oFIQUIC: Leveraging QUIC in OSPF for seamless network topology changes

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Agenda

- **Topology changes in IGPs**
- Ordered FIB updates (oFIB)
- oFIQUIC design
- oFIQUIC performances

Seamless topology changes is necessary

Topology changes in IGPs

Planned modification

Unplanned modification

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Topology changes in IGPs

Planned modification

- Adding / removing links / nodes
  - Physically upgrading backbone network
  - Logically reconfiguring optical underlay
    - e.g. add virtual link, disable link, modify available bandwidth

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  - Reflect link bandwidth
  - Traffic engineering

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  - e.g. Fiber cut, failed NIC
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Table 2
About topological changes, a spatial aggregation attempt of listener events (per day statistics).

Types	Average	Median	Max	Total
Link down/up	37.35	6	2074	16,848
Router down/up	0.3	0	8	136
Weight change	0.12	0	4	57

Merindol, P., David, P., Pansiot, J. J., Clad, F., & Vissicchio, S. (2018). A fine-grained multi-source measurement platform correlating routing transitions with packet losses. *Computer Communications*, *129*, 166-183.

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Issue: IGPs not designed for frequent changes

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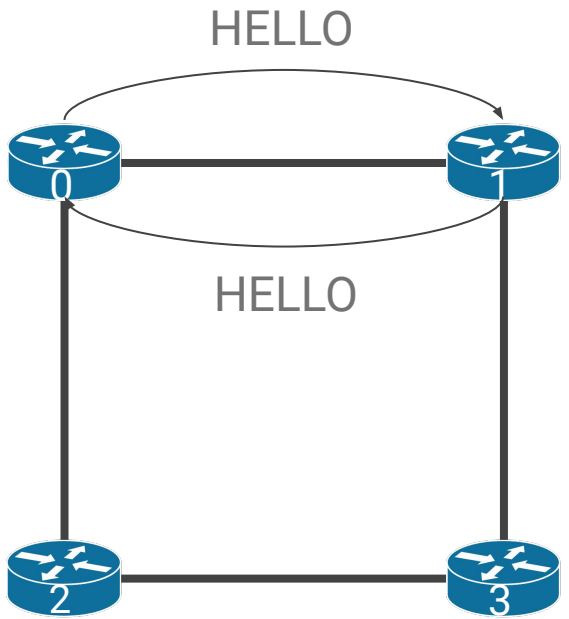
OSPF discovers neighbors

IGP remainder

1. Neighbor discovery
   (2-way connectivity check)



All metrics are unitary

OSPF floods Link State Advertisments (LSAs)

IGP remainder

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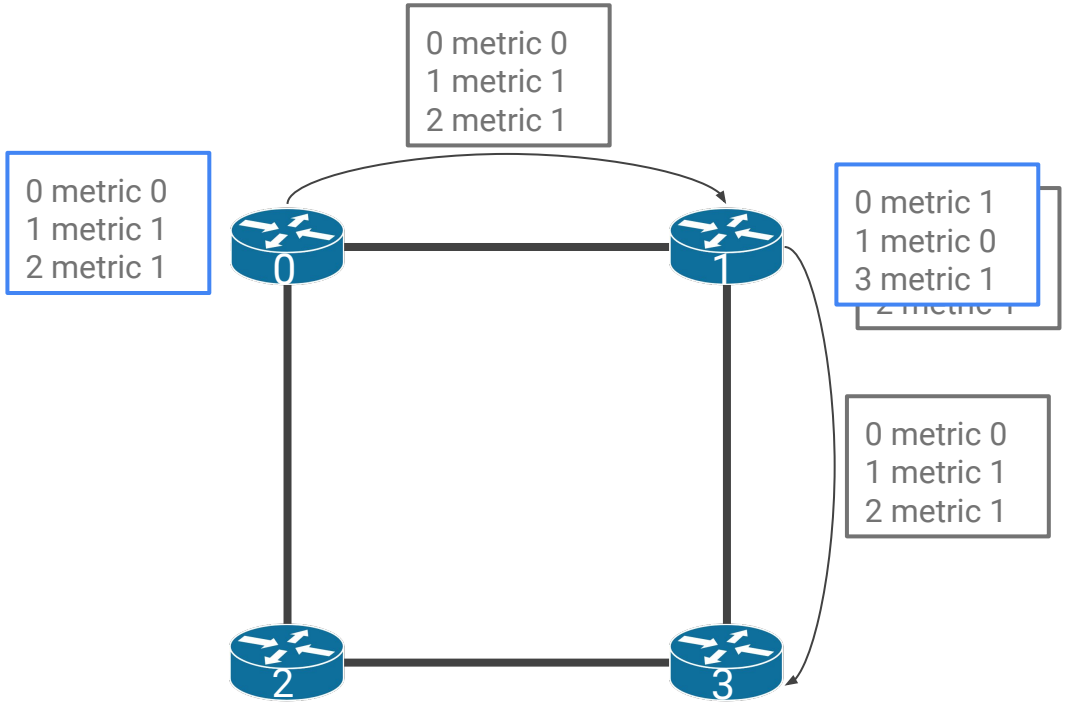

All metrics are unitary

OSPF computes the shortest paths
IGP remainder

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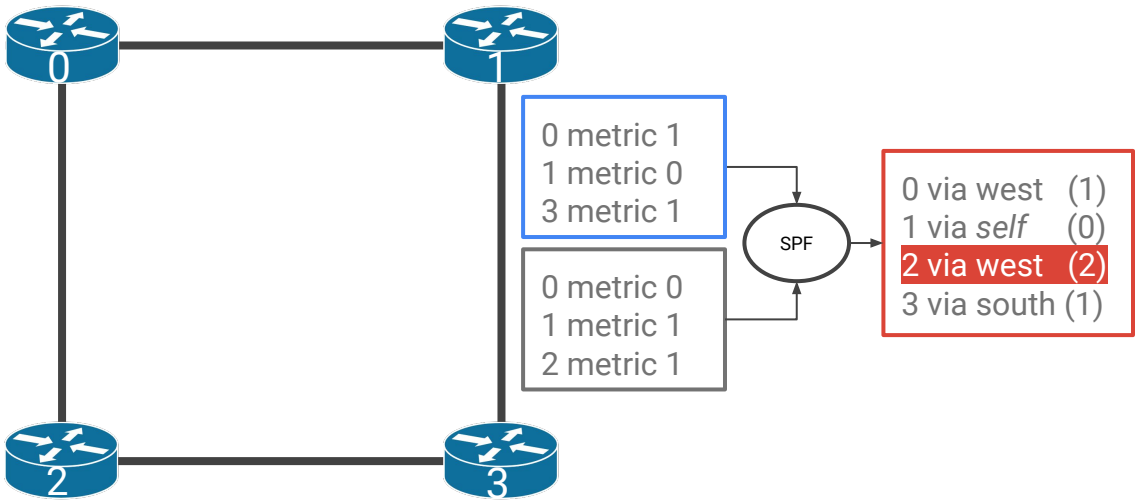
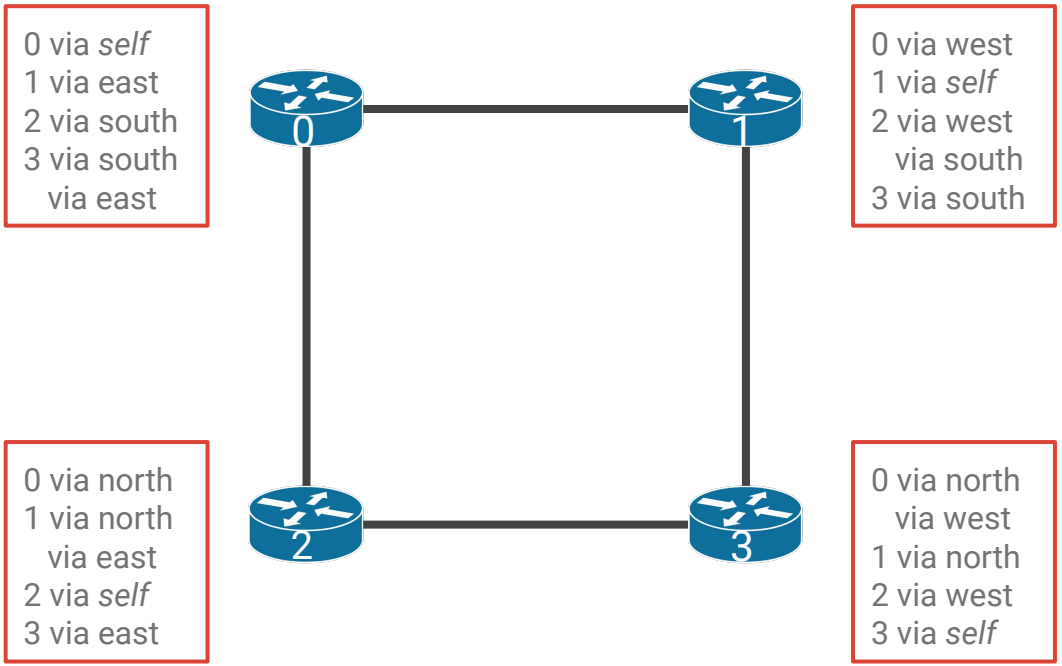
2. Flood Link State Advertisement (LSAs)
3. Shortest paths computation



