# Multi-radio Coexistence and Collaboration on an SDR Platform

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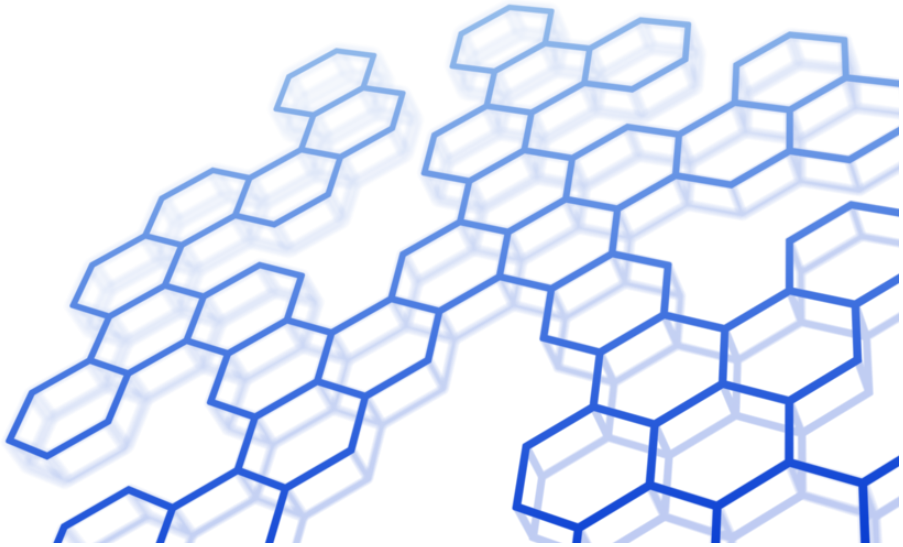
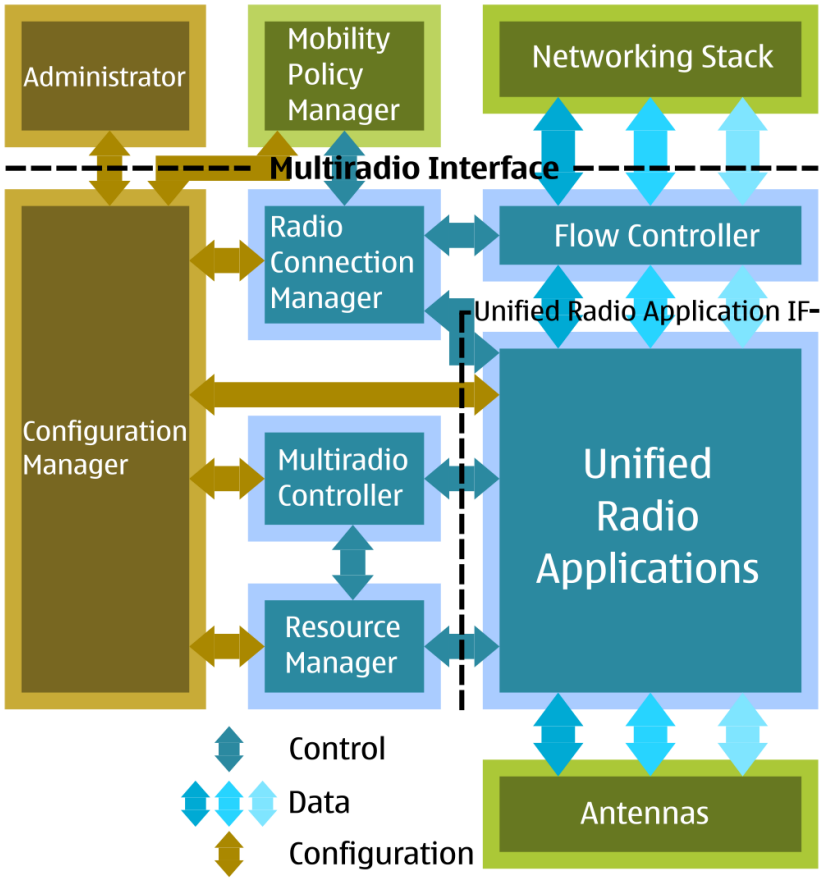


# Presentation outline

- Multi-radio coexistence architecture
- Resource management framework
- Multi-radio scheduling framework
  - Benefits and implementation considerations
- Experimental scheduling results
  - Utilizing fine-grained spectrum holes
  - Traffic offloading
- Conclusions

