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Cross-Layer Based Scheduling in Wireless LANs Based on OFDMA and SDMA

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ITG Workshop Aachen, 12 Feb 2009

Overview

- Motivation
- Concept of Xlayer Project
- Scheduler Design, Example Results
- Fluid-Model Based Scheduling
- Serving applications
- Conclusions

Motivation

- Consider WLAN working in indoor scenario
- Legacy WLANs
  - work with independent MAC and PHY layers
  - no cross-layer communication
  - MAC layer is unaware of varying channel conditions
  - no knowledge about application needs (Quality-of-Service)
  - inefficient usage of channel resources
  - inappropriate service of applications

Project “XLayer”

- DFG project “Xlayer”
- Joint project with Communications Engineering Working Group, University of Bremen, Prof. Kammeyer

Project concept: PHY layer

Compare performance for different PHY transmission methods, with and without influence of MAC

- Multi-user access
  - time, frequency, space
- Antenna arrangements
  - SISO, MISO, MIMO
- Utilisation of spatial diversity
  - Space Time Block Codes, Cyclic Delay Diversity, Beamforming
- Power allocation

Project Concept: MAC/application layer

- Design a cross-layer WLAN system with centralised channel access control
- Introduce cross-layer communication between MAC and PHY layer
- Provide a QoS-enabled scheduler which keeps throughput and delay requirements
- Introduce cross-layer communication between MAC layer and application
- Optimize handover of packets between MAC and PHY
- Provide interface to applications
- Distinguish RT/non-RT applications
- Application adaptivity

Scheduler design (1)

- Similar to IEEE 802.11e
  - central station has full control on the channel similar to HCF
  - serves *n* mobile terminals in the downlink
  - each flow is stored in its own queue
- Similar to draft IEEE 802.11n
  - MIMO transmission
- Cross-layer scheduler integrates
  - MAC scheduling methods
  - physical transmission methods
  - adaptive applications

Scheduler design (2)

