On trains and wagons: switching variable length packets in slotted OPS

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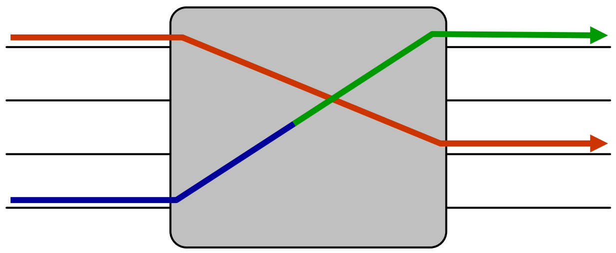
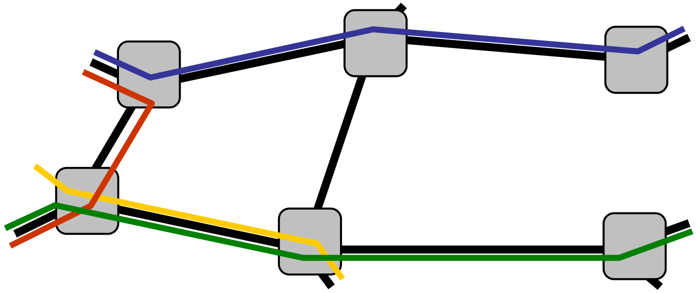
Outline

- Intro
- Slotted variable length packets
- Switch architecture
- Performance criteria
- Simulation set-up
- Trains or wagons?
  - influence of load
  - influence of granularity
  - service differentiation
- Conclusions

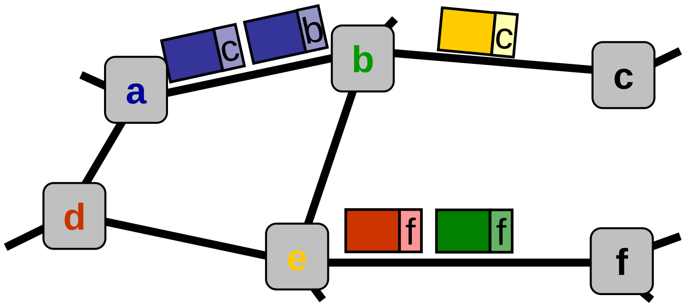
- Optical switching:
  - direct light from an input port to an output port
  - possibly wavelength conversion



- circuit-switching:
  - continuous bit-stream
  - pre-established light-paths
  - set-up: “manually” or automatic

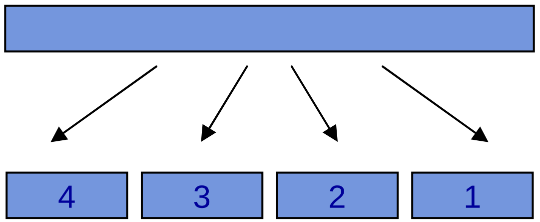


- packet/burst switching
  - chunks of bits, encapsulated in packets
  - packet header determines forwarding
  - e.g. label switching, GMPLS based

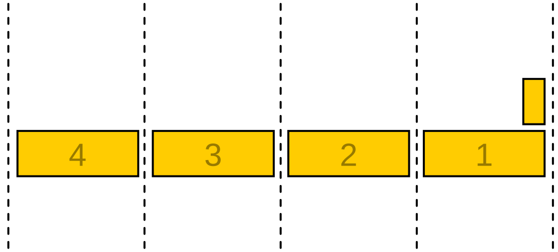


Variable length packets in OPS

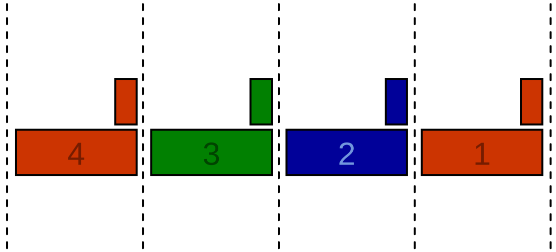
- Segmentation & reassembly:
  - chop variable length packets into OPS slots
  - calls for extra S&R info in header
  - S&R functionality resides at edges



