Route-Over Forwarding Techniques in a 6LoWPAN

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IPv6 over low power WPAN (6LoWPAN)

Vision: Internet of Things

Every device should have its own IP address and should be directly accessible through the Internet.

- IPv6 supports approximately $3.4 \cdot 10^{38}$ addresses, but:
  - 802.15.4 supports frames up to 127 byte
  - IPv6 requires a MTU of at least 1280 byte!
- Solution for using IPv6 on 802.15.4 is 6LoWPAN:
  - Intermediate layer for header compression,
  - Packet fragmentation and
  - Mesh routing (Mesh under) ability

The base specification document is RFC 4944

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  - Route-over

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Motivation

- Fragmentation can cause trouble!

  One lost fragment results in a lost datagram

- Big packets needed by:
  - Smart Metering
  - Firmware Updates
  - ...
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- Compare different forwarding techniques
- introduce enhancements

Route-Over Forwarding Strategies

Assembly:

- On each hop: Wait for every fragment
- Reassemble datagram and send to IP Layer
- IP Layer sends datagram back to 6LoWPAN
- 6LoWPAN recreates fragments

Direct:

- On each hop: Look into the first fragment
- If not for this node lookup route
- Directly send to next Hop
- Safe routing information for next fragment

Problems

Assembly:

- Needs a big buffer

  A node needs a buffer for every incoming datagram

- Does not allow pipelining

Direct:

- Can lead to heavy losses

  A node tries to forward a frame while the next is being send

Enhanced Modes

Direct-RR:

- sending rate of the queue is restricted
- Inter frame delay (between 15 and 21 ms)

Direct-ARR:

- Similar to Direct-RR
- Adaptive delay (EWMA filter on last delay)

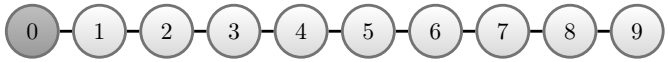
Retry Control:

- Progress-based Retry Control (PRC)
- Later Fragments of a datagram get increased number of maximum retries

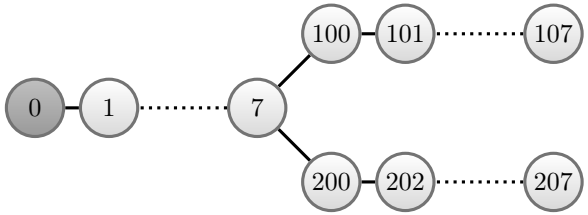
CometOS

- A **Com**ponent-based, **e**xtensible, **t**iny **O**perating **S**ystem for wireless sensor networks
- Developed at the Institute of Telematics (TUHH)
- Code written in C++
- One implementation for OMNeT++ and hardware
- Own implementation of the 6LoWPAN stack

