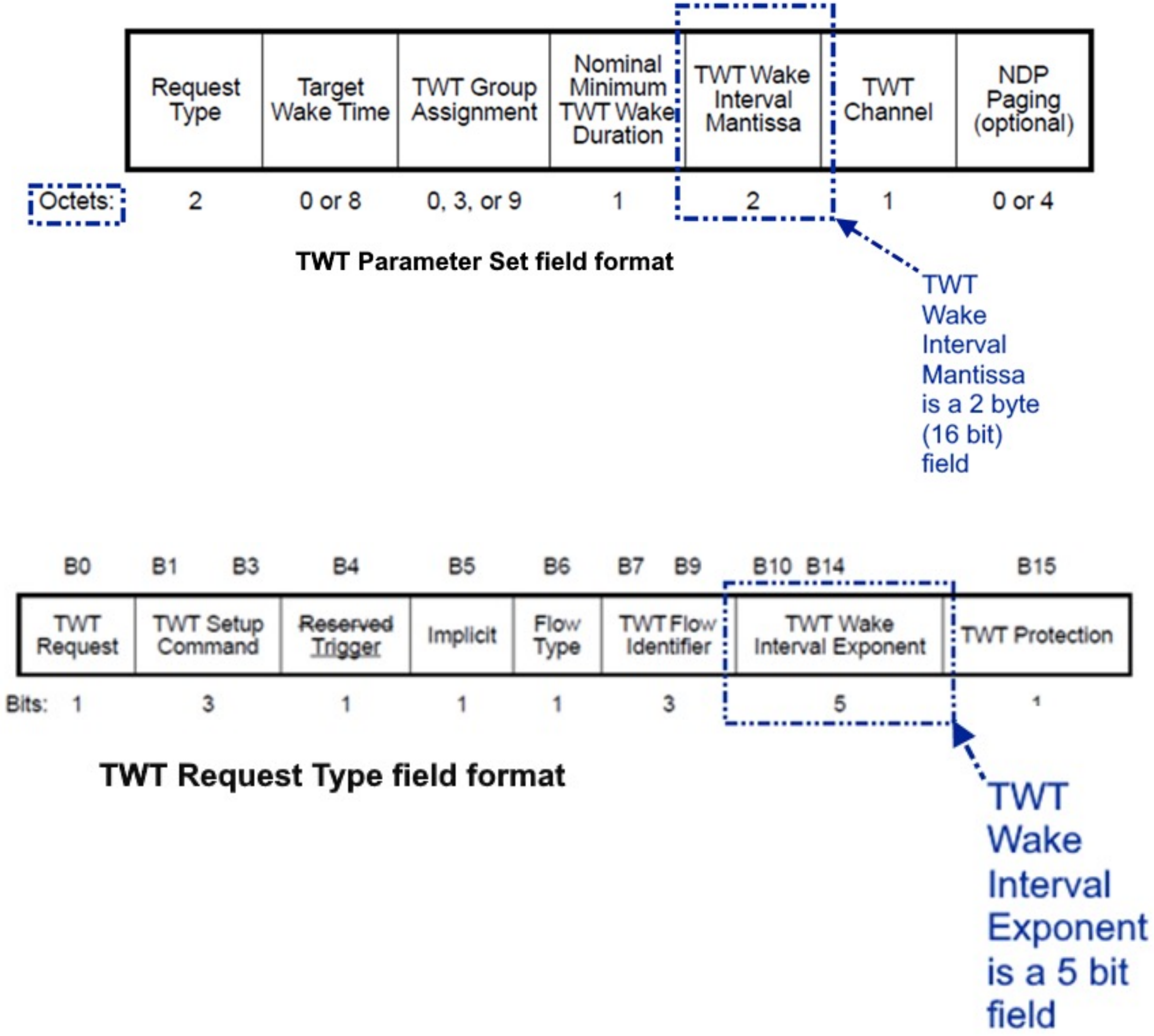


Broadcast TWT

- **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



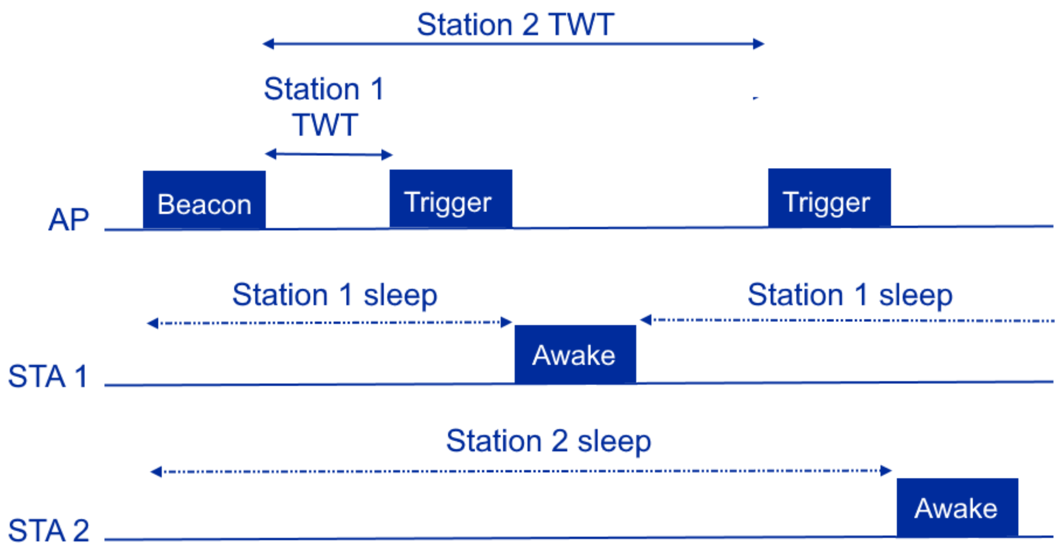
- **How does TWT allow for increased sleep times?**
  - As legacy power save modes (legacy and WMM) are tied to beacons they are limited in the time stations can remain asleep
  - From the 802.11ax standard:

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

  - 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

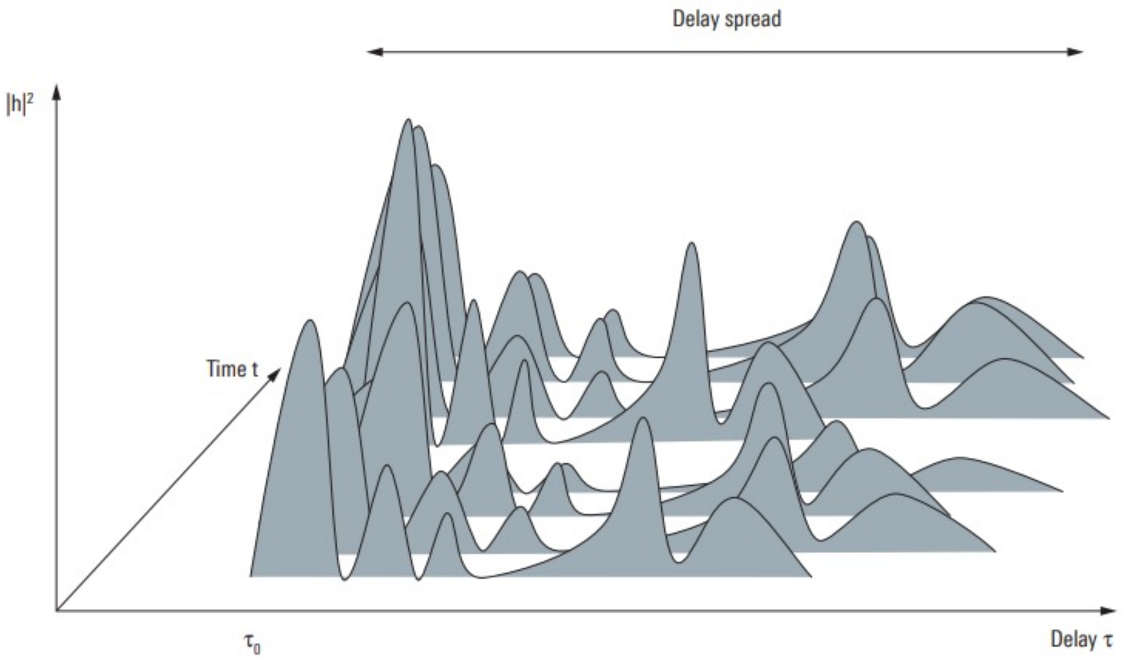
- **Considerations to take when selecting sleep times**
  - While TWT enables the use of VERY long sleep times, there are other considerations that should be carefully taken when selecting the durations of sleep periods for your IoT devices. Some of them are the following:
    - Application layer timeouts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

