Overview on UWB standard 802.15.4-2024

Gabriele Da Re
School of Computer Engineering
University of Padua
Padua, Veneto, Italy
Email: gabriele.dare00@gmail.com
Mat: 2158818

***Abstract*—The purpose of this survey is to understand and address these topics of the standard IEEE 802.15.4-2024, ”IEEE Standard for Low-Rate wireless networks”: Architecture, where we will s**

I. Introduction

The standard covers many physical layers and one Medium Access Control layer (MAC) for low rate wireless personal area networks (LR-WPAN). There are some special applications such as Smart Utility Network, Rail Communications and Control, Radio Frequency Identification (RFID), Medical Body Area Networks. Among many others it covers the one we are interested in, the Ultra Wide Band (UWB) technology. UWB is a technology generally defined like others in the standard as a Wireless Personal Area Network (WPAN). So we will give an quick overview of the standard and then focus on the UWB technology.

II. General Description

A. Network Topologies

Topologies for LR-WPAN are two, star and peer-to-peer. In the star topology, the coordinator is the central device and the other devices are the end devices. The coordinator is the only device that can communicate with the end devices, and is usually wall powered, whilst end devices are battery powered. Suited for home automation, personal health care and games. The peer-to-peer topology is a network of devices that can communicate with each other, thus allowing for more complex networks, such as mesh networks, using multiple hops, implemented at higher level, thus not discussed in this standard. Suited for sensor networks, enabling smart agriculture, industrial control and monitoring and asset and inventory traking.

Each indipendent PAN selects a UID (PAN Identifier) thus allowing for multiple PANs to coexist, moreover each device in a PAN can communicate within with a short address, permits to communicate also with another device from another PAN.

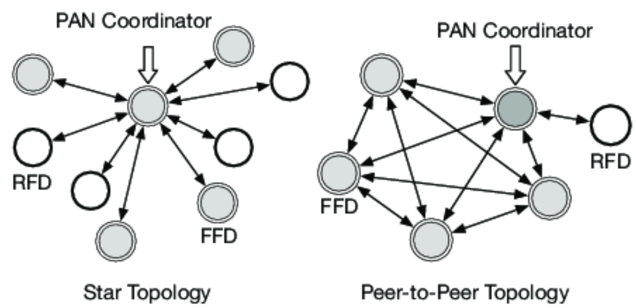

Fig. 1. Star and peer-to-peer topologies

B. Architecture

The architecture is composed of three layers:

- Physical Layer (PHY)
- Medium Access Control (MAC)
- Higher layers

Only PHY and MAC are defined in the standard, the higher layers, such as network, that involves its configuration, message routing and manipulation are left to the implementer. as well as the application layer.

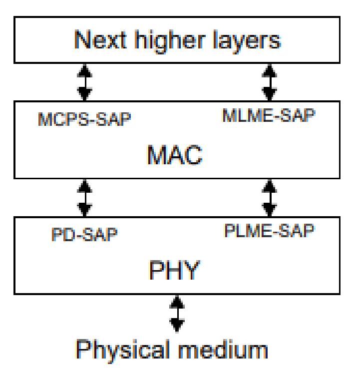

Fig. 2. IEEE 802.15.4-2024 architecture

1) Physical Layer (PHY): The PHY layer has its main focus on the activation and deactivation of the radio transceiver, energy detection, link quality indication, channel selection, clear channel assessment, ranging and data transmission and reception. In the specific case of High Rate Pulse repetition frequency UWB, it also serves the purpose of precision ranging.

2) Medium Access Control (MAC): The MAC overlay provides 2 services:

- Data service
- Management service

The data service is responsible for the MAC protocol data units transmission and reception, whilst the management service is responsible for the interfacing with the MAC sublayer management entity service access point (MLME-SAP fig.2). In particular the MAC overlay provides the possibility to manage beacons, channel access, association and disassociation, acknowledged frame delivery, guaranteed time slots management and frame validation. In addition can provide security features (TODO: UWB?).