All metrics are unitary

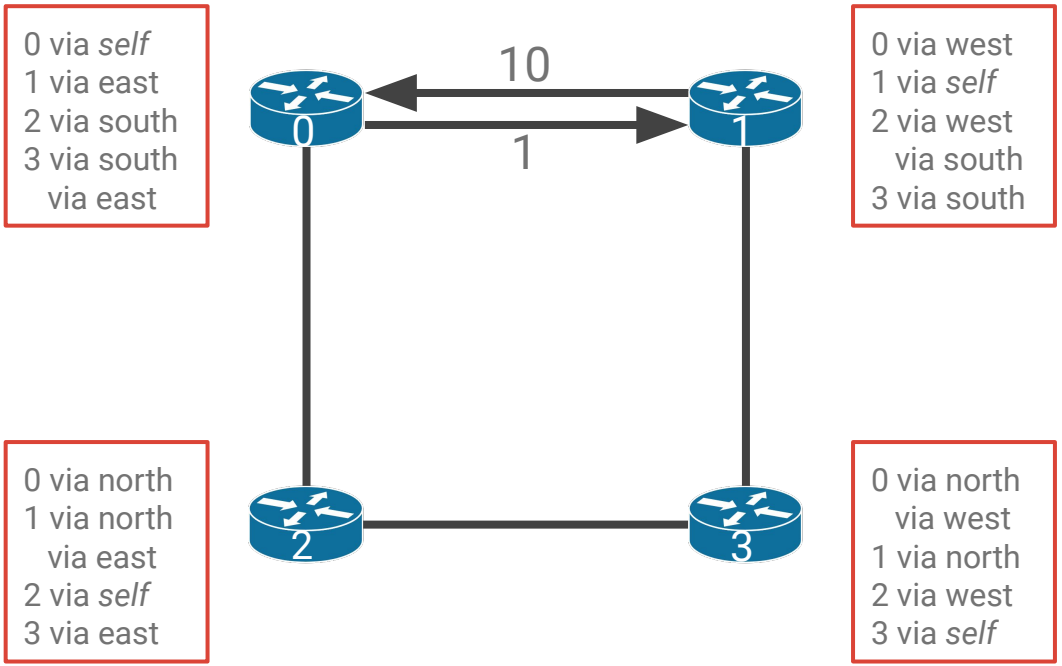
OSPF converges

IGP remainder



Increasing link metric
Topology changes in IGPs

Virtually remove a link with max metric - 1



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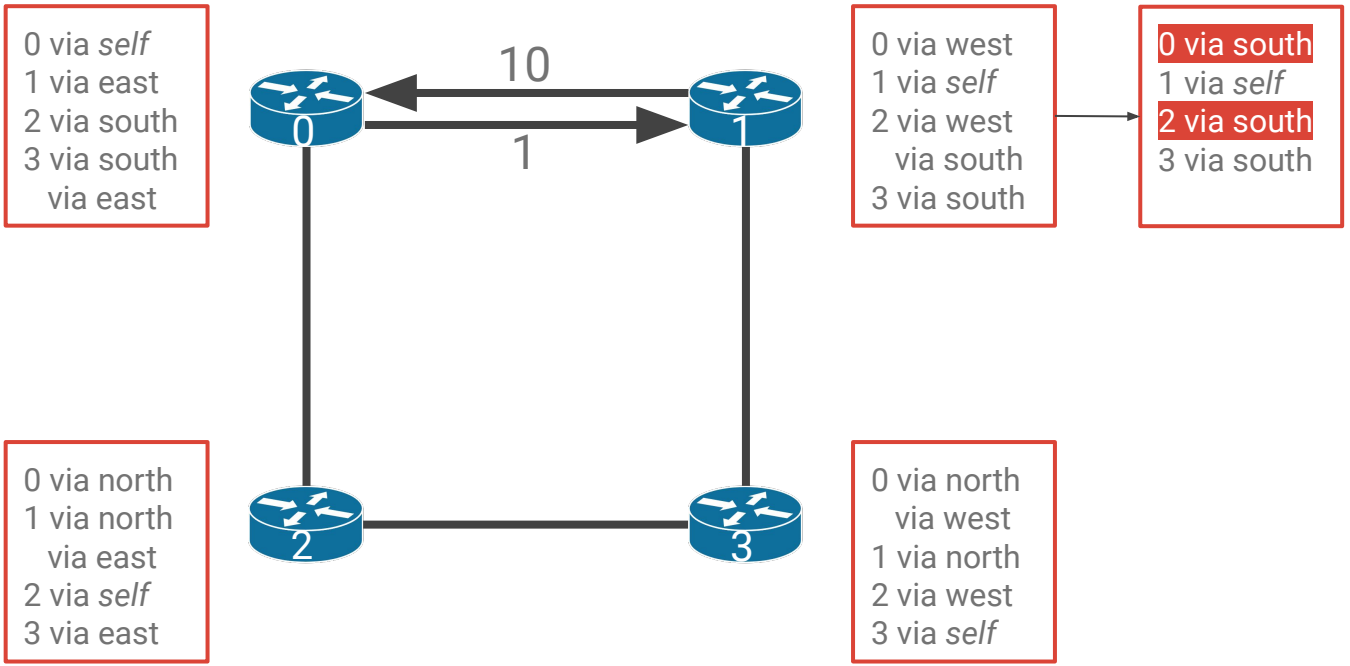
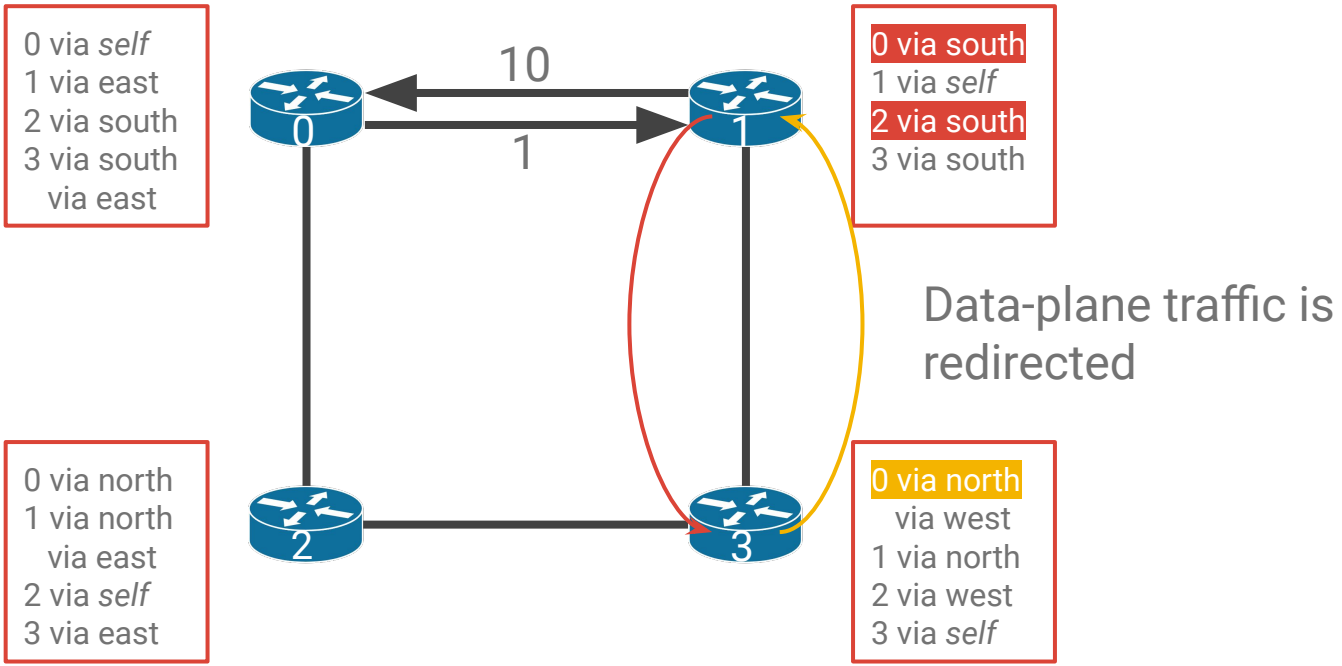


Increasing link metric triggers micro-loops

Topology changes in IGPs



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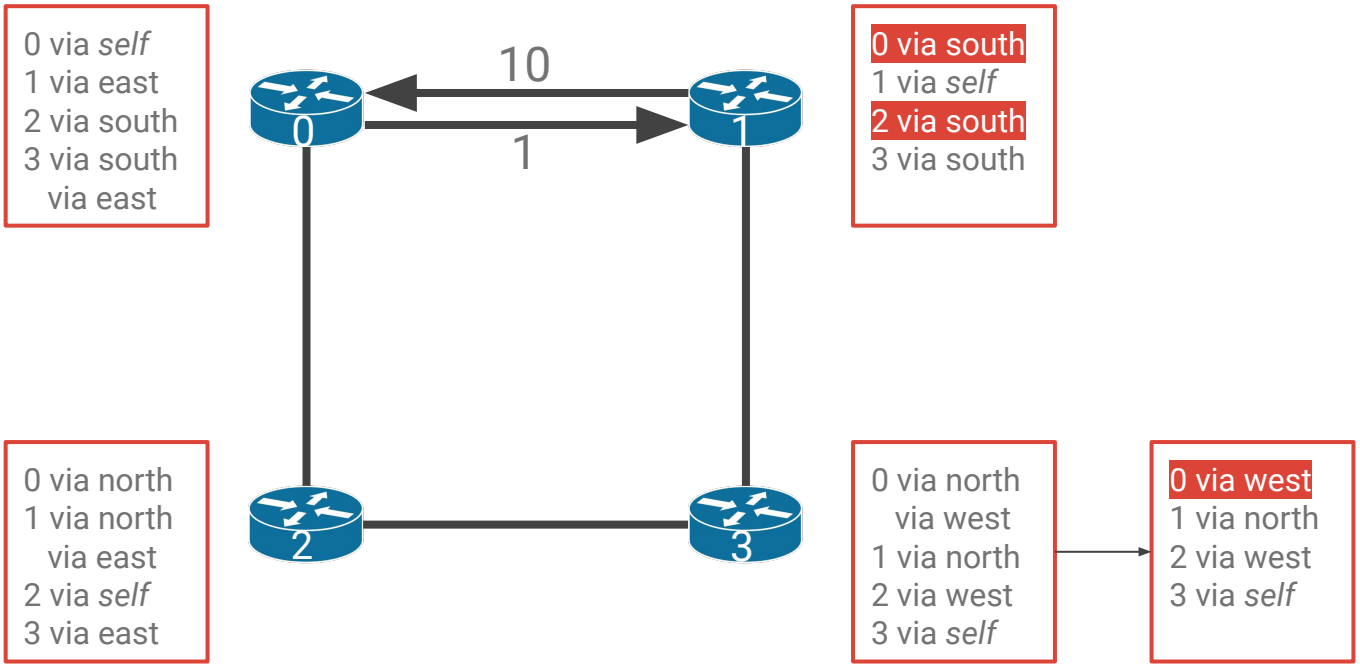
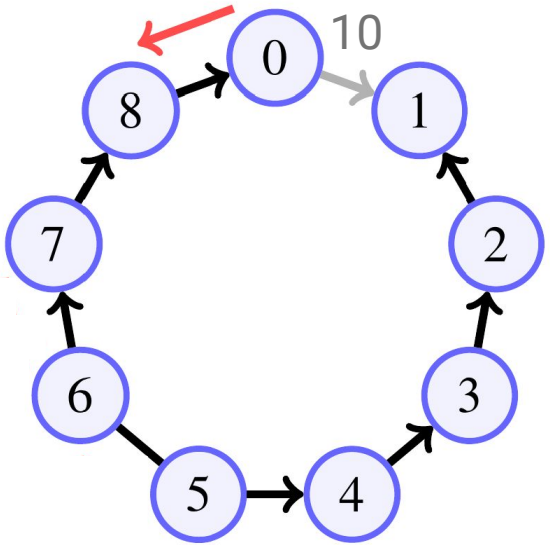


Micro-loops propagate
Topology changes in IGPs

- Unitary link metric



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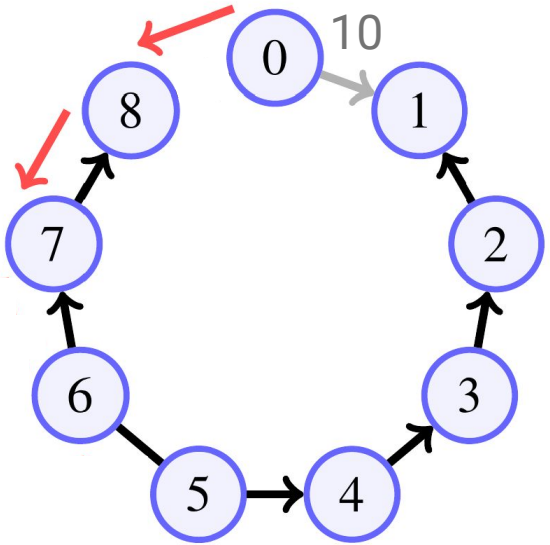

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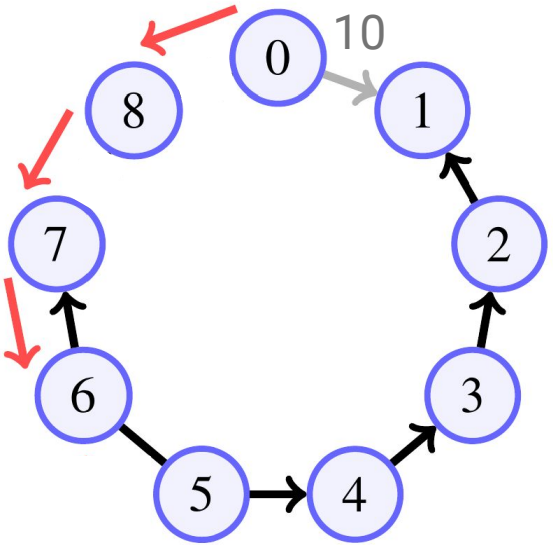

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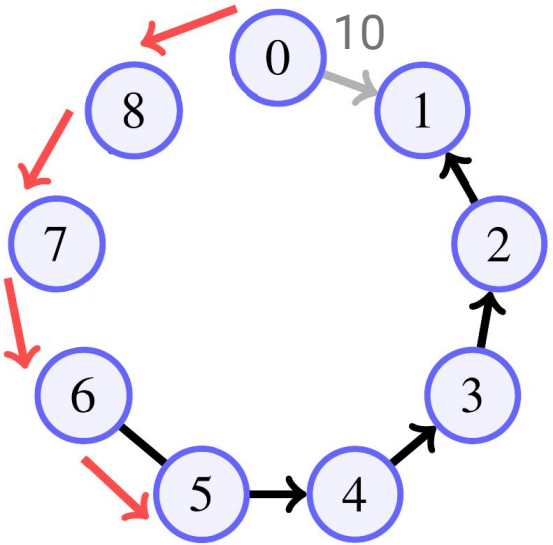
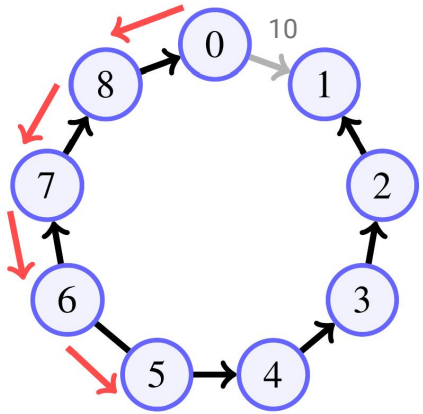
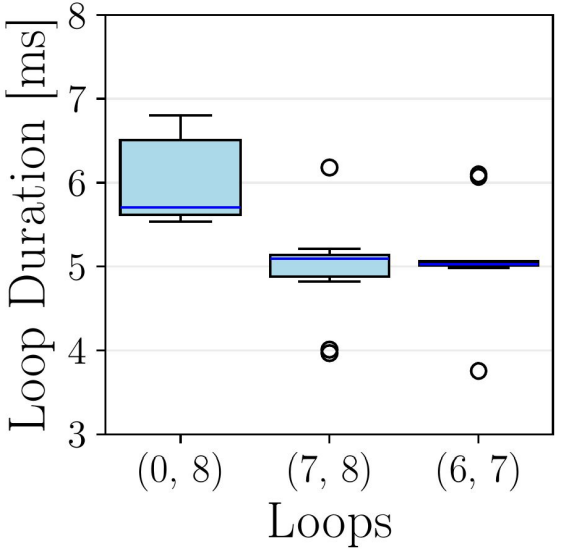