TWT Reduces Congestion



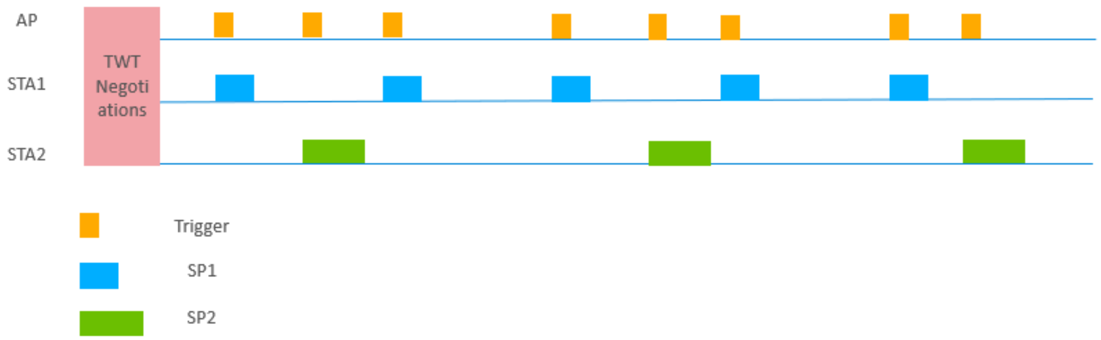
- **How does TWT reduce congestion?**
  - In legacy Wi-Fi networks, stations that go to sleep can wake up at random times and attempt to transmit packets once they are awake
  - Stations have no knowledge of the wake-up times of other stations
  - This can cause packet collisions
  - In Wi-Fi 6, as APs 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



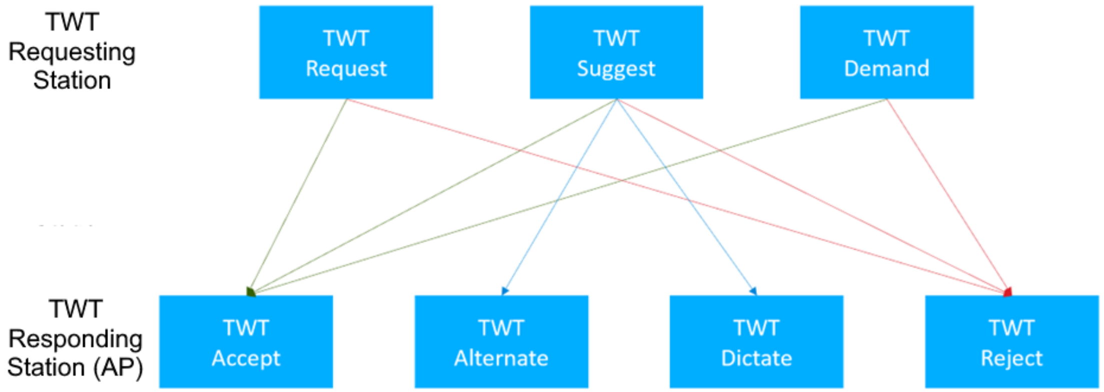
- **How can TWT help collect channel information?**
  - TWT allows APs to schedule the stations that are associated to it
  - This scheduling allows stations to be spaced in time
  - The time spacing of stations can then be taken advantage to use methods such as channel sounding to collect the state 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?

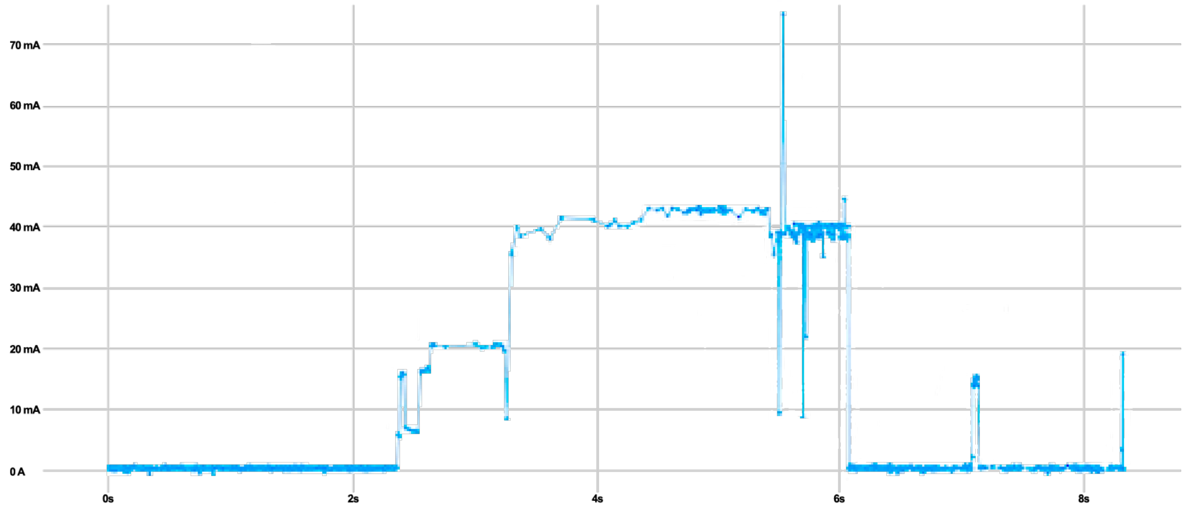


- **TWT Request messages can be:**
  - **Suggest:** Requesting STA suggest parameters for TWT session but will consider accepting an alternative set.
  - **Request:** Requesting STA lets replying STA specify TWT parameters
  - **Demand:** Requesting STA demands TWT parameters and will not accept a different 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