- "Trains or wagons":
  - trains: treat train as a whole
    - S&R trivial since wagons are kept together and in sequence
    - only a single header, i.e. minimal control overhead

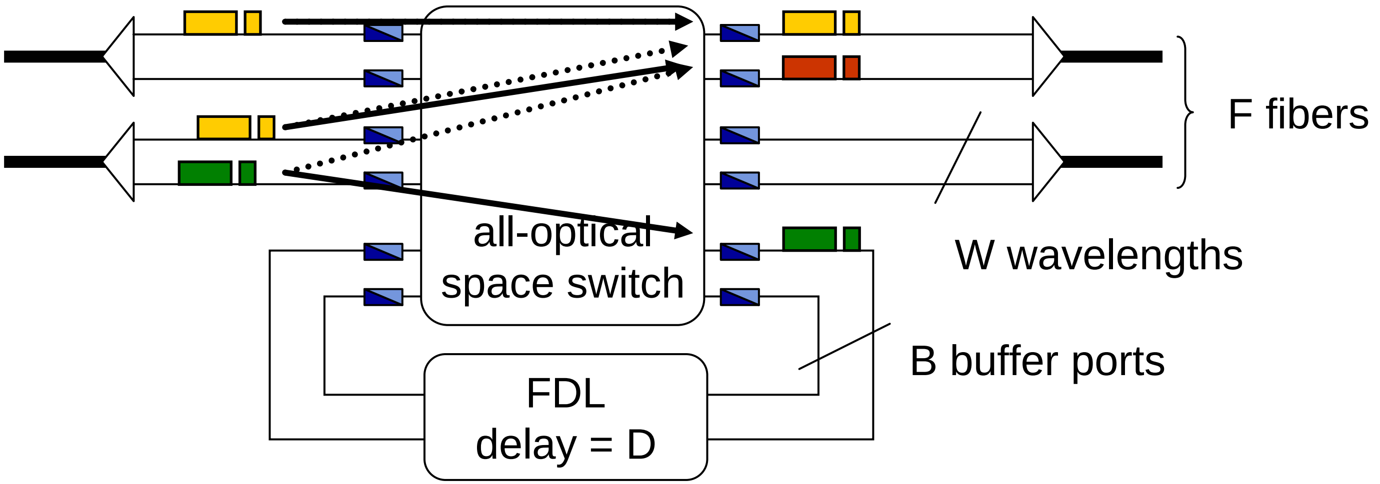


  - wagons: treat each wagon individually
    - simpler scheduling algorithms



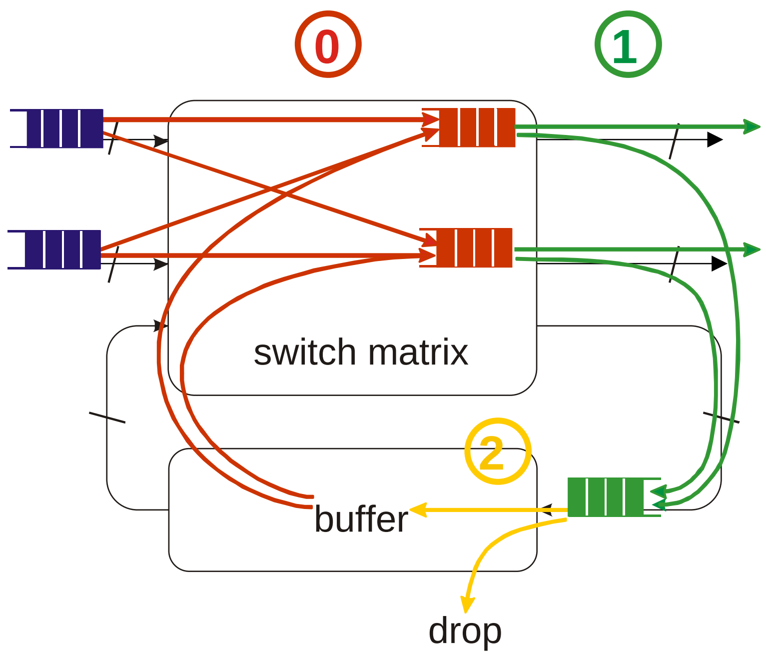
Switch Architecture

- Node in core OPS network (backbone)
- Switch functionality:
  - slotted operation
  - WDM ports
  - fully non-blocking switching matrix (SOA based)
  - wavelength conversion to solve contention
  - FDLs to provide buffering



Scheduling

- Scheduling: each timeslot:
  - (0) collect packets (from inputs + FDLs) per destination output port
  - (1) select packets for **forwarding** along outgoing fibres;
  - (2) elect packets for **buffering** from excess packets; drop remaining packets



