ZigBee™ Alliance

Wireless Control That Simply Works

Network Layer Overview

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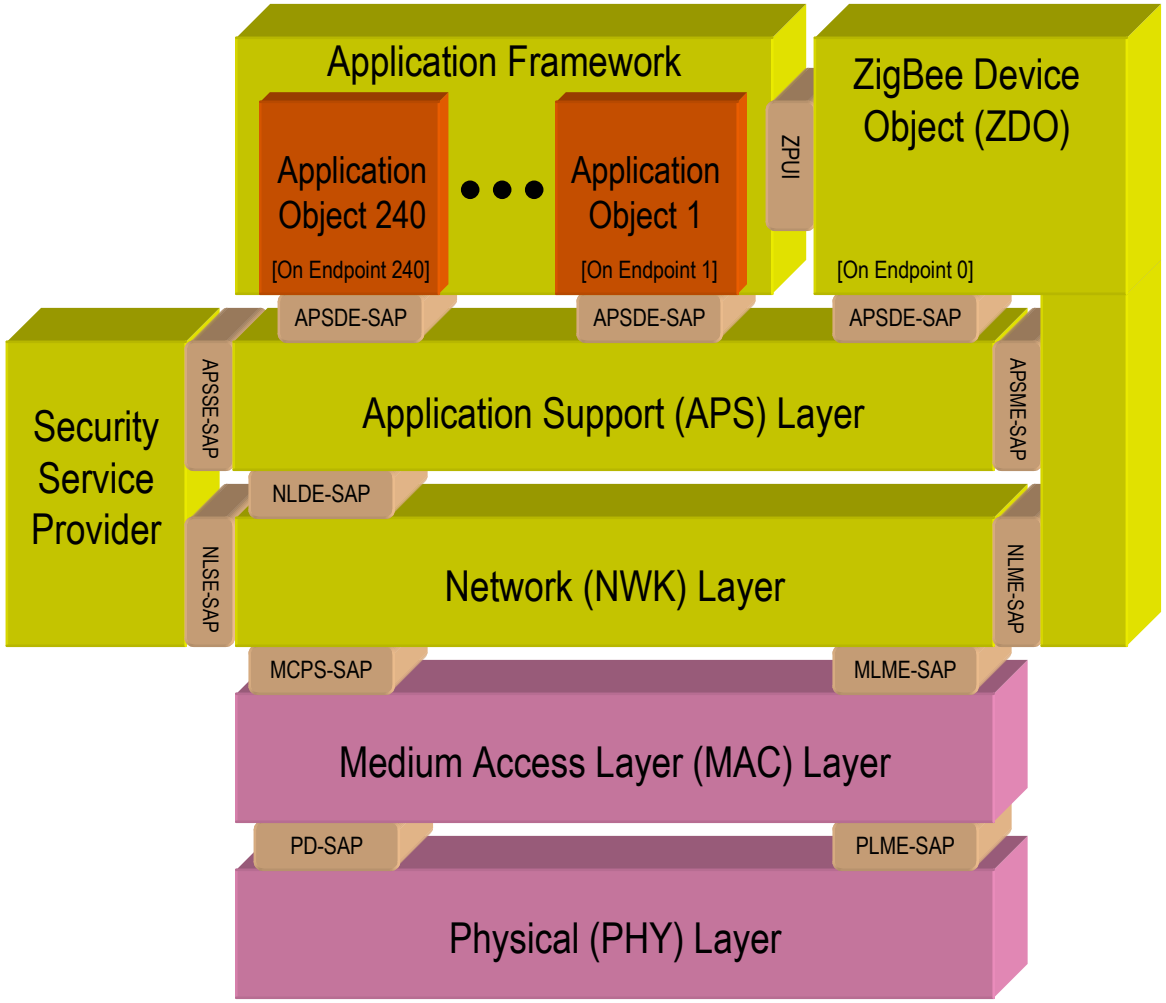
ZigBee Stack

