Multi-Sourced Data Retrieval in Groomed Elastic Optical Networks

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2017 International Conference on Optical Network Design and Modeling (ONDM)
@ Budapest, Hungary, May 15, 2017

CARGONET project CNS-1406370
CCDNI project CI-1541434

PROPER project
DESC0012115TDD

Outline

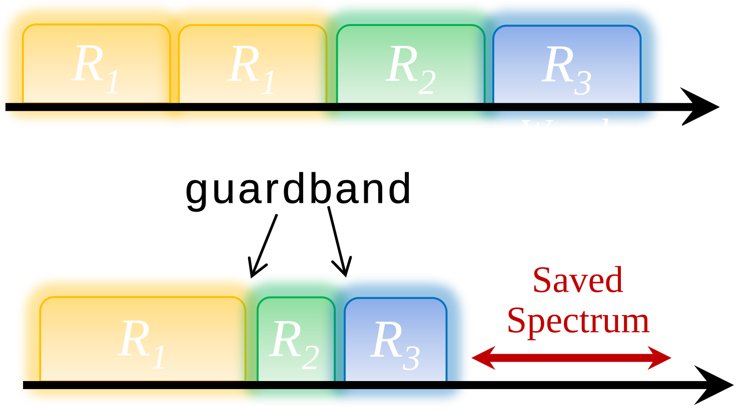
- ✓Introduction
- ✓Problem Statement
- ✓Proposed Heuristic
- ✓Numerical Results
- ✓Conclusions and Future Work

Elastic Optical Networks

✓ A promising solution for next-generation high-speed optical transport that provides higher levels of flexibility and efficiency to the spectral domain

- **Flexible subcarrier allocation**
- **Bit rate - different modulation level based on transmission reach limit**

Request	Bandwidth
R_1	14 Gbps
R_2	5 Gbps
R_3	7 Gbps
Fixed-grid WDM	10 Gbps



M. Jinno, H. Takara, B. Kozicki et al. "Spectrum-efficient and scalable elastic optical path network: architecture, benefits, and enabling technologies" IEEE Communications Magazine, 2009, 47(11).

Multi-Sourced Data Retrieval

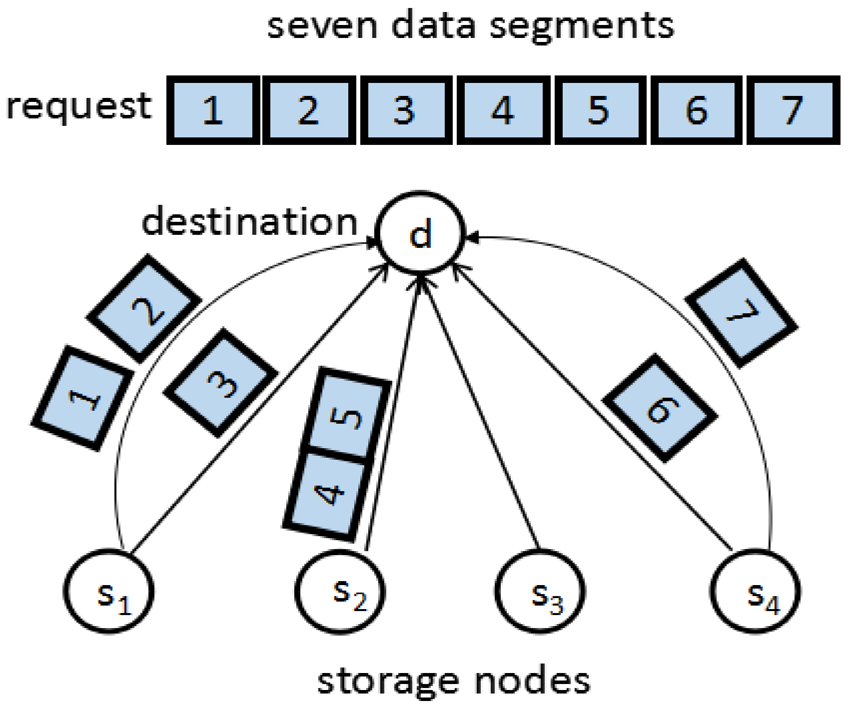
- ✓ Data is replicated at many locations in Today's data center networks
- ✓ Traditional data retrieval: a user has the choice between several storage sites, but can at most pick one (Single-Sourced)
- ✓ Multi-sourced data retrieval: parallel data transfer from several repositories to one destination
- ✓ Large datasets can be efficiently transported over multiple paths from multiple replicas

