ZigBee .

Davide Quaglia

History

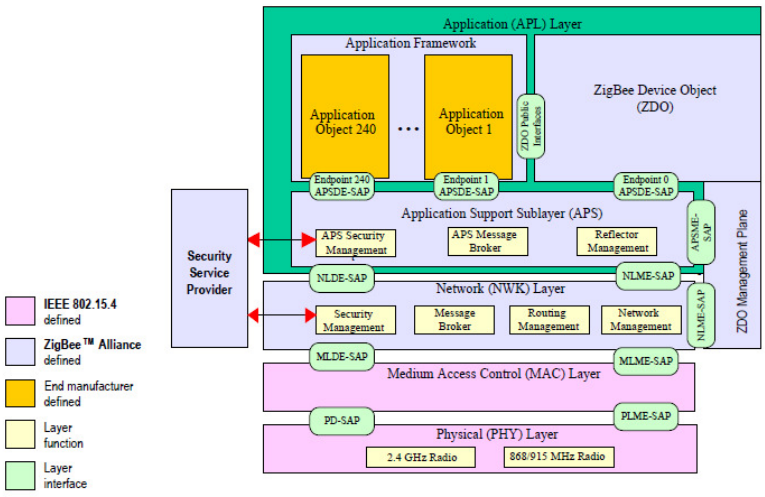
- IEEE 802.15.4
  - 2003
  - 2006
  - 2007 (only for PHY layer for UWB annex)
- ZigBee
  - 2004
  - 2006
  - 2008 (ZigBee Pro)
  - On going for application profiles

ZigBee elements

- Application support sub-layer (APS)
- ZigBee device objects (ZDO)
- ZigBee device profile (ZDP)
- Application framework
- Network layer (NWK)
- ZigBee security services

3

ZigBee stack architecture



4

NETWORK LAYER

Network layer overview

- Types of topologies
  - Star
  - Tree
  - Mesh
- Routing
  - Hierarchical in tree topology
  - Ad-hoc routing protocols for mesh topology
- ZigBee covers networks with only 1 PAN ID

Network Layer Data Entity (NLDE)

- The NLDE shall provide a data service to allow an application to transport application protocol data units (APDU) between two or more devices. The devices themselves must be located on the same network.
- The NLDE shall be able to transmit an NPDU to an appropriate device that is either the final destination of the communication or the next step toward the final destination in the communication chain.
- The ability to ensure both the authenticity and confidentiality of a transmission.

7

Network Layer Management Entity (NLME)

- Configuring a new device: this is the ability to sufficiently configure the stack for operation as required. Configuration options include beginning an operation as a ZigBee coordinator or joining an existing network.
- Starting a network: this is the ability to establish a new network.
- Joining, rejoining and leaving a network: this is the ability to join, rejoin or leave a network as well as the ability of a ZigBee coordinator or ZigBee router to request that a device leave the network.
- Addressing: this is the ability of ZigBee coordinators and routers to assign addresses to devices joining the network.

8

Network Layer Management Entity (NLME)

- Neighbor discovery: this is the ability to discover, record, and report information pertaining to the one-hop neighbors of a device.
- Route discovery: this is the ability to discover and record paths through the network, whereby messages may be efficiently routed.
- Reception control: this is the ability for a device to control when the receiver is activated and for how long, enabling MAC sub-layer synchronization or direct reception.
- Routing: this is the ability to use different routing mechanisms such as unicast, broadcast, multicast or many to one to efficiently exchange data in the network.

9

APPLICATION LAYER

10

Application layer

- Application framework
- ZigBee device objects (ZDO)
- Application support sub-layer (APS)

11

APPLICATION FRAMEWORK

12

Application framework

- The environment in which application objects are hosted on ZigBee devices
- Up to 240 application objects can be created
  - Identified by Endpoint=1..240
  - Endpoint=0 is for ZDO
  - Endpoint=255 is broadcast address for all application objects

13

Application profiles

- Agreements for messages, message formats, and processing actions that enable developers to create an interoperable, distributed application employing application entities that reside on separate devices.
- Application profiles enable applications to send commands, request data, and process commands and requests.

14

Standard profiles

- For generically useful applications
- Developed publicly by members of the ZigBee Alliance
- Managed within the Application Framework Working Group
- Development follows the profile lifecycle
- Enables products to undergo logo certification so that the ZigBee logo can be used

15

Private profiles

- For manufacturer specific proprietary applications
- Developed privately by individual manufacturers
- Private profiles must use a ZigBee allocated profile identifier
- Commercial products built using private profiles must undergo “no harm” testing

16

Why profiles ?