Simulation set-up

- Parameters:
  - F=6 input/output fibres
  - W=8 wavelengths per i/o fibre
  - B=0..8 recirculating buffer ports
  - D=2L delay in buffer
  - L=1.5…20 wagons per train (average)

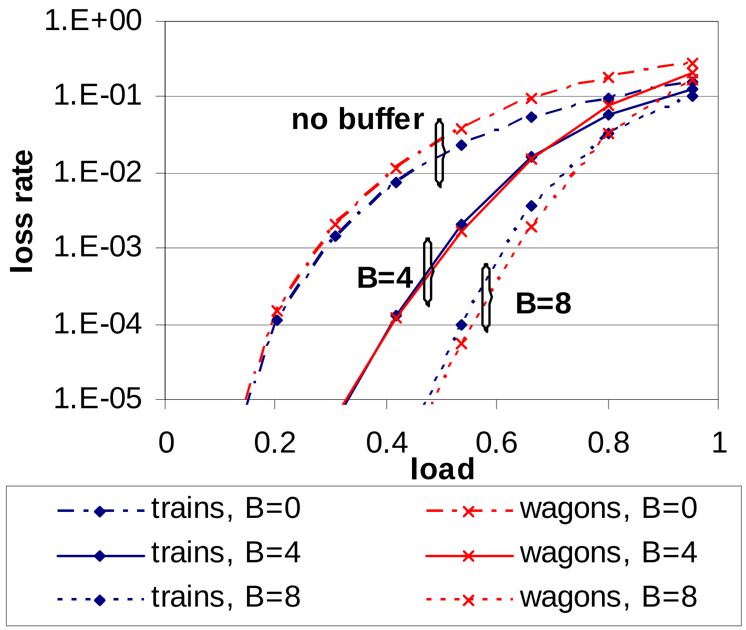
- Traffic model:
  - train length: neg. exponential distribution rounded to slot length
  - train inter-arrival: Poisson process

Performance criteria

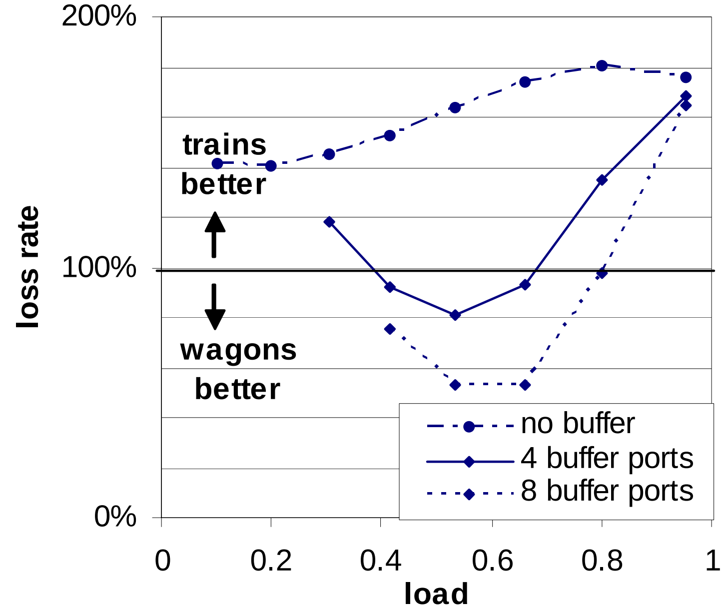
- (byte) loss rate:
  - amount of data lost / amount of data sent
  - main indicator of service quality for end user
- delay:
  - of secondary importance
    (delay in OPS switches only small fraction of end-to-end delay)
- fairness:
  - large trains should not be discriminated against
- service differentiation:
  - the scheduling mechanism should allow for efficient class of service differentiation