Multi-Sourced Data Retrieval

Retrieval request:

$$R=(\{S_1,S_2,...,S_H\},\ d,\ F)$$

- Destination: *d*
- Data replicas at H nodes
- Data is divided into F segments



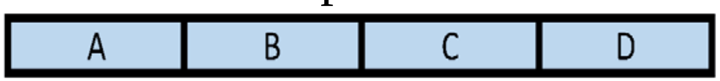
F=7
H=4

J. Zhao and V. M. Vokkarane, “Reverse manycast data retrieval in Elastic Optical Networks”, ICNC'17

Erasure-coded Data Retrieval

- ✓ Erasure coding to increase reliability (Azure and Google)
- ✓ (n, m) code ($m \leq n$): data is encoded and stored in n storage nodes such that the pieces stored in any m of these n nodes suffice to recover the entire data

4 pieces



code rate (4, 2)

- ✓ Erasure-coded data retrieval from distributed repositories to a single site

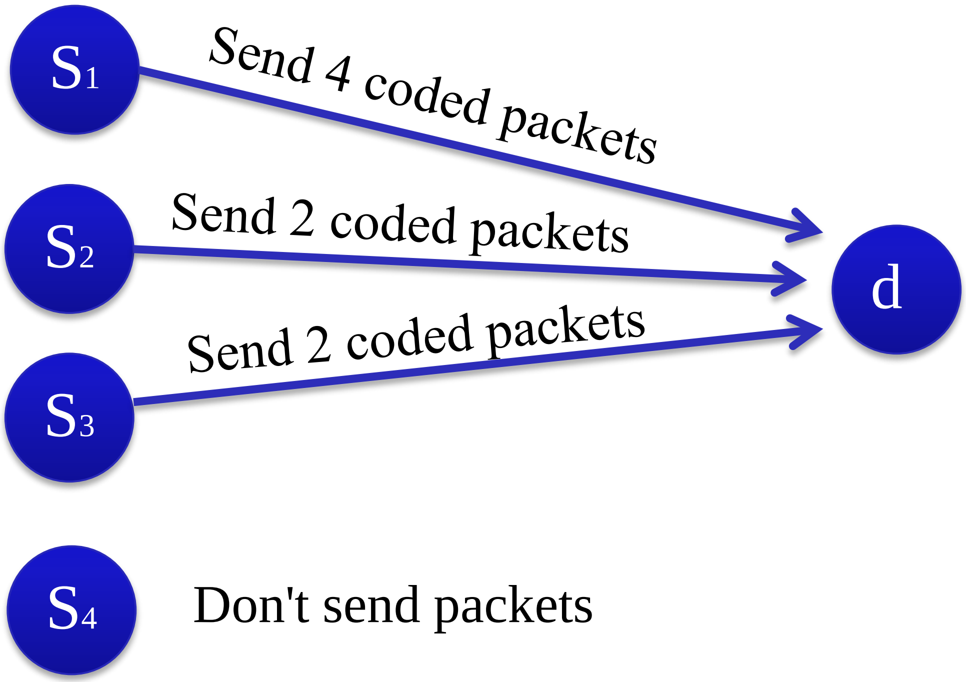
C. Huang, H. Simitci, Y. Xu, A. Ogus, B. Calder, P. Gopalan, J. Li, and S. Yekhanin, “Erasure Coding in Windows Azure Storage,” USENIX ATC, 2012.

