Resource management and QoS in IEEE 802.16d/e and 802.16j networks

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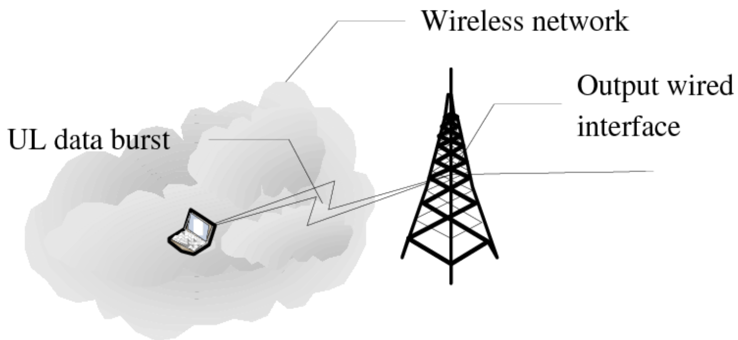
Outline

- Short introduction
- Resource management in 802.16d/e
    - Frame structure
    - QoS model
    - Scheduling algorithms
- Resource management in multi-hop 802.16j
- Power management in 802.16e networks

Scheduling in IEEE 802.16d/e

Scheduling points

- 802.16 network
  - Responsibility of the BS scheduler
  - Resource allocation in the UL and DL directions
- BS output wired interface
  - Usually, no special actions are required
  - The BS output wired interface should not be a bottleneck
  - FCFS suffices
- Station radio interface
  - Responsibility of the SS uplink scheduler
  - Resource allocation for local UL transport connections



