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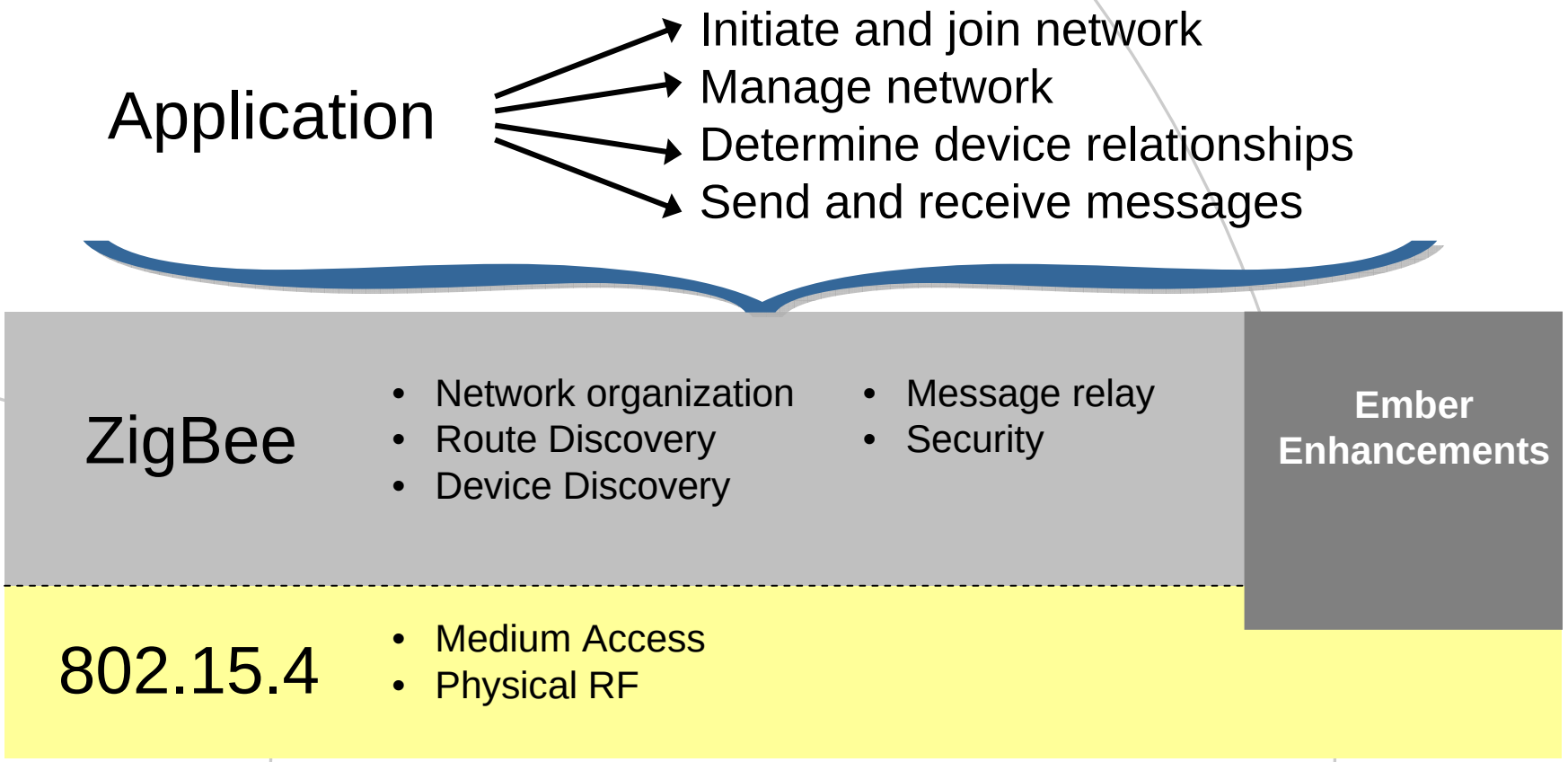
ZigBee

How it works

ZigBee PRO Feature Set

ZigBee Functional Overview



ZigBee Device Types

ZigBee Type	Notes
ZigBee Coordinator (ZC)	Exactly 1 per network
ZigBee Router (ZR)	No duty cycling available
ZigBee End Device (ZED)	Does not relay packets

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ZigBee Devices

Coordinator

- A ZigBee coordinator is responsible for forming the network.
- After forming the network it acts as a router in a Mesh stack
- Only a network coordinator can be designated as a trust centre

Routers

- Router devices provide routing services to network devices. They can also send and receive messages themselves. Unlike end devices, routers are not designed to sleep and should generally remain on as long as a network is established.

End Devices

- communicate with the network only through their parent nodes & cannot relay messages intended for other nodes.
- **Sleepy end devices** power down their radio when idle, and thus conserve resources.
- **End Devices** do not power down their radio, but do not route messages.
- **Mobile end devices** is a sleepy end device with enhanced capabilities that enable it to change its physical location and quickly switch to a new parent.