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



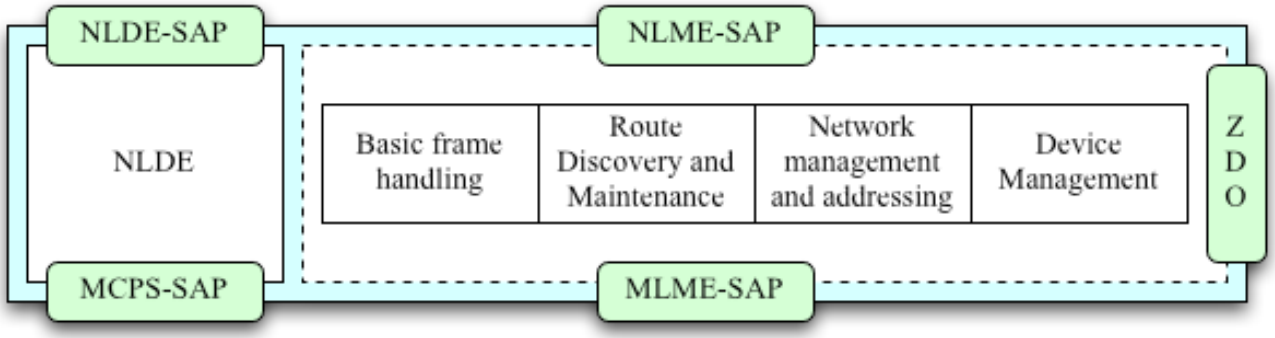
ZigBee Stack

ZigBee NWK Layer Design Goals

- Enable low-cost, low-power embedded mesh networking.
- Support a wide variety of technical requirement and design tradeoffs.
  - Battery life vs. throughput.
  - Latency vs. spatial coverage.
  - Code size vs. “Ease of use” and “Feature richness”.

Architecture: NWK layer details

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



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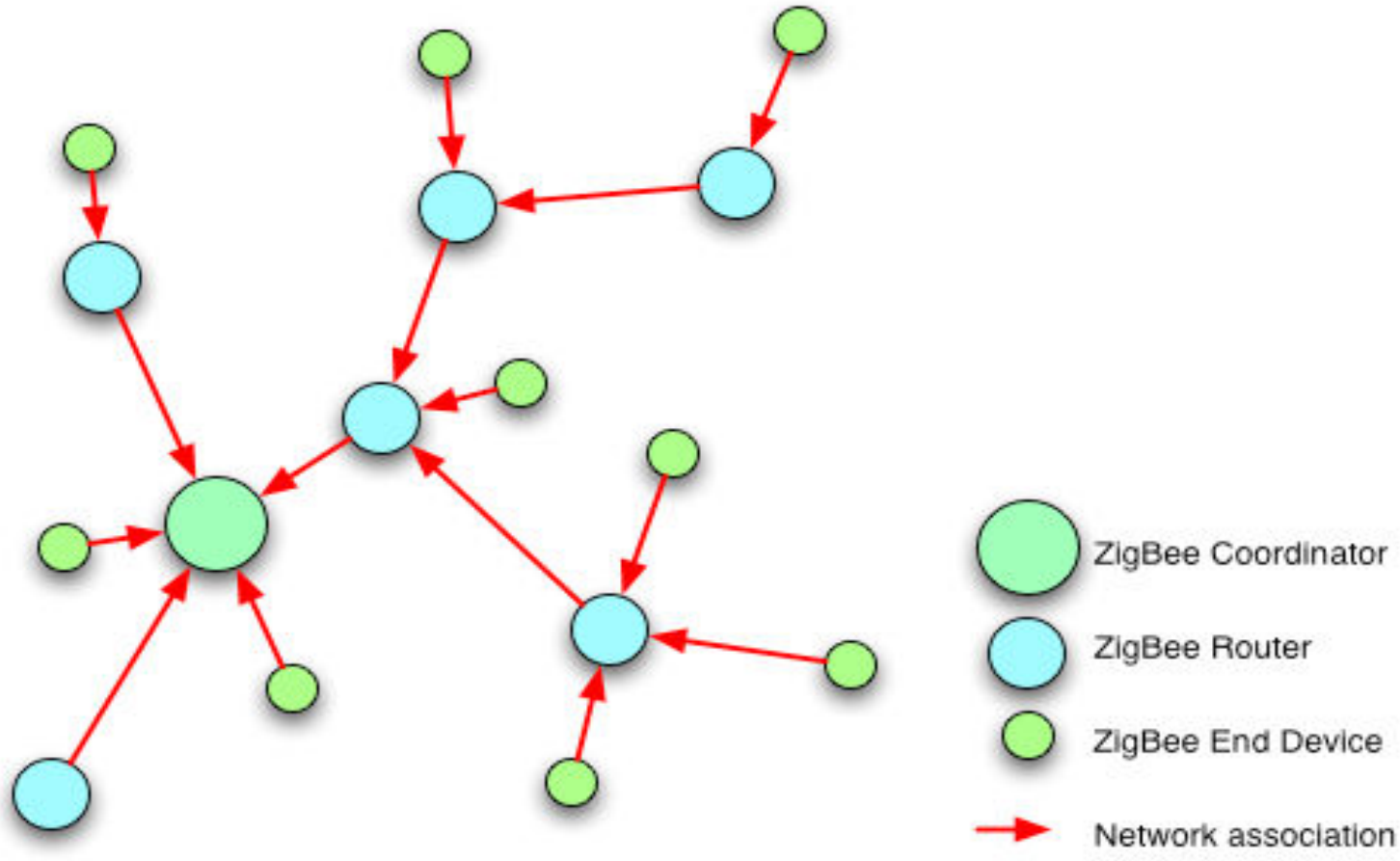
Architecture: Network Structure in ZigBee