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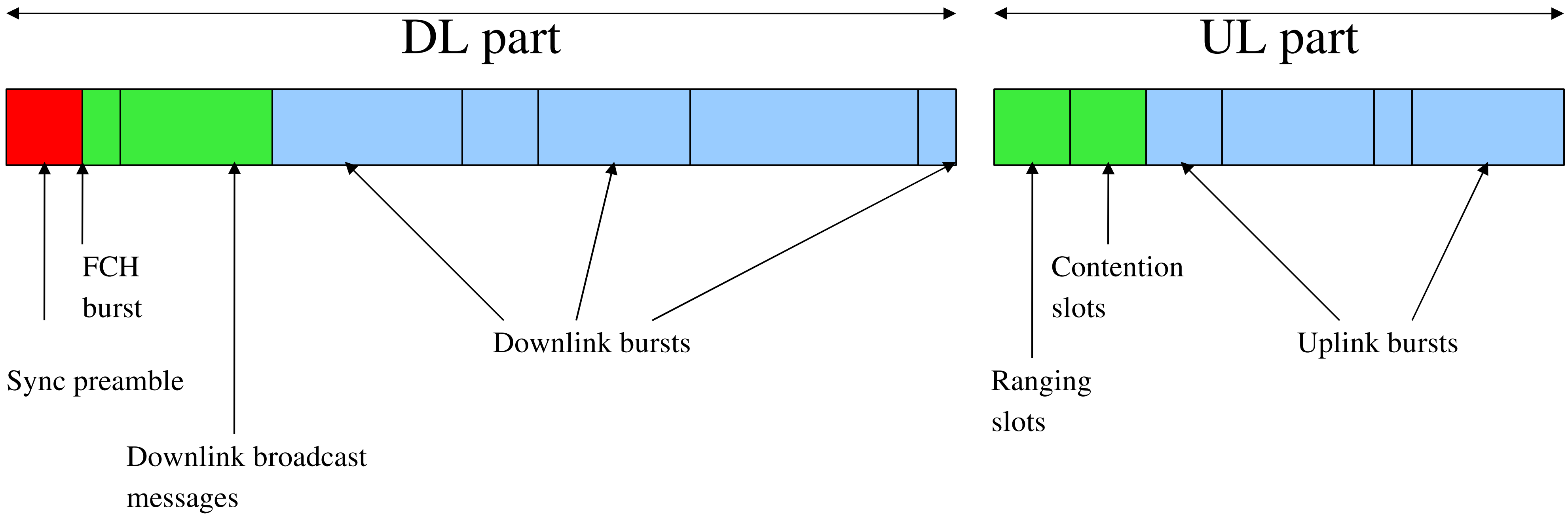
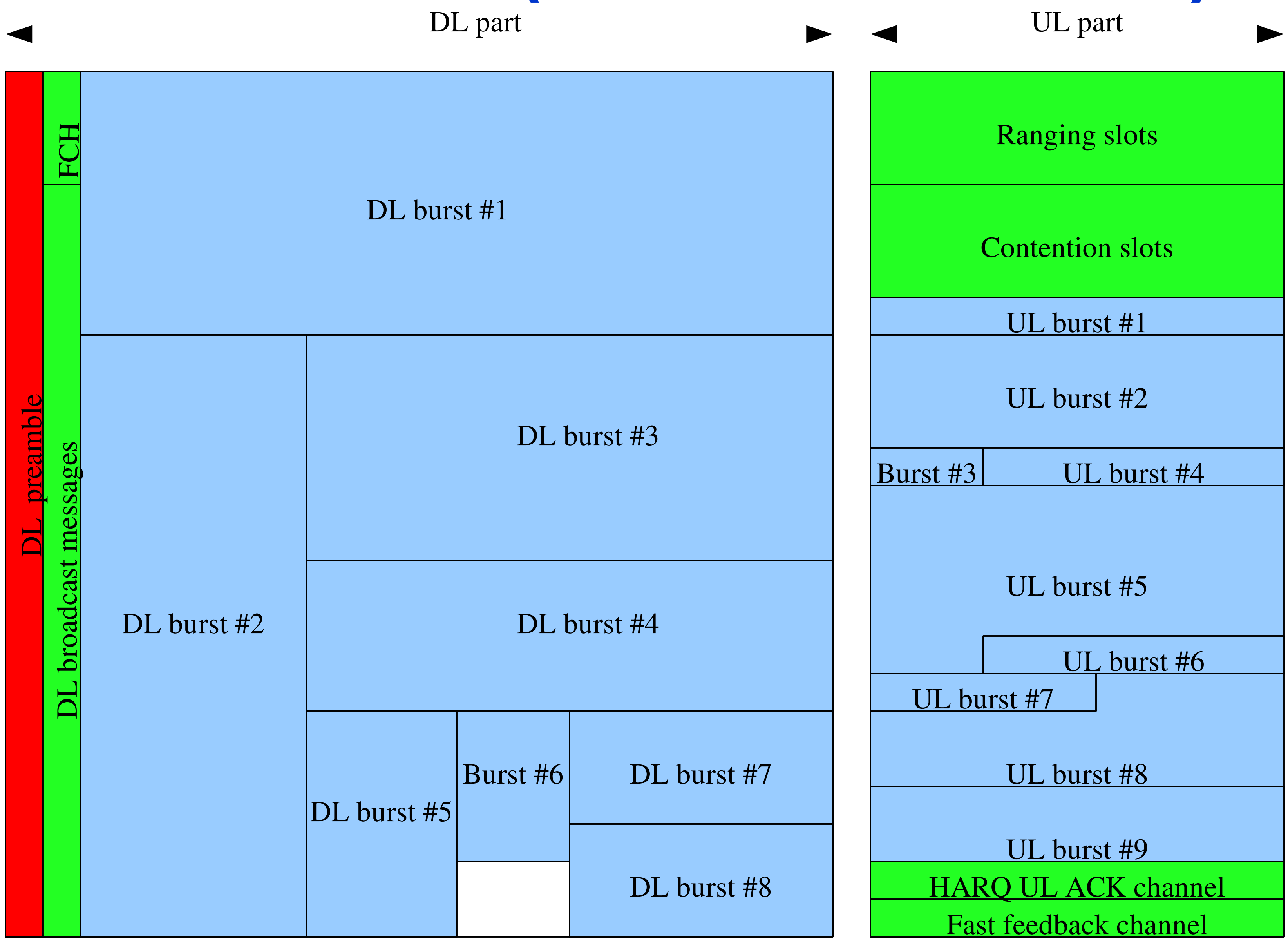
Frame structure (IEEE 802.16 OFDM)