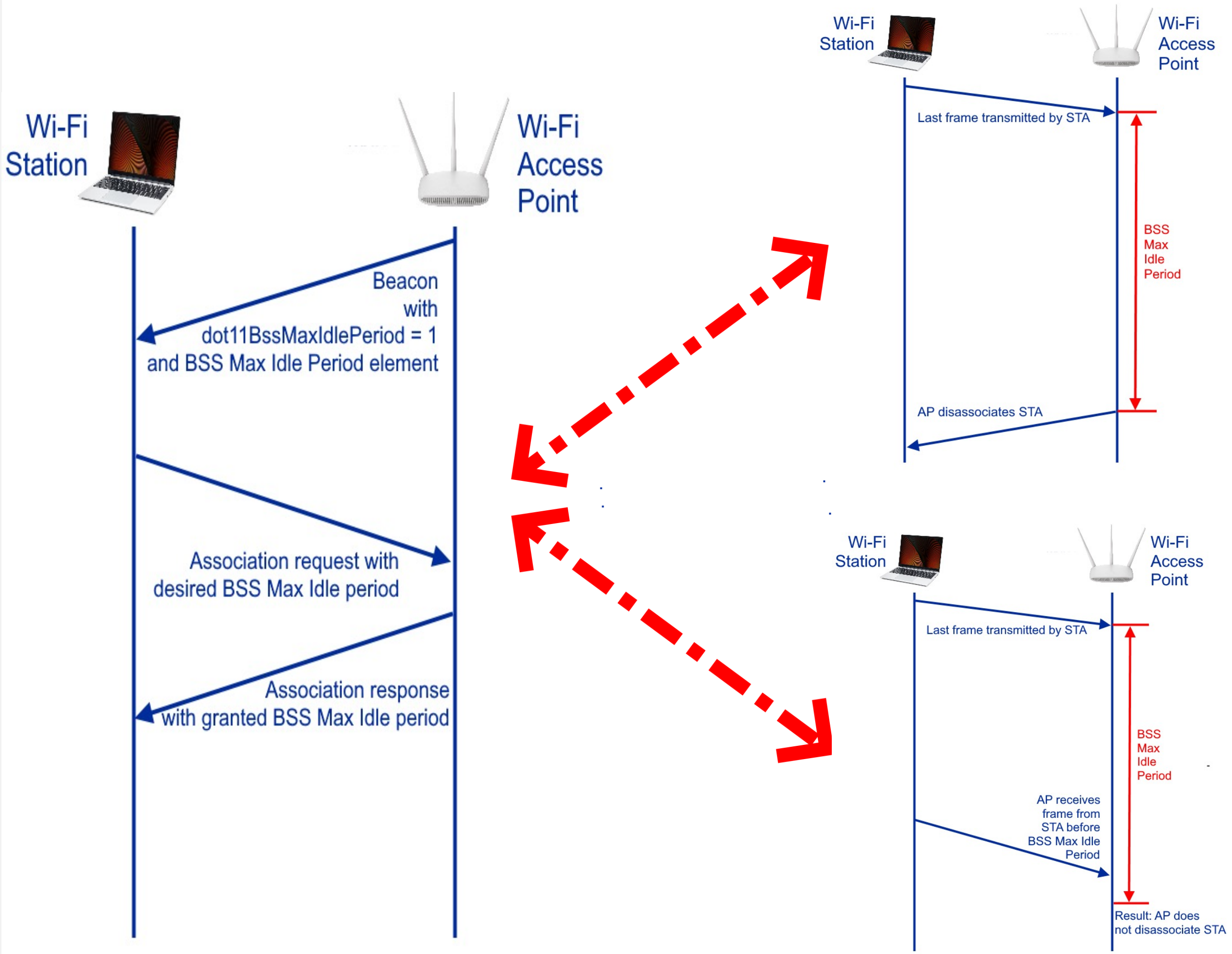
BSS Max Idle Sleep



WPA2 association current consumption

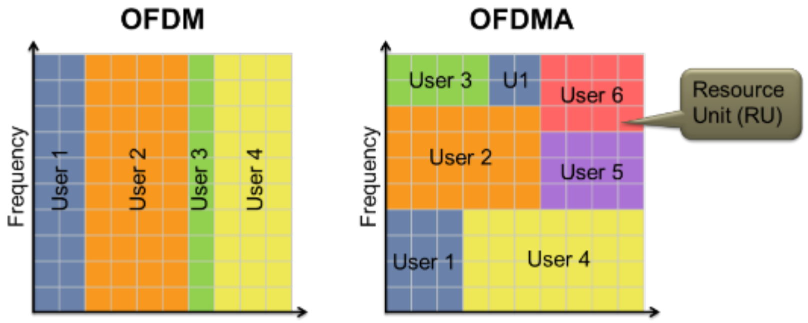
- **BSS Max Idle**
  - In typical Wi-Fi networks, stations associated to an AP must transmit frames within timeouts defined by the AP to avoid being disassociated
  - Typically APs set those timeouts to be one or a couple of minutes long, thus limiting how long clients can sleep
  - BSS Max Idle feature 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

