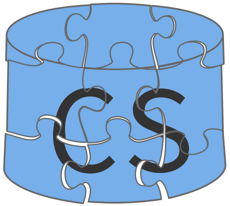

Connecting the Dots: Selective Fragment Recovery in ICNLoWPAN

Martine S. Lenders[*] , Cenk Gündoğan[†], Thomas C. Schmidt[†], Matthias Wählisch[*]

[*]Freie Universität Berlin
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[†]HAW Hamburg
{cenk.guendogan,t.schmidt}@haw-hamburg.de

Outline

Motivation & Background

A Virtual Reassembling Endpoint in ICN

Evaluation of the VREP extension

Conclusion & Outlook

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PDU: $\sim$1500 bytes

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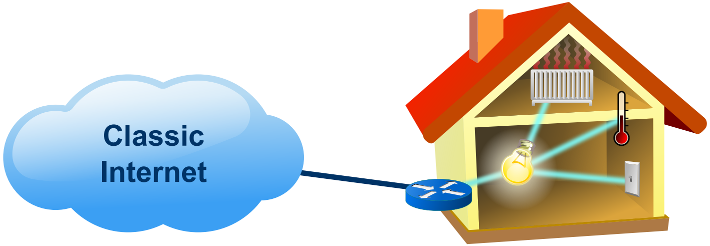

IoT devices

PDU: ∼1500 bytes

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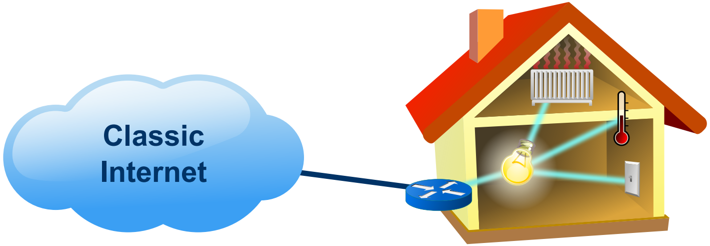

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6LoWPAN / ICNLOWPAN: Header compression + **Fragmentation**

How to forward fragments?

Fragmentation needs: Forwarding information 🟧 + Datagram tag 🟩🟦

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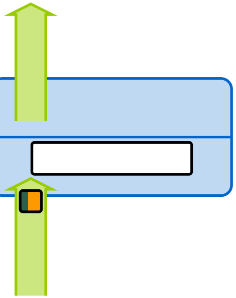
Hop-wise reassembly



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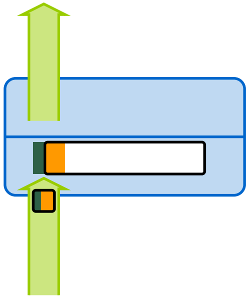

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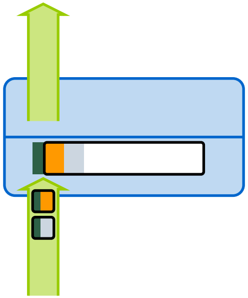

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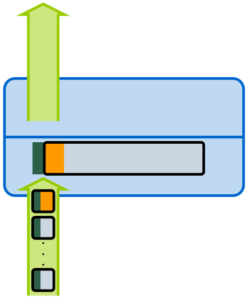

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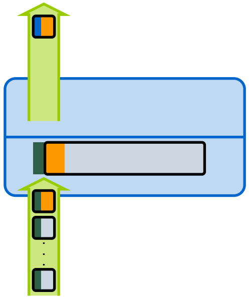

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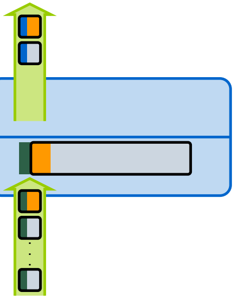

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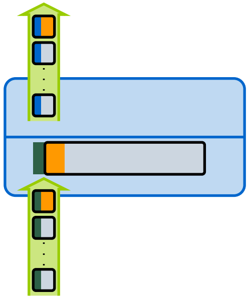

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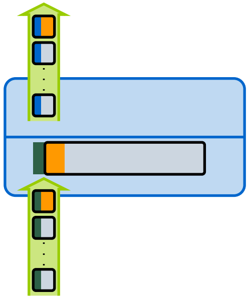

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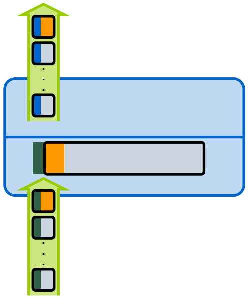

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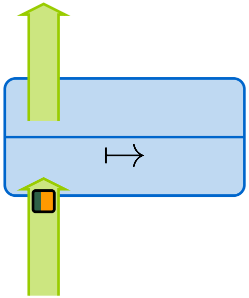

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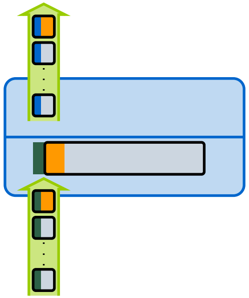

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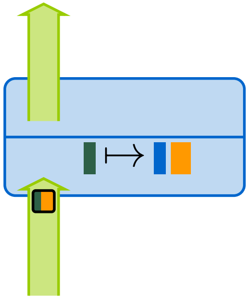

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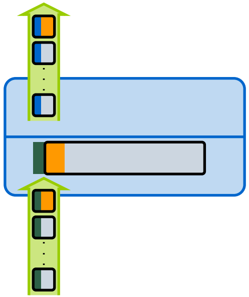

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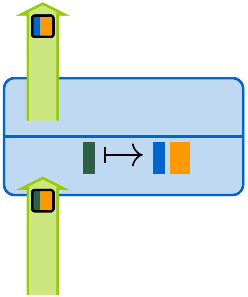

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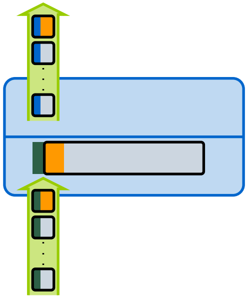

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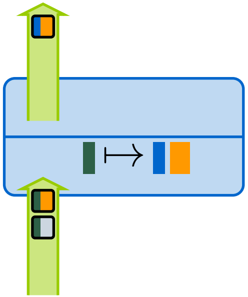

