Tutorial 802.15.5
High-Rate Mesh WPANs

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This version has been edited for publication as PDF file at ComNets, RWTH Aachen University.

The full tutorial (including the introduction and the Low-Rate part) is available at
http://www.ieee802.org/802_tutorials/index.htm

Some animations may not be displayed correctly in PDF format. If you are interested at the ppt-format of this presentation, please contact

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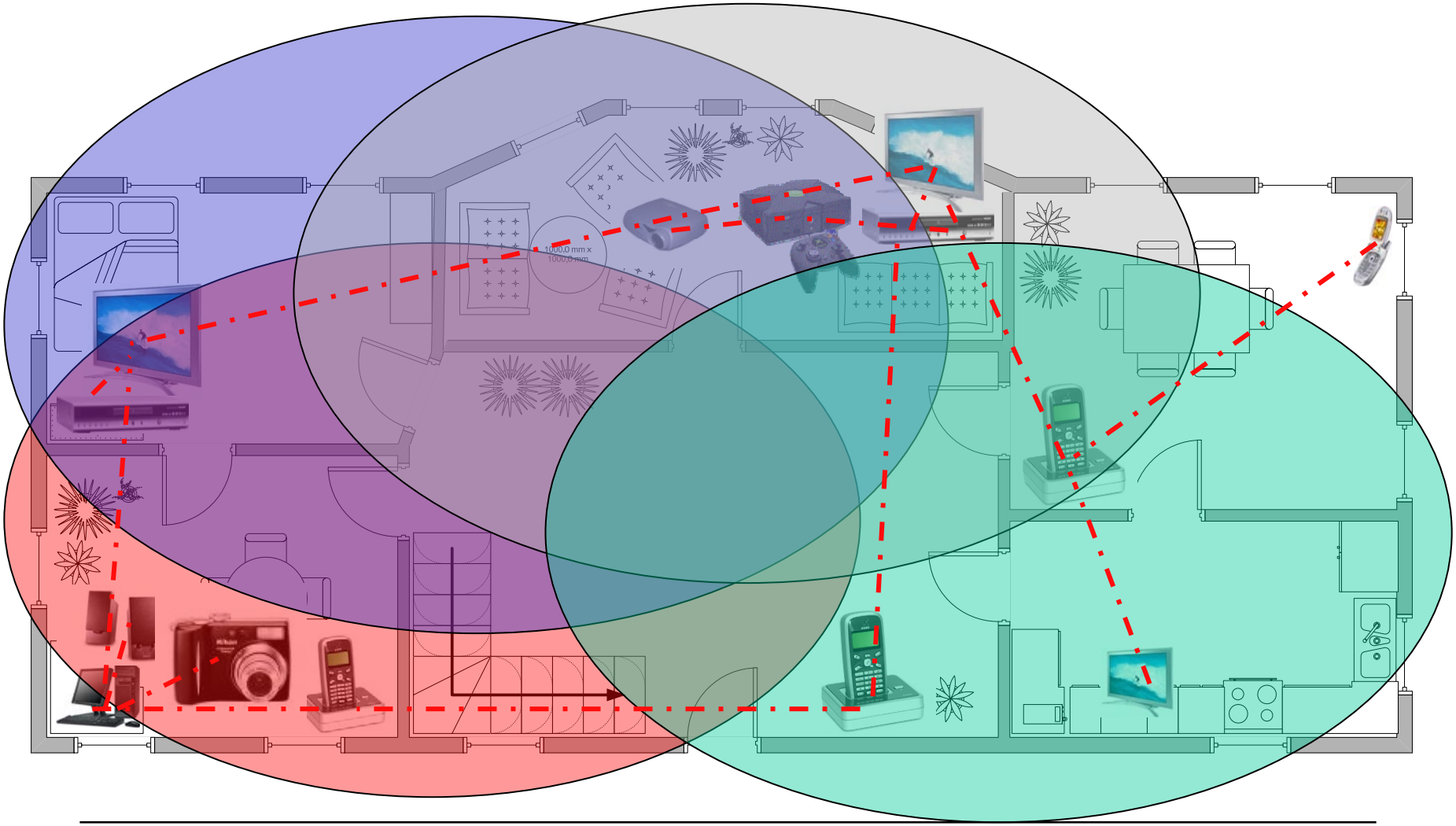
Usage Scenario HR WPAN