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

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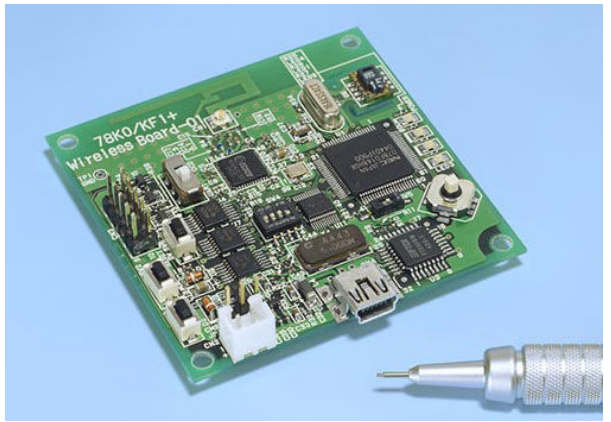
Architecture: ZigBee Device Types

ZigBee Coordinator (ZC)

- One and only one required for each ZigBee network.
  - First one to the party
- 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.



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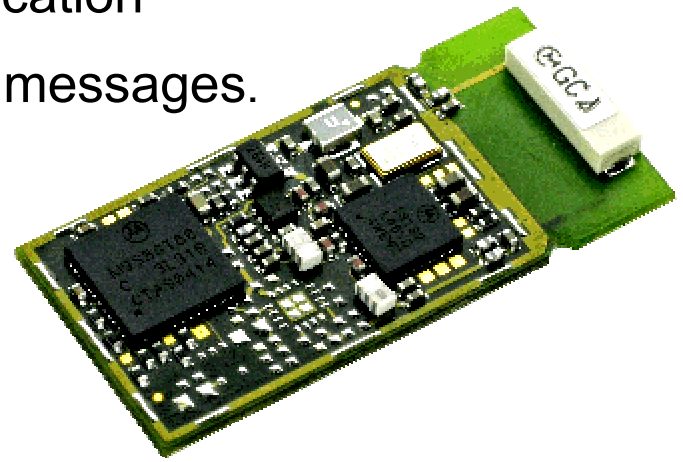
Architecture: ZigBee Device Types

ZigBee Router (ZR)

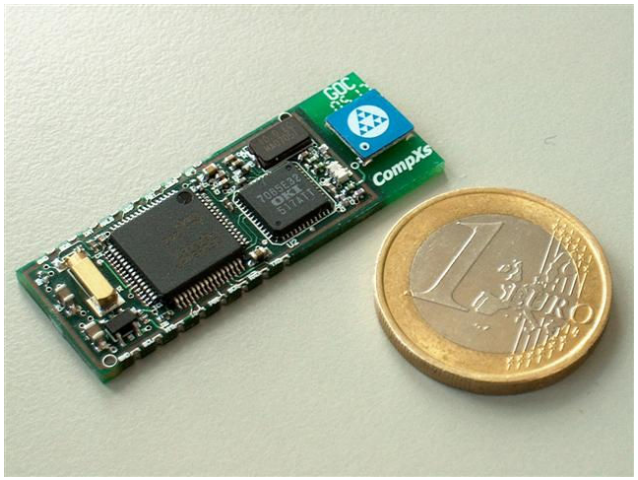
- Optional network component.
- Discovers and associates with ZC or ZR.
  - Extends the network coverage
- Acts as IEEE 802.15.4 2003 coordinator (FFD).
- Manages local address allocation / de-allocation
- Participates in multi-hop / mesh routing of messages.
- Looks after its ZED's when it comes to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



