

Advanced Topics in Wireless Networks

Low Power Local Area Networks

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Table of contents

1 Introduction to IoT Communication

- WiFi
- BLE
- Zigbee

2 A Closer look to Zigbee

Introduction to IoT Communication

- Multitude and variety
 - diverse Quality of Service (QoS)
 - huge amount of traffic
 - huge address space
- Self-organization
- Reliability and robustness
- Security and privacy

Introduction to IoT Communication

- Capillary M2M
 - low power
 - low cost
 - short range
- Cellular M2M
 - long distance

Introduction to IoT Communication

- LPWAN
 - NB-IoT
 - LoRaWAN
 - Sigfox
- LPLAN
 - BLE
 - Zigbee
 - WiFi

IEEE 802.11/WiFi

IEEE 802.11.ah

- It uses **900 MHz** license exempt bands to provide *extended range* Wi-Fi networks, compared to conventional Wi-Fi networks operating in the 2.4 GHz and 5 GHz bands.
- It also benefits from lower energy consumption.
- It aims at providing connectivity to thousands of devices under an access point.
- Relay Access Point
- Power Saving:
 - TIM
 - non-TIM

IEEE 802.11/WiFi

802.11 proto- col	Release date	Frequency (GHz)	Bandwidth (MHz)	Stream (Mbit/s)	data rate
ac	Dec 2013	5	20, 40, 80, 160	Up to 346.8, 1733.2, 3466.8	800,
ad	Dec 2012	60	2, 160	Up to 6,757	
ah	Dec 2016	0.9	1–16	Up to 347	

IEEE 802.15.1/Bluetooth



- Robustness
- Low Power
- Low Cost

IEEE 802.15.1/Bluetooth

- Bluetooth 1.1
- Bluetooth 4.0 + LE (Bluetooth Smart)
 - As an alternative to the Bluetooth standard protocols that were introduced in Bluetooth v1.0 to v3.0, it is aimed at very low power applications running off a coin cell.
- Bluetooth 5
 - Double the speed (2 Mbit/s burst) at the expense of range
 - Up to fourfold the range at the expense of data rate
 - Eightfold the data broadcasting capacity of transmissions, by increasing the packet lengths.

IEEE 802.15.1/Bluetooth

Piconets

- Bluetooth enabled electronic devices connect and communicate wirelessly through short-range, ad hoc networks known as *piconets*.
- Each device can simultaneously communicate with **up to seven other devices** within a single piconet.

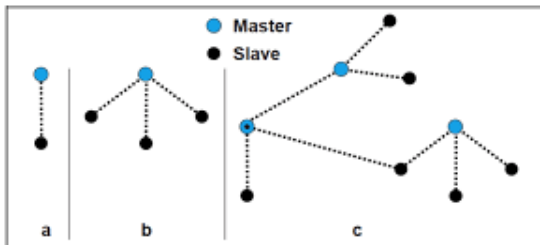
Features

- Bluetooth wireless technology is geared towards voice and data applications and able to penetrate solid objects.
- It is omni-directional and does not require line-of-sight positioning of connected devices.

IEEE 802.15.1/Bluetooth

PHY Layer

- 2.4 GHz frequency band
- 79 Channels, each channel has 1 MHz bandwidth
- 3 Power class for 1, 10 and 100 meter transmission distance
- Physical Links
 - Data Link: Asynchronous Connectionless (ACL)
 - Voice Link: Synchronous Connection Oriented (SCO)



Zigbee

- IEEE 802.15 serial standards are established by IEEE 802.15 Working Group for Personal Area Network or short distance wireless networks.
- Zigbee is built on the IEEE 802.15.4. The two lower layers: the physical (PHY) layer and the medium access control (MAC) sub-layer of Zigbee stack architecture is specified in IEEE 802.15.4.

IEEE 802.15.4 Features

- Data rates of 250 kbps, 40 kbps, and 20 kbps. Symbol rate is 62.5 ksymbol/sspm
- Two addressing mode: 16-bits short and 64-bit IEEE addressing
- Optional use Star-topology or Peer to Peer topology, and also supposes Cluster Tree nowadays.
- CSMA-CA channel access
- Automatic network establishment by the coordinator
- Full handshake protocol for transfer reliability
- Power management to ensure low power consumption

IEEE 802.15.4 Features

- 16 channels in the 2.4GHz ISM band, 10 channels in the 915MHz and one channel in the 868MHz
- Optimal to use Acknowledgement packet
- Transmit Power: About 1 mW transmit power
- RSSI (Received signal strength indication) measurement

Zigbee

Type of Device

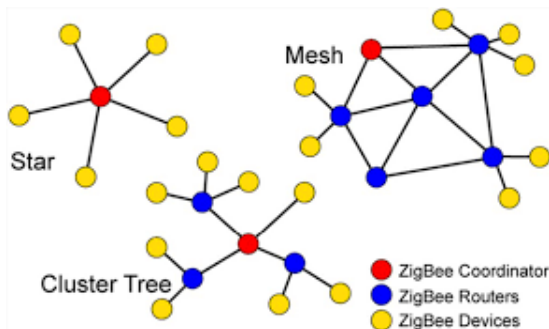
- FFD (Full Function Device)
 - Coordinator
 - Router
 - End Device
- RFD (Reduced Function Device)
 - End Device