Usage Scenario - Analysis

- (Semi) stationary backbone
  - *Mesh Piconet Controllers (MPNCs)*

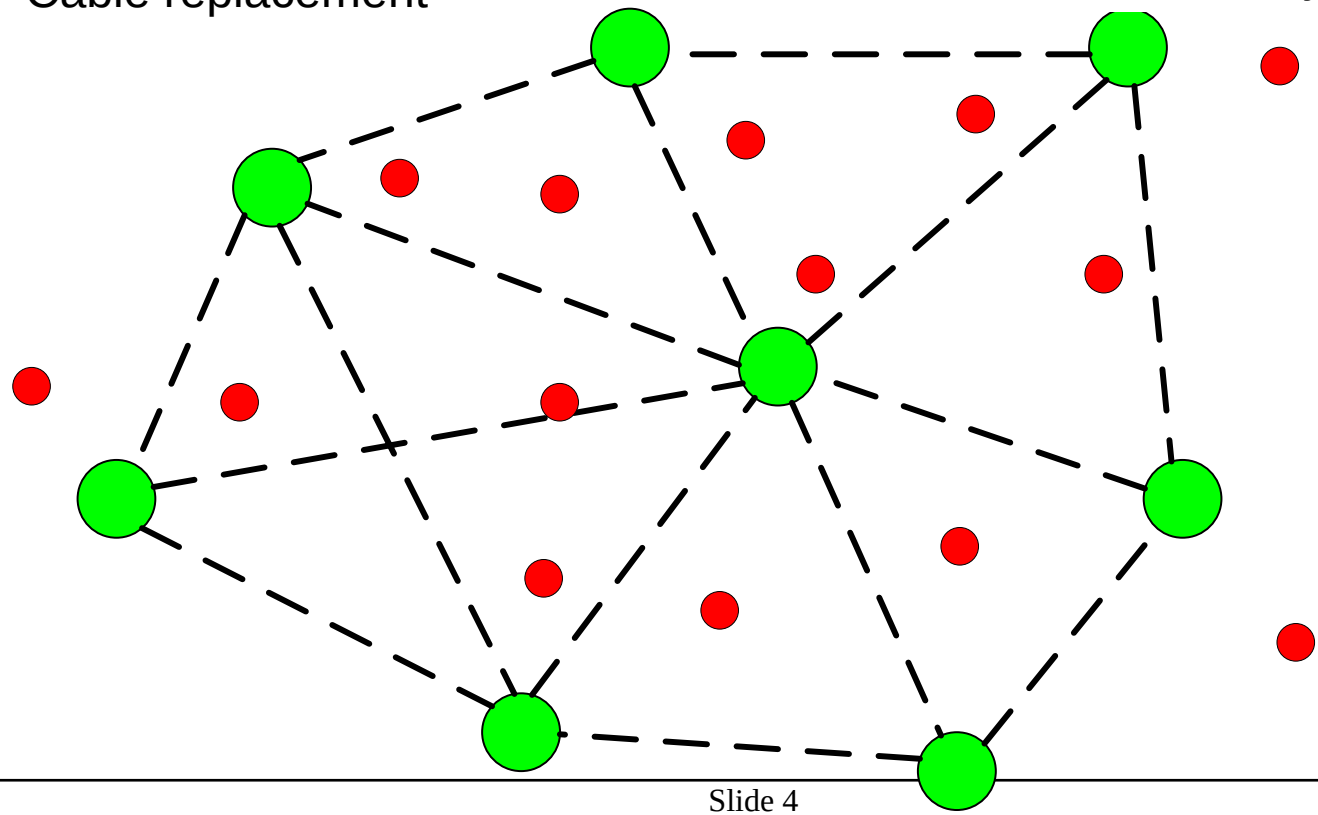
  → Convenience

  → Cable replacement

- Mobile clients
  - *Devices (DEVs)*

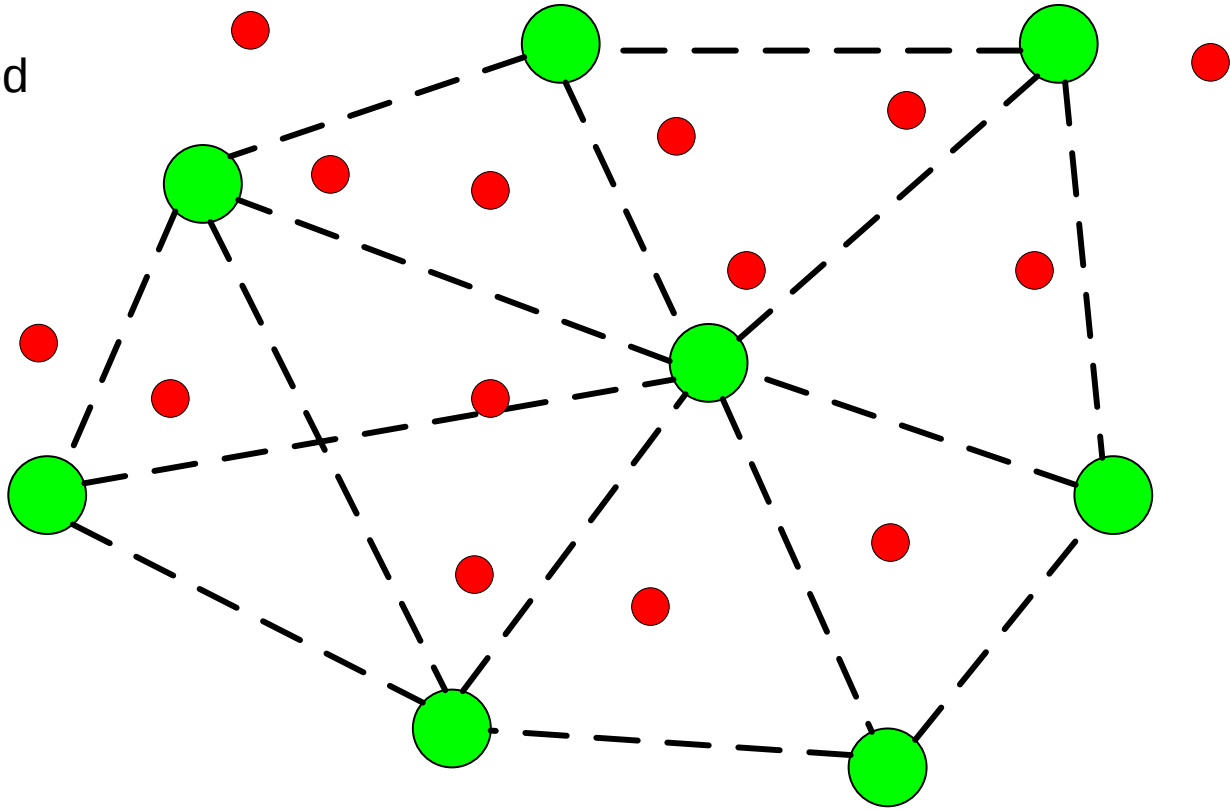
  → Coverage extension

  → Connection everywhere



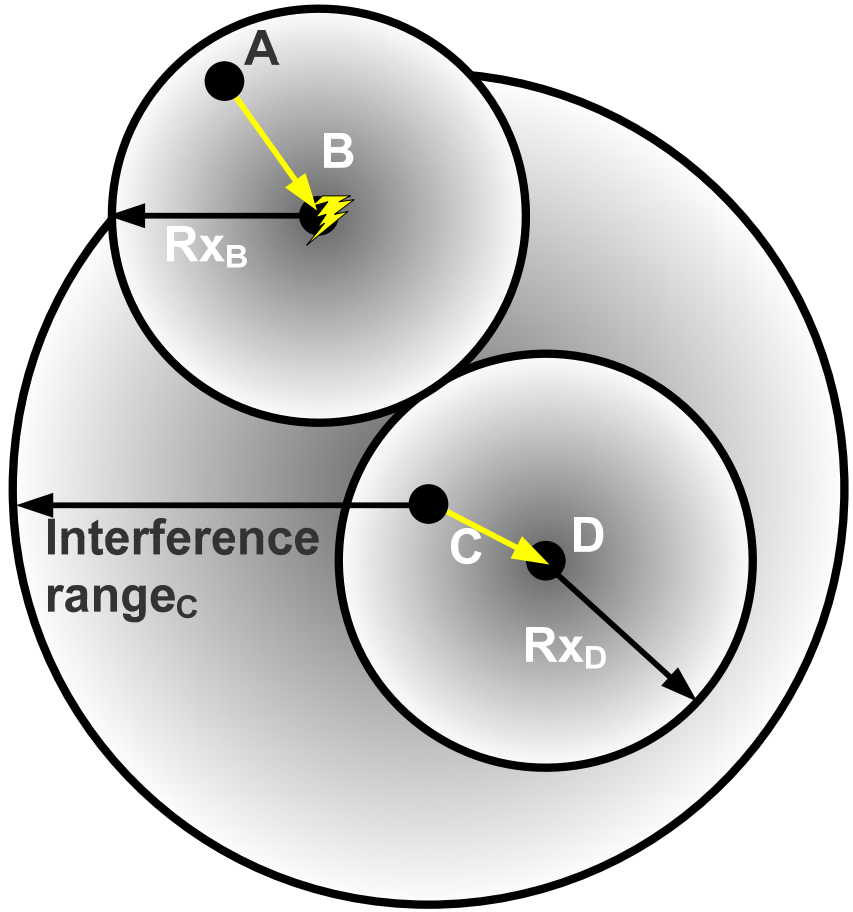
Challenges in WPAN Mesh Scenarios

- **Medium Access Control**
  - Mobility
  - Hidden and Exposed nodes
  - Interference
  - → Unnecessary capacity decrease
- **Path selection**
  - Self organizing
  - Redundant links
  - Loop prevention
  - Broadcast data
- **(Security)**
  - Ad hoc deployment
  - Access Control
  - Secure distribution of path selection info