BSS Max Idle Period Negotiation

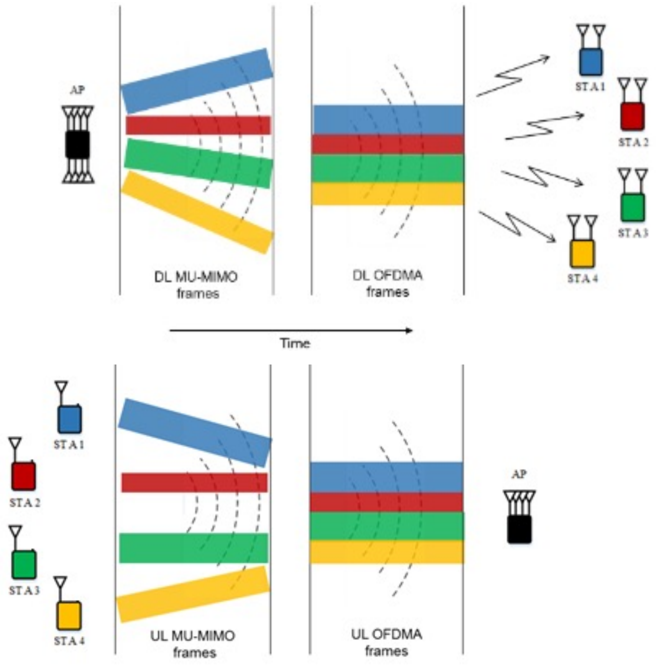


- **BSS Max Idle Period Negotiation**
  - AP Indicates BSS Max Idle support through the following elements in beacons:
    - dot11BssMaxIdlePeriod = 1
    - BSS Max Idle Period Element
  - Seeing the above, Stations request desired BSS Max Idle period in (re)association request frames
  - APs reply with 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

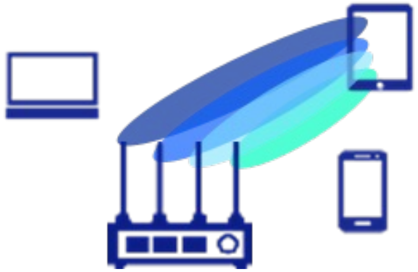
Other Wi-Fi 6 features that help current consumption