- Need a common language for exchanging data
- Need a well defined set of processing actions
- Device interoperability across different manufacturers
- Allows solid conformance test programmes to be created
- Simplicity and reliability for the end users
- Realistic application specifications developed through OEM experience

17

Current public profiles

- ZigBee Building Automation (Efficient commercial spaces)
- ZigBee Remote Control (Advanced remote controls)
- ZigBee Smart Energy (Home energy savings)
- ZigBee Health Care (Health and fitness monitoring)
- ZigBee Home Automation (Smart homes)
- ZigBee Input Device (Easy-to-use touchpads, mice, keyboards, wands)
- ZigBee Light Link (LED lighting control)
- ZigBee Retail Services (Smarter shopping)
- ZigBee Telecom Services (Value-added services)
- ZigBee Network Devices (Assist and expand ZigBee networks)

18

Cluster

- Clusters are identified by a cluster identifier, which is associated with data flowing out of, or into, the device.
- Cluster identifiers are unique within the scope of a particular application profile.

19

ZIGBEE DEVICE OBJECT (ZDO)

20

ZigBee Device Object

- Provides an interface between the application objects, the device profile, and the APS.
- The ZDO is located between the application framework and the application support sub-layer.
- It satisfies common requirements of all applications operating in a ZigBee protocol stack.

21

ZDO responsibilities

- Initializing the application support sub-layer (APS), the network layer (NWK), and the Security Service Provider.
- Assembling configuration information from the end applications to determine and implement discovery, security management, network management, and binding management.
- The ZDO presents public interfaces to the application objects in the application framework layer for control of device and network functions by the application

22

Device discovery

- Device discovery is the process whereby a ZigBee device can discover other ZigBee devices.
- There are two forms of device discovery requests:
  - IEEE address request is unicast to a particular device and assumes the NWK address is known.
  - NWK address request is broadcast and carries the known IEEE address as data payload.

23

Service discovery

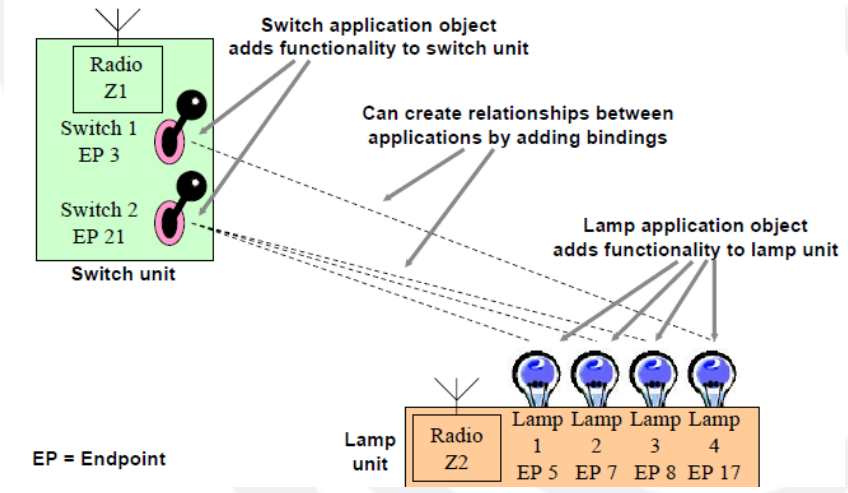
- It is the process whereby the capabilities of a given device are discovered by other devices.
- Service discovery can be accomplished by issuing a query for each endpoint on a given device or by using a match service feature (either broadcast or unicast).
- The service discovery facility defines and utilizes various descriptors to outline the capabilities of a device.

24

APPLICATION SUPPORT SUB-LAYER (APS)

