How to squeeze more performance out of your wifi

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Motivation and Background

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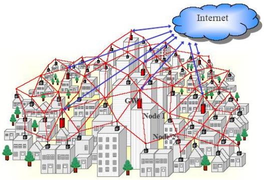

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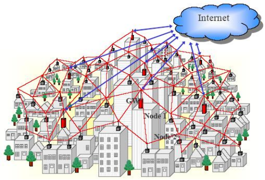

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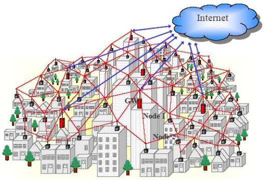

- Internet access in all buildings of a scattered university campus is often very slow or expensive.
- Point-to-Point Radio Links can provide a sufficient and cost-effective service.
- Radio Mesh Networks can be used to improve performance and robustness, and open the possibility for a wide range of optimization strategies.

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- ...these technologies can not guarantee availability.

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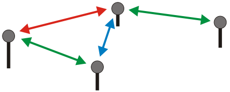
  - Open source scene: e.g. freifunk.net
  - Academic projects: e.g. MIT RoofNET
  - Upcoming IEEE 802.11s standard for Mesh Networking
- But there is still a lot of research needed until these networks can stand any competition with their wired counterpart.

Motivation and Background

WLAN scenarios of interest...

long-range point-to-point links



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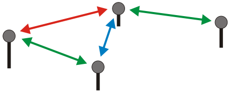

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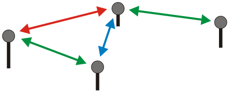

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- We are interested in relatively static radio links based on the IEEE 802.11e MAC.
- IEEE 802.11 was designed for »2 users, short distances, a lot of frame errors and the presence of multipath propagation.
- On ptp-links these assumptions changed. Therefore a closer look at the performance issues become meaningful.

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- Channel bonding requires a complex adaption layer to abstract different delays, errors, retransmissions, SNR, etc.pp.

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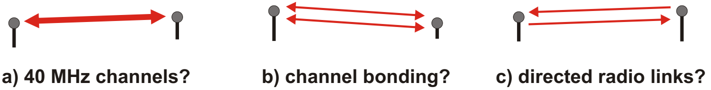

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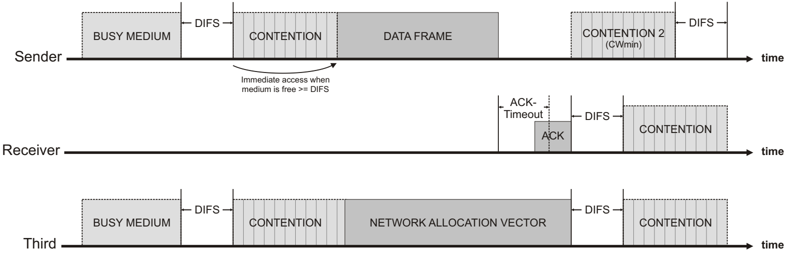
- Directed radio links eliminate the concurrency between both directions and give us the possibility to reduce the effects of the TCP ACK Congestion.
- By optimizing the 802.11e QoS parameters we can maximize the throughput without increasing the delay.

IEEE 802.11 Basic Access Method



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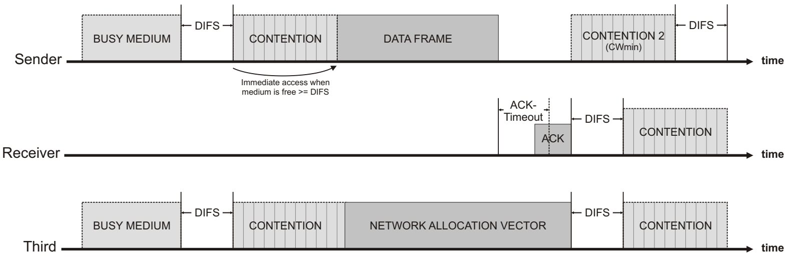

- Contention phase:
  Wait a random number of time slots $[0;2^{CW}-1]$.
  Start with $CW = CW_{min}$.
  Double CW by every retransmisson attempt, till CW_{max} is reached.