ZigBee Network Formation

Forming a Network

- The coordinator initiates network formation.
- After forming the network, the coordinator can function as a router & can accept requests from other devices wishing to join the network.
- Depending on the stack and application profile used, the coordinator might also perform additional duties after network formation.

Joining a Network

- A device finds a network by scanning channels.
- When a device finds a network with the correct stack profile that is open to joining, it can request to join that network.
- A device sends its join request to one of the network's router nodes & the device receiving the request can then use the emberTrustCenterJoinHandler() callback to accept the request or deny it.

Network Communication

- All nodes that communicate on a network transmit and receive on the same channel, or frequency. ZigBee uses a *personal area network identifier* (PAN ID) to identify a network this provides a way for two networks to exist on the same channel while still maintaining separate traffic flow

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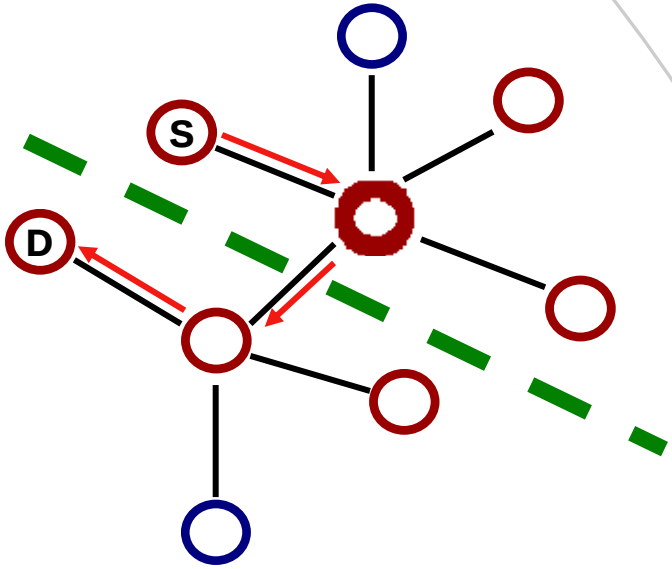
Route Discovery

Discovering routes

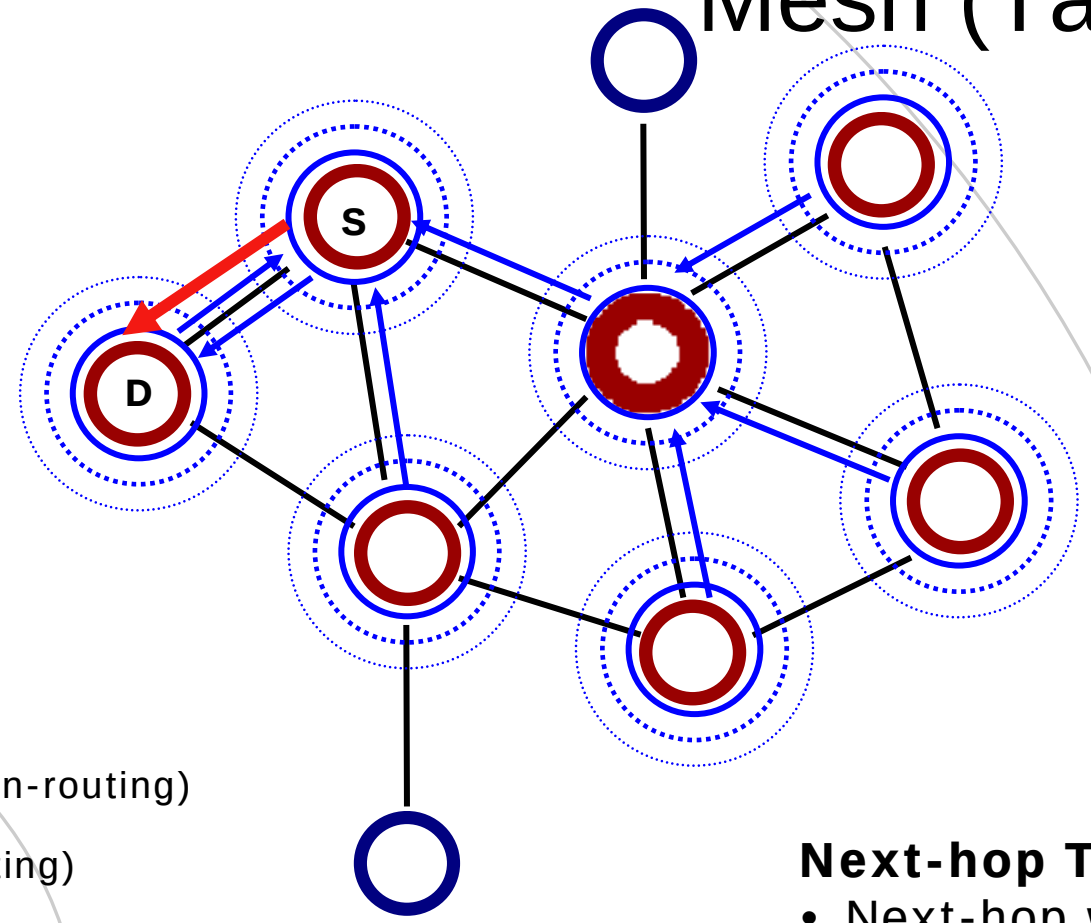
- ZigBee PRO uses on-demand route discovery
- One node sends a message to another by discovering a route. This process happens automatically
- The source node broadcasts a route-discovery message, specifying the destination node's 16-bit network address (node ID).
  - Each node that receives the broadcast relays it to all nodes within listening range. As a result, multiple copies of the broadcast message eventually reach the destination via different paths.
  - When each broadcast message reaches the destination node, the node evaluates the ‘cost’ of each message's path.
  - The destination node then sends a route reply message to notify the source node that it received the route request.