Measuring micro-loops duration

Topology changes in IGPs

- Unitary link metric
- 5ms link delay





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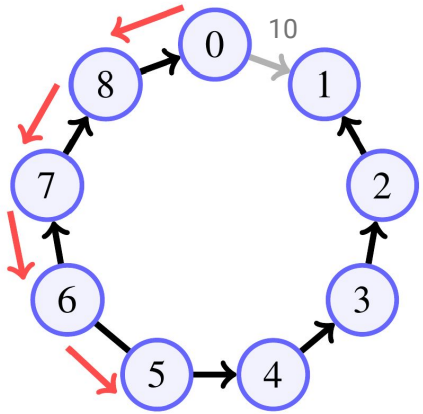
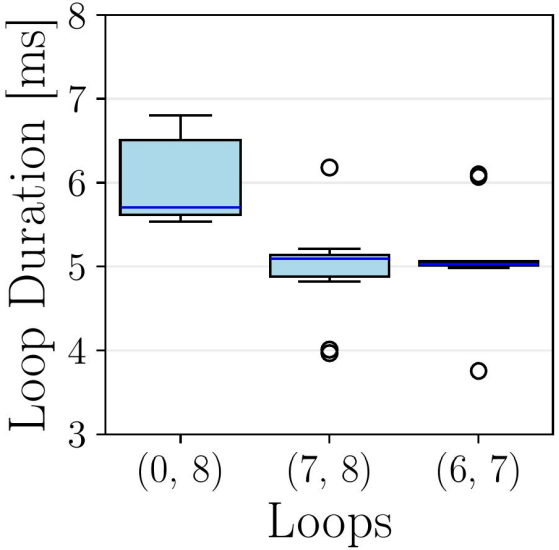


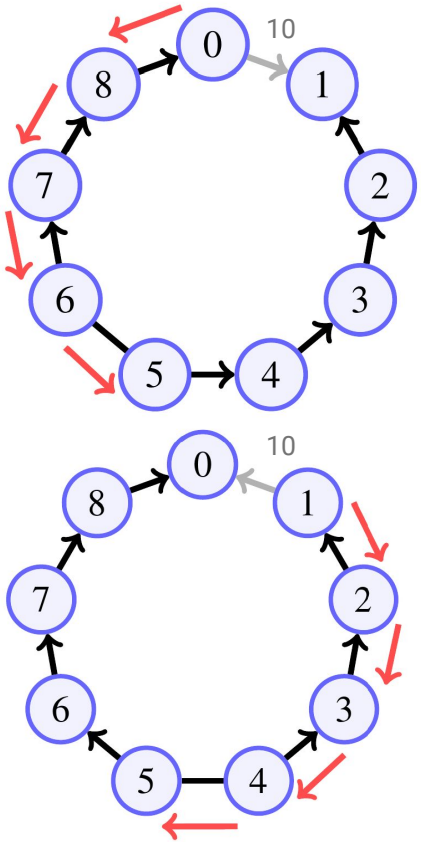


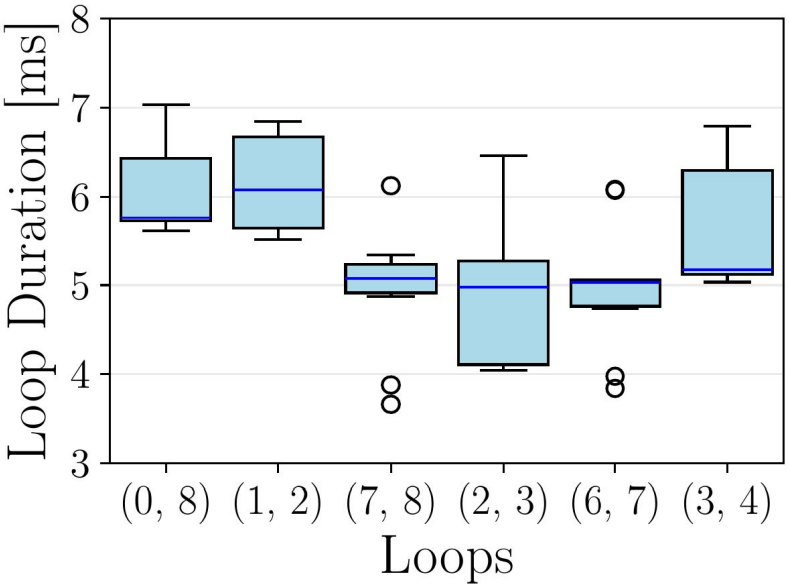
- Micro-loop duration factors
  - Link delay
  - # prefixes
    - SPF computation
    - FIB injection duration (injection rate)
  - ...

Symmetric update increases the number of loops

Topology changes in IGPs

- Unitary link metric
- 5ms link delay





Impact of micro-loops
Topology changes in IGPs

- Packet reordering

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- TTL reaches 0 if micro-loop lasts long enough => transient black-hole

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IGPs trigger traffic disruption by design

Agenda

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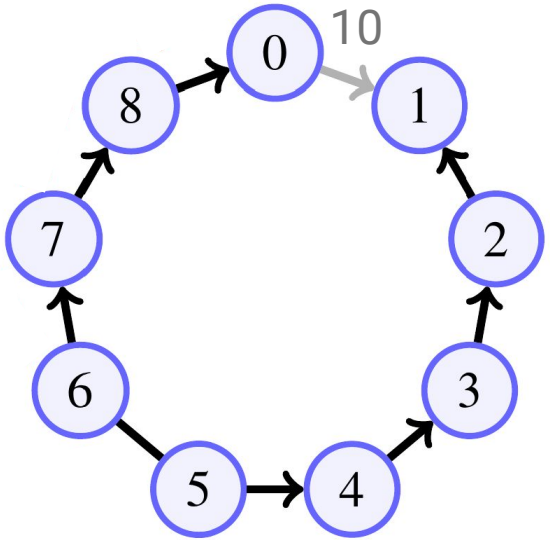
- **Ordered FIB updates (oFIB)**
- oFIQUIC design
- oFIQUIC performances

Ordering FIB updates suppresses micro-loops

Ordered FIB updates (oFIB)



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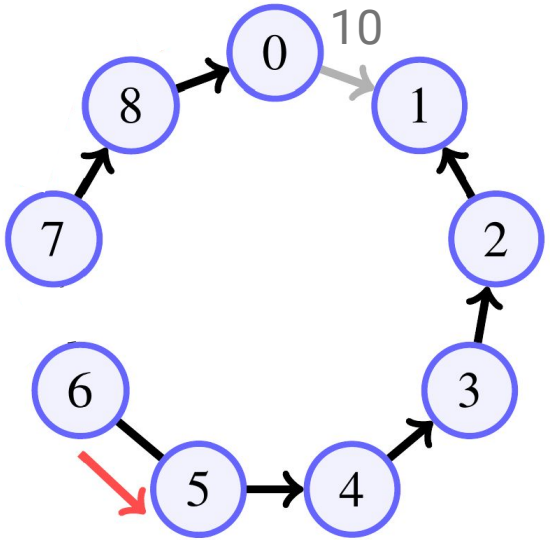

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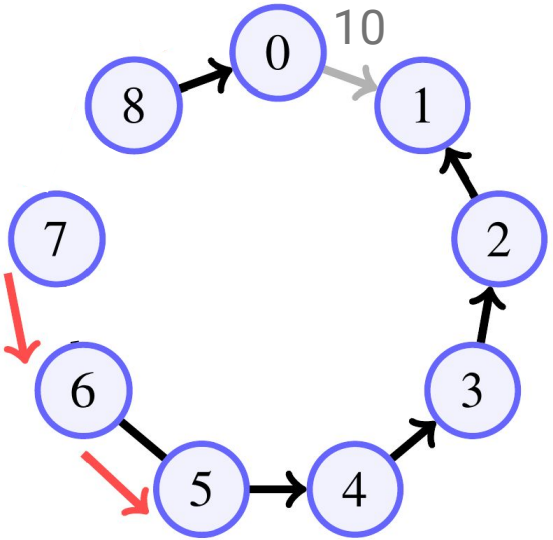

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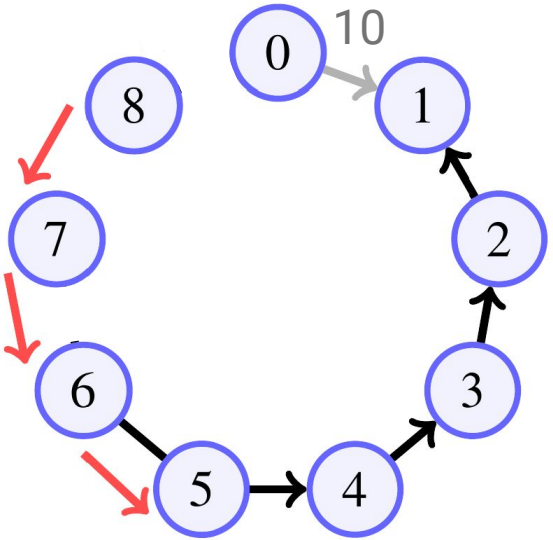

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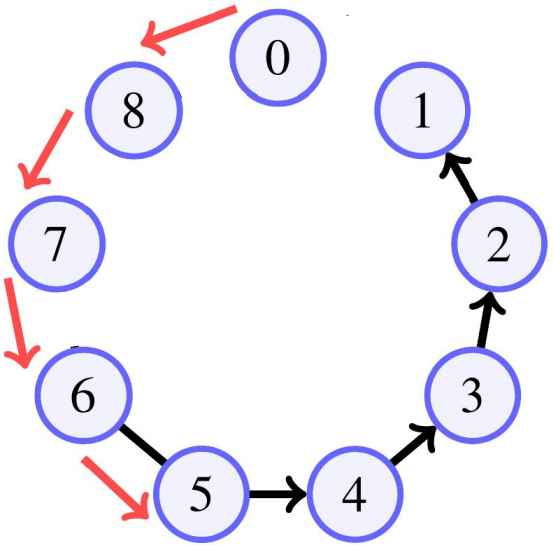
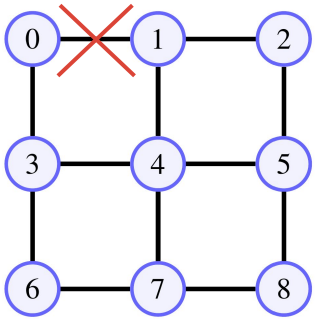


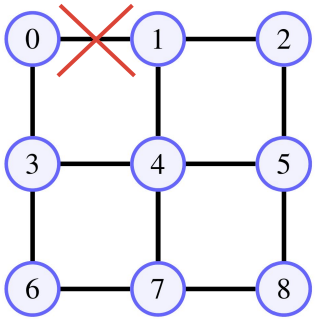
Defining FIB update ordering
Ordered FIB updates (oFIB)

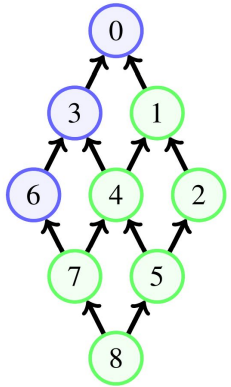


[1] François, P., & Bonaventure, O. (2007). Avoiding transient loops during the convergence of link-state routing protocols. *IEEE/ACM Transactions On Networking*, *15*(6), 1280-1292.

