ZigBee™ Alliance

Wireless Control That Simply Works

Network Layer Overview

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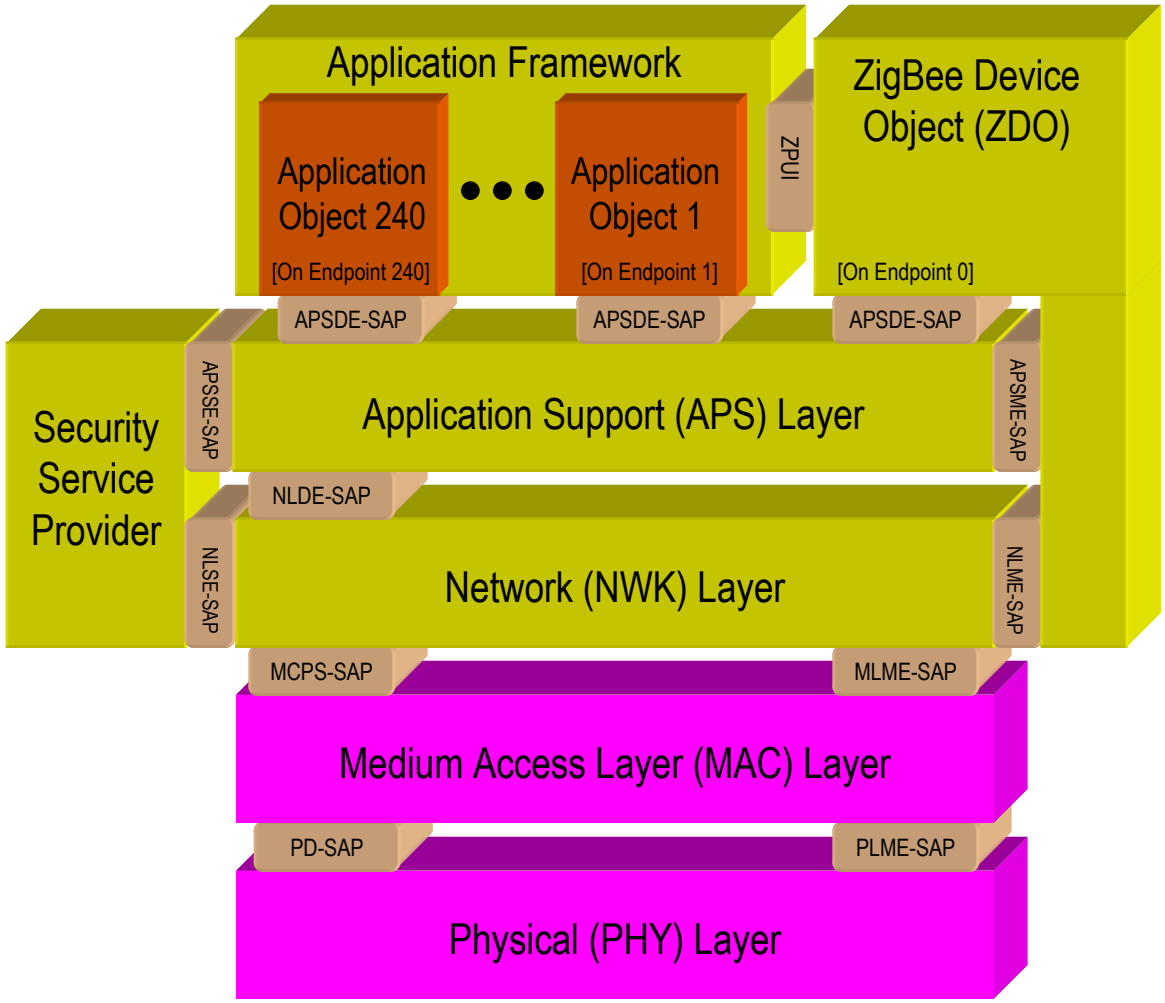
ZigBee Stack

ZigBee is built upon the foundations provided by the IEEE 802.15.4 standard.



ZigBee Stack

802.15.4 Architecture:

- PHY Frequency Options
- Network Structure
- 802.15.4 Device Types
- Locating Networks
- Joining / Rejoining Networks
- Direct / Indirect Data Transmission

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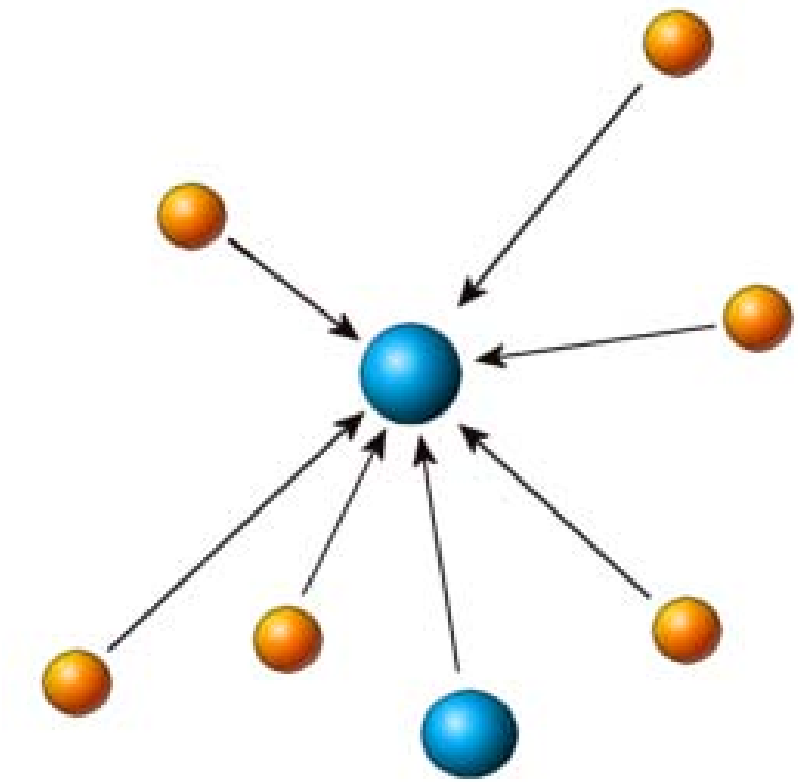
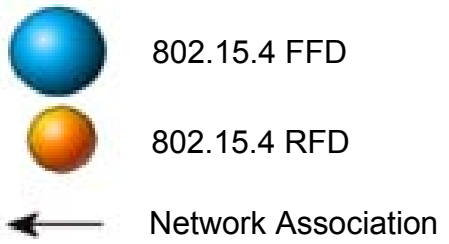
Architecture: 802.15.4 PHY Options