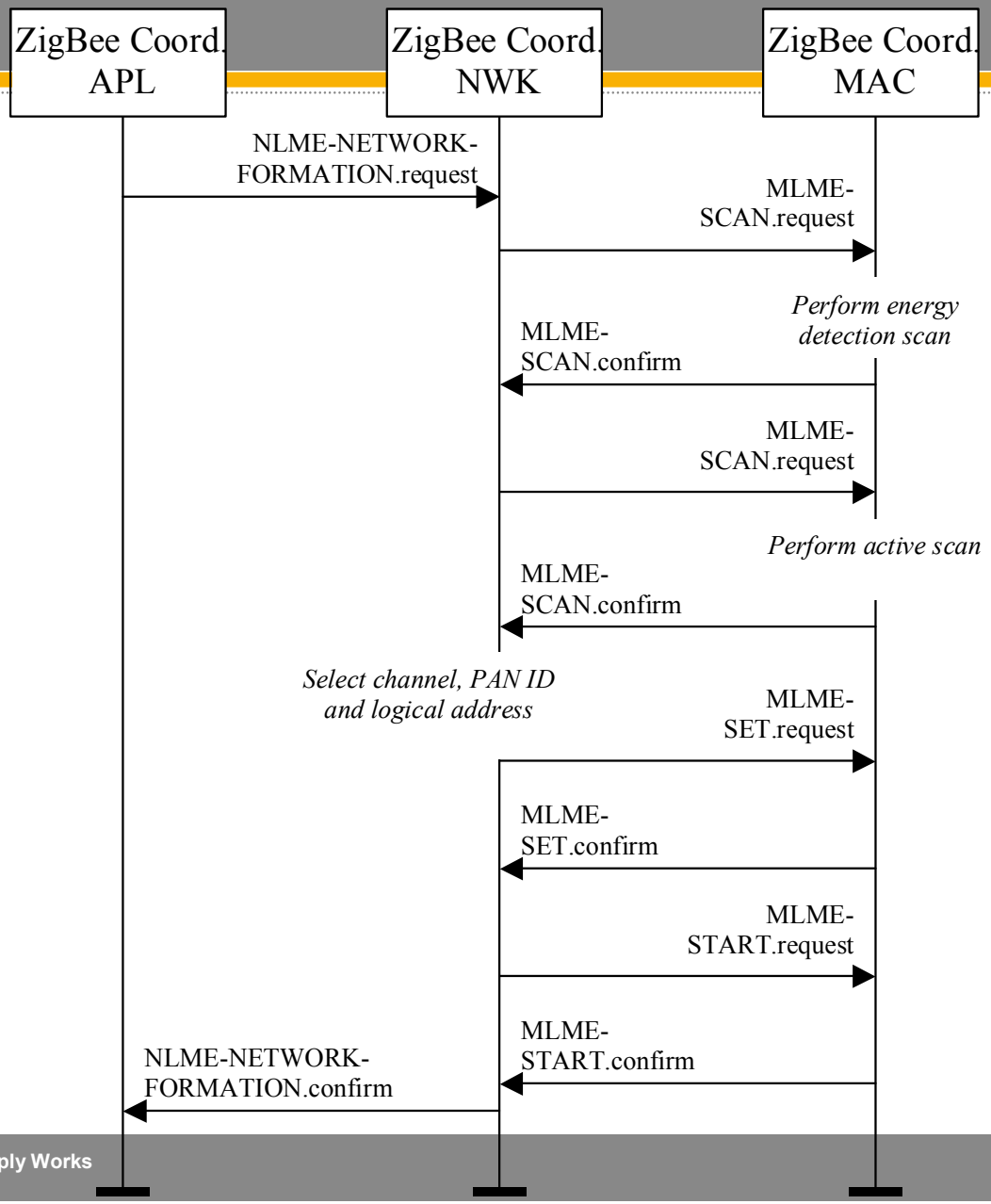
Architecture: ZigBee Device Types

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
- Shall not allow association.
- Shall not participate in routing.