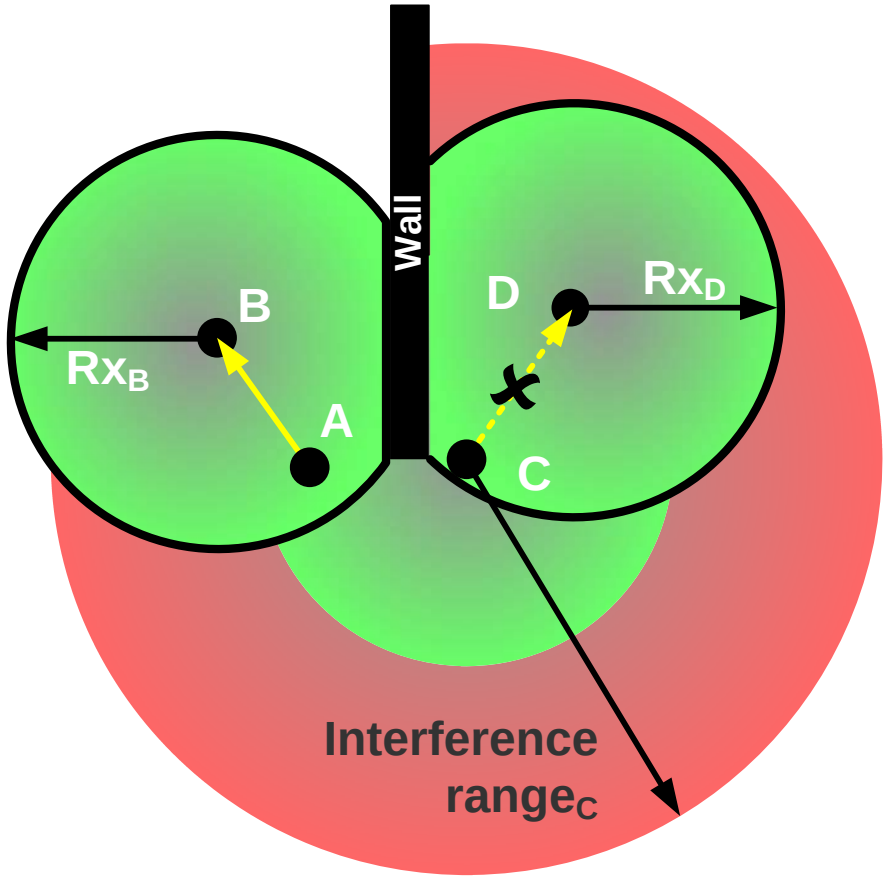
Hidden entities – Threat to WMN communication

- C cannot sense A's transmission
- C cannot sense neither A's nor B's medium reservation
- C detects wireless medium as idle
- C transmits to D
- B' reception of A is interfered by C's transmission → collision



Exposed entities – Limiting capacity of WMNs

- A sends data to B
- B & C separated by wall
  - B cannot be interfered by C
  - → Opportunity for spatial frequency reuse (concurrent transmission)
  - C could transmit to D
- C blocked by reservation from A