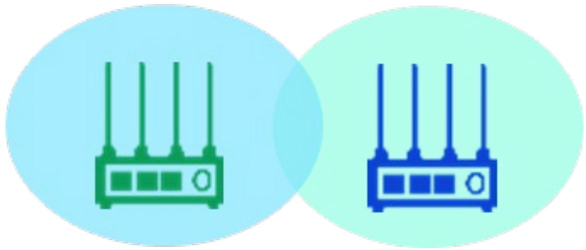
OFDMA



MU-MIMO



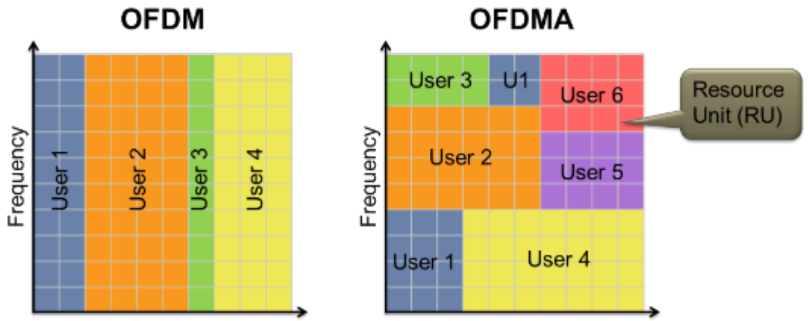
Beamforming



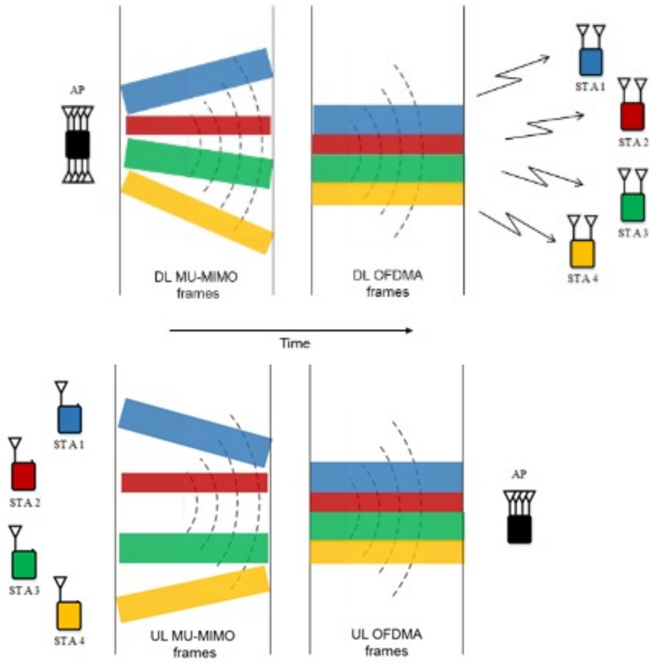
BSS Coloring

- **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**

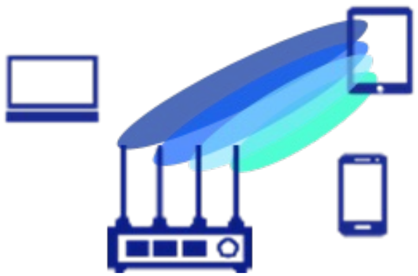
How do these features help current consumption?



