Performance and Analysis for Deflection Routing in Buffer-less Networks Using ns-3

ENSC833: Network Protocol and Performance - Spring 2019 (Final Project)

- Lucy Malsawmtluangi & Renjie Wang

lmalsawm@sfu.ca renjiew@sfu.ca

Roadmap

- Introduction/Motivation/Goal
- Related Work
- Technical Details/Problem Description
- Implementation – Tools/Design/Simulation/Result
- Challenges

Goal

- Study Contention resolution in buffer-less networks such as OBS
- Enhance existing routing protocols by adding viable contention solution
- Delve Deflection Routing implementation using ns-3

**OBS – Optical Burst Switching*

**ns -3 Network Simulator*

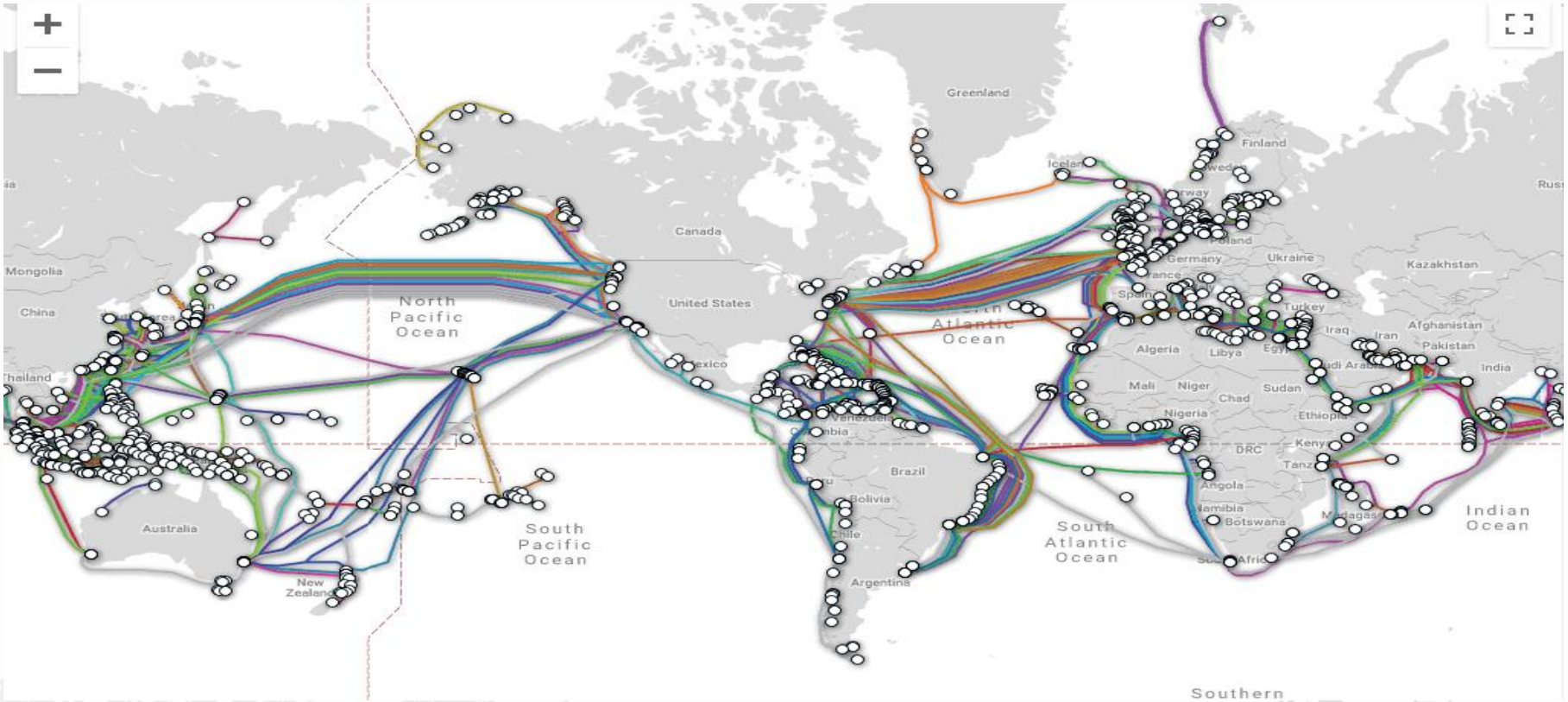
Motivation

- Improve transmission in switch and routers
  - Reduce packet loss and delay

- Existing technology – OBS

Motivation

Subsea Optical Fiber Cable



https://www.submarinecablemap.com/

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Related Work

- Traditional routing algorithms
  - map the network topology to a weighted graph
  - set the weight of each edge such as number of hops to destination, congestion, latency, link failure, or the business relationships between the edge nodes
  - minimum cost
    - S. Haeri and L. Trajkovic´, "Deflection Routing in Complex Networks," in *Complex Systems and Networks*, Berlin, Springer, 2015, pp. 395-422.
- However, reinforcement learning is used in a dynamic environment.
    - L. P. Kaelbling, M. L. Littman, and A. W. Moore, “Reinforcement learning: a survey,” *J. of Artificial Intelligence Research*, vol. 4, pp. 237–285, 1996.

