Enabling Wi-Fi Internet of Things with 802.11ah Technology

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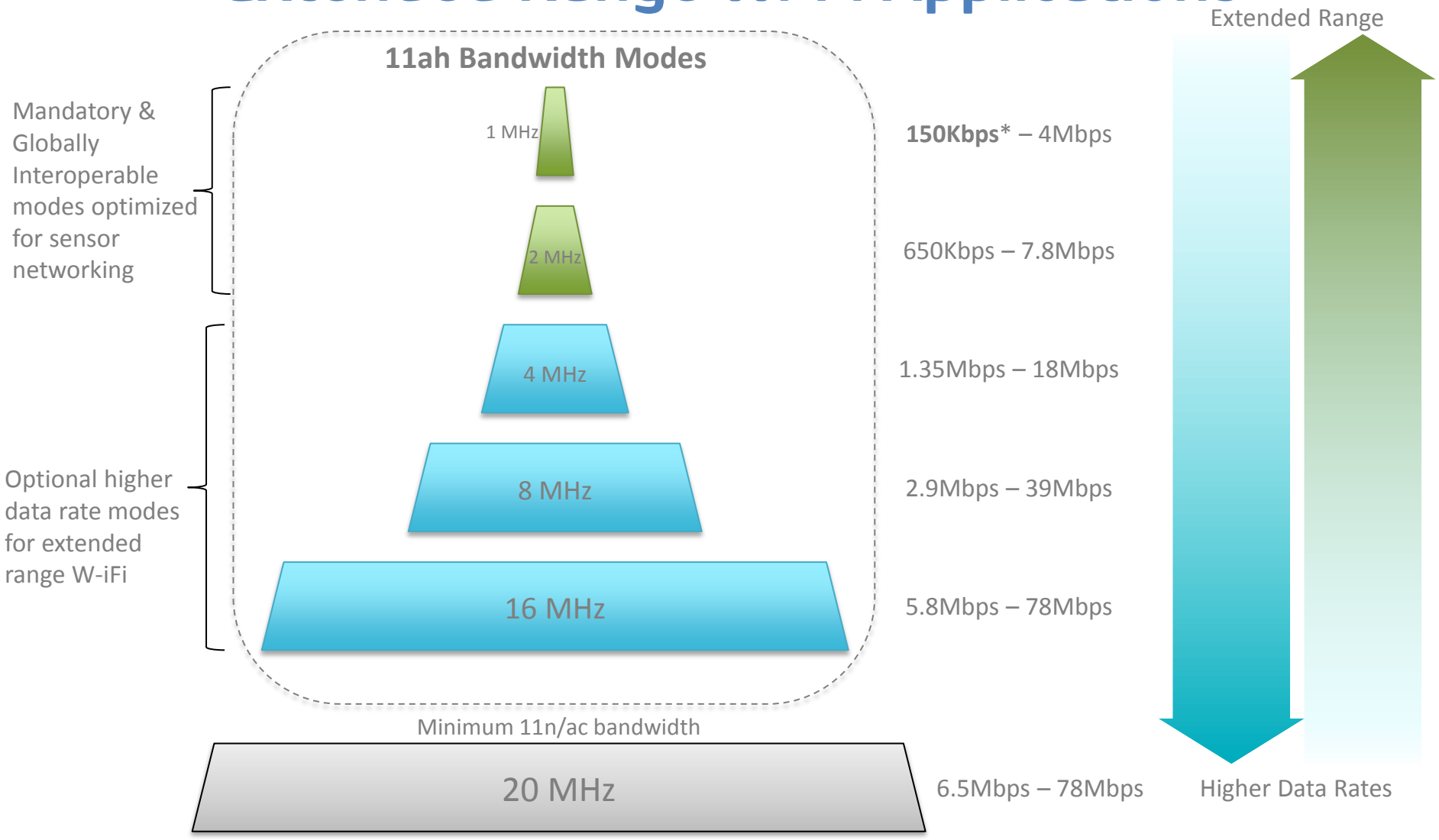
Introduction

- The 802.11ah amendment provides new modes and mechanisms to address low power devices, longer range links, and scalable solutions
- This portion of today's talk will illustrate some of the 802.11ah PHY and MAC layer features that address these goals