Network Initiation: ZC



NLME-NETWORK-FORMATION.request

NLME-NETWORK-FORMATION.request	{
	ScanChannels,
	ScanDuration,
	BeaconOrder,
	SuperframeOrder,
	PANId,
	BatteryLifeExtension
Directs the MAC to start up a PAN with the specified parameters using the MLME-START.request{} primitive.	}

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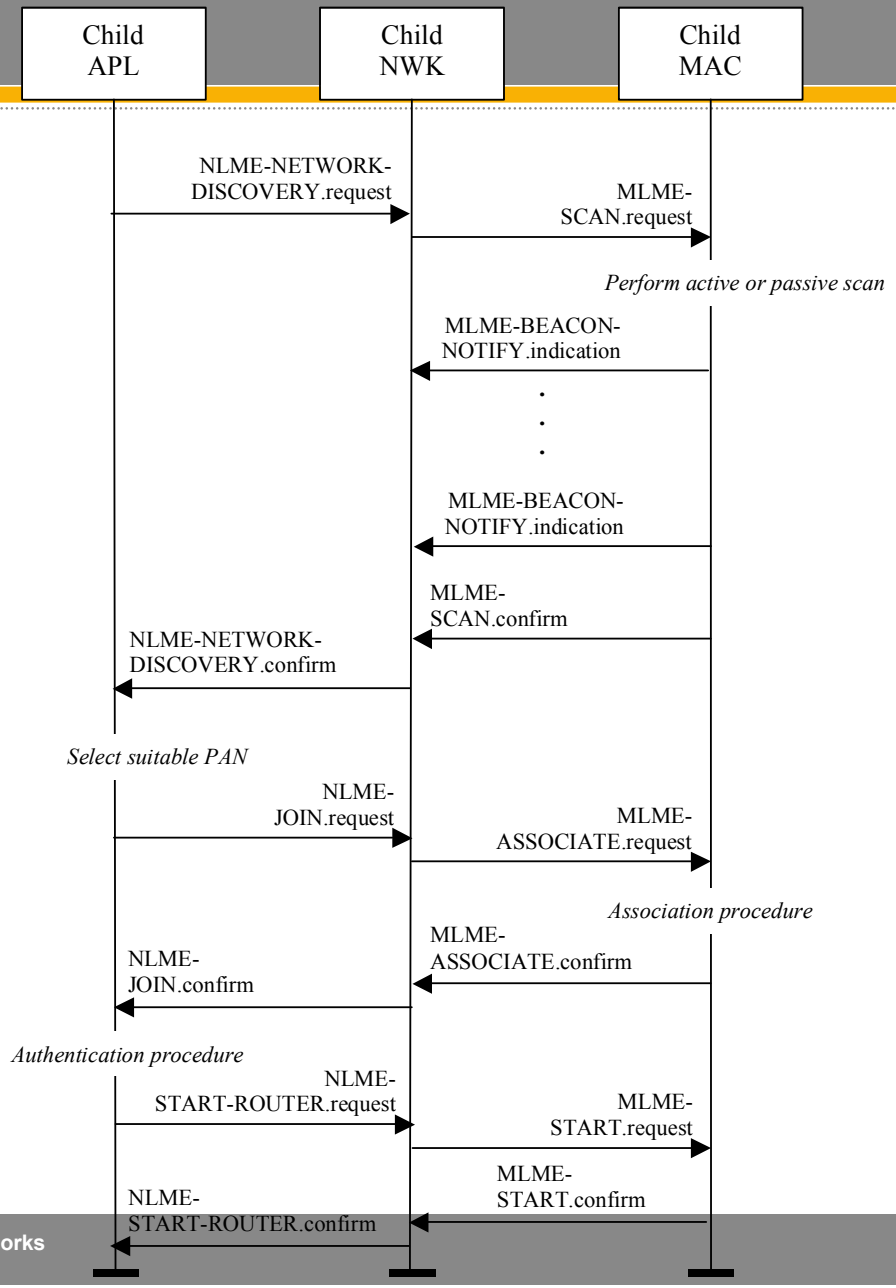
NLME-NETWORK-FORMATION.confirm

NLME-NETWORK-FORMATION.confirm	{
	Status
	}

Reports the results of a network formation attempt. Status values are INVALID_REQUEST, STARTUP_FAILURE or any status value returned from the MLME-START.confirm{} primitive.

Network Association: ZR & ZED



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NLME-NETWORK-DISCOVERY.request

NLME-NETWORK-DISCOVERY.request	{
	ScanChannels,
	ScanDuration
	}

Directs the NWK layer to scan for existing networks on a specified set of channels. The parameters are passed through to MLME-SCAN.request{}.