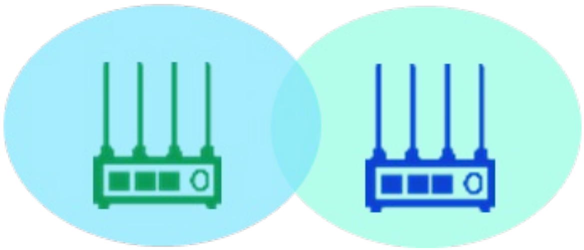
OFDMA



MU-MIMO



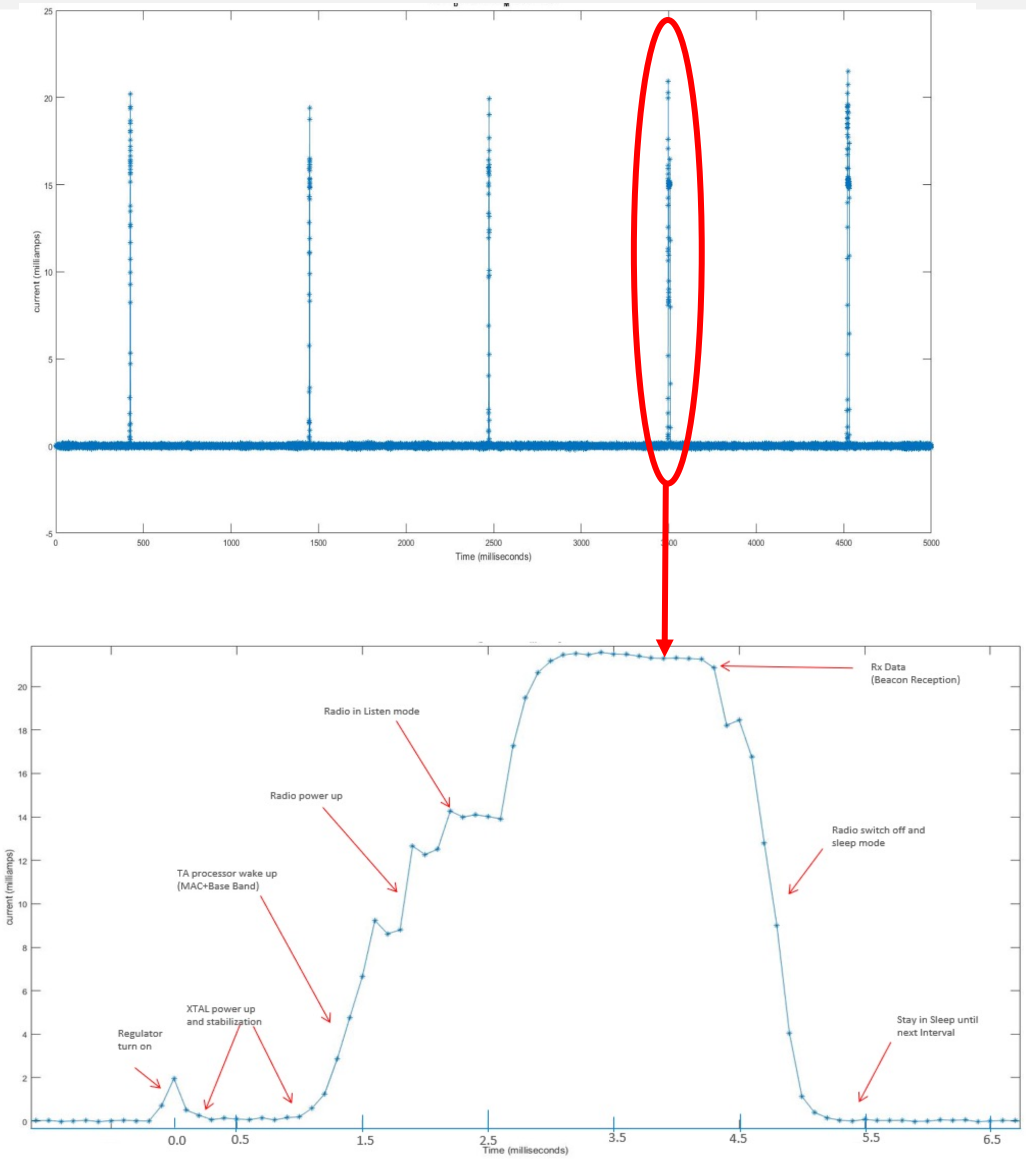
Beamforming



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

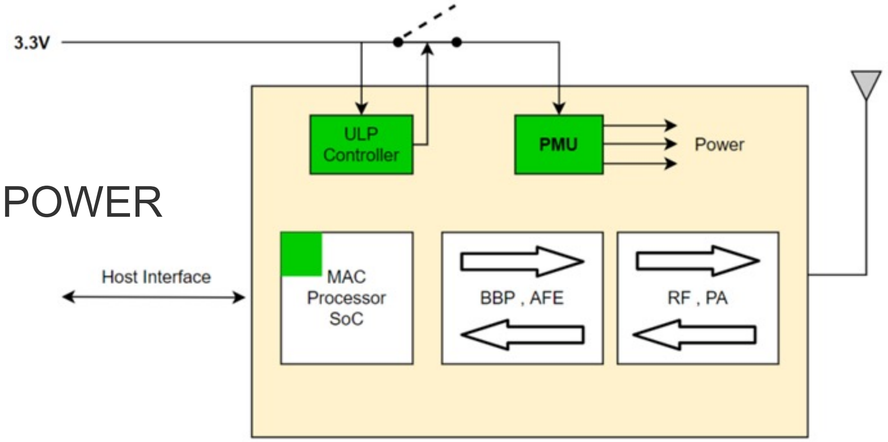


- **Multiple Low Power Modes and embedded stack enable ultra low system power consumption**
- **Wi-Fi Standby associated with automatic periodic wake-up**
  - DTIM, listen interval or TWT based
  - Device remains associated to AP
- **Low power optimized at each device wake-up**

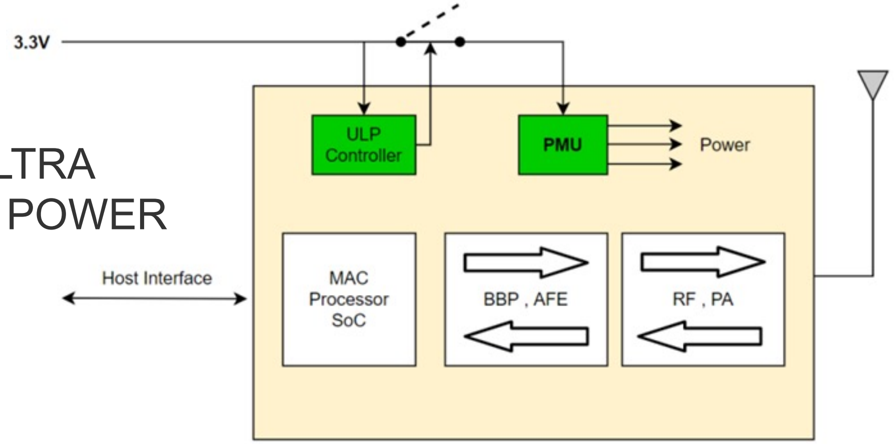
Description	Comments