802.11ah PHY – Interesting Features

- 802.11ah PHY inherits the baseline design from 802.11ac/n
  - 20, 40, 80, 160 MHz bandwidth modes down clocked to 2,4,8,16 MHz
  - Up to 4 spatial streams
- Extended range support (~1km)
  - New 1 MHz bandwidth modes based on 32 pt FFT
  - 150kbps mode via 2x repetition, BPSK, r=1/2, 1MHz mode (=MCS10)
- Specific support for outdoor environment
  - Traveling pilots for high Doppler environment
  - Longer guard interval with “double guard interval” (16 usec)
- Type specific CCA levels
  - Type 1: predominantly used for sensor STAs
    - favor protection of ongoing transmissions and increase transmission range of devices
    - -98 dBm in 1 MHz channel
  - Type 2: predominantly used for non-sensor STAs
    - favor wider bandwidth and higher data rate transmissions, increasing spatial reuse
    - -89 dBm in 1 MHz channel

Rich Data Set Enables IoE (sensors) and Extended Range Wi-Fi Applications



*** Single spatial stream rates shown.**

Channel Bandwidth and Number of Channels

	1MHz	2MHz	4MHz	8MHz	16MHz
US	26	13	6	3	1
EU	5	2	-	-	-
Korea	6	3	1	-	-
China	32	4	2	1	-
Japan	11	-	-	-	-

Modulation Coding Schemes

- PHY rate ranges from 150Kbps to 86.67 Mbps for 1 spatial stream
- 11ah supports up to 4 spatial streams
- PHY rates for 1 spatial stream:

	Modulation	Coding Rate	1 MHz (Mbps)	2MHz (Mbps)	4MHz (Mbps)	8MHz (Mbps)	16MHz (Mbps)
MCS0	BPSK	1/2	.300	.650	1.5	3.25	6.5
MCS1	QPSK	1/2	.600	1.3	3	6.5	13
MCS2	QPSK	3/4	.900	1.95	4.5	9.75	19.5
MCS3	16QAM	1/2	1.2	2.6	6	13	26
MCS4	16QAM	3/4	1.8	3.9	9	19.5	39
MCS5	64QAM	2/3	2.4	5.2	12	26	52
MCS6	64QAM	3/4	2.7	5.85	13.5	29.25	58.5
MCS7	64QAM	5/6	3	6.5	15	32.5	65
MCS8	256QAM	3/4	3.6	7.8	18	39	78
MCS9	256QAM	5/6	4	N/A for 1 spatial stream	20	43.33	86.67
MCS10	BPSK	1/2	.150				

Extra 2x repetition mode to increase range

Range Enhancement

Parameter	Improvement of 900 MHz 11ah over 2.4 GHz	
	Robust 900 MHz client device	Low power / small form factor 900 MHz client device
Transmit power compared to 17dBm	0 dB	-17 dB
Tx antenna gain	0 dB	-3 dB
Free space path loss	+8.5 dB	+8.5 dB
Noise Bandwidth (2MHz)	+ 10 dB	+ 10 dB
Flat Fading	-4.5 dB	-4.5 dB
Sub Total	**14 dB**	**-6 dB**
1 MHz channel width	3 dB	3 dB
2x repetition coding	3 dB	3 dB
Total	**20 dB**	**0 dB**

- 11ah has ~20 dB better link budget than 2.4GHz

802.11ah MAC – Interesting Features

- Reduced active Tx/Rx time
  - **NDP MAC frames**
  - Short MAC header
  - Short management frames
  - **Support for energy limited STAs**
- Increased standby time
  - **Target wakeup times (TWT)**
  - Non-TIM (traffic identification map) Operation: whereby STA does not to periodically wake for beacon reception
  - Extended Listen/MAX BSS Idle periods: stations can sleep hours/days and stay associated
  - AP Power Management: provides a mechanism for a battery powered AP to go to sleep
- Reduced contention and channel access time with pseudo-scheduling and grouping stations
  - **Restricted Access Window (RAW)**
  - **Slotted medium access with sync frame**
  - Bidirectional TXOP (BDT) for quick data transaction
- Frequency selective fading mitigation
  - **Subchannel selective transmission (SST)**
- Relay and sectorized operations
- Support for large number of stations (8K stations)
  - New TIM structure and efficient encoding

