A Design Method for Logical Topologies with Consideration of Wavebands

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