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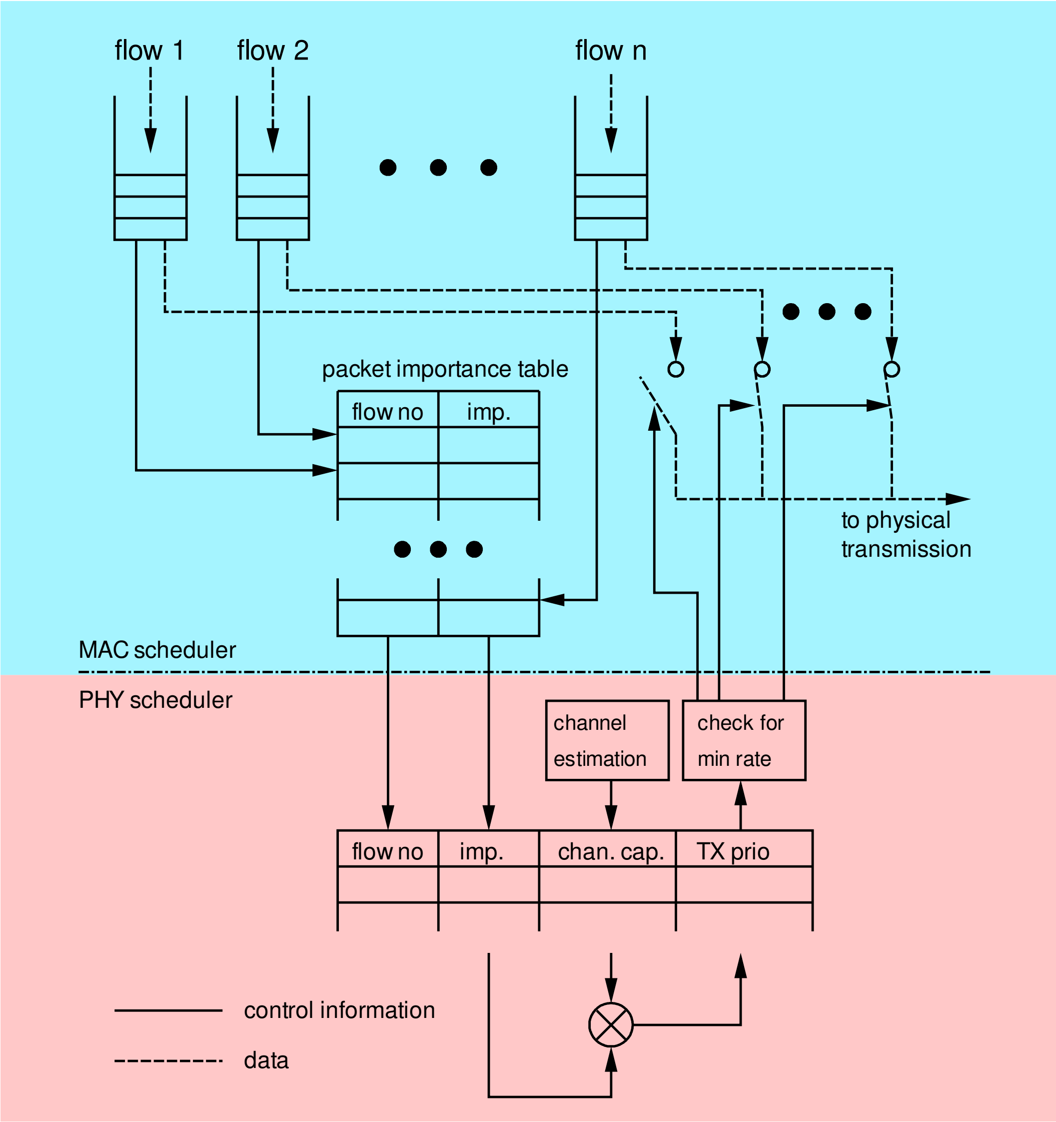
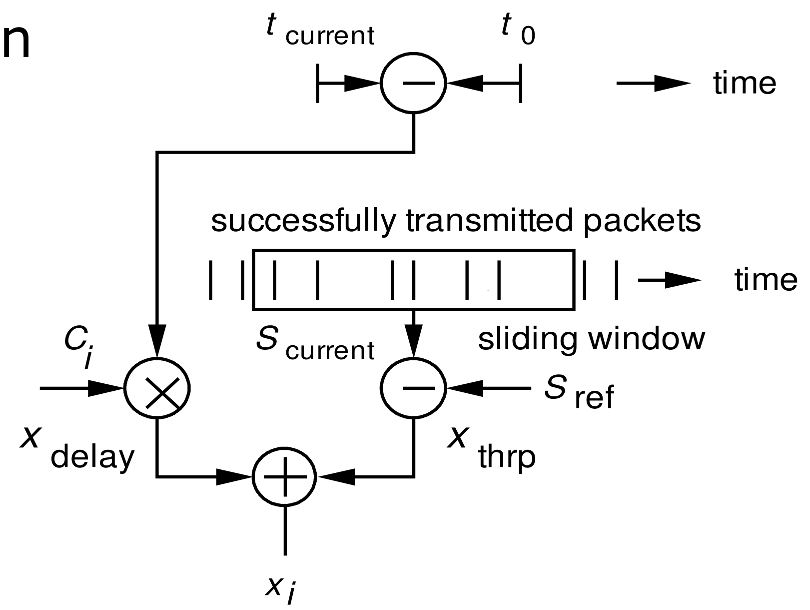


Scheduling methods

- Simple methods
  - Random selection
  - Round Robin
- Relative weighting
  - Queue length
  - Packet age
- QoS aware scheduling
  - Similar to control circuit
  - Fluid-model based