NDP frames

- Null Data Packet frame: SIG field contains MAC payload

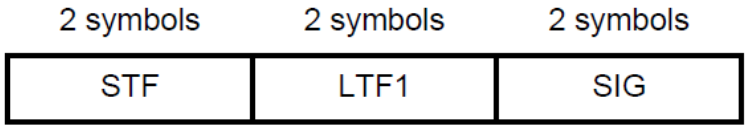


Figure 24-18—S1G NDP CMAC frame for ≥ 2 MHz

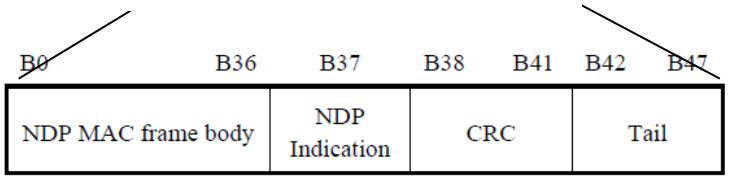


Figure 24-40—SIG field format for >=2MHz NDP MAC frame

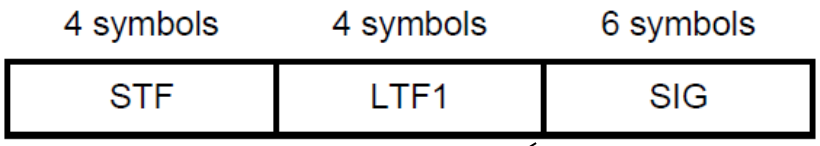


Figure 24-19—S1G NDP CMAC frame for 1 MHz

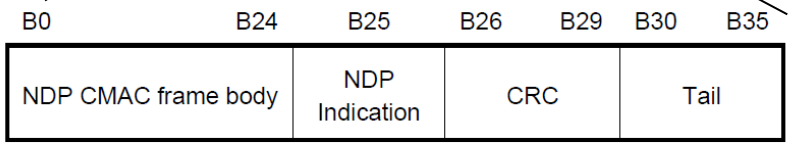


Figure 24-20—SIG field format for 1 MHz NDP CMAC frame

Support for Energy Limited STAs

- Many sensor devices, due to form-factor and/or cost considerations, are powered by very small batteries (e.g., coin cell batteries). These devices can only be TX/RX active for a short period of time and can additionally require some gap between active periods for recharging.
- Energy limited operation is a mode that limits the maximum duration of frame exchanges and that allows the STA to recover its ability to TX/RX between two consecutive frame exchanges.

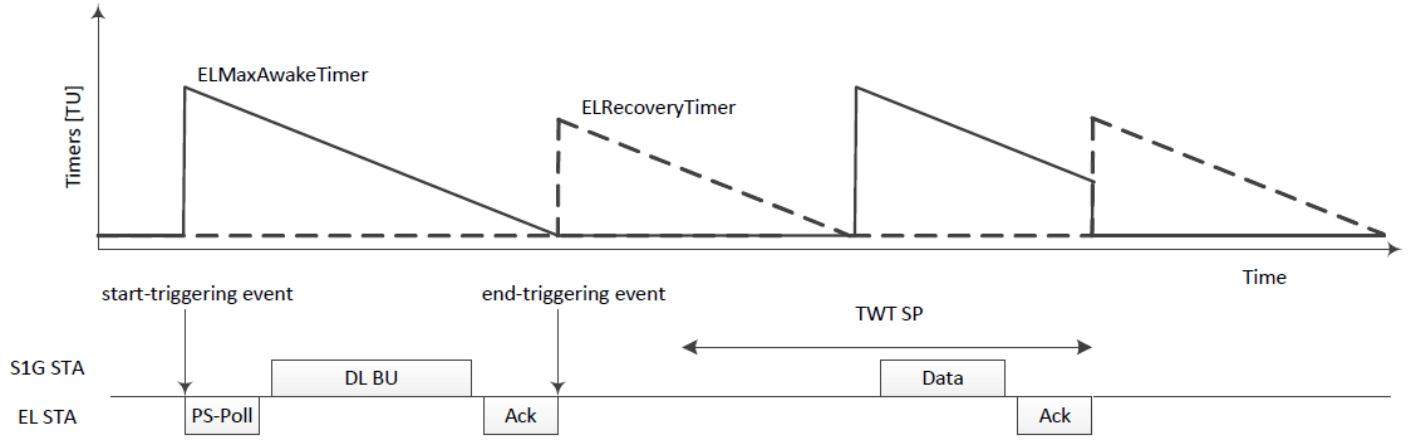
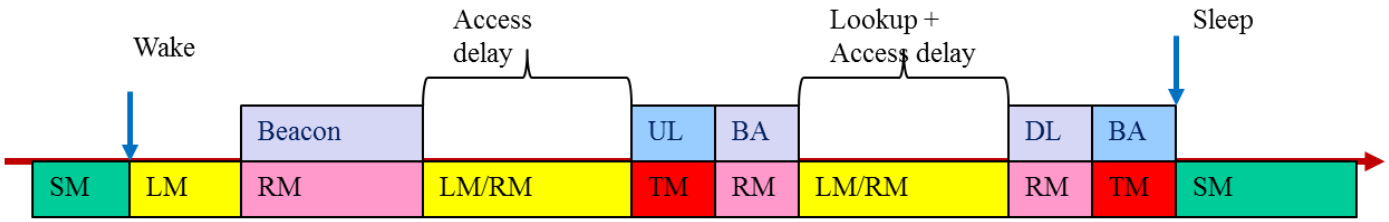