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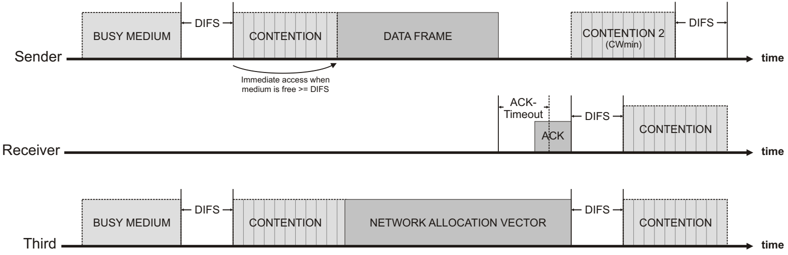
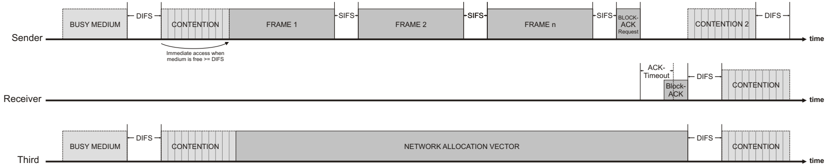


- Contention phase:
  May be omitted if the medium was sensed free during first DIFS.
  If the transmission was successful do *Contention 2* using $CW = CW_{min}$.

IEEE 802.11e Frame Bursting



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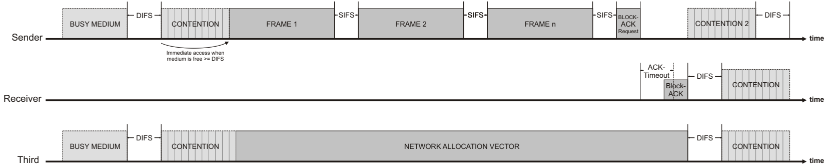

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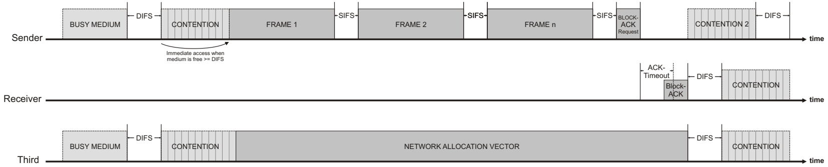

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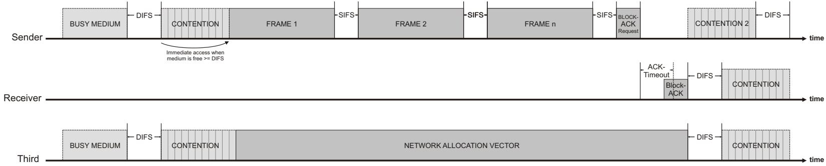

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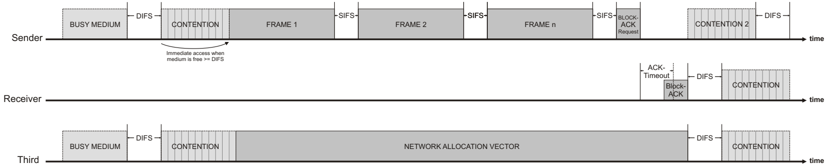

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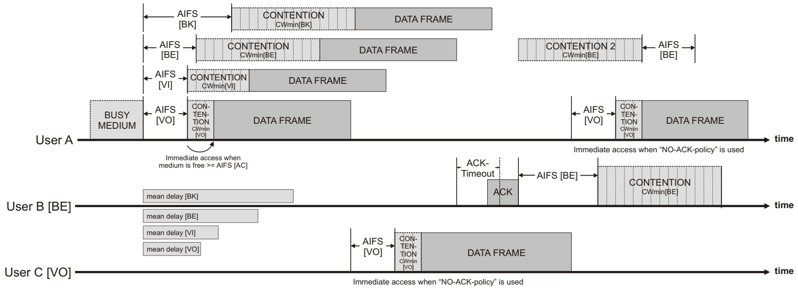
- This increases the overall throughput (and delay) significantly.