Influence of load (1)

loss rate

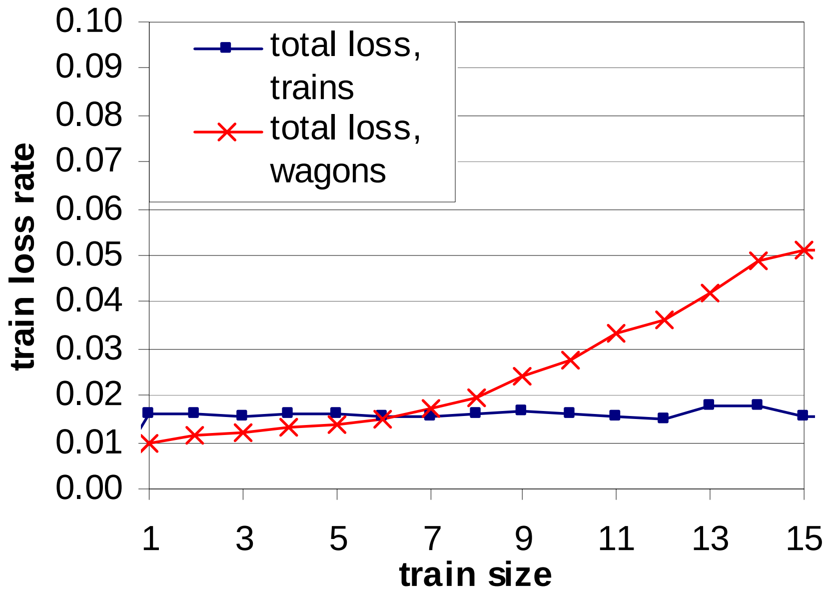


loss wagons / loss trains



- no buffer: trains better
  - wagon approach results in losing parts of multiple overlapping trains
- with buffer: wagons can be better for medium loads
  - buffer allows to store wagons for multiple overlapping trains; wagon-approach allows to exploit buffer more efficiently than train approach

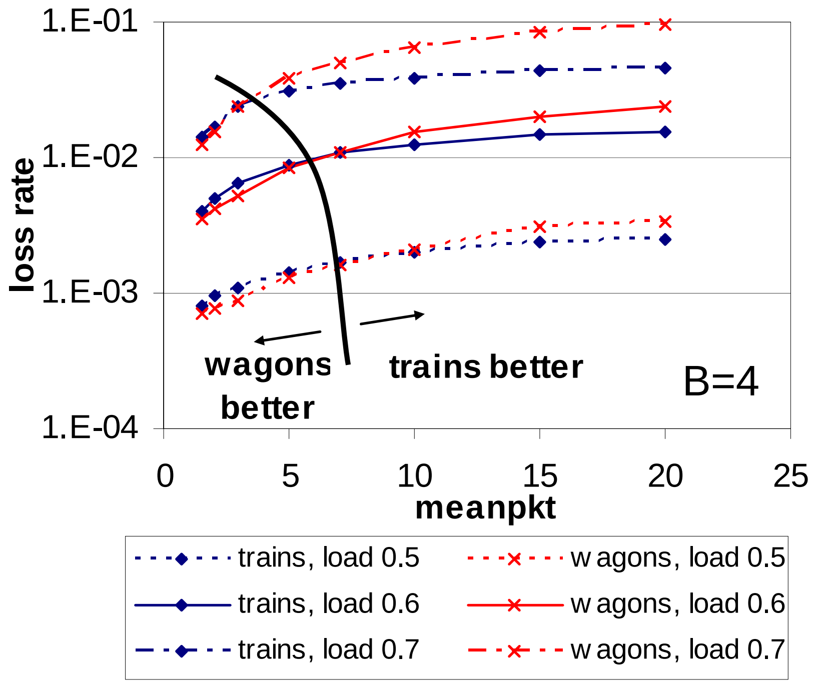
Influence of load (2)