Freq Band	Bit Rate	Channels
868 / 915 MHz	20 / 40 kbps	1 / 10
2.4 GHz	250 kbps	16

IEEE 802.15

Architecture: Network Structure in 802.15.4





Architecture: 802.15.4 Device Types

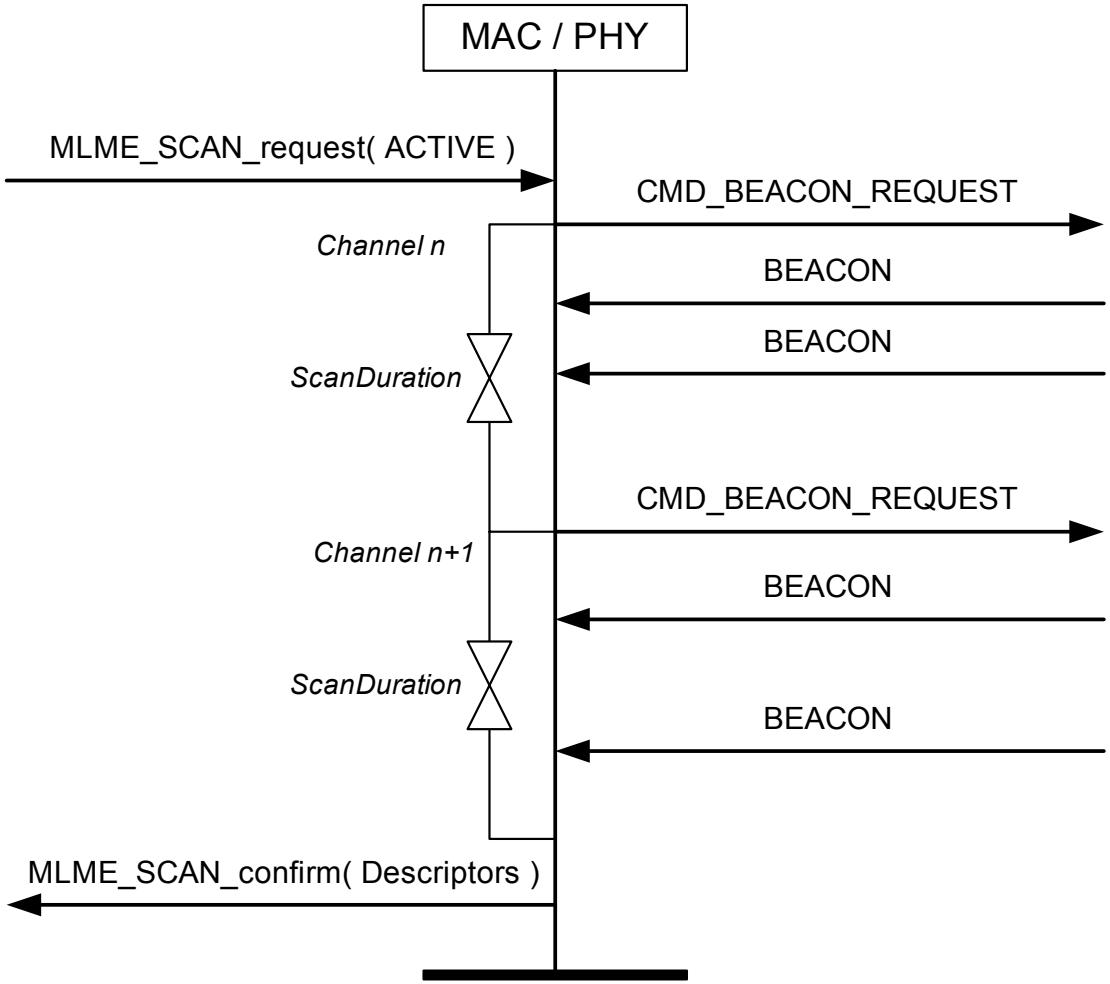
Full Function Device (FFD)

- Capable of being the PAN Coordinator
- Implements processing of “Association Request”
- Implements processing of “Orphan Notification”
- Implements processing of “Start Request”
- Implements processing of “Disassociation Notification”