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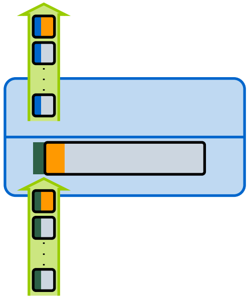
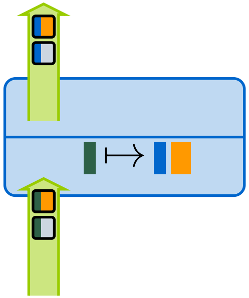
Hop-wise reassembly | **Direct fragment forwarding**





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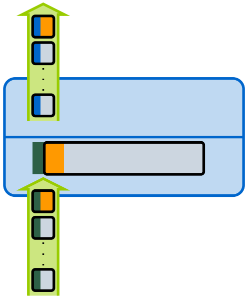

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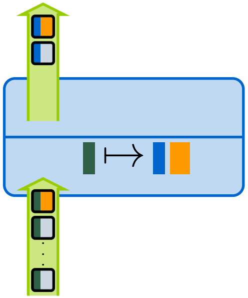

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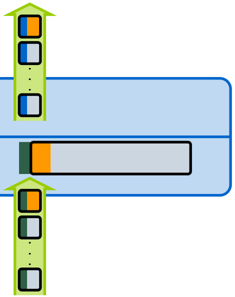

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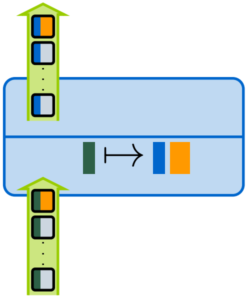

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Minimal memory usage

How to recover fragments?

Loosing one fragment requires resending of whole datagram! Solution: Use selective ACK

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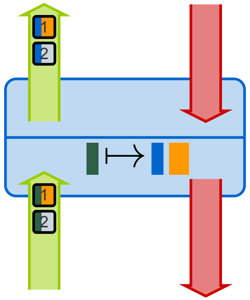

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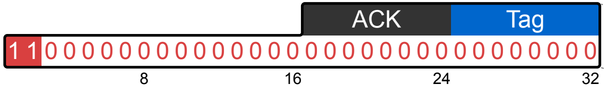

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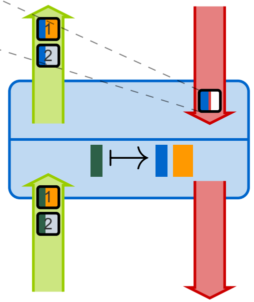

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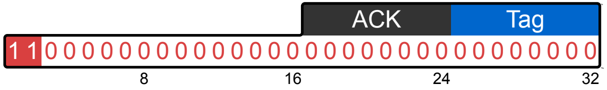

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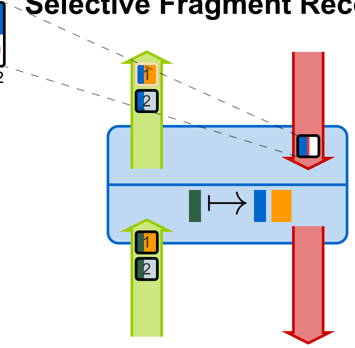

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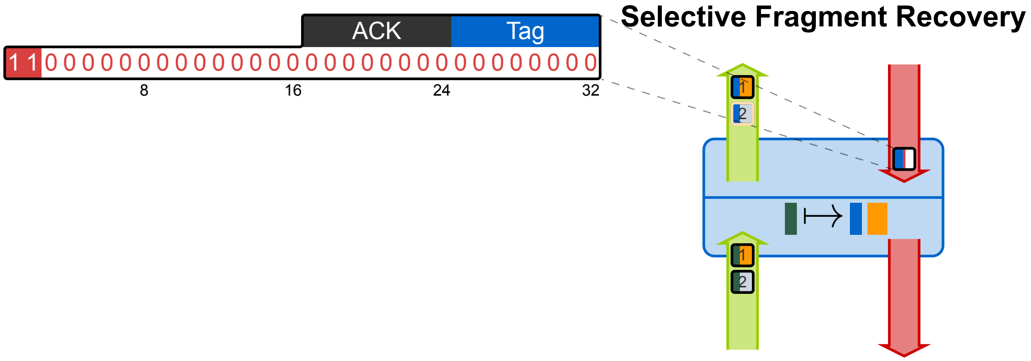

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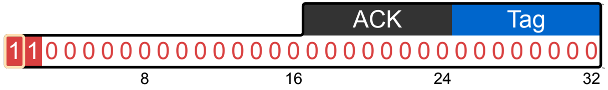

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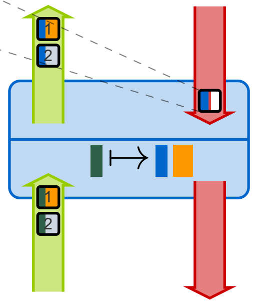

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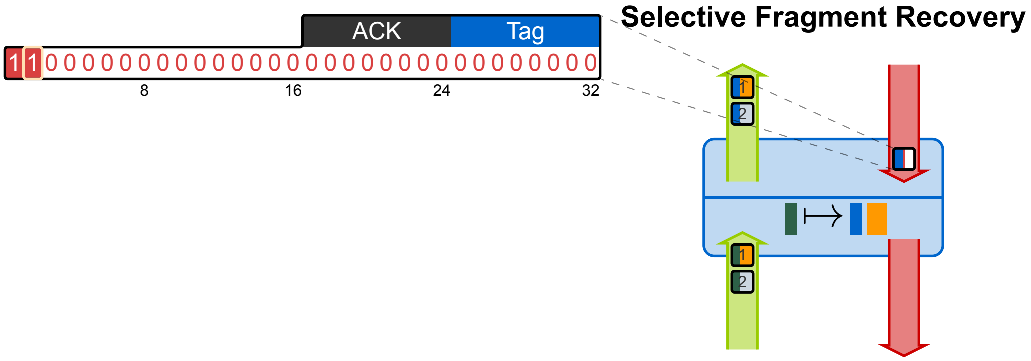