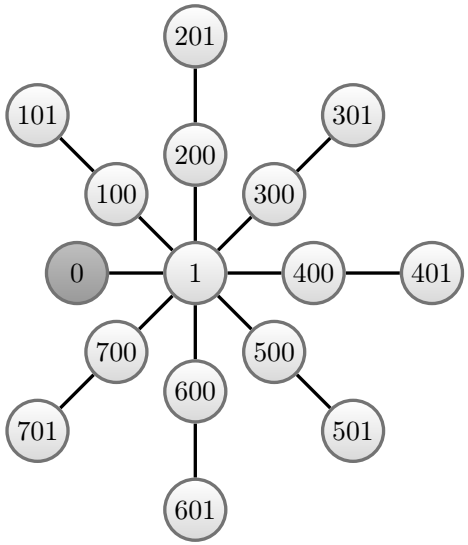
Topologies



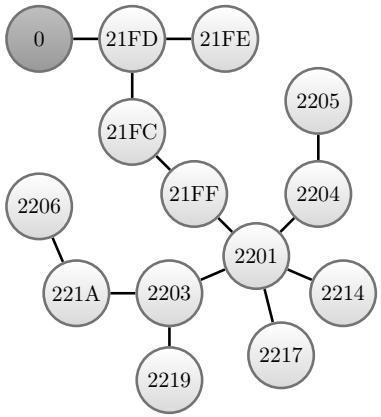
Chain-Network



LongY-Network



Star-Network



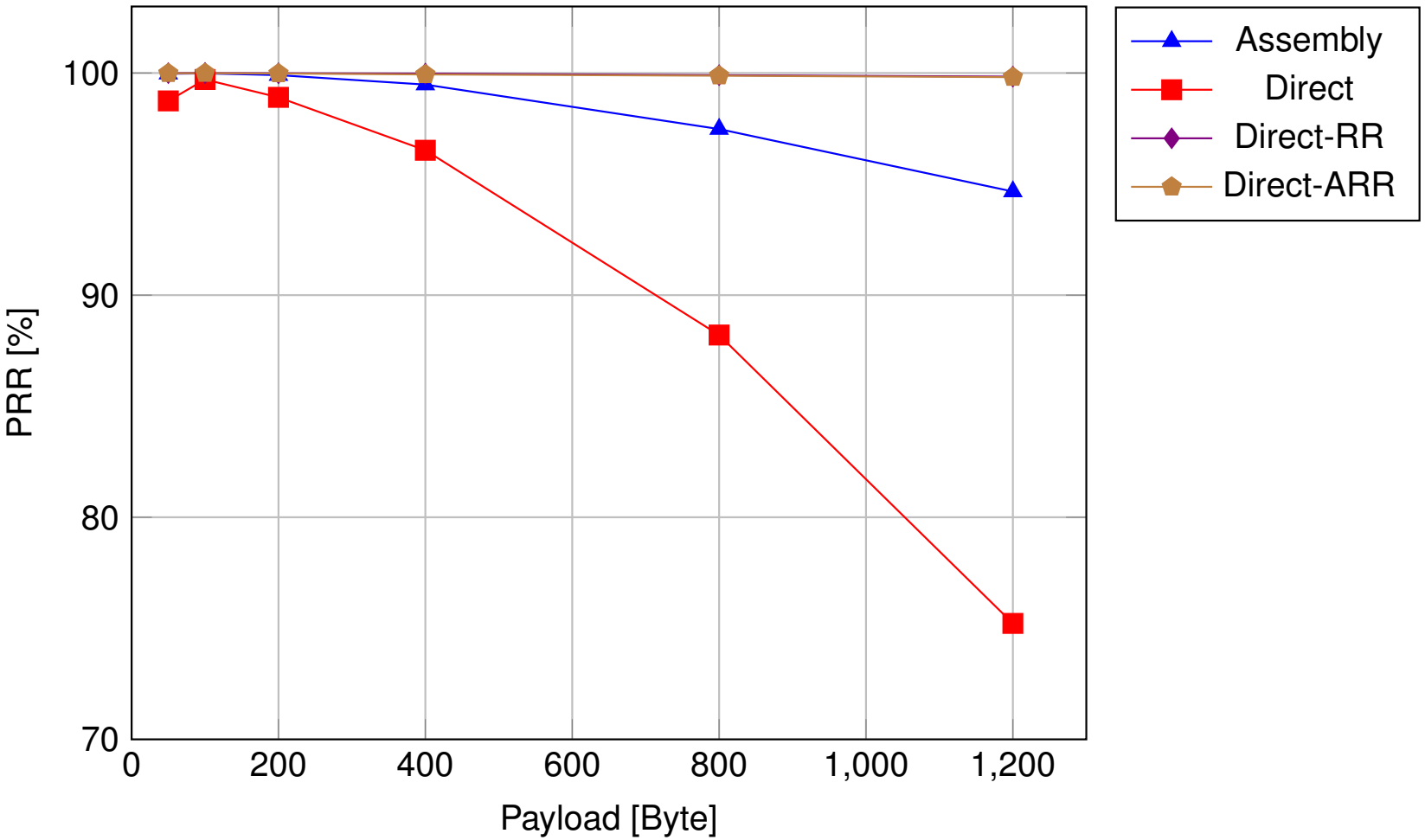
RealSim

Edges represent static routes, the dark gray node is the sink.

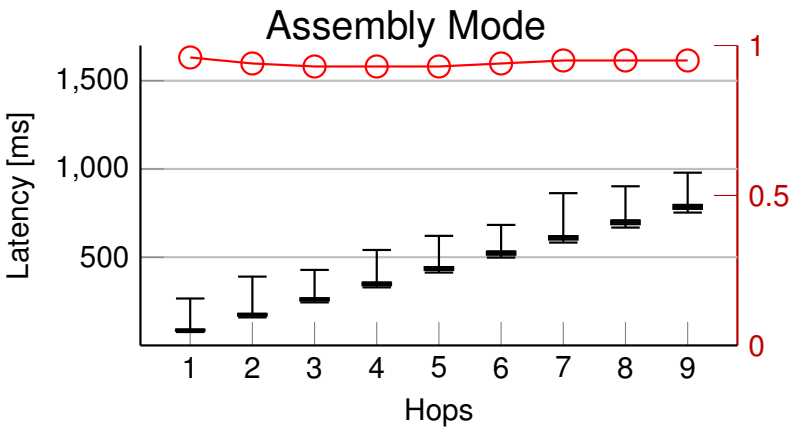
Settings

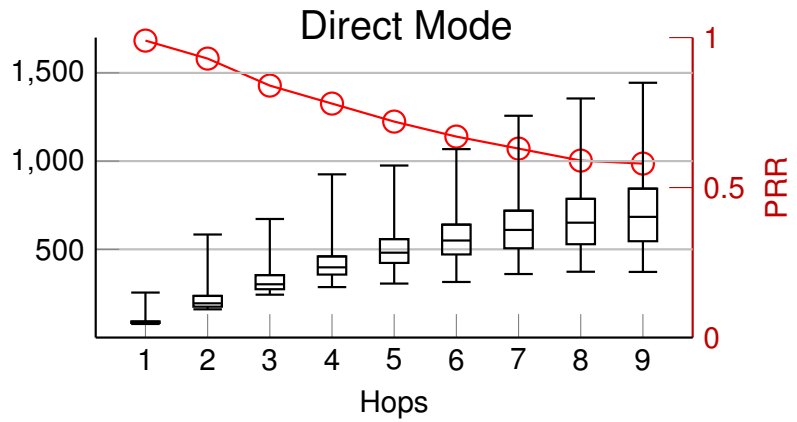
- Static Routing
- All implementations use same amount of RAM
- Perfect Links in the Chain- and Star-Network
- UDP Packets
- Sending Rate for each Node: $37.5 \frac{\text{Byte}}{\text{s}}$
- Simulation:
  - payload [Byte] $= 50, 100, 200, 400, 800, 1200$
  - 2000 Packets, 5 runs
- Testbed:
  - 48 000 Bytes in
  - payload [Byte] $= 100, 400, 1200$