Sleep Time Between Wakeups	Micro-amp drain
Fast Boot Up times	WLAN still asleep
Wake up Wireless to listen for Beacons using low power receiver	Reduced radio power consumption
Transmit only if needed	Lower average current

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

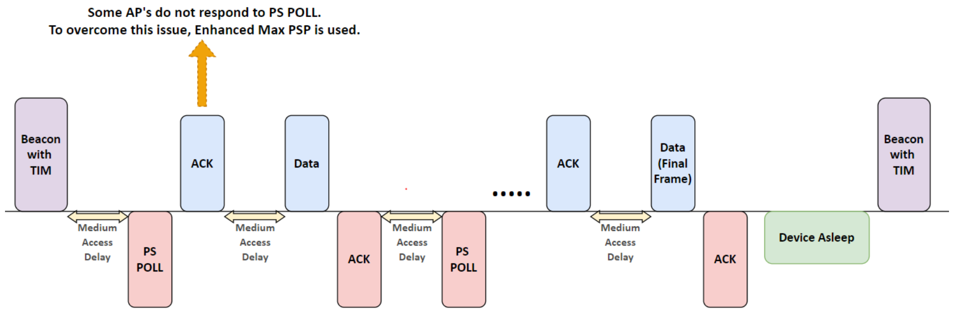
- Radio and Modem is turned off but rest of SoC is on in low power state
- System maintains state, Host interface is active and can respond to packets from Host
- Recommended for line-powered or rechargeable battery designs that want low power consumption