Tree-based Routing?



- ZigBee allows for a less robust form of networking based on a tree structure (not supported in EmberZNet PRO).
  - If a path is blocked, fails or is interfered with, the branch breaks and cannot be repaired.
  - A Mathematical algorithm is used to route through parent device
  - The shortest route is not always chosen

Mesh (Table) Routing



ZED (Non-routing)

ZR (Routing)

ZC (Routing and co ordinator)

Possible Route

Routing Entry

Message

Next-hop Table Routing:

- Next-hop weighted algorithm is used to route to optimal device
- Routes are discovered when unknown or failed giving a very robust network

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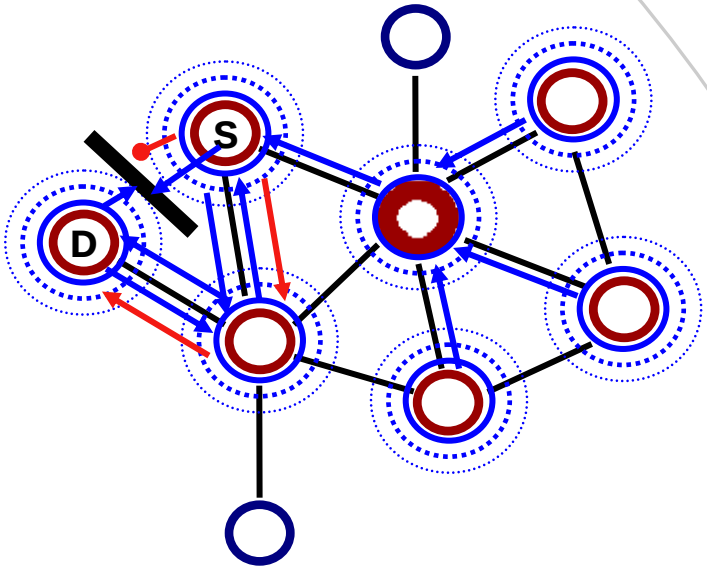


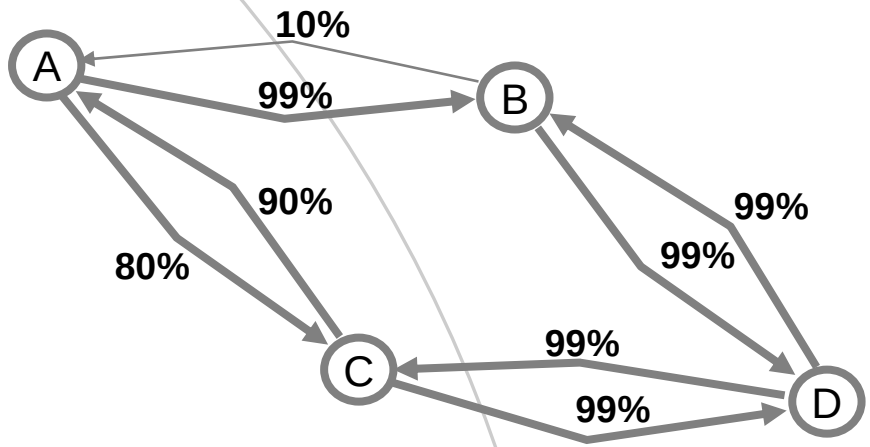
- Available in ZigBee - a self-repairing mesh network.
- ZigBee PRO enhanced mesh networking overcomes interference and link problems

ZigBee PRO Enhanced Features

- Robust Messaging: Asymmetric Links
- Large & Dense Network Support
- Mobile End Device (ZED) Support
- Security
- Scaleable Addressing Scheme

ZigBee PRO: Asymmetric Links

In real-world mesh networks, asymmetrical links are the rule, not the exception.