Related Work

- Reinforcement learning agent that generates deflection decisions:
  - the state of the environment
  - reinforcement signals from the environment
  - a learning algorithm
    - S. Haeri and L. Trajkovic´, "Deflection Routing in Complex Networks," in *Complex Systems and Networks*, Berlin, Springer, 2015, pp. 395-422.

Related Work

- Q-learning
  - a simple reinforcement learning algorithm that has been employed for path selection in deflection routing
    - C. J. C. H. Watkins and P. Dayan, “Technical note, Q-learning,” *Machine Learning*, vol. 8,no. 3, pp. 279–292, May 1992.

$$Q^{new}(s_t, a_t) \leftarrow (1-\alpha) \cdot \underbrace{Q(s_t, a_t)}_{\text{old value}} + \underbrace{\alpha}_{\text{learning rate}} \cdot \overbrace{\left(\underbrace{r_t}_{\text{reward}} + \underbrace{\gamma}_{\text{discount factor}} \cdot \underbrace{\max_a Q(s_{t+1}, a)}_{\text{estimate of optimal future value}} \right)}^{\text{learned value}}$$

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Related Work

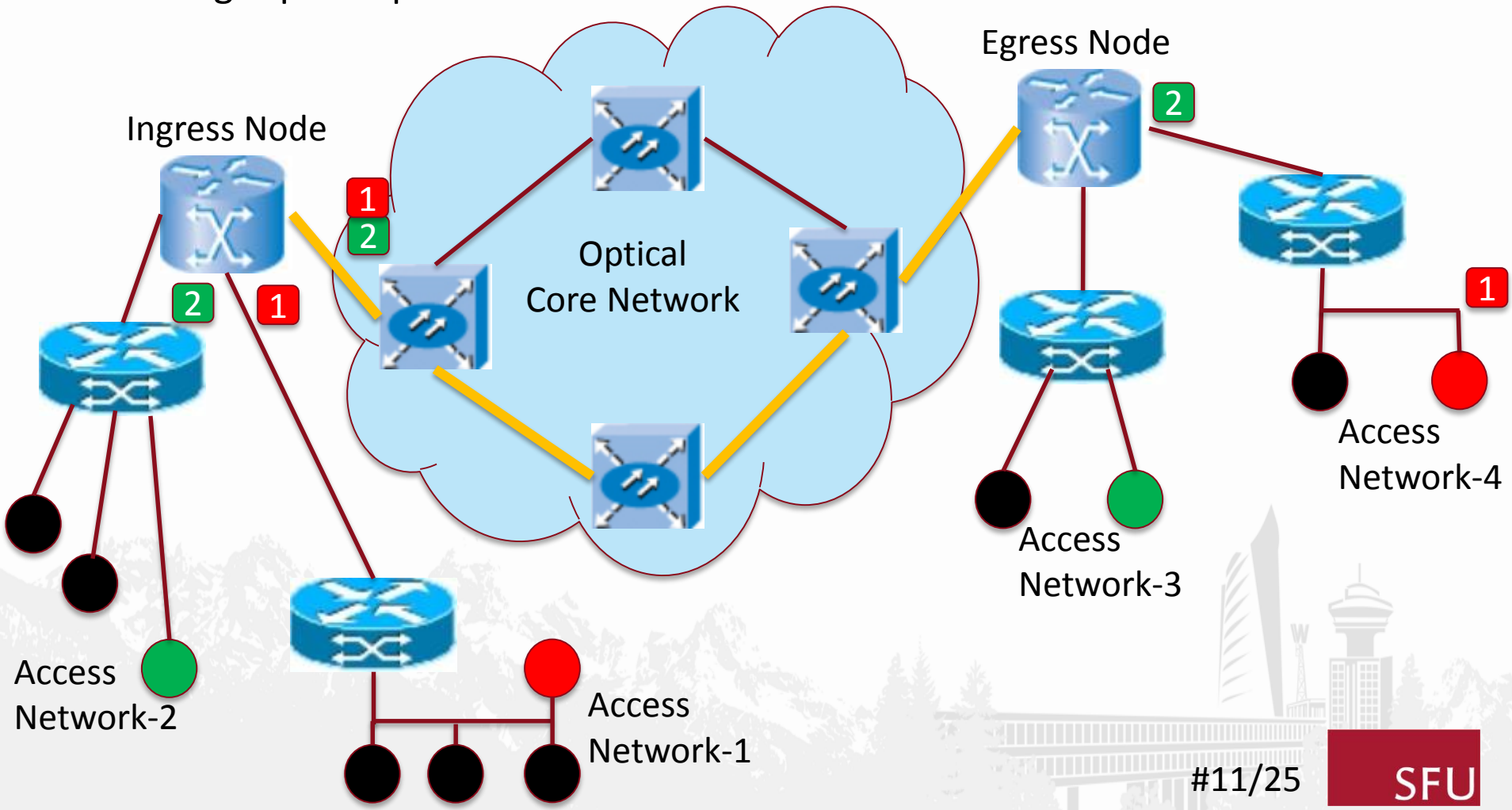
- Q-learning
  - Does not generate an optimal routing policy
    - S. Haeri and L. Trajkovic´, "Deflection Routing in Complex Networks," in Complex Systems and Networks, Berlin, Springer, 2015, pp. 395-422.
  - Distributed gradient ascent policy search
    - L. Peshkin and V. Savova, “Reinforcement learning for adaptive routing,” in Proc. Int. Joint Conf. Neural Netw., Honolulu, HI, USA, May 2002, vol. 2, pp. 1825–1830.
- Reinforcement learning are not widely used
  - Business relationships between Internet service providers
  - Randomness is not a desired property
    - S. Haeri and L. Trajkovic´, "Deflection Routing in Complex Networks," in *Complex Systems and Networks*, Berlin, Springer, 2015, pp. 395-422.