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

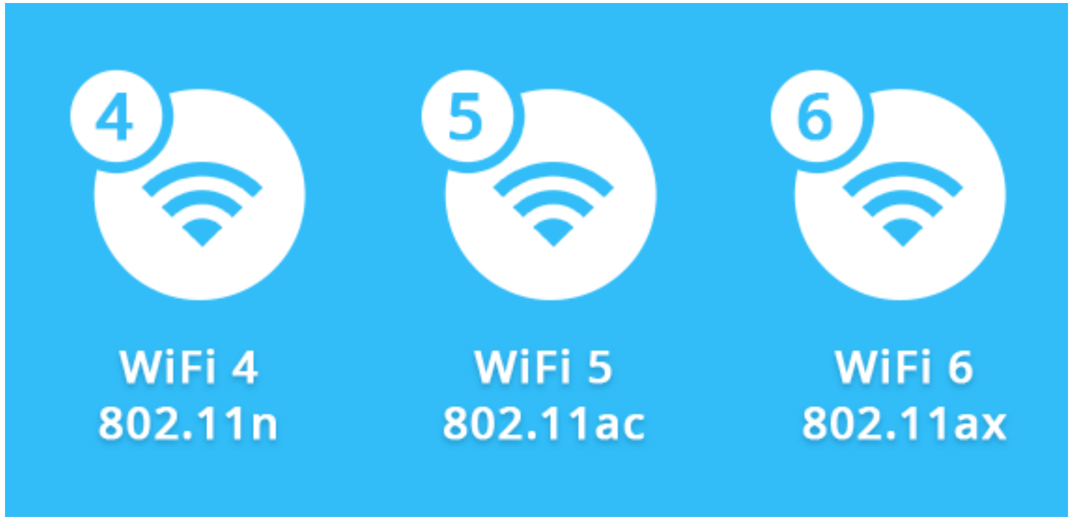
- **Based on Application usage, the following power save profiles can be used to optimize battery life**
  - MAX Power Save and Enhanced Max Power Save Profile (PSP)
  - FAST Power Save Profile
  - UAPSD Power Save Profile

- **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)

Summary of Available Wi-Fi Power Save Options



Legacy Power Save (Wi-Fi 4)	TWT (Wi-Fi 6)
Based on AP DTIM Interval	Based on TWT interval negotiated between AP and station
STA decide using a station selected listen interval or AP-defined DTIM	AP manages activities in the BSS in order to minimize contention between STAs and to reduce the required amount of time that STA in Power Save mode needs to be awake.
STA needs to be awake after a few beacons	STA wakes up only during the TWT interval.
Listen intervals limited to order of seconds	TWT sleep intervals can be extended to far longer durations of time
Recommended use: Shorter sleep cycles with low latency	Recommended use: Longer sleep cycles
Example application: - Smart locks	Example application: - Low power sensors

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

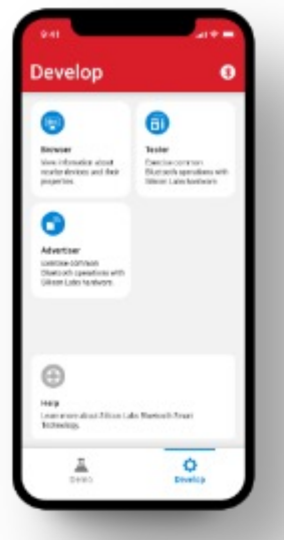
Application	
API	
TCP/IP	BT/BLE stack/profile
Wi-Fi and Bluetooth Link Layer	

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

Q&A

WI-FI SERIES

WI-FI SERIES

Presentation Will Begin Shortly

tech talks UPCOMING SESSIONS

- FEB 2nd | Wi-Fi 6 Benefits for IoT Applications
- MAR 2ND | Designing Low-Power Applications with Wi-Fi 6
- MAR 30TH | Fast Track Your Wi-Fi 6 Device Certification
- APR 27TH | Design with our New Multiprotocol Wi-Fi Module
- MAY 25TH | Building Smart Home Devices with Always-On Wi-Fi 6
- JUN 22ND | Developing Wi-Fi 6 Sensors Using SiWx917 and Matter

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Thank You

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