



# Towards Understanding TCP Performance on LTE/EPC Mobile Networks

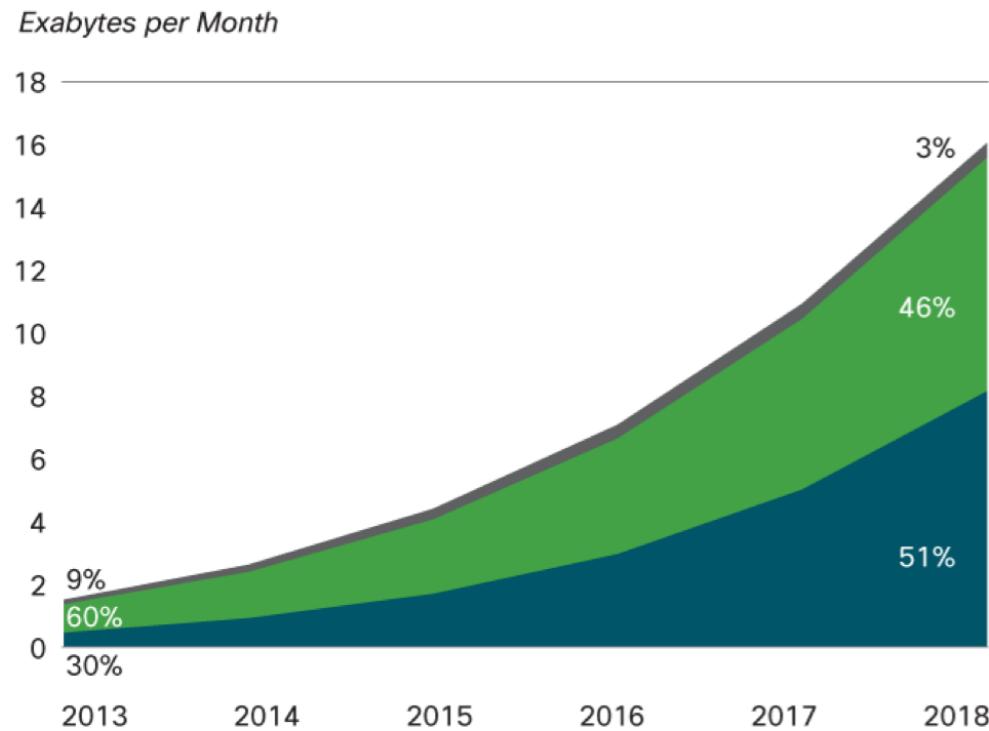
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Aman Shaikh<sup>2</sup>, and Jacobus (Kobus) Van der Merwe<sup>1</sup>**

<sup>1</sup>School of Computing, University of Utah

<sup>2</sup>AT&T Labs - Research

# Motivation

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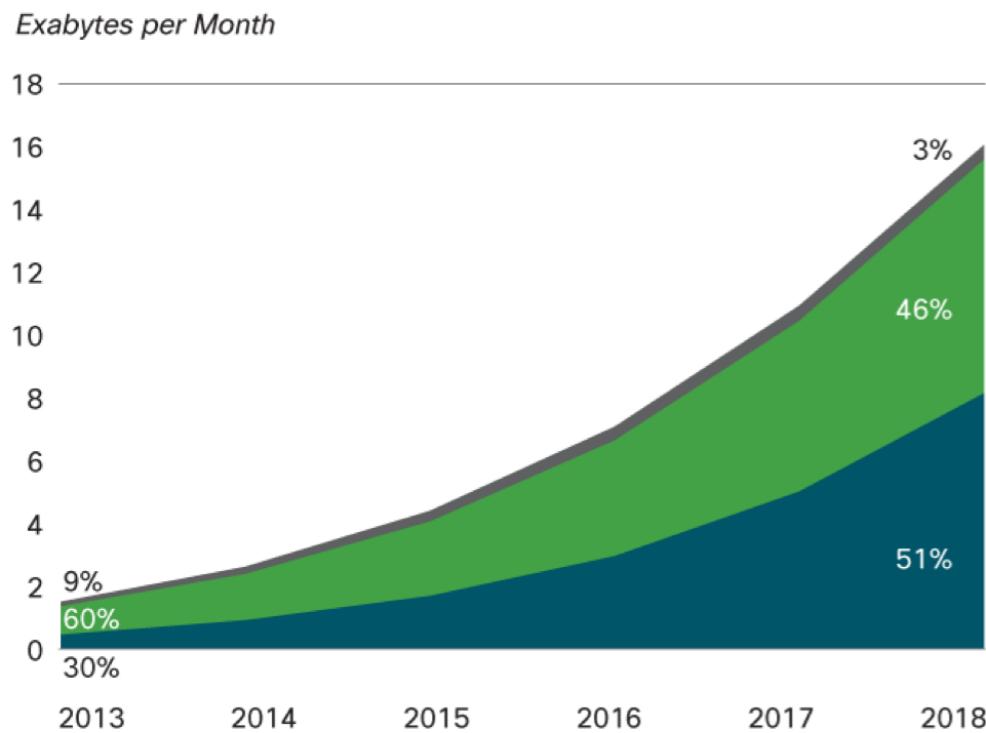


“4G traffic will be more than *half* of the total mobile traffic by 2018.”

“In 2013,..., they (4G-connections) already account for **30 percent** of mobile data traffic”

Source: Cisco VNI Mobile, 2014

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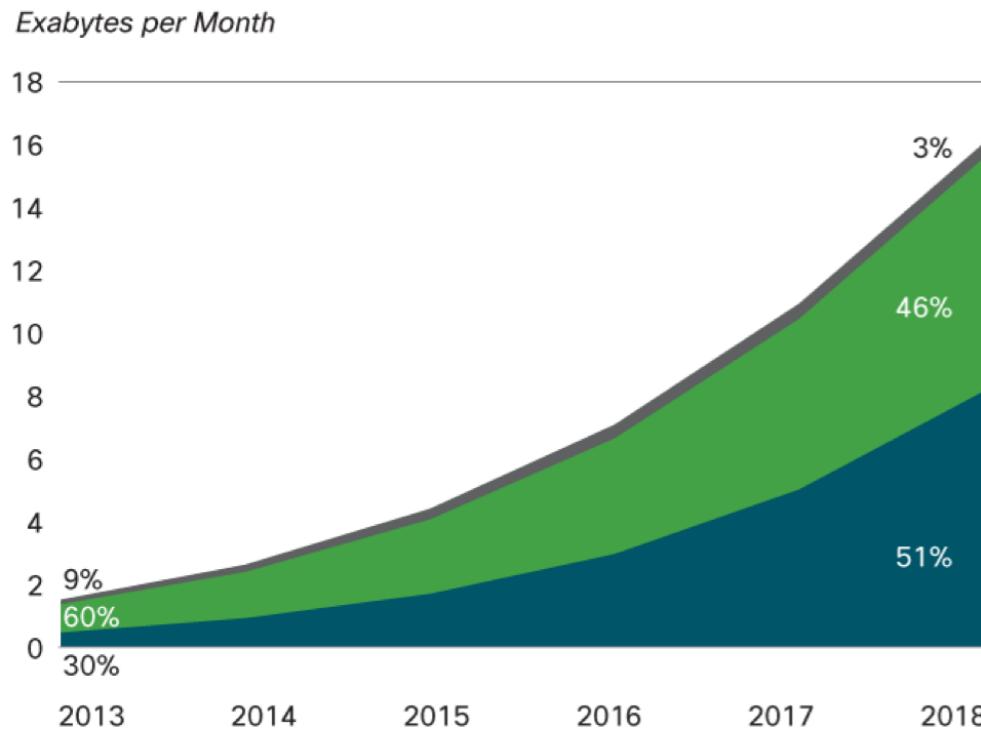


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- Does TCP work well in LTE/EPC networks?
  - TCP only utilize 50% of the available bandwidth in cellular networks (Huang et al. SIGCOMM’ 13)
  - SPDY is not faster in cellular networks because of the interaction between TCP with cellular networks (Erman et al. CoNEXT’ 13)

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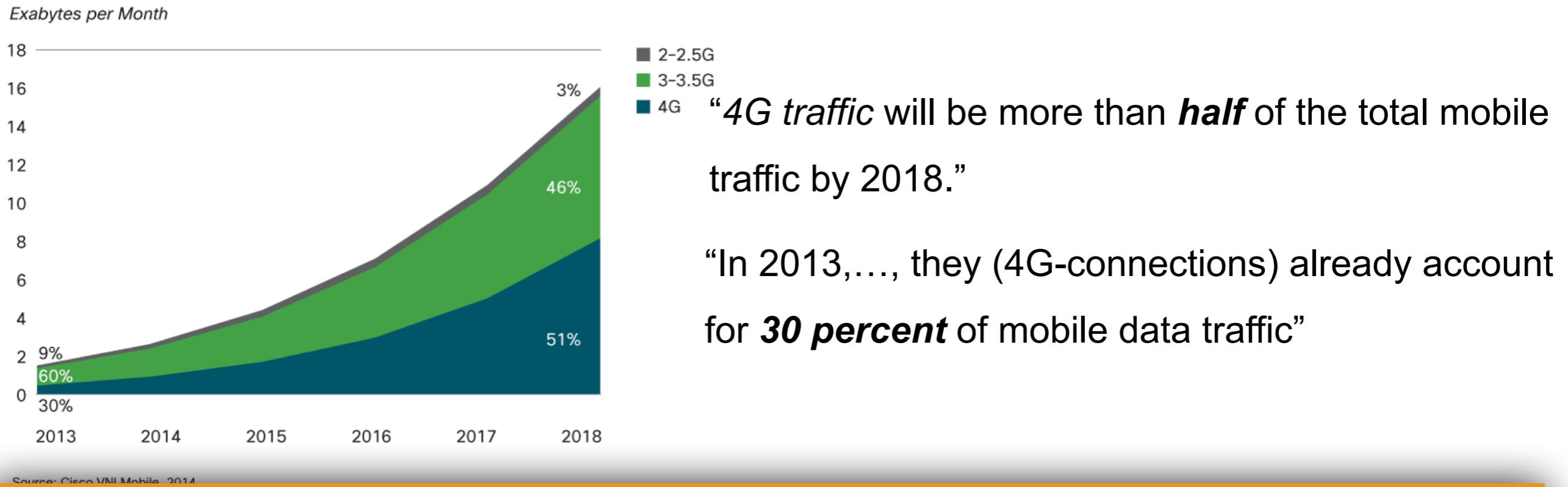


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- Treat the cellular network as a *black-box*.
  - *Speculate* the root causes of performance problems.

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We look “*under the hood*” to answer: **how cellular specific events impact TCP’s performance?**

between TCP with cellular networks (Ermak et al. CONEXT ’15)

- Treat the cellular network as a *black-box*.
- *Speculate* the root causes of performance problems.

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  - Seamless handover.
  - Lossless handover.

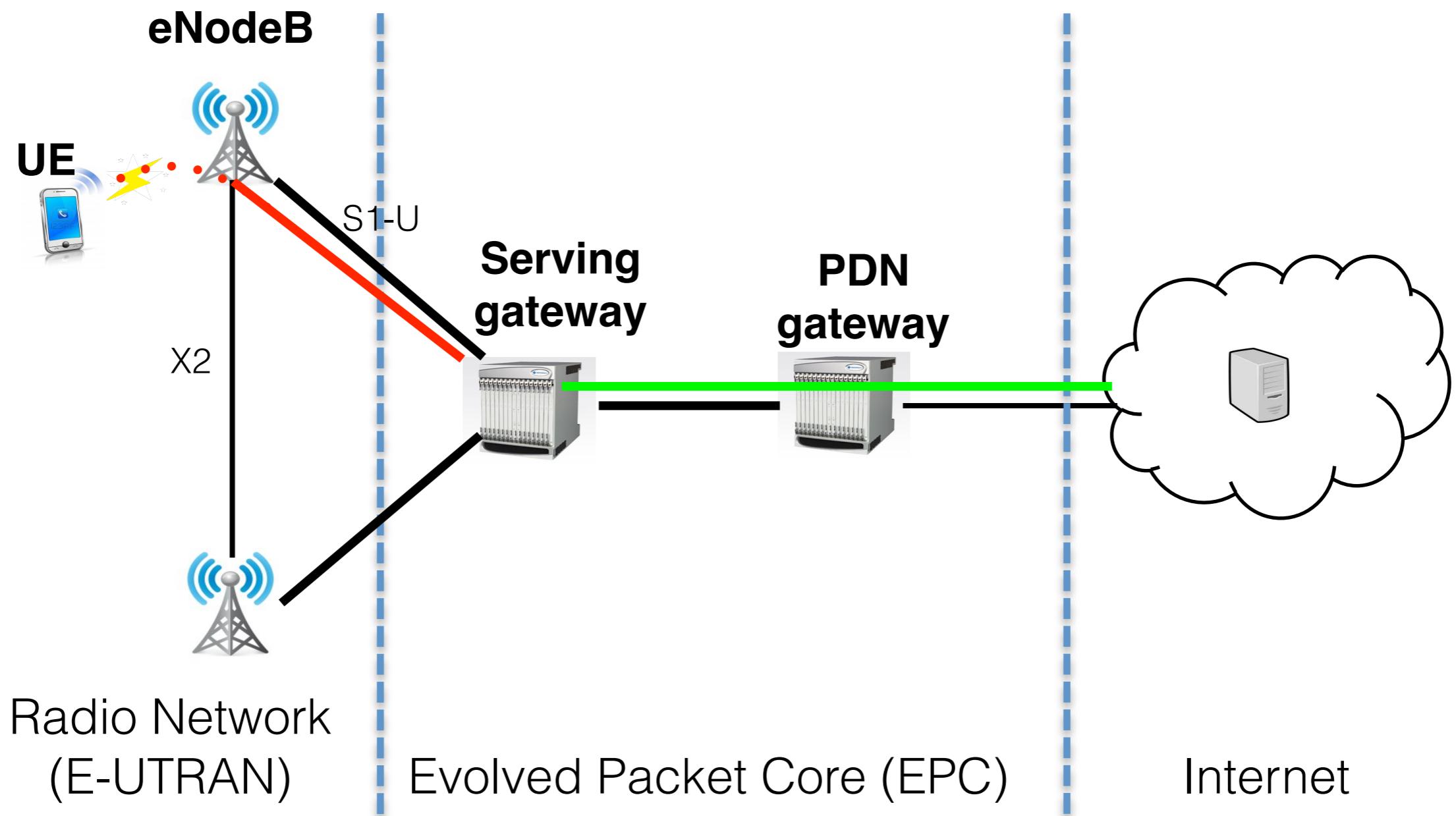
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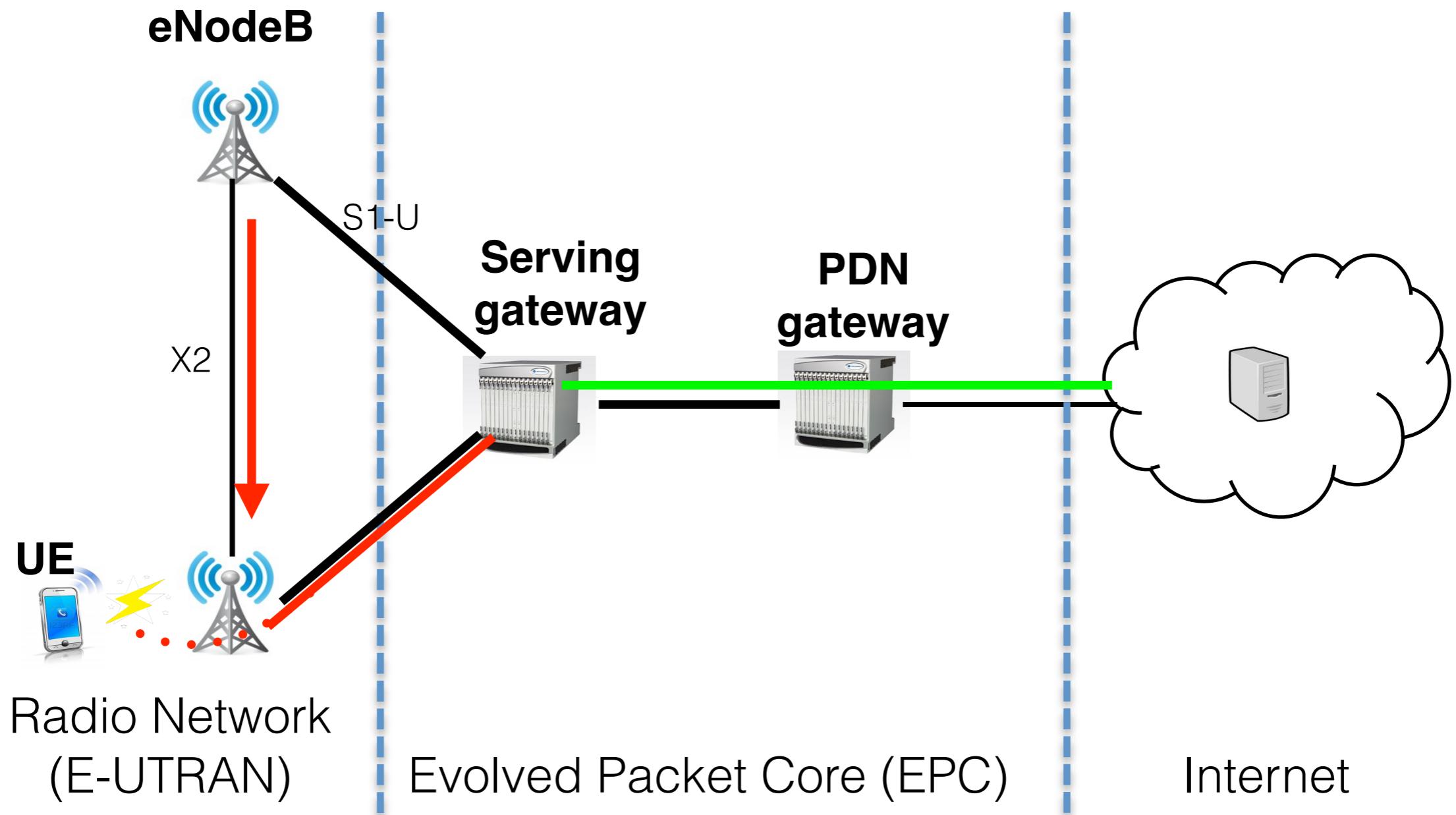
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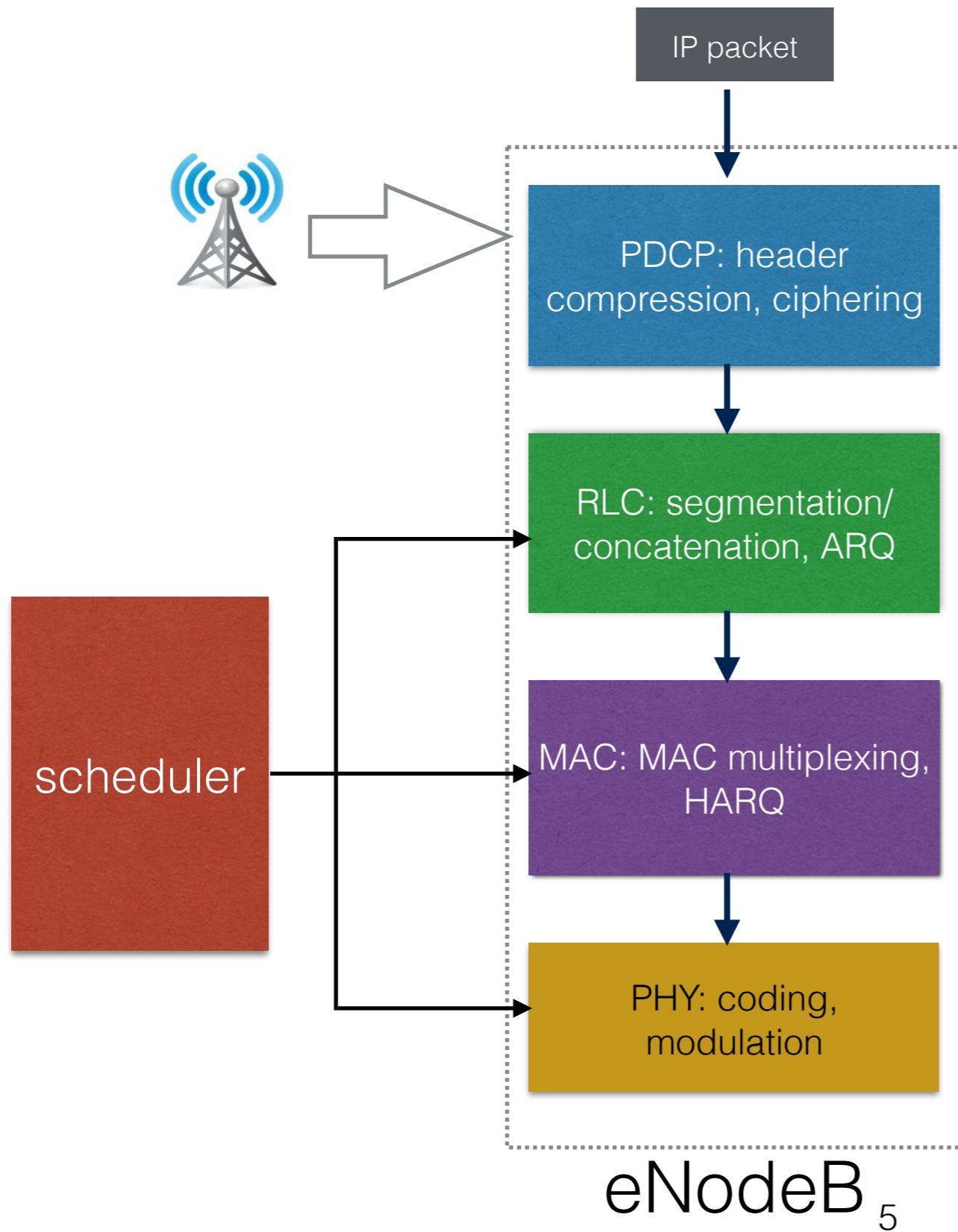
# LTE/EPC network architecture