Technical Details – Problem Statement

- Optical Networks (Metro, Long haul, Subsea) are **facing unprecedented growth and challenges** to deliver a consistent quality end-user experience.
- Multiple researches are conducted by Universities and Industry (leaders such as Ciena and Coriant)
  - To provide **scalable and secure network** capacity that is both faster and smarter giving them a huge competitive advantage.
- Deflection routing is one such solution which can **effectively reduce the traffic loss** due to contention hence providing high quality end-user experience.

Optical Burst Switching (OBS)

- Packets with the same destination are aggregated at ingress nodes to form bursts.
- A control packet is sent ahead of a burst to create optical cross connects to reserve wavelength per hop.



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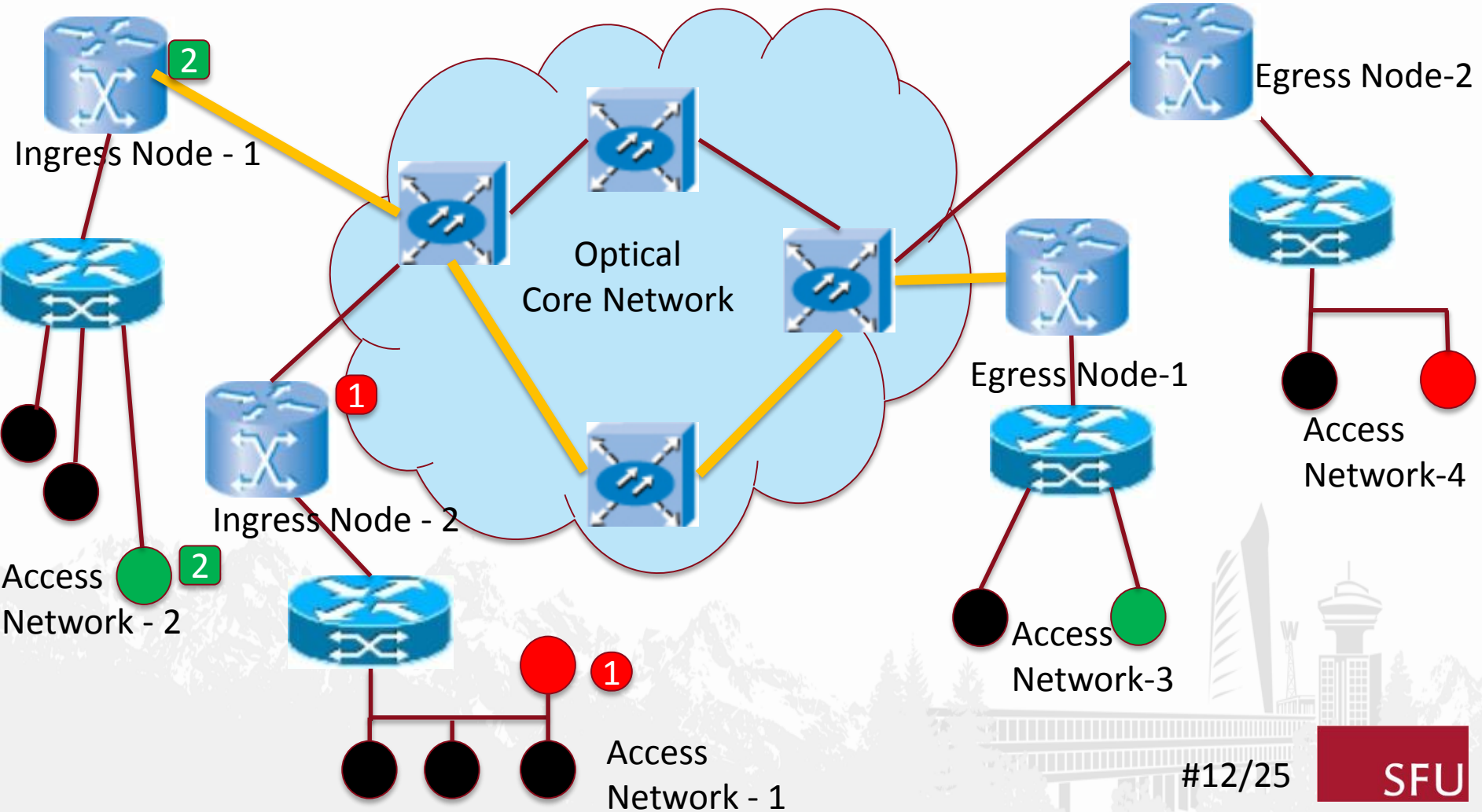
OBS – Contention Scenario

- Since only one cross connect can be formed at a given point of time, if another burst arrives when the first burst is still in progress, the latter burst is dropped due to contention.