Defining FIB update ordering
Ordered FIB updates (oFIB)

i. Compute Reverse Shortest Path Directed Acyclic Graph (rspDAG) rooted at R0 [1]





$rspDAG_{1\rightarrow 0}(0)$

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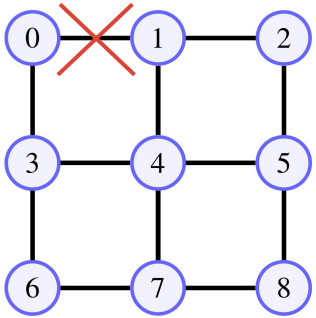
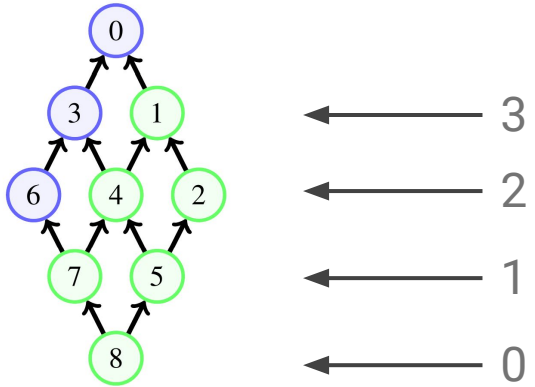
Defining FIB update ordering
Ordered FIB updates (oFIB)

ii. Attribute a rank to each node in the sub-tree [1]





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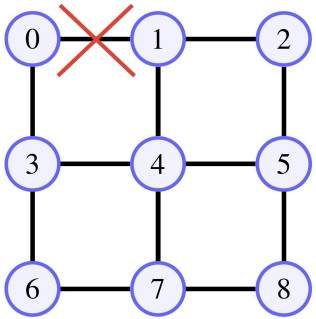
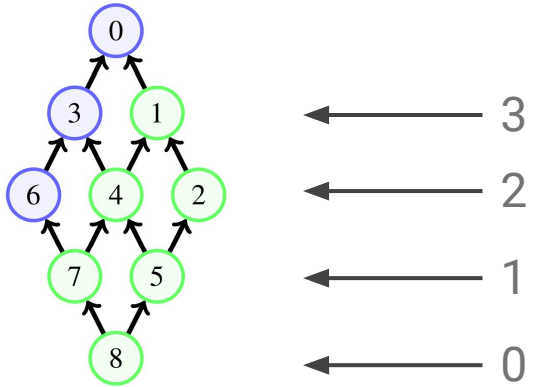
iii. Associate a timer to each node in the sub-tree [1]

T(R) = Rank(R) x MAX_FIB_TIME

=> Update FIB at timer expiration





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Drawbacks of time-based ordering
Ordered FIB updates (oFIB)

- Worst-case timer delays whole convergence
  - Possible shortcut with completion messages [1]
- Distributed computation
- Asynchronous update

=> not suitable for frequent changes

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- oFIQUIC performances

Connecting remote IGP peers
oFIQUIC design

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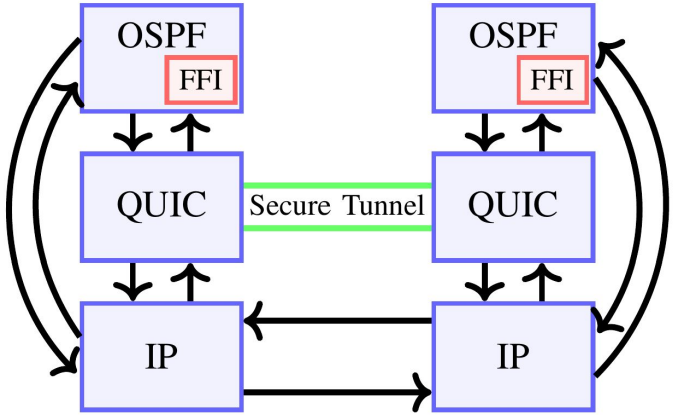
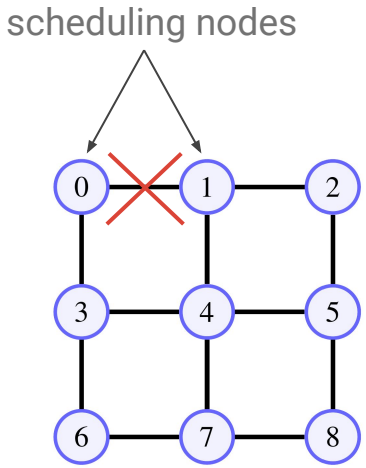


Ordering FIB updates with oFIQUIC

oFIQUIC design



Ordering FIB updates with oFIQUIC
oFIQUIC design

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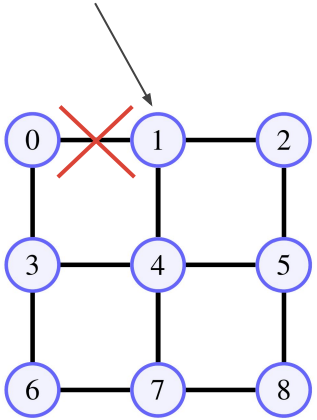

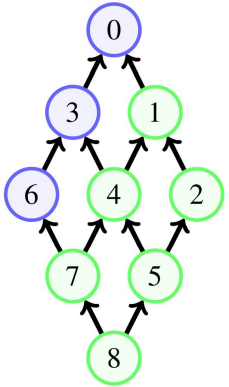

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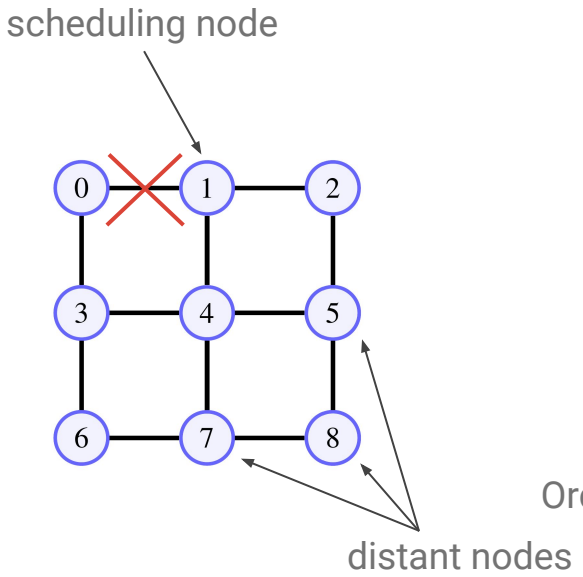
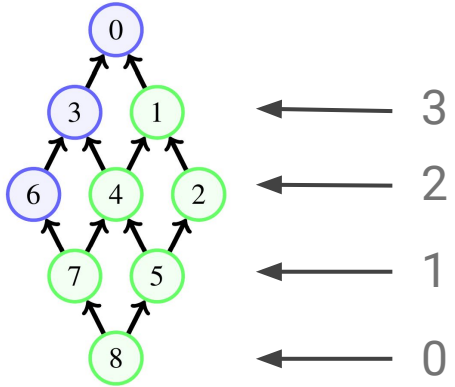
Ordering FIB updates with oFIQUIC

oFIQUIC design

1. Compute rspDAG
2. Derive an ordered list of (distant) nodes





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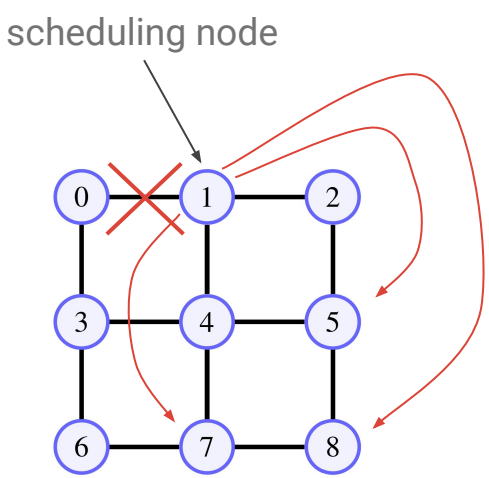
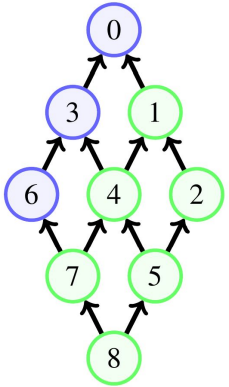
Ordered list: [R8, R5, R7, R2, R4]

Ordering FIB updates with oFIQUIC

oFIQUIC design

1. Compute rspDAG
2. Derive an ordered list of (distant) nodes
3. Initiate QUIC tunnels





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Ordering FIB updates with oFIQUIC

oFIQUIC design

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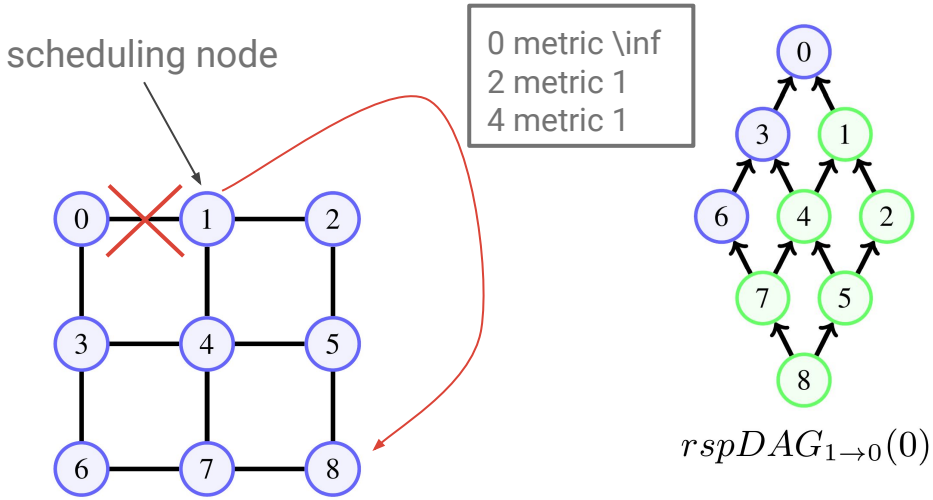
2. Derive an ordered list of (distant) nodes
3. Initiate QUIC tunnels
4. Send LSA to first node



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Ordering FIB updates with oFIQUIC

oFIQUIC design

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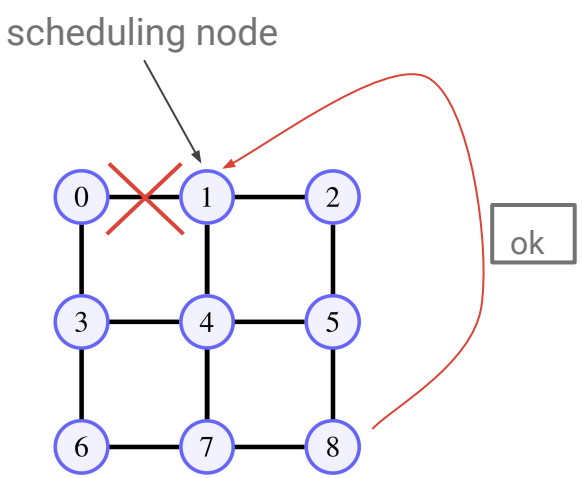
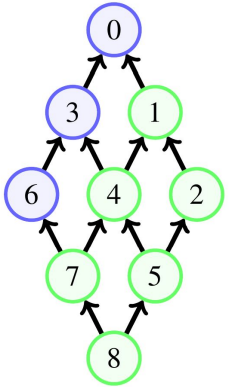
3. Initiate QUIC tunnels
4. Send LSA to first node
5. Wait for distant node confirmation





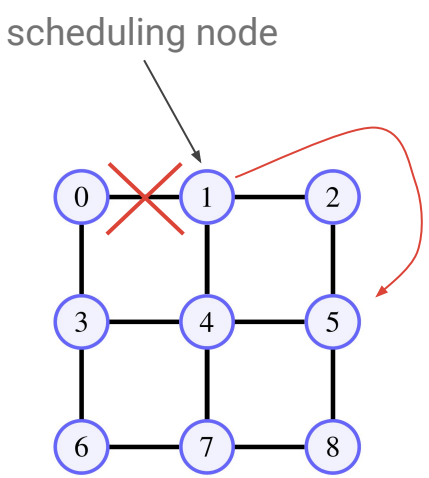
$rspDAG_{1\rightarrow 0}(0)$

Ordered list: [R8, R5, R7, R2, R4]