IEEE 802.11e QoS Access Method



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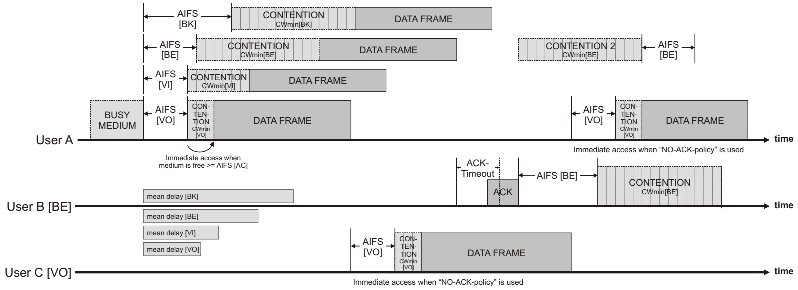

- Four priority classes: BAckground, BEst Effort, VIdeo, VOice.

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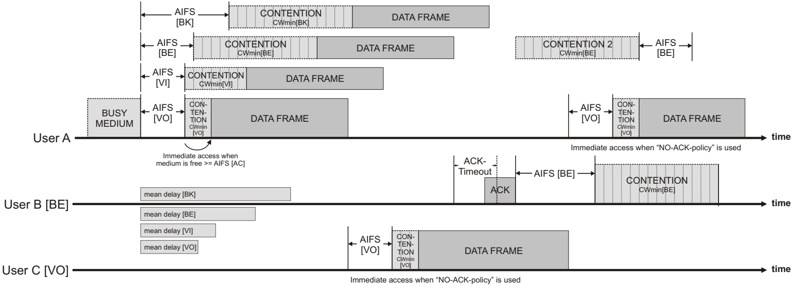

- Four priority classes: BAckground, BEst Effort, VIdeo, VOice.
- 802.11e parameters: AIFS, CW_{min}, CW_{max}, NoACK and TXOP.

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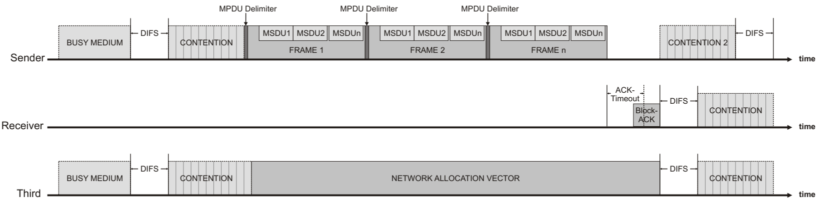
- *TXOPLimit* is a tradeoff between increasing throughput and increasing the delay... This is a classical optimization problem.

IEEE 802.11n Frame Aggregation



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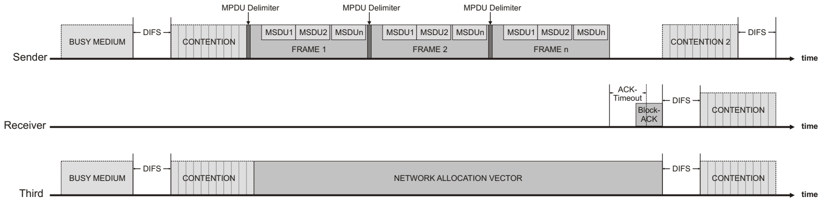

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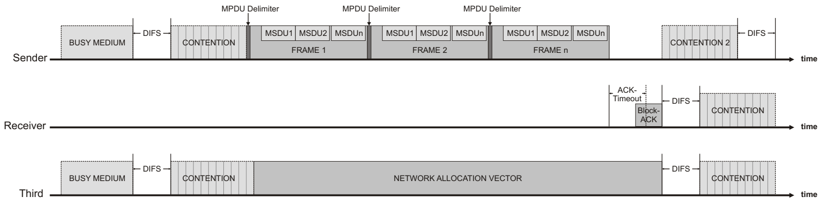