- fairness:
  - wagon approach seriously discriminates against longer trains

- **wagons can reach lower overall loss rate if sufficient buffer, and for medium load, but at the price of more unfairness (and possibly higher delays)**

Influence of granularity



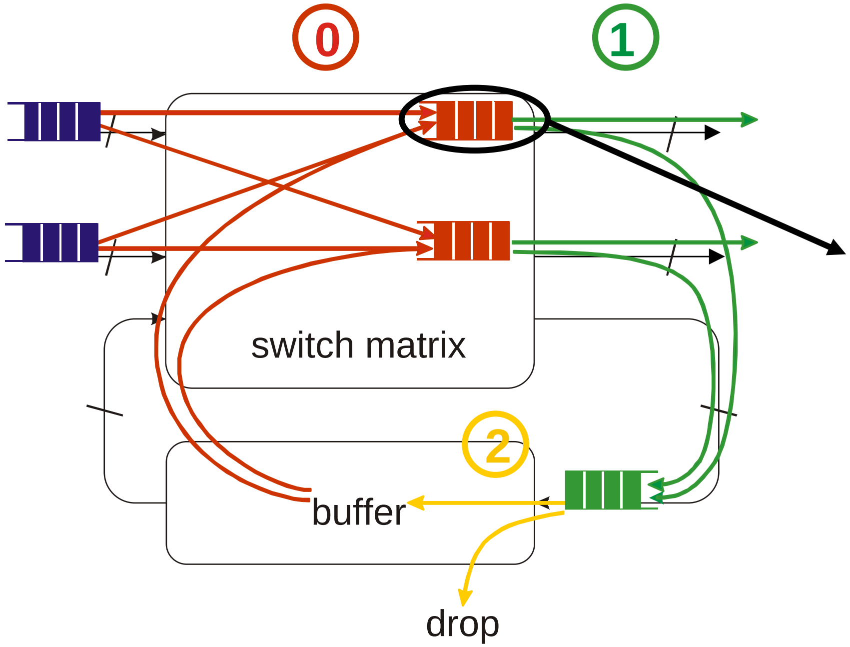
- granularity:
  - performance of trains/wagons depends on ratio train length and OPS slot length

- **wagon approach better if trains are short**
  (cross-over point shifts to slightly larger lengths for lower loads)

Service differentiation (1)

- Scheduling: each timeslot:
  - **(0)** collect packets (from inputs + FDLs) per destination output port
  - **(1)** select packets for **forwarding** along outgoing fibres;
  - **(2)** elect packets for **buffering** from excess packets; drop remaining packets