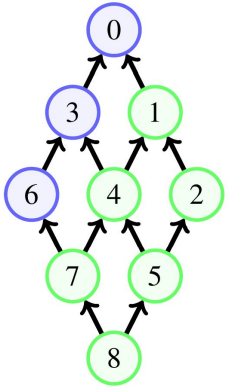
Ordering FIB updates with oFIQUIC

oFIQUIC design

1. Compute rspDAG
2. Derive an ordered list of (distant) nodes
3. Initiate QUIC tunnels
4. Send LSA to first node
5. Wait for distant node confirmation
6. Repeat steps 4 - 5 until list is empty



0 metric \inf
2 metric 1
4 metric 1



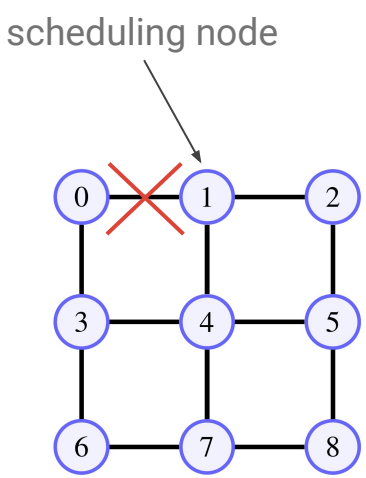
$rspDAG_{1\rightarrow 0}(0)$

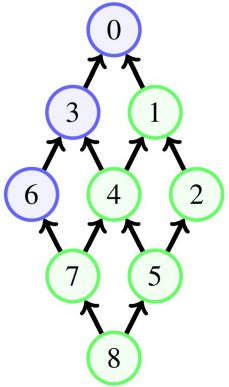
Ordered list: [R8, R5, R7, R2, R4]

Ordering FIB updates with oFIQUIC

oFIQUIC design

1. Compute rspDAG
2. Derive an ordered list of (distant) nodes
3. Initiate QUIC tunnels
4. Send LSA to first node
5. Wait for distant node confirmation
6. Repeat steps 4 - 5 until list is empty
7. Final flooding



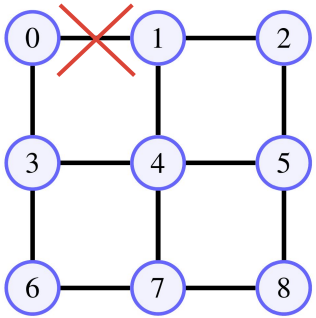


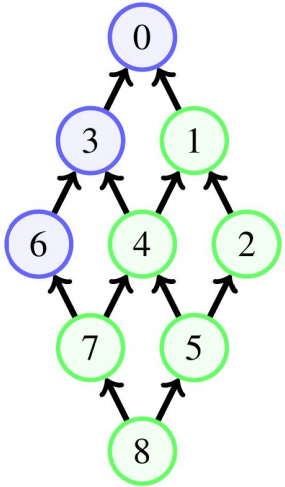
$rspDAG_{1\rightarrow 0}(0)$

Ordered list: [R8, R5, R7, R2, R4]

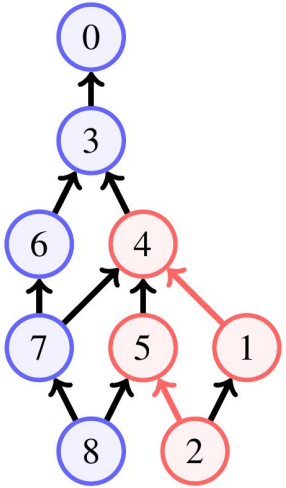
Partial order vs Total order

oFIQUIC design





pre-convergence



post-convergence

Total order list: [R8, R5, R7, R2, R4]

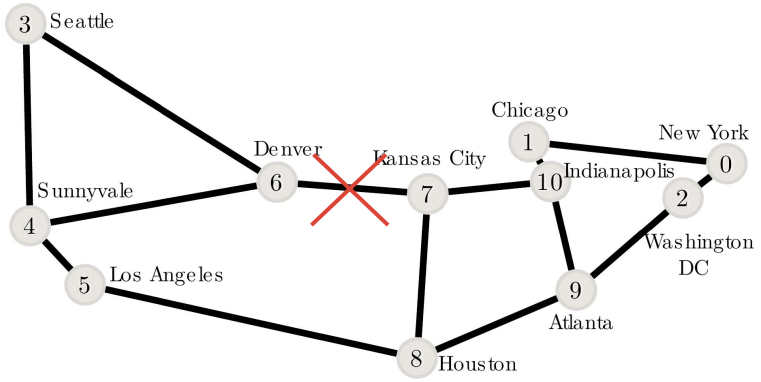
Partial order list: [R5, R2, R4]

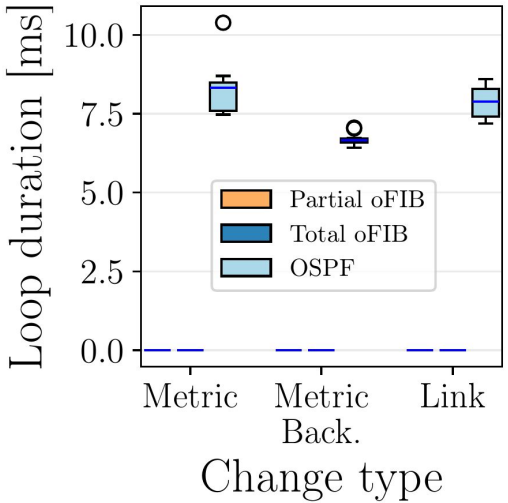
Agenda

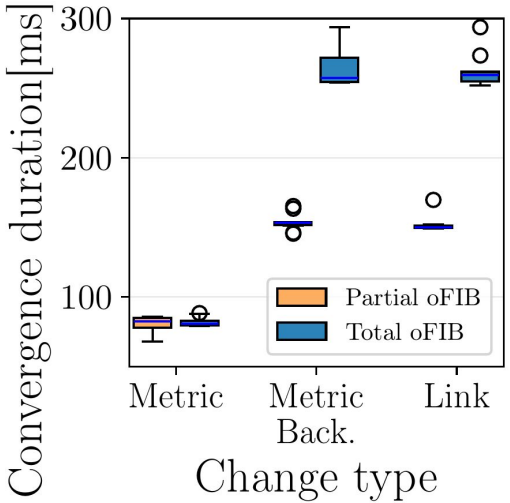
- Topology changes in IGPs
- oFIB: Ordered FIB updates
- oFIQUIC design
- **oFIQUIC performances**