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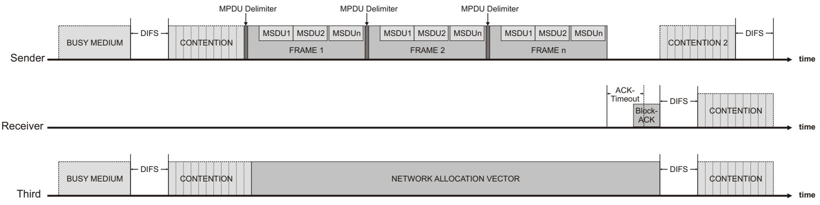

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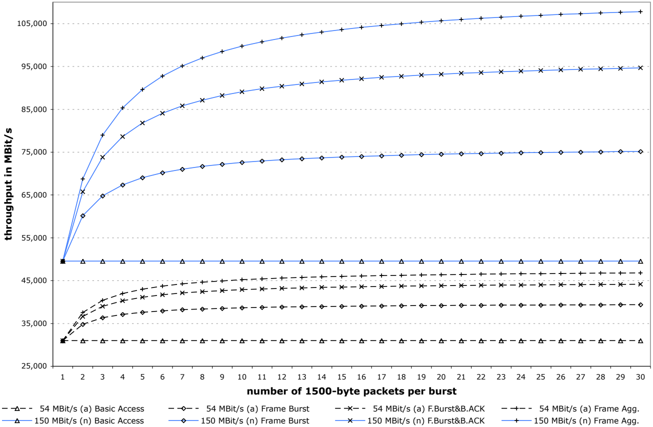
- Should be easily deployable with every WLAN chipset

IEEE 802.11e/n Throughput

Throughput Calculation of a 54 MBit/s MAC channel:

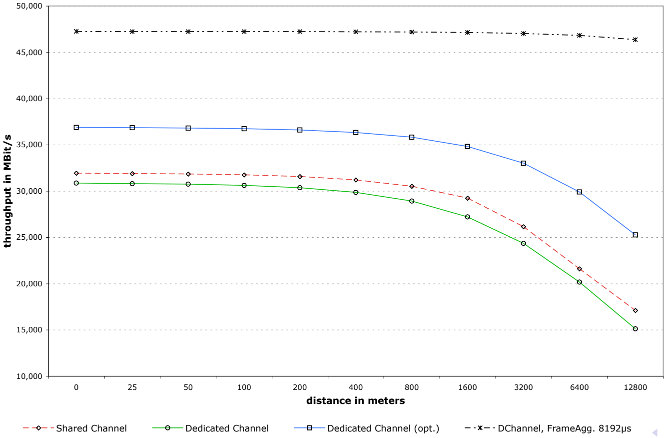
Throughput improves with the number of frames per burst



IEEE 802.11e/n Throughput

OmNet++ simulation of a 54 MBit/s MAC channel:

Throughput degenerates if distance becomes larger



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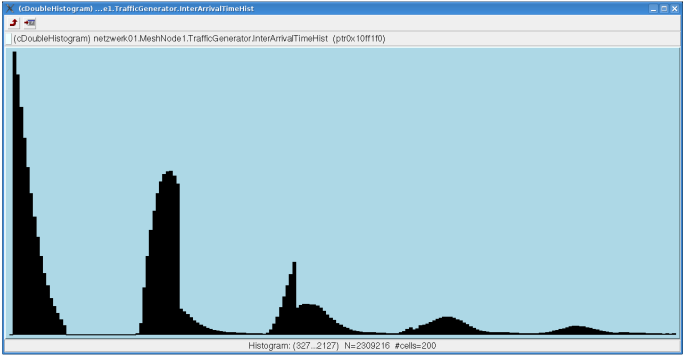