IEEE 802.15.4 Topologies

- Star
- Peer to Peer

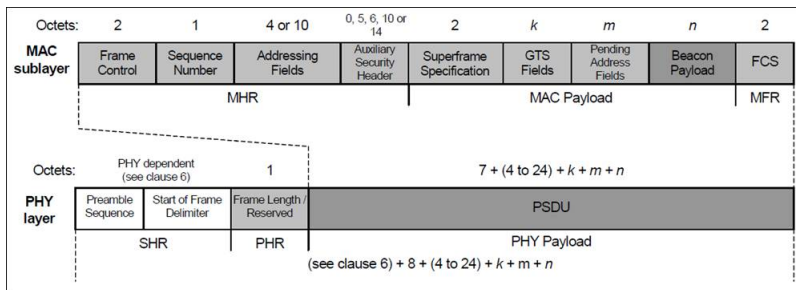
Zigbee

Zigbee Topologies



Zigbee

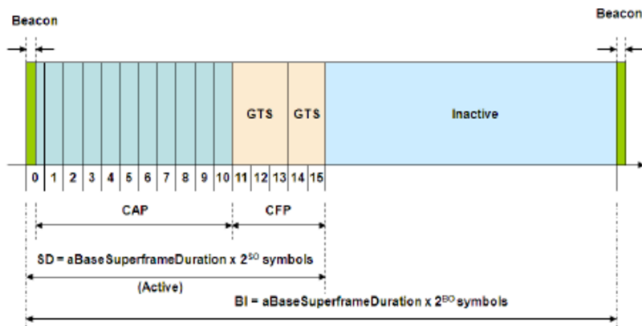
IEEE 802.15.4 MAC-PHY



Zigbee

Superframe Structure

- CAP: Contention Access Period
- CFP: Contention Free Period
- GTS: Guaranteed Time Slots



Zigbee

Zigbee Stack

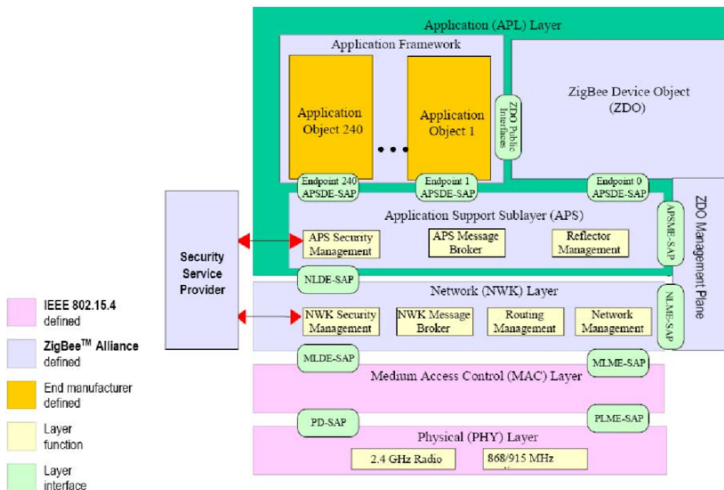


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A Closer look to Zigbee

Zigbee Problems

- Energy Efficiency
- Routing
- Localization
- Data management
- Reliability
- Security

A Closer look to Zigbee

An Energy Efficient Schedule for IEEE 802.15.4/Zigbee Cluster Tree WSN with Multiple Collision Domains and Period Crossing Constraint

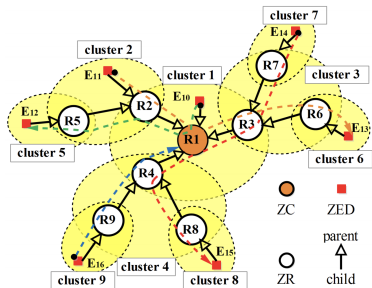
- A collision-free cluster schedule that meets all the data flows deadlines
- Minimization of the energy consumption of the nodes

*

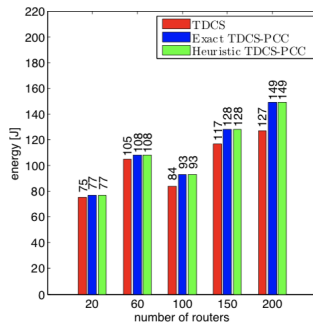
* A. Ahmad and Z. Hanzalek, "An energy efficient schedule for IEEE 802.15.4/ZigBee cluster tree WSN with multiple collision domains and period crossing constraint", *IEEE Transactions on Industrial Informatics*, vol. 14, no. 1, pp. 12–23, Jan. 2018. DOI: 10.1109/tii.2017.2725907. [Online]. Available: <https://doi.org/10.1109/tii.2017.2725907>.

Zigbee

flow ID k	source(s) (α_{fk})	sink (β_{fk})	e2eDeadline [s] [ptu]		reqPeriod [s]	sampleSize [bit]	sampleACK
1	1	5	1.5	1563	1	64	0
2	2	6	2	2083	2	16	1
3	7	8	2	2083	1	16	1
4	9	1	2	2083	2	64	0



Average network energy consumption within 40 min



Zigbee

Network retransmissions