TCP

- ✓ TCP with coding
  - Google's Quic (Quick UDP Internet Connections)
  - Support a set of multiplexed connections between two endpoints
- ✓ Multi-path TCP with single sender
- ✓ TCP for Multi-source (multi-destination) connections for coded data

Multi-Source TCP

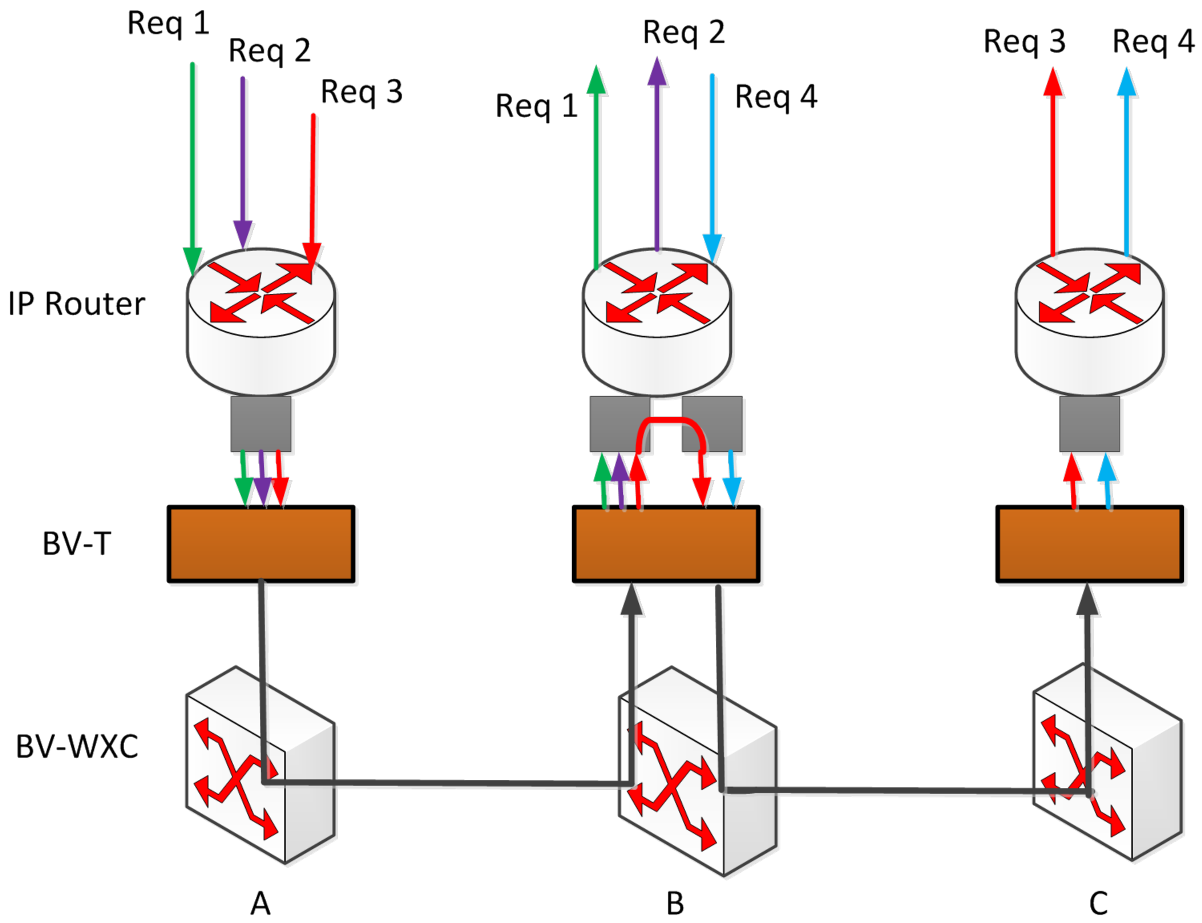
✓ Network coding based multi-sourced content retrieval service



send content request with a control parameter to all source nodes

D. Xie, X. Wang, and Q. Wang, “Network Codes-based Multi-Source Transmission Control Protocol for Content-centric Networks”, 2016 IEEE/ACM 24th International Symposium on Quality of Service (IWQoS), June 2016.