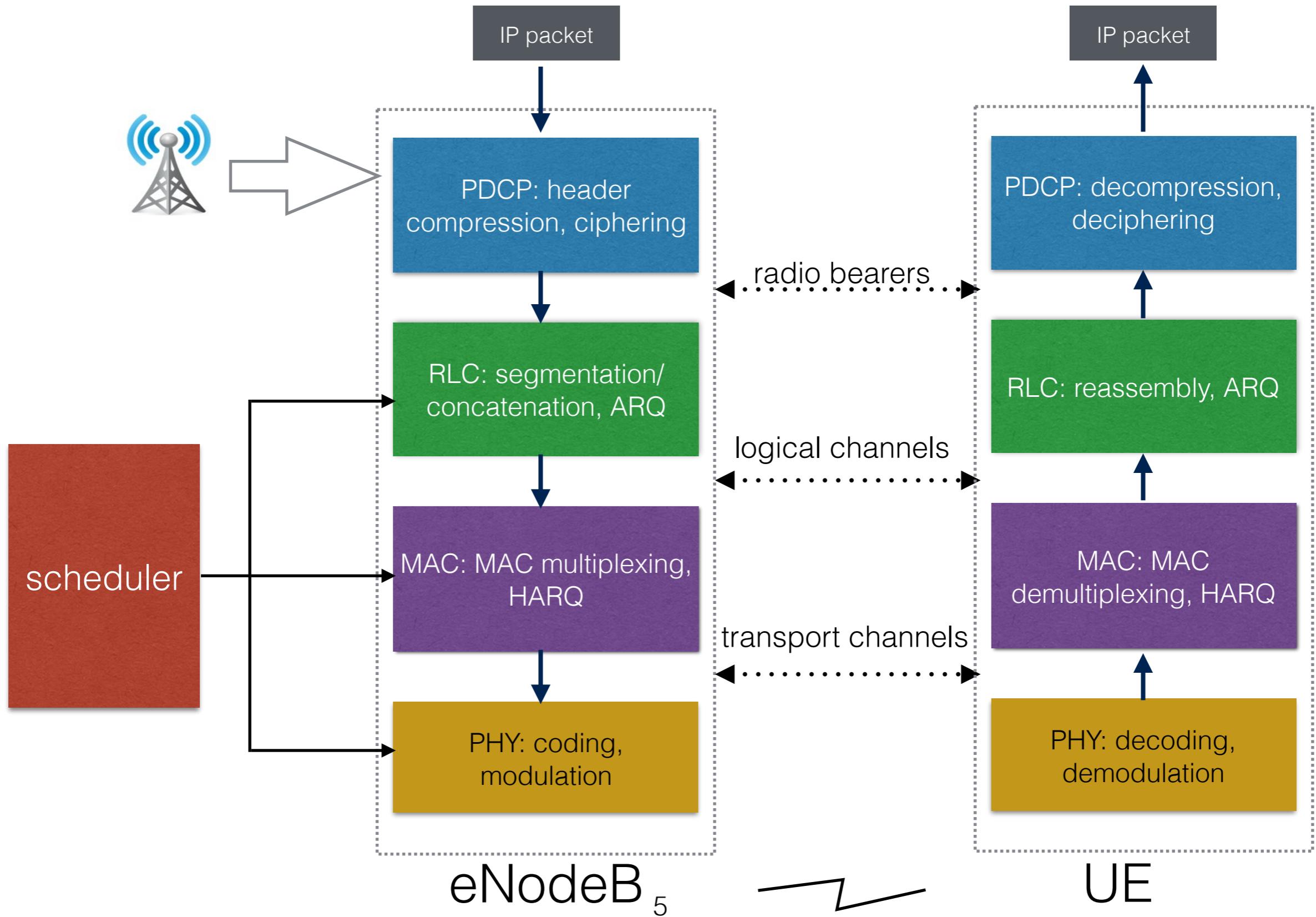
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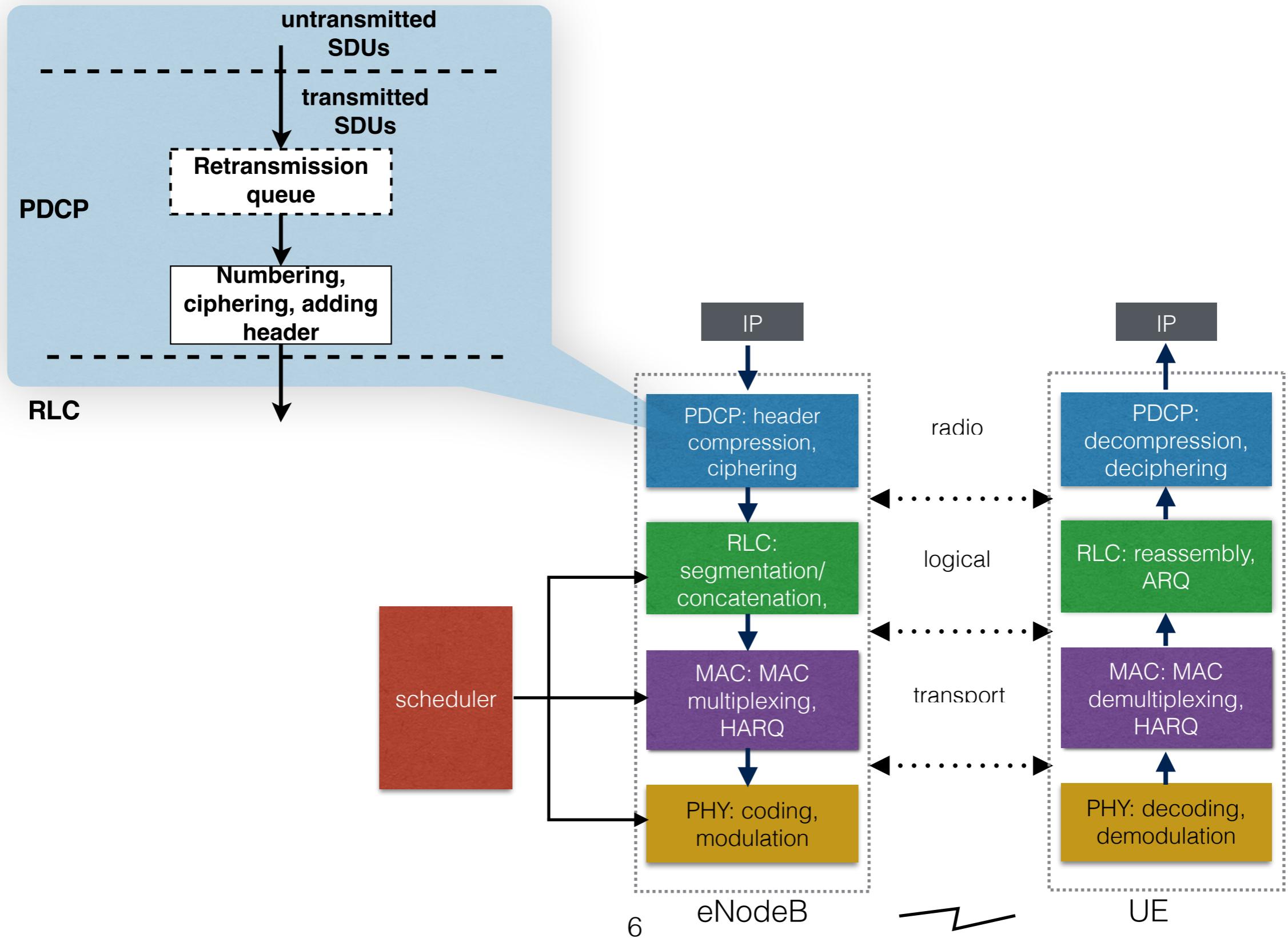
# LTE stack



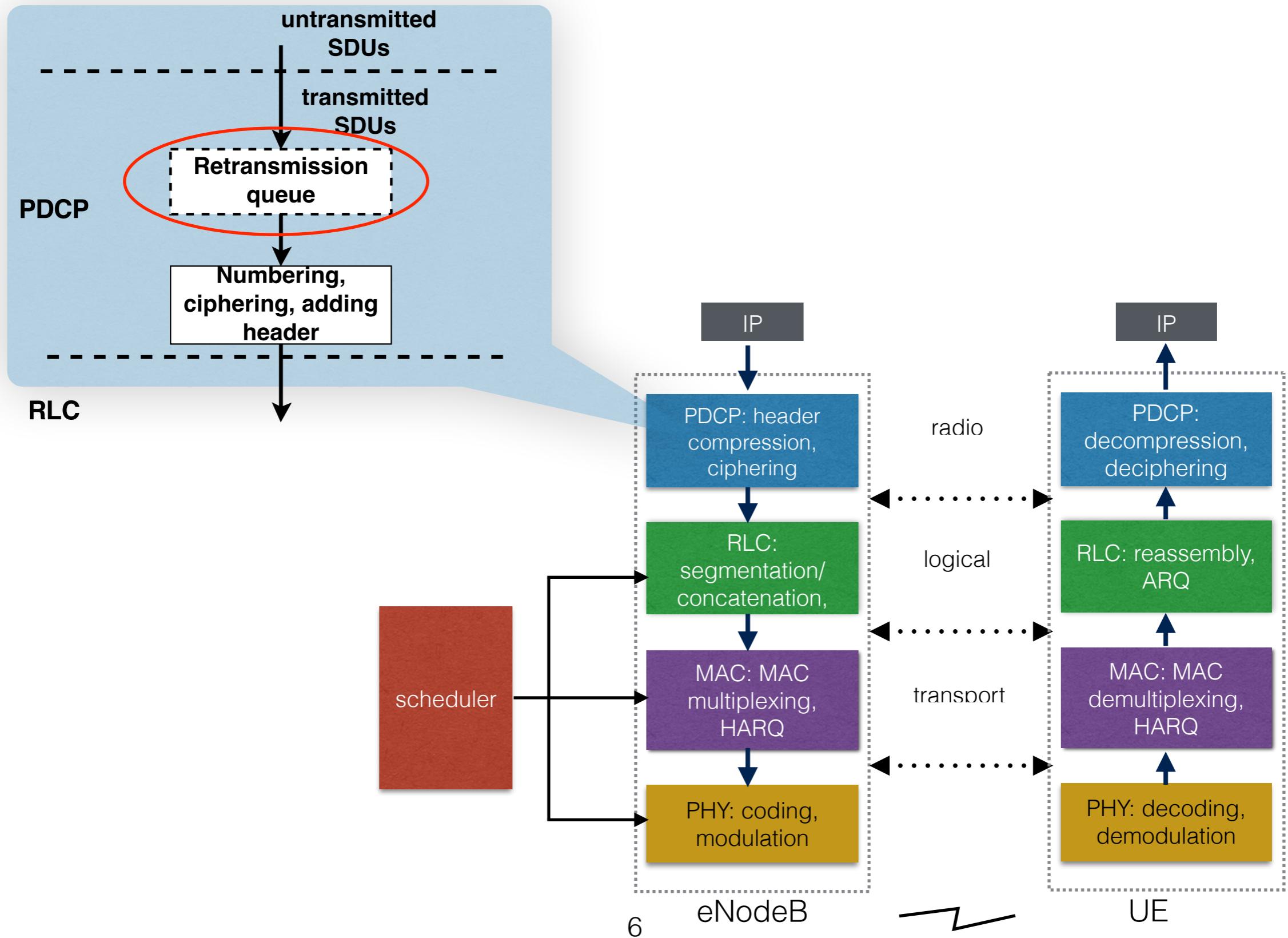
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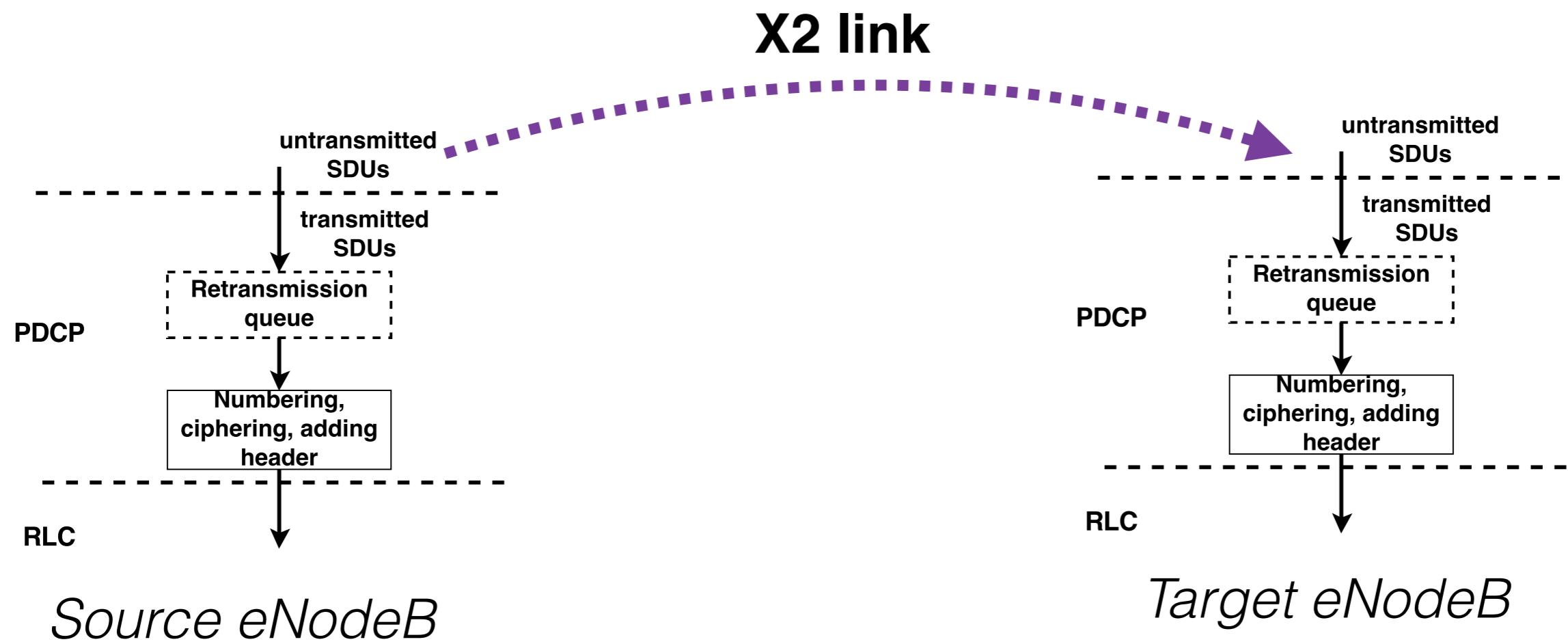
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# PDCP seamless handover

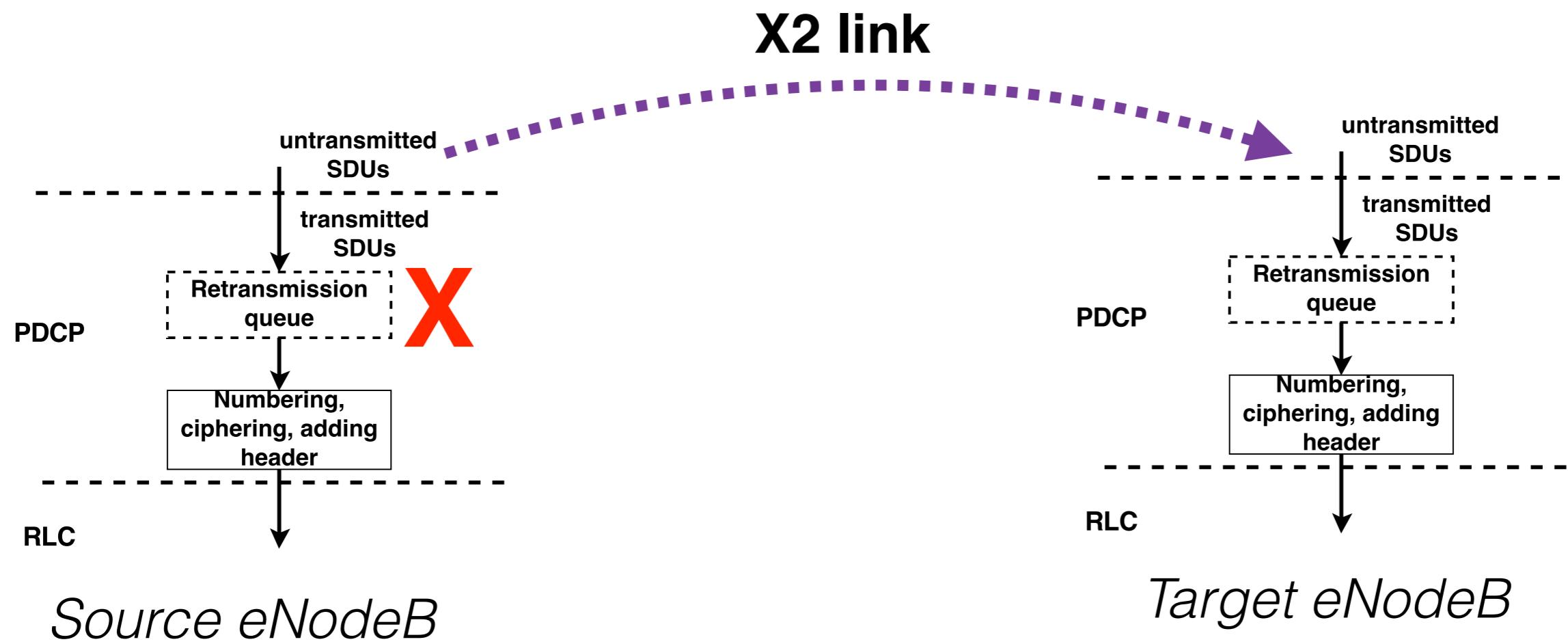


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- SDUs in the retransmission queue *are discarded*.