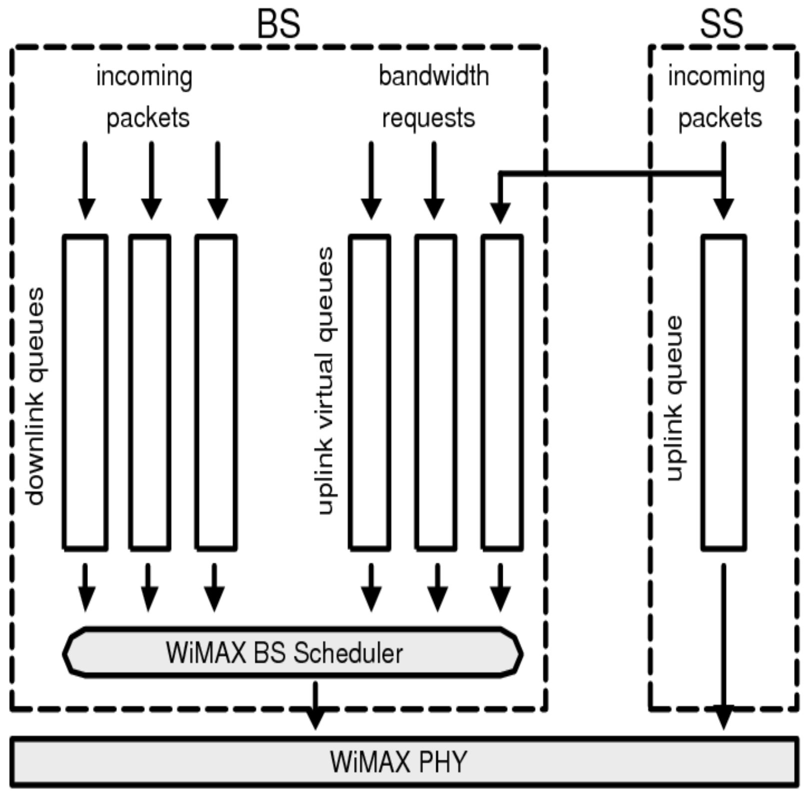


Frame structure (IEEE 802.16 OFDMa)



QoS model

- The BS allocates physical queues for downlink connections
- The BS keeps uplink virtual queues that are updated by the bandwidth requests
- The BS scheduler allocates resources, UL and DL, based on the queue sizes and QoS requirements
    - The scheduler can serve both UL and DL directions
    - There could be separate UL and DL schedulers



- It is possible to apply AQM to the BS DL queues and SS UL queues

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QoS classes (IEEE 802.16)

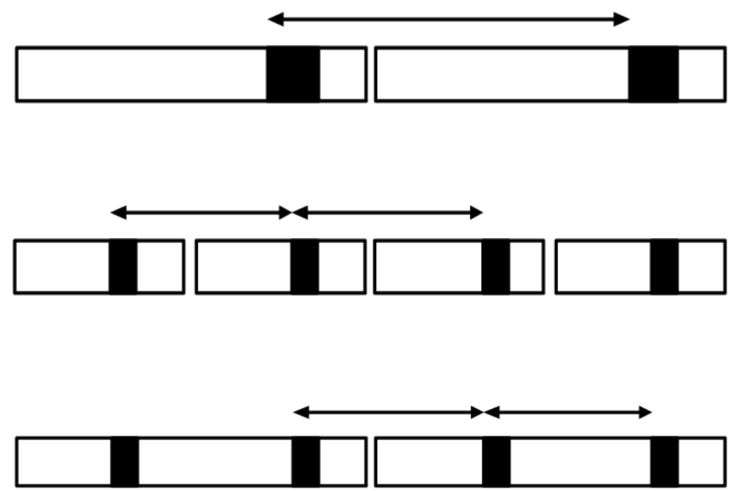
QoS parameter	UGS	ErtPS	RtPS	NrtPS	BE
Min BW	X	X	X	X	
Max BW		X	X	X	X
Latency	X	X	X		
Jitter		X			
Grant interval	X	X			
Polling interval		X	X		
Traffic priority		X	X	X	X
BW requests		X	X	X	X
Contention		X		X	X
Purpose	VoIP	VoIP	Video	Web/FTP	

802.16 scheduling

- Several BWA facts:
    - Fixed frame duration
    - Fixed, integer number of slots per frame
    - Fixed duration of one slot
- Scheduling algorithms
    - Similar to ATM, it is possible to base “conceptually” resource allocation on the round-robin schedulers
        - We have to allocate an integer number of slots -> similar to the weight value
        - Number of slots is determined by the QoS requirements and queue sizes
        - BE connections are served by the DRR-like scheduler
    - Fair-queuing is feasible, but is too complicated
    - Deadline-based schedulers cannot be applied to uplink
- Other scheduling ideas:
    - Proportional fair queuing
        - Picks up a connection with the best MCS
        - For the BE connections to achieve a better spectral efficiency
        - Is not a good solution for the QoS connections