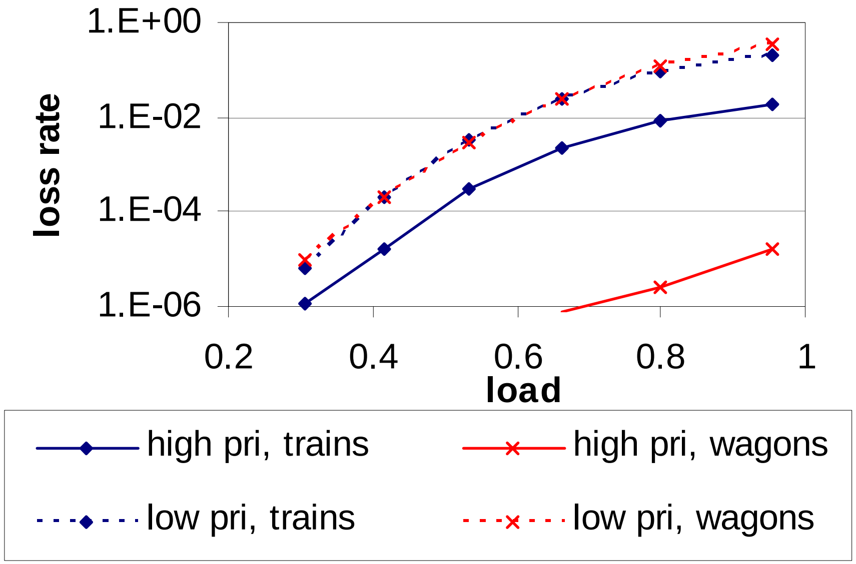
⇒ **simple priority mechanism: first high priority packets**



"priority queue":
1) first higher priority packets;
2) same priority: first "oldest"
3) same timestamp: random (uniform over same pri and tstamp)

tstamp = when packet enters switch

Service differentiation (2)



- service differentiation:
  - train approach does not allow strong service differentiation with a simple differentiation mechanism without preemption of earlier arrived low priority trains

- **wagon approach achieves strong separation with very simple differentiation mechanism**

Conclusions

- wagon approach is advantageous…
  - …to achieve strong service differentiation
  - …to achieve lower overall loss for medium loads *if there is a buffer*
  - …to slightly reduce average delay *when load is limited*

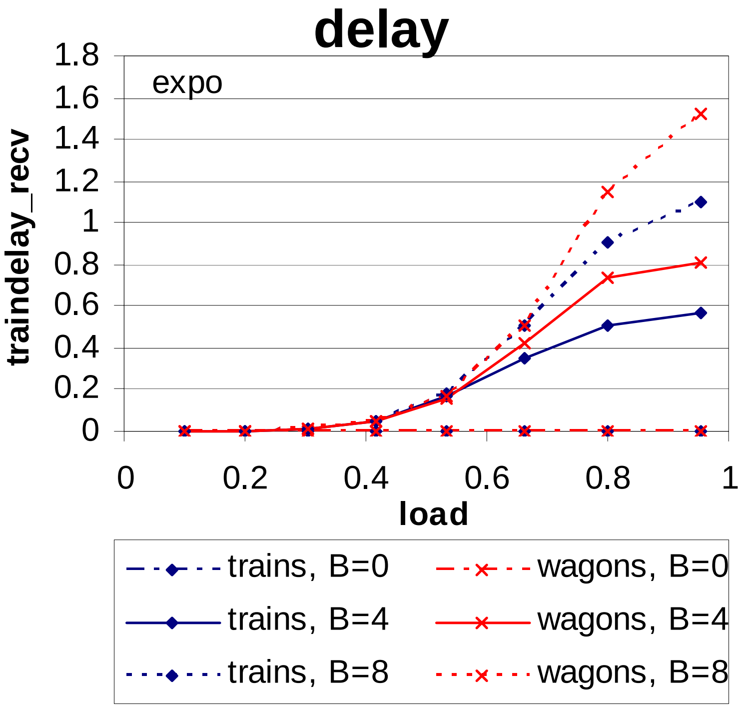
- … but at the price of
  - …stronger discrimination against long trains
  - …increased control overhead (header information + higher load on scheduler)