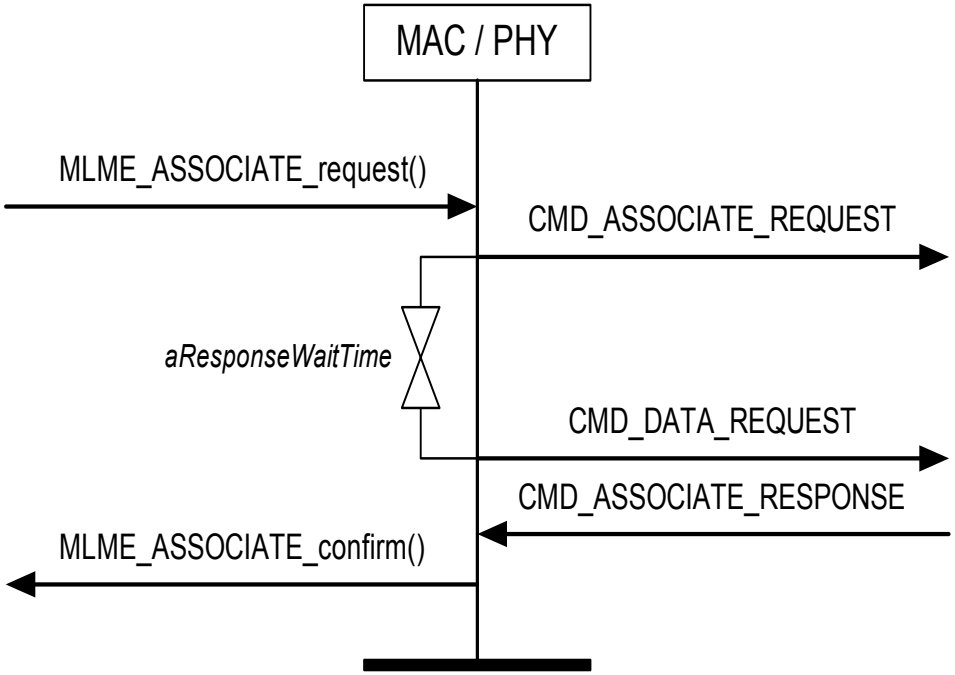
Reduced Function Device (RFD)

- Can only associate and communicate with a FFD
- Reduced stack removes optional components

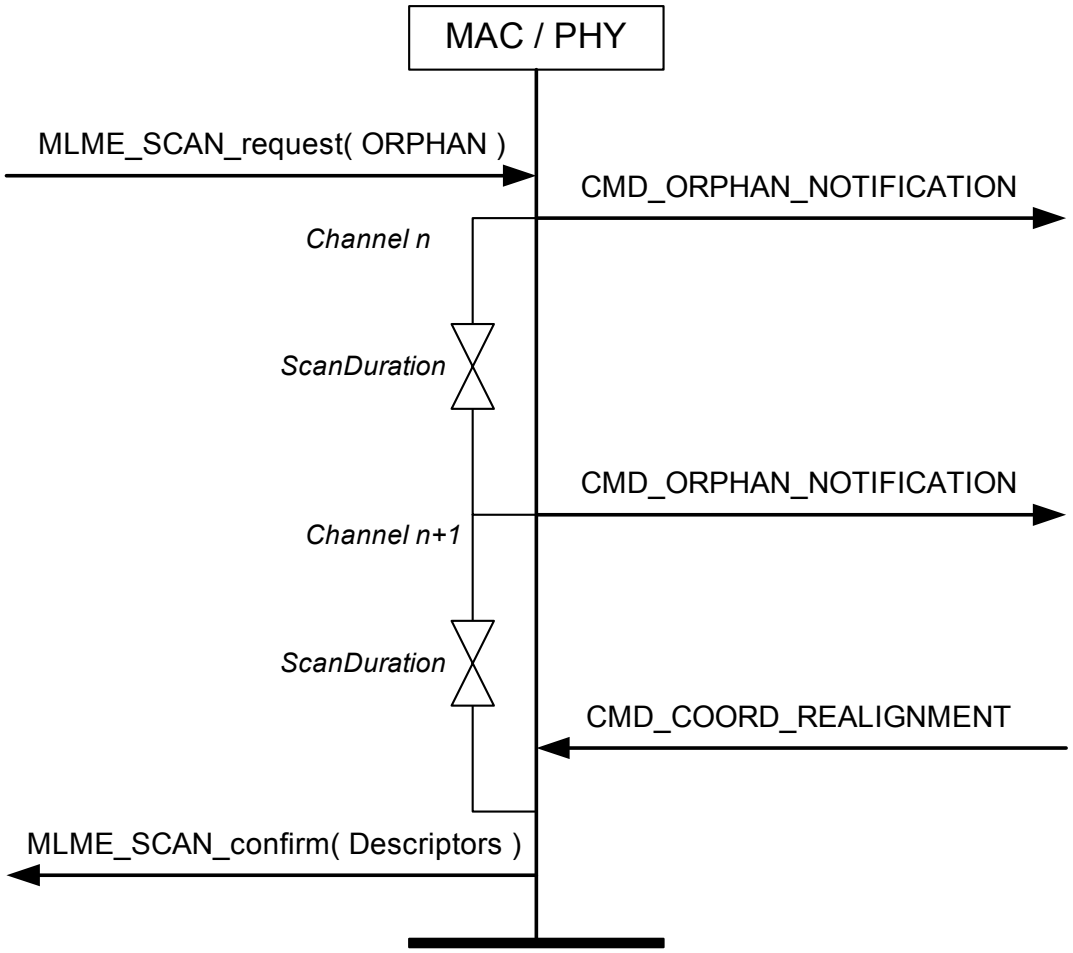
MLME_SCAN: Locating Networks



MLME_ASSOCIATE: Joining a Network



MLME_SCAN: Rejoining a Network



Data Transmission:

Direct (FFD → FFD, or RFD → FFD)

- The receiving device has its receiver on (RxOnIdle)
- The data packet can be set unsolicited
- The MAC schedules it for immediate delivery (using CSMA-CA)

Indirect (FFD → RFD)

- The receiving device is asleep with its receiver off
- The data packet has to be requested (Polled)
- The FFD MAC stores it for later retrieval by the RFD.