802.16 scheduling steps

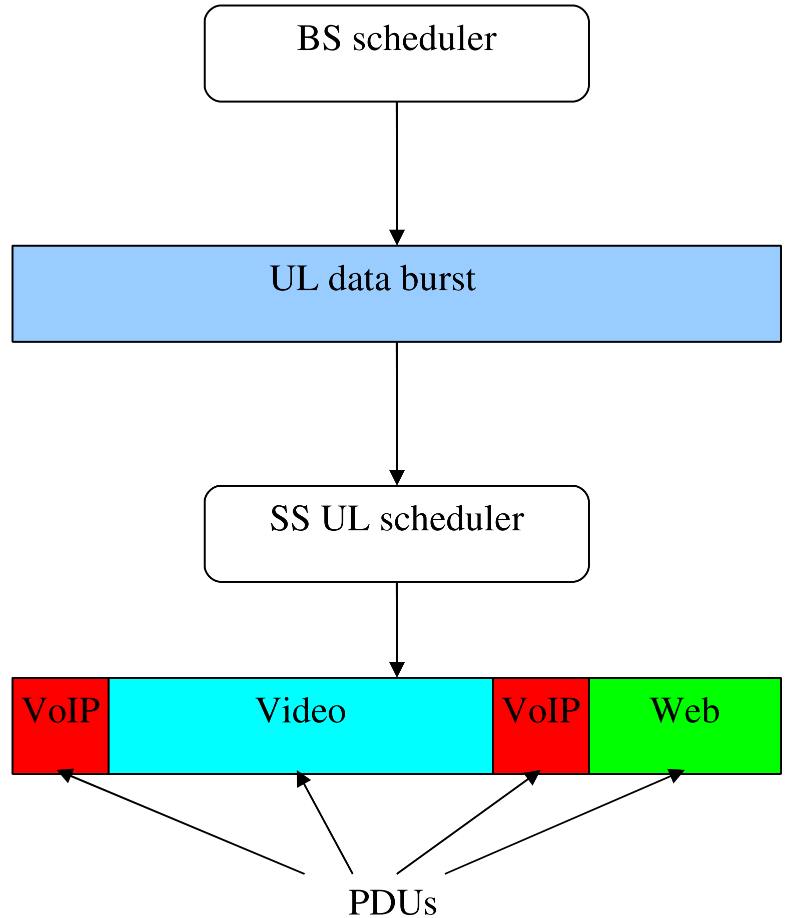
- Reserve slots for connections
  - Account for the QoS requirements, queue sizes, and MCS
  - Calculate the number of slots to assign
- Split allocated slots between data bursts
  - Is one data burst enough?
  - For large frame durations, several data bursts might be necessary
  - It is possible to decouple delay provisioning from the bandwidth provisioning
  - Usually, frame duration is 5ms, one burst suffices
- Allocate unused slots
  - BWA systems are non-work-conserving by nature
  - If there are unused slots, they might be allocated for other purposes:
    - BE connections
    - Polling



SS uplink scheduler

- Grant per connection
  - The BS scheduler allocates explicitly resources to each uplink connection
  - The complexity is pushed to BS
  - Larger MAP overhead
  - No need to do any scheduling at SS
  - Slot granularity
- Grant per station
  - The BS scheduler allocates uplink resources to a whole SS
  - The complexity is pushed to SS
  - Less MAP overhead
  - An SS has to run an uplink scheduler algorithm
  - Byte granularity