oFIQUIC convergence duration in Abilene

oFIQUIC performances

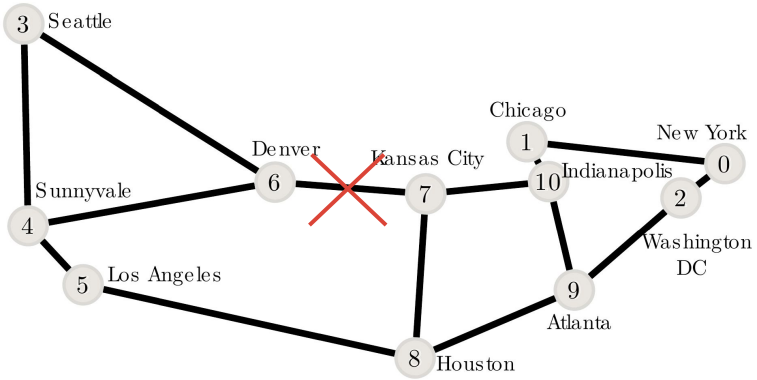


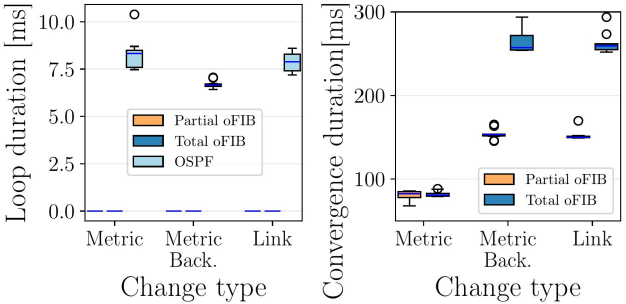


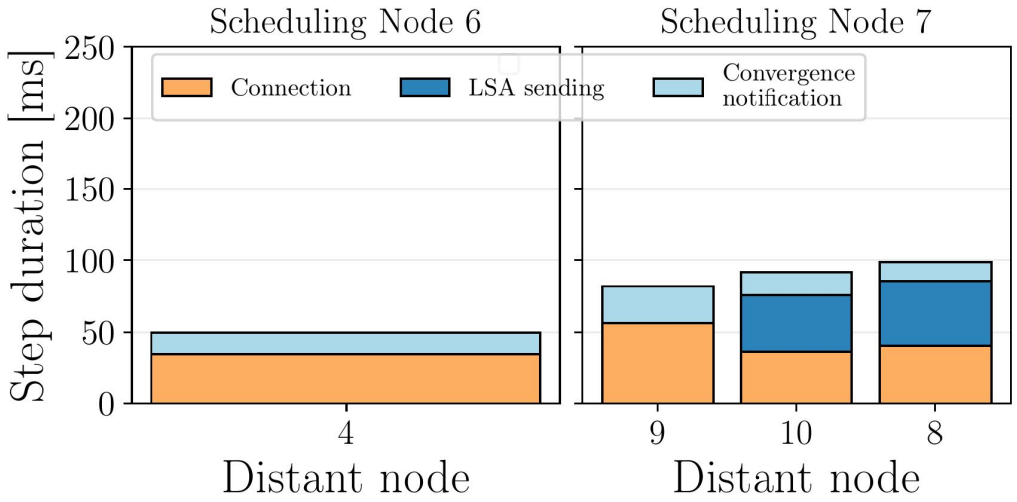


oFIQUIC contributions in Abilene

oFIQUIC performances

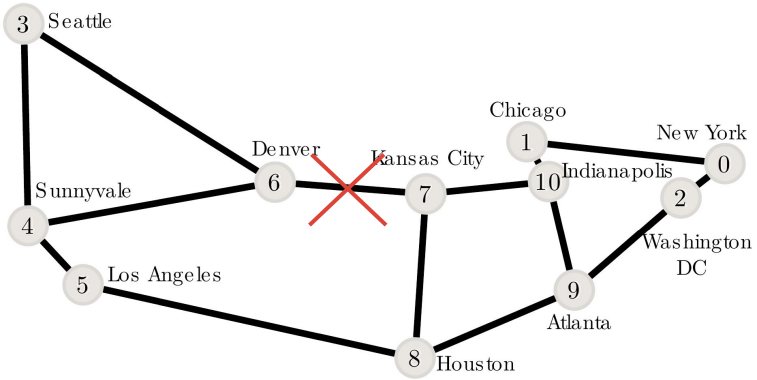


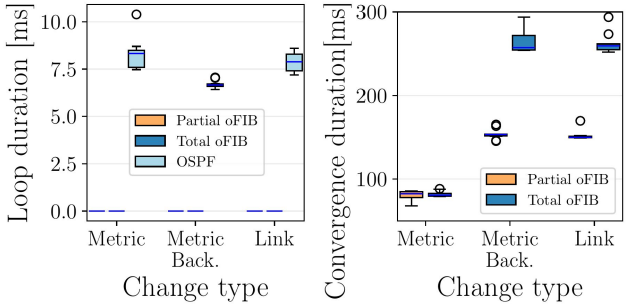


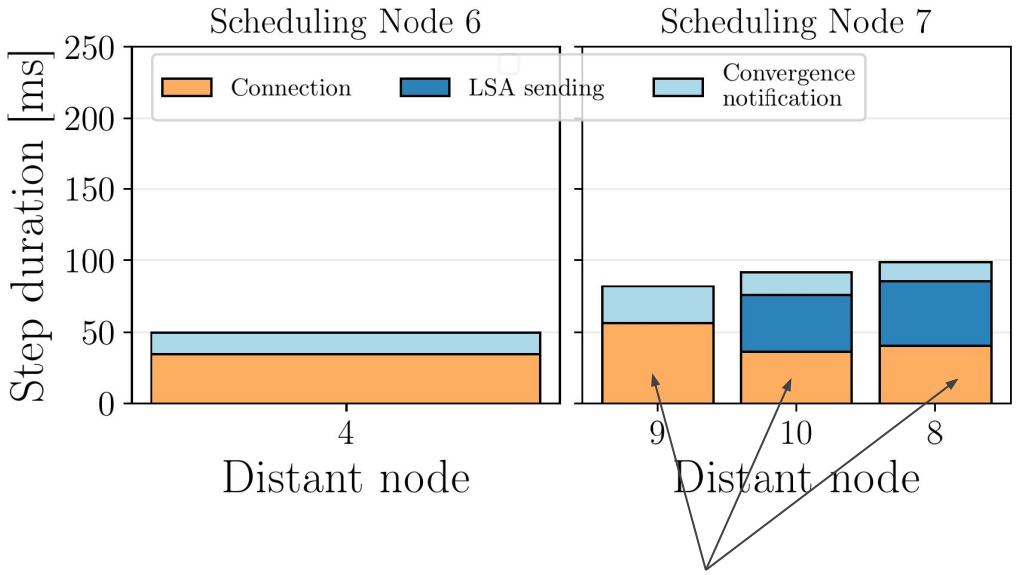


oFIQUIC contributions in Abilene

oFIQUIC performances



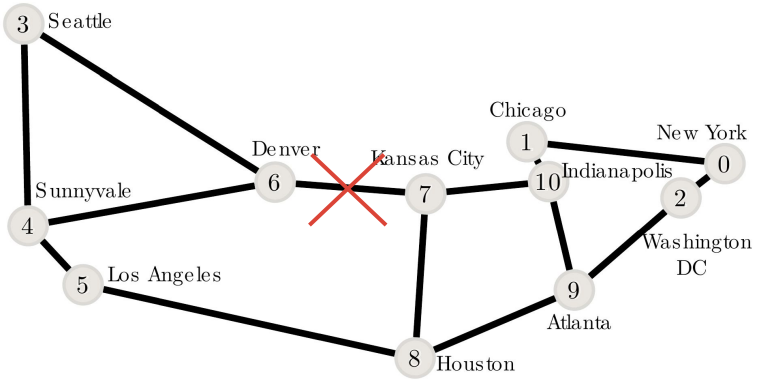


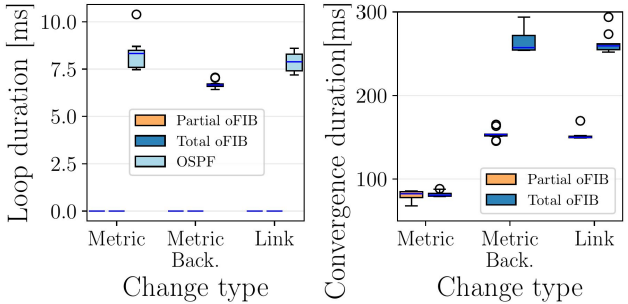


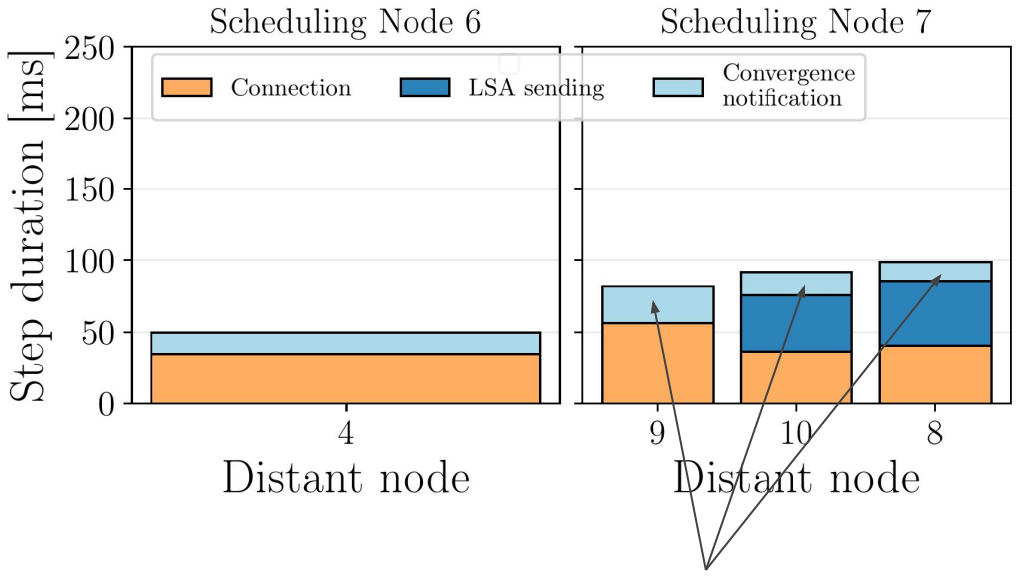
Related to path length

oFIQUIC contributions in Abilene

oFIQUIC performances



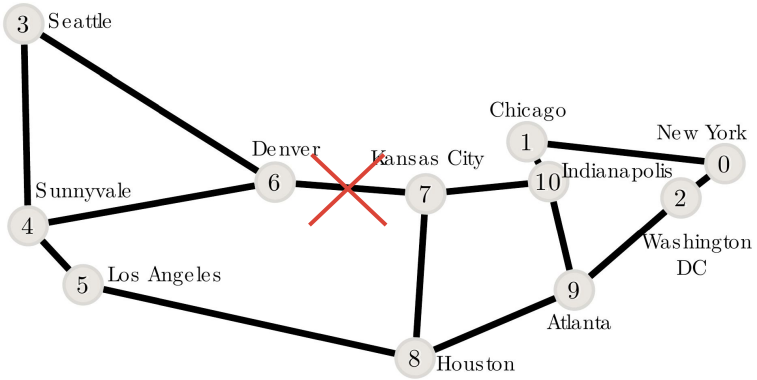


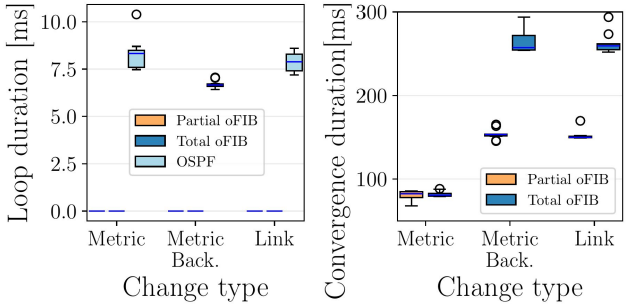


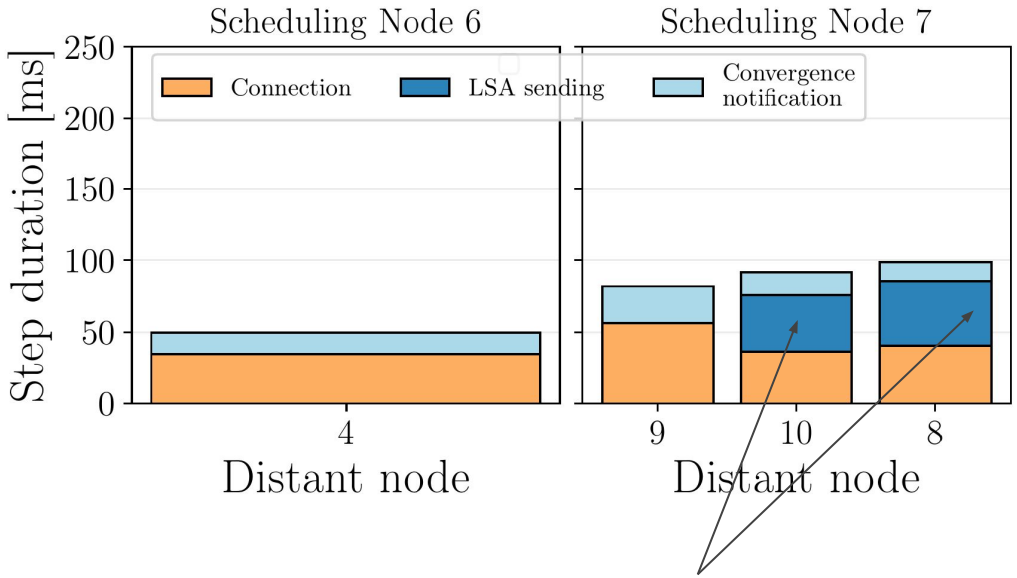
Related to path length

oFIQUIC contributions in Abilene

oFIQUIC performances



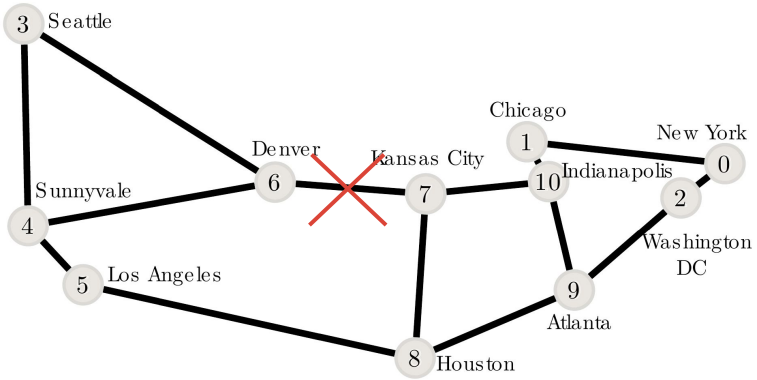


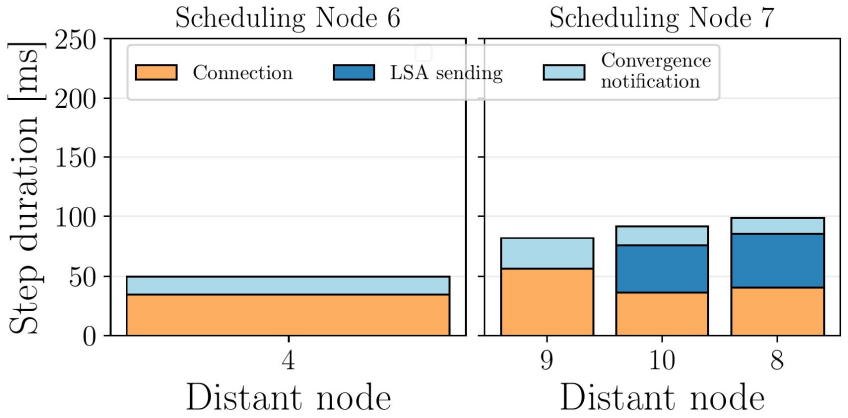


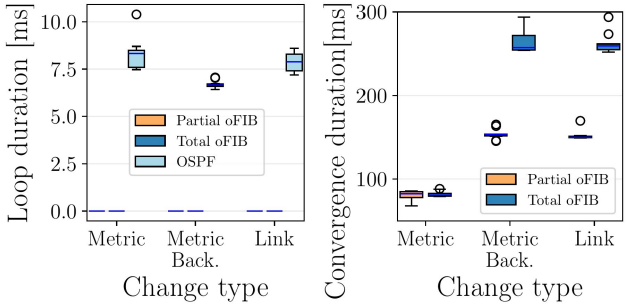
Related to previous step