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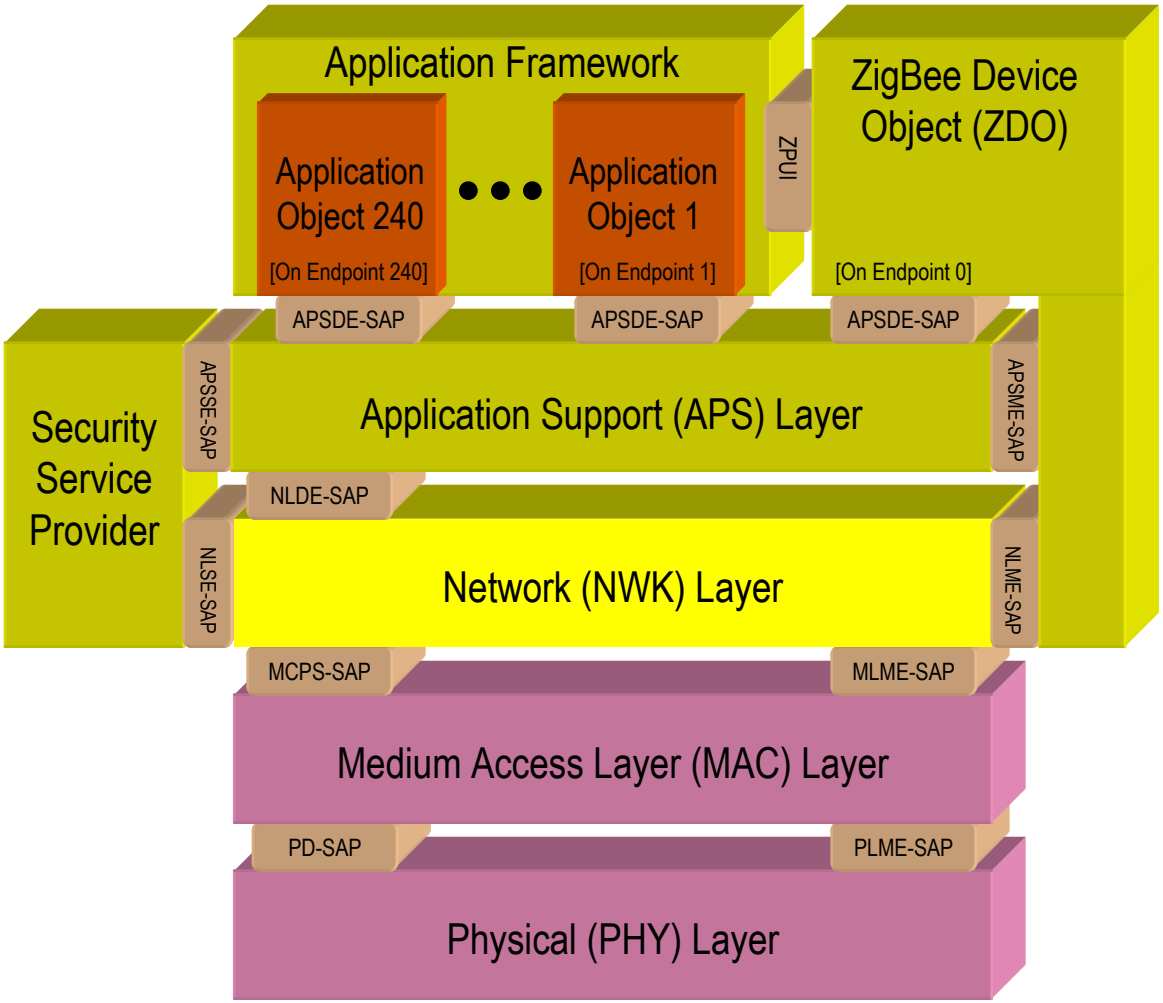
802.15.4 Summary

- Wireless Personal Area Network (WPAN)
  - Used to convey information over short distances.
- Star network topology
- Devices communicate only with the Coordinator
- In-direct data transmission enables small, power efficient, inexpensive solutions to be implemented.
- But…
- 802.15.4 does not provide multi-hop networking
- 802.15.4 does not provide mesh networking
- Enter ZigBee

IEEE 802.15

ZigBee Stack

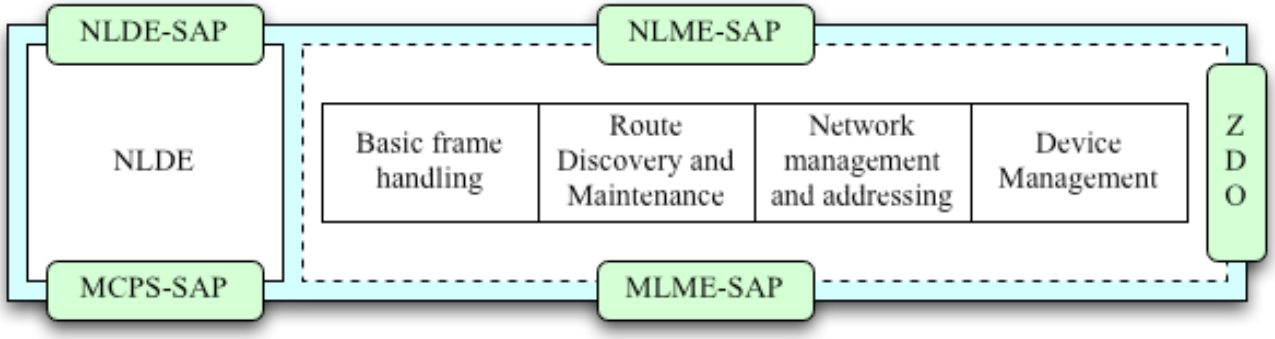
ZigBee is built upon the foundations provided by the IEEE 802.15.4 standard.