# Multi-radio coexistence architecture

- The SDR functional architecture [1,2] separates the common HW/SW platform and the specific RATs
- Radio applications use generic platform services to access HW
- Dynamic resource sharing between radios
  - Semi-static resource budget
  - Resource overbooking with mutex rules
  - Dynamic scheduling of mutually exclusive radios





[1] Ahtiainen et al., “Multi-radio Scheduling and Resource Sharing on a Software Defined Radio Computing Platform”, Proceedings of SDR`08

[2] van Berkel et al., “A Multi-Radio SDR Technology Demonstrator”, Proceedings of SDR`09

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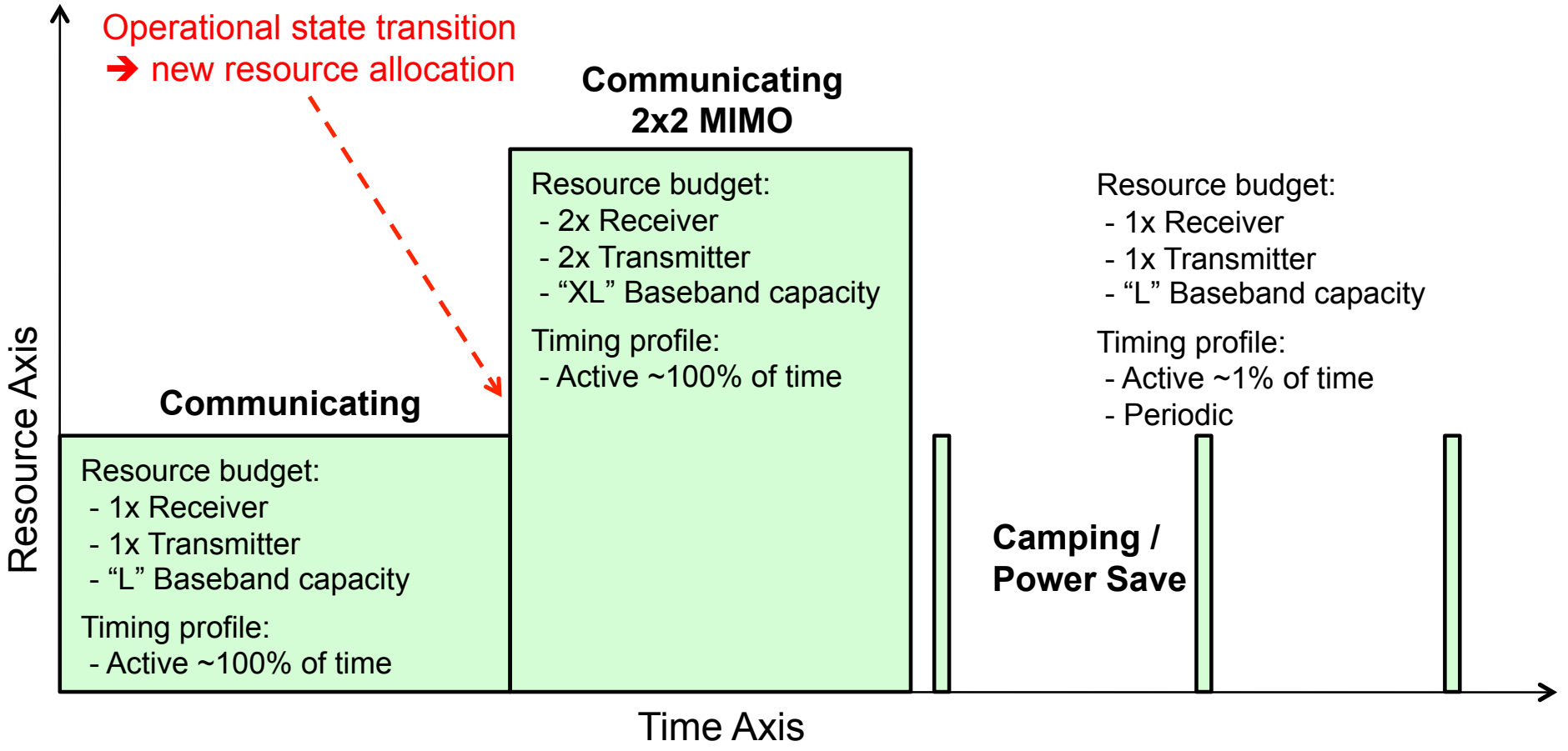
# Resource management framework (1/2)