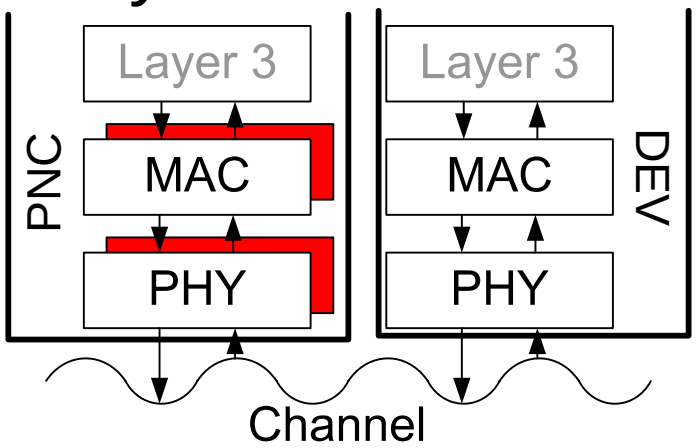


IEEE 802.15.5-HR Recommended Practice

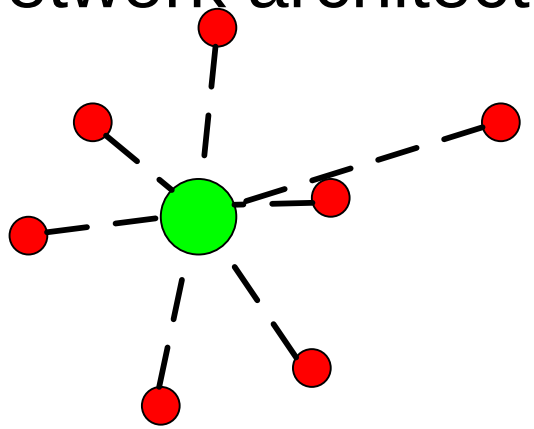
Entities, Architecture, Extensions

Single-Hop WPANs

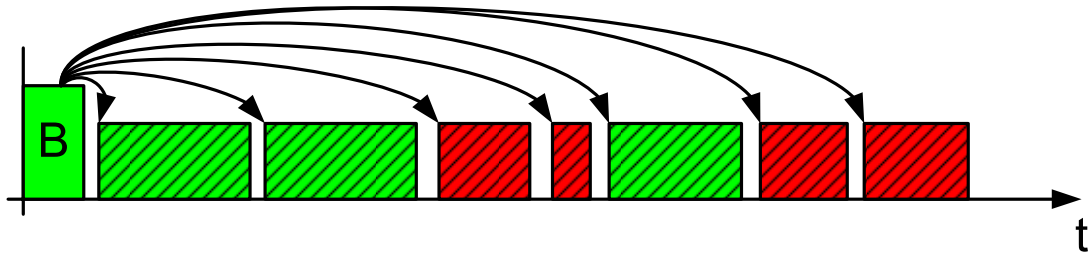
- Layer architecture



- Network architecture

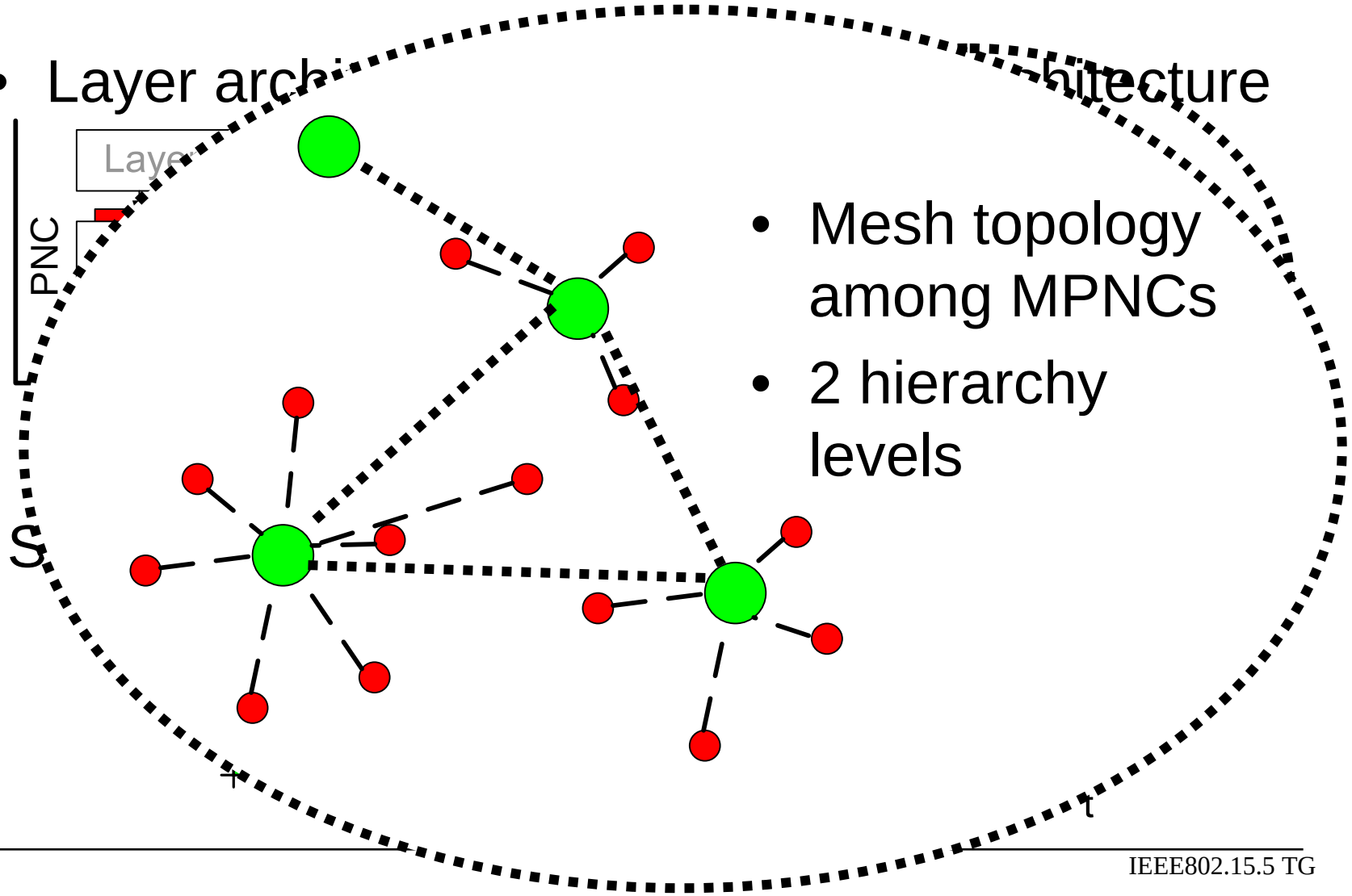


- Superframe architecture



Single-Hop WPANs

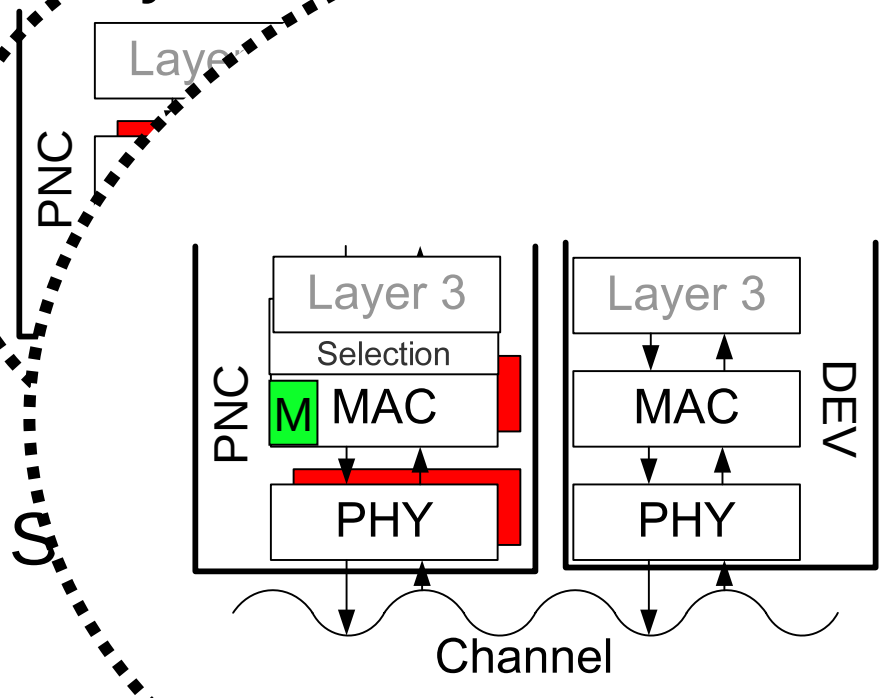
- Layer architecture
- Star



- Mesh topology among MPNCs