ZigBee Stack

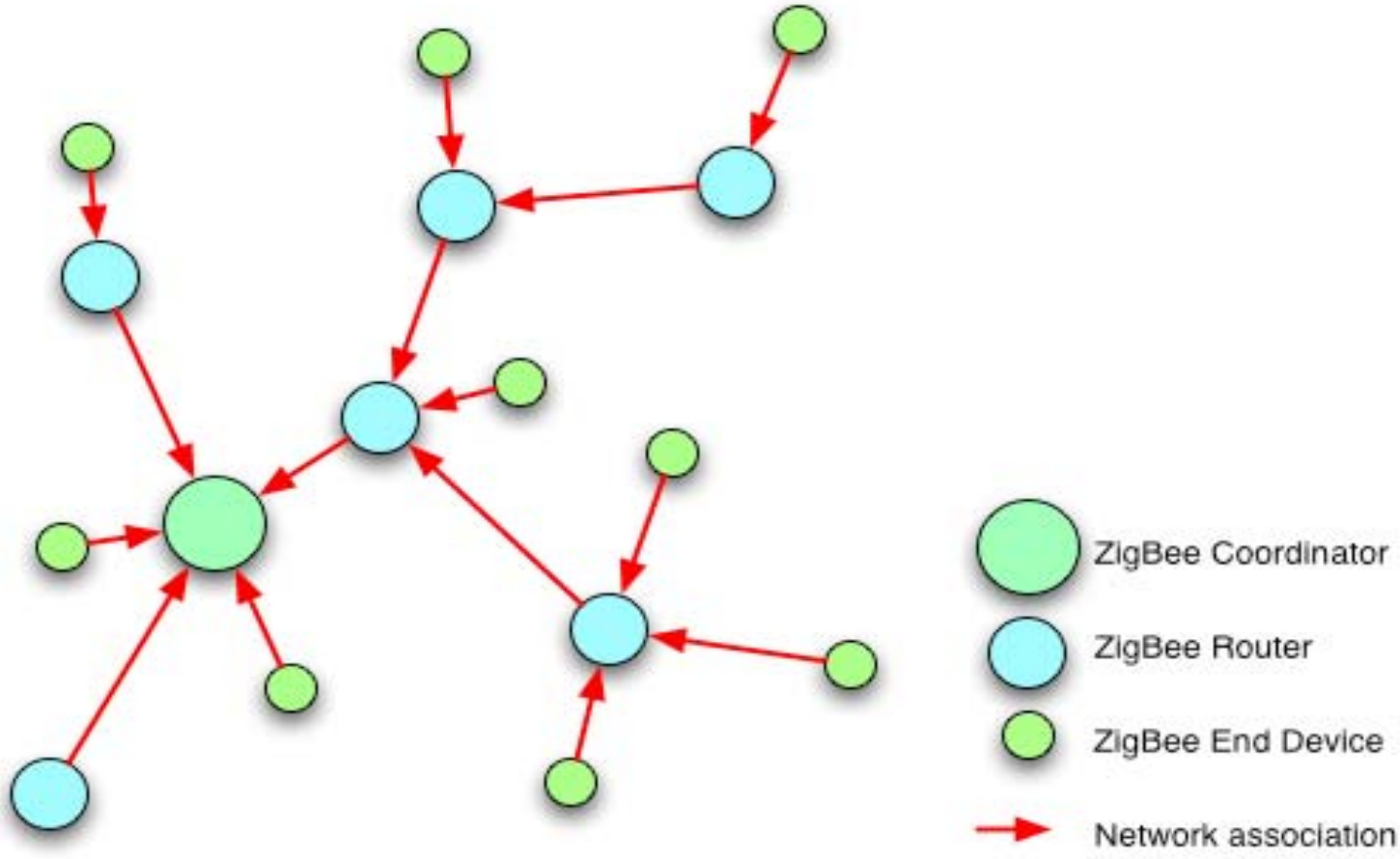
Architecture: NWK layer details

- ZigBee Device Types
- Stack Profile, Network Rules
- Network Management and Addressing
- Message Routing
- Route Discovery and Maintenance
- Security



ZigBee™ Alliance

Architecture: Network Structure in ZigBee



Architecture: Stack Profile

Sets the rules that the network adheres to:

- nwkMaxDepth
- nwkMaxChildren
- nwkMaxRouters
- nwkSecurityLevel

And many more

- Table sizes
- Timeouts
- Route Cost Calculation Algorithm

Architecture: ZigBee Device Types

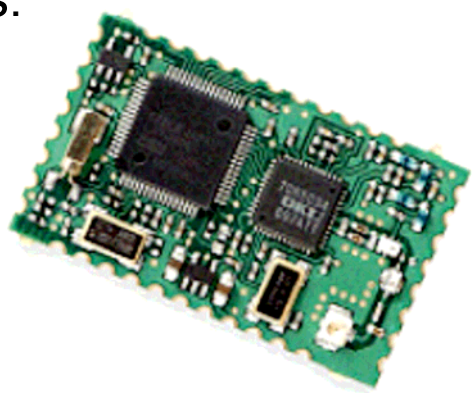
ZigBee Coordinator (ZC)