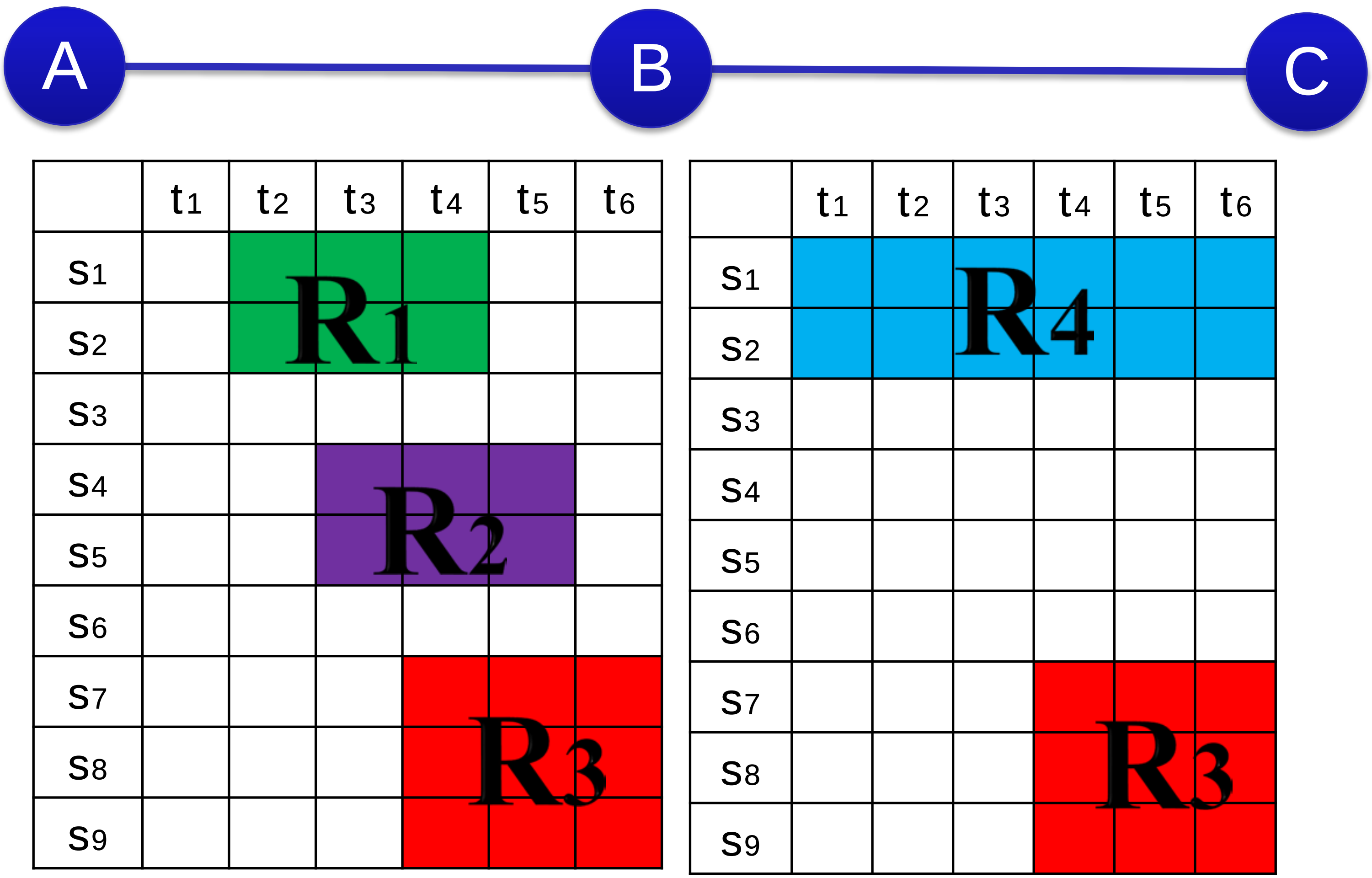
Traffic Grooming Architecture in EONs



Single-Hop Requests R_1, R_2, and R_4
Multi-Hop Request R_3

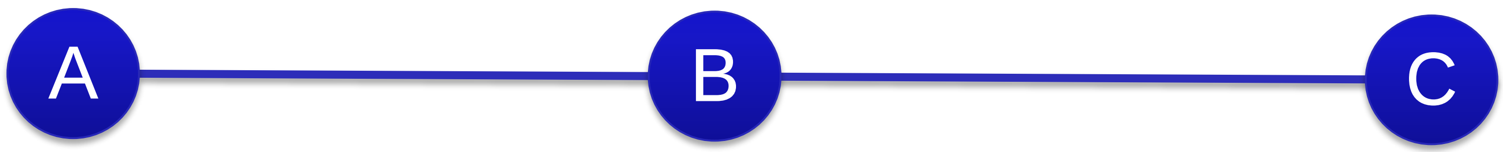
Scheduling - without grooming

R$_1$ (A, B, t_2, t_4), R$_2$ (A, B, t_3, t_5), R$_3$ (A, C, t_4, t_6), R$_4$ (B, C, t_1, t_6)