- **Operational states:** static or semi-static resource budget



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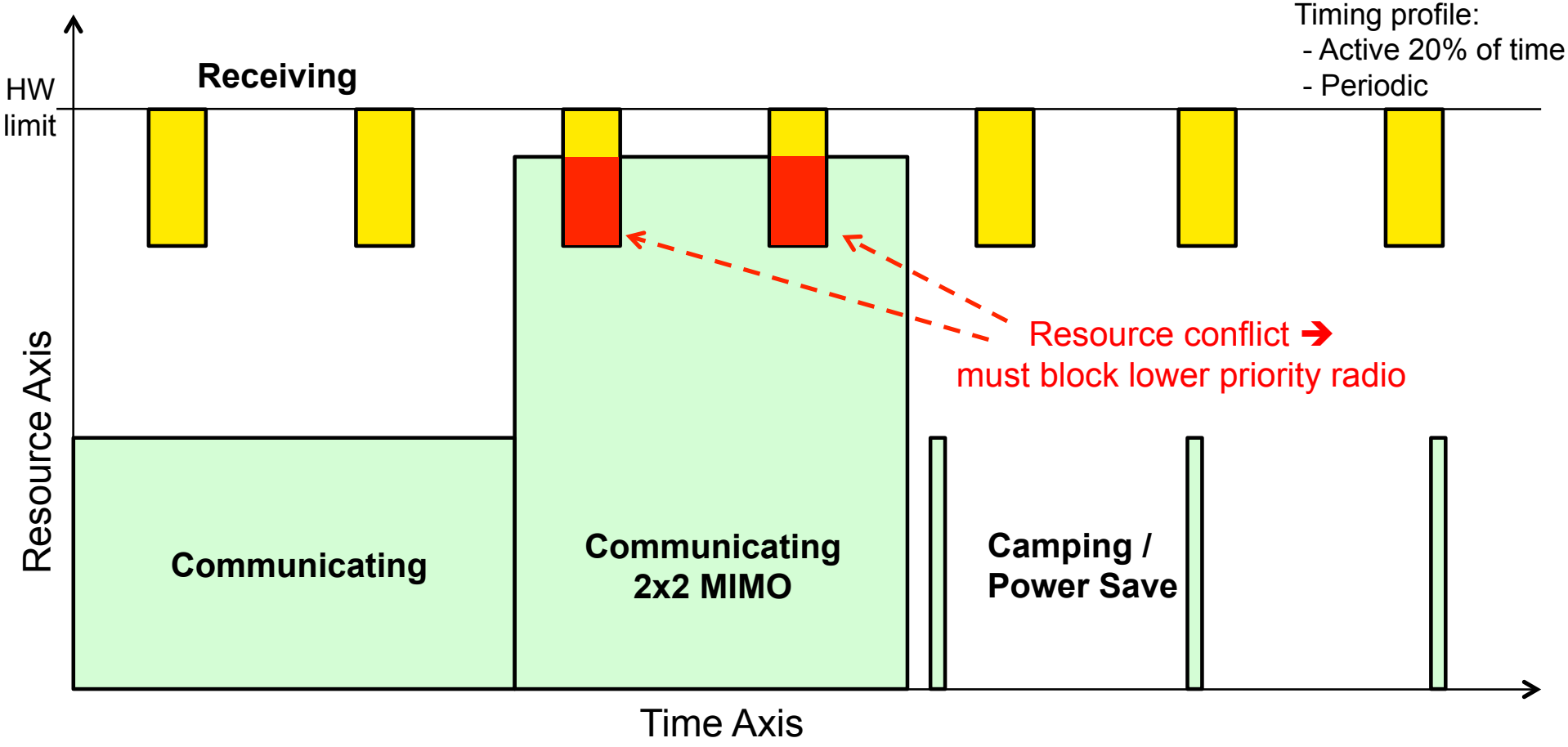
# Resource management framework (2/2)