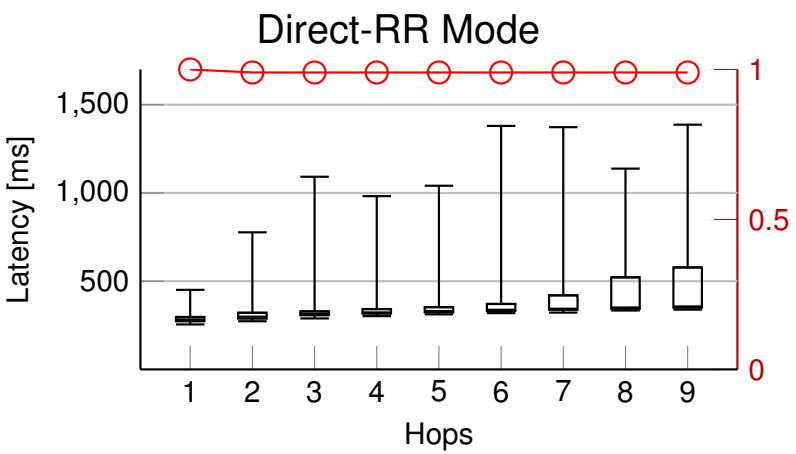
Chain-Network - PRR

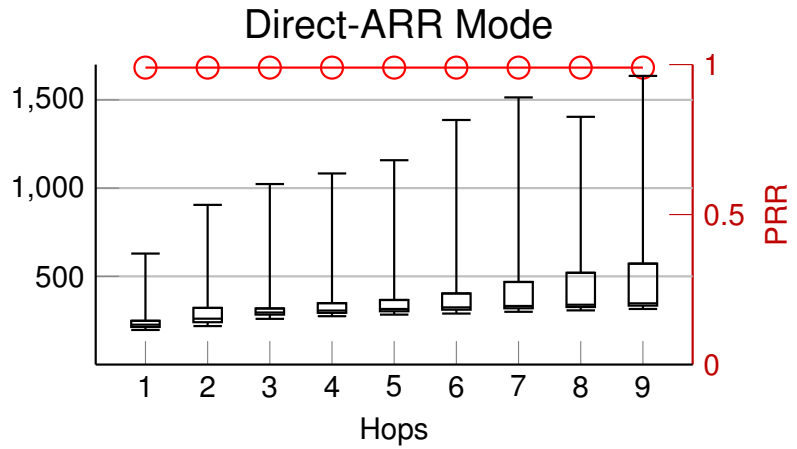


Chain-Network - Latency



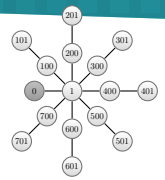


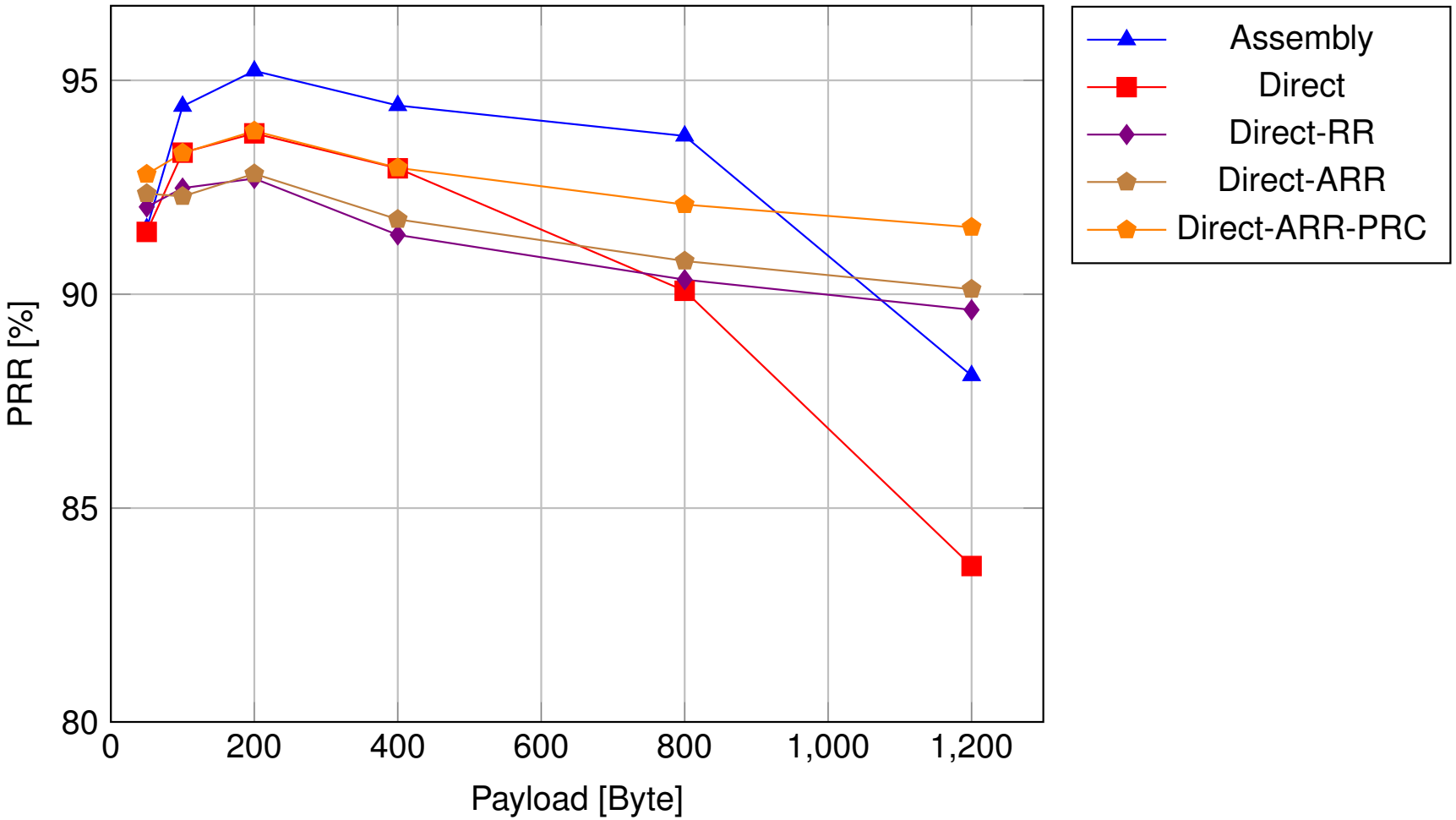




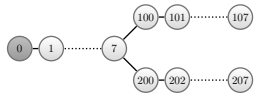
Per hop latency and PRR for 1200 Byte Payload