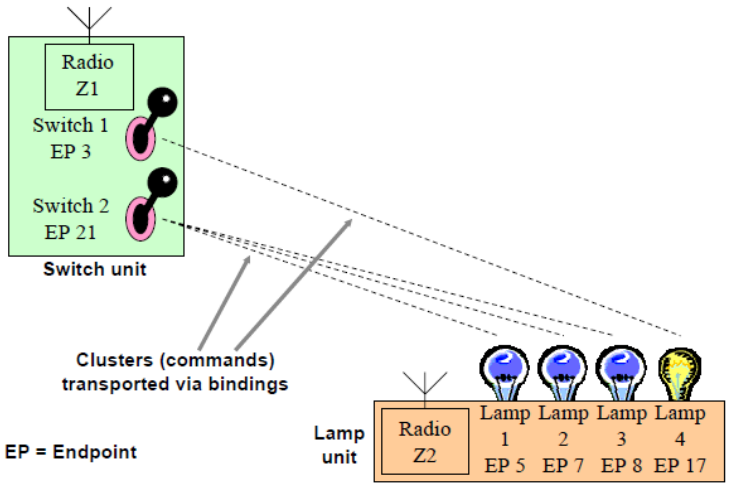
25

Addressing and Binding



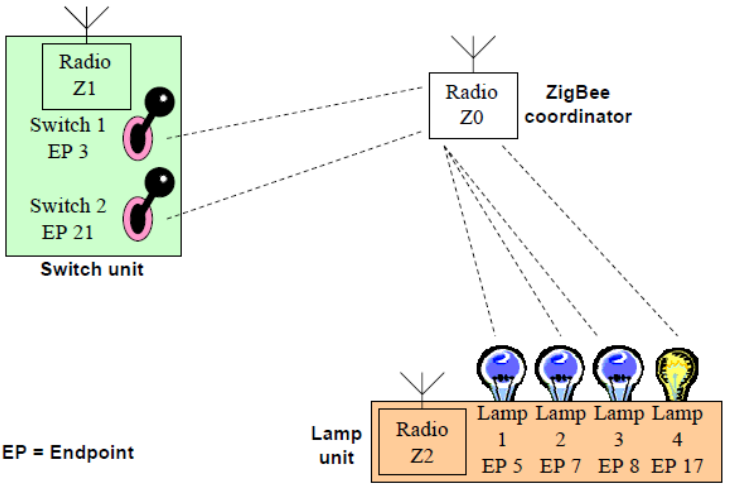
26

Transporting clusters



27

Indirect transmission



28

Binding table

The binding table forms the mapping:

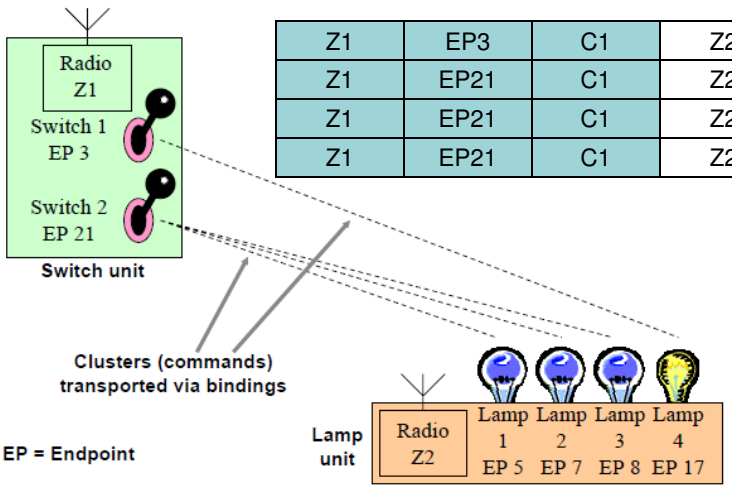
$$(a_s, e_s, c_s) = \{ (a_{d1}, e_{d1}), (a_{d2}, e_{d2}), \ldots, (a_{dn}, e_{dn}) \}$$

Where

a_s	= the address of the device as the source of the binding link
e_s	= the endpoint identifier of the device as the source of the binding link
c_s	= the cluster identifier used in the binding link
a_{di}	= the i^{th} address of the device as the destination of the binding link
e_{di}	= the i^{th} endpoint identifier of the device as the destination of the binding link

29

Binding table example



Z1	EP3	C1	Z2	EP17
Z1	EP21	C1	Z2	EP5
Z1	EP21	C1	Z2	EP7
Z1	EP21	C1	Z2	EP8

30

Device & Service discovery commands

Command	Addressing	
	Request	Response
NWK address	Broadcast	Unicast
IEEE address	Unicast	Unicast
Node descriptor	Unicast	Unicast
Power descriptor	Unicast	Unicast
Simple descriptor	Unicast	Unicast
Active endpoint	Unicast	Unicast
Match descriptor	Broadcast/unicast	Unicast
Complex descriptor	Unicast	Unicast
User descriptor	Unicast	Unicast
End device announce	Unicast to ZC	Unicast

ZC = ZigBee Coordinator

31

Binding commands

Command	Addressing	
	Request	Response
End device bind	Unicast to ZC	Unicast
Bind	Unicast to ZC or Src	Unicast
Unbind	Unicast to ZC or Src	Unicast

32

Network management commands

Command	Addressing	
	Request	Response
Network discovery	Unicast to ZC/router	Unicast
Neighbour table	Unicast to ZC/router	Unicast
Routing table	Unicast to ZC/router	Unicast
Binding table	Unicast to ZC/router	Unicast
Leave network	Unicast	Unicast
Direct network join	Unicast to ZC/router	Unicast