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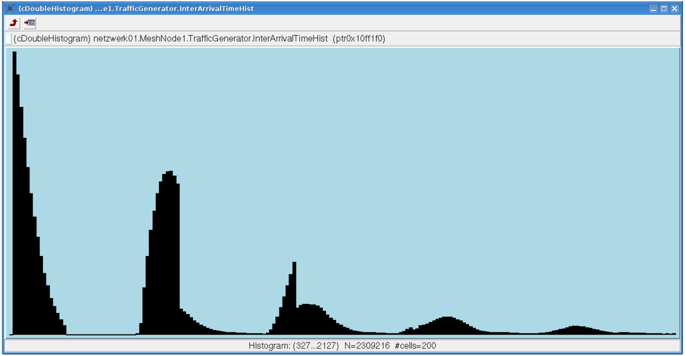

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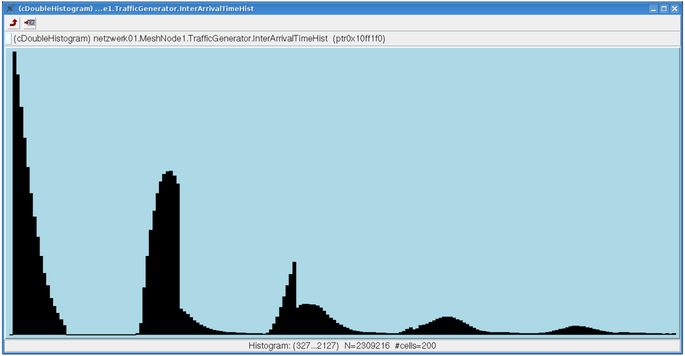

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e.g. the congestion avoidance algorithm of TCP

Overview on IEEE 802.11, 11e, 11n

Any questions so far?

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The assumptions taken in the WLAN standard do not reflect the 2-user-scenario on a ptp-link very well. At least the collision avoidance and the QoS techniques are good candidates for optimization:

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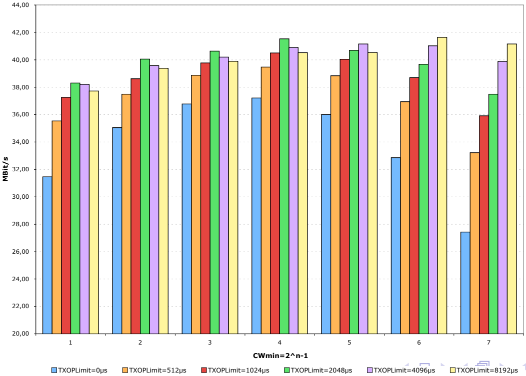
- The CW_{max} value can be reduced to CW_{min}.
  This saves you from adding unnecessary delay as reaction on transmission failures. The improvement depends on your link quality.

Optimization of a point-to-point link

- The CW_{min} and TXOPLimit value can be optimized, but they are also dependent on the length of your ptp-link and the distribution of the traffic (here 50:50). UDP Throughput at a distance of 2m:



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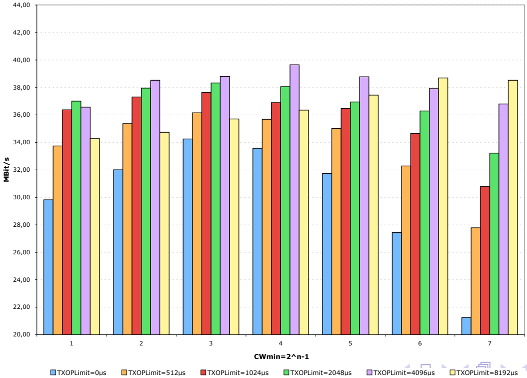
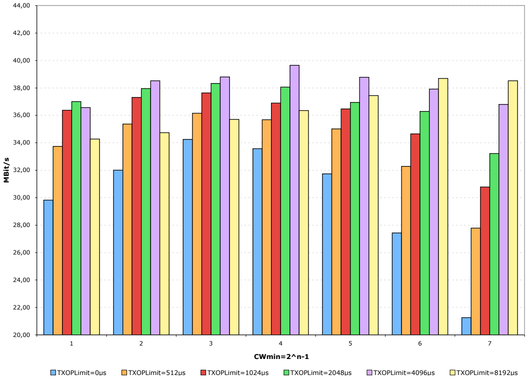