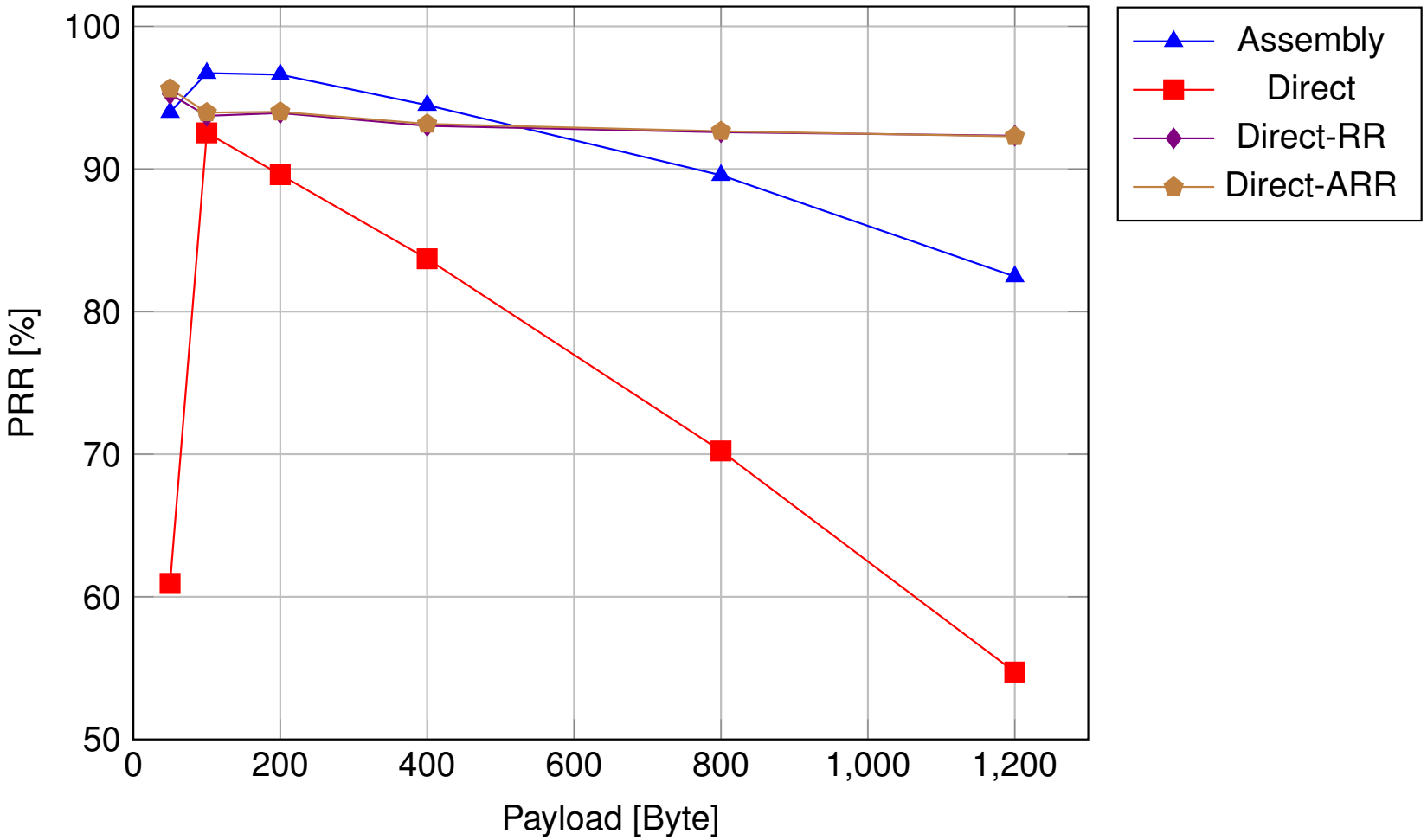
Star-Network PRR





LongY-Network - PRR





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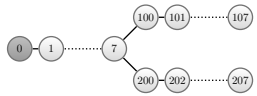