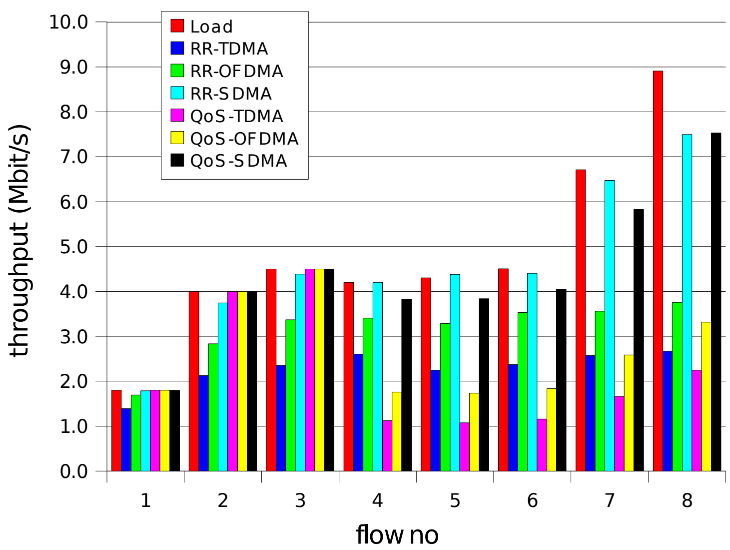
Scheduling methods: control circuit

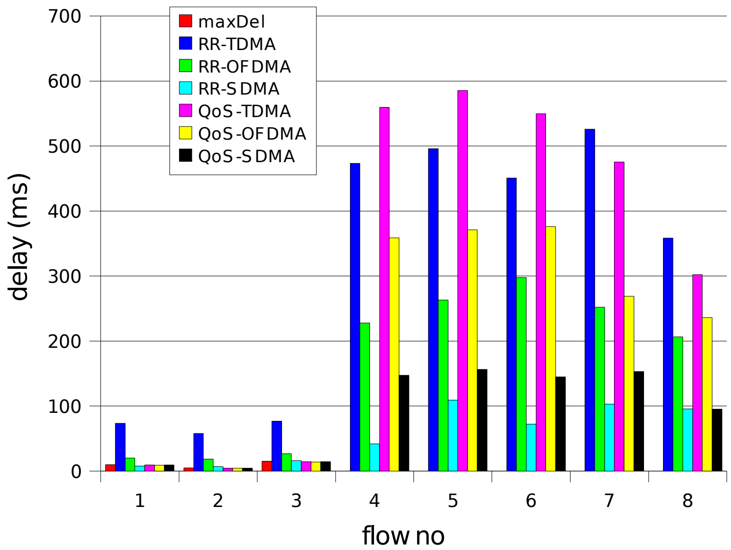
t_0	target time for transmission
$t_{current}$	current time
$S_{current}$	current throughput
S_{ref}	target throughput
C	weighting factor
x_{delay}	prio due to delay
x_{thrp}	prio due to throughput