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Implementation - Deflection Routing

- It is a viable **contention resolution scheme** that are employed in buffer-less networks.
- It comprises of algorithms that can **deflect the packets/traffic through another sub-optimal path** in case two or more bursts have to be routed through the same outgoing link (based on routing decisions that computed the best path).
- Using BRITE, we generated multiple **Waxman** topologies with node counts of **10, 20, 50, 100, 200, 500 and 1000** to validate **Q-NDD, PQDR Deflection Routing Algorithms**.

Q-learning-based Node Degree Dependent (Q-NDD)

Predictive Q-learning Deflection Routing (PQDR)

Implementation - Tools

- Network Simulator (**Ns-3**) – It is a discrete-event computer network simulators written in C++ and widely used for research purpose.

  ns-3 [Online] https://www.nsnam.org/docs/models/html/index.html (Accessed Jan,2019)

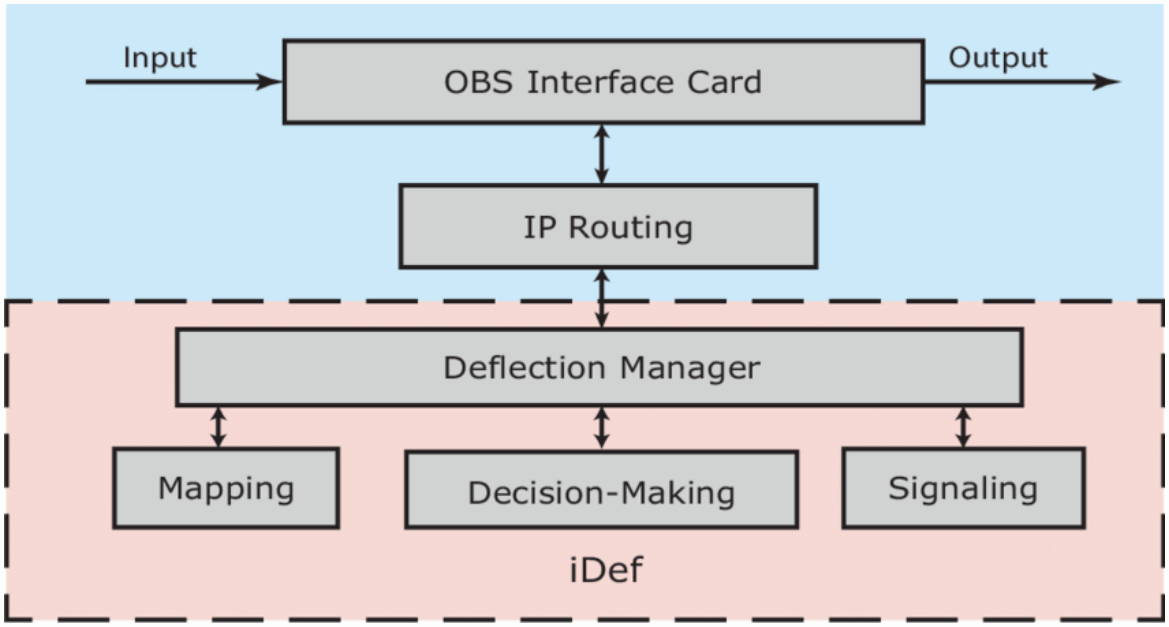
- Google Test Framework (**G-Test**) – It is a Unit Testing Library from Google primarily used for C++ programming language.

  G-Test [Online] https://github.com/google/googletest (Accessed Feb,2019)

- Boston University Representative Internet Topology Generator (**BRITE**) – It is a synthetic topology generator that accurately reflect many aspects of the actual Internet topology.

  BRITE [Online] https://www.cs.bu.edu/brite/ (Accessed Feb, 2019)

Implementation – iDef Framework[$]



iDef Framework – designed to facilitate development of reinforcement learning based deflection routing protocols.

Deflection Manager – It glues together iDef modules (***mapping*** – map received variables into *state*, ***decision-making*** – implements learning algorithm, ***signaling*** – adds header fields to the Deflected bursts)

[$]Intelligent Deflection Routing in Buffer-Less Networks – *Soroush Haeri and Ljiljana Trajkovic (Fellow, IEEE)*
Intelligent Deflection Routing in Buffer-Less Networks

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iDef Framework[$]

- To download the software package, either click on the link below to directly fetch the tar files.
  1) idef_framework.tar
  2) Or, if you have Mercurial installed, the following command can be used:
     > *hg clone https://www.bitbucket.org/shaeri/hmm-deflection*
- Compilation:
  > ***CXXFLAGS='-Wno-error -std=c++98' ./waf --enable-examples configure***
  > ***./waf***
- Running test scripts:
  > ***./waf --run 'rldrs-brite-waxman --NumFlows=2200 --nNodes=1000'***