- 2 hierarchy levels

Mesh WPANs

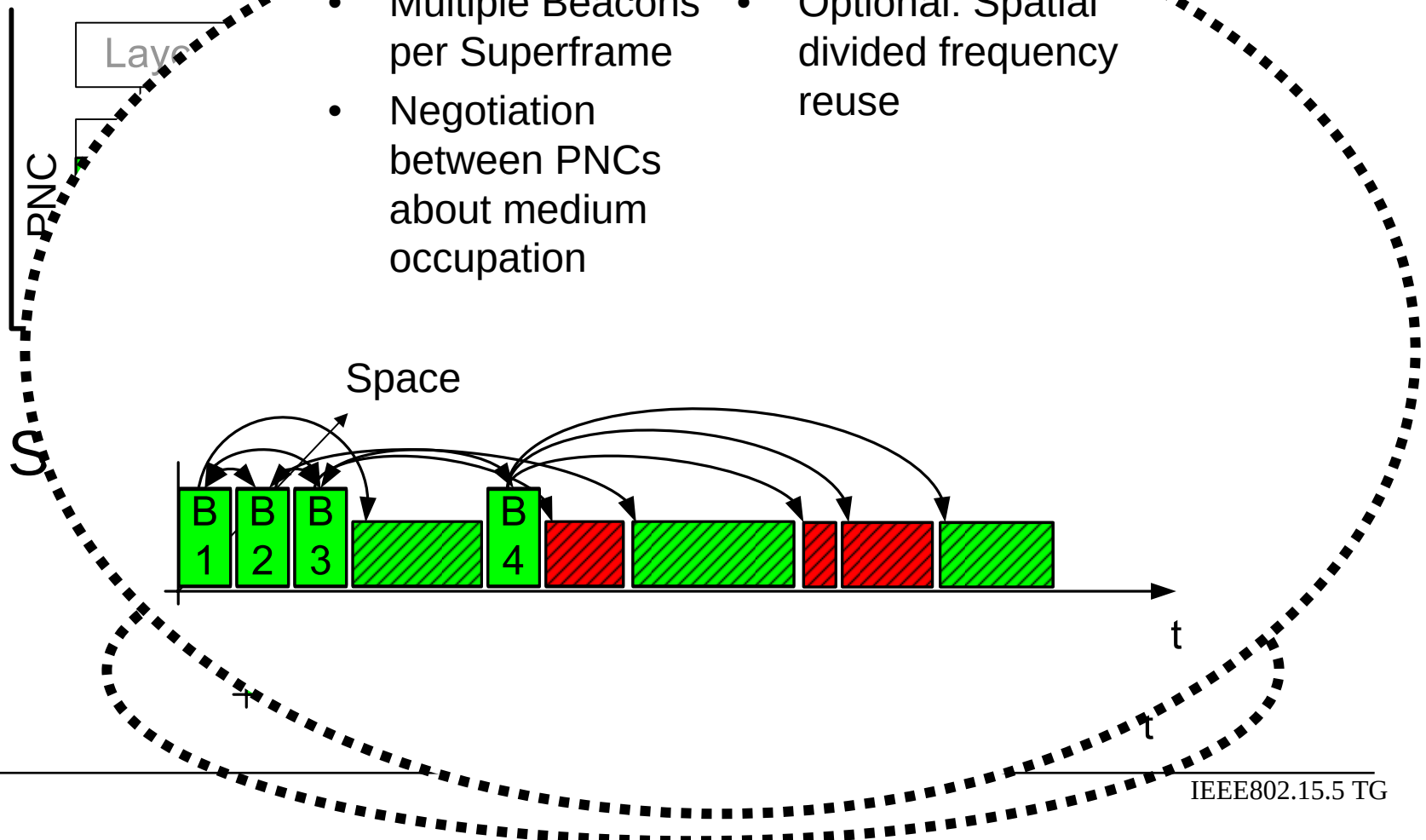
- Layer architecture
- S



- Wireless Path Selection & Mesh Services
- Extensions to the MAC
  - Multiple Beacons
  - Reservation Negotiation

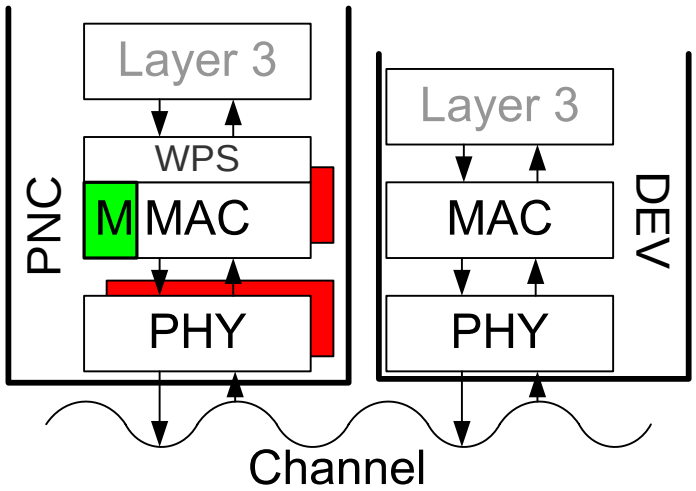
Mesh WPANs

- Layer architecture
- Superframe
  - Multiple Beacons per Superframe
  - Negotiation between PNCs about medium occupation
  - Optional: Spatial divided frequency reuse