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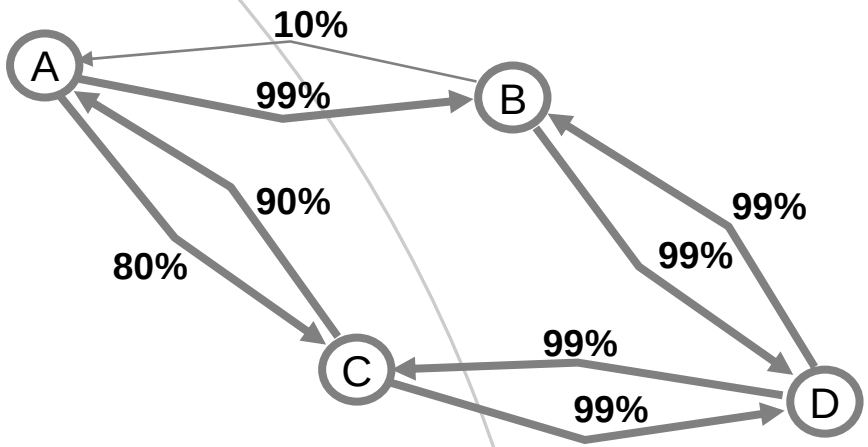

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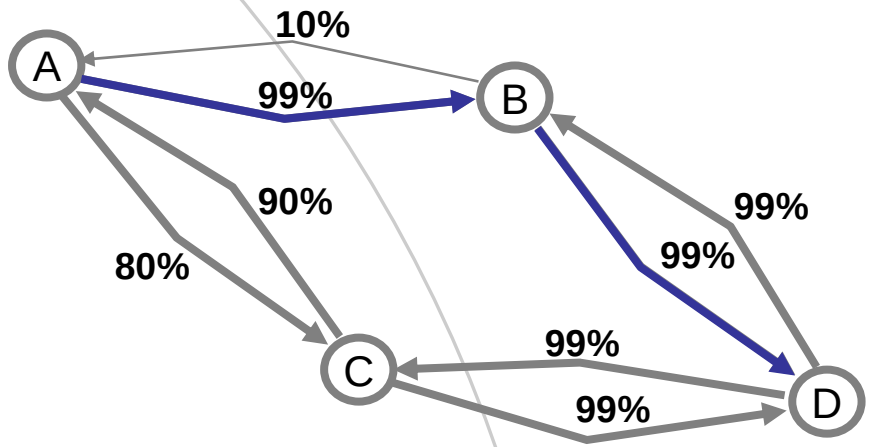

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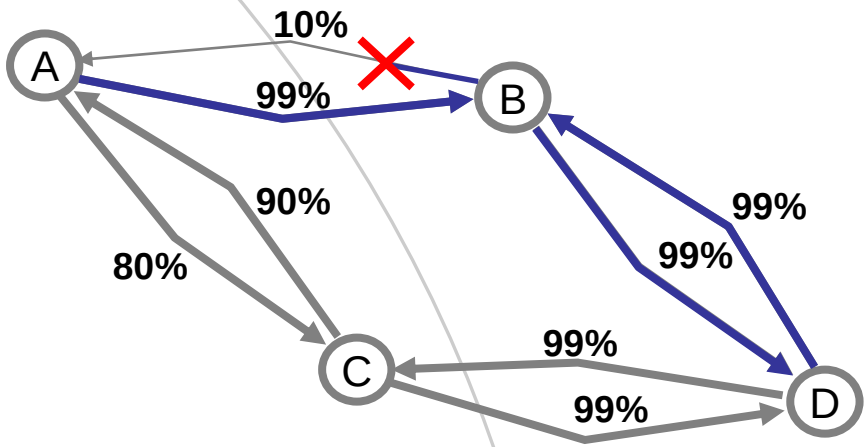

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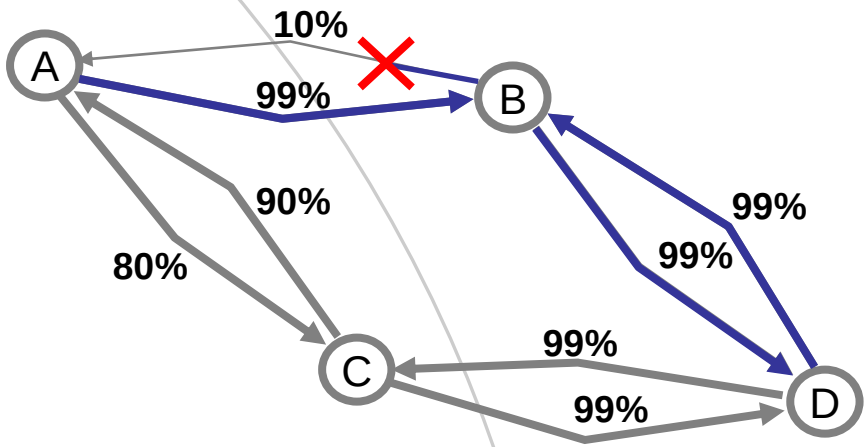

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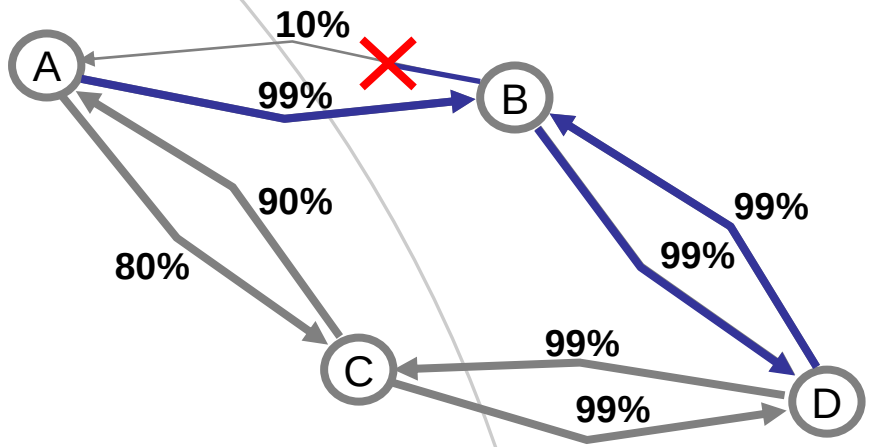

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ZigBee PRO accounts for link symmetry during route discovery to ensure the most reliable paths.