Example of the grant per station mode



SS uplink scheduler algorithms

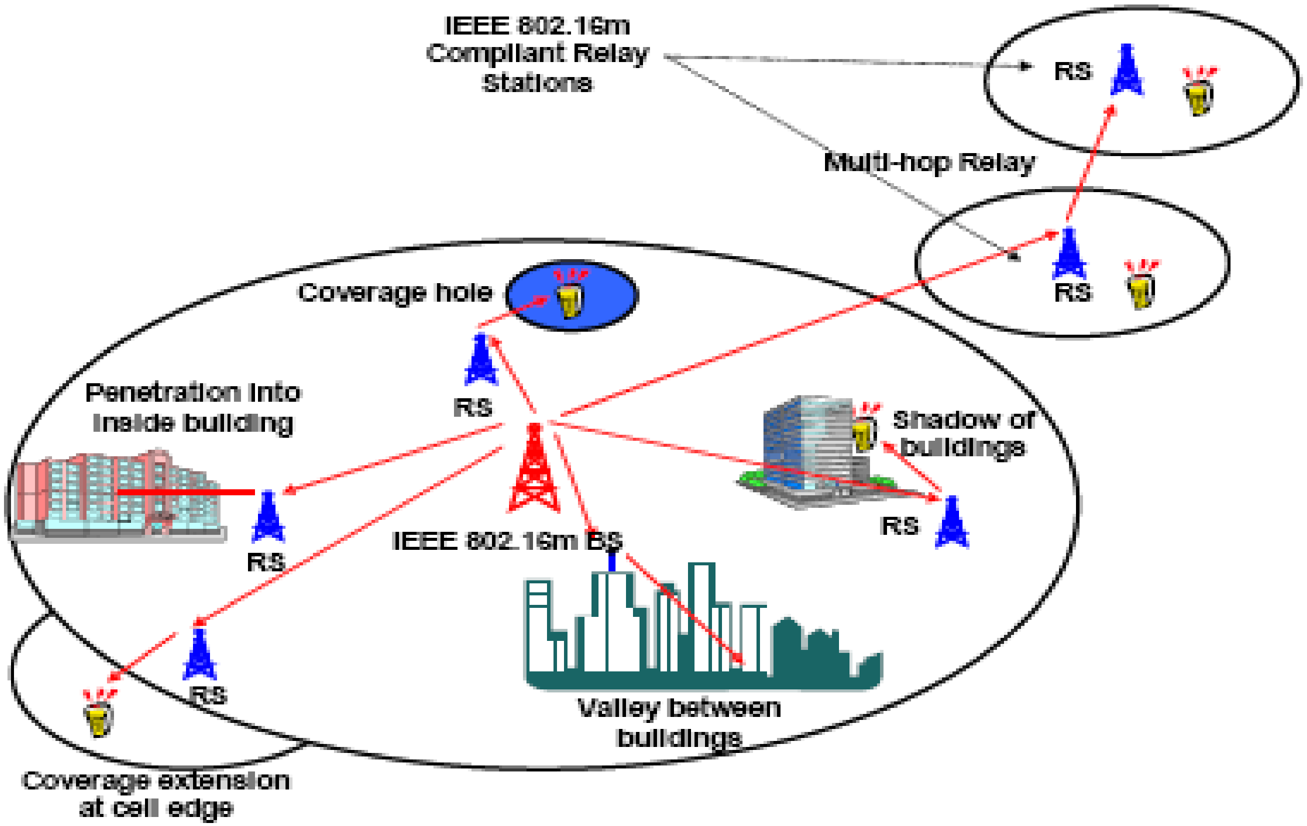
- The general considerations are the same as for the BS scheduler:
  - Burst of a known size
  - A task is to allocate a certain, integer, number of bytes to each connection
- The final choice may depend on the terminal type
  - Mobile terminal with scarce power resources:
    - PQ
    - Simple WRR based schedulers
  - Fixed stations
    - Sophisticated WRR schedulers
    - FQ

Polling

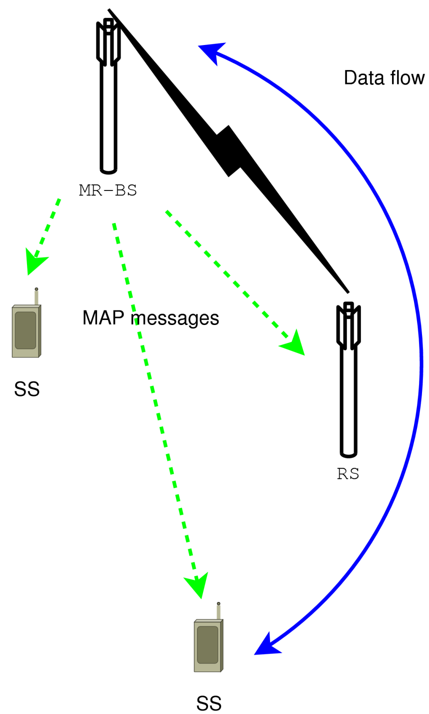
- Purpose of the polling
  - Ask a connection for data (rtPS)
  - Improve timing characteristics (ertPS)
  - If there are free slots, we can poll nrtPS connections
- Price for the polling
  - It is enough to allocate one slot in the uplink direction so that a connection can send the bandwidth request
  - One uplink burst, size of which is one slot, should be allocated
  - A burst requires an entry in the UL-MAP message, size of which is 4 bytes
  - UL-MAP message is encoded with QPSK-1/2 MCS repetition factor 2,4,6
  - In the case of QPSK-1/2 Rep 6, 1 byte needs 1 slot
  - One polling data burst needs 5 slots
- Alternative solutions
  - Rely upon uplink contention (cannot be applied to rtPS)
  - Multicast polling
  - Uplink fast feedback channel (OFDMa only)