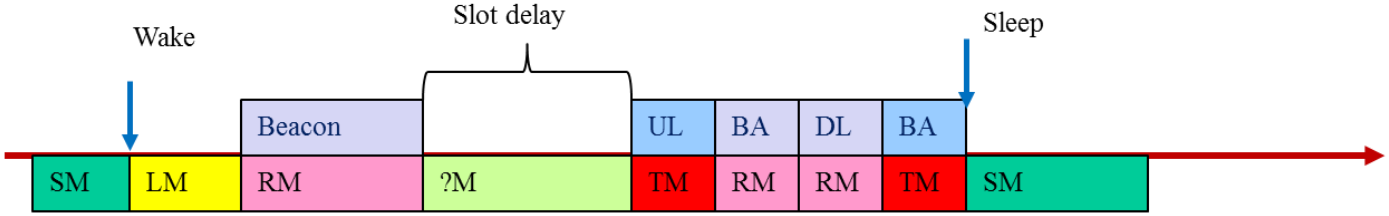
Figure 10-54—EL STA operation

Target Wake Time

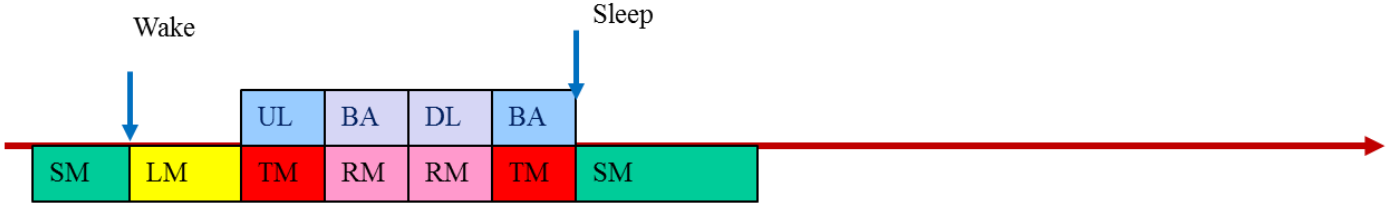
- Target Wake Time (TWT) is a power saving mechanism, negotiated between a STA and its AP, which allows the STA to sleep for periods of time, and wake up in pre-scheduled (target) times to exchange information with its AP.



- **Baseline PS-POLL**



- **Beacon-based access**



- **TWT-based access**

Restricted Access Window

- Restricting uplink channel access to a small number of STAs and spreading their uplink access attempts over a much longer period of time improves the medium utilization's efficiency by reducing collisions
- If the station belongs to the RAW group, it is allowed to contend for medium access at the start of its assigned RAW slot and shall not contend for medium access within a RAW slot not assigned to it during that RAW
- Basic RAW time diagram:

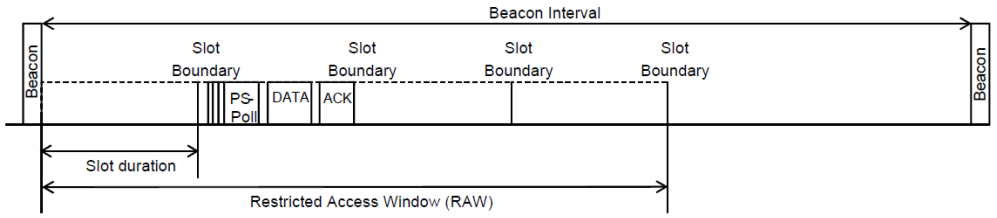


Figure 9-30a—Restricted Access Window (RAW)

Slotted medium access with sync frame

- Synchronization (sync) frame transmission procedure for uplink traffic minimizes the time for medium synchronization for a STA that is changing from Doze to Awake in order to transmit