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NLME-NETWORK-DISCOVERY.confirm

NLME-NETWORK-DISCOVERY.confirm	**{** **NetworkCount,** **NetworkDescriptor,** **Status** **}**

Returns data on a list of found networks. Descriptor data Includes PAN ID, channel, stack profile, ZigBee version, beacon order, superframe order, permit joining.
Status reports the results of the MLME-SCAN.confirm.

NLME-JOIN.request

NLME-JOIN.request	**{** **PANId,** **JoinAsRouter,** **RejoinNetwork,** **ScanChannels,** **ScanDuration,** **PowerSource,** **RxOnWhenIdle,** **MACSecurity** **}**
Used on a ZigBee router or ZigBee end device to request association with a particular PAN. Some MLME-ASSOCIATE.request{} parameters are passed through, e.g ScanChannels, some are synthesized, e.g. CapabilityInfo.	

NLME-JOIN.confirm

NLME-JOIN.confirm	**{** **PANId,** **Status** **}**

Reports the results of an attempt to join a particular network. Status values are INVALID_REQUEST, NOT_PERMITTED or any status value returned from the MLME-ASSOCIATE and MLME-SCAN.confirm{} primitives.

NLME-JOIN.indication

NLME-JOIN.indication	**{** **ShortAddress,** **ExtendedAddress,** **CapabilityInformation** **SecureJoin** **}**

On a ZigBee coordinator or ZigBee router reports the successful joining of a child device. The parameters are as received from the MLME-ASSOCIATION.indication{} primitive.

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NLME-START-ROUTER.request

NLME-START-ROUTER.request	{
	BeaconOrder,
	SuperframeOrder,
	BatteryLifeExtension
	}

Used on a ZigBee router to start beaconing and other router activities after a network has been joined. Parameters are passed through to the MLME-START.request{} primitive.

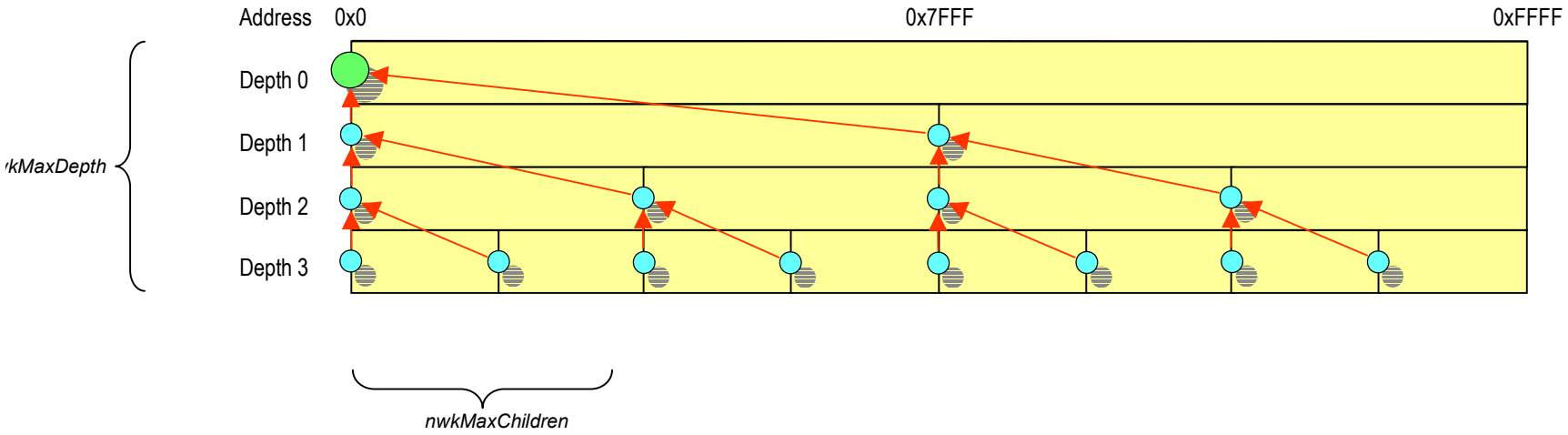
NLME-START-ROUTER.confirm

NLME-START-ROUTER.confirm	{
	Status
	}

Reports the results of an attempt to start up a ZigBee router. Status values are INVALID_REQUEST or any status value returned from the MLME-START.confirm primitive.