Scheduling – with Single-hop grooming

R_1 (A, B, t_2, t_4), R_2 (A, B, t_3, t_5), R_3 (A, C, t_4, t_6), R_4 (B, C, t_1, t_6)

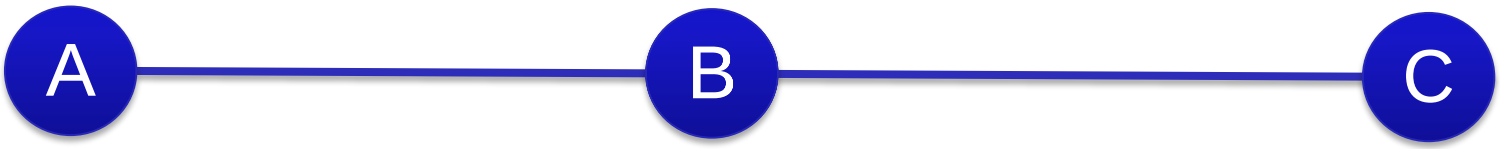


	t_1	t_2	t_3	t_4	t_5	t_6
S_1		R_1	R_1	R_1		
S_2		R_1	R_1	R_1		
S_3			R_2	R_2	R_2	
S_4			R_2	R_2	R_2	
S_5						
S_6				R_3	R_3	R_3
S_7				R_3	R_3	R_3
S_8				R_3	R_3	R_3

	t_1	t_2	t_3	t_4	t_5	t_6
S_1	R_4	R_4	R_4	R_4	R_4	R_4
S_2	R_4	R_4	R_4	R_4	R_4	R_4
S_3						
S_4						
S_5						
S_6				R_3	R_3	R_3
S_7				R_3	R_3	R_3
S_8				R_3	R_3	R_3

Scheduling – with Multi-hop grooming

R_1 (A, B, t_2, t_4), R_2 (A, B, t_3, t_5), R_3 (A, C, t_4, t_6), R_4 (B, C, t_1, t_6)



	t_1	t_2	t_3	t_4	t_5	t_6
s_1			R_1			
s_2						
s_3				R_2		
s_4						
s_5					R_3	
s_6						

	t_1	t_2	t_3	t_4	t_5	t_6
s_1			R_4			
s_2						
s_3					R_3	
s_4						
s_5						
s_6						

EON Node Model

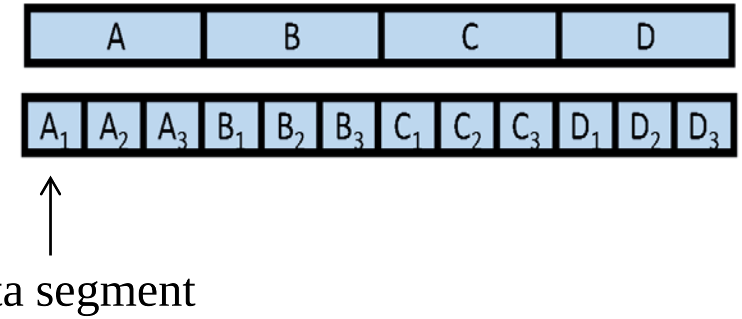
- ✓ Each node has a fixed number of transponders
- ✓ Each link has a fixed number of subcarriers
- ✓ Transmission reach limit for each modulation format
- ✓ K pre-computed shortest distance paths for each pair of nodes
- ✓ Guardband between subcarrier bands
- ✓ Spectrum continuity and contiguity constraint
- ✓ Time-slotted system

Erasure-coded Multi-sourced Data Retrieval in EONs

Request:

- a destination node
- code rate *(n, m): select m out of n* candidate source nodes
- *F* data segments on each source node
- deadline requirement

code rate (4, 2): $n=4, m=2; F=3$



Problem Statement

- ✓ **Traffic**: Dynamic requests with time deadline
- ✓ **Objective**: minimize the request blocking
- ✓ **Scheduling**:

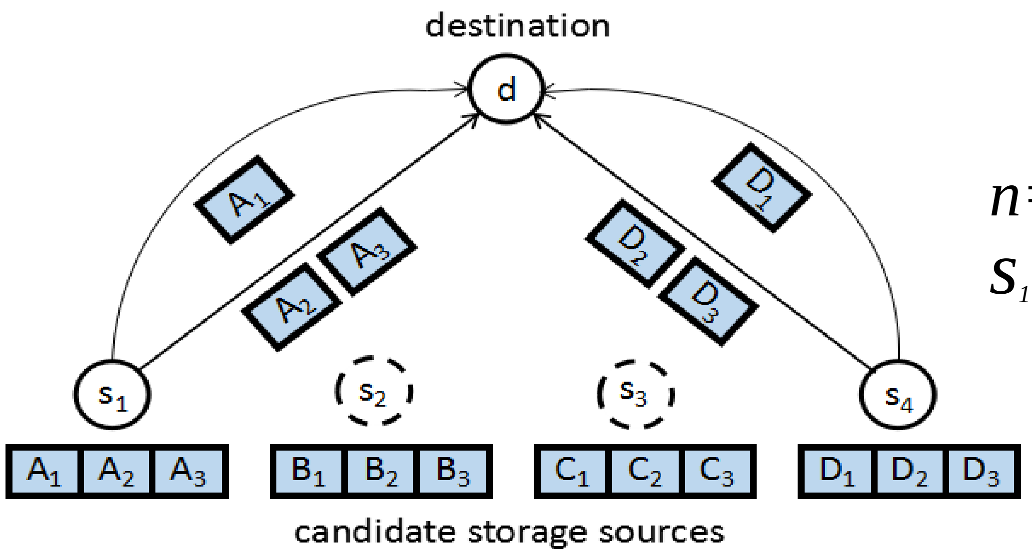
for each request:

Select *m* nodes from *n* candidate source nodes

for each data segment transfer (from selected source)

- ✓ transmission starting time slot
- ✓ path
- ✓ subcarriers
- ✓ modulation format
- ✓ transponder resources (with or without grooming)

Problem Statement



n=4, m=2; F=3

s_1 & s_4 *selected*

- ✓ Meet the deadline of each request
- ✓ Efficiently utilize the subcarriers and transponders

Grooming-enabled Minimum Resource Algorithm (GMinR)

- ✓ **Step 1**: Select *m* of *n* candidate source nodes based on transponder and subcarrier resources at each node
- ✓ **Step 2**: Schedule the transmission of each data segment one by one using a weighted auxiliary graph
  - Minimum resources (transponder, subcarriers) that satisfies the deadline is allocated to the data segment
  - Considering existing lightpaths for grooming
  - Dijkstra's minimum weight end-to-end path used
- ✓ **Step 3**: If any data segment transmission exceeds the deadline, block the entire request

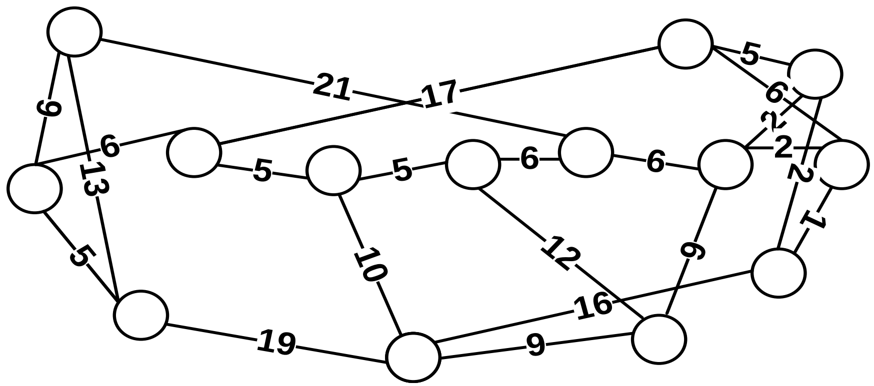
Multi-source Data Retrieval Policies

- **Baseline**
  - multi-source coded retrieval with no traffic grooming
  - New lightpath for each data segment transmission