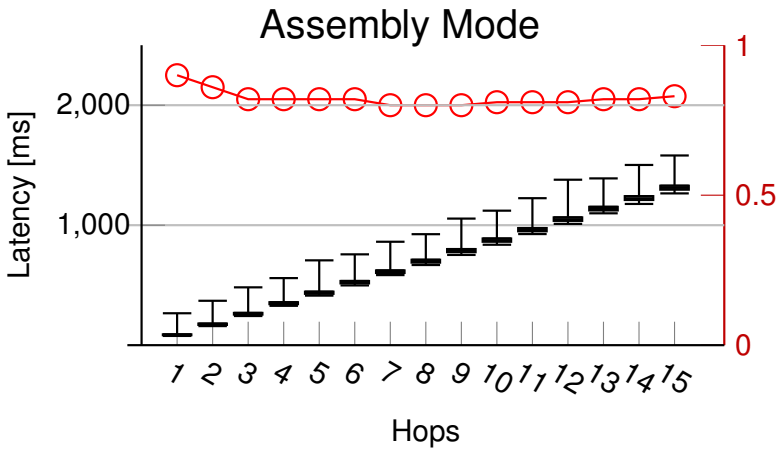

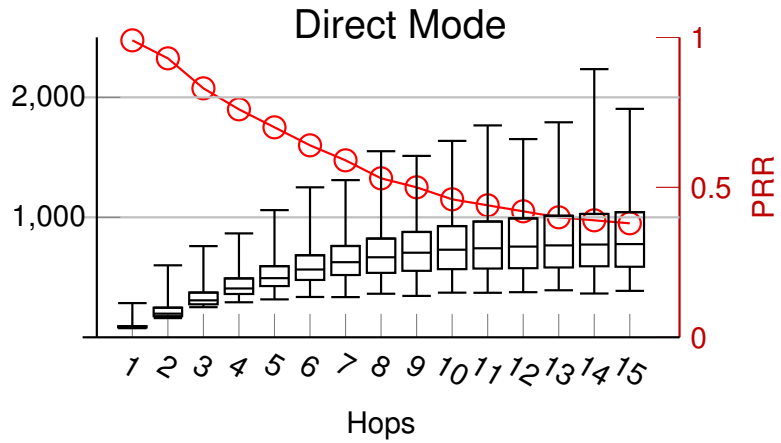

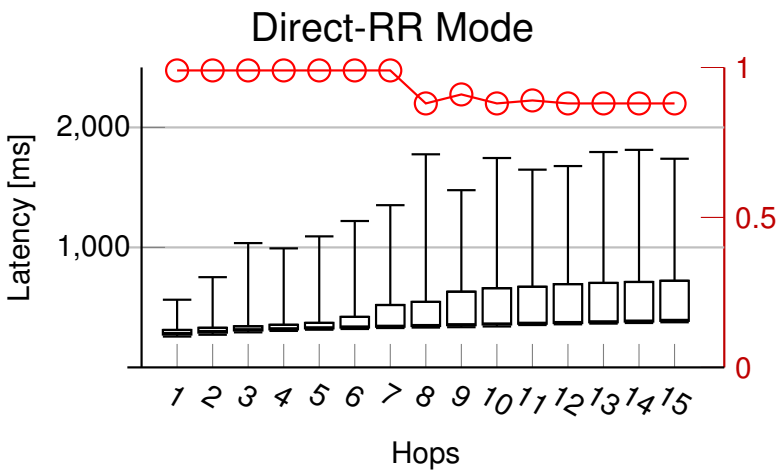

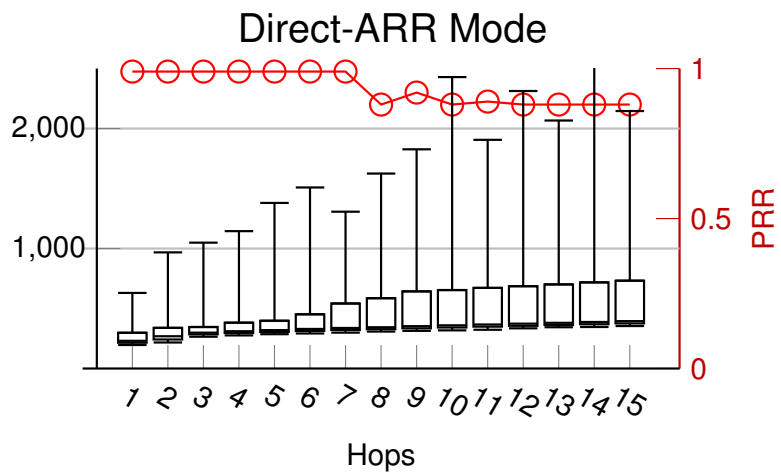

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