[$]Intelligent Deflection Routing in Buffer-Less Networks – *Soroush Haeri and Ljiljana Trajkovic (Fellow, IEEE)*
Intelligent Deflection Routing in Buffer-Less Networks

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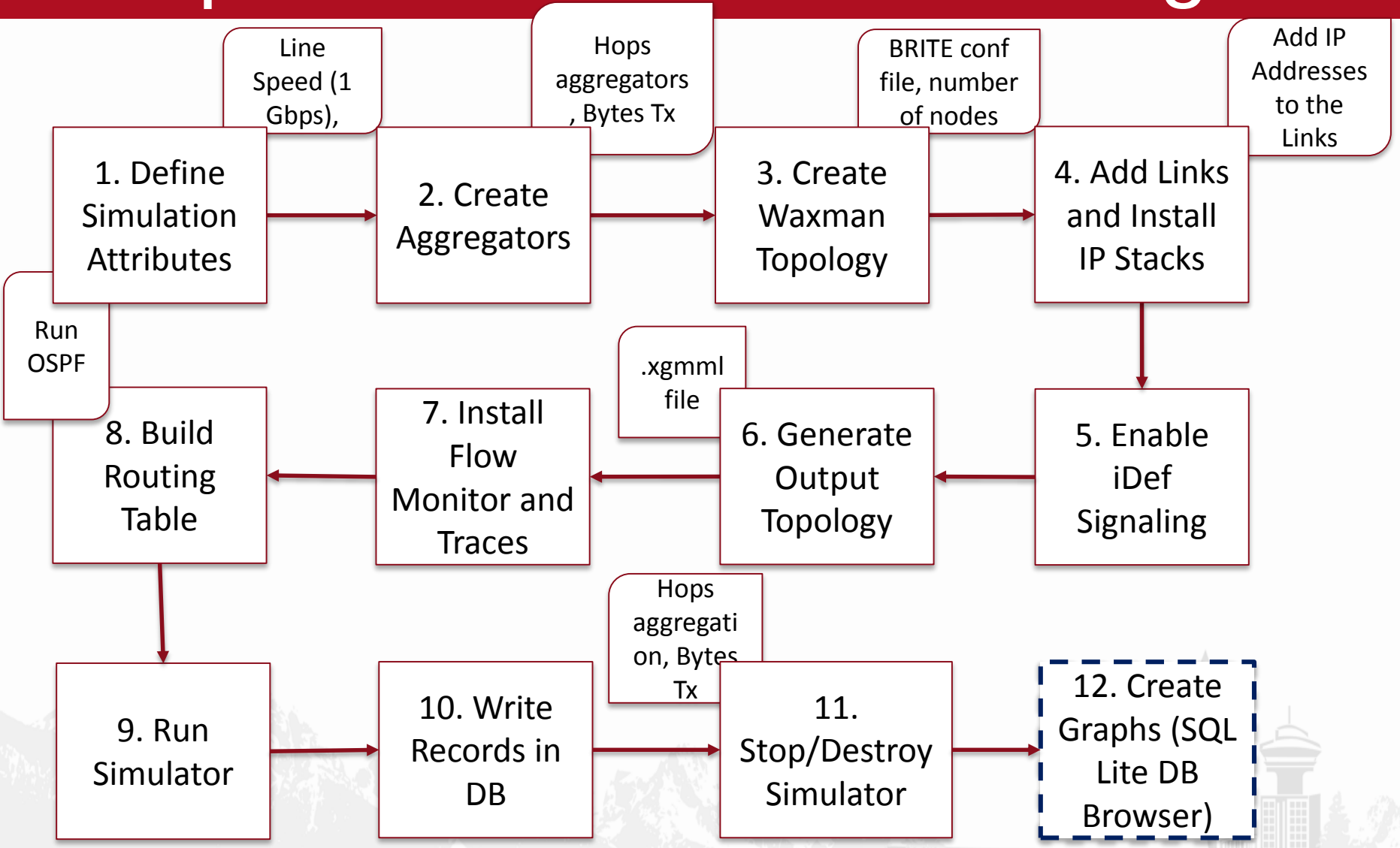
Implementation – Block diagram