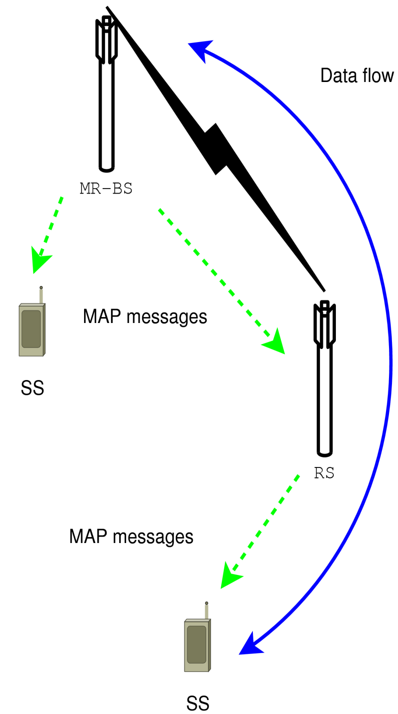
IEEE 802.16j multi-hop relays

Multi-hop relays



IEEE 802.16j multi-hop relays

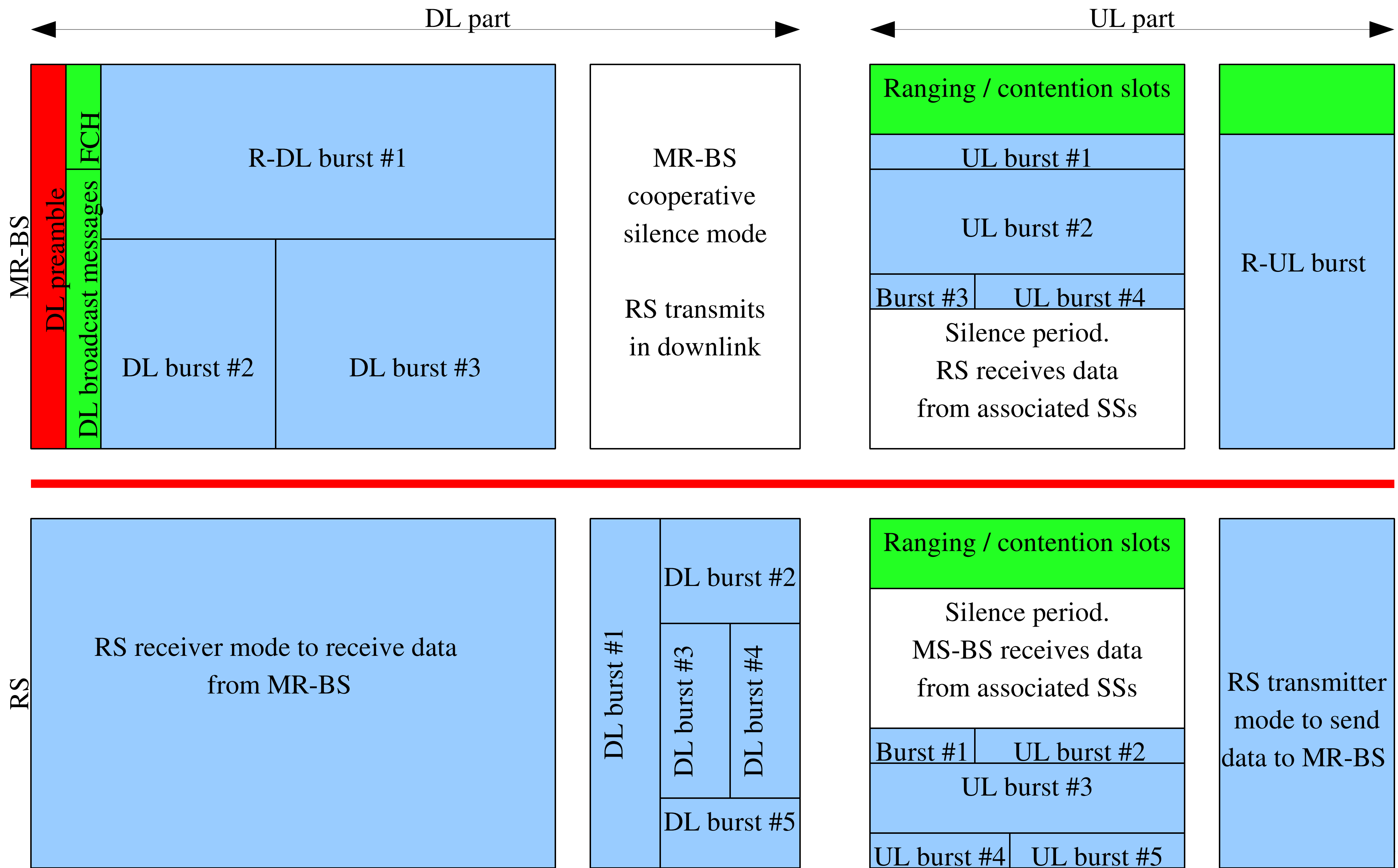