Adaptation for weighting factors and window size

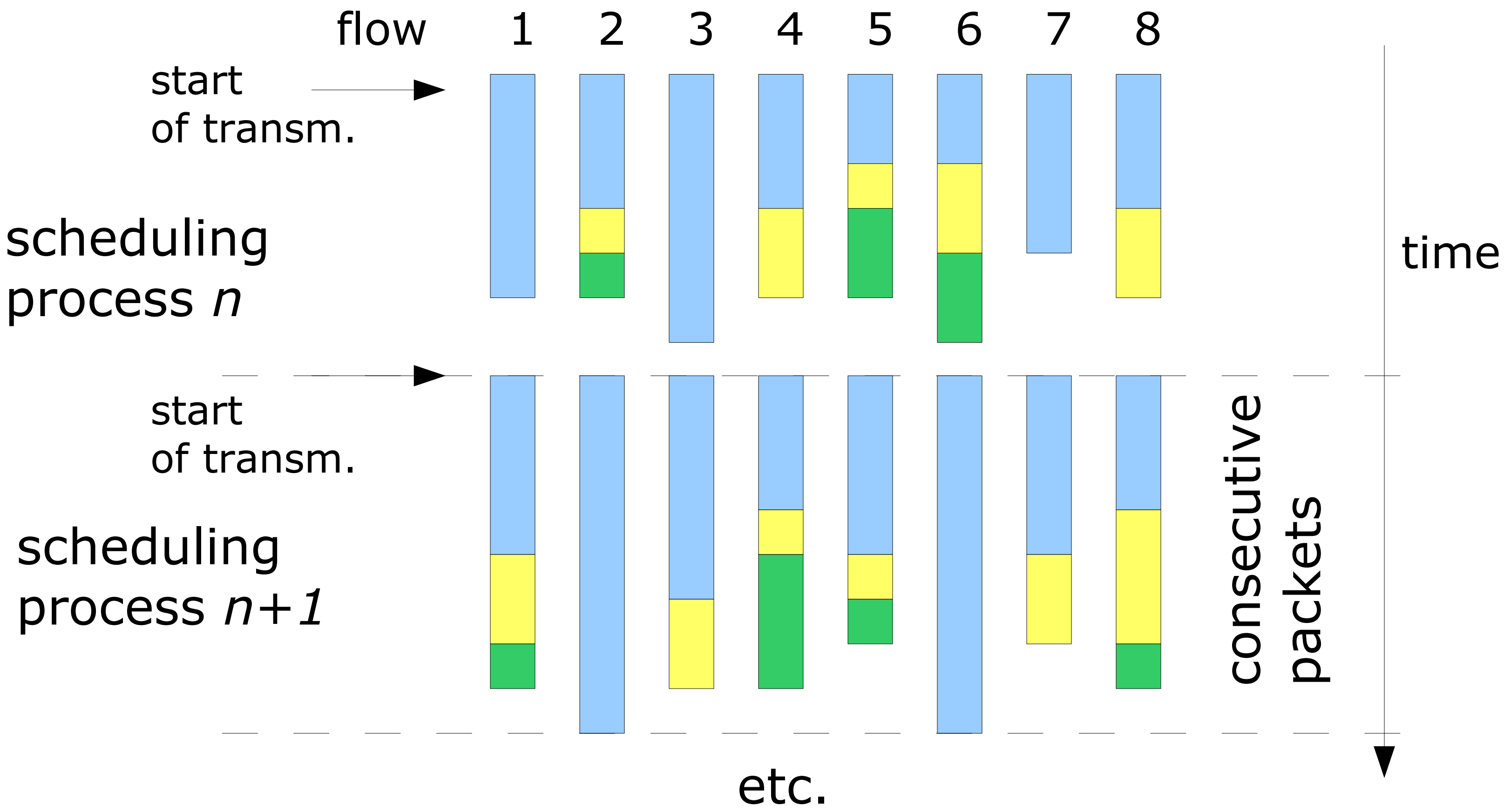
Results example





- delay requirements are kept by QoS scheduler
- Further enhancements possible by packet aggregation