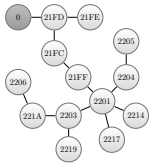
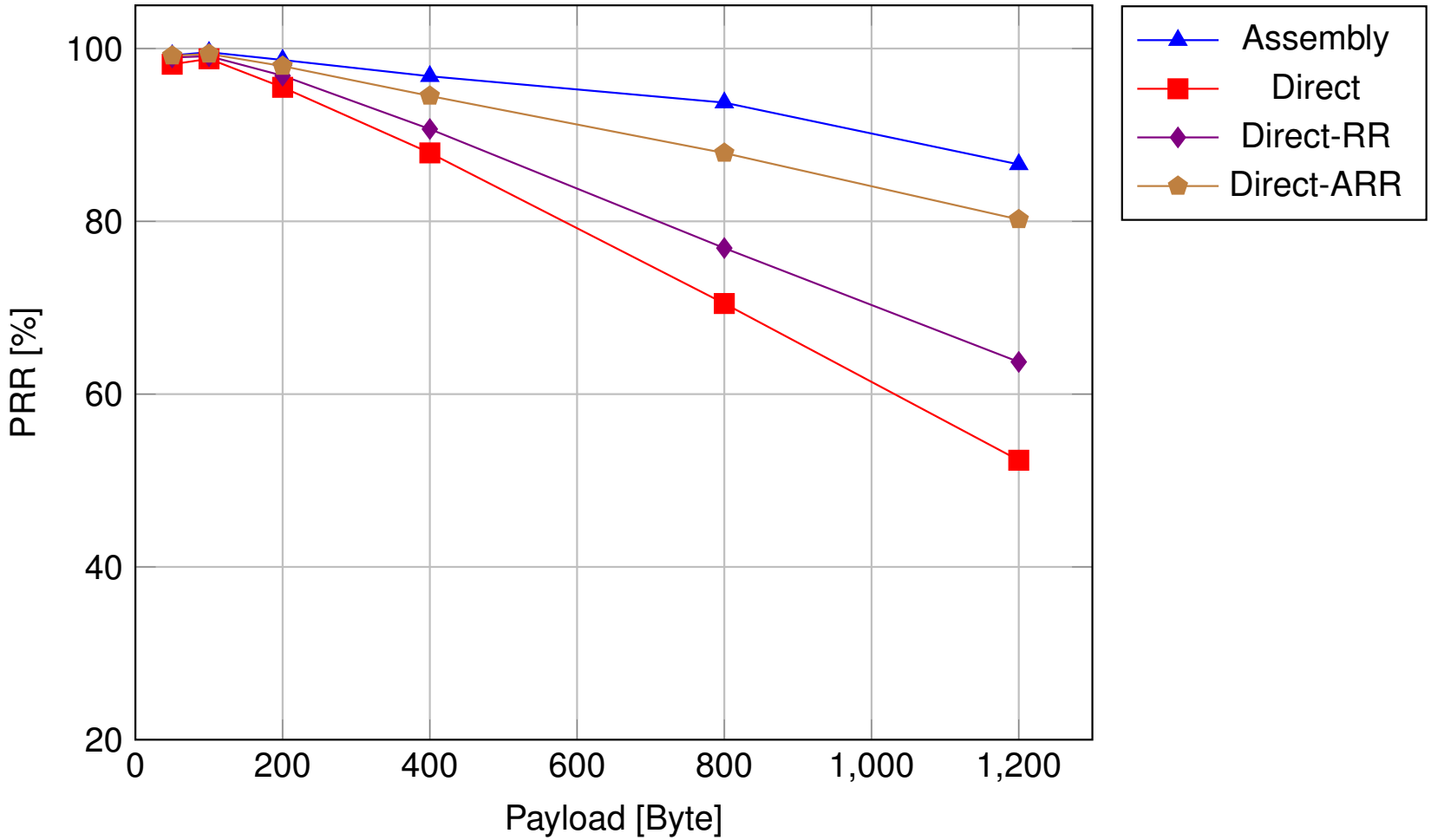
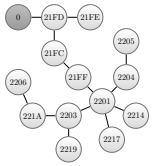
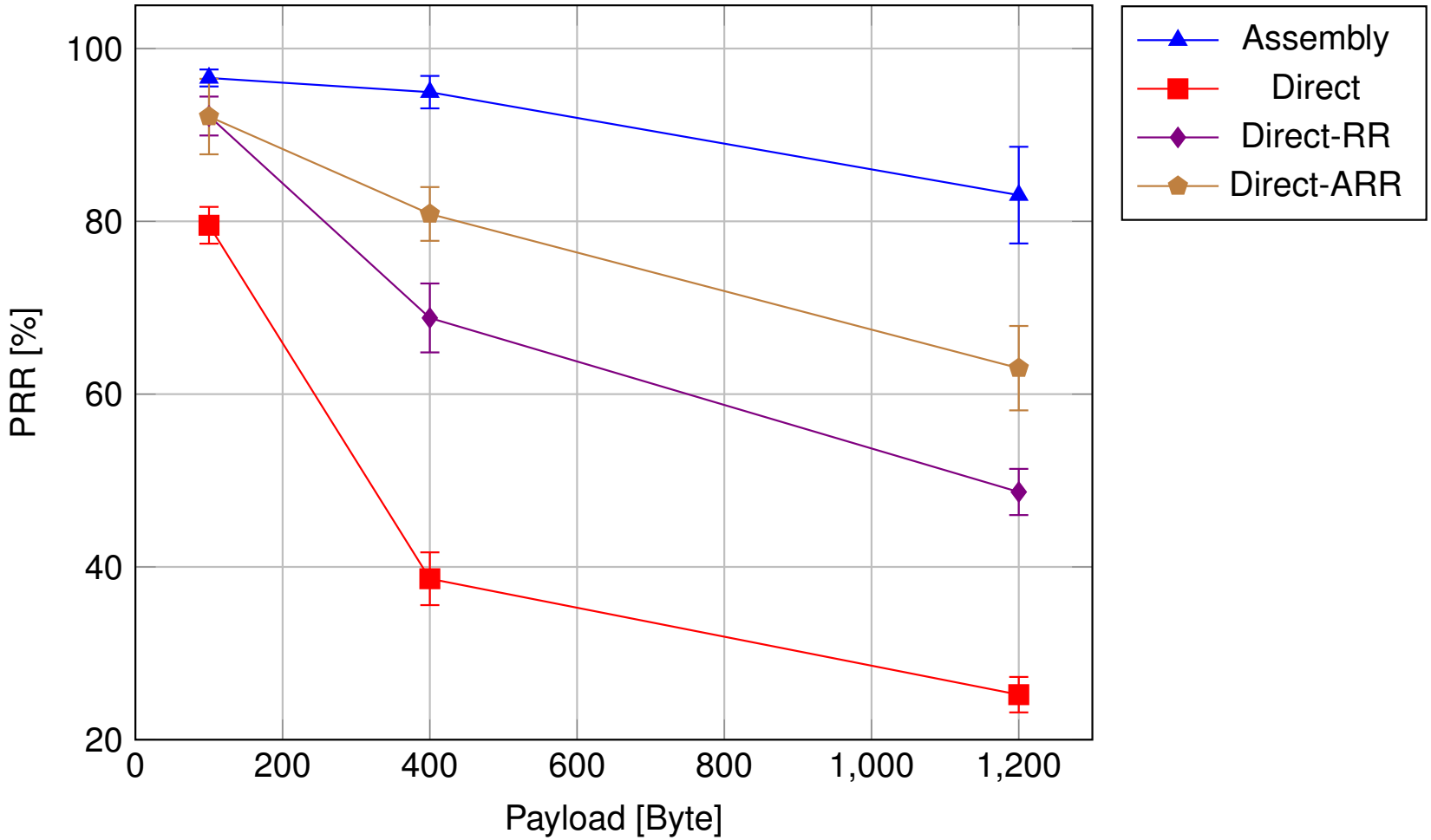
RealSim-Network - PRR