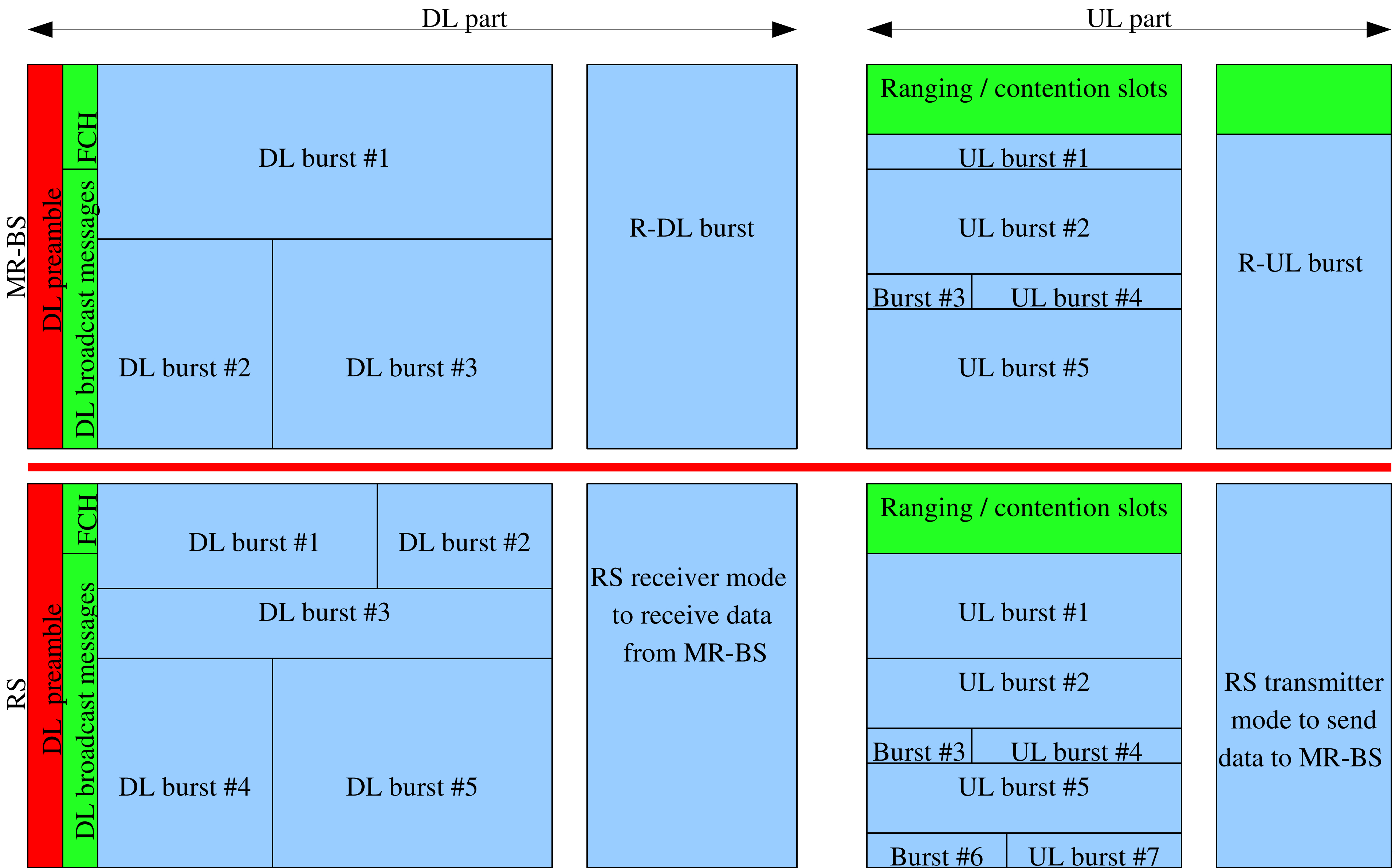
Transparent relay
- Is completely invisible to SS
- Does not send MAP messages
- Supports only the centralized scheduling