- One and only one required for each ZigBee network.
  - First one on the scene
- Initiates network formation.
  - Selects the time and place (Channel, PANId, Stack Profile)
- Acts as IEEE 802.15.4 2003 PAN coordinator (FFD).
- Also performs as router once network is formed.
- Not necessarily a dedicated device can perform an application too.
- One extra function: Acts as Bind Request Controller

Architecture: ZigBee Device Types

ZigBee Router (ZR)

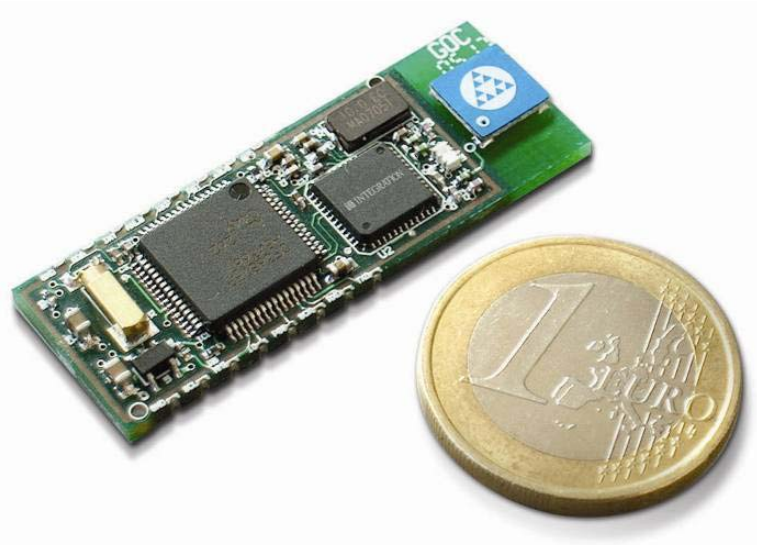
- Optional network component.
- Discovers and associates with ZC or ZR.
  - Extends the network coverage
- Acts as IEEE 802.15.4 2003 coordinator (FFD).
- Manages local address allocation / de-allocation
- Participates in multi-hop / mesh routing of messages.
- Looks after its ZED's when it comes to broadcasting and routing messages
- Maintains Neighbor Table to allow Neighbor Routing



Architecture: ZigBee Device Types

ZigBee End Device (ZED)

- Optional network component.
- Discovers and associates with ZC or ZR.
- Acts as IEEE 802.15.4 2003 device (RFD).
- Can be optimised for very low power operation
- Relies on its parent to let it sleep
  - RxOnIdle is off
- Shall not allow association.
- Shall not participate in routing.



Network Initiation: ZC

NLME_NETWORK_FORMATION.request

- Performs an Energy Detect Scan
  - Looks for other wireless devices on the channel
- Performs an Active Scan
  - Looks for other 802.15.4 networks on the channel
- Selects the *"nicest"* channel
  - Weights up channels based on noise level and PANs
- Selects an unused PANId
- Starts a network

Network Discovery: ZR & ZED

NLME_NETWORK_DISCOVERY.request

- Performs an Active Scan
  - Looks for other ZigBee networks on the channel
- Selects a compatible network
  - Stack Profile

Network Association: ZR & ZED

NLME_JOIN.request

- Selects the highest acceptable router
  - Link Quality, with capacity
- Associates with the router
- Allocated an address on the network

- Device authenticates with network

Network Association: ZR Cont.