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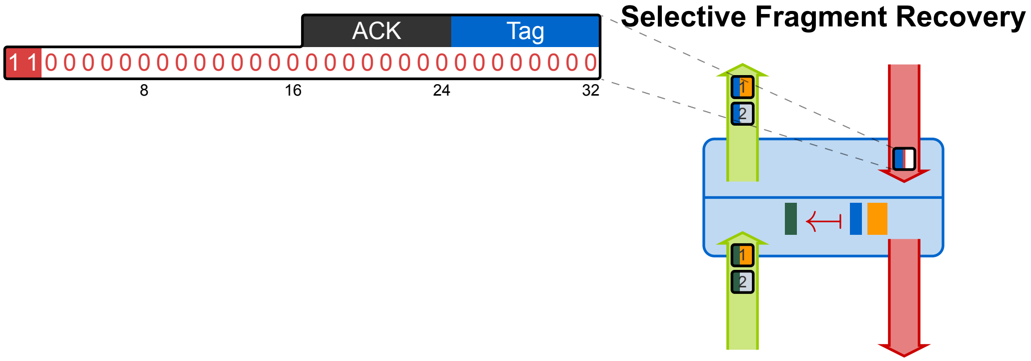

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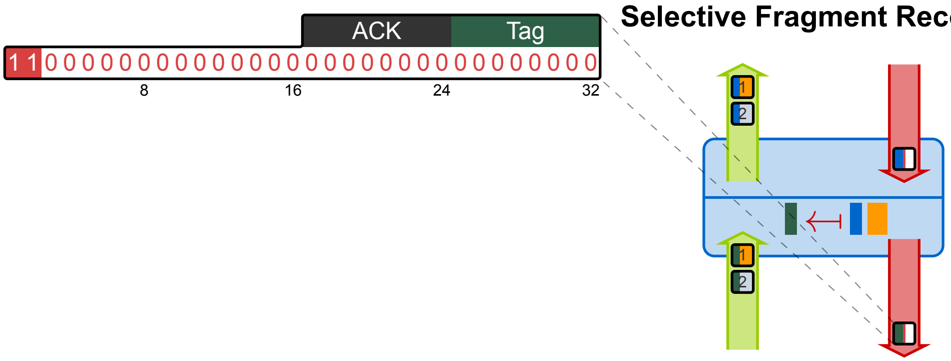

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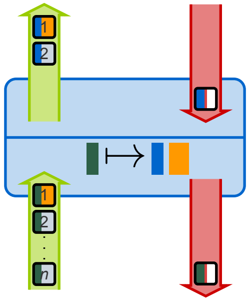

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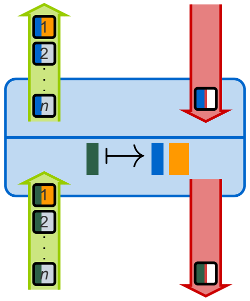

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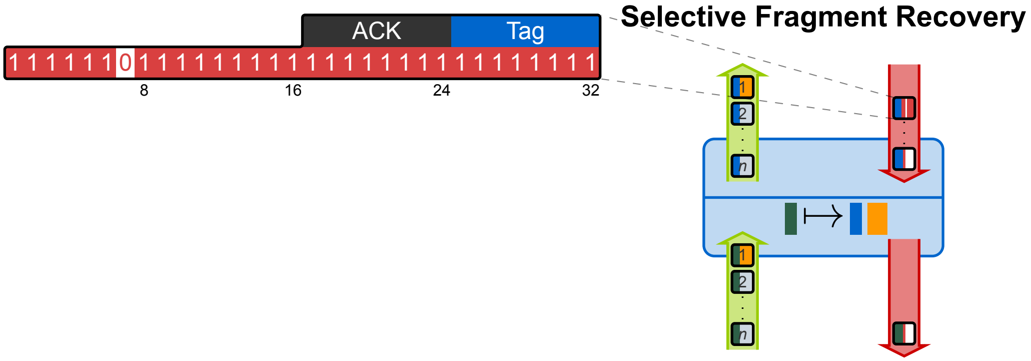

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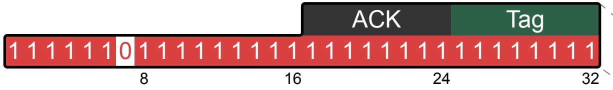

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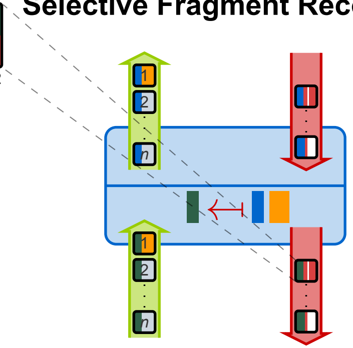

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Design of the Virtual Reassembling Endpoint

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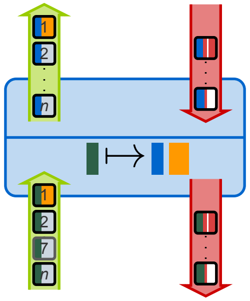

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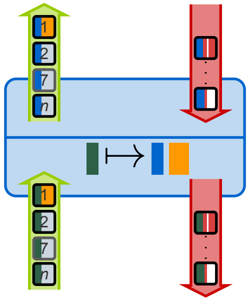

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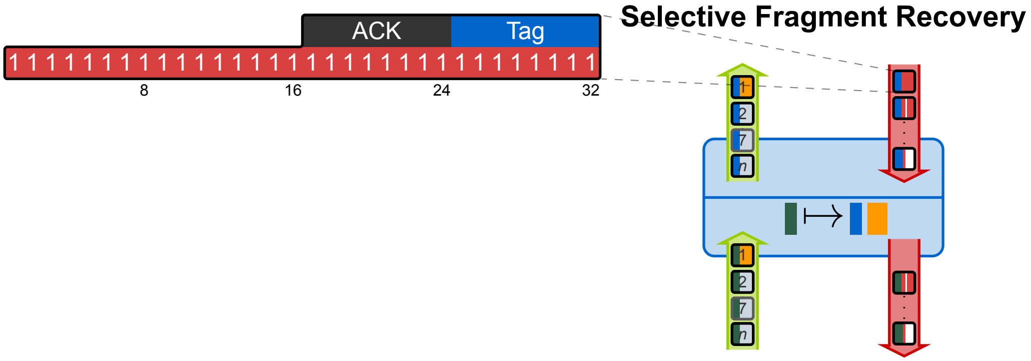

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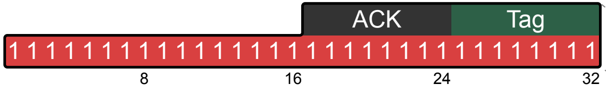

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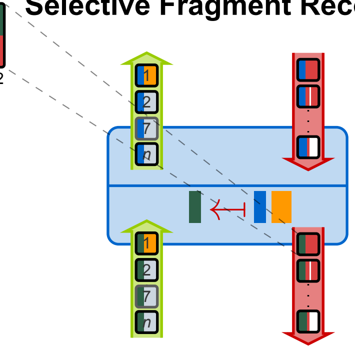