Packet aggregation

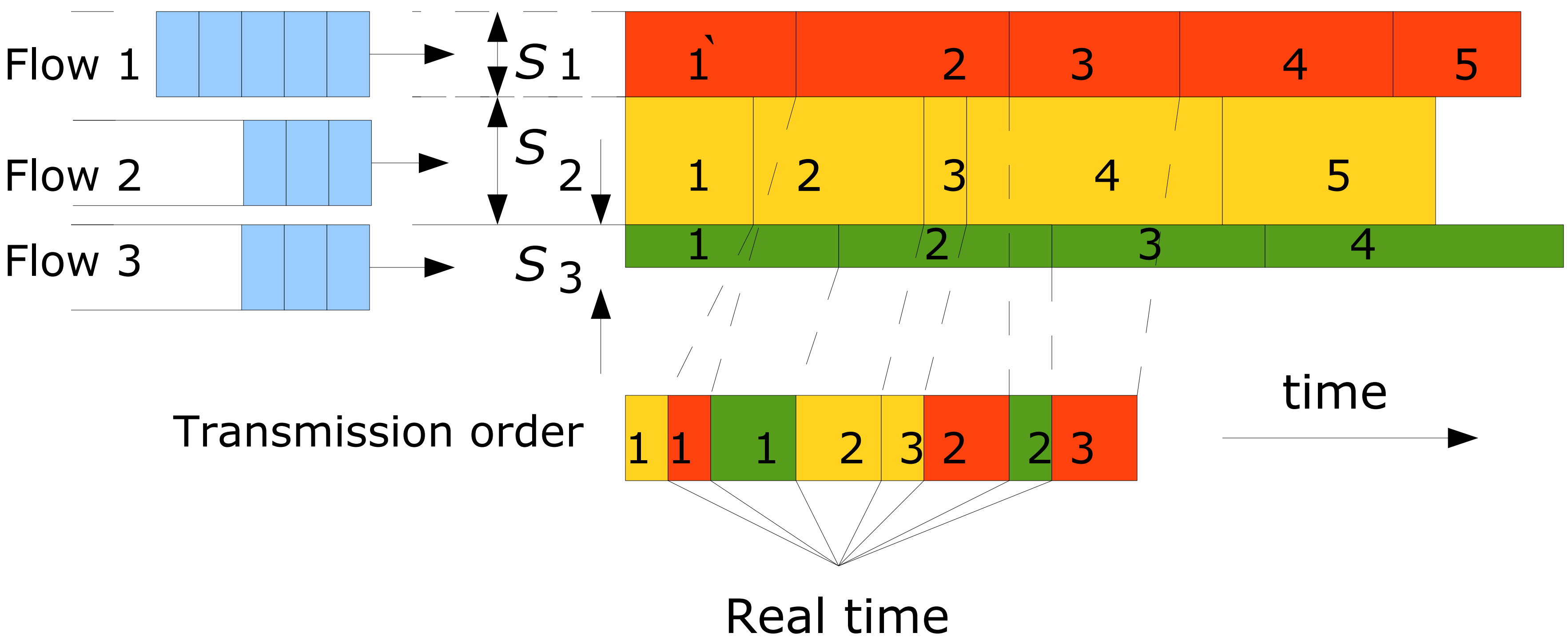


Fluid-model based scheduling

- Weighted Fair Queueing: Frequently used scheduler in based on a continuous fluid model
- A number of input queues is mapped to one output
- For the packets, virtual times of fluid model are mapped to real times of packet transmission