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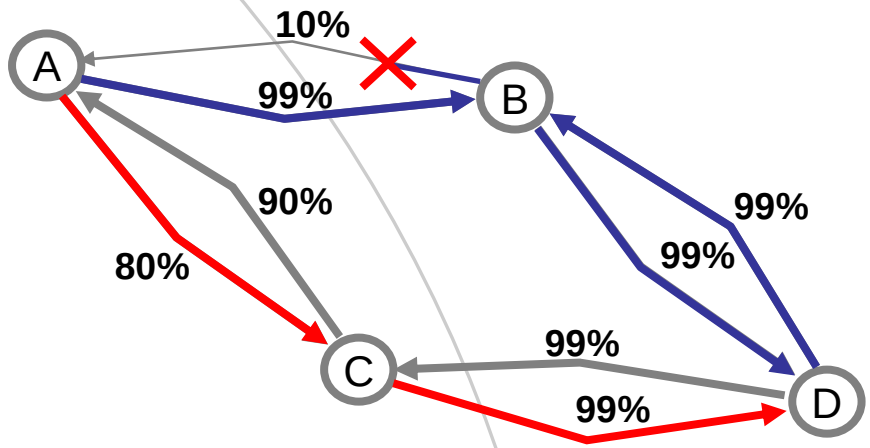

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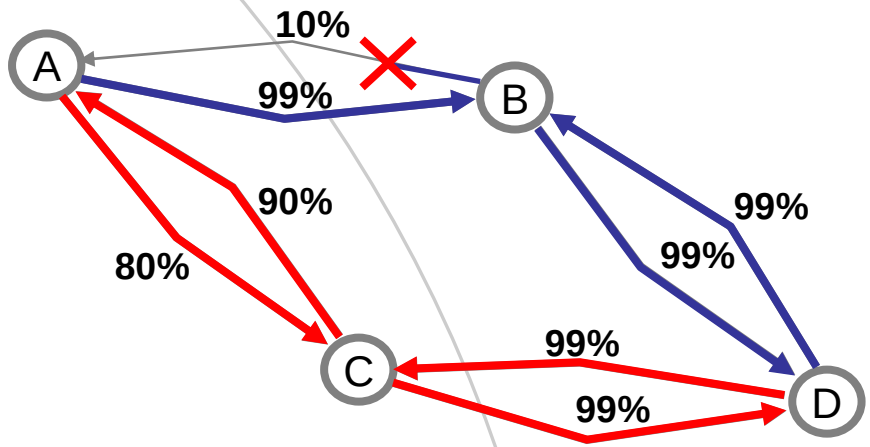


ZigBee PRO exchanges information among neighbors to discover asymmetric links.

ZigBee PRO accounts for link symmetry during route discovery to ensure the most reliable paths.

ZigBee PRO will choose A - C - D (79%)…with a good return path (89%)

ZigBee PRO Enhanced Features

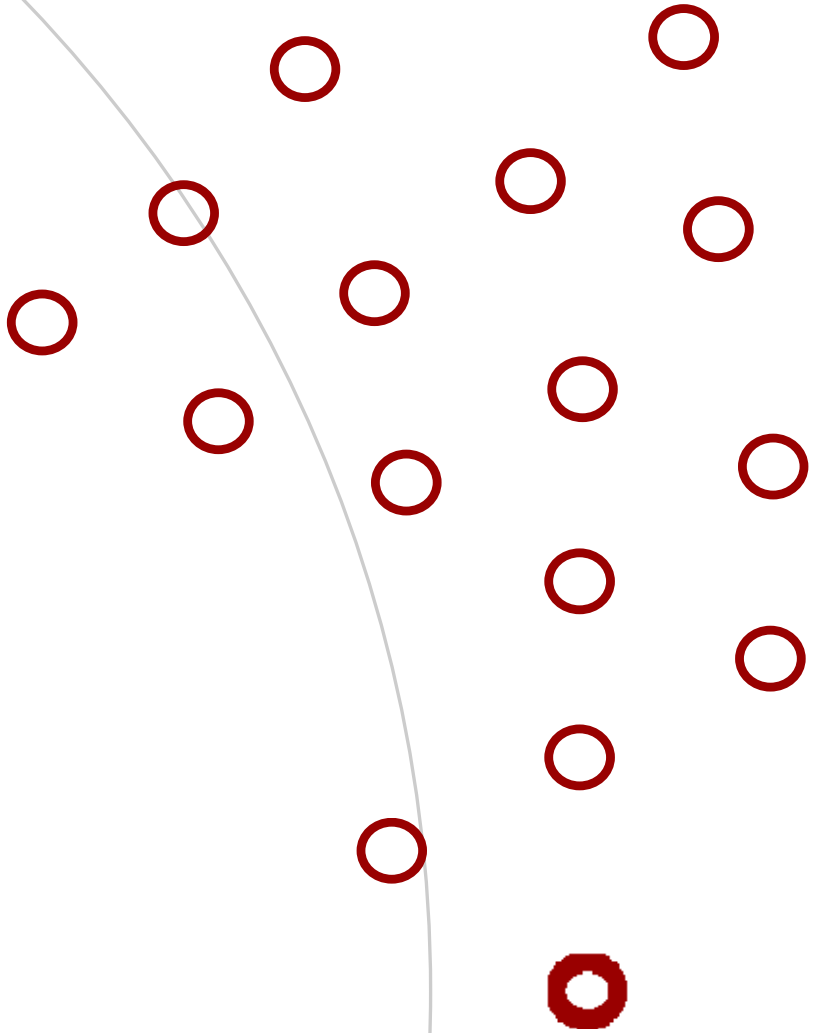
- Robust Messaging: Asymmetric Links
- Large & Dense Network Support
- Mobile End Device (ZED) Support
- Security
- Scaleable Addressing Scheme