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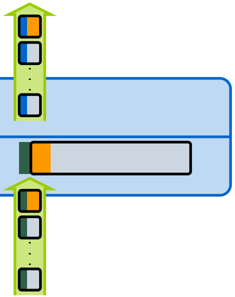
Forwarding fragments with ICN Content Store (CS)

Hop-wise reassembly



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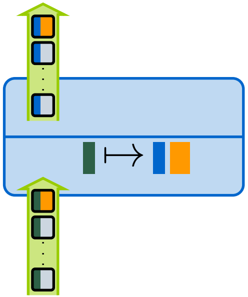

Wastes Memory

→ Forwarding bottlenecks

Minimal memory usage

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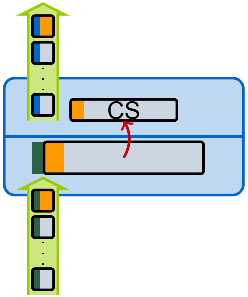

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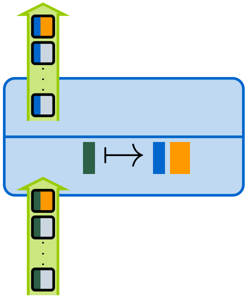

Full content chunk served to ICN

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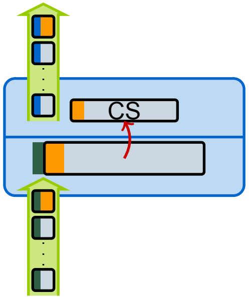

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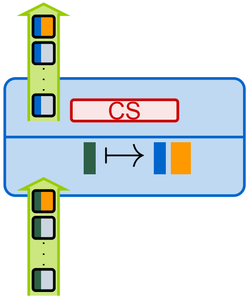

CS never gets complete datagram

→ ICN unable to cache content chunks

Forwarding fragments with ICN Content Store (CS)

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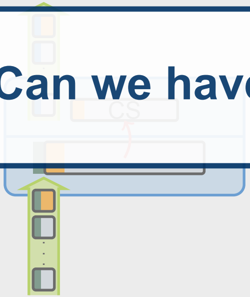

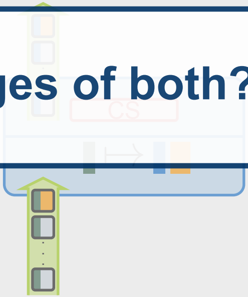

Can we have the advantages of both?

Full content chunk served to ICN

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- Standard compliancy
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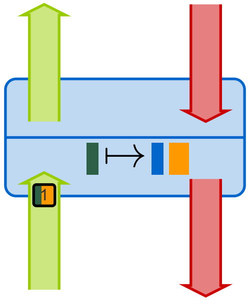
  - Cached content chunk behaves like any other content chunk
  - Prevent content poisoning with incomplete content chunks

Design of the Virtual Reassembling Endpoint

Reassemble tentatively in CS *en-route*

Selective Fragment Recovery



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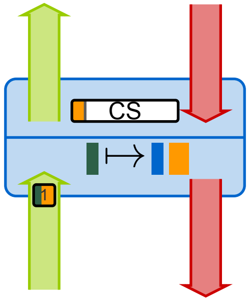

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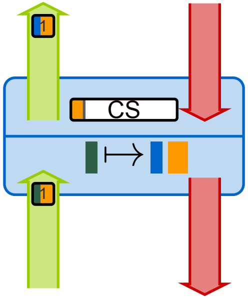

(ACK window size = 2)

Design of the Virtual Reassembling Endpoint

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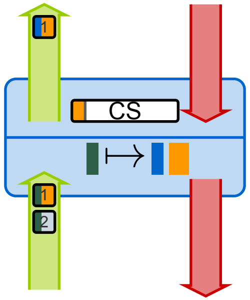

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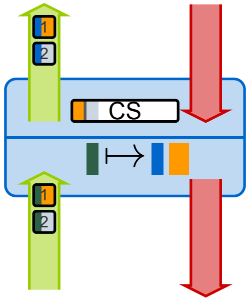

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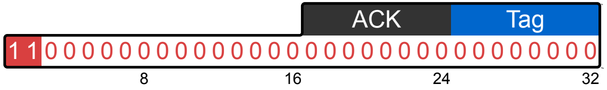

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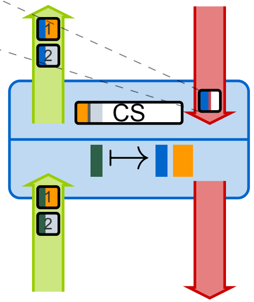

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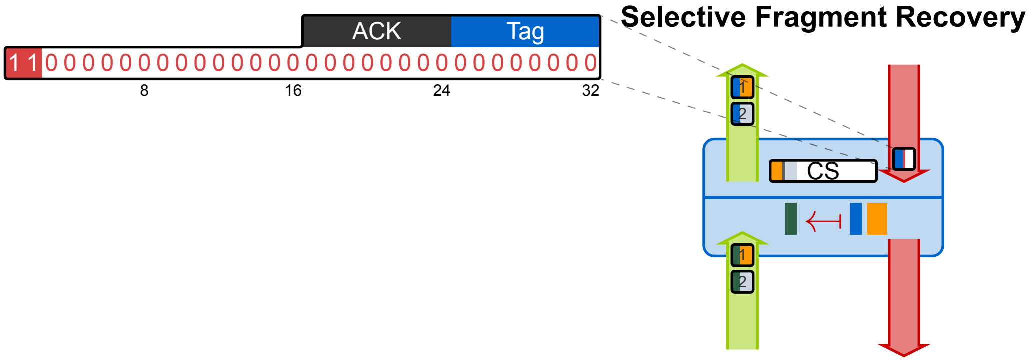