Fluid-model based scheduling: Weighted Fair Queueing

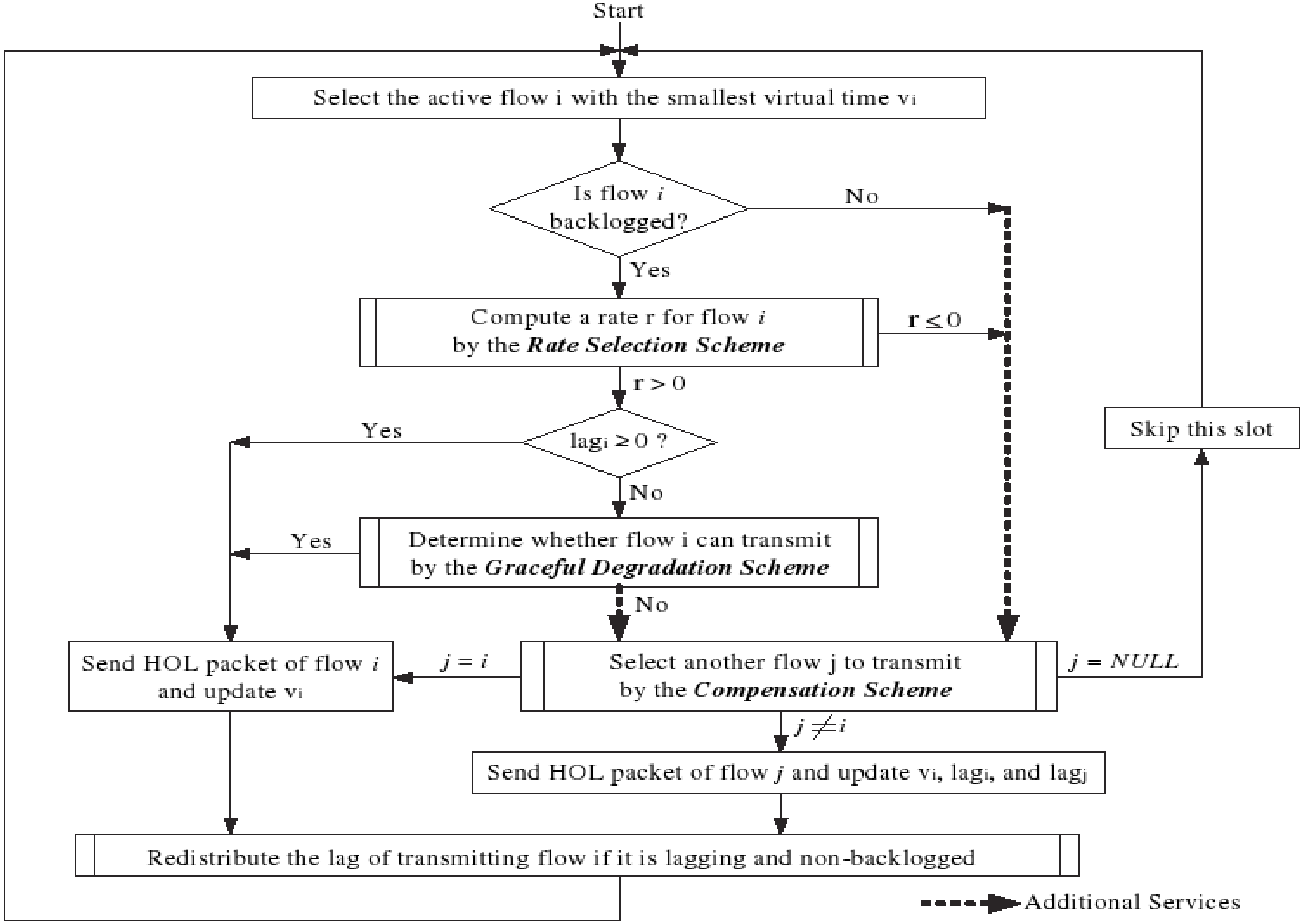
S_i throughput for flow i



Fluid-model based scheduling: Service fairness vs. time fairness

- Model designed for wired networks with fixed total bandwidth
- Challenges in wireless networks
  - varying per-user bandwidth
  - packet loss
- Tradeoff
  - service fairness (long term): All users with similar QoS requirements should get approx. same service
  - time fairness (short term): For time-critical flows, packets should be transmitted as close to the schedule as possible

Fluid-Model Based Scheduling:
Wireless WFQ for TDMA



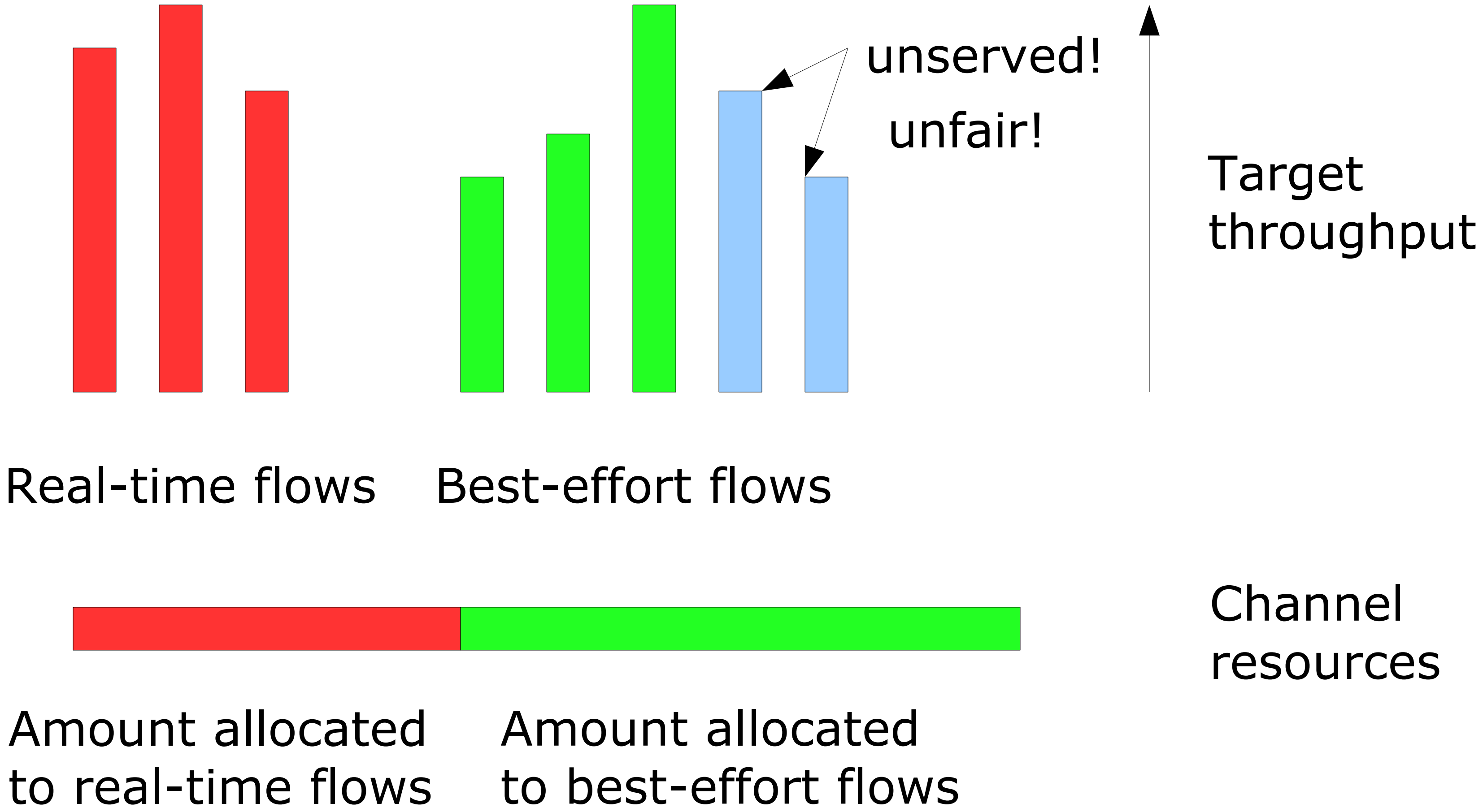
[Wang et al. 2005]