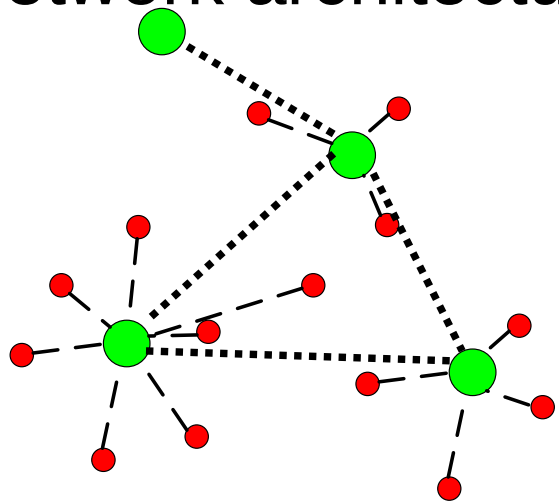


Mesh WPANs

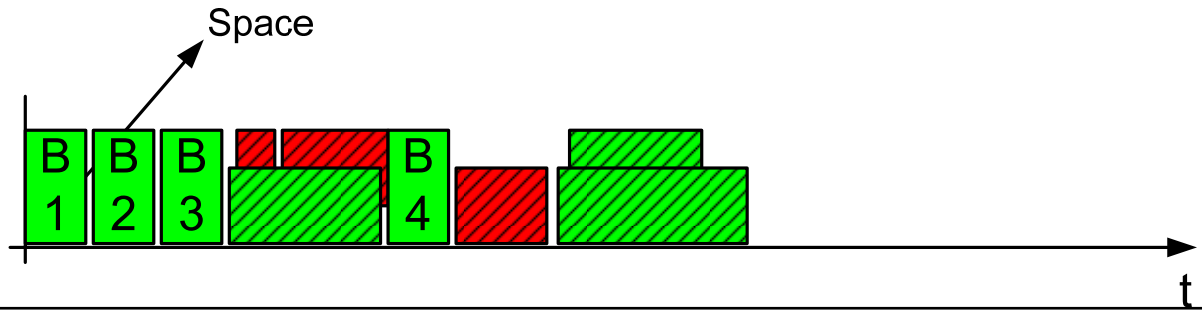
- Layer architecture



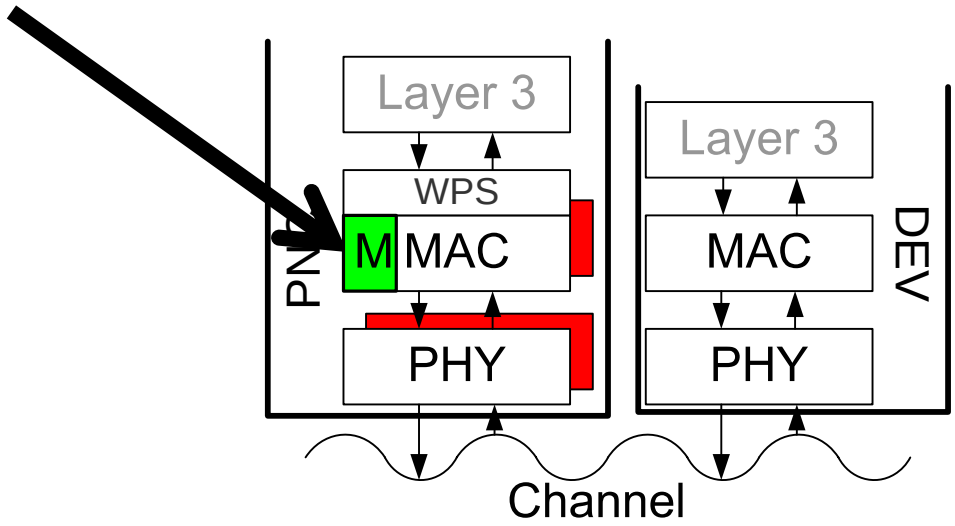
- Network architecture



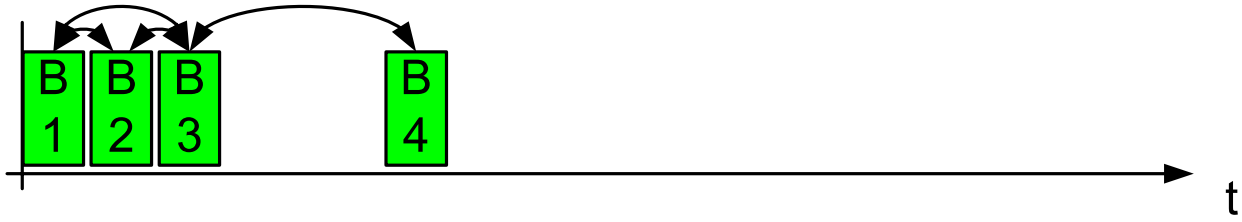
- Superframe architecture



802.15.5 Tutorial
High Rate MAC Extensions



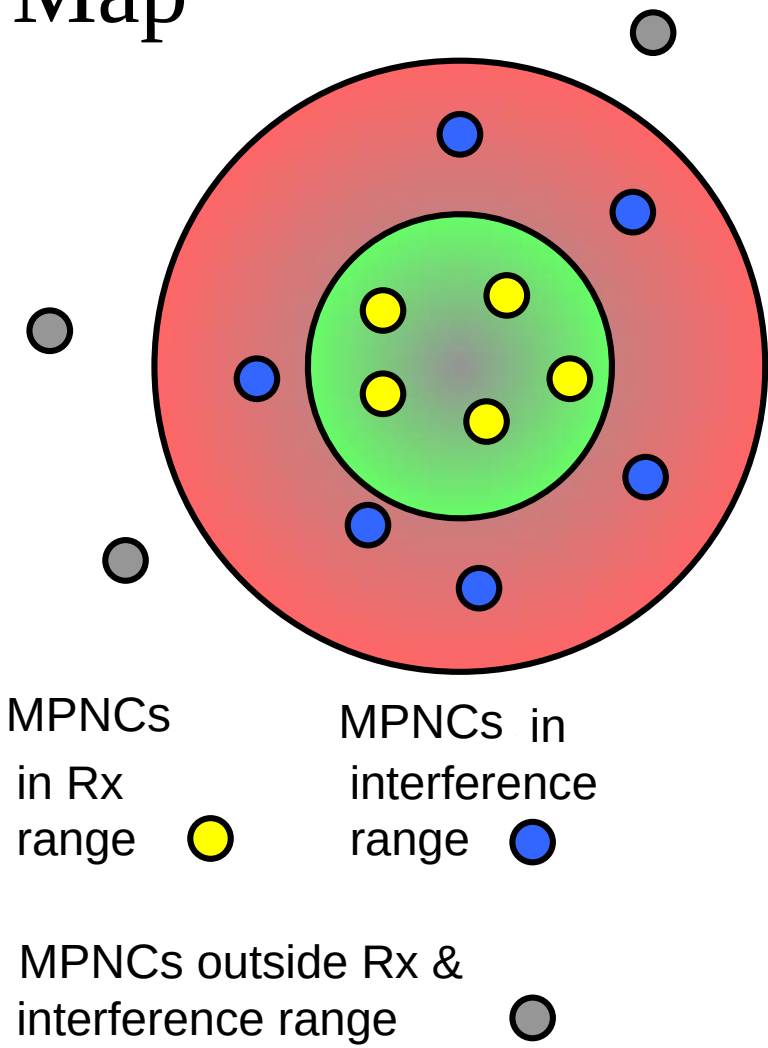
Multiple Beacons



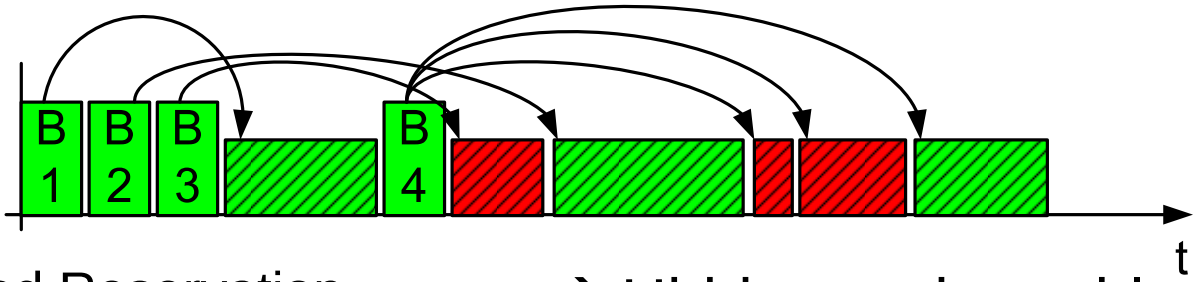
- Every Mesh Piconet Controller (MPNC) transmits beacon
- Beacon carries
  - ID
  - Synchronization information
  - Neighborhood information
  - Neighbor's neighbors
  - Medium Access Information
- New MPNC is switched on
  - Scan for beacons
  - Select idle space for beacon transmission, incorporating
    - Channel sensing
    - Information from neighbors
  - Provide local viewpoint of occupancy to neighbors
    - → Increase their knowledge
- Hidden node problem
  - Information of occupancy is disseminated over three hops

Neighborhood Map

- Beacons send at most robust PHY mode
  - Reception close to interference range
- MPNCs store neighborhood information
- → Neighborhood table



Data Transmissions



- Distributed Reservation Protocol (DRP)
  - Scheduled transmissions
  - Medium is reserved by transmitter and receiver
  - Occupation is announced in beacon
  - Neighbors are aware of transmissions
  - Support for different reservation categories
    - Broadcast
    - MPNC to DEVs
    - MPNS to MPNC

→ Hidden node problem solved by information dissemination

→ Exposed node problem remains

- Medium is blocked in large area
  - around transmitter and receiver
- Capacity degrades

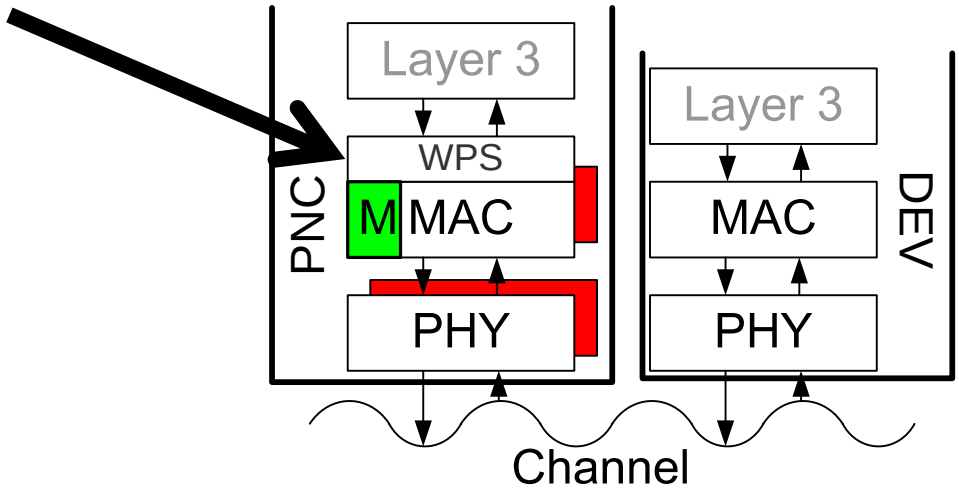
Interference Prediction

Tx Device	Rx Device
1. Search table for tx opportunity	3. Evaluate proposed time
2. Indicate proposed time to rx device in beacon	4. Search local occupancy map
7. Wait for rx respond	5. Estimated expected interference using Neighborhood map
8. Accept rx respond or decline	6. Accept or propose different time