- **SGMinR:** Source Grooming-enabled Minimum Resource Algorithm
  - Only consider existing lightpaths with the same source in the auxiliary graph

- **GMinR:** Grooming-enabled Minimum Resource Algorithm
  - Both source and intermediate grooming is applied
  - Consider grooming on existing lightpaths at any hop in the auxiliary graph

Simulation Assumptions

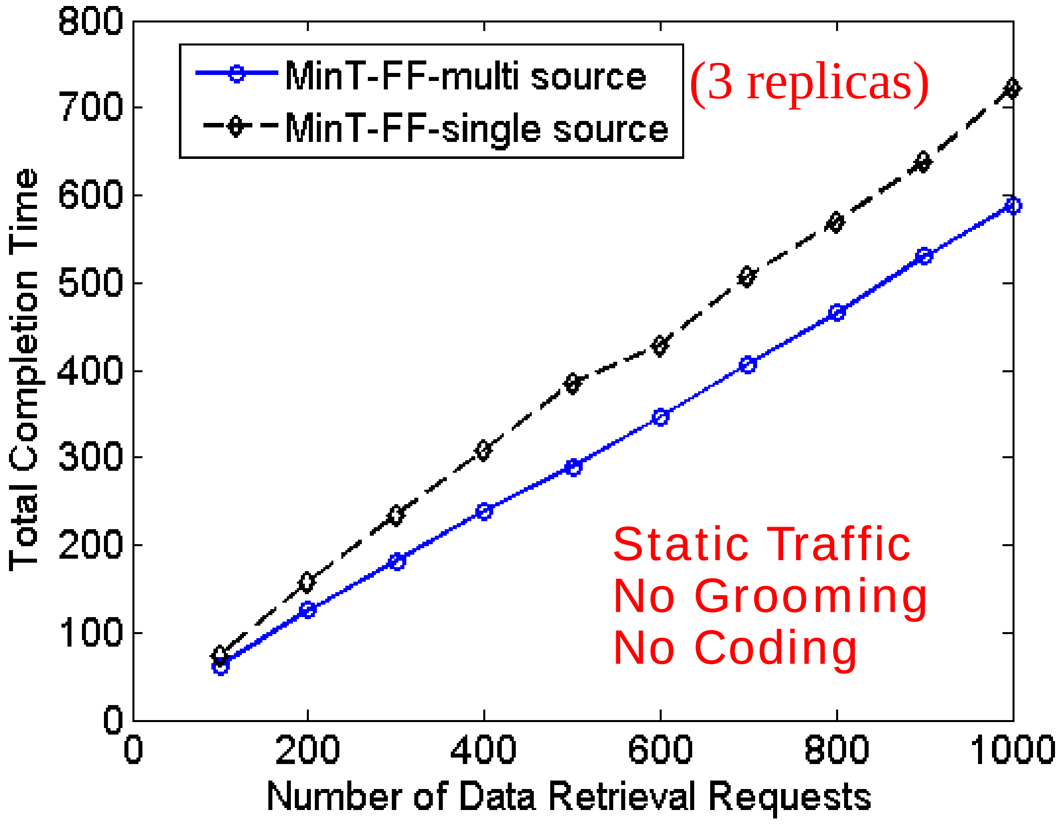


14-node NSF network

K paths	3	Transmission reach (TR) for BPSK	5000km
Guardband	1	TR for QPSK	2500km
Simulation seeds	30	TR for 8QAM	1250km
Source-Destination pairs	random	TR for 16QAM	625km
Transponder capacity	400Gbps	Number of requests	10,000
α	0.5	Sub-carriers per link	320
Data segments/request (F)	uniform [3, 5]	Erasure coding	(9, 6)
Data segment size	15,000 Gb	Deadline	50 time slots

Single Vs Multi-source Retrieval Results

✓ Multi-source data retrieval saves 37% in completion time compared with single-source policy