Optimization of a point-to-point link

- Improvement (TXOP==0μs) $\simeq$ 14,9%
  Improvement (overall) $\simeq$ 29,7%



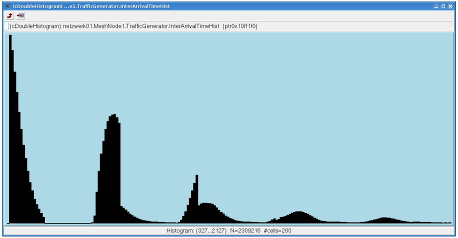
Optimization of a point-to-point link

These results are really nice, but measurements using TCP are still more than 25% behind UDP :(

Why? And what could be done to optimize this?

Optimization of a point-to-point link

Remember the delay spread of frames on a WLAN channel:



TCP uses smoothed measurements of the Round-Trip-Time to size the sliding window and to setup the timeout values. A high delay variability leads to false timeouts and unnecessary retransmissions resulting in a false congestion avoidance.

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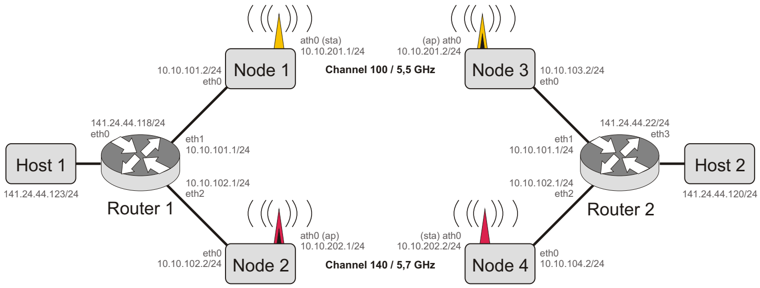

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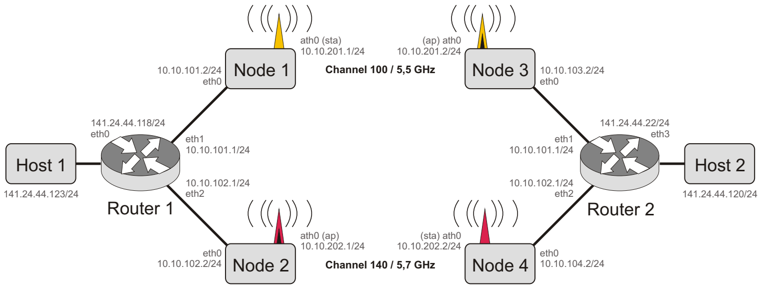

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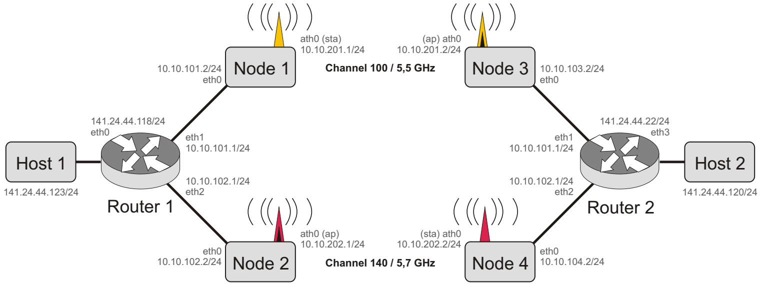