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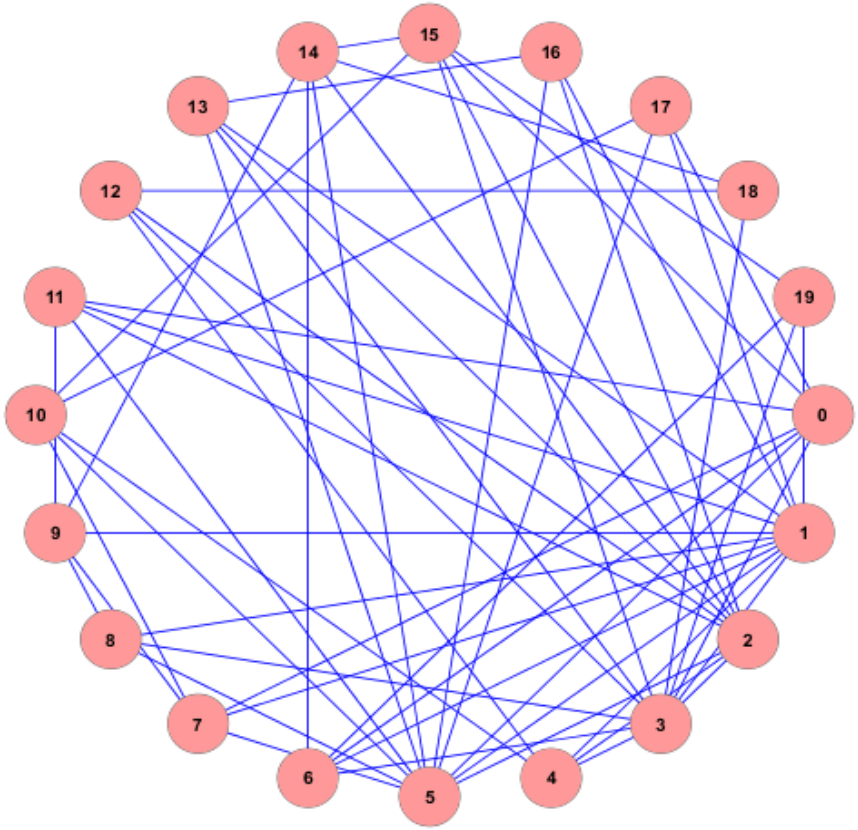
Implementation – Output File

- XGMML File shows the topology.
- A sample topology with 20 nodes



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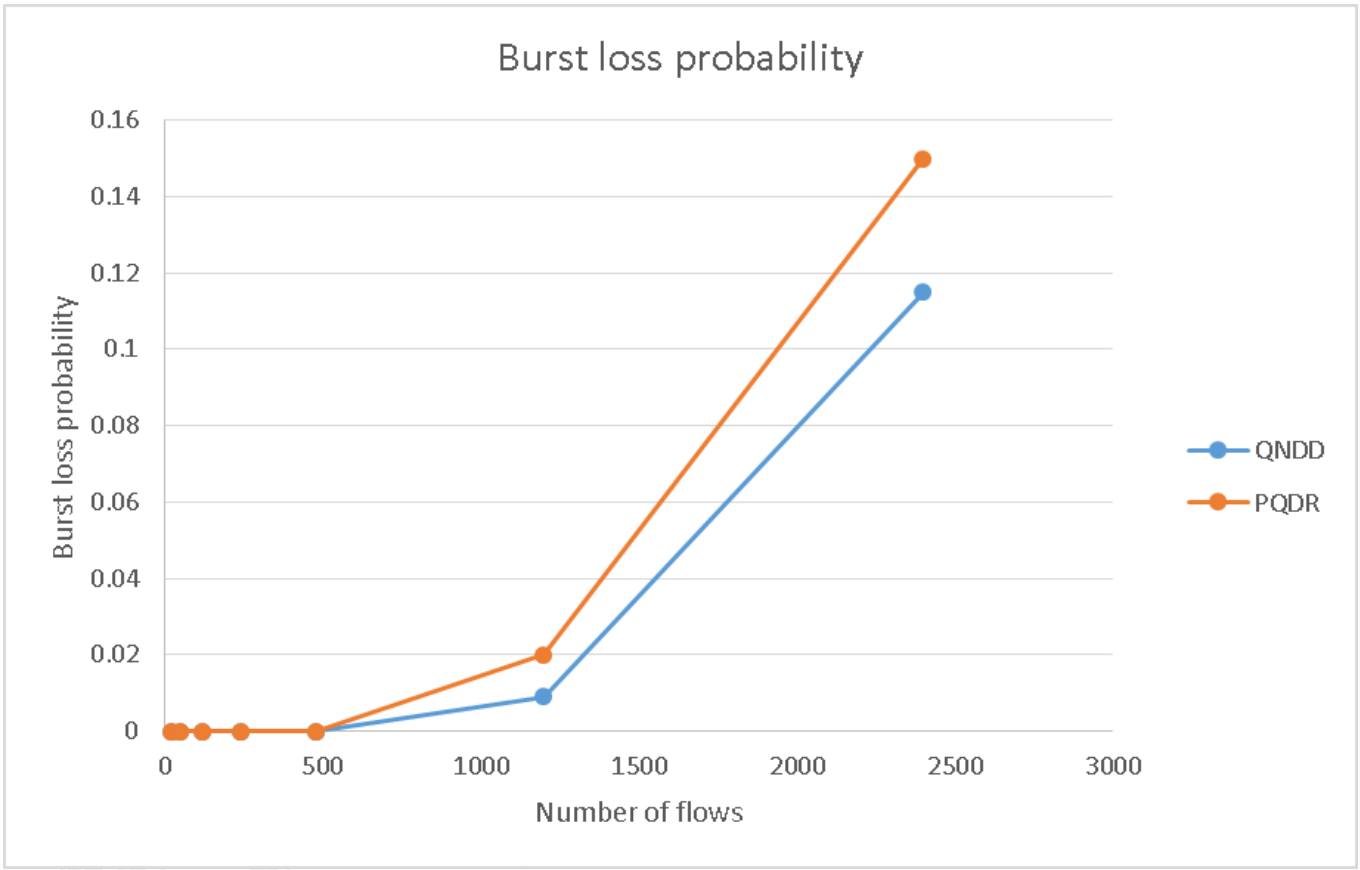
Graphs and Results – Burst loss



Burst loss probability = (Number of burst loss / Total number of transmitted burst)

Q-learning-based Node Degree Dependent (Q-NDD)

Predictive Q-learning Deflection Routing (PQDR)

Comparison shows that with increase in the number of flow the burst loss probability increases and PQDR algorithm has more burst loss.