Large Network Support

Large networks must manage bandwidth and memory.

In ZigBee (2006):

Each outlying device will broadcast separately to find a route to the gateway.



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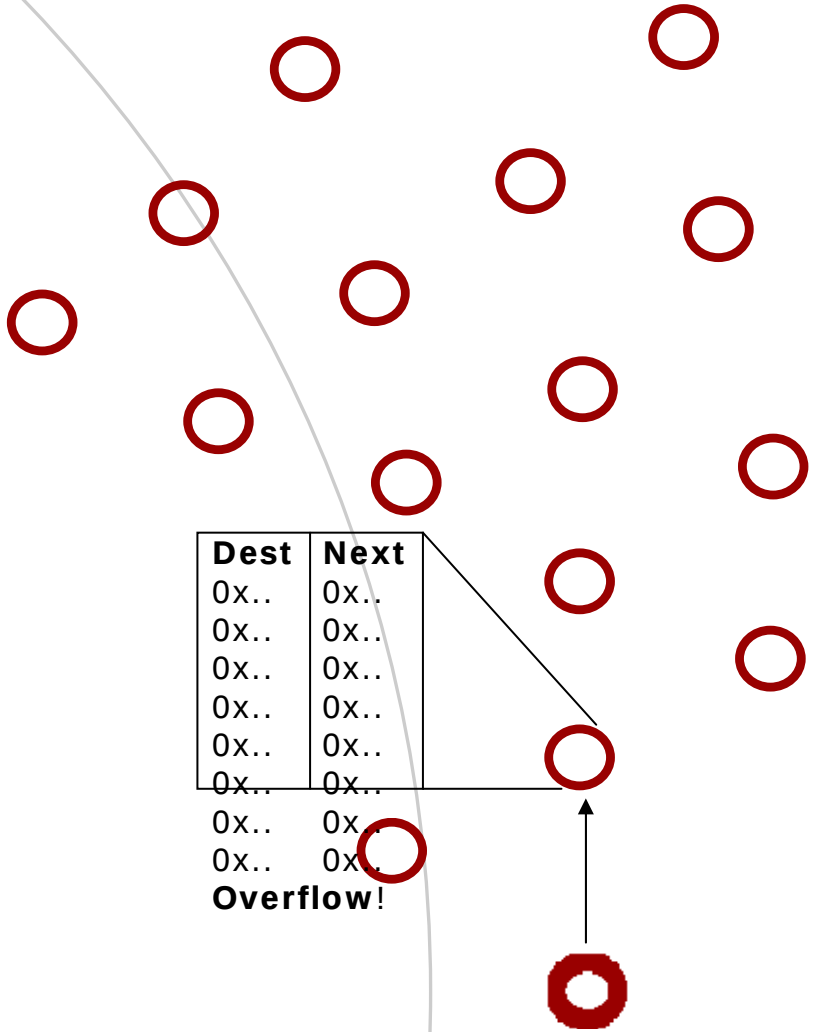