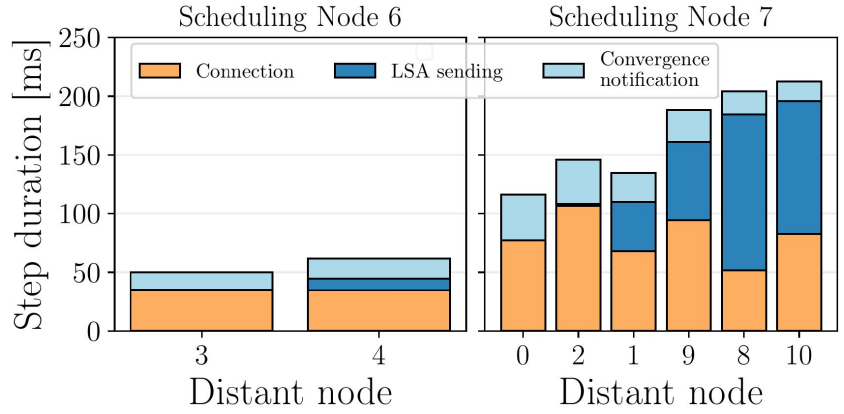
oFIQUIC contributions in Abilene

oFIQUIC performances



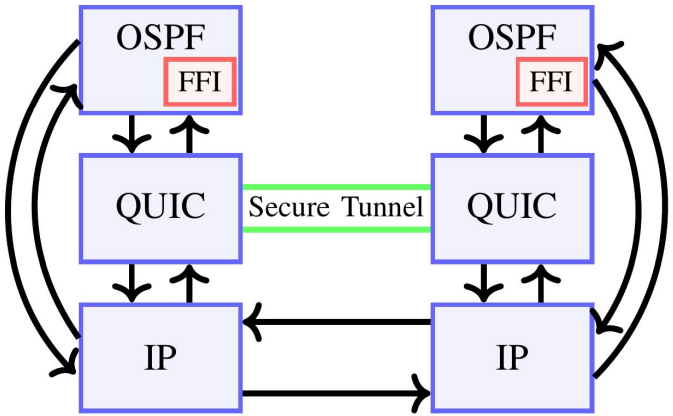






Summary

paper



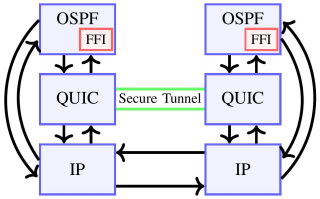
artefacts

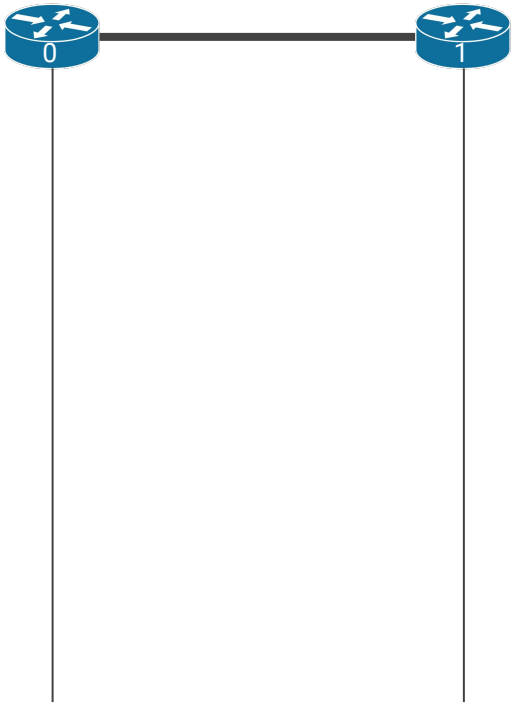
nicolas.rybowski@uclouvain.be

Backup slides

Establishing QUIC tunnels with direct IGP peers

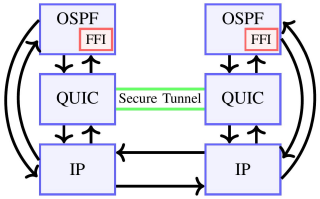
oFIQUIC design

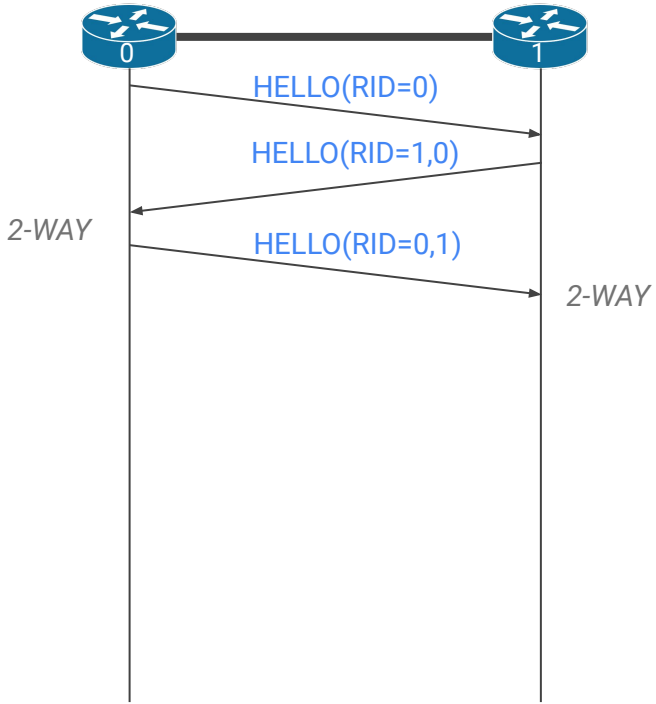




Establishing QUIC tunnels with direct IGP peers

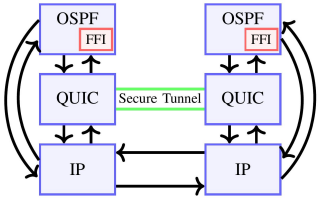
oFIQUIC design

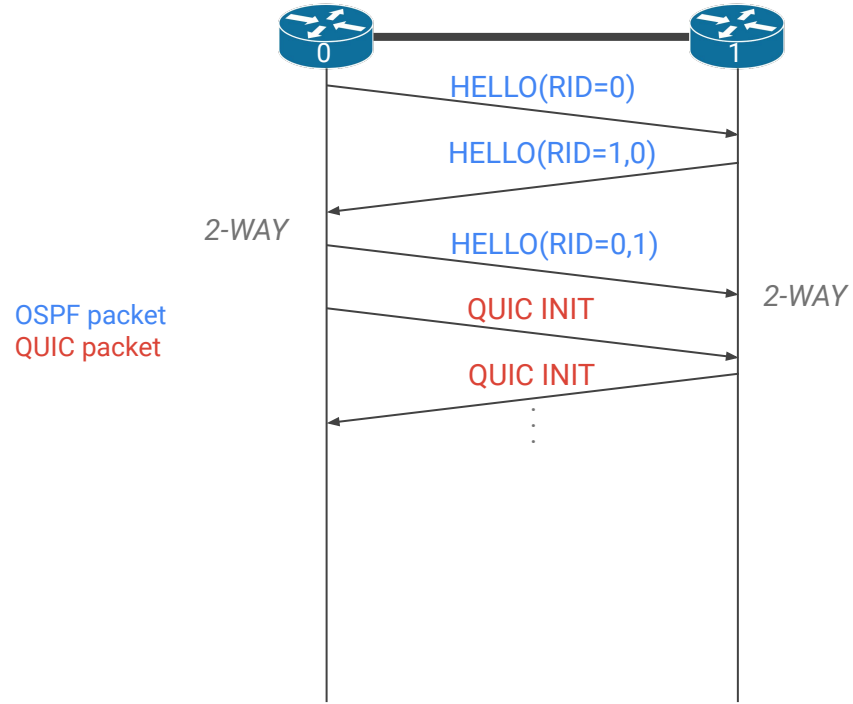




Establishing QUIC tunnels with direct IGP peers

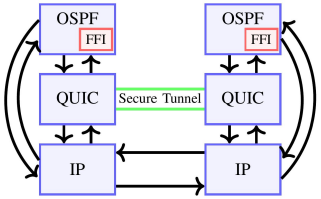
oFIQUIC design

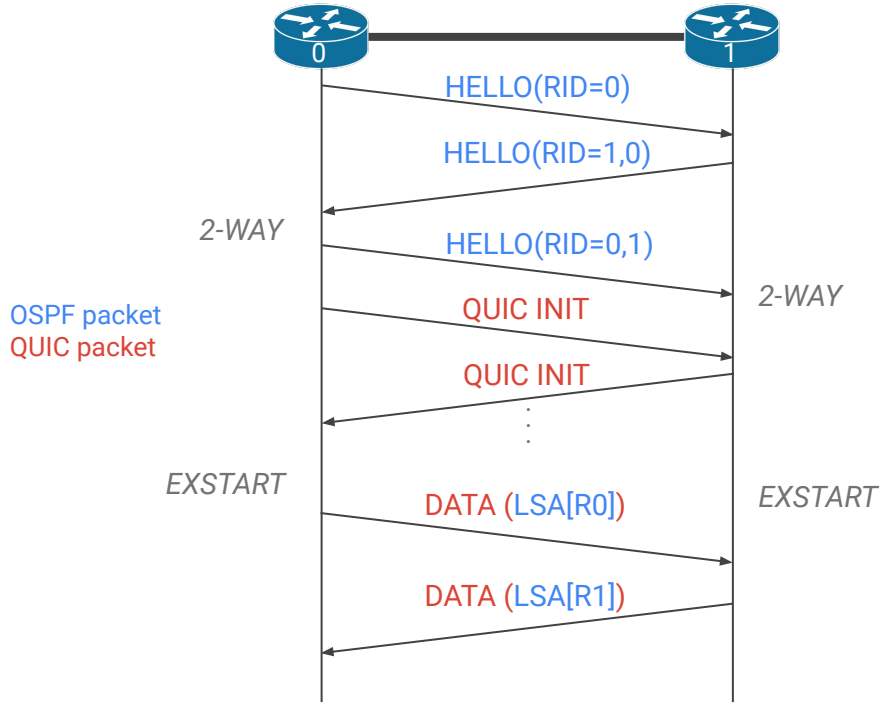




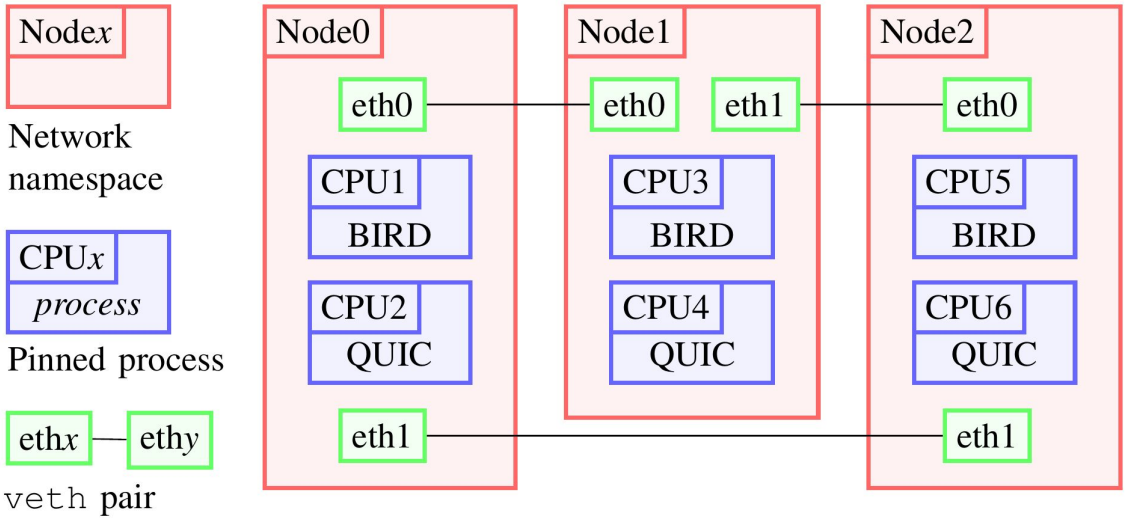
Establishing QUIC tunnels with direct IGP peers

oFIQUIC design



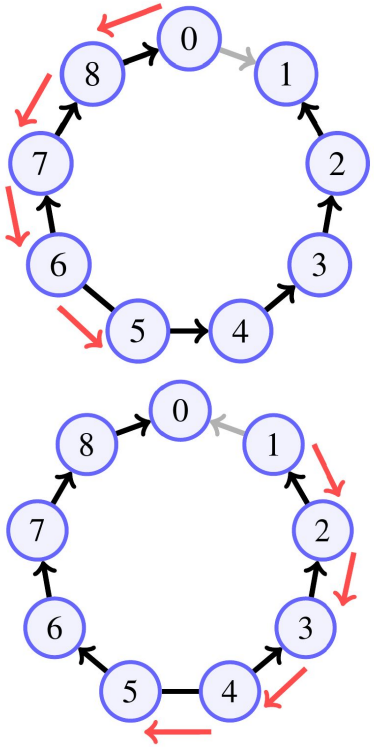


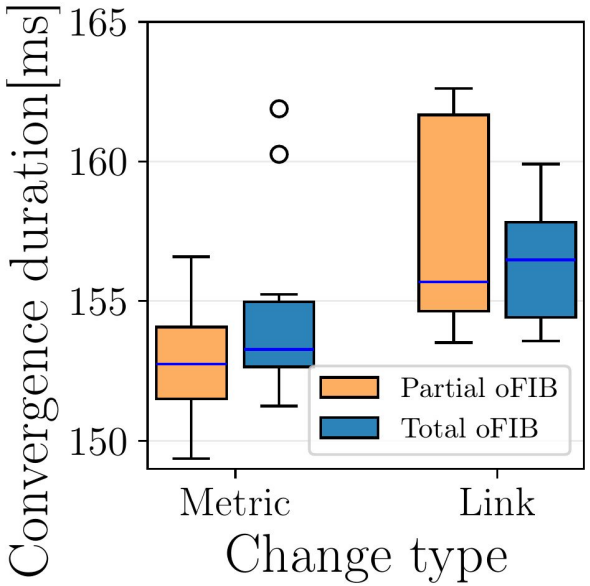
Distributed Micro Network Emulation (DUNE) framework