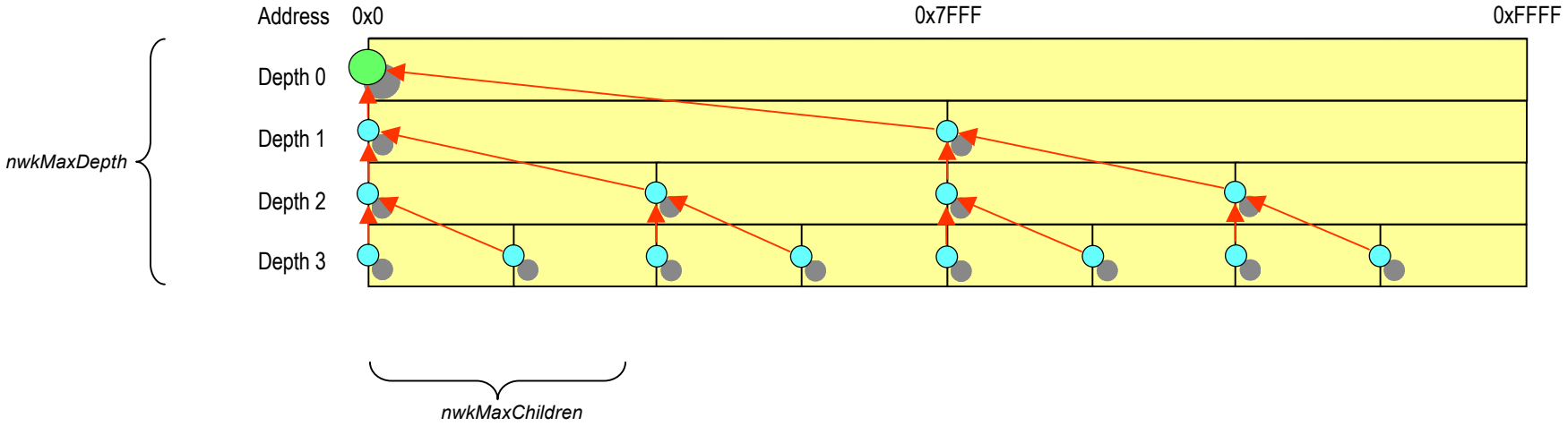
NLME_START_ROUTER.request

- Updates Beacon Payload
  - Depth, Capacity
- Starts a router

- Updates Association Permit Status

Addressing: Tree-structured Address Assignment

- CSkip based address assignment
- Address determined from tree location



Transmitting Data

NLDE-DATA.request

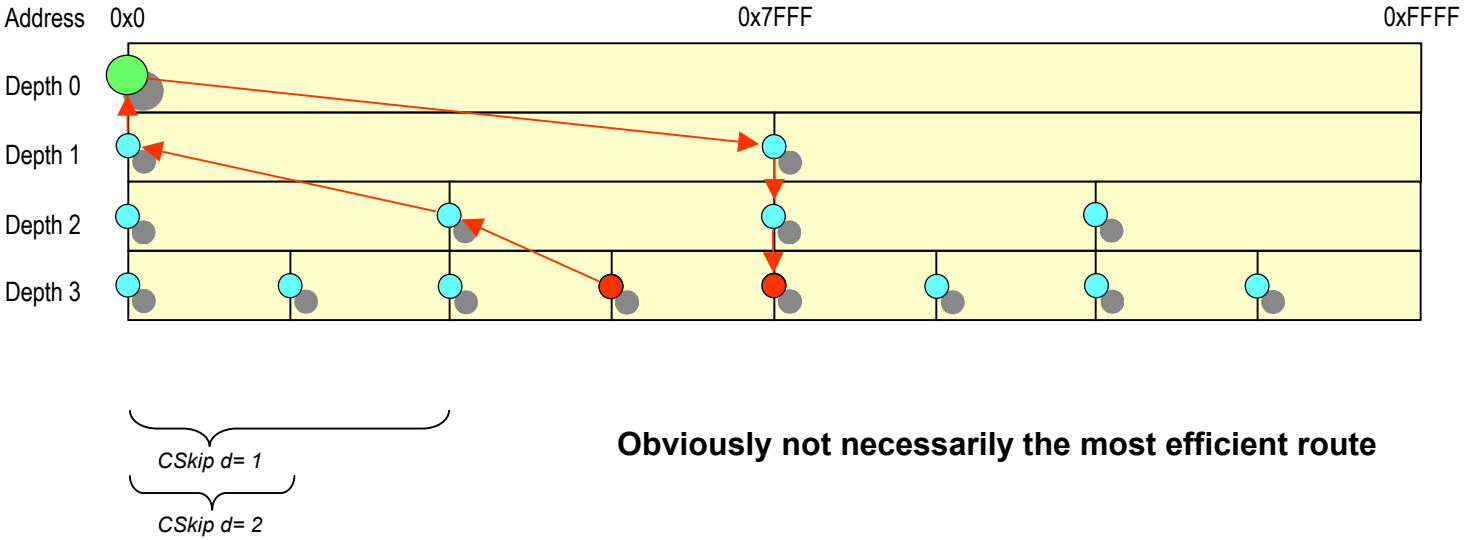
- Used by NHL for all data transmissions
  - Uni-casts and broadcasts
- Accepts the following parameters
  - Destination Address
  - Radius
  - Discover Route

NLDE-DATA.indication

- Reports the receipt of a data transmission
- Includes the following parameters
  - Source Address

Tree Routing:

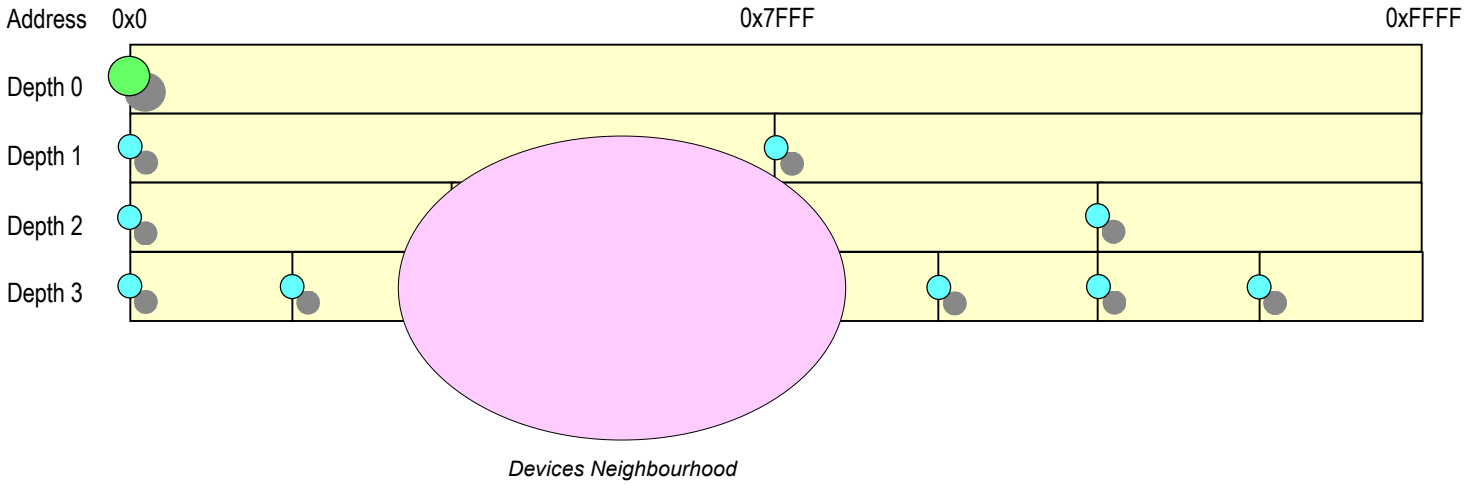
- The address tells you where the destination is
- Simple equation gives ‘route up’ or ‘route down’
- If *LocalAddr < DestAddr < LocalAddr + CSkip(d-1)* Route Down
- Else Route Up