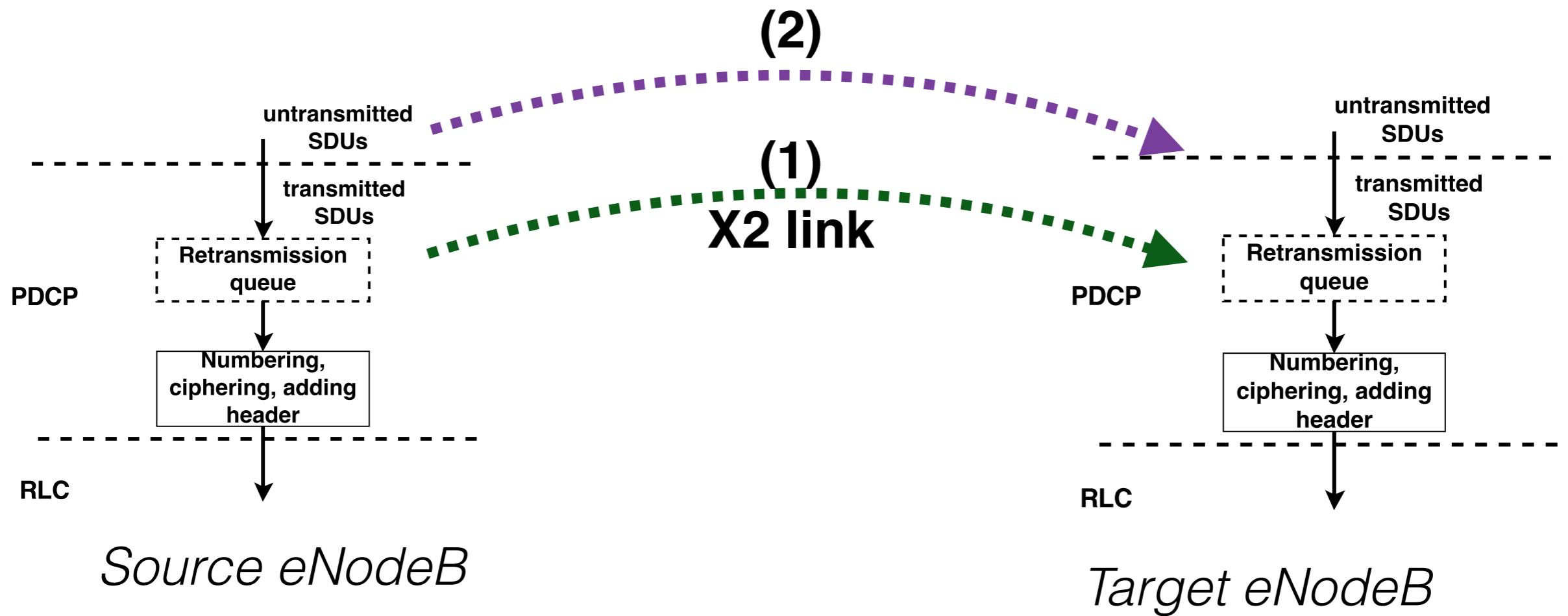
# PDCP lossless handover



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- *Both un-transmitted SDUs and SDUs in the retransmission queue are forwarded to the target eNodeB via the X2 link.*

# Methodology



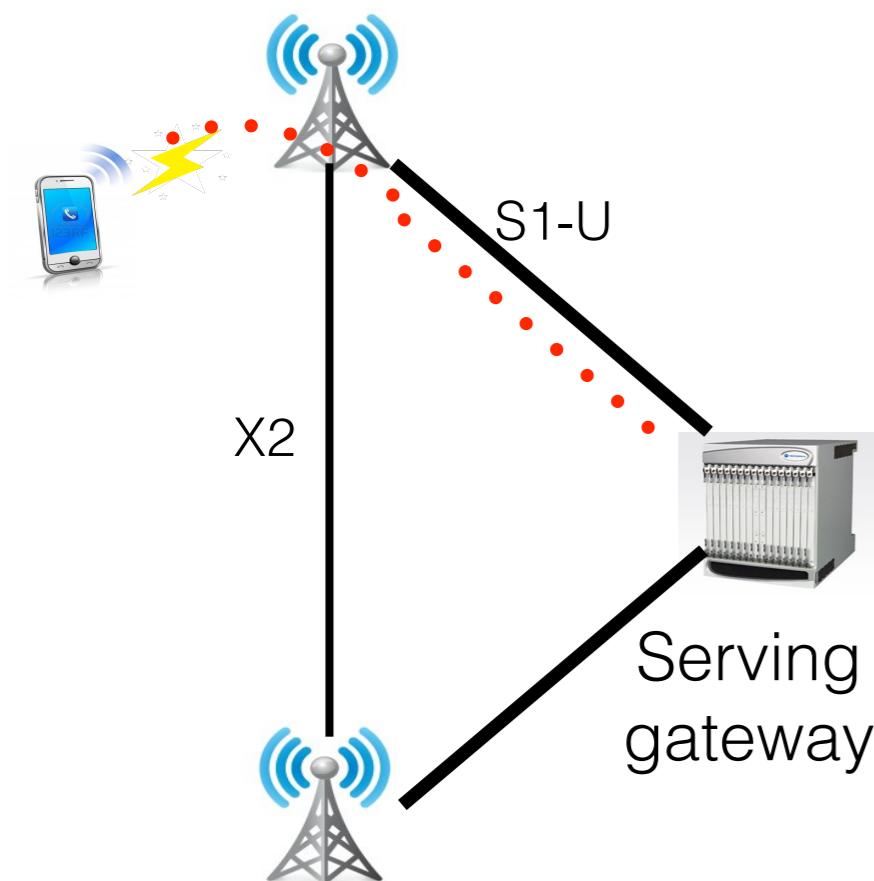
- Use simulations (NS-3) for better controls and modifications.
- Real network stack: Linux v2.6.26 with TCP CUBIC.
- Workload: downlink bulk-transfer TCP application.

# Modifications to NS3

- Radio Link Control Acknowledged Mode (RLC AM).
- Lossless handover according to 3GPP TS 36.323 2009.
- Retrieving TCP parameters from the Network Simulation Cradle (NSC) integration.

# Scenario 1: PDCP handovers

*source eNB*

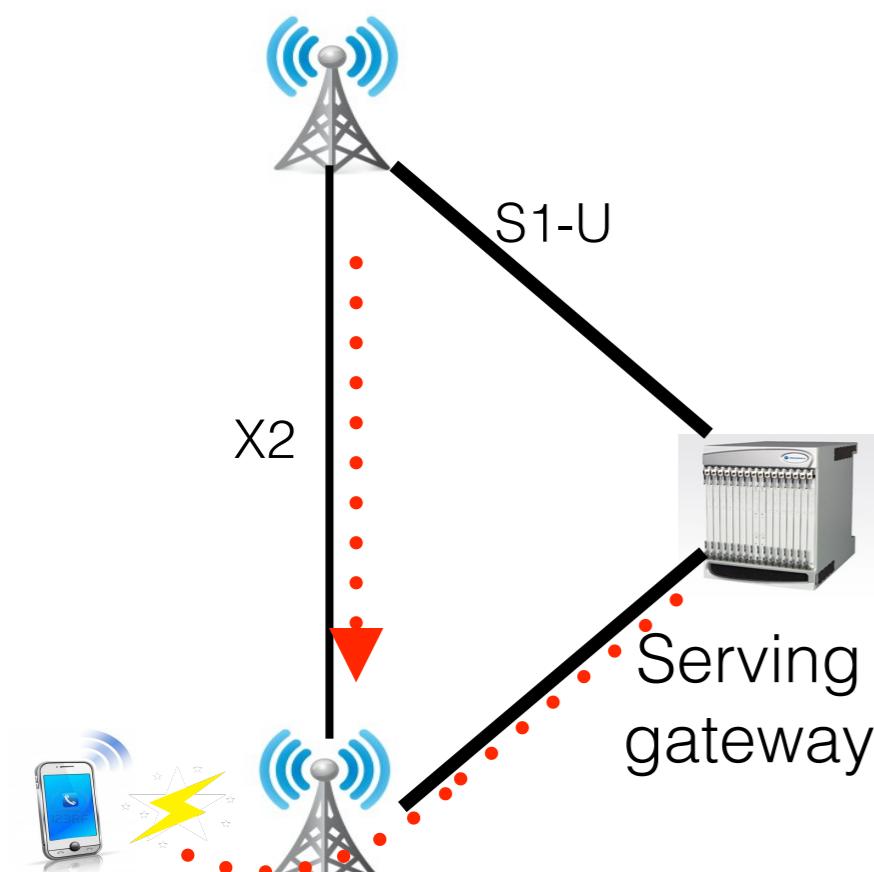


*target eNB*

- Source eNB - target eNB: 750m.
- X2 interface: 6ms delay.
- UE's velocity: normal distribution with mean 40 km/h, variance 5 km/h.
- PDCP retransmission queue size: 64KB to 4096KB.

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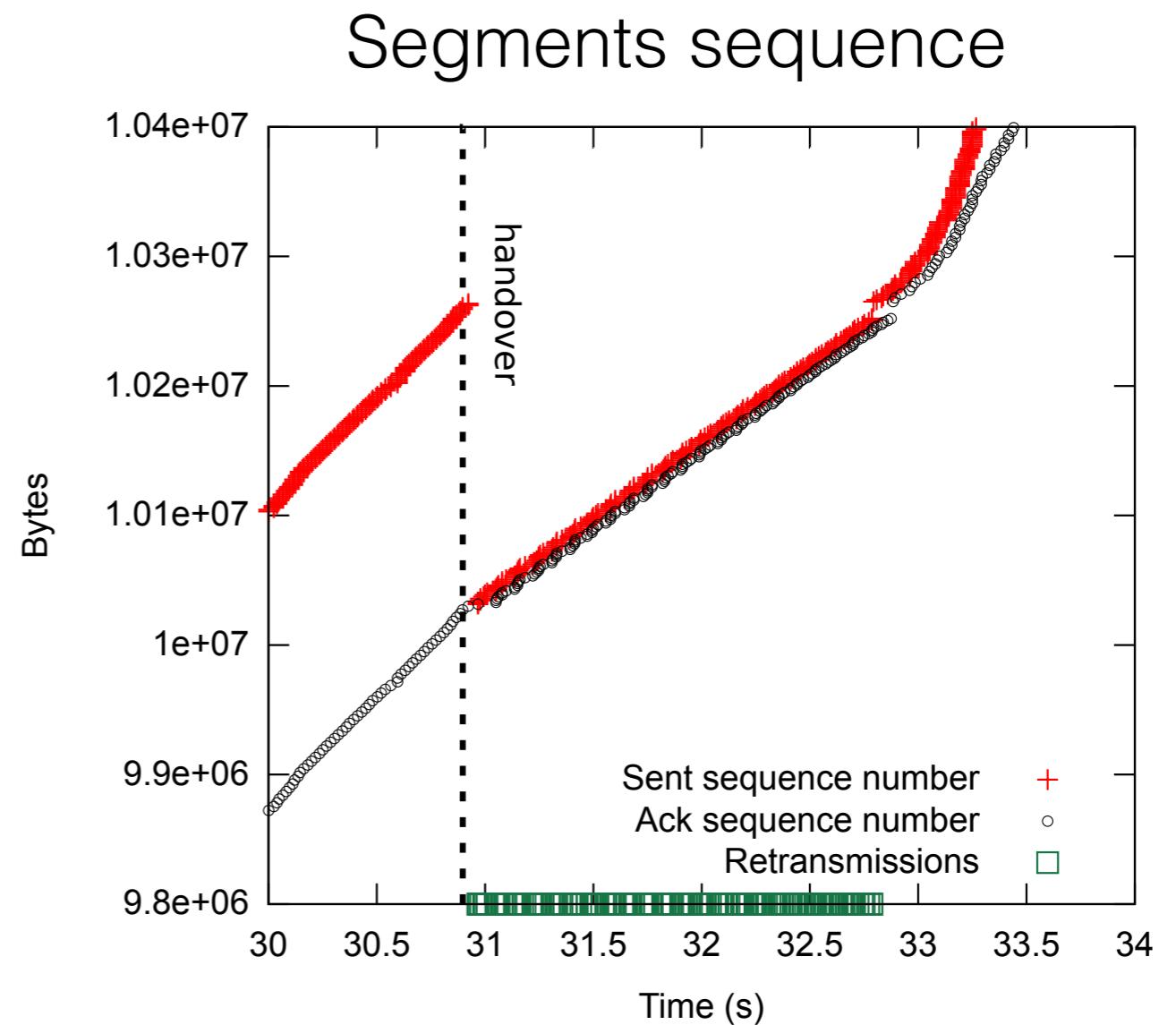
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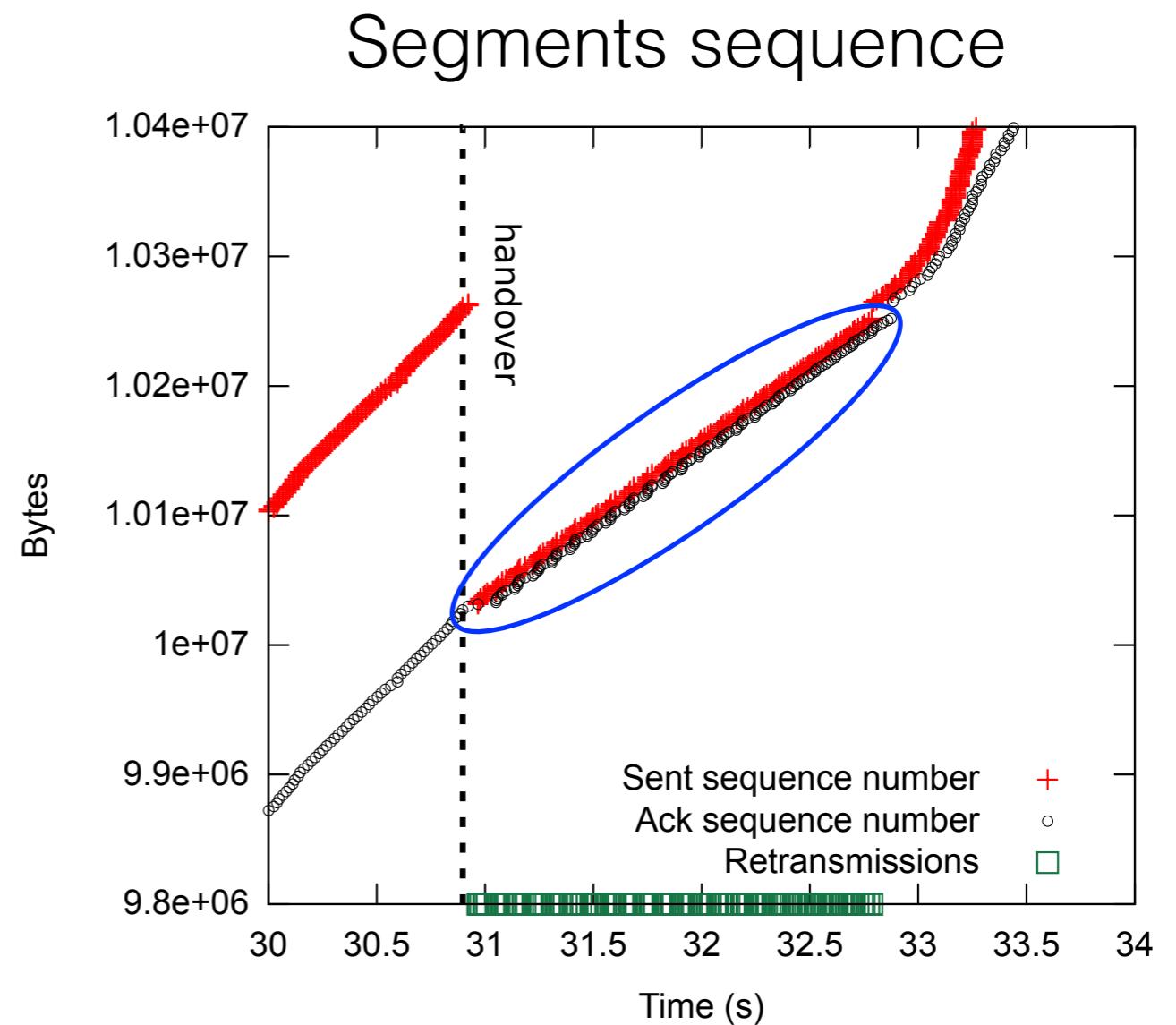
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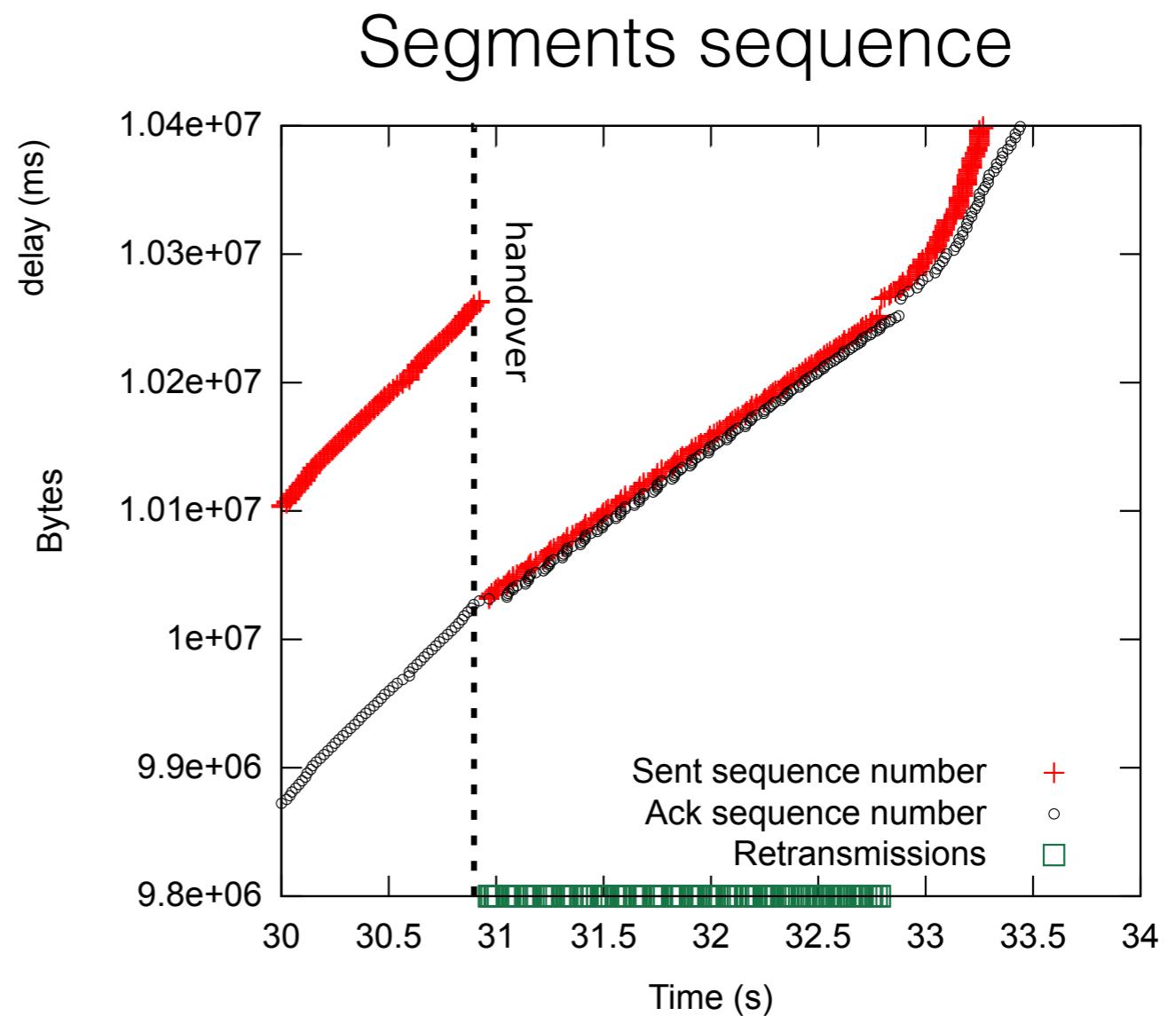
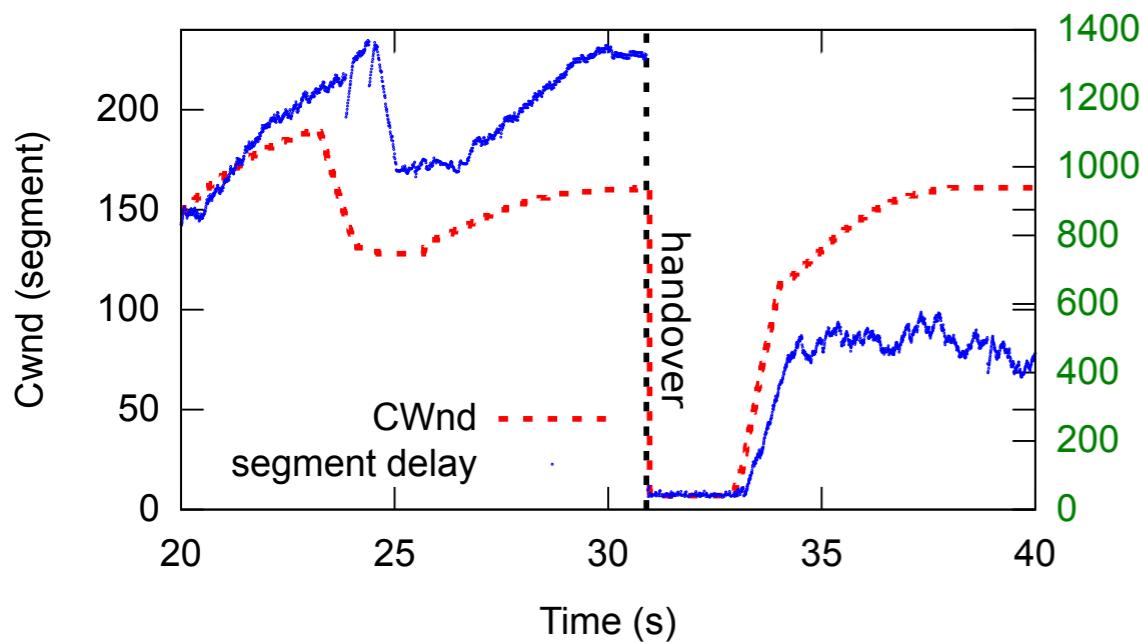