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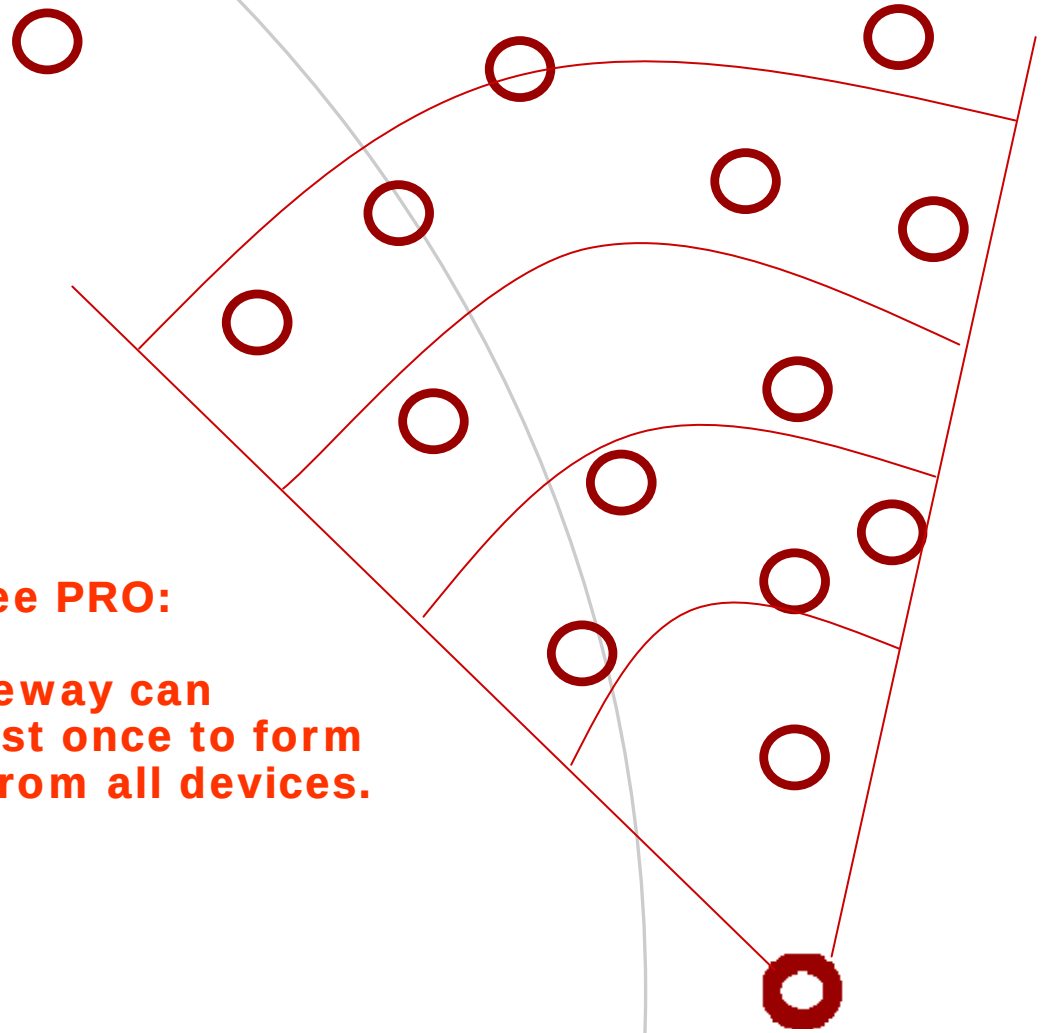
In ZigBee PRO:

The gateway can broadcast once to form routes from all devices.



Large Network Support

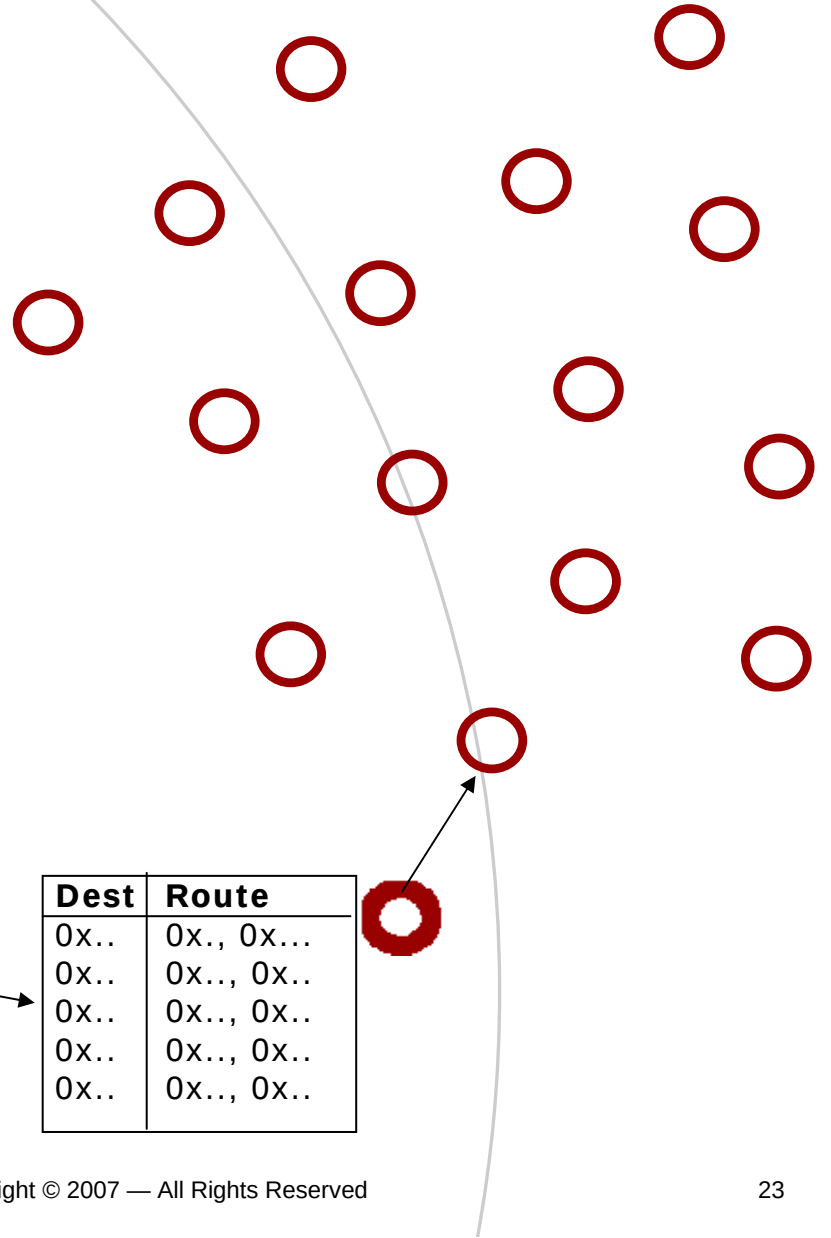
Large networks must be able manage bandwidth and memory.