Obviously not necessarily the most efficient route

Neighbour Routing:

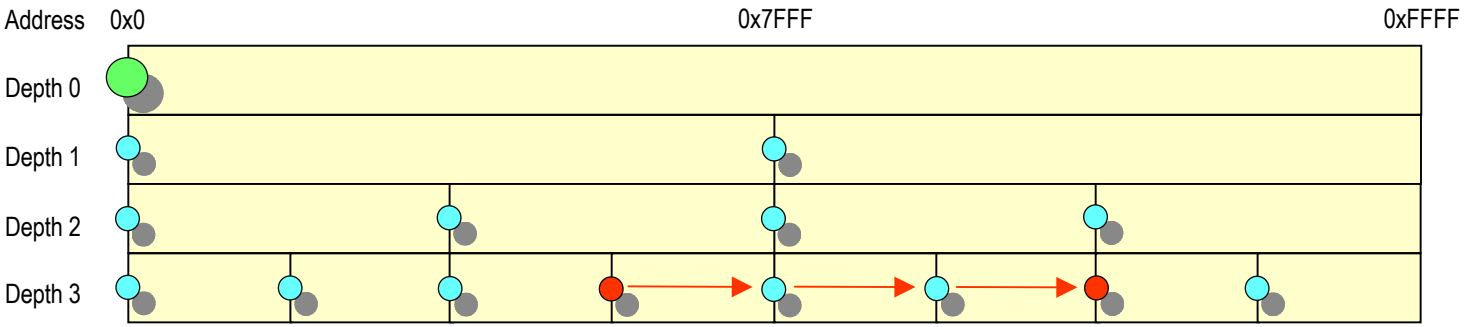
- A ZC or ZR maintains a table of devices in its neighbourhood
- If the target device is physically in range it can send the message directly.



But what happens if the destination is not in the local neighbourhood?

Mesh Routing:

- ZC or ZR maintains a routing table of next hop addresses
- If the target device has a routing table entry then the message can be sent using this route.



That's great, but where do the routing table entries come from?

Routing: Route Discovery

- A device wishing to discover a route issues a route request command frame
  - Specialized broadcast frame transmitted throughout the network.
  - Path cost is computed by intermediary nodes on receipt
- Nodes pass on the route request if new or better route request
- Intended destination responds to the route request command frame if new or better route request with a route reply command frame
  - Unicast frame, returns along the reverse path
  - Reports the path cost
- Nodes pass on the route reply and update their routing tables

Message Routing: The Basic Algorithm

1. See if the destination is in the Neighbour Table
2. Check for a Routing Table entry
3. Finally resort to Tree Routing

NB. ZRs store messages for sleeping ZED's

Broadcast: The Basic Algorithm

- Transmit broadcast message
- Rebroadcast by local ZRs if it is new.

- Time & radius limited.
- ZRs store messages for sleeping ZED's
- ZRs issue broadcasts on behalf of sleeping ZEDs

Security: NWK Layer

- The Stack Profile defines the security level in use.
- Uses Network Key unless Link Key has been applied.
- Tool box offers both authentication and encryption facilities.
- Auxiliary Header and Message Integrity Code add overhead to the packet.

nibSecurityLevel	*Security Suite*
0	NONE
1	MIC-32
2	MIC-64
3	MIC-128
4	ENC
5	ENC-MIC-32
6	ENC-MIC-64
7	ENC-MIN-128

Network Layer Management Primitives

NLME-PERMIT-JOINING.request
NLME-PERMIT-JOINING.confirm

NLME-DIRECT-JOIN.request
NLME-DIRECT-JOIN.confirm

NLME-LEAVE.request
NLME-LEAVE.confirm
NLME-LEAVE.indication

NLME-SYNC.request
NLME-SYNC.confirm
NLME-SYNC.indication

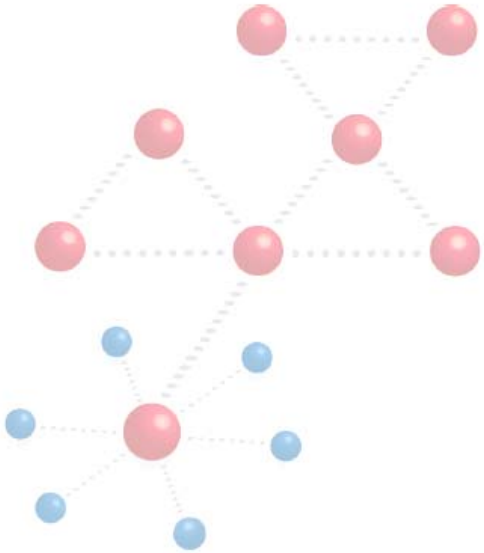
NLME-RESET.request
NLME-RESET.confirm

NLME-GET.request
NLME-GET.confirm

NLME-SET.request
NLME-SET.confirm

To summarise the ZigBee network layer:

- Has 3 device types; ZC, ZR and ZED.
- Performs network discovery and formation
- Performs address allocation
- Performs message routing
- Configured by the stack profile
- Provides network wide security
- Allows low power devices to maximize their battery life



ZigBee turns 802.15.4 into a low power multi-hop mesh network.

Any Questions

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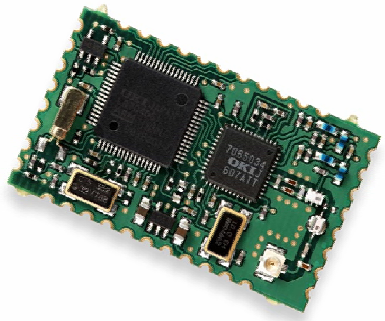

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