- **Mutual exclusivity rules:** for resource conflicts

Resource budget:
- 1x Receiver
- "S" Baseband

Timing profile:
- Active 20% of time
- Periodic



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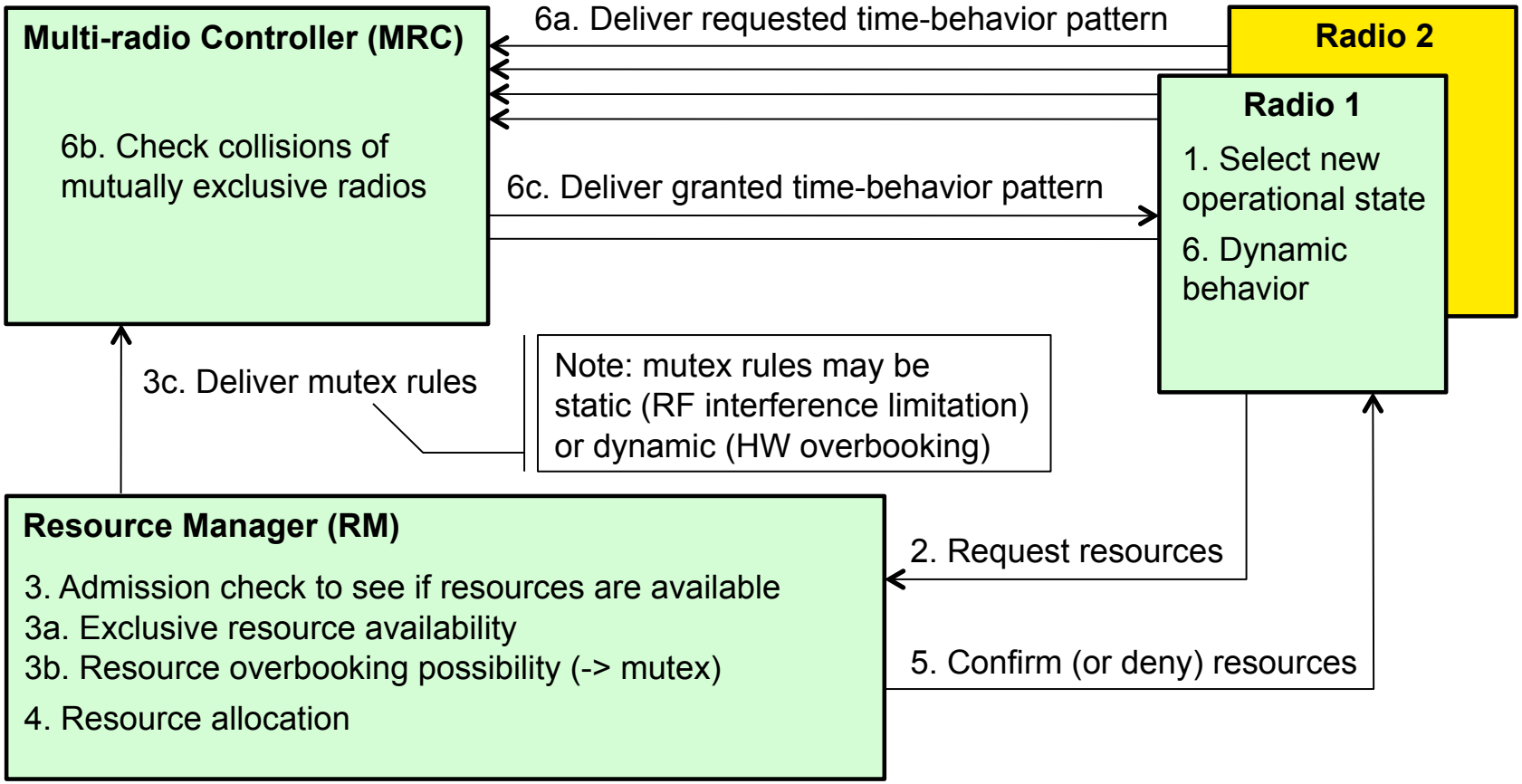
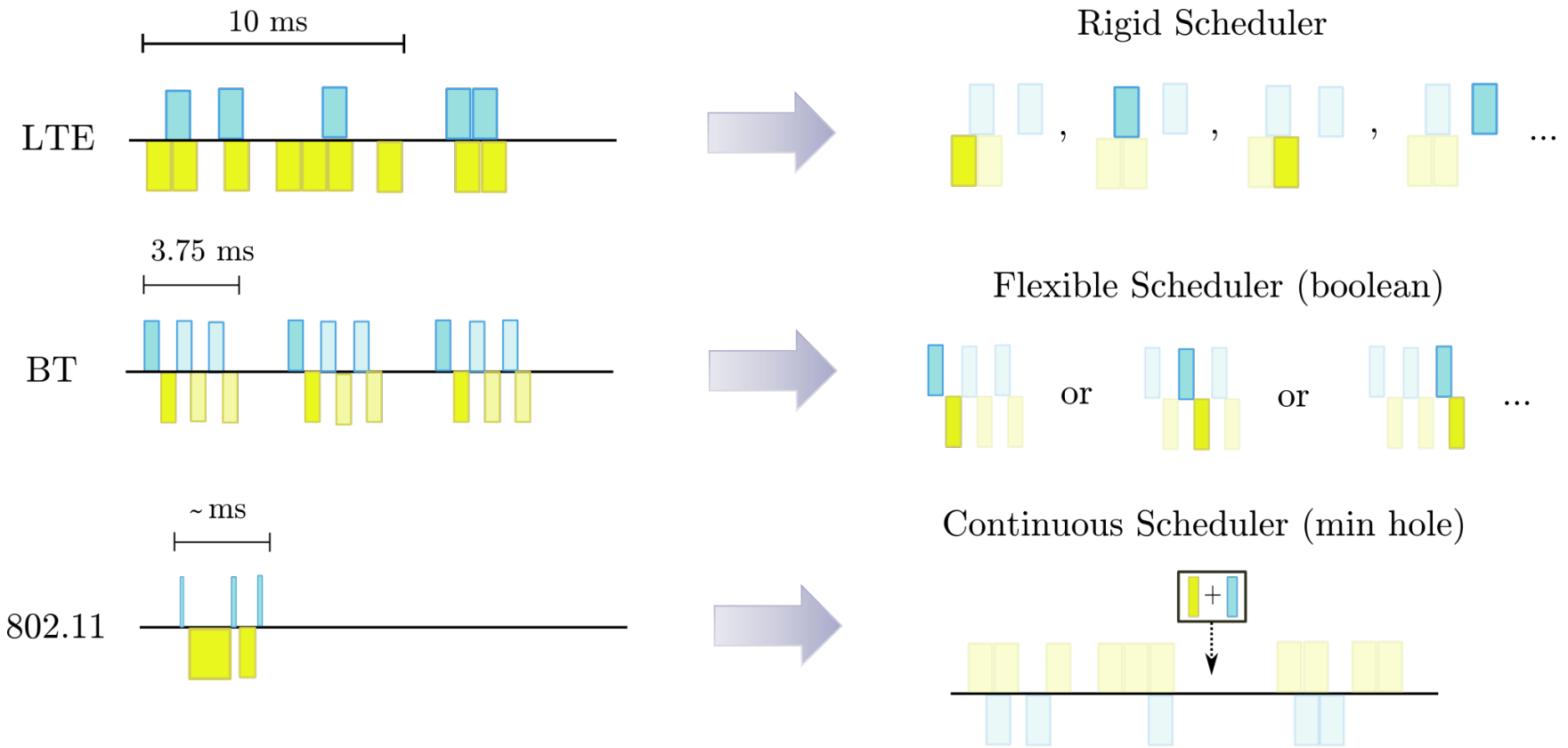
# Multi-radio scheduling framework