Fluid-Model based scheduling: Limitations and extensions of Wireless WFQ

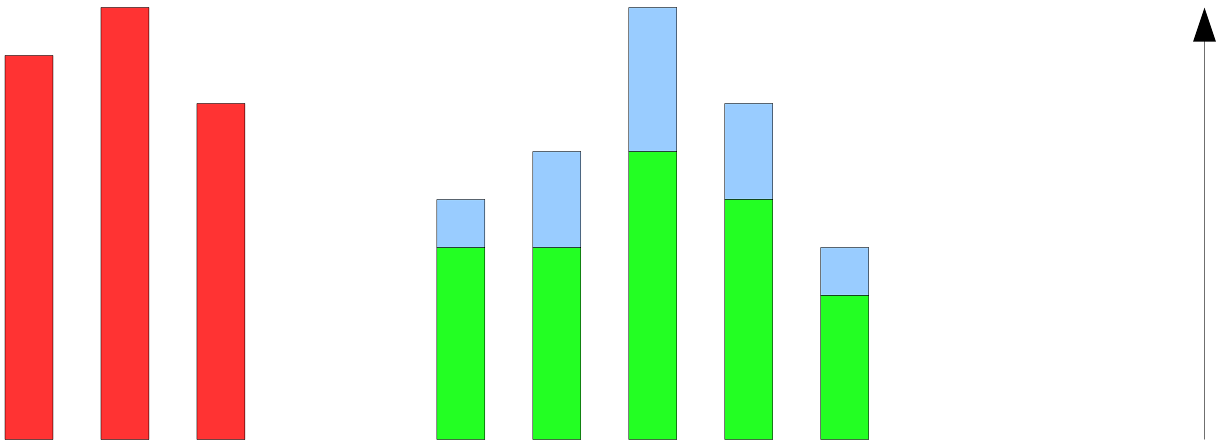
- Limitations
  - only considers TDMA
  - assumes transmit powers as given
  - cross-layer communication exists, but only to check available data rates, not to adjust them

- Proposed extensions
  - management of simultaneous data flows
  - provide priority information between MAC and PHY layer
  - dynamically allocate channel resources

Serving applications:
unfair resource allocation



Serving applications: fair resource allocation



Target throughput

Real-time flows Best-effort flows

Channel resources

Amount allocated to real-time flows

Amount allocated to best-effort flows

Serving applications: Adaptive RT applications

- Mutual communication between MAC and application
  - Application specifies minimum and optimum requirements
  - MAC layer specifies if and to what extent application can be served
  - RT Application adapts traffic load according to signalled resource
  - Non-RT application works with best effort
- Reject applications whose demands cannot be satisfied (Call Admission Control)

Conclusion and Outlook

- Various extensions applicable for Wireless LANs highlighted
- Cross-Layer functionality can be deployed
  - Between PHY and MAC
  - Between MAC and application
- Enhancement of performance, meeting QoS requirements of time-critical flows

- Validation of the proposals for the future work by simulations
- Further ideas ...

Thank You!