C. Functional overview

1) Scheduled access: Access is managed by different implementations of the superframe structure.
Beacon superframe, defined and sent by the coiordinator, dependant on beacons. Can have an active and inactive portion, during the latter the coordinator is able to enter low-power mode (sleep), thus saving energy. Beacon transmission is executed at the beginning of each superframe by the coordinator, in order to synchronize and identify the devices of the PAN. It can be avoided by the coordinator bypassing the beacon transmission. The Superframe Duration $\leq$ Beacon Interval, is divided in two parts:

- Contention Access Period (CAP)
- Contention Free Period (CFP)

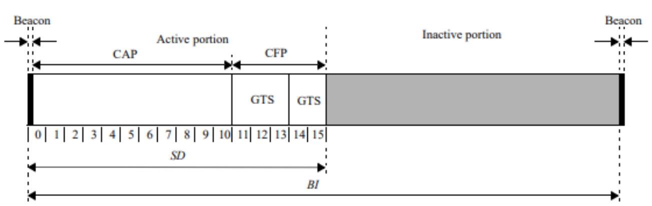

Fig. 3. Beacon superframe with Guaranteed Time Slots (GTS) in the CFP

Deterministic and synchronous multichannel extension (DSME) multi-superframe, as in beacon, starts with the PAN coordinator sending an Enhanced Beacon frame, containing DSME PAN Descriptor Information Element (IE). The multi-superframe is divided in cycles of repeated superframes 4, composed as usual, of enanched beacon frame, CAP and CFP.

Time Slotted Channel Hopping (TSCH) sees the substitution of the superframe with a slotframe, also containing guaranteed or CSMA-CA periods. The difference is the shared notion of time between partecipants, thus allowing for automatic repetition of the slotframe, without involving beacon transmission. It can also communicate the device's assigned

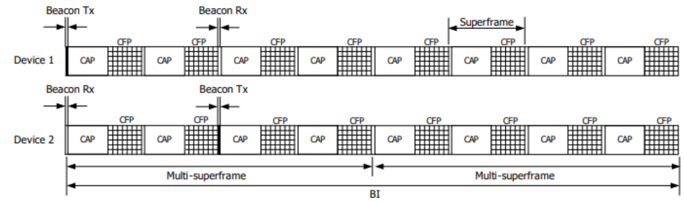

Fig. 4. DSME multi-superframe

timeslot(s) in the slotframe by beacon, but tipically is handled at higher layers. Since all devices are synchronized and share channel information, they can hop over channels decreasing interference and multipath fading, doing so in slotted channels to avoid collisions, avoiding retransmissions, usefull in industrial environments.

TWVS multichannel cluster tree PAN (TMCTP). A cluster tree network is a mesh of clusters, each with a coordinator, that can communicate with other clusters, forming a tree. The easiest is a single cluster, with a coordinator and end devices, but can be extended to multiple clusters by the first PAN coordinator, that instructs a device to become a coordinator of a new cluster. This augment the coverage area, with the downside of augmenting the message latency. The TMCTP is a cluster tree network with a Master PAN coordinator(Super Pan Coordinator), that synchronizes other PAN coordinators over different channels, that in turn synchronize their clusters. Parent PAN coordinator(s) communicate with their PAN-coordinator child(s) in its own channel CAP or CFP, whilst childs send beacons to their parent in a dedicated channel, Dedicated Beacon Slot (DBS) assigned by the coordinator in the Beacon Only Phase (BOP). So the TMCTP has an enhanced superframe structure, with a BOP, a CAP and a CFP.

2) Data Transfer Model: The transfer models of the standard are:

- Transfer to a Coordinator from a device.
- Indirect transfer from a coordinator in which the device recives the data.
- Transfer between two peer devices.

On a correctly recived frame, if requested, the receiver sends an acknowledgment frame that can be of 3 types:

- Immediate acknowledgment
- Enanched acknowledged
- Fragment acknowledgment

Data transfer to a coordinator is managed in two ways depending on beacon enabled or not. If synchronization beacons are enabled, the device listens for the beacon, when found it sinchronizes to the PAN, and sends the data frame to the coordinator at an appropriate time.
If not enabled it transmits directly to the coordinator.

Indirect data transfer using the superframe structure, the coordinator that has data for a device, indicates in the

beacon that a data message is pending. Since devices are synchronized through the beacon, they can listen for pending messages, if present, they send a Data Request command to the coordinator, that in turn sends the data frame and when succesfuly completed, removes the message from the pending list in the beacon.
If not using the superframe structure, and a Data Frame is pending, the coordinator stores the data and sends it to the device up on request by the latter. Else the coordinator that has no data, either indicates it on the returned ACK if requested by the device that sent the Data Request, or in a Data Frame with zero payload.

Data transfer between two peer devices is managed either by a device that constantly recives or sichronizes with the sending device. In the first case the device attempts to send data when channel access is gained, in the second case other measures are taken to achieve sync.

3) Frame Structure:

III. Conclusion

The conclusion goes here.

Acknowledgment

The authors would like to thank...

References

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.