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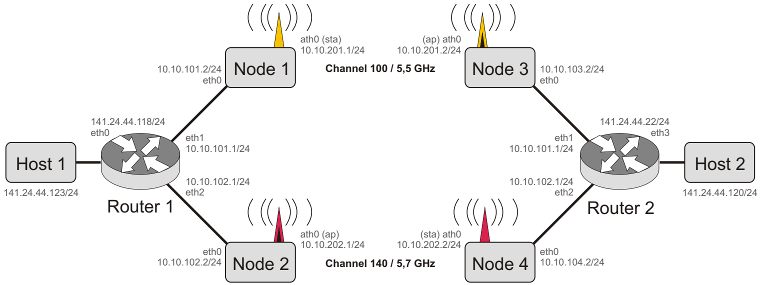

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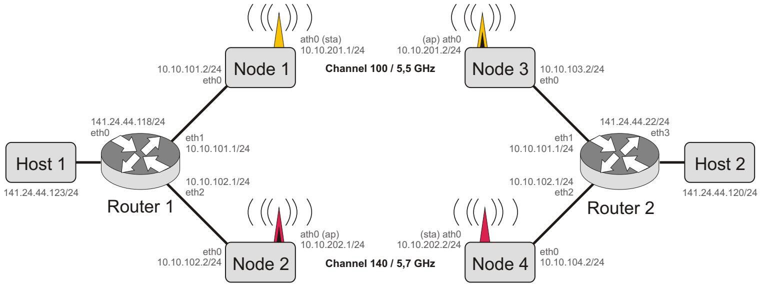

Second WLAN link for full-duplex traffic flows

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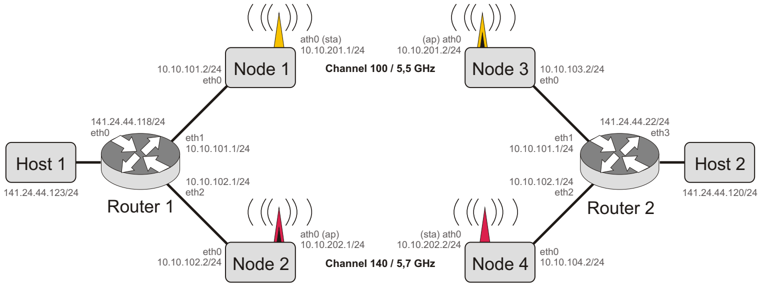
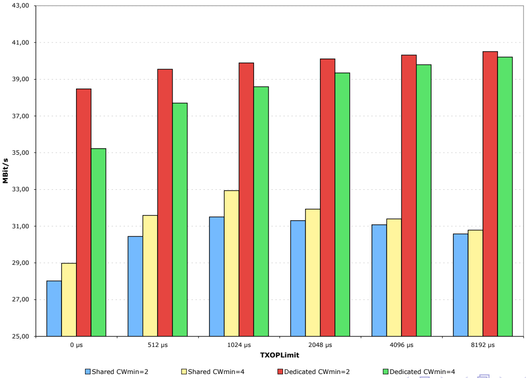
TXOPLimit can be maximized (8192μs).



Second WLAN link for full-duplex traffic flows

Measurements using an unidirectional TCP-stream...
The throughput improvement caused by the direction differentiation is about 40,4% (25,7% compared to a optimized shared channel).



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- ACK Congestion Control

1. Motivation and Background
2. Overview on IEEE 802.11, 11e, 11n
   - IEEE 802.11 Basic Access Method
   - IEEE 802.11e Quality-of-Service
   - IEEE 802.11n Frame Aggregation
   - IEEE 802.11 Long-range links
   - IEEE 802.11e/n Throughput and Delay
3. Performance Optimizations
   - Optimization of a point-to-point link
   - Second WLAN link for full-duplex traffic flows
4. Conclusion and Prospect
   - Conclusion
   - Prospect on future work

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- Using a second WLAN channel and separating the direction of the traffic flows can result in a dramatic throughput and delay improvement especially for TCP flows.

  (up to 40%/26% for unidirectional TCP flows; ACK Prioritization 5,2% for bidirectional TCP flows).

Prospect on future work

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- First tests look promising. Expect more in the near future.

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Questions?