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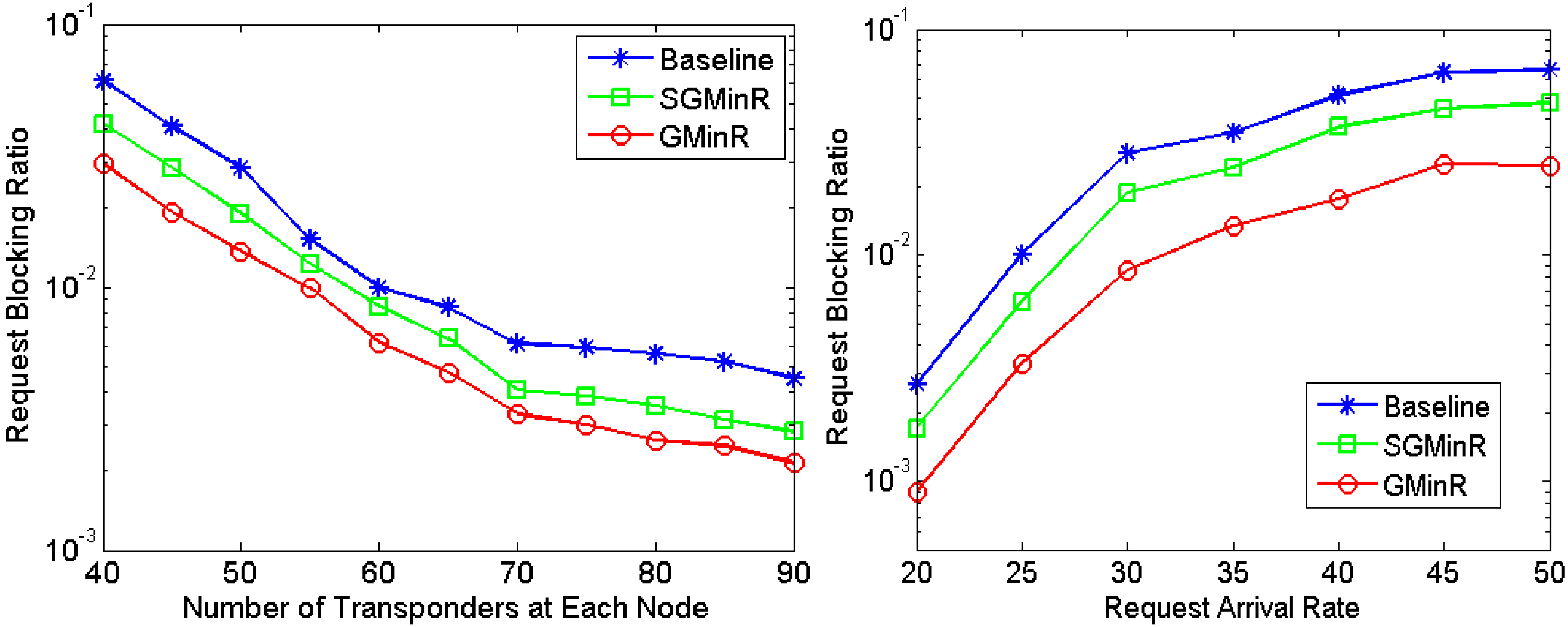
Dynamic Multi-Source Retrieval Grooming



30 new requests per time slot

50 transponders per node

- ✓ GMinR-70 better than Baseline-90
- ✓ SGMinR-60 better than Baseline-65
- ✓ Average Logical Hops: 1.132-1.093

- ✓ GMinR reduces blocking by upto a factor of 3
- ✓ Average Logical Hops: 1.091-1.184

Conclusions

- ✓ We investigated the dynamic multi-sourced erasure-coded data retrieval problem in groomed elastic optical networks
- ✓ We proposed both multi-hop grooming (GMinR) and single-hop grooming algorithm (SGMinR)
- ✓ GMinR can reduce 30% request blocking and 22% transponders compared with the case without grooming
- ✓ Future work:
  - Sliceable/Multi-flow Bandwidth Variable Transponders
  - Batch request allocation

Thank you

Questions?

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