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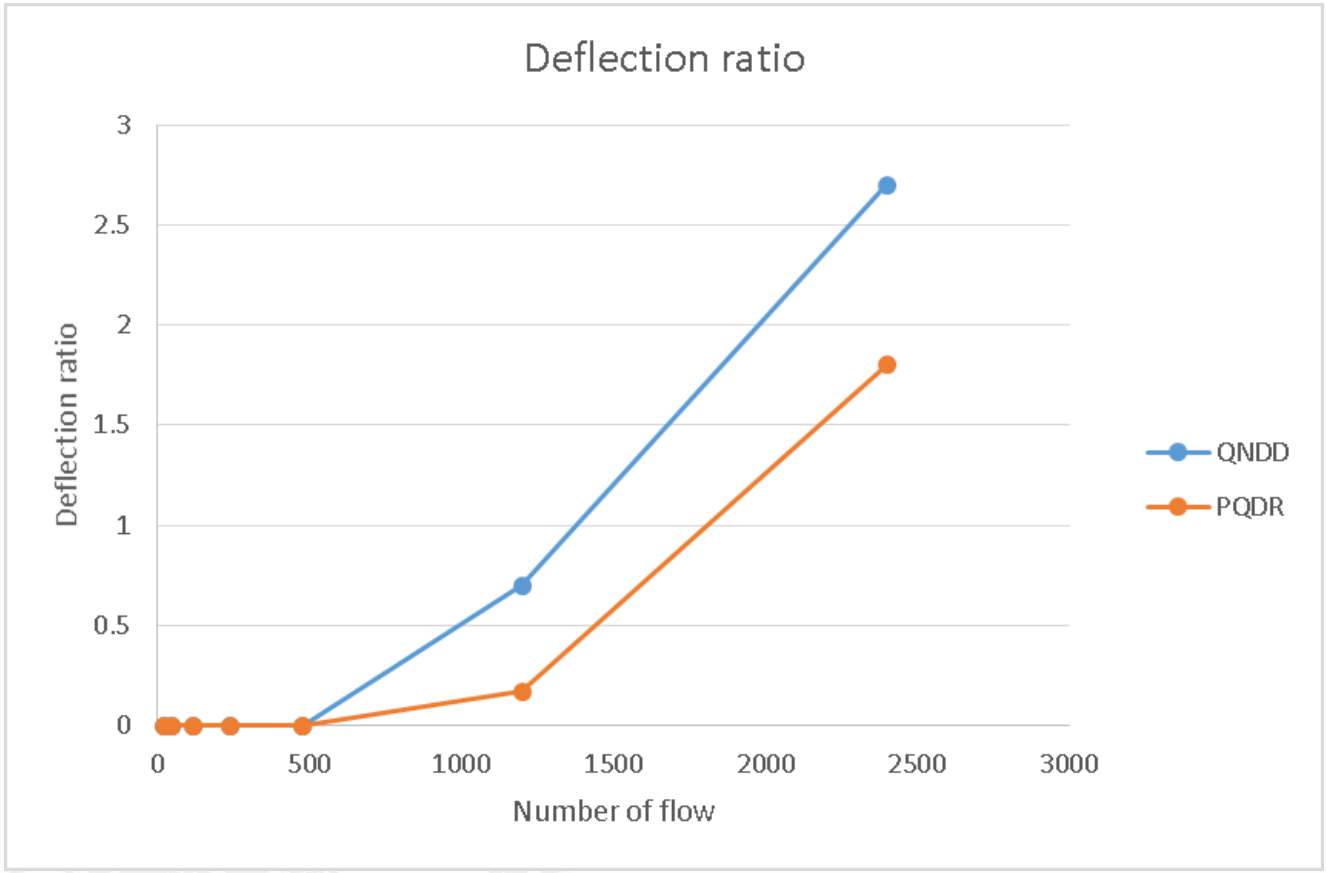
Graphs and Results – Deflection ratio



Deflection ratio = Number of deflected bursts / Total number of transmitted bursts

Q-learning-based Node Degree Dependent (Q-NDD)

Predictive Q-learning Deflection Routing (PQDR)

Comparison shows that the deflection ratio also increases with the number of flows and the QNDD algorithm has higher deflection ratio.