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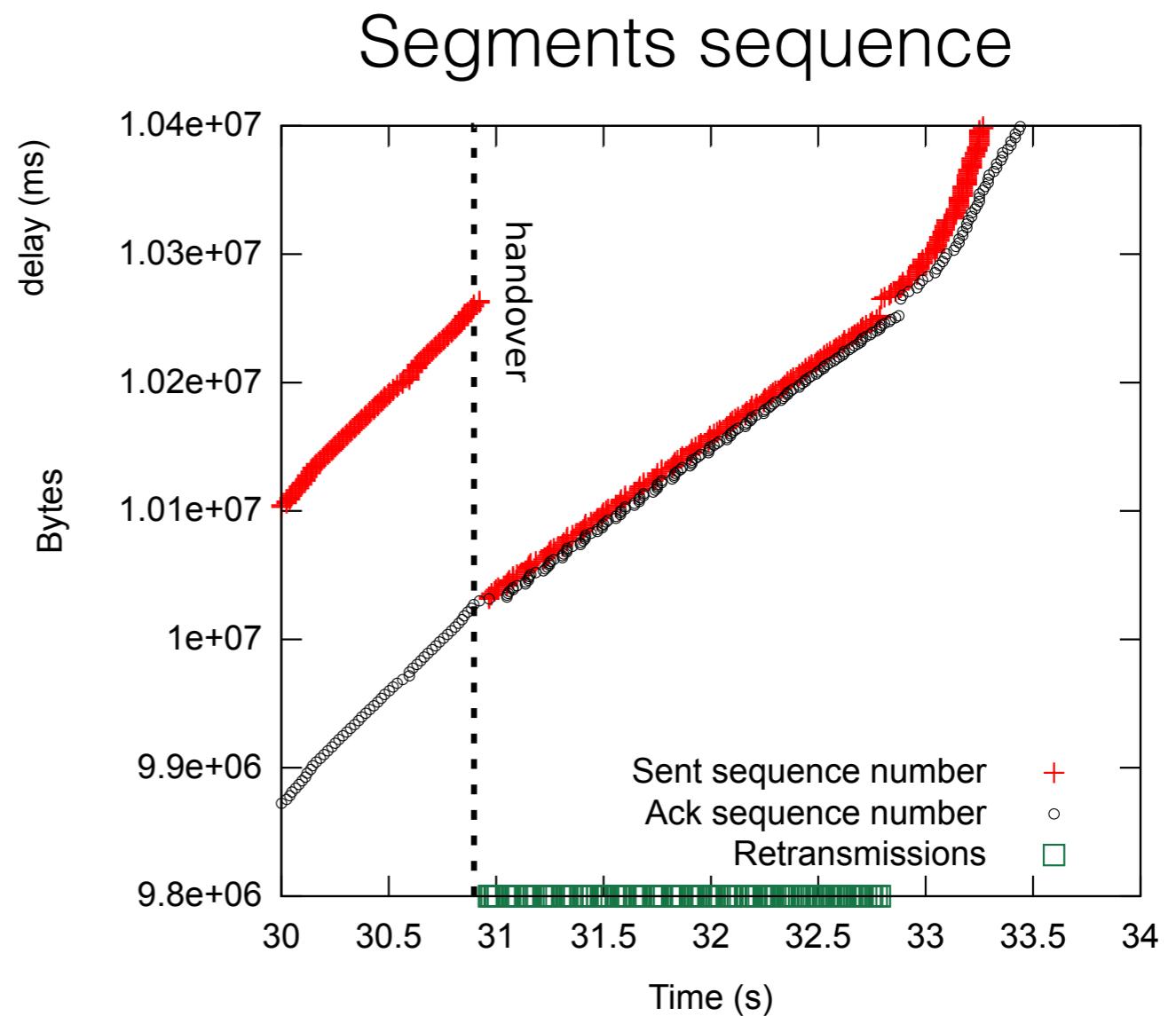
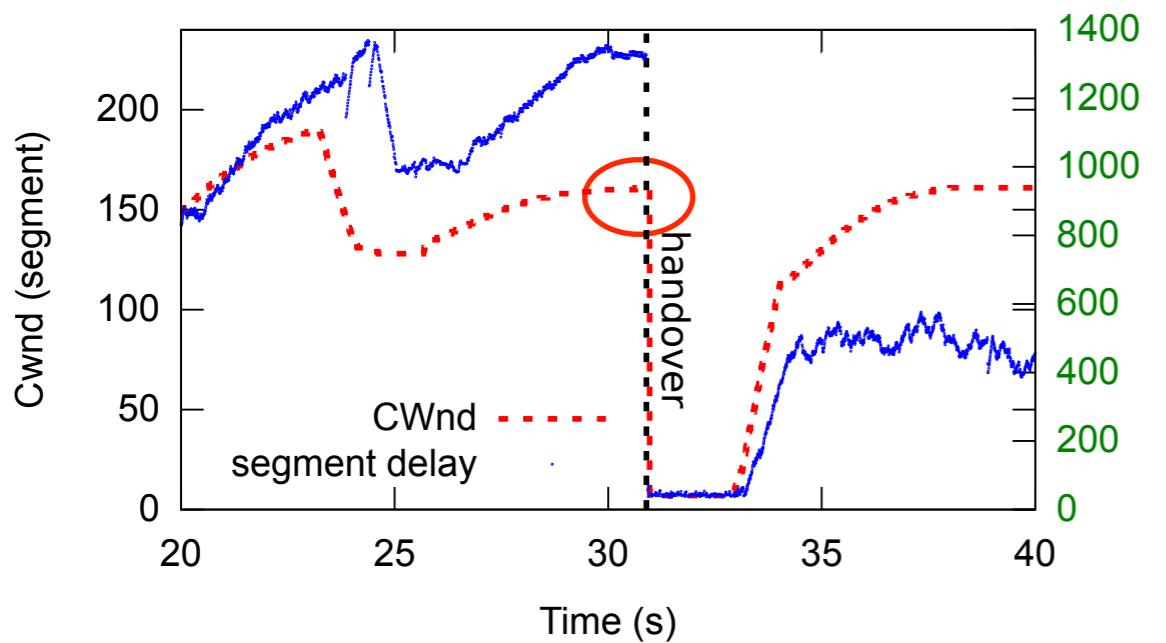
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Congestion window  
and throughput



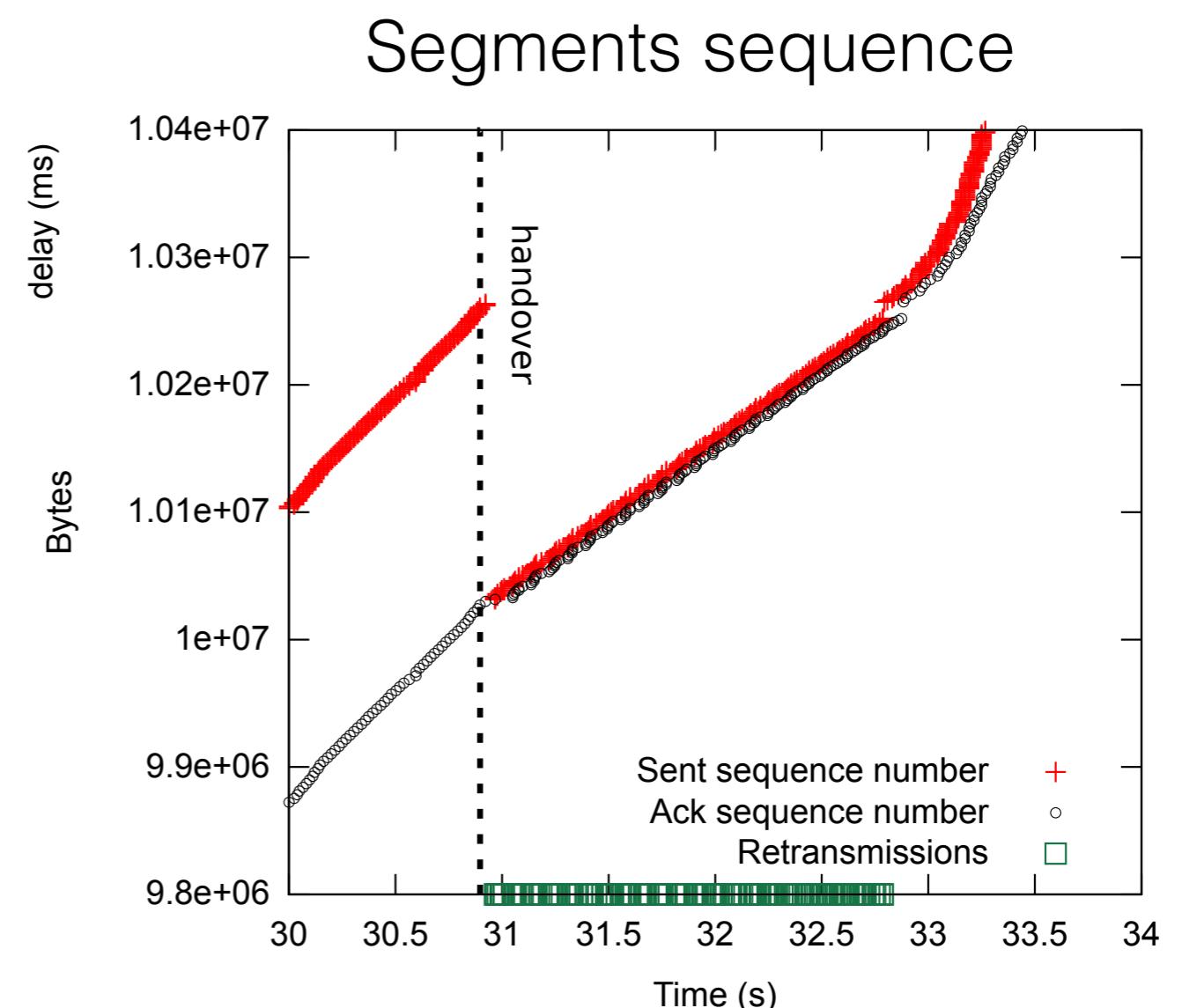
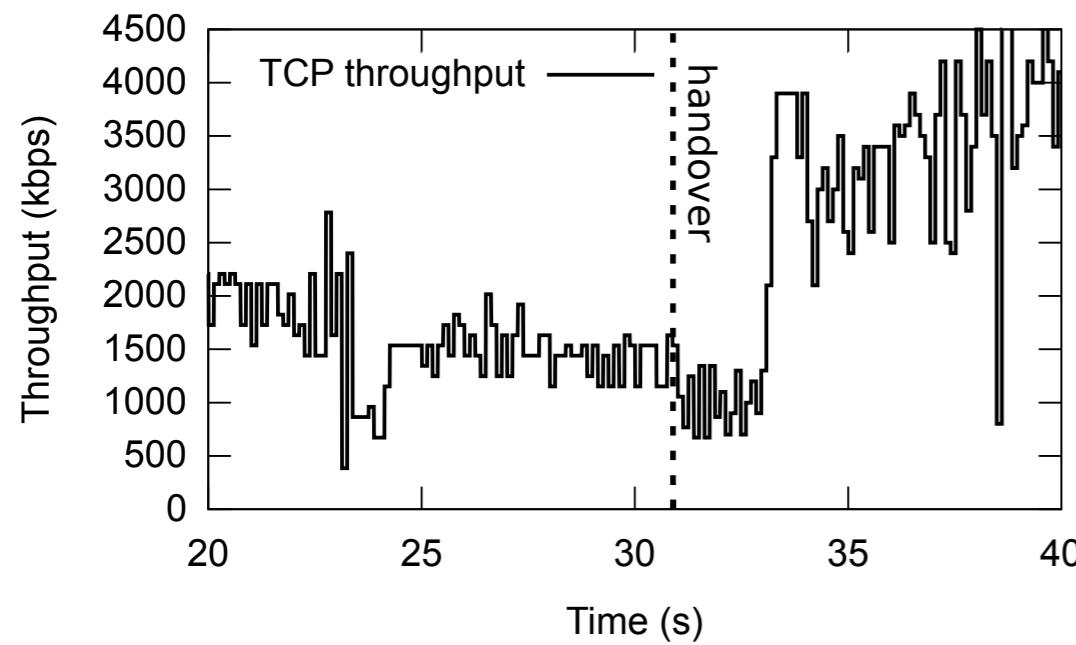
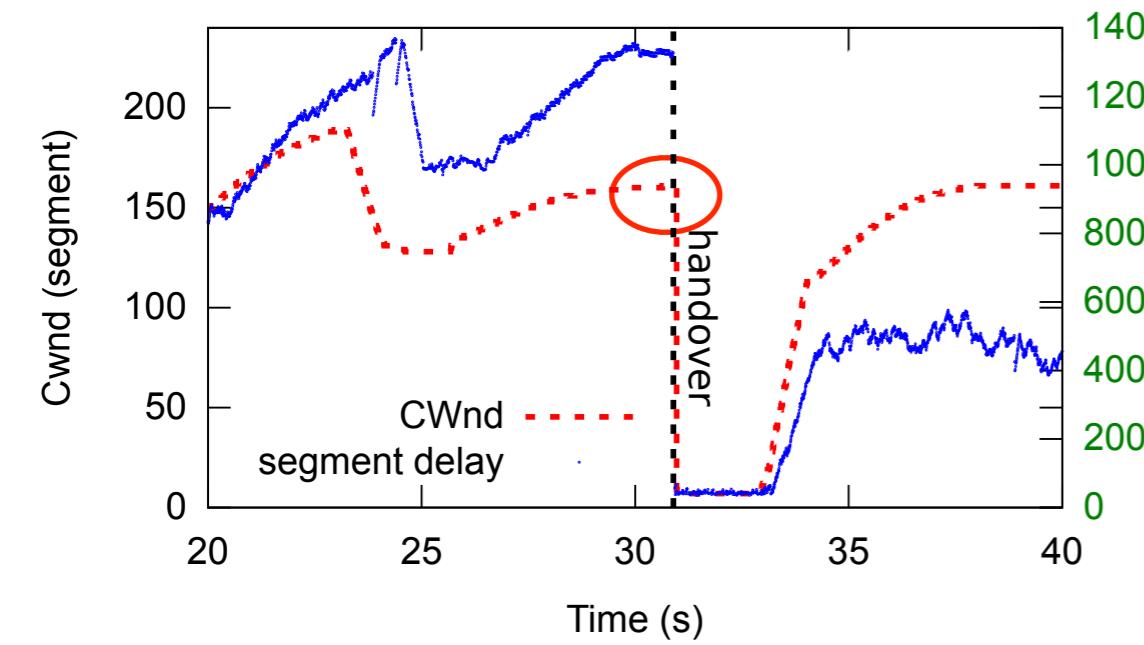
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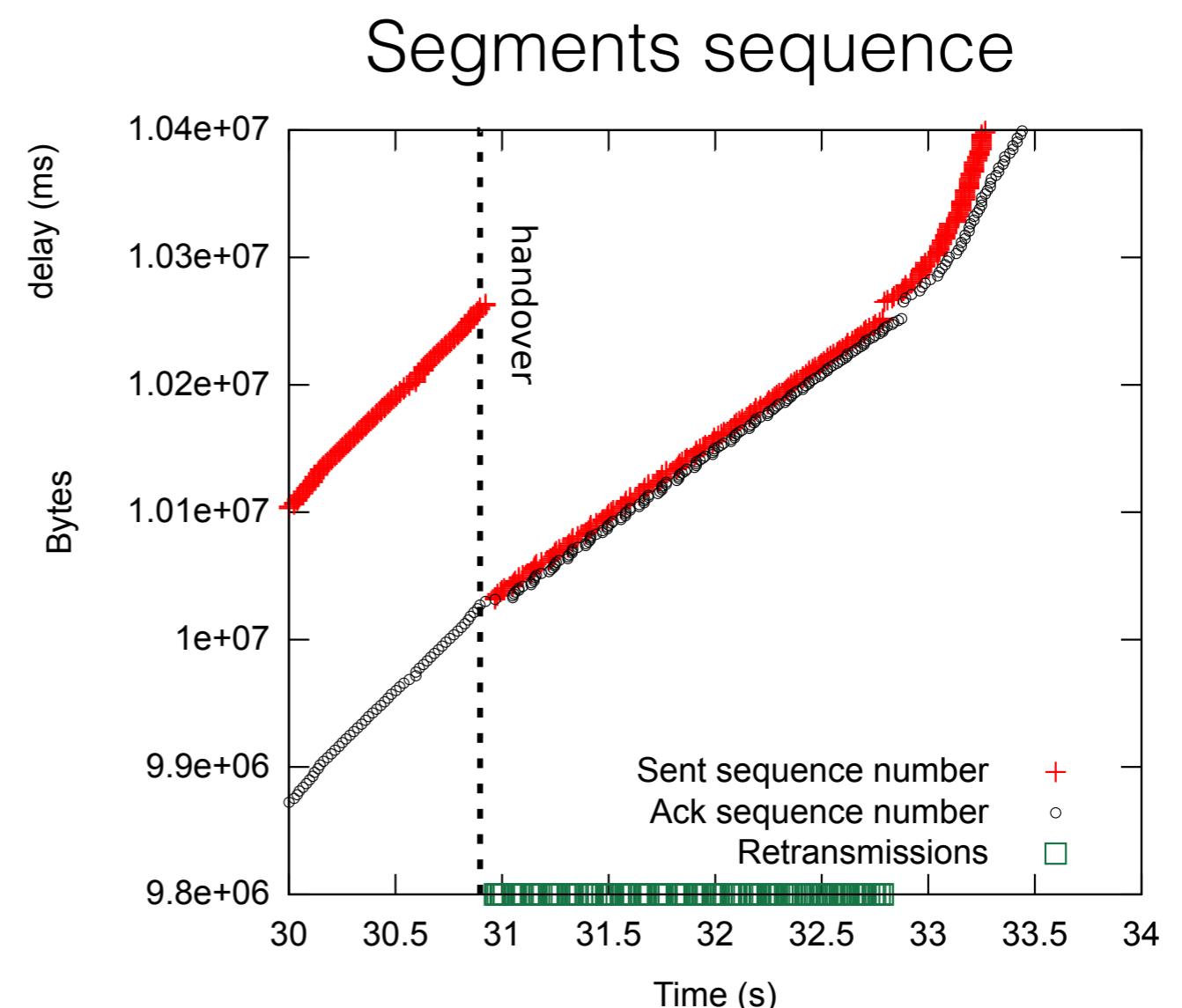
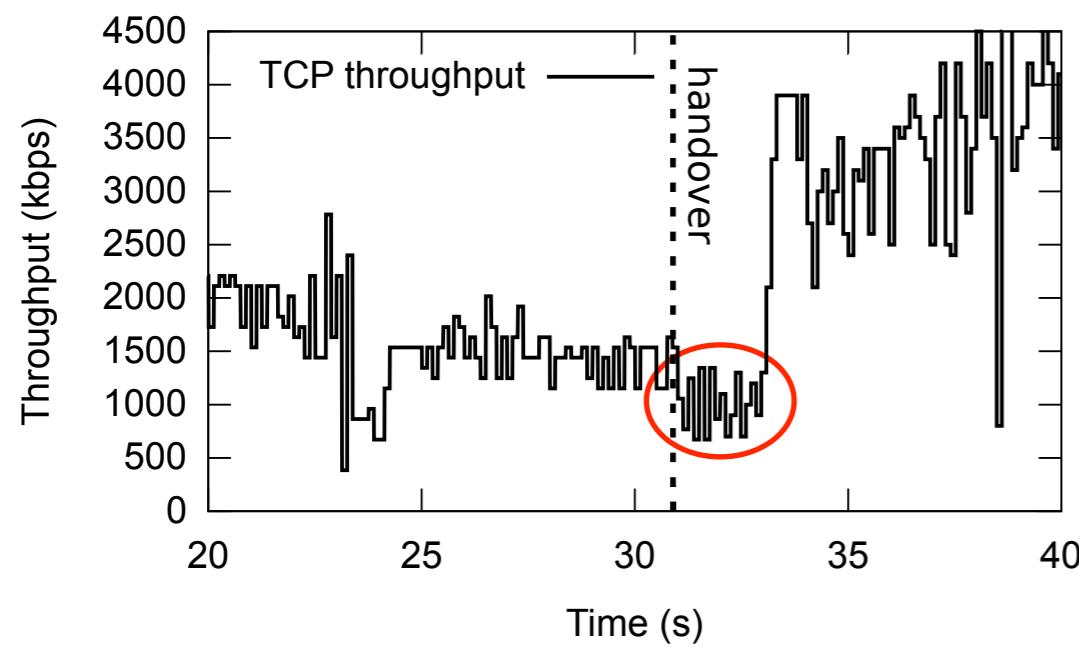
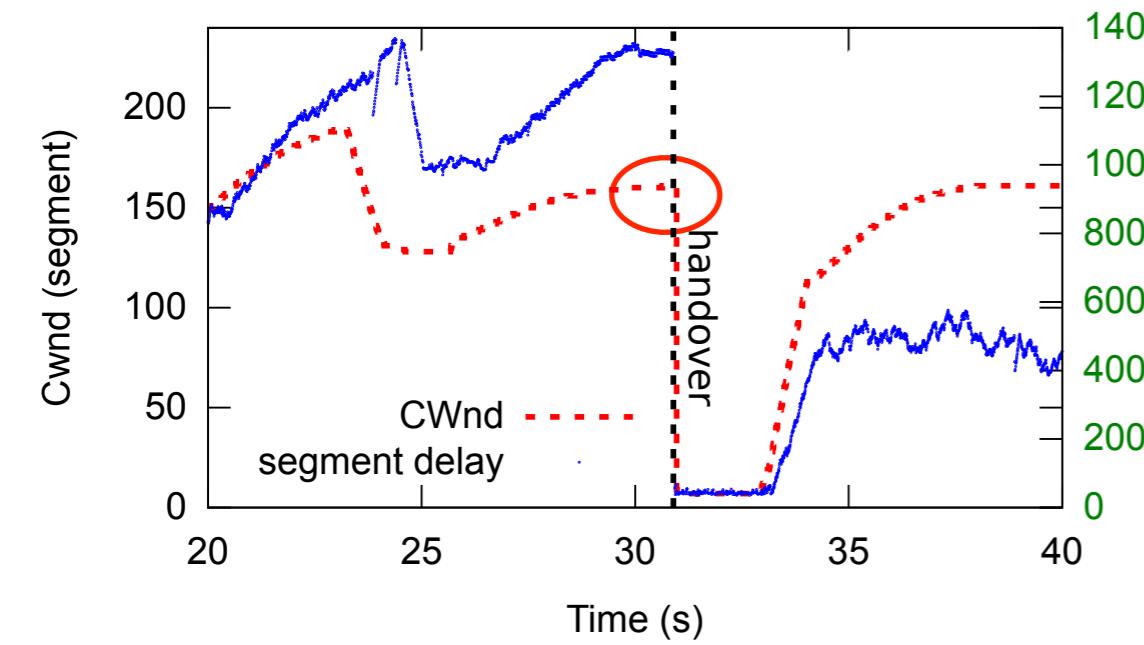
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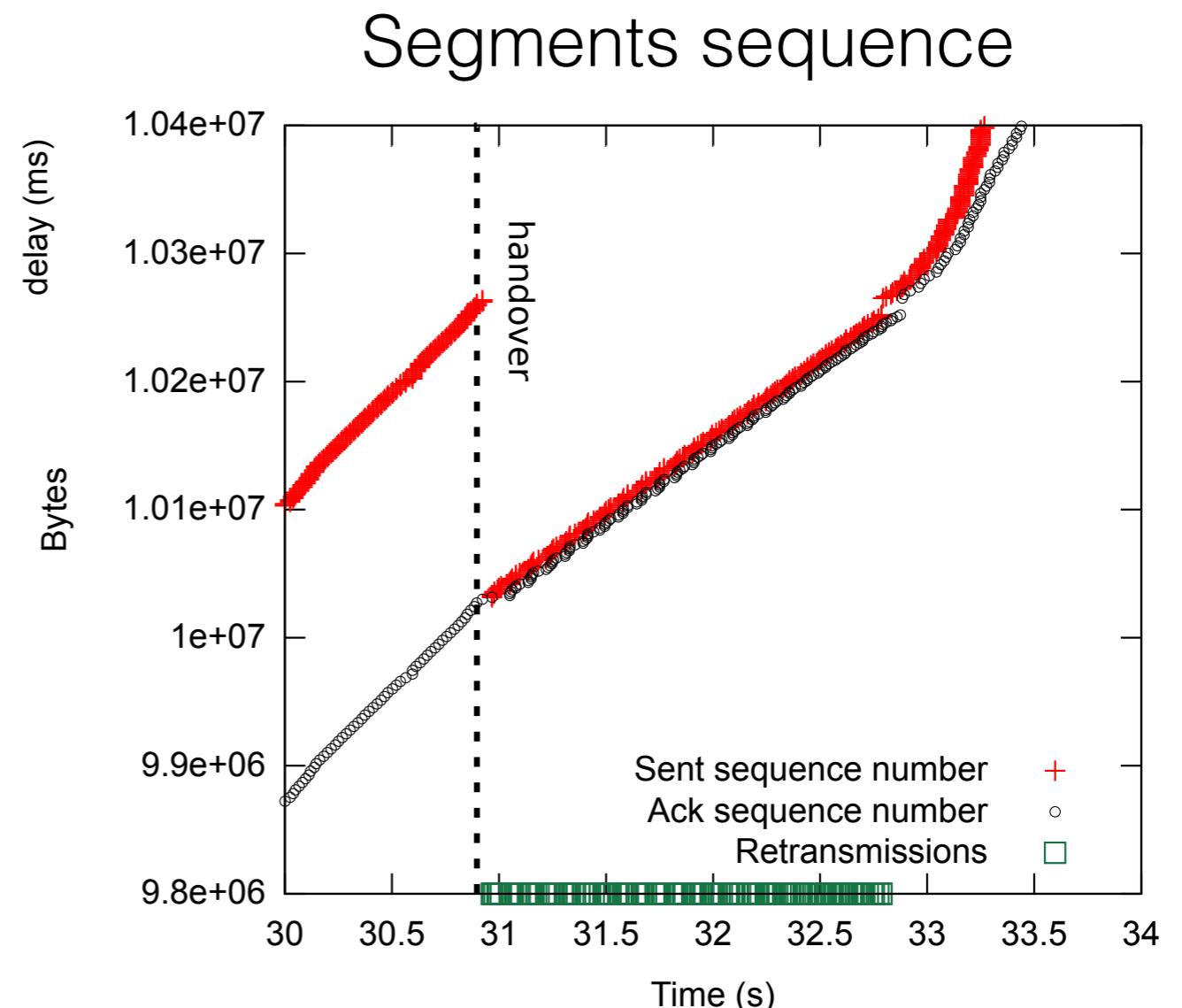
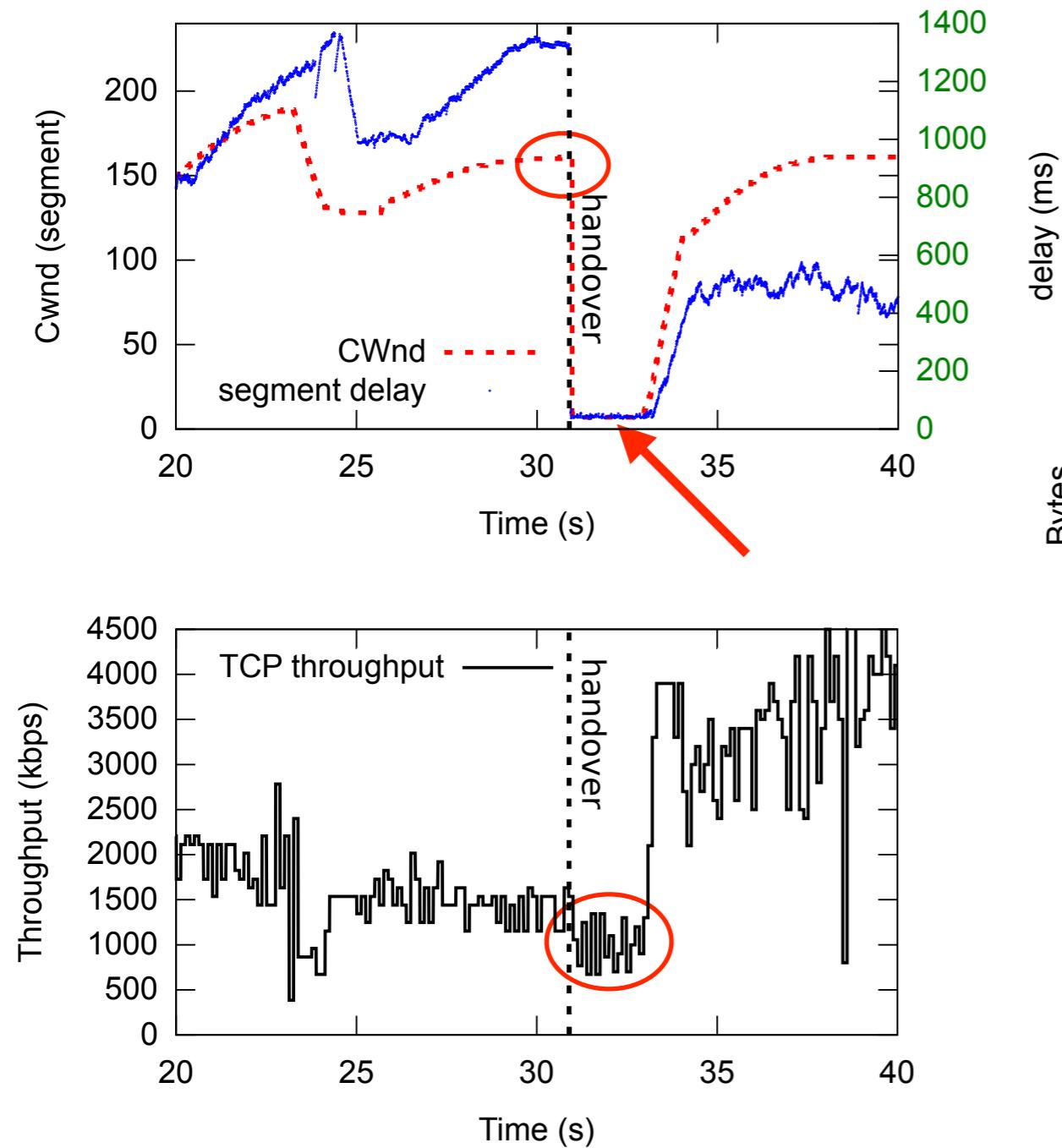
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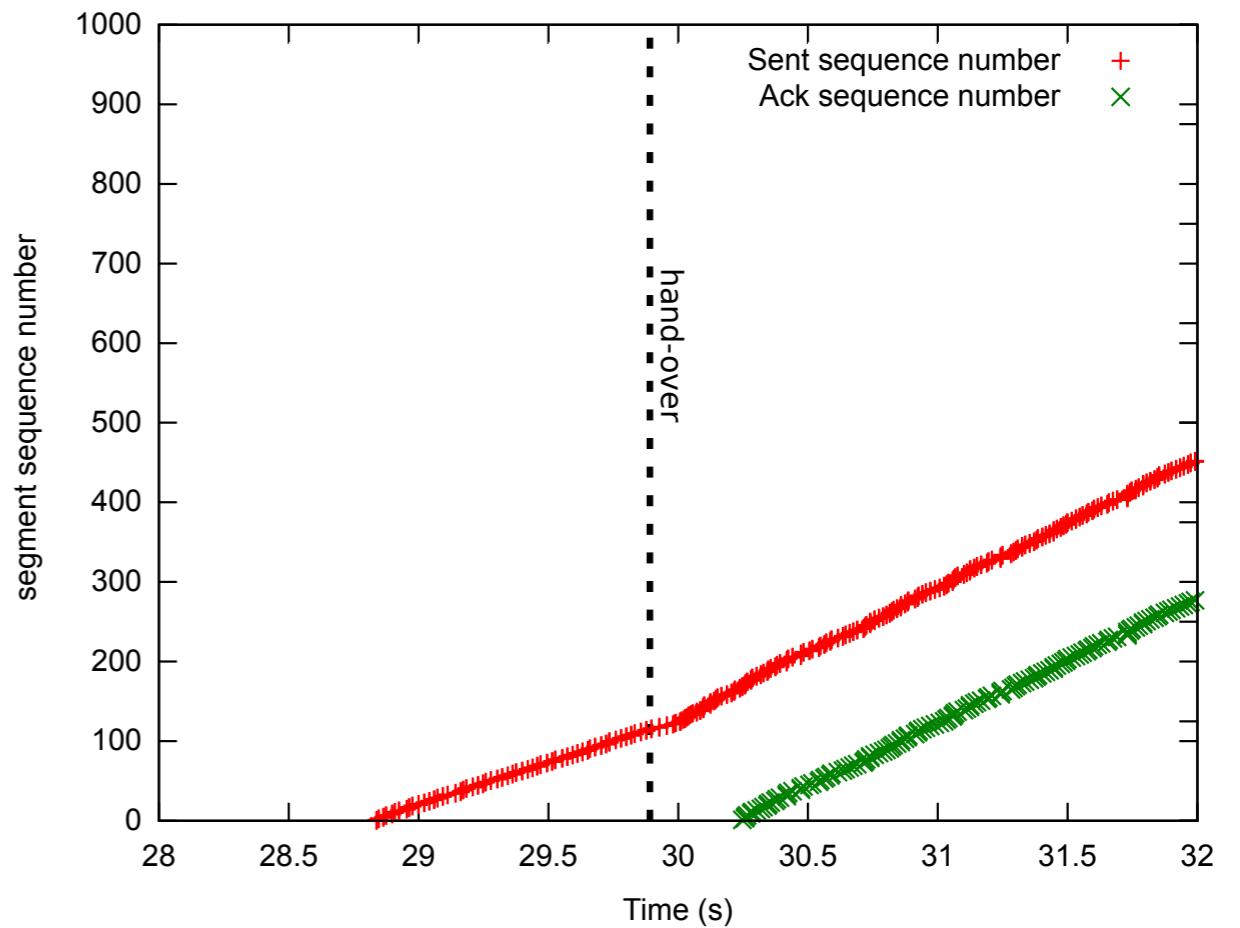
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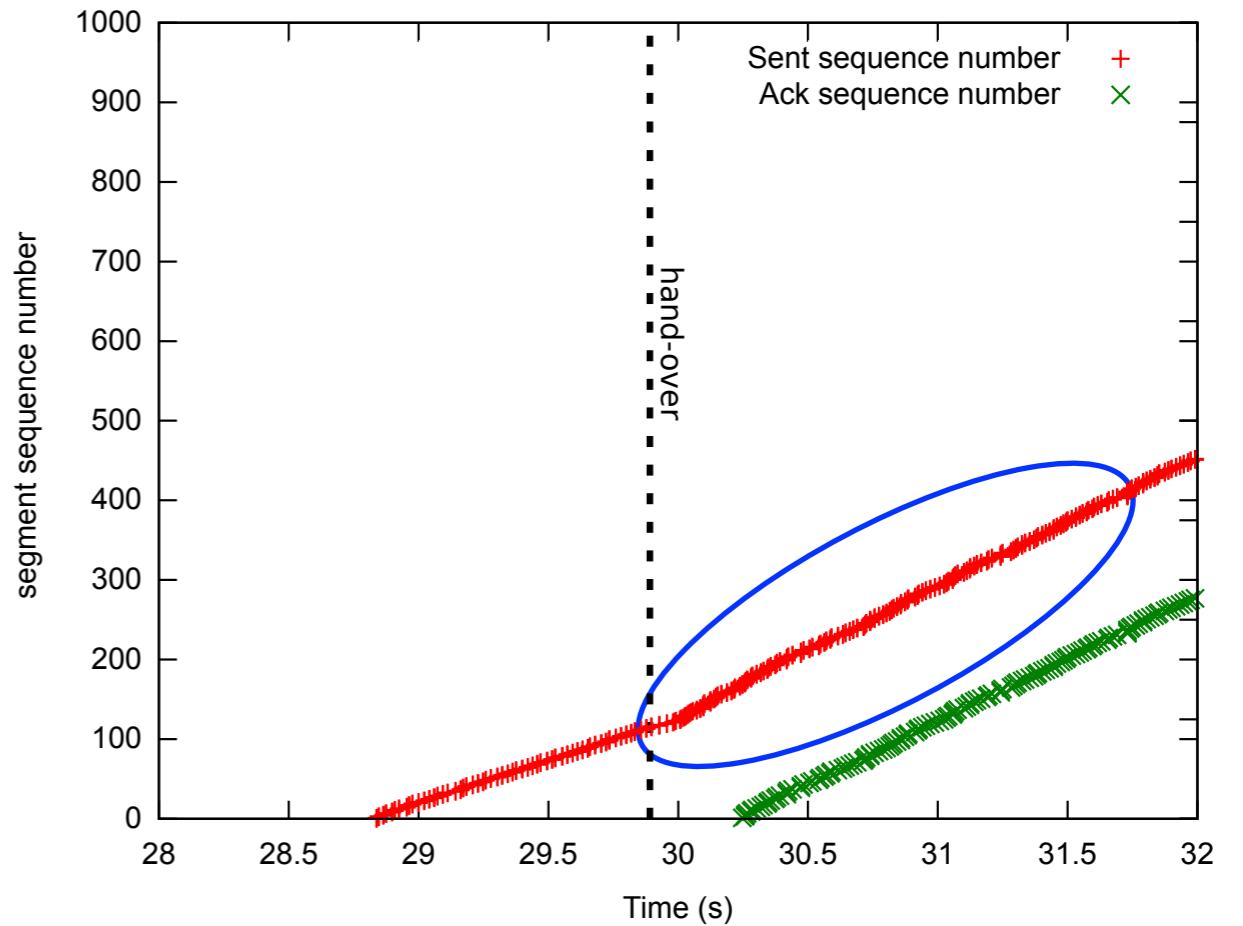
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Segments sequence