Addressing: Tree-structured Address Assignment

- CSkip based address assignment
- Address determined from tree location



NLDE-DATA.request

NLDE-DATA.request	{
	DstAddr,
	NsduLength,
	Nsdu,
	NsduHandle,
	Radius,
	DiscoverRoute,
	SecurityEnable
	}

Used by higher layers for all data transmissions, broadcast and unicast.

NLDE-DATA.confirm

NLDE-DATA.confirm	{
	NsduHandle,
	Status
	}

Reports the status of a transmission indexed by handle. Status values are INVALID_REQUEST or any status returned by the MCPS-DATA.confirm{} primitive.

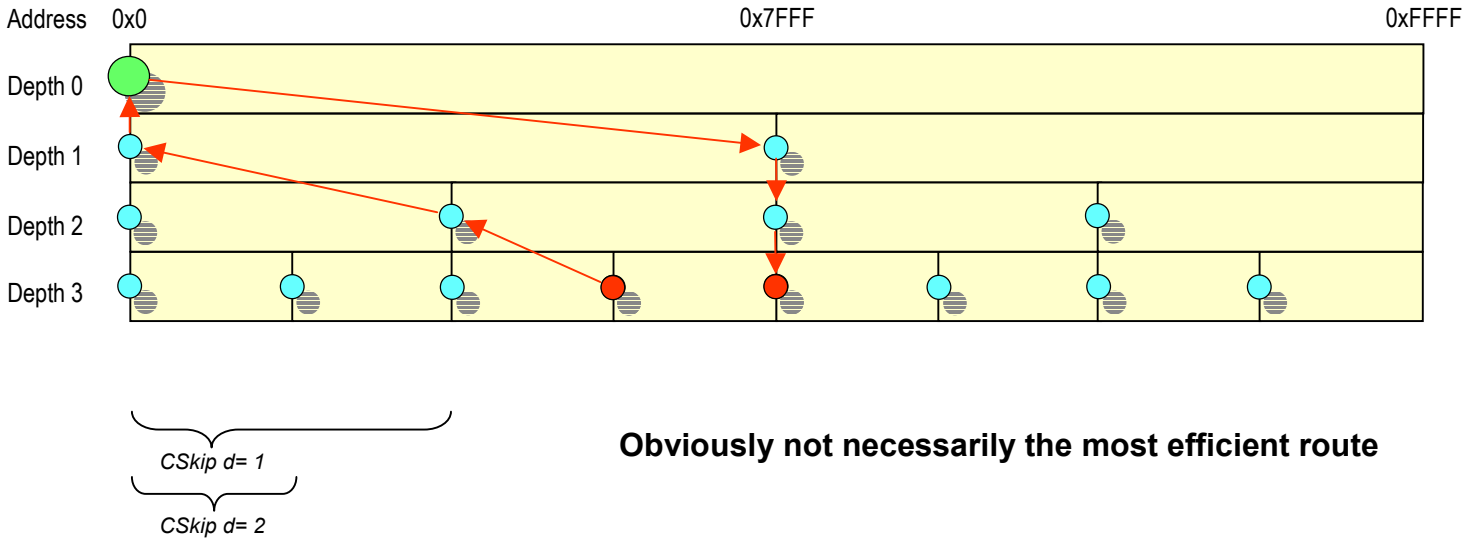
NLDE-DATA.indication

NLDE-DATA.indication	{
	SrcAddress,
	NsduLength,
	Nsdu,
	LinkQuality
	}

Reports the receipt of a NWK data frame.

Tree Routing:

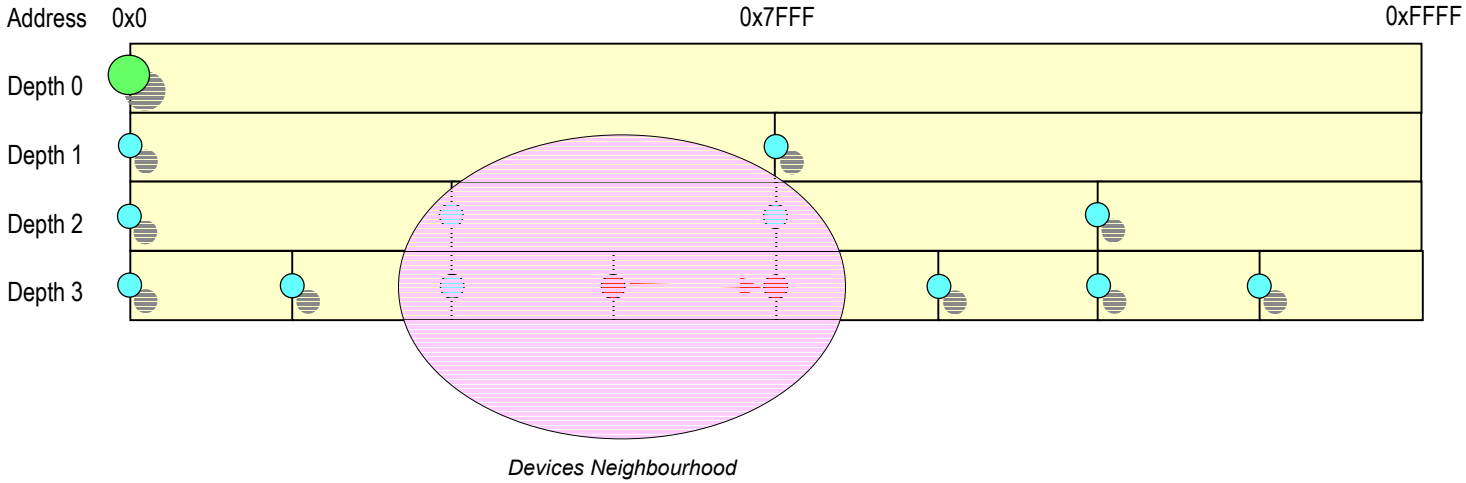
- The address tells you where the destination is
- Simple equation gives ‘route up’ or ‘route down’
- If *LocalAddr < DestAddr < LocalAddr + CSkip(d-1)* Route Down
- Else Route Up



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.

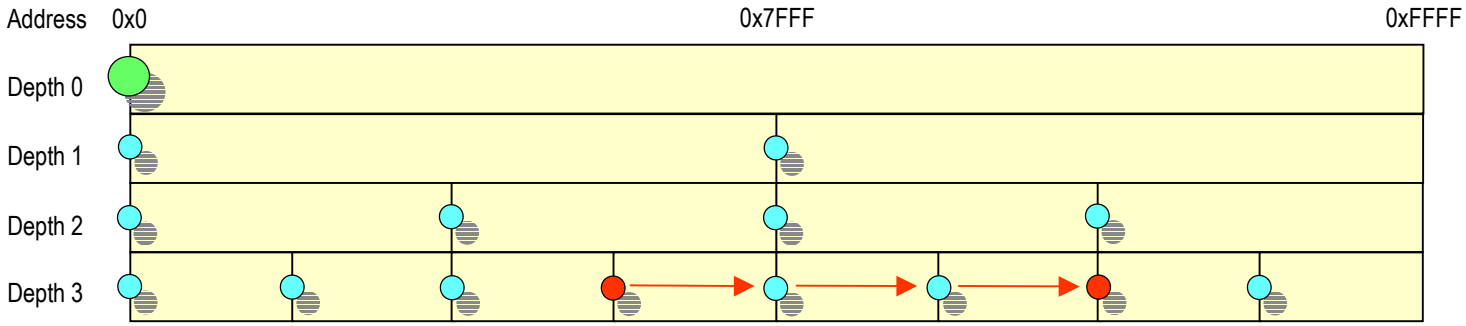


Devices Neighbourhood

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 which is broadcast throughout the network.
- When the intended destination receives the route request command frame it responds with a route reply command frame.
- Potential routes are evaluated with respect to a routing cost metric.
- Best route is added to the routing tables of all devices on the route

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

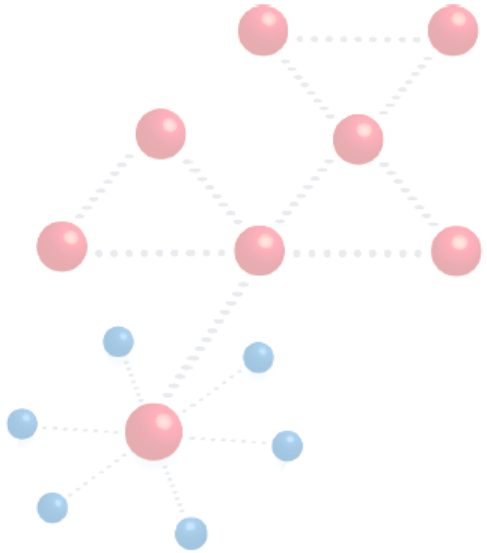
NLME-RESET.request
NLME-RESET.confirm

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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