- **Multi-radio scheduling:** dynamic behavior



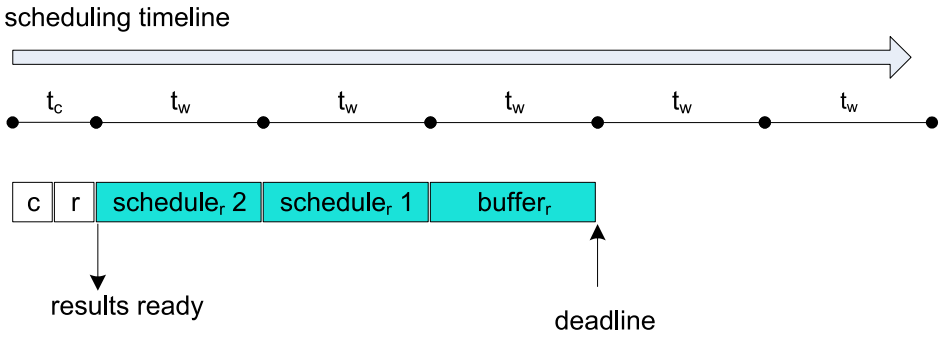
# Radio scheduling patterns

- Three semantic patterns to capture the typical behavior of different radios

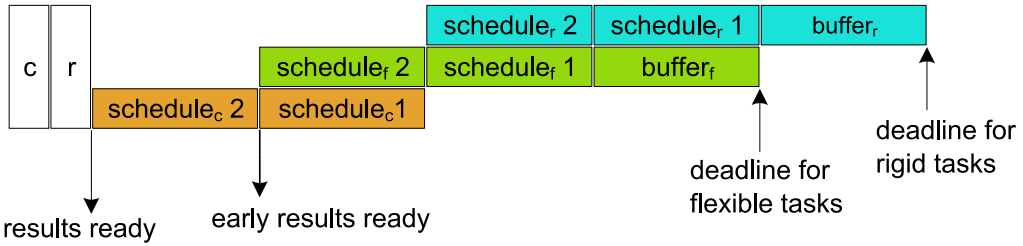


# Scheduling timeline

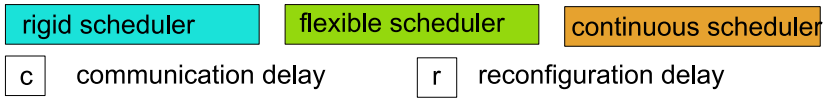
- Scheduler deployment depends on the active set of radios
  - May change dynamically
- Scheduling done in pieces (scheduling window $t_w$)
- Three stages:
  - *buffer* = gather slots starting during the same $t_w$
  - *schedule1* = perform scheduling
  - *schedule2* = slots overlapping $t_w$ boundary are hold because the next scheduling cycle may affect them
- $t_w$ is typically few milliseconds




1) deployment of stand-alone rigid scheduler



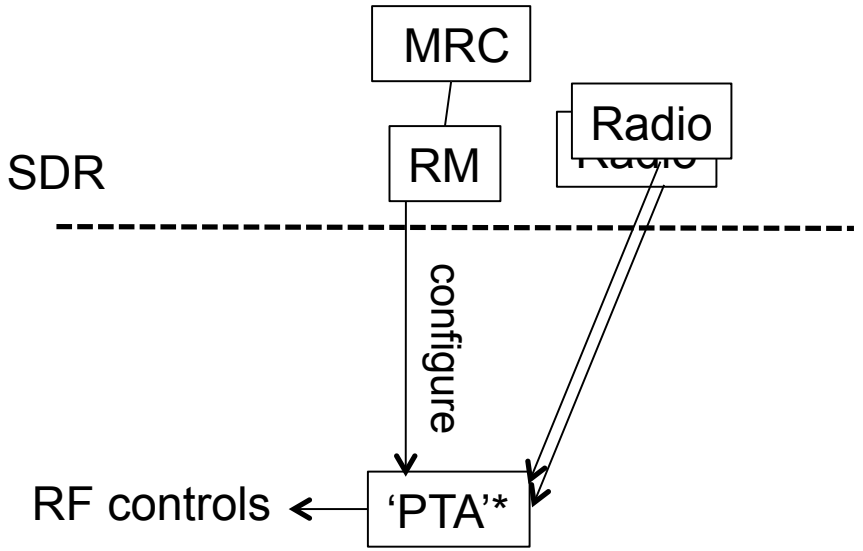

2) deployment of all schedulers



# Proactive scheduling benefits

- Radio-agnostic mechanism
- The behavior of radios can be changed to nullify or minimize the consequences of interference
- If the scheduler can't solve the conflict otherwise than preventing lower priority radio to operate temporally, the affecting radio is informed beforehand.