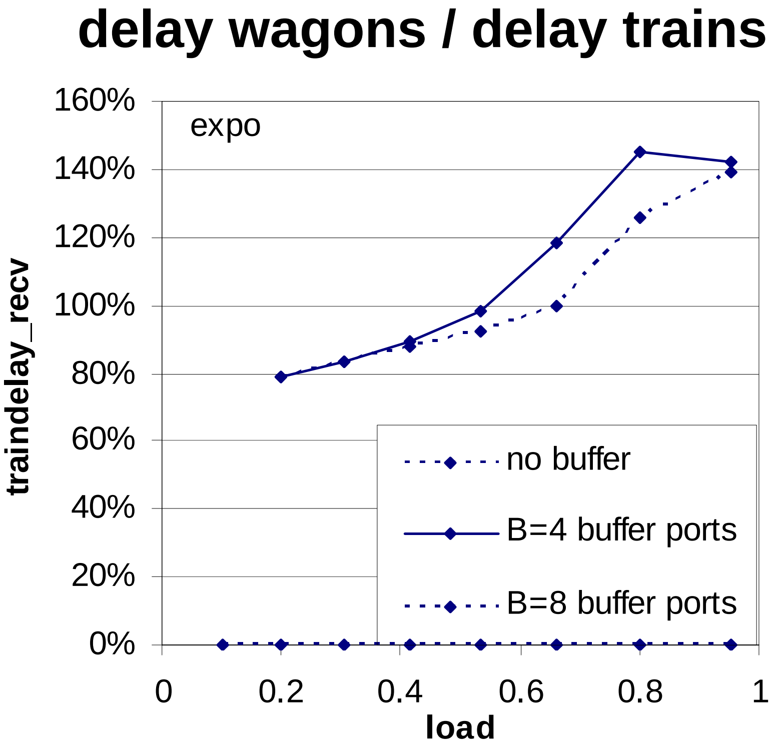
That’s all, folks!

… thanks for your attention

… any questions?

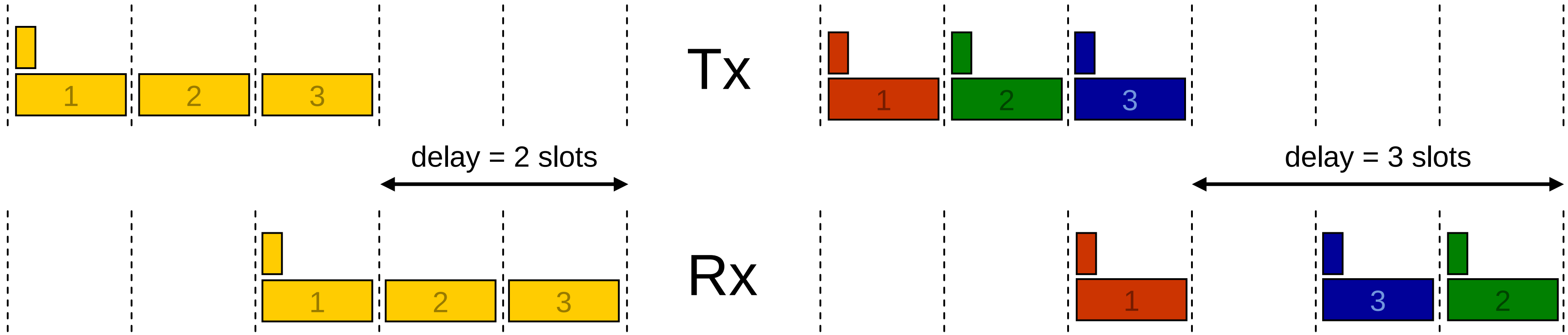
Influence of load (3)





- low loads: wagon approach has slightly lower delays
  - only a few of the train's wagons need to be buffered, whereas the train approach buffers complete trains (thus also the last wagon)
- high loads: train approach has lower *average* delays
  - in wagon approach under high loads, the chance of having trains with no buffered wagons is substantially reduced

Delay measurement



- delay:
  - delay induced by buffering
  - time elapsed between end of transmission of packet and completion of its reception
- we account for possible re-ordering (with wagon approach)