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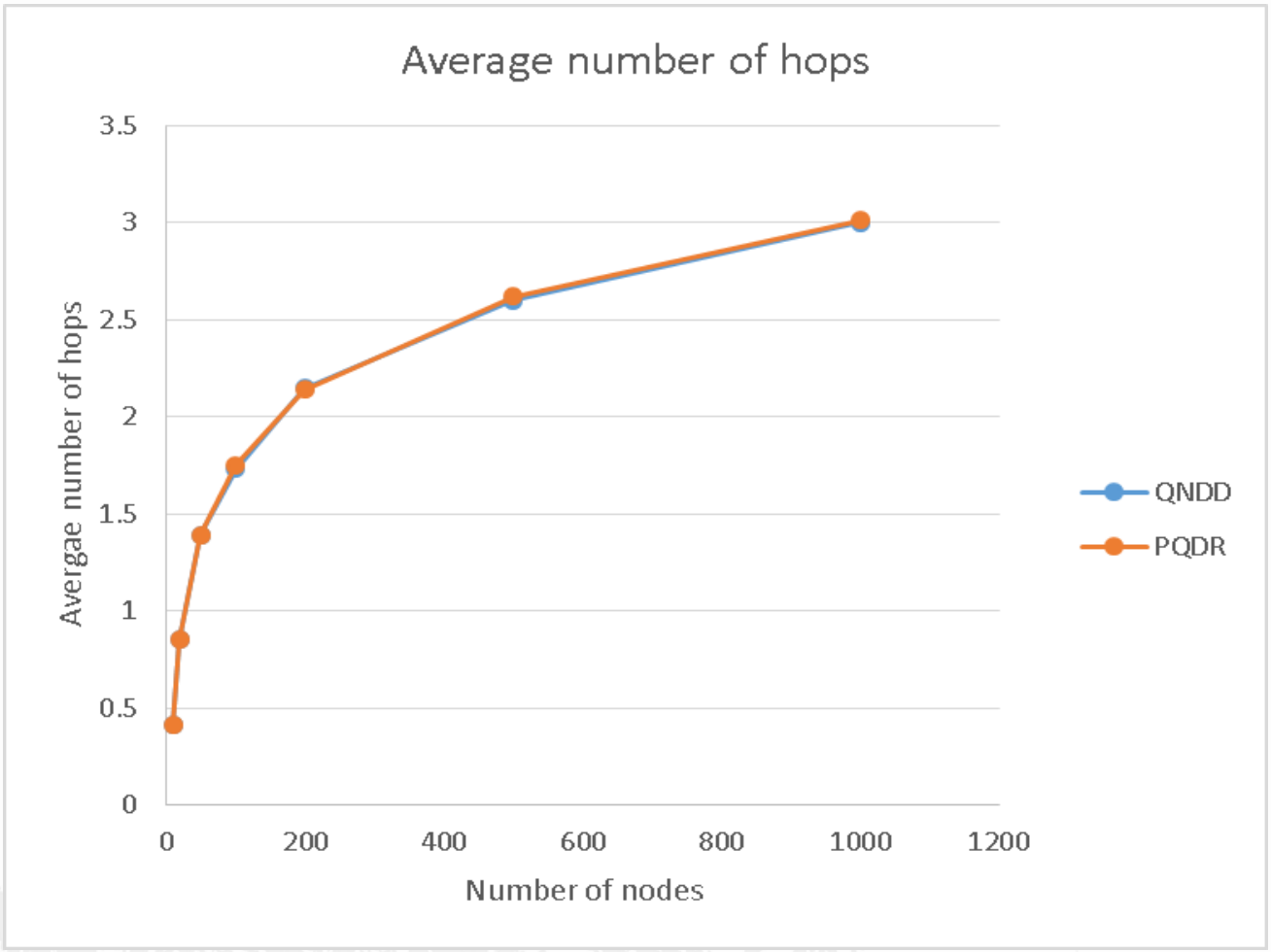
Graphs and Results – Hop count



Q-learning-based Node Degree Dependent (Q-NDD)

Predictive Q-learning Deflection Routing (PQDR)

Comparison shows that average hop count for both QNDD and PQDR algorithm are the same.

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Results Summary

Parameters	QNDD Algorithm	PQDR Algorithm
Burst loss	Low	High
Number of deflection	High	Low
Average hop count	Equal	Equal

Q-NDD Algorithm performs much better than PQDR algorithm.

Challenges

- Porting code to Ubuntu 18.04 and latest ns-3.29 simulator
- Calculation for burst loss probability
- Result for plotting the graph

References

- S. Haeri and L. Trajkovic´, "*Deflection Routing in Complex Networks*," in Complex Systems and Networks, Berlin, Springer, 2015, pp. 395-422.
- S. Haeri and L. Trajkovic, "*Intelligent deflection routing in buffer-less networks*," IEEE Transactions on Cybernetics, vol. 45, no. 2, pp. 316-327, Feb. 2015.
- C. Qioa and M. Yoo, "*Optical burst switching (OBS) - a new paradigm for an optical internet*," Journal of High Speed Networks, vol. 8, no. 1, pp. 69-84, Mar. 1999.
- A. Zalesky, H. Vu, Z. Rosberg, E. Wong and M. Zukerman, "*OBS contention resolution performance*," Performance Evaluation, vol. 64, no. 4, p. 357–373, May 2007.
- D. H. Patel and D. K. Kothari, "*Overview and framework for dynamic deflection contention resolution in OBS network*," in 2013 Nirma University International Conference on Engineering (NUiCONE), Ahmendabad, India, Nov 2013.

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Thanks!

Questions?