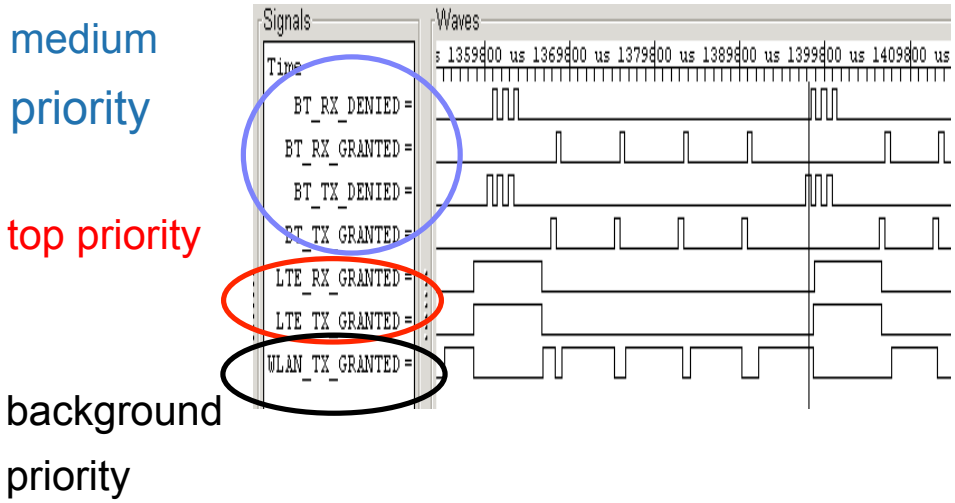
- Implementation considerations:
  - The response time of protocol level scheduling is several milliseconds (e.g. with all three schedulers in demonstrator  9.5ms
  - Could co-operate with PTA-like mechanisms to gain faster response when needed (e.g. HARQs)

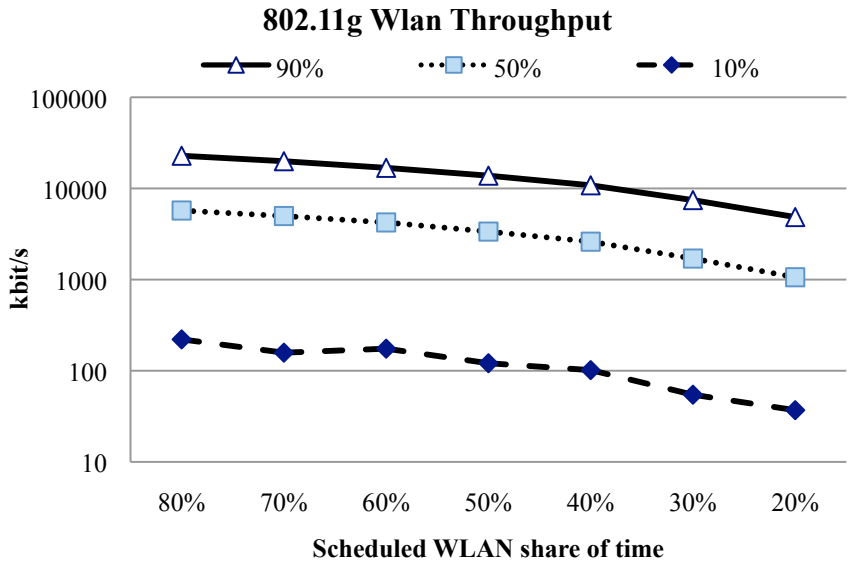



* Packet Traffic Arbitration IEEE 802.15.2

# Utilizing fine-grained spectrum holes

- Scheduler can dynamically report unoccupied time slots beforehand
  → Secondary radio can use short unoccupied pieces of spectrum
- E.g. 802.11 WLAN radio is configured to use long enough unoccupied time periods of collocated Bluetooth and LTE radios, captured scheduling decisions:



# Traffic offloading

- If the quality of primary radio link decreases, data flow can be transferred to secondary radio (e.g. LTE -> WLAN)
- The priority of the primary radio is transferred with the flow

*flow movement to the secondary radio*

*flow movement back to the primary radio*


- Flow movement can be done automatically inside SDR modem when the triggering condition is detected
  - The operational state has resources allocated for both radios; within a state, the service can be made **transparent** to the SDR user

# Conclusions

- The feasibility of multi-radio scheduling framework was demonstrated, with
  - holistic resource allocation, both for computing and spectrum resources
  - run-time control for radio coexistence
- Co-existence of a “flexible” radio together with a non-flexible radio can be made possible with fine-grained scheduling
- With scheduling it is possible to improve the performance of both flexible and non-flexible radios in resource-constrained operation

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