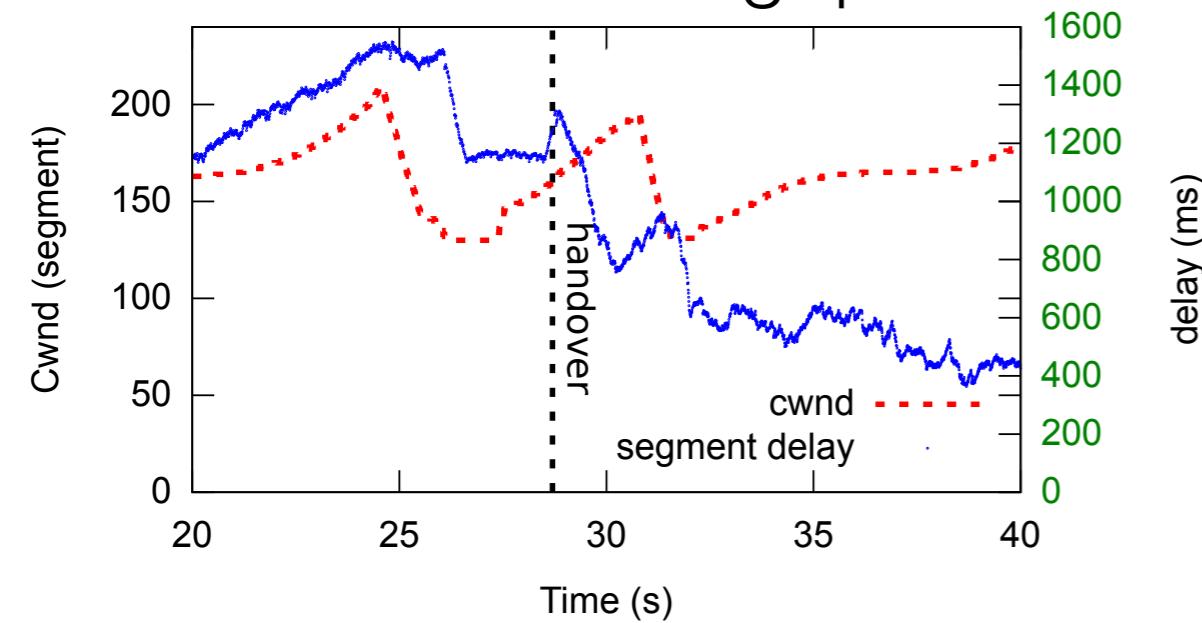
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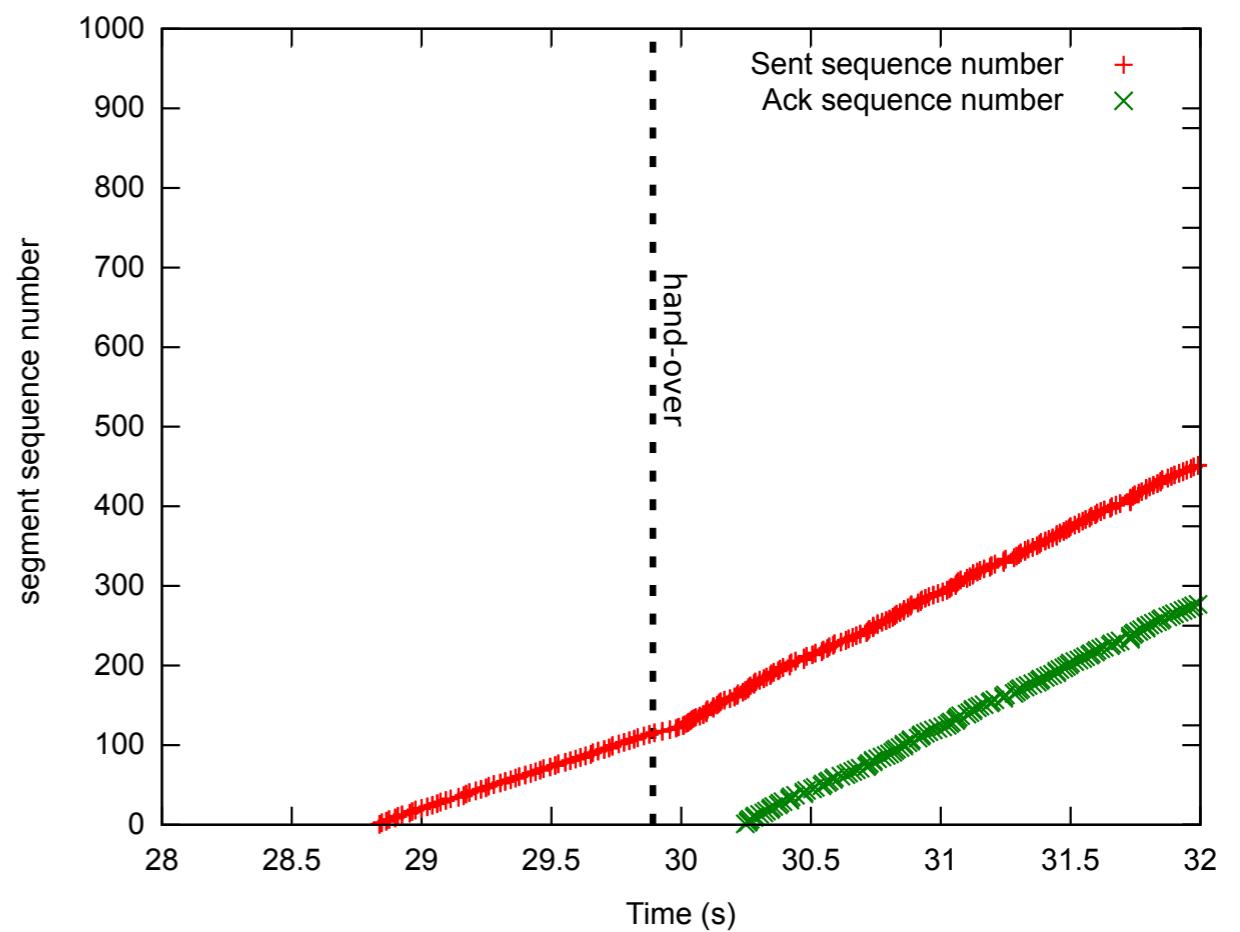