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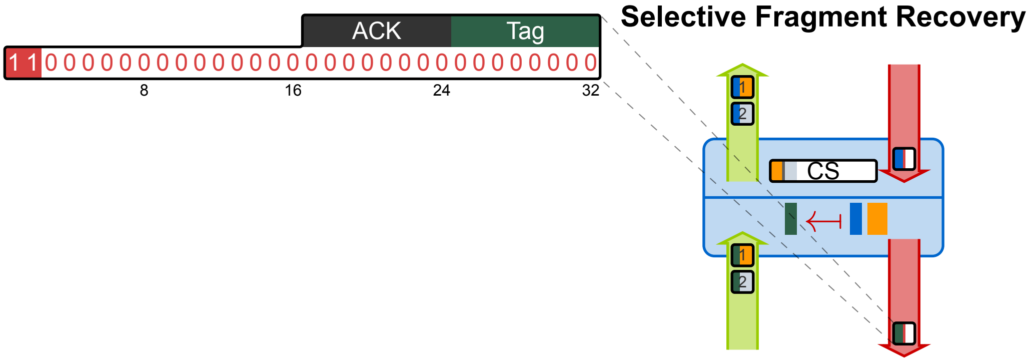

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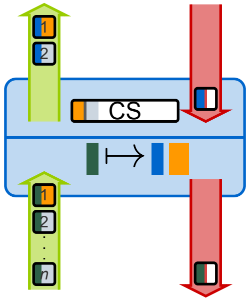

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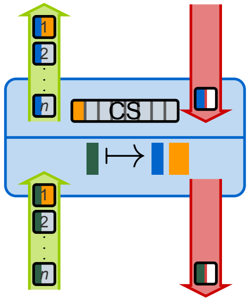

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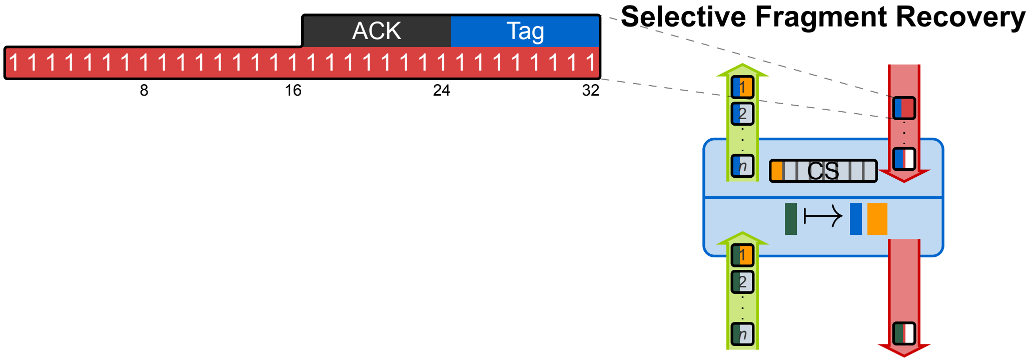

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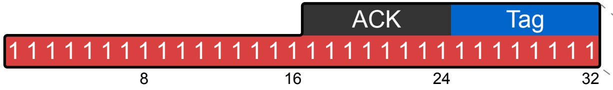

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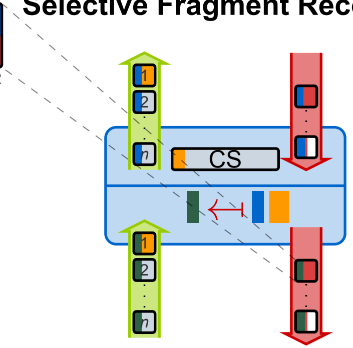

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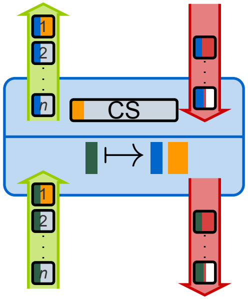
- Full ACK enables CS entry to be served to incoming Interests

Design of the Virtual Reassembling Endpoint

Reassemble tentatively in CS *en-route*

Another benefit:

Selective Fragment Recovery



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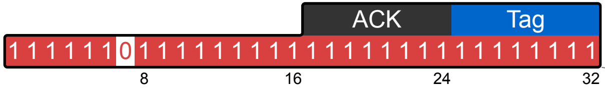
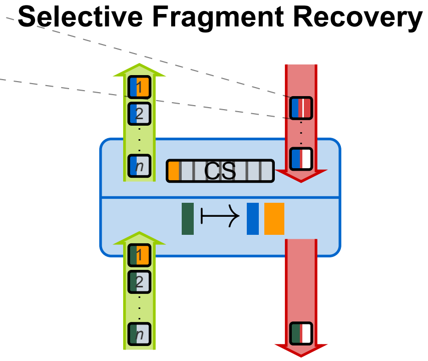


Another benefit: Restore lost fragments



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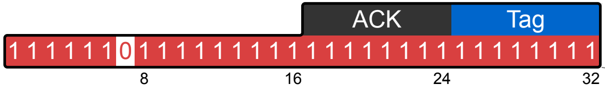

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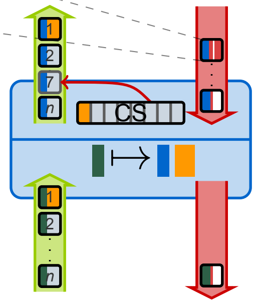

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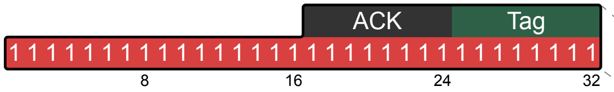

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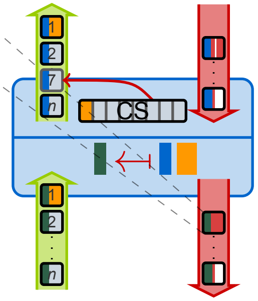

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Evaluation of the VREP extension

Conclusion & Outlook

Evaluation setup

Comparing 3 fragment forwarding approaches

Hop-wise Reassembly
(*HWR*)

Classic
Selective Fragmente Recovery
(*SFR w/o VREP*)

Selective Fragmente Recovery
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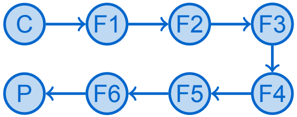
Deployment at FIT/IoT-LAB testbed in Grenoble:

Daisy chain topology
(benefits caching)


$$\begin{tikzcd} C \arrow[r] & F1 \arrow[r] & F2 \arrow[r] & F3 \arrow[d] \\ P & F6 \arrow[l] & F5 \arrow[l] & F4 \arrow[l] \end{tikzcd}$$