33

APS data transmission

- Endpoint numbers as APS addresses
- Stop&wait ack/re-tx can be used
- Fragmentation
  - If an APS PDU is larger than an IEEE 802.15.4 payload

34

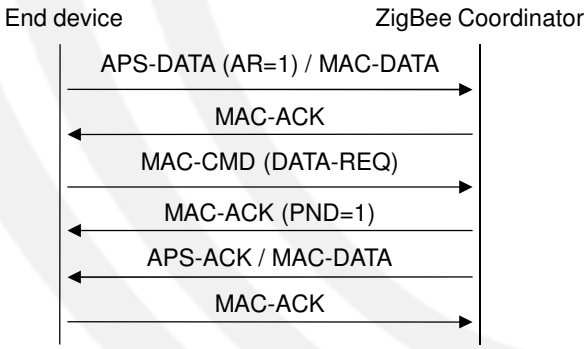
ACK and retransmission

- APS PDU (both DATA and ACK) has a field named “counter”, a source endpoint and a destination endpoint
- Source APS requests ack through the AR bit set to 1 in the APS-DATA PDU
  - The received ack is valid if the counter has the same value and source/destination endpoints are switched.

35

APS-ACK and MAC-ACK

- The APS ack is a IEEE 802.15.4 DATA PDU
- Example:



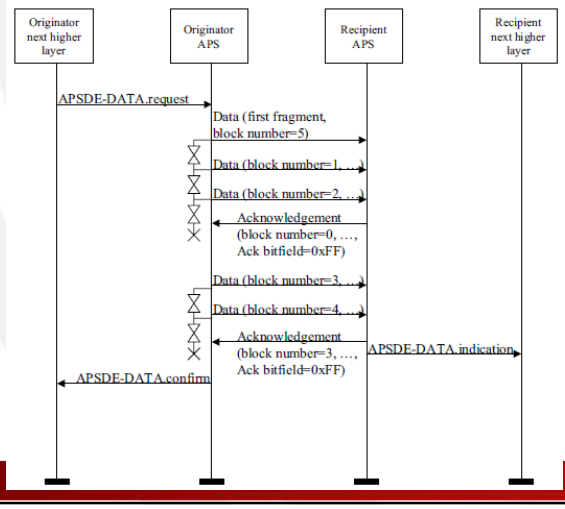
36

Fragmentation

- All the blocks have the same counter
- Specific fields are used to indicate
  - The number of blocks
  - Block order in the sequence
- Definition of a “transmission window” grouping up to 8 blocks
  - An acknowledgement is sent when the last block of the window is received either to confirm that all blocks in the transmission window have been successfully received or to request retransmission of one or more unreceived blocks.

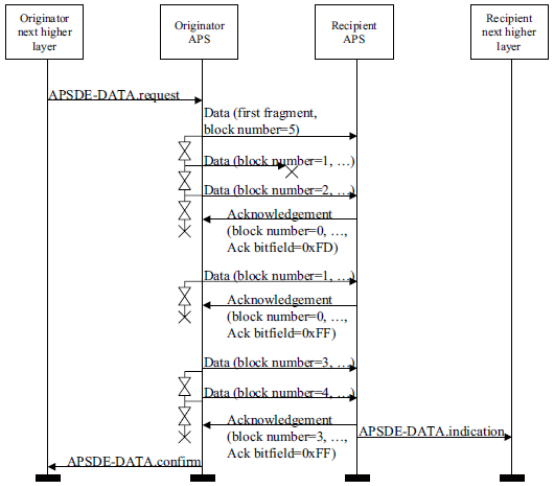
37

Example of fragmentation and successful transmission



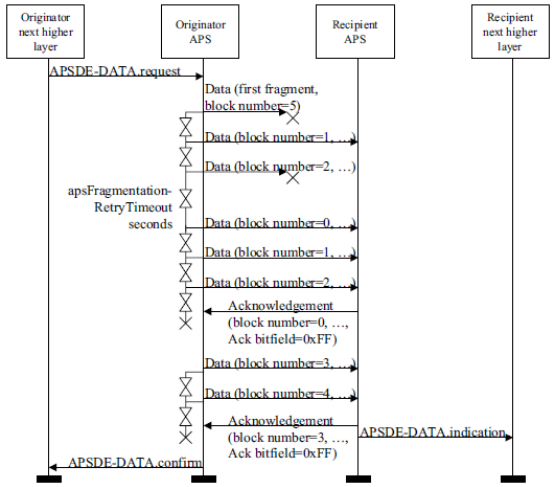
38

Example of fragmentation with single retransmission



39

Example of fragmentation with multiple retransmissions



40