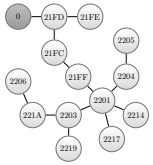


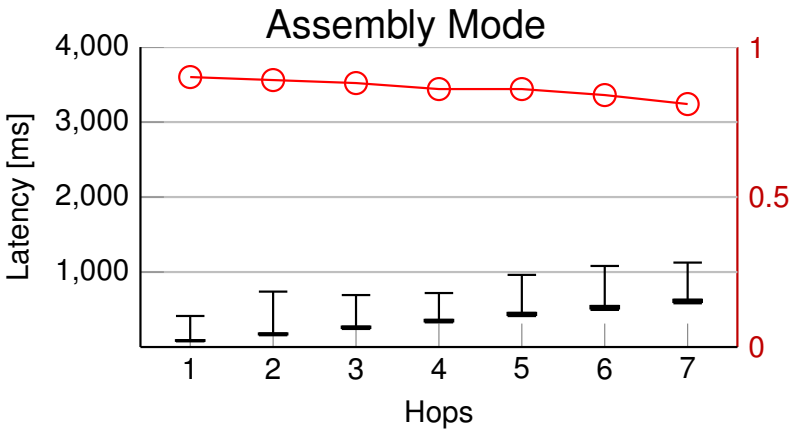
Testbed - PRR

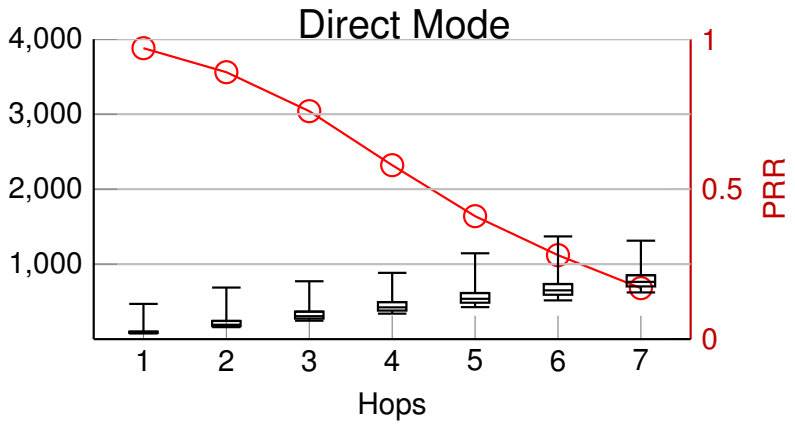

0
21FD
21FE
21FC
2205
21FF
2204
2206
2201
221A
2203
2214
2219
2217

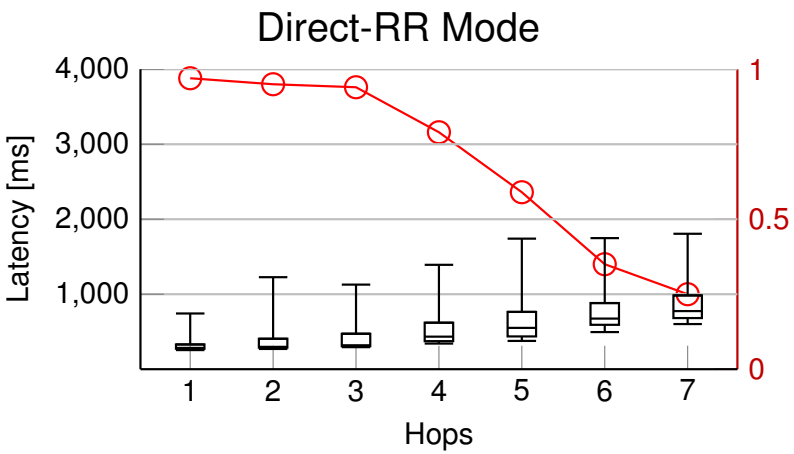

PRR [%]
100
80
60
40
20
0
200
400
600
800
1,000
1,200
Payload [Byte]
Assembly
Direct
Direct-RR
Direct-ARR

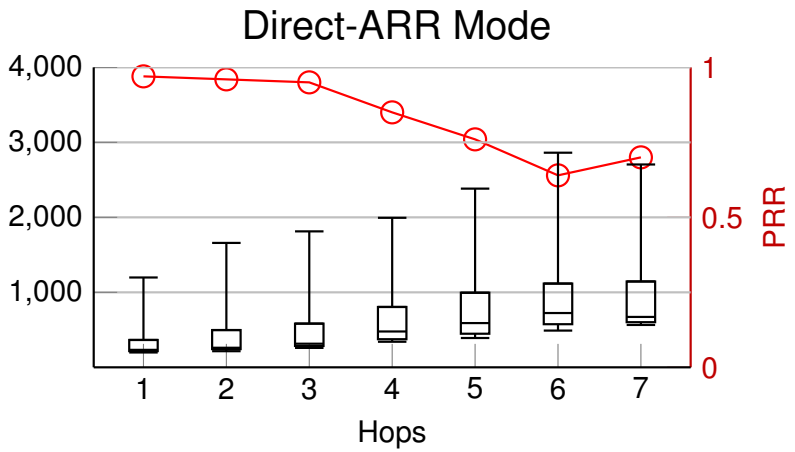
RealSim-Network - Latency











Per hop latency and PRR for 1200 Byte Payload

Conclusion

- 6LoWPAN enables 802.15.4 nodes to use IPv6
- Different forwarding strategies for fragments
- Significant difference between Direct and Assembly Mode
- Rate Restriction provides better PRR
- Direct-ARR scales best, but may increase latency for small hop distances
- Retry Control has very limited impact

Outlook

- Compare selective retry control with flat increased retries
- Implement a Hop-based Retry Control
- Implement a fragment recovery mechanism
- Evaluate different settings of the MAC configuration

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Appendix

Packet Fragmentation

- Header with 4 for first and 5 byte for following fragments
- Allowed fragmented datagram size of up to 2048 byte
- Header inherits size and tag of the IP datagram
- Position of the fragment in the datagram is in header

  $\Rightarrow$ Fragments do not need to arrive in order, but

  one lost fragment results in a lost datagram