- Non-transparent relay
  - Is recognized by SS as a base station
  - Sends MAP messages and other downlink broadcast information
  - Supports centralized and distributed scheduling

Transparent relay



Non-transparent relay



Power management in IEEE 802.16

What do we spend energy for?

- Hardware components
  - Chipsets
  - DSPs
  - Processors
- Hardware design
  - Interfaces
  - Buses
  - Regulators/Amplifiers
- Applications
- Backlight
- Radio interface
  - Data transmission
  - Exchange of management information with a BS and a network controller

Key findings

- Radio interface
  - A terminal can perform power consumption optimizations, but
  - Network operational configuration has also a big impact
  - A terminal should be able to spend more time in the sleep mode, and
  - Should be able to switch quickly between active and sleep modes

- Multiradio access
  - Usually, 2/3G power consumption is higher than in 802.11
  - Use a transparent handover between different wireless technologies
  - Cellular networks may broadcast information on, e.g., 802.11 availability
  - IEEE 802.21 may assist in this process

- Reduce power consumption of always-on applications
  - Keep-alive messages
  - Non-synchronized periodical updates

- Less you do, less you consume

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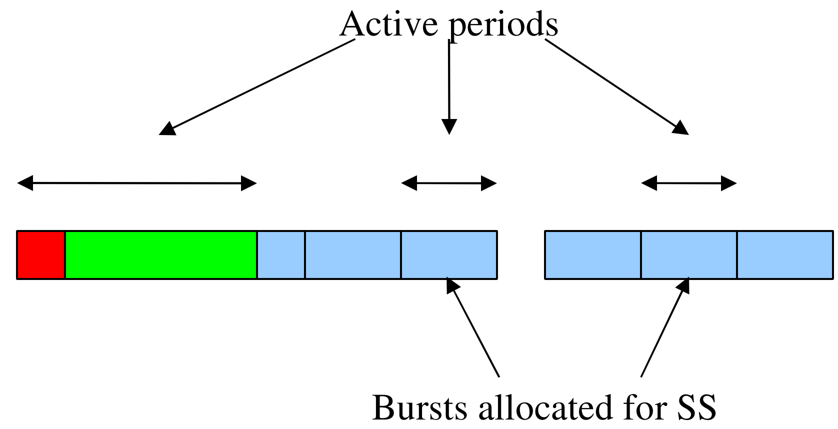
Power management solutions

- Information on when a burst starts
  - No need to be active during bursts allocated for other stations
  - We still have to listen for the downlink broadcast messages
- Sleep mode
  - A station is inactive for a certain period of time
  - Sleep time is negotiated with the BS
  - Can be used with an active data transmission
- Idle mode
  - A station listens periodically to the DL data sent by the BS
  - Is suitable for a “stand-by” mode
- Disconnected mode



Publications

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- A. Sayenko, O. Alanen, T. Hämäläinen. “Adaptive contention resolution for VoIP services in IEEE 802.16 networks”. In the 8th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks. Jun 2007
- A. Sayenko, O. Alanen, T. Hämäläinen. “Adaptive contention resolution parameters for the IEEE 802.16 networks”. Proceedings of QShine. Aug 2007
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- O. Alanen. “Multicast Polling and Efficient VoIP Connections in IEEE 802.16 Networks”. In the 10th IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems. 2007. accepted for publication
- A. Sayenko, O. Alanen, T. Hämäläinen. “Scheduling solution for the IEEE 802.16 base station”. Special Issue of Computer Networks. accepted for publication
- Several submitted papers

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