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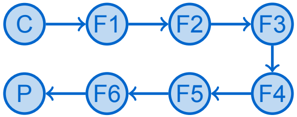
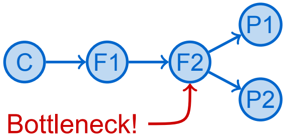
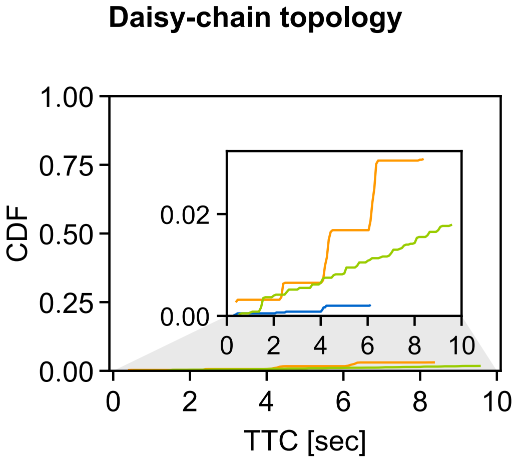
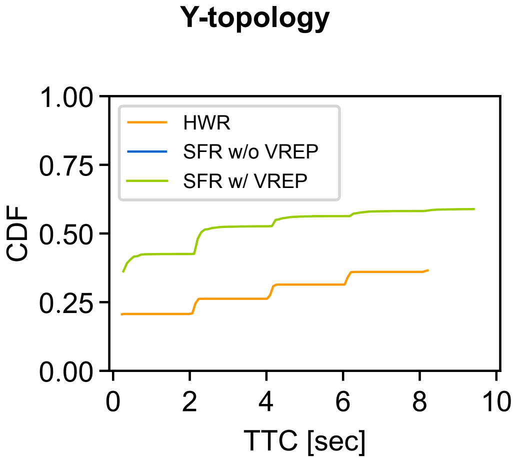


Y-topology
(benefits fragment forwarding)



Time to Completion (TTC)





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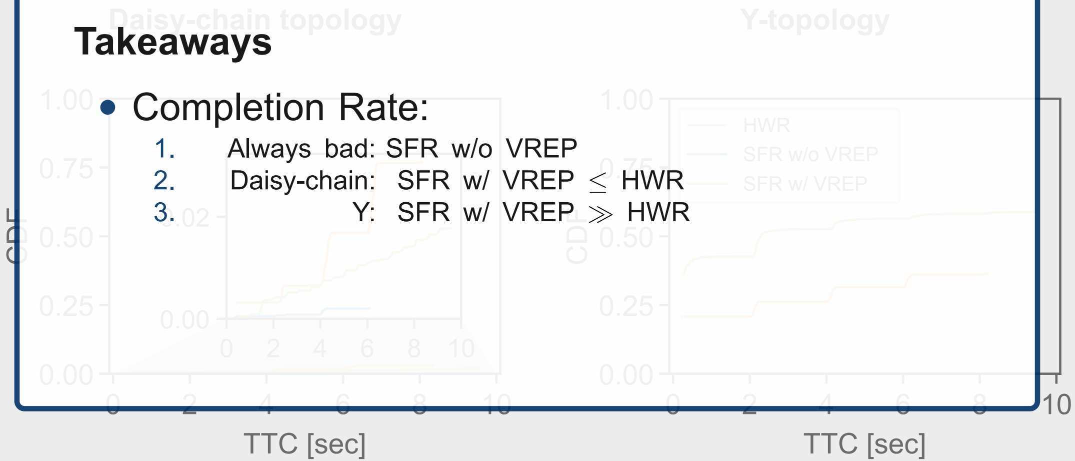

Takeaways

- Completion Rate:
  1. Always bad: SFR w/o VREP
  2. Daisy-chain: SFR w/ VREP $\leq$ HWR
  3. Y: SFR w/ VREP $\gg$ HWR

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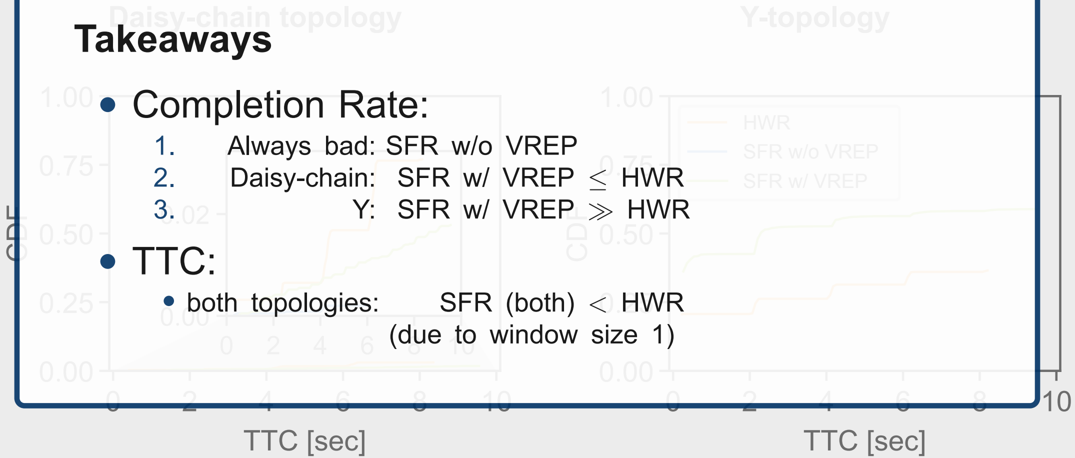

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  2. Daisy-chain: SFR w/ VREP $\leq$ HWR
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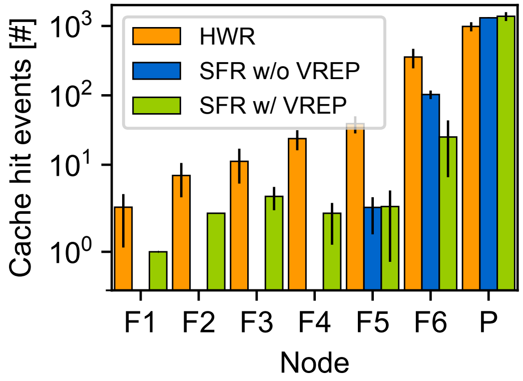
- TTC:
  - both topologies: SFR (both) $<$ HWR (due to window size 1)