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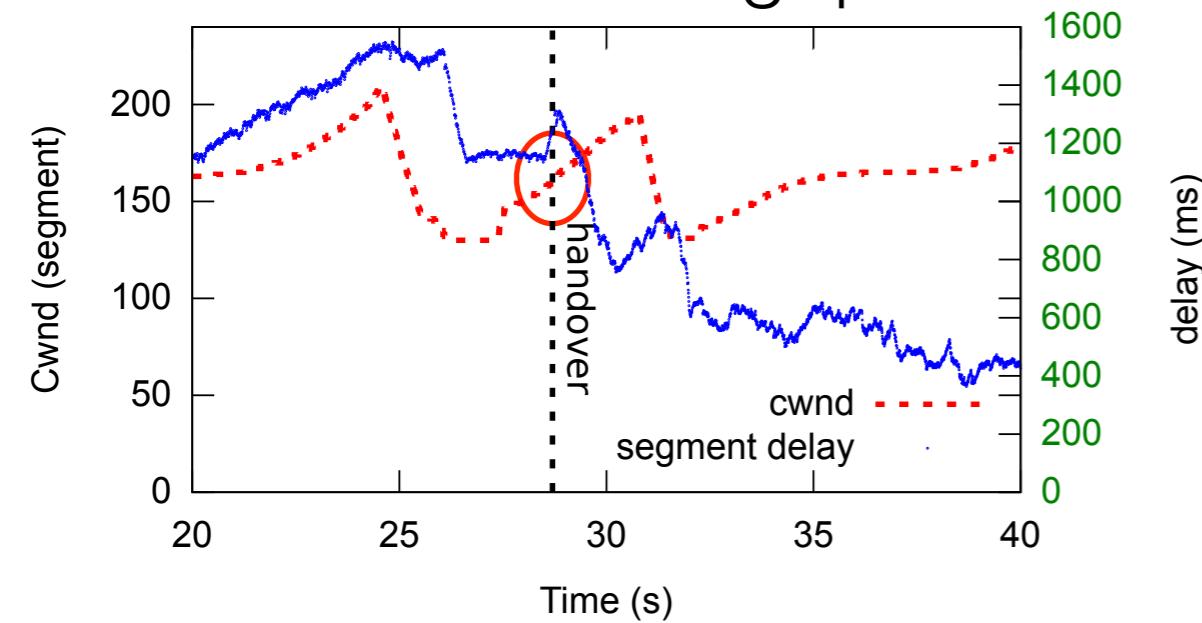


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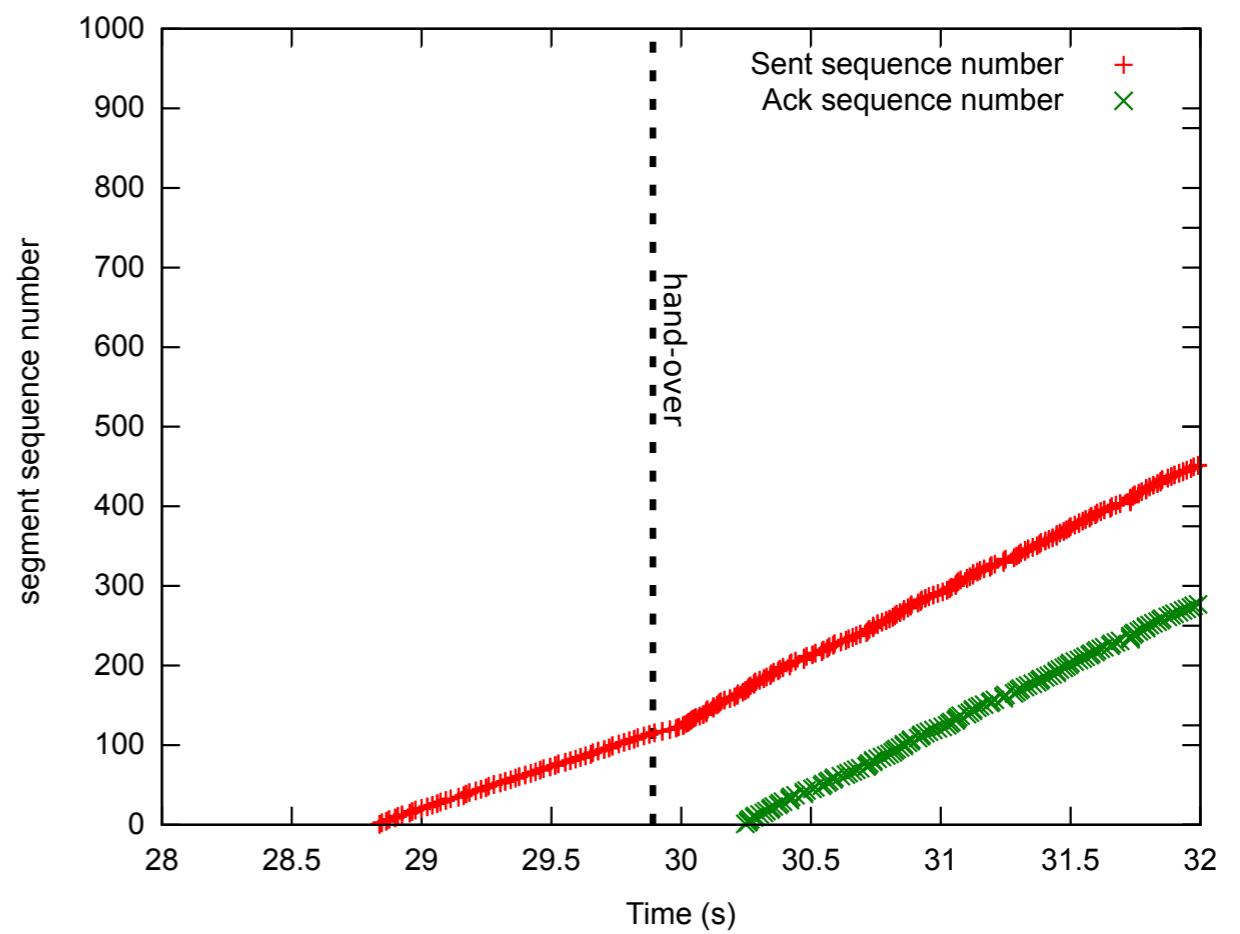


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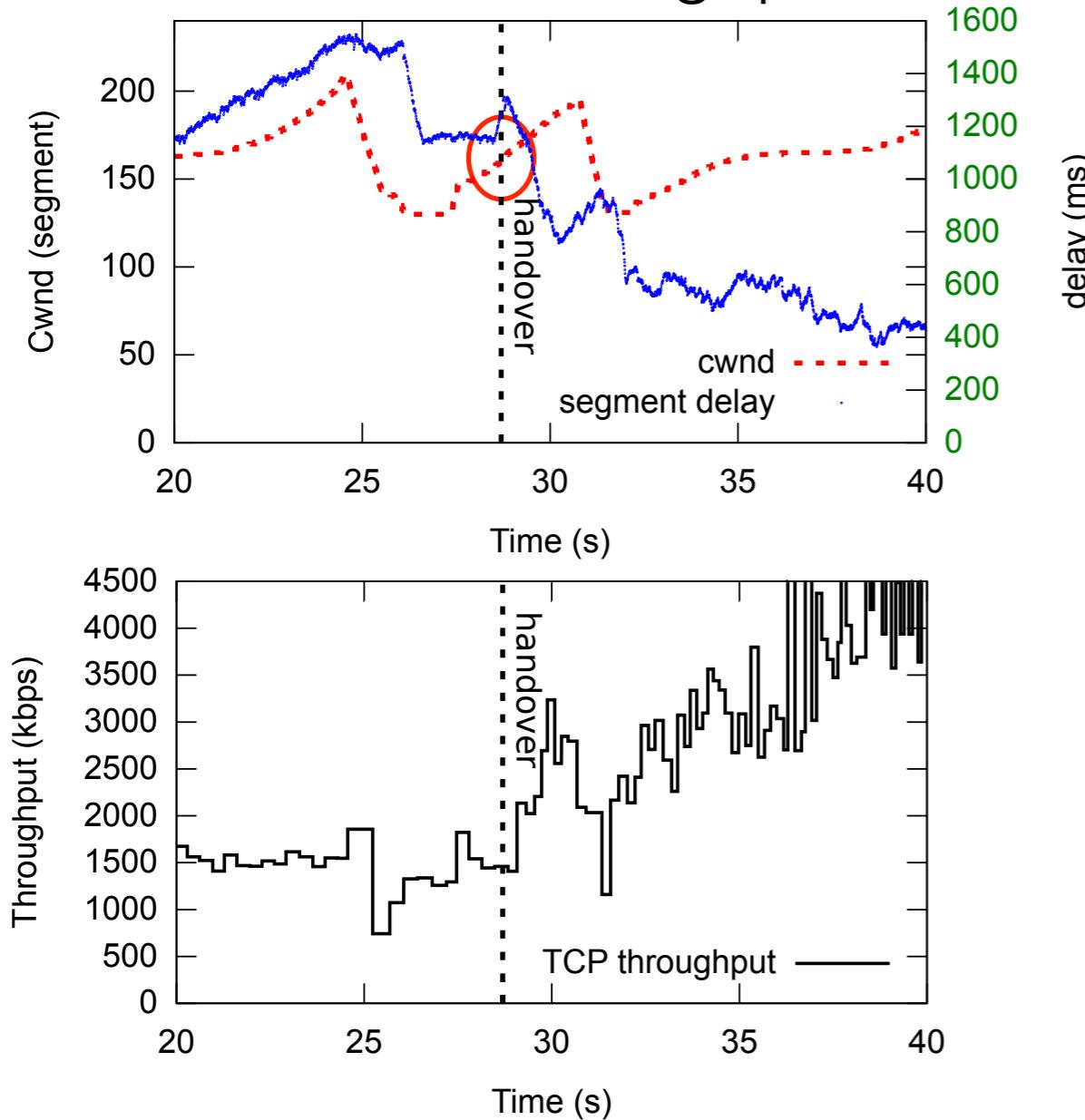


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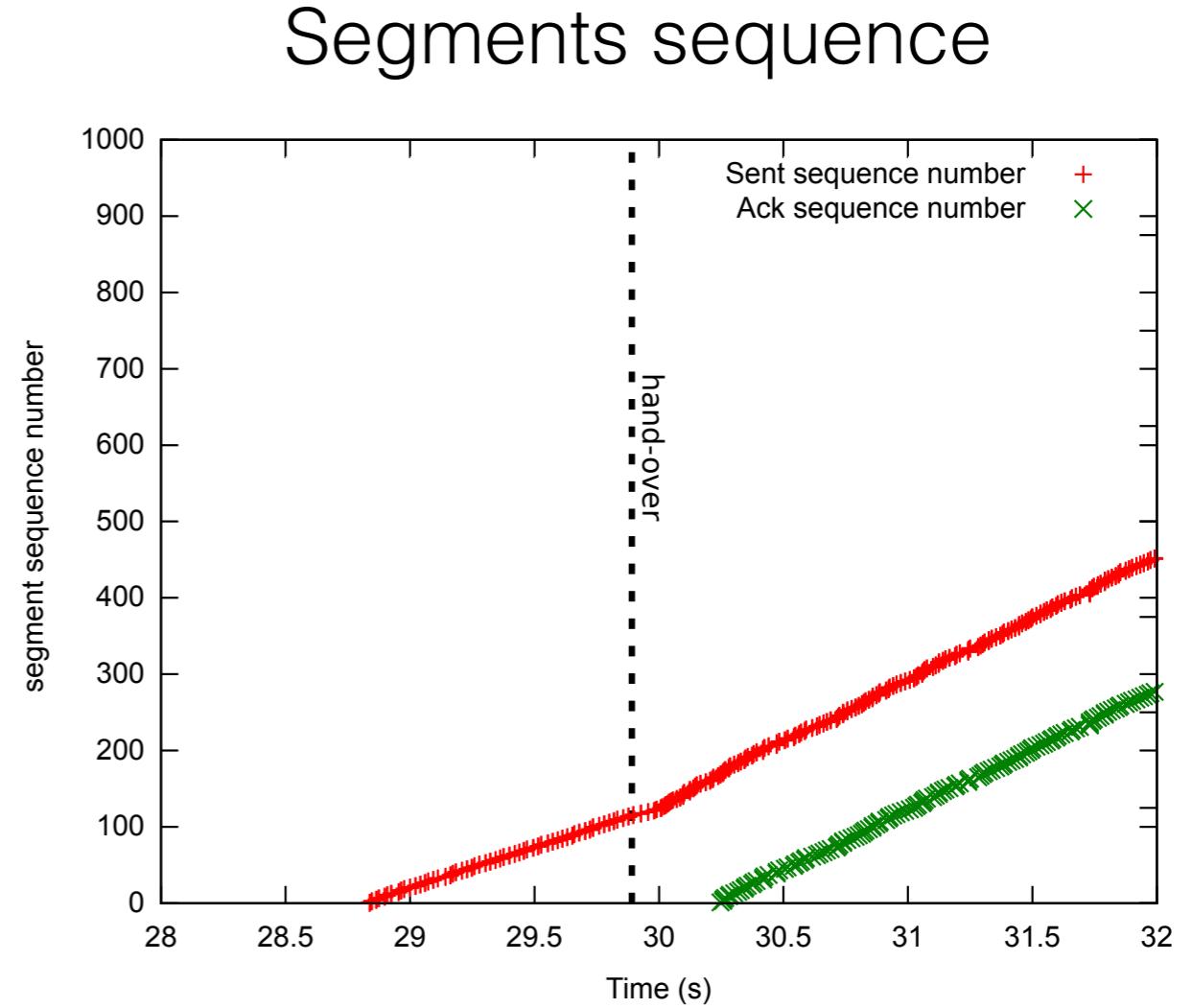


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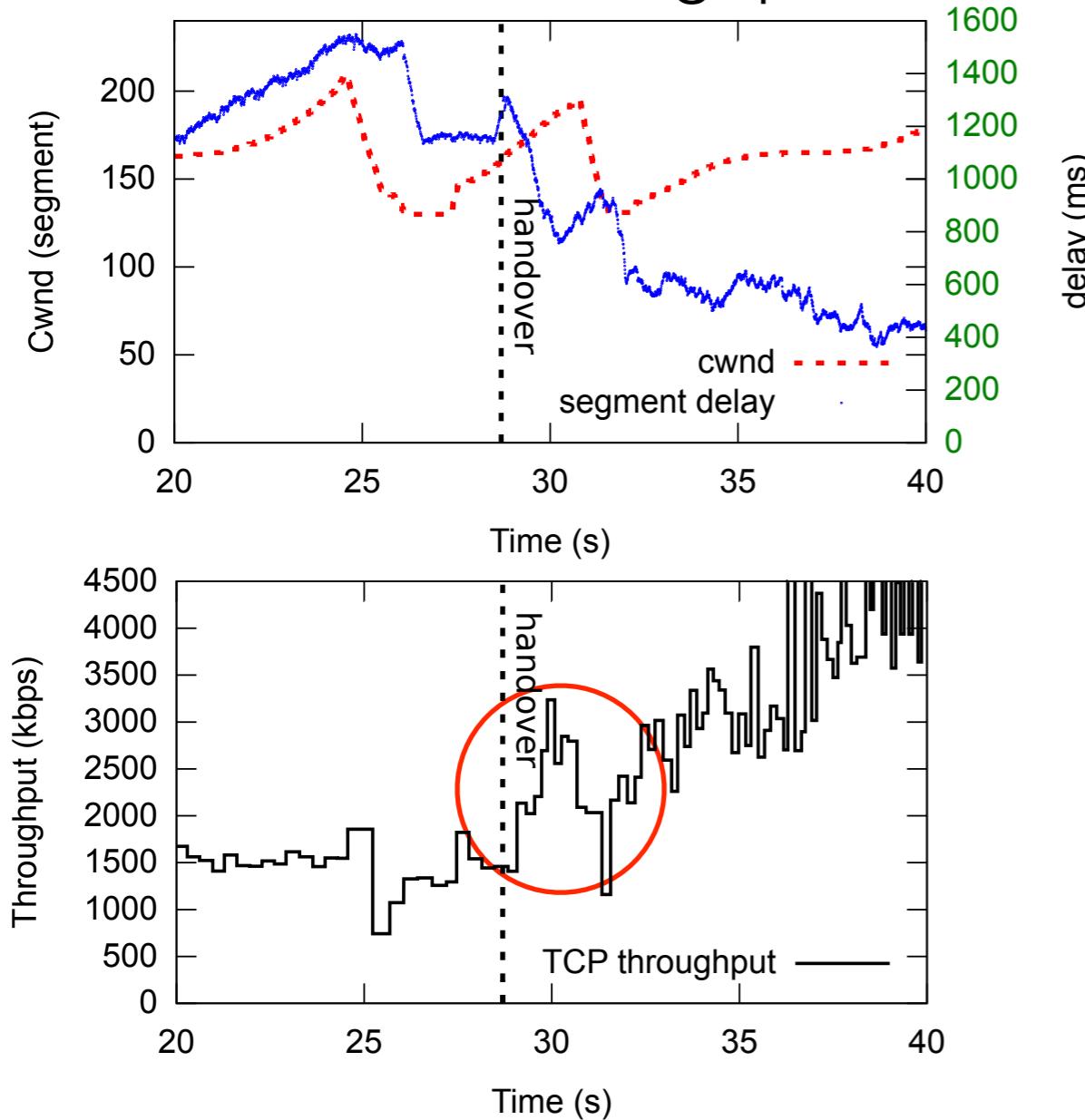


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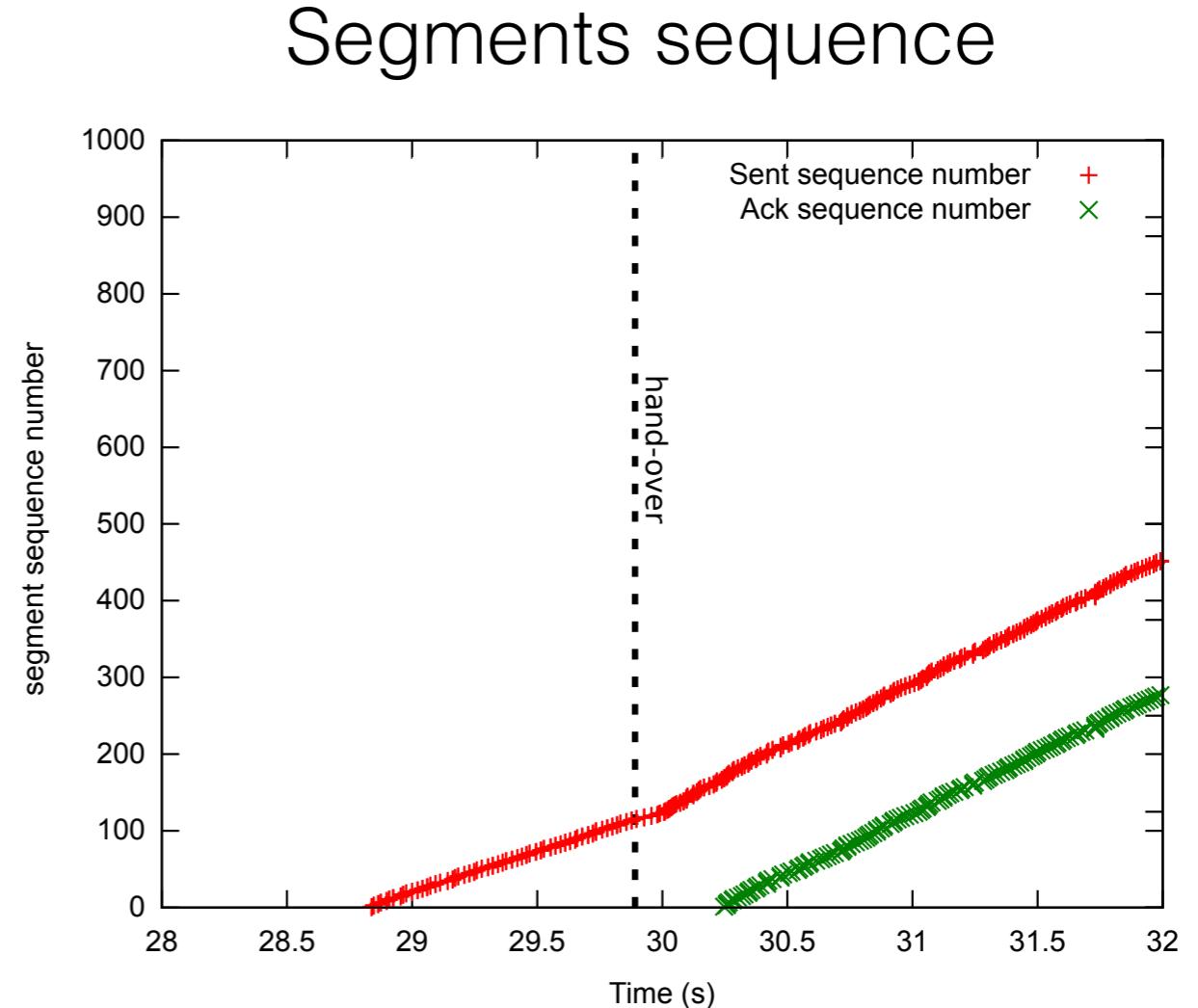