→ Hooks to solve the exposed node problem are available

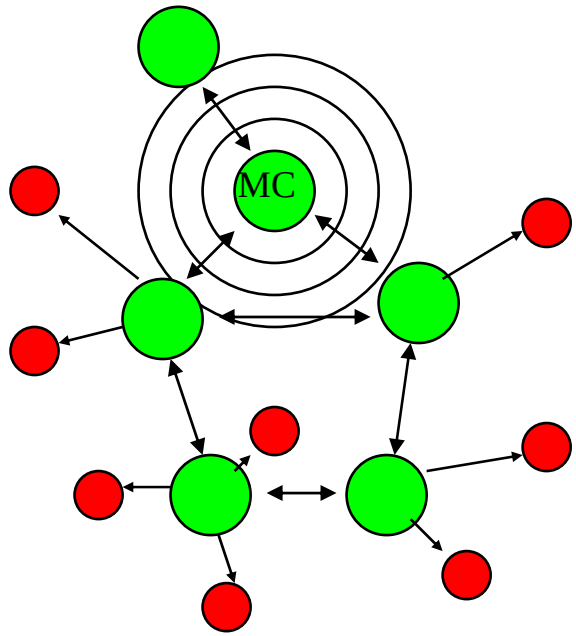
→ Capacity increase possible

802.15.5 Tutorial
High Rate Mesh Service Support



Network Setup

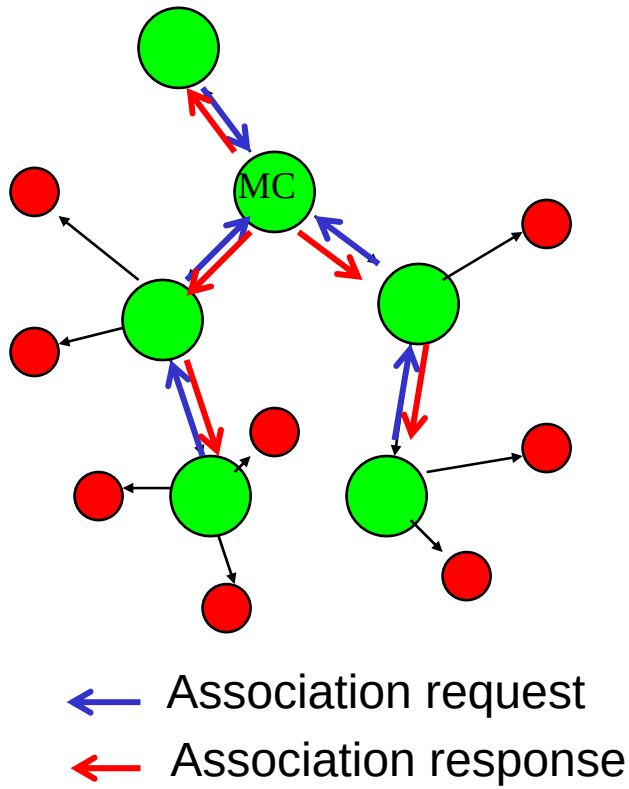
- Mesh Coordinator (MC) initializes the mesh network
  - Regularly announces mesh capability in its beacon
- New MPNCs scan for beacons
- MPNCs choose free time to send beacons



Beacon reception

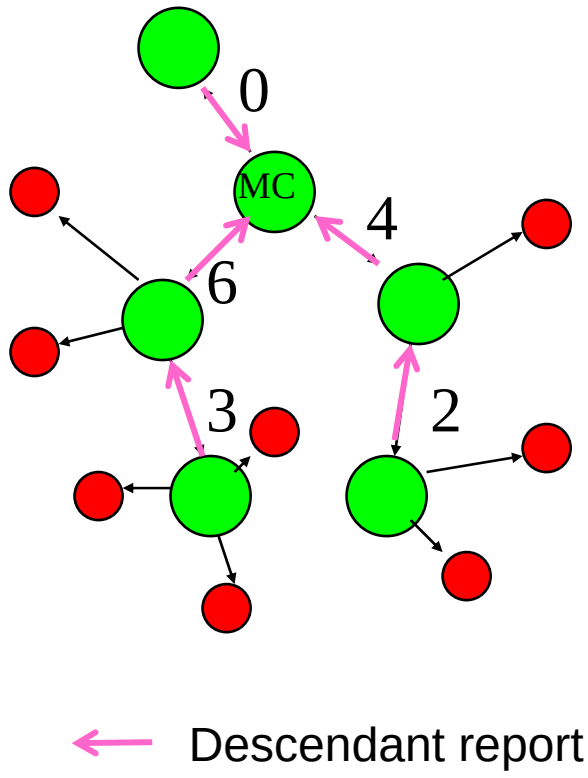
Network Setup

- Mesh Coordinator (MC) initializes the mesh network
  - Regularly announces mesh capability in its beacon
- New MPNCs scan for beacons
- MPNCs choose free time to send beacons
- MPNCs join the network by sending a tree association request
- MPNCs / MC repsonds with a tree association response
- → Tree structure based on local knowledge
  - One parent (None for MC)
  - Children (Zero to max. children)



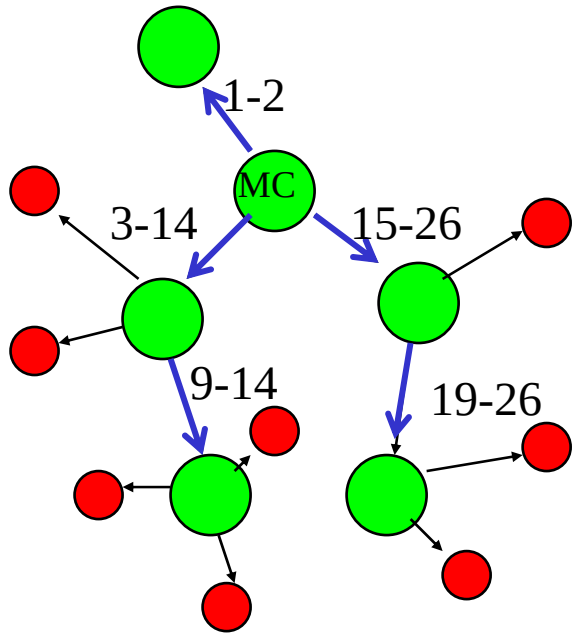
Tree Topology Discovery

- Each Mesh Piconet Controller (MPNC) belonging to the tree
  - Waits for descendant report(s) from its children
  - Estimates the number of own descendants
  - Reports number of descendants to parent
- Process is repeated upon
  - Topology discovery request from MC
  - Association of new descendants