Cache (CS) Hits

Daisy-chain topology



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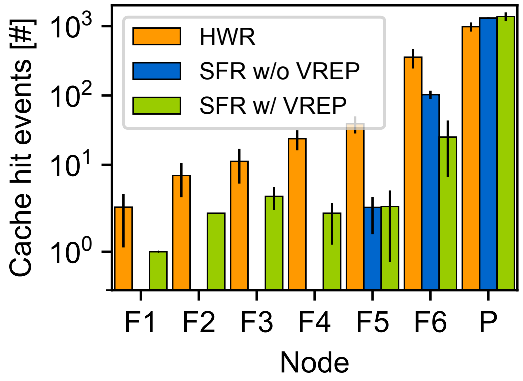

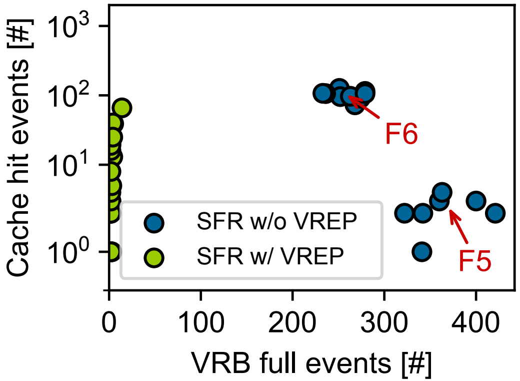

(SFR in RIOT falls back to HWR when Virtual Reassembly Buffer [VRB] is full)

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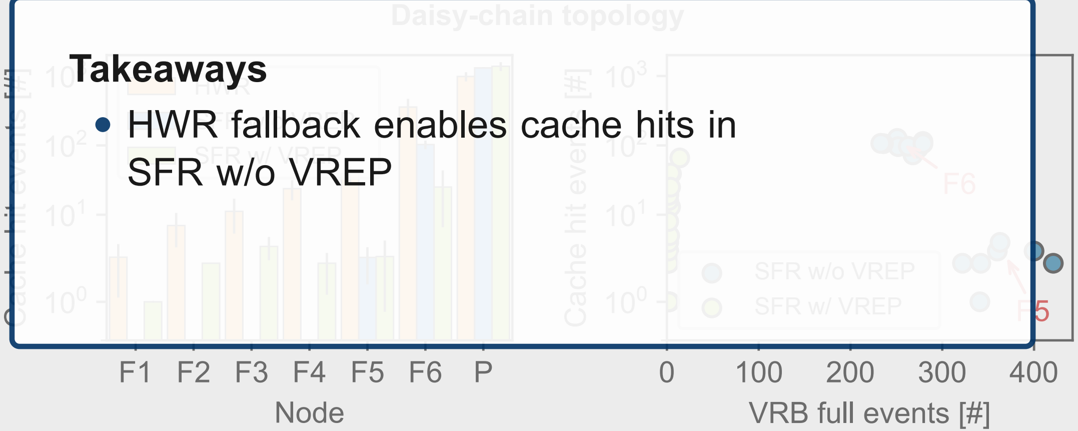

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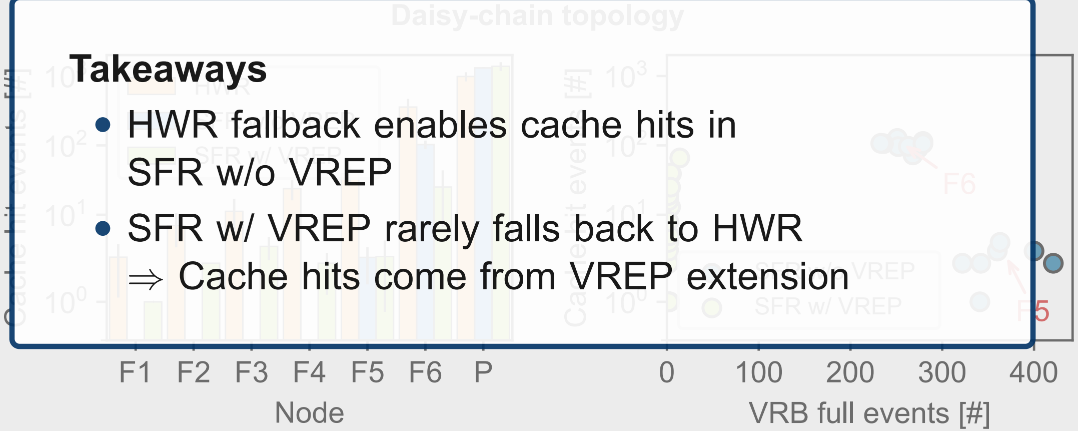

Takeaways

- HWR fallback enables cache hits in SFR w/o VREP
- SFR w/ VREP rarely falls back to HWR
  $\Rightarrow$ Cache hits come from VREP extension

(SFR in RIOT falls back to HWR when Virtual Reassembly Buffer [VRB] is full)

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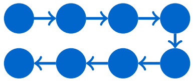

HWR $\geq$ SFR w/ VREP

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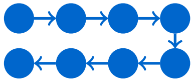

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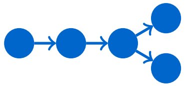

HWR $\ll$ SFR w/ VREP

Next steps

Evaluation of Virtual Reassembling Endpoint extension impact with

- More complex MAC layers, e.g. IEEE 802.15.4e
- Congestion control mechanisms within SFR
- Different ICN caching strategies

Reproducible research? Yes!
Find the code of our experiments at

https://github.com/5G-I3/ACM-ICN-2020-SFR
or in the ACM Digital Library.

m.lenders@fu-berlin.de

ICNLoWPAN: ICN adaption to LoWPAN networks

Challenge

- IEEE 802.15.4: 127 bytes PDU

Common approaches

- Header compression + **Fragmentation**

ICNLoWPAN also supports *PLC*, BLE, etc.

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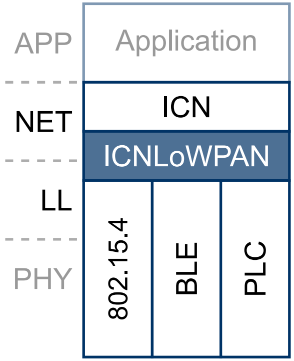

Memory requirements in reassembly buffer (RB)

(L2 src, DG tag)

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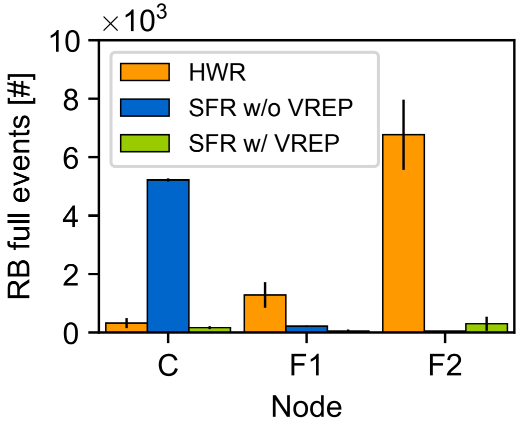
Per RB entry	**1291 bytes** $\approx$ **1.25 KiB**
Typical IoT node RAM	$\sim$ **10 KiB** $-$ **50 KiB**

$\Rightarrow$ Many implementations: only 1 reassembly buffer entry.