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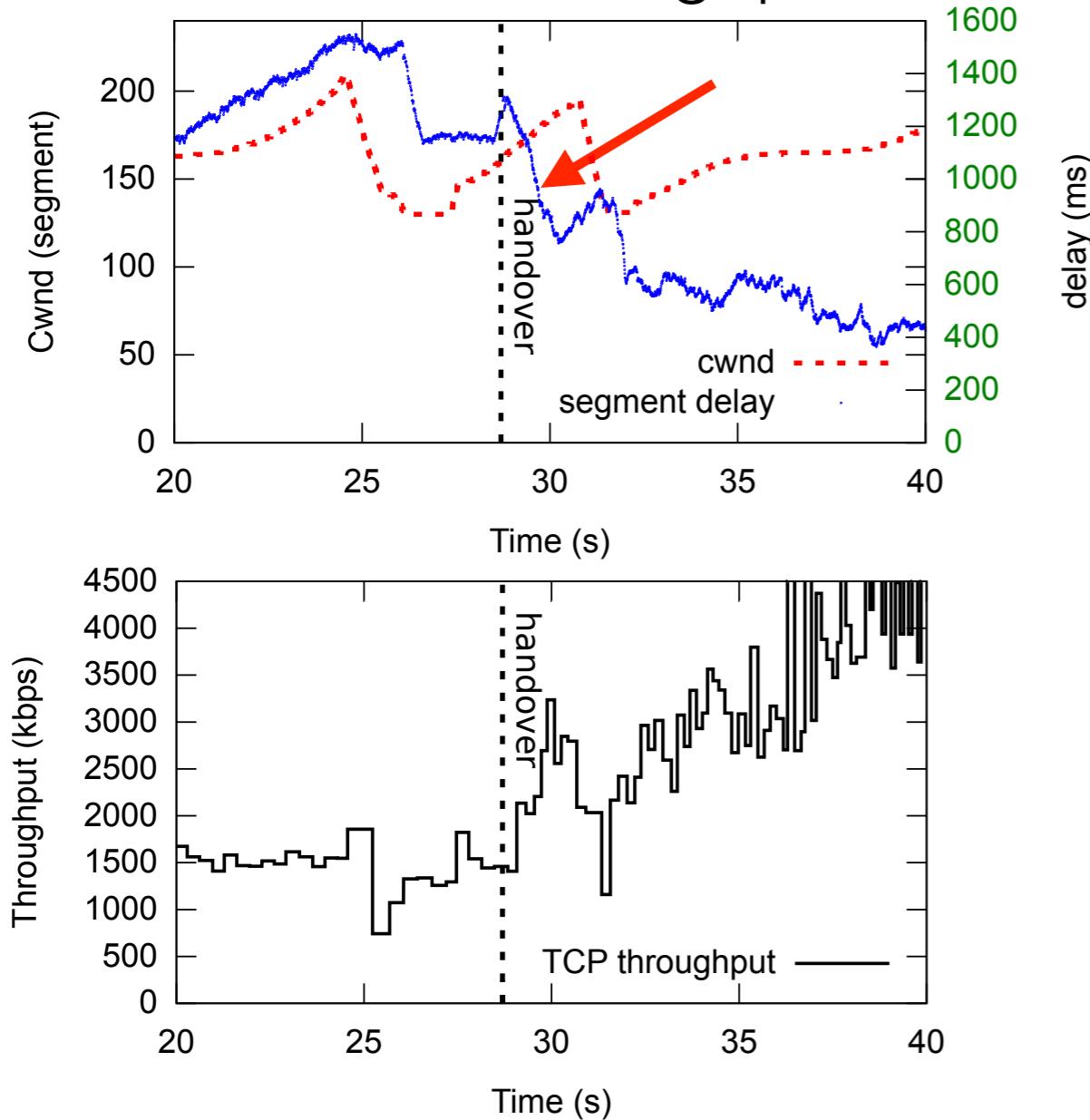


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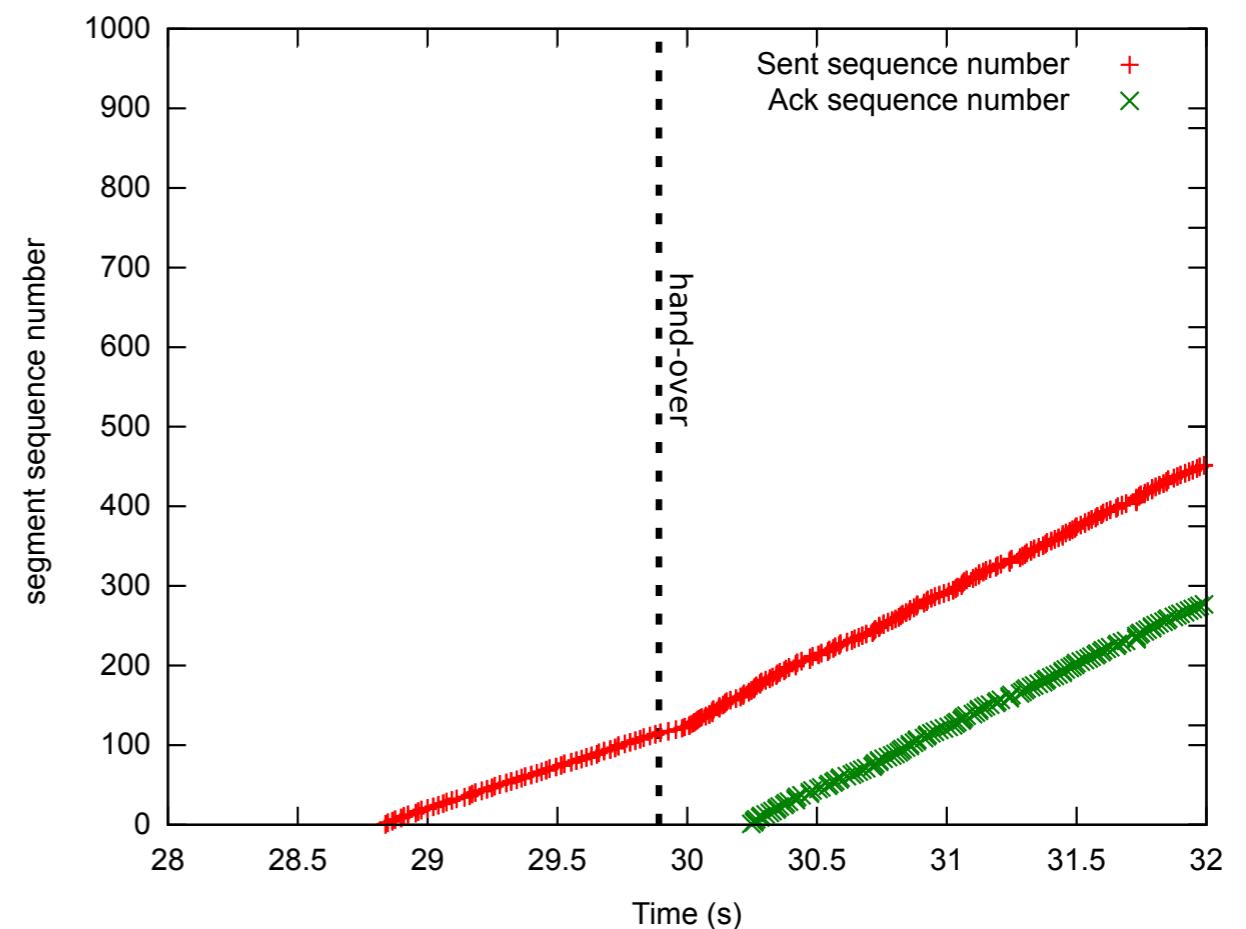


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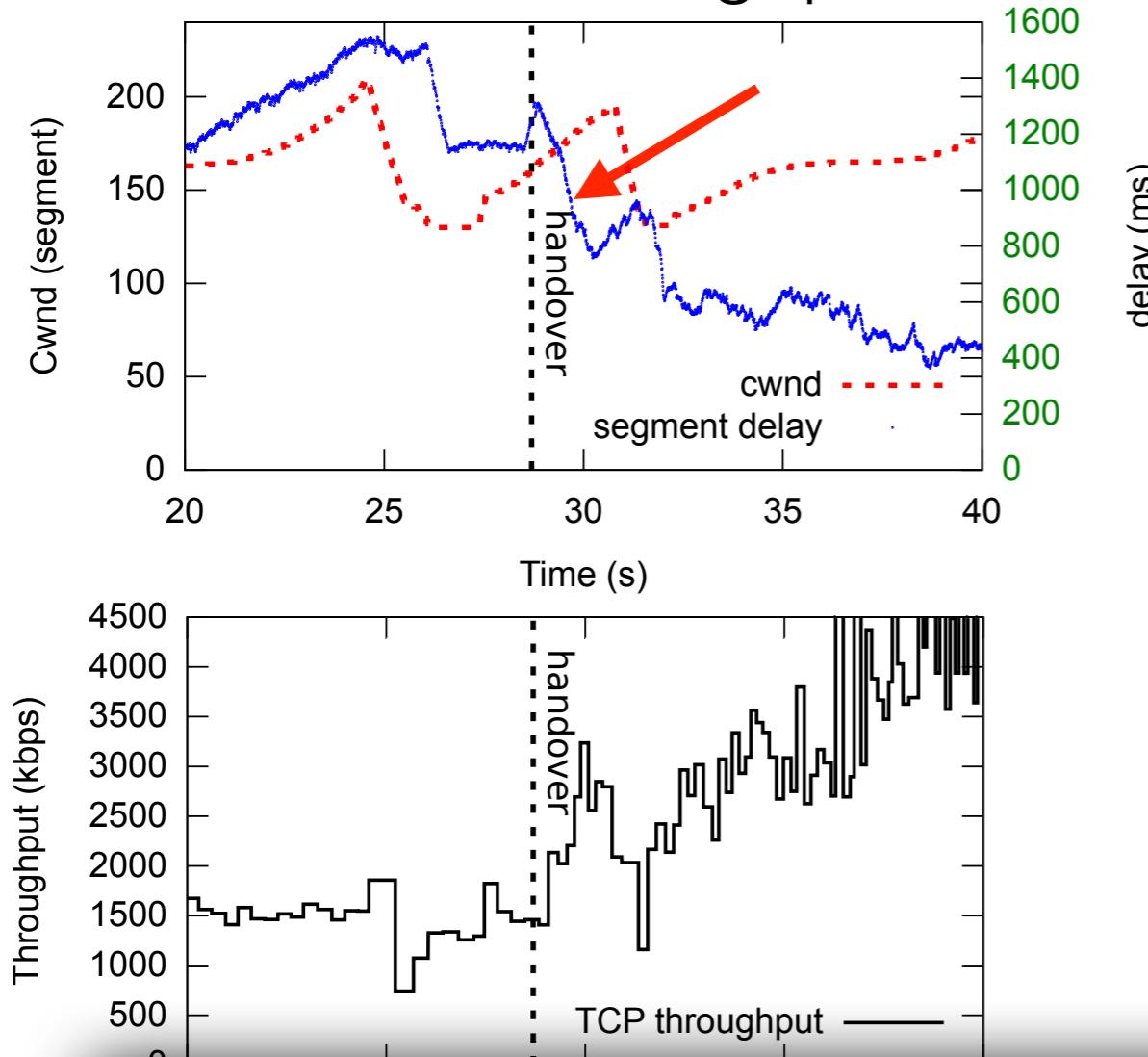


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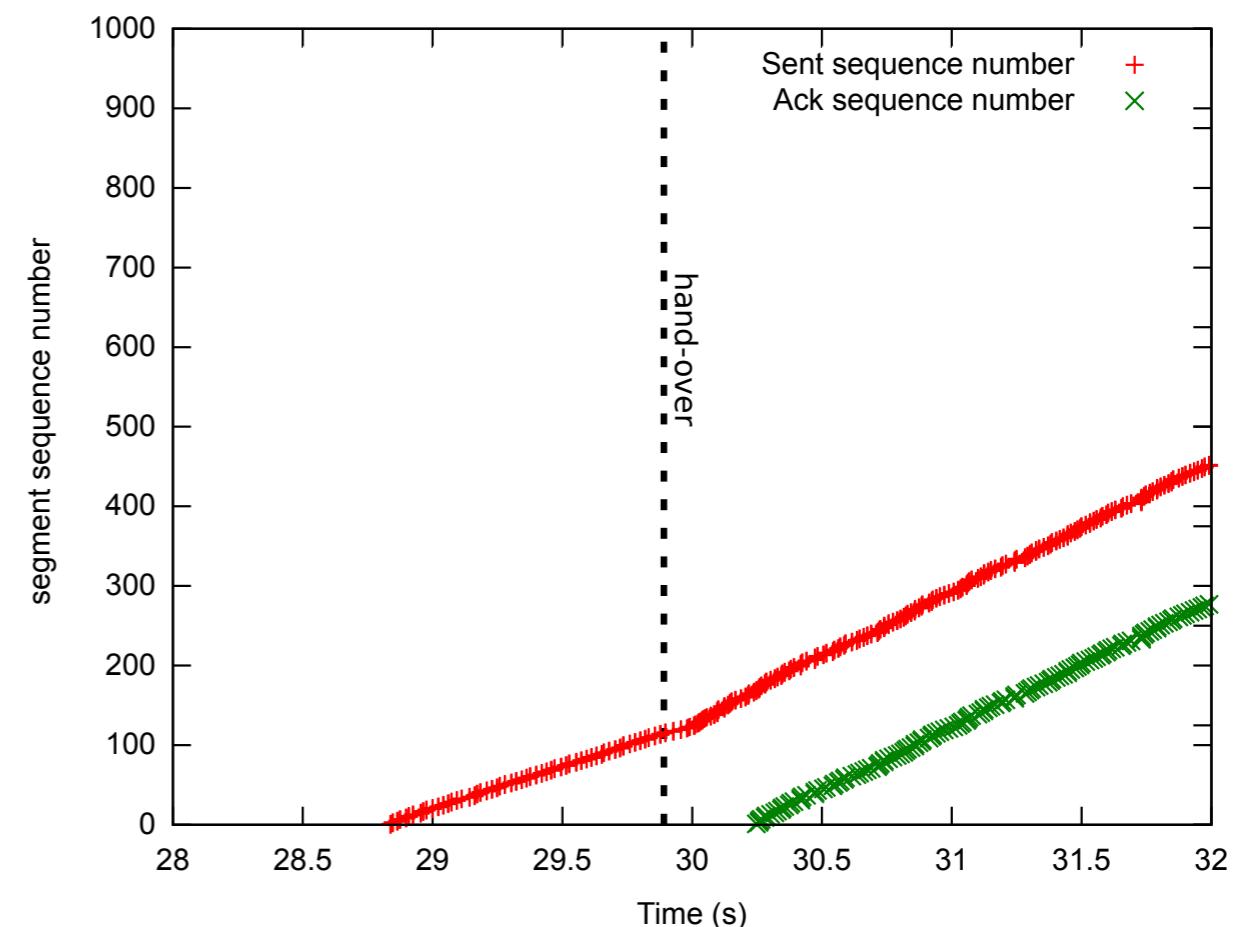


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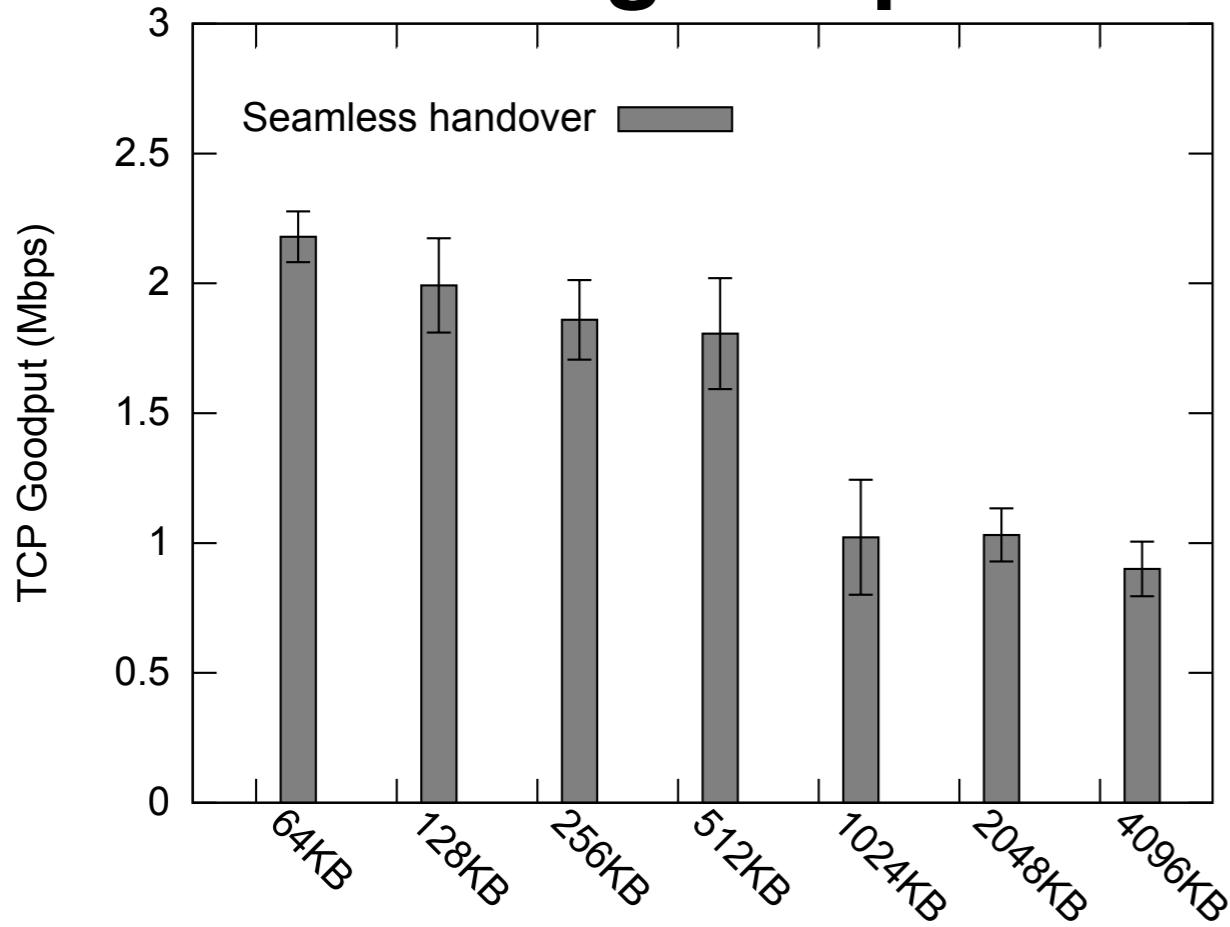
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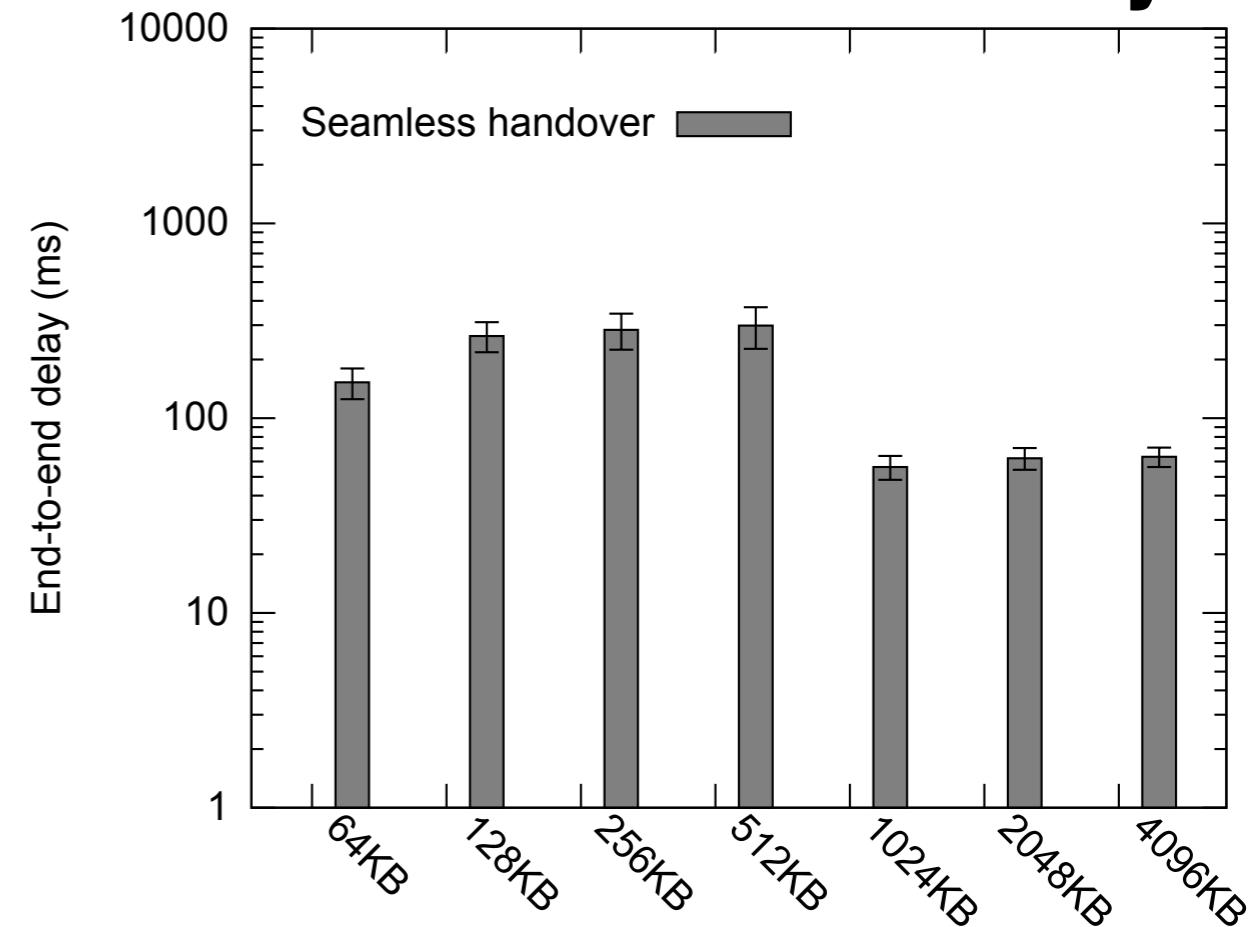
Seamless HO suffers from a throughput reduction  
while lossless HO experiences a high delay.