ID Assignment

- After receiving topology update frames from all children:
  - MC reserves a block of IDs
  - Assigns intervals of IDs to children
    - Size of interval is proportional to reported number of children
- MPNC receives an ID block
  - Division and assignment is repeated for children



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  - MC reserves a block of IDs
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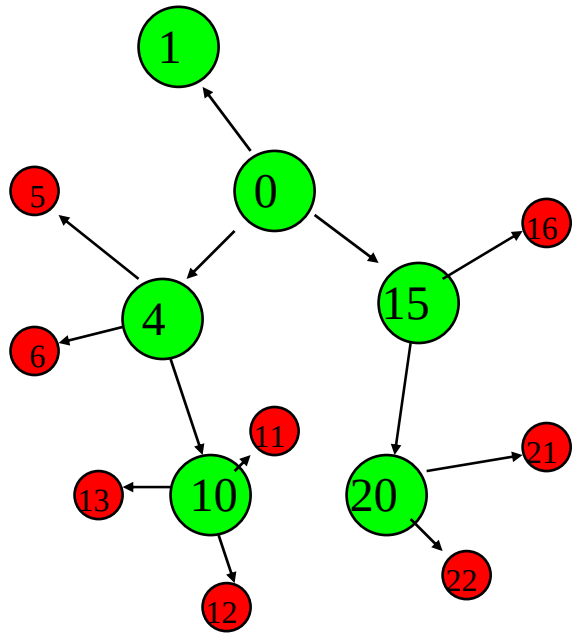
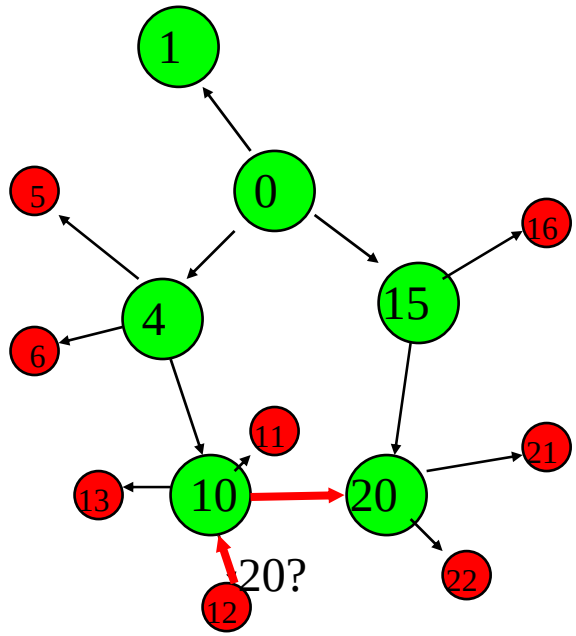
- MPNC receives an ID block
  - Division and assignment is repeated for children
- MPNC assigns ID to himself and its DEVs



Neighborhood-based Wireless Path Selection

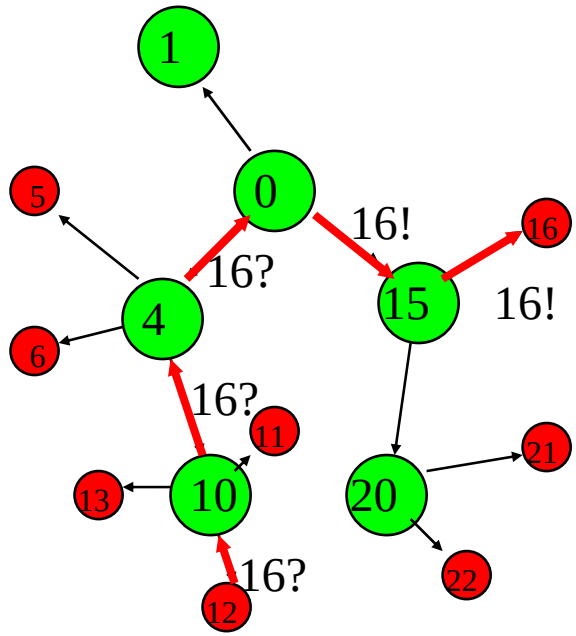
- Each MPNC keeps Neighborhood Map
  - Result from beaconing
  - Consists of neighbors and neighbors' neighbors
- Routing in 2-hop neighborhood is trivial



← Data Transmission

Tree-based Wireless Path Selection

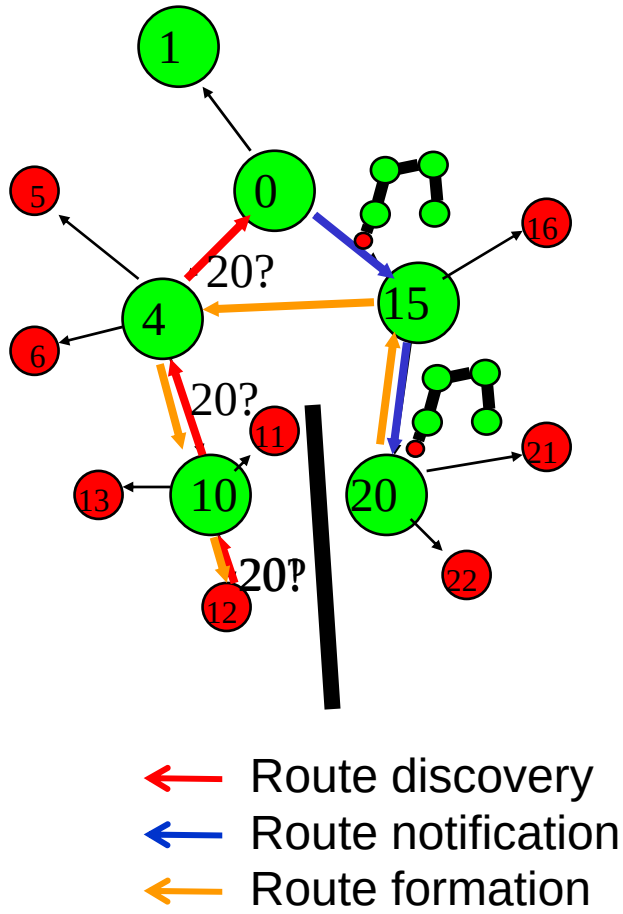
- DEV sends to MPNC
- MPNC
  - Destination in ID block?
    - NO: Forward to parent
    - YES: Deliver to DEV or appropriate child



← Data Transmission

Centralized Wireless Path Selection

- One or more MPNCs act as topology server
  - MPNCs register link states
- Centralized WPS
  - MPNC 0 is topology server
  - Route discovery via Tree-based WPS
  - Calculation of route at topology server
  - Route notification via Tree-based WPS
  - Route formation



Conclusion

- Architecture for High-Rate Mesh WPANs
  - Based on Single-Hop MAC & PHY
  - Extensions for MAC
    - Multiple Beacon operation
    - Distributed Reservations
    - Optional frequency reuse to increase the capacity
  - Mesh Service Support
    - ID assignment
    - Wireless Path Selection
      - Neighborhood
      - Tree
      - Centralized