In ZigBee PRO:

The gateway can broadcast once to form routes from all devices.

After the broadcast, each node sends a “route record” command to the gateway

This gives the gateway a source route for outbound messages



Dense Network Support

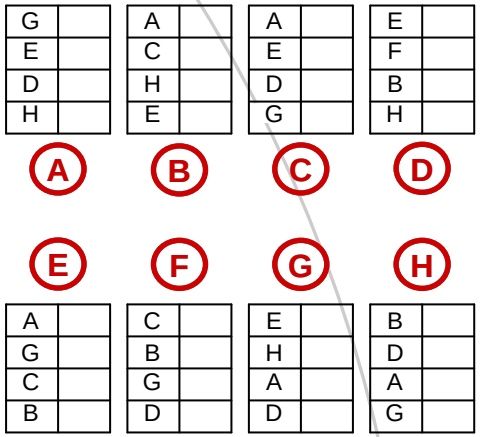
ZigBee PRO solution:

- Send neighbor table information to neighbors
- Prefer to store neighbors *not already* stored by other neighbors.

Advantages –

Avoids

- ‘churn’ in the neighbor tables, resulting in better network stability.
- network partitions.
- Too many hops to get message across dense network.



Devices exchange neighbor table information to assure greatest diversity of devices, resulting in better connectivity.

(EmberZNet PRO is tested to 32 neighbors/device).

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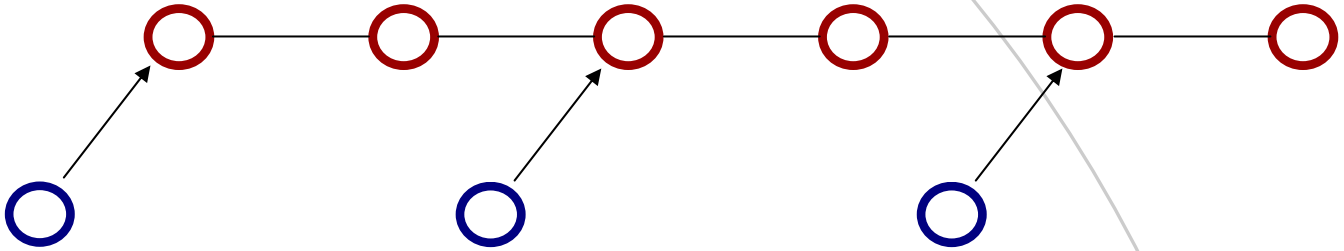
Mobile ZED Support



- Mobile device requirements:
  - Sleep as much as possible (usually battery powered)
  - Change parents quickly when necessary
  - Send/Receive messages even when parent has changed
- EmberZNet PRO optimizes this activity:
  - Fast rejoin: default 802.15.4 implementation is 0.5 secs
  - When an end device moves, packets will be automatically re-routed to the new parent in 10's of ms (depending on options)

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ZigBee Security

- ZigBee defines Security Policies:
  - None
  - Standard Security (Medium) *[EmberZNet PRO]*
    - Includes support for Residential Security (Low) *[ZigBee Stack (2006)]*
  - High Security (High) *[EmberZNet PRO]*

Policy	Joining	Network Key Updates	Link Key Updates	Encrypted Links
Standard	Link Key – unencrypted Network Key – encrypted	Broadcast, encrypted w/old network key	Unencrypted (if not pre-installed)	Router – Router Router – ZED
(Residential - included)	Unencrypted	Broadcast, encrypted w/old network key	N/A : Uses only Network Key	Router – Router Router – ZED
High	Link Key – encrypted Network Key – encrypted	Unicast, encrypted with link key	Unencrypted (if not pre-installed)	Router – Router Router - ZED

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Stochastic Addressing

- Each node gets a random address from parent
  - 2 Byte Network Address / Node ID
  - Enables fuller use of address range (65k addresses)
  - Collision detection built in
- End devices also get random address
  - Easier to move around the network
  - Easier to survive loss of parent (no rejoin required)