Reassembly Buffer (RB) usage

Y-topology



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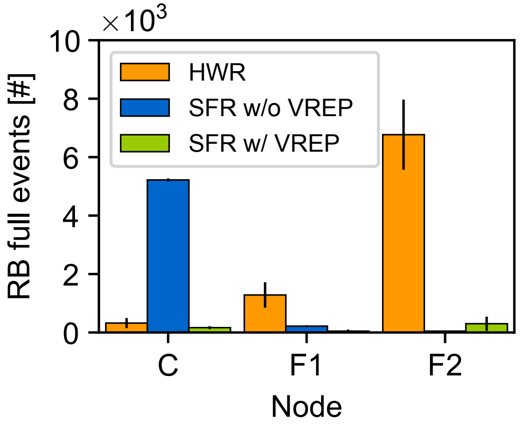

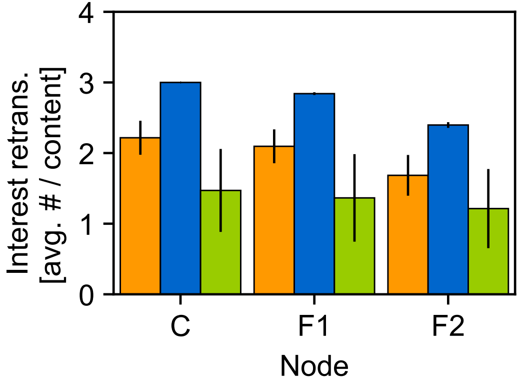

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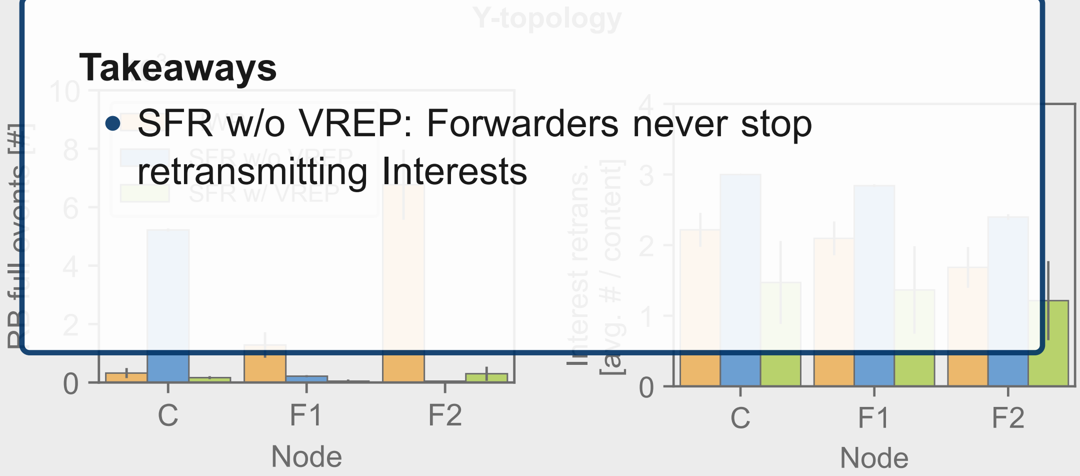

Takeaways

- SFR w/o VREP: Forwarders never stop retransmitting Interests

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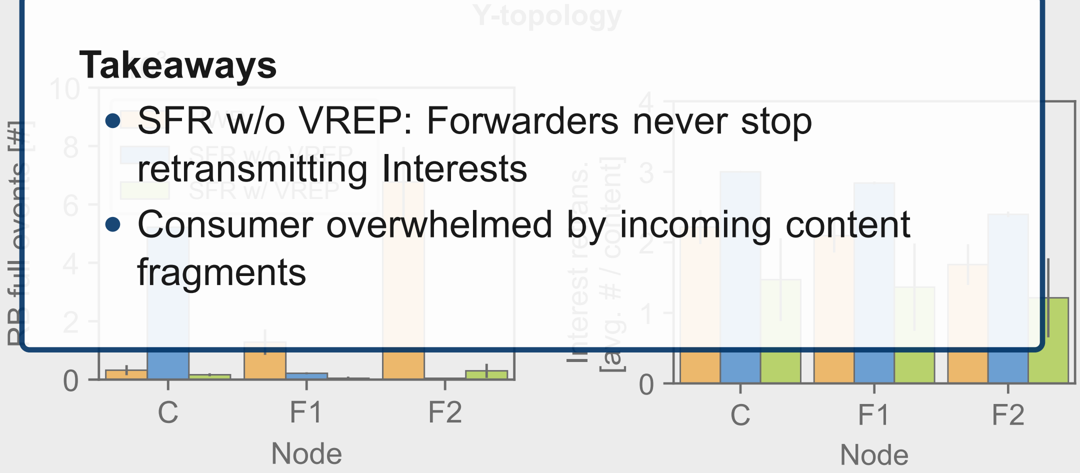

Takeaways

- SFR w/o VREP: Forwarders never stop retransmitting Interests
- Consumer overwhelmed by incoming content fragments

Memory Consumption

	HWR	SFR w/o VREP	SFR w/ VREP
ROM	1.7 KiB	5.5 KiB	6.4 KiB
RAM	1.2 KiB	5.2 KiB	7.5 KiB

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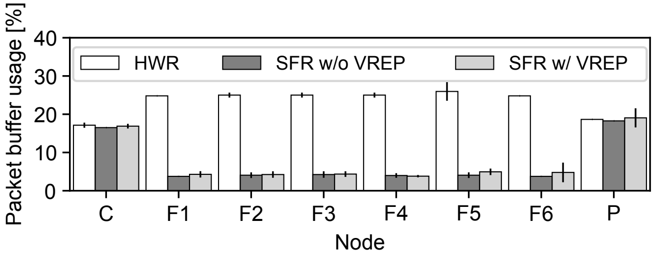

(Packet buffer size: 8 KiB)