oFIQUIC convergence duration in a ring

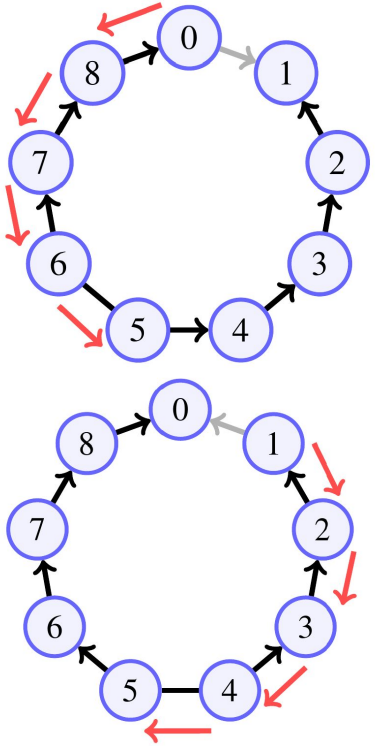
oFIQUIC performances

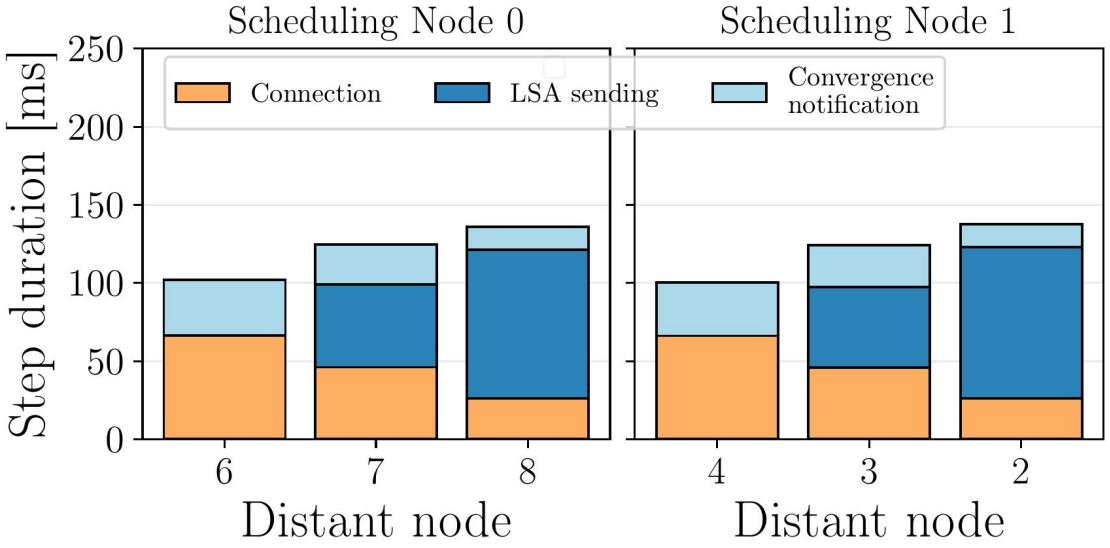




oFIQUIC contributions in a ring

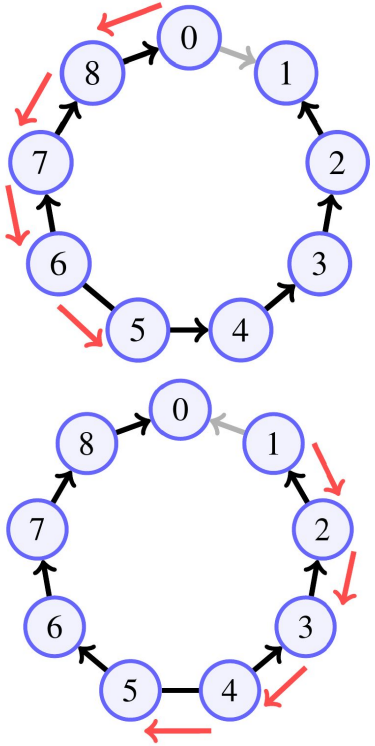
oFIQUIC performances

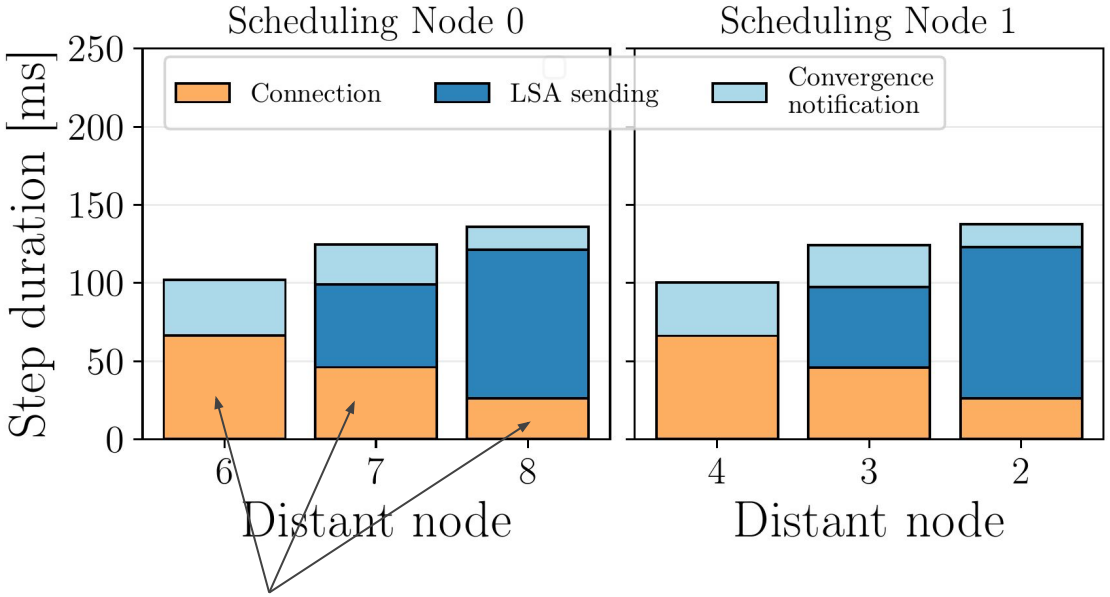




oFIQUIC contributions in a ring

oFIQUIC performances

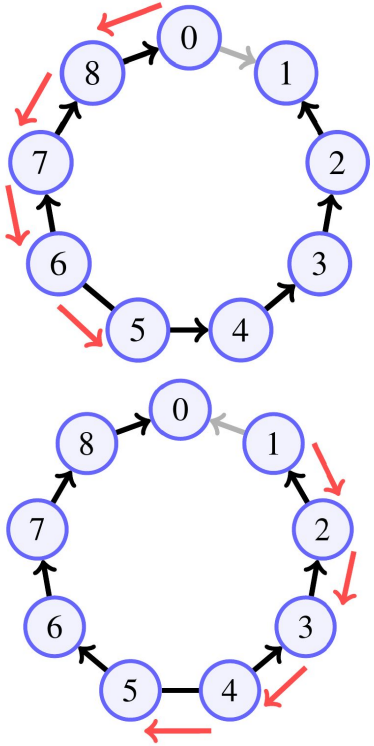


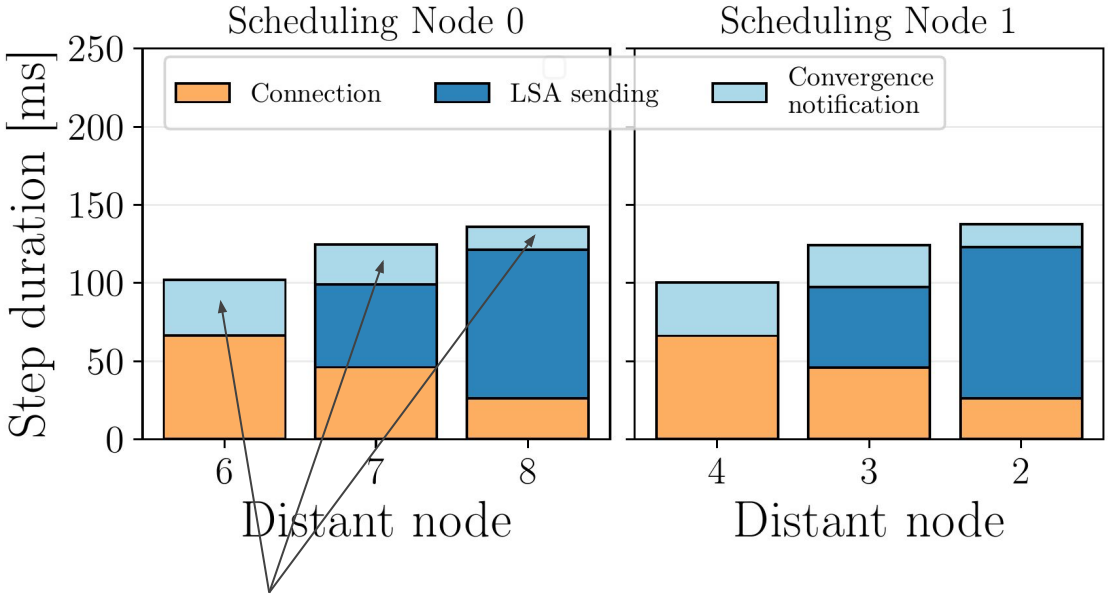


Related to path length

oFIQUIC contributions in a ring

oFIQUIC performances

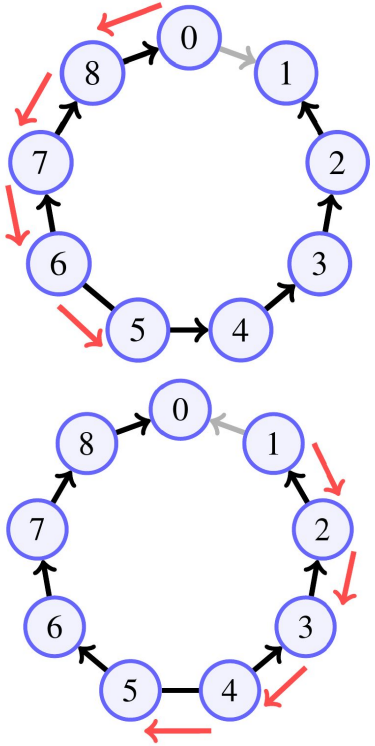


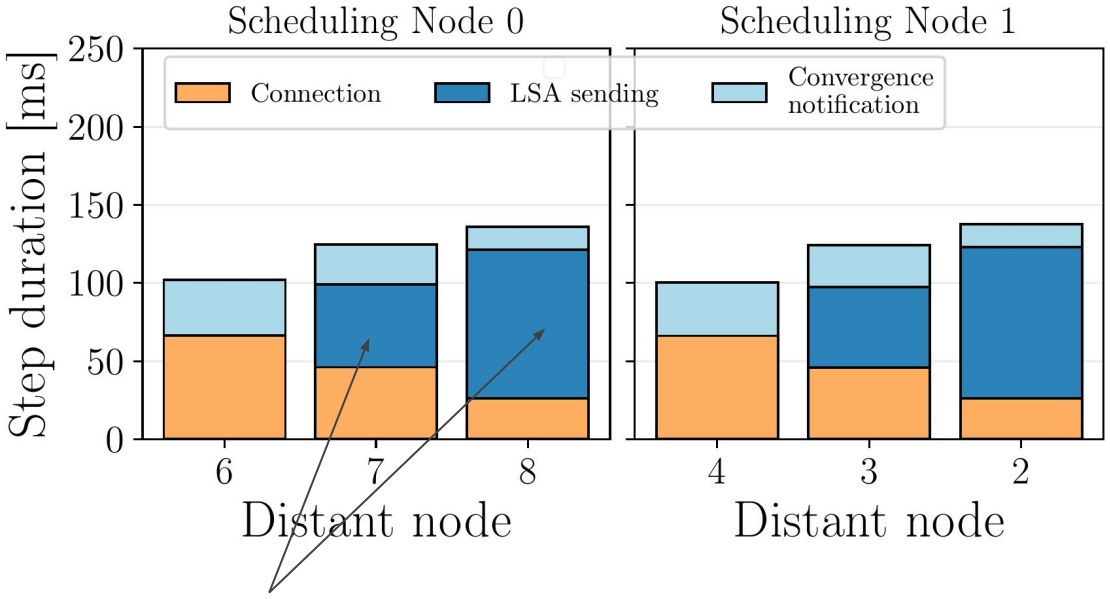


Related to path length

oFIQUIC contributions in a ring

oFIQUIC performances





Related to previous step