# TCP's performance during handovers

**TCP good-put**



**End-to-end delay**

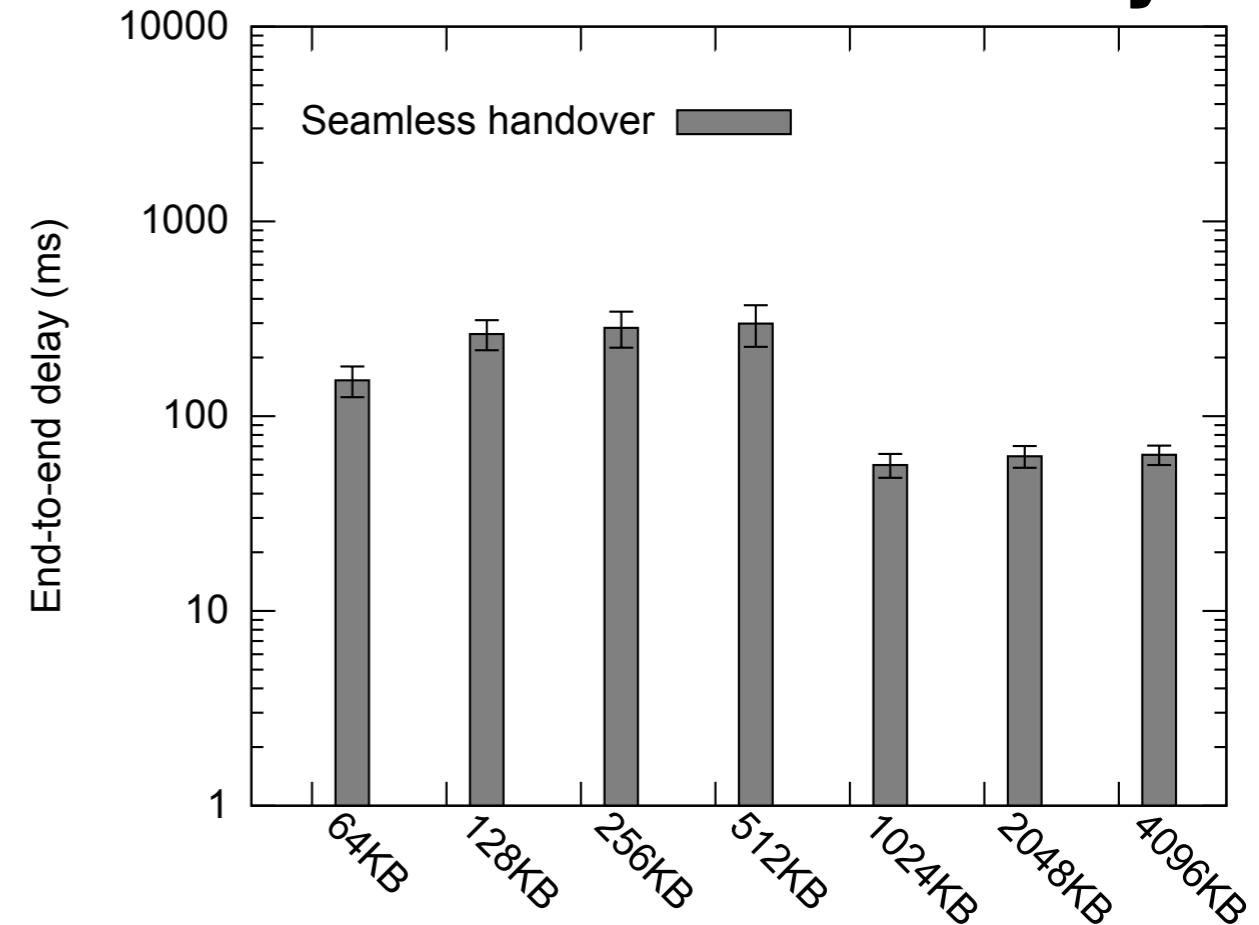


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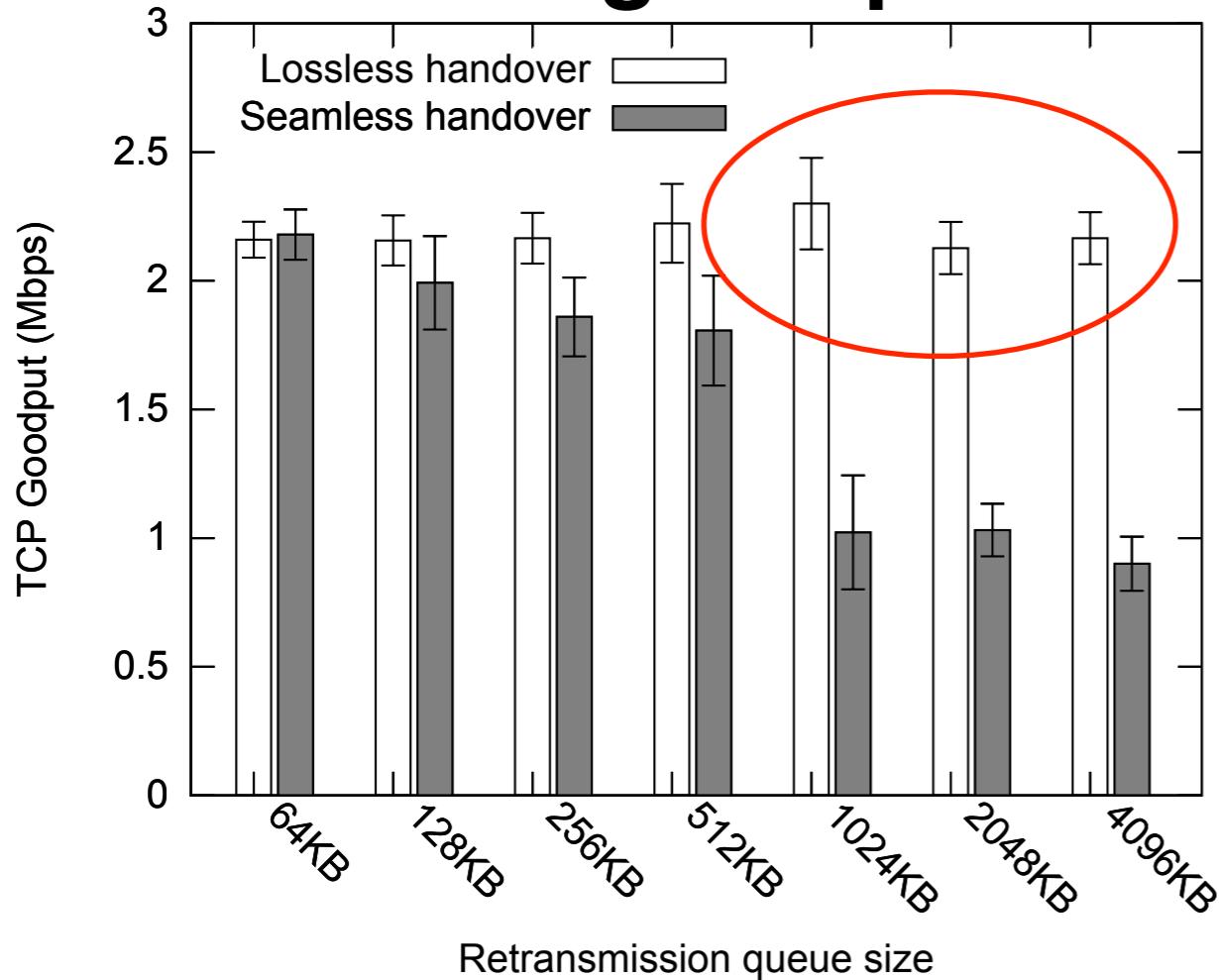


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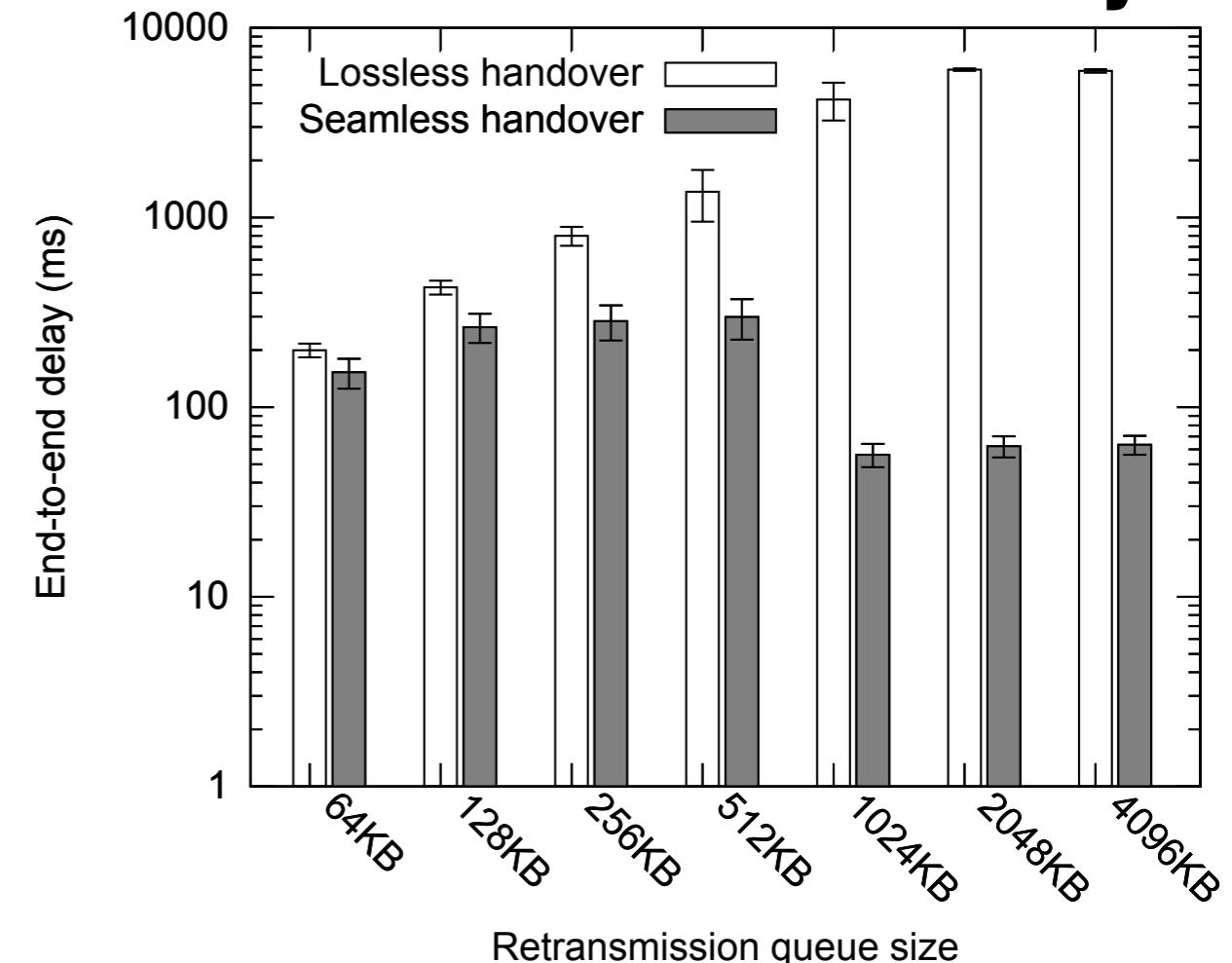


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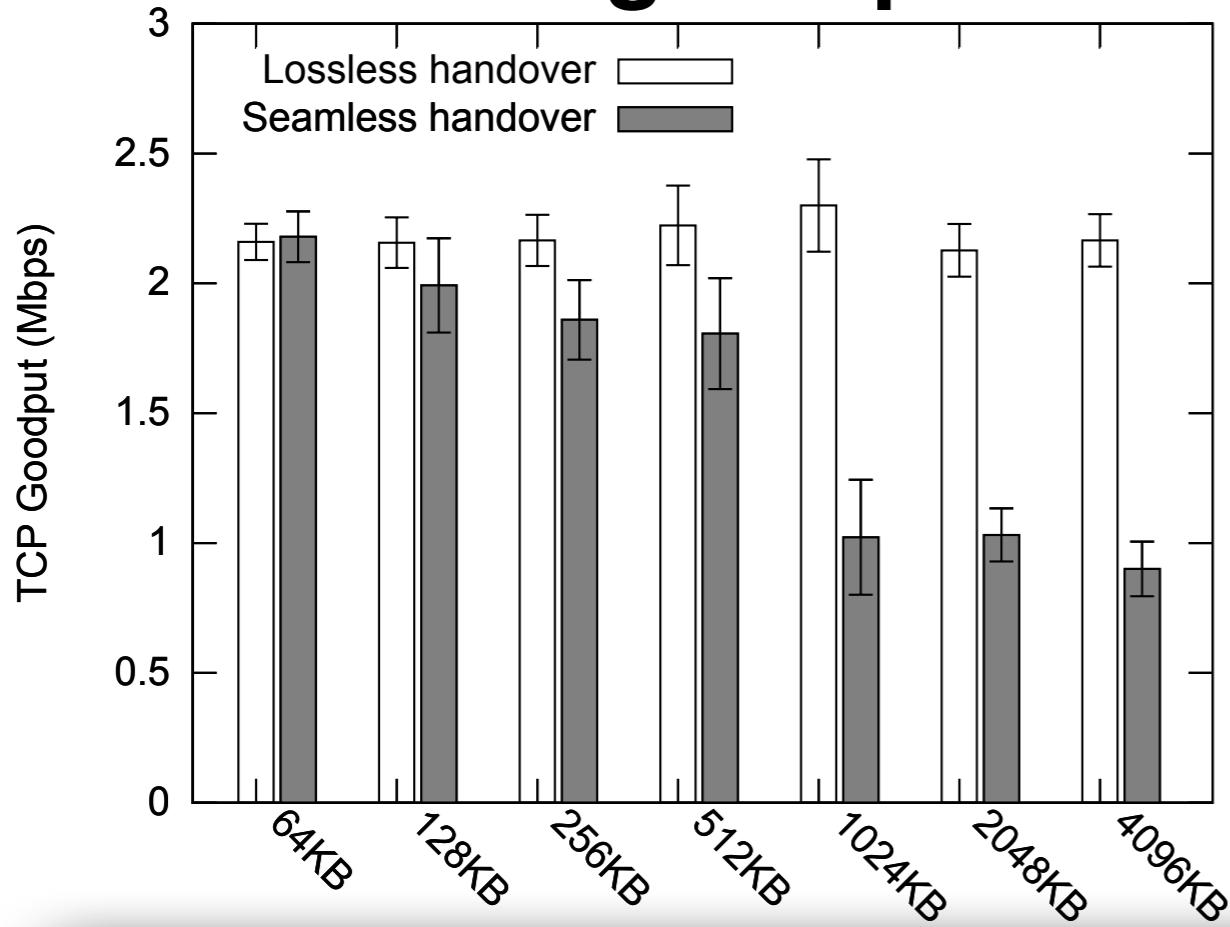


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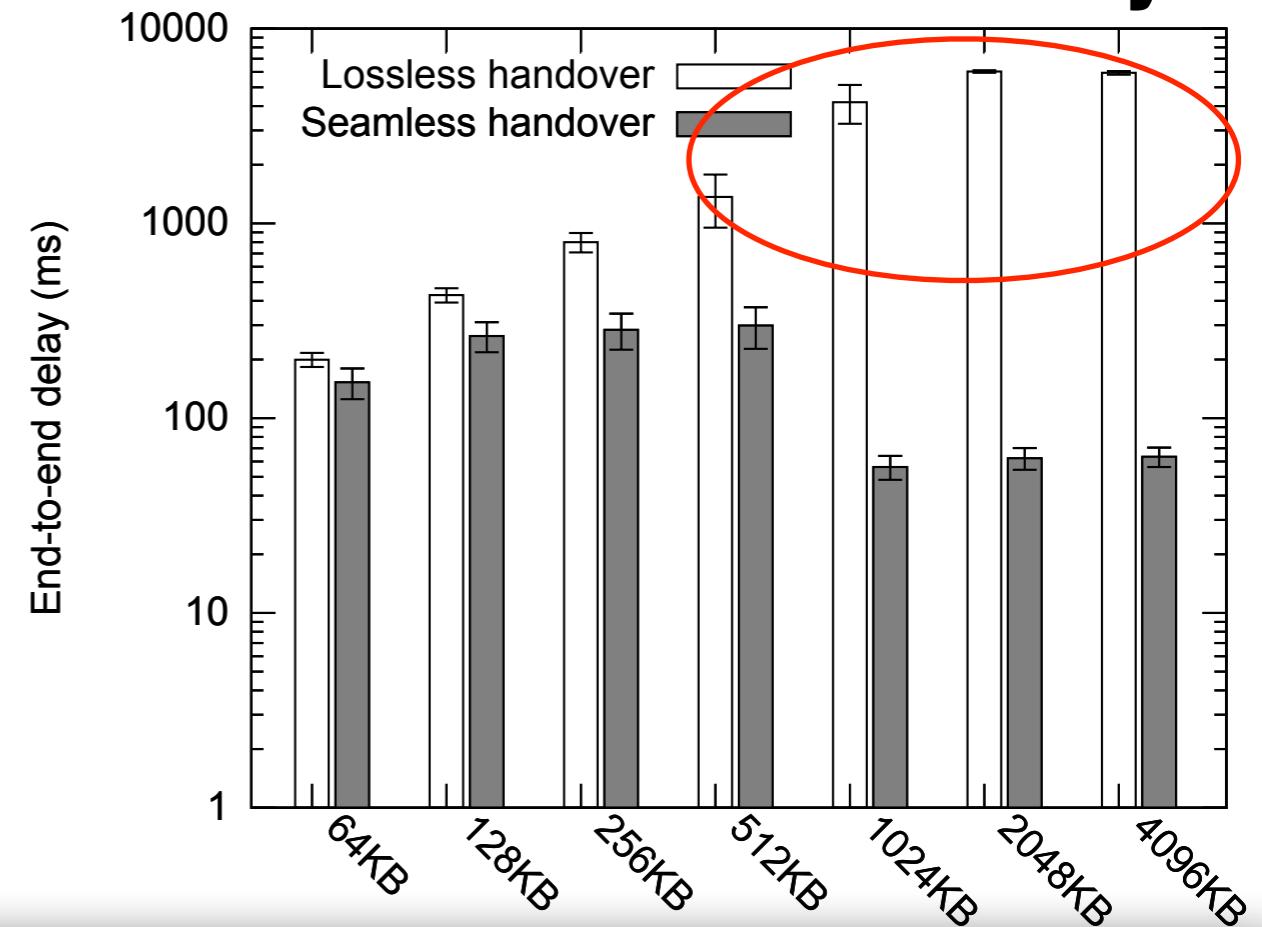


# TCP's performance during handovers

## TCP good-put



## End-to-end delay



- In seamless handovers, the higher the PDCP queue size, the lower TCP good-put.
- In lossless handovers, the higher the PDCP queue size, the larger end-to-end delay.

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Need a closer interaction between applications and the network?

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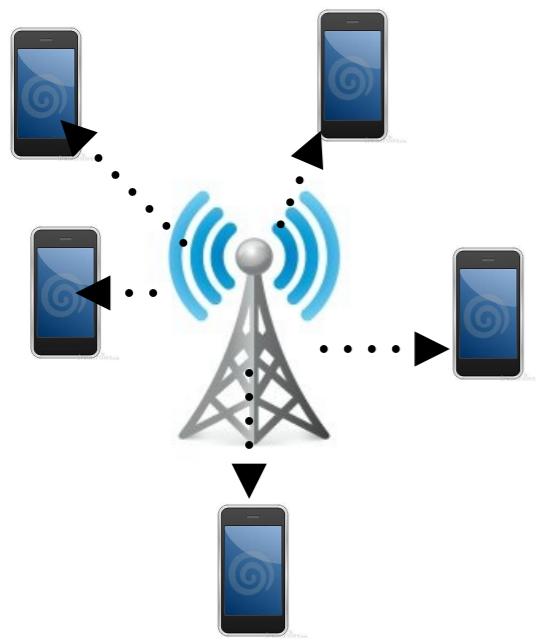


# Scenario 2: Sudden load increase in an eNodeB



- Assume an area with 250m of radius from the eNodeB where UEs are uniformly distributed.
- Users mobility: Levy-walk pedestrian mobility.
- UEs are attached to the eNodeB at the beginning of the experiment and start downloading data at a specific time.

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- Possible future work:
  - More investigations on the TCP's performance problems.
  - Cross-layer interactions: e.g., applications and the mobility stack.
  - Base station congestion prediction and mitigation.

Thank you!