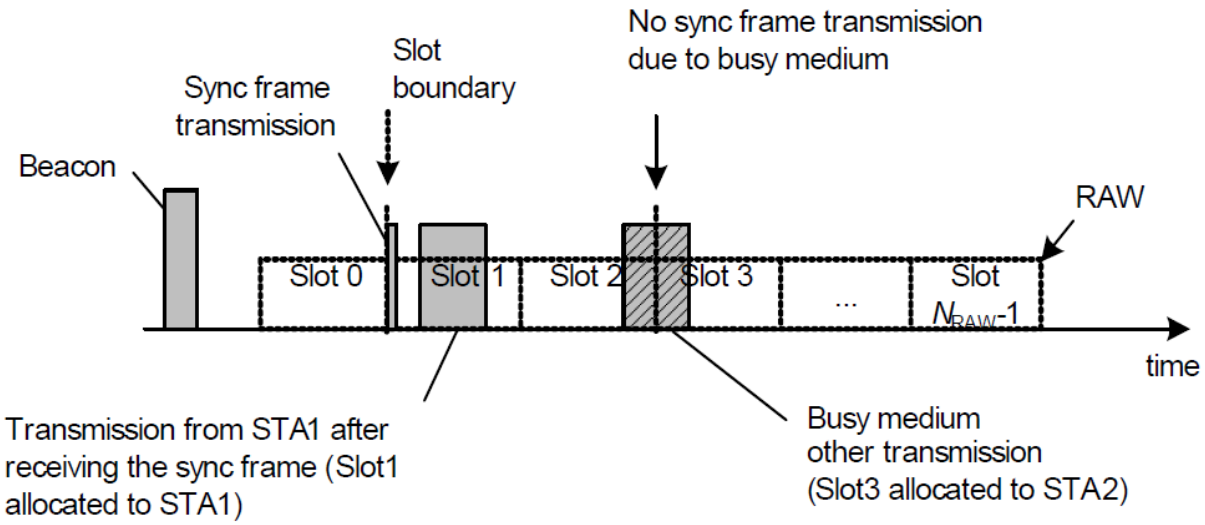


Figure 9-93—Example of the uplink sync frame transmission procedure in a RAW

Subchannel selective transmission

- By default, the primary channel of a BSS set up by an AP is static and likely not to change throughout the existence of the BSS.
- However, because of the STA's location, channel conditions, etc the quality of the primary channel may be significantly degraded as compared to other channels.
- Subchannel Selective Transmission (SST) enables a STA to select the best temporary "primary" channel among multiple SST-enabled operating channels to communicate with its peer STA

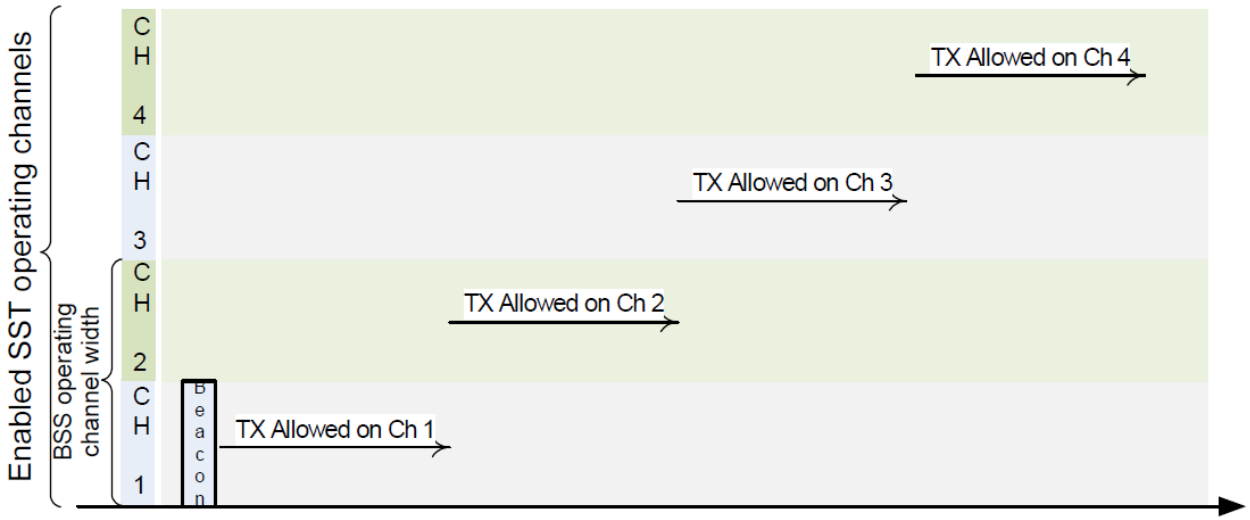


Figure 9-96—Selective Subchannel Transmission channel transmission permission allocations from SST element

Summary: 802.11ah is Well Optimized for IOE

Range

Significant range advantage over 2.4GHz technologies

150 Kbps data rate at maximum range to cover whole home

Low Power

No external power amplifier required compared to 2.4GHz technologies

Energy-efficient protocols & frame formats

Scalable

Thousands of nodes

Efficient use of the medium

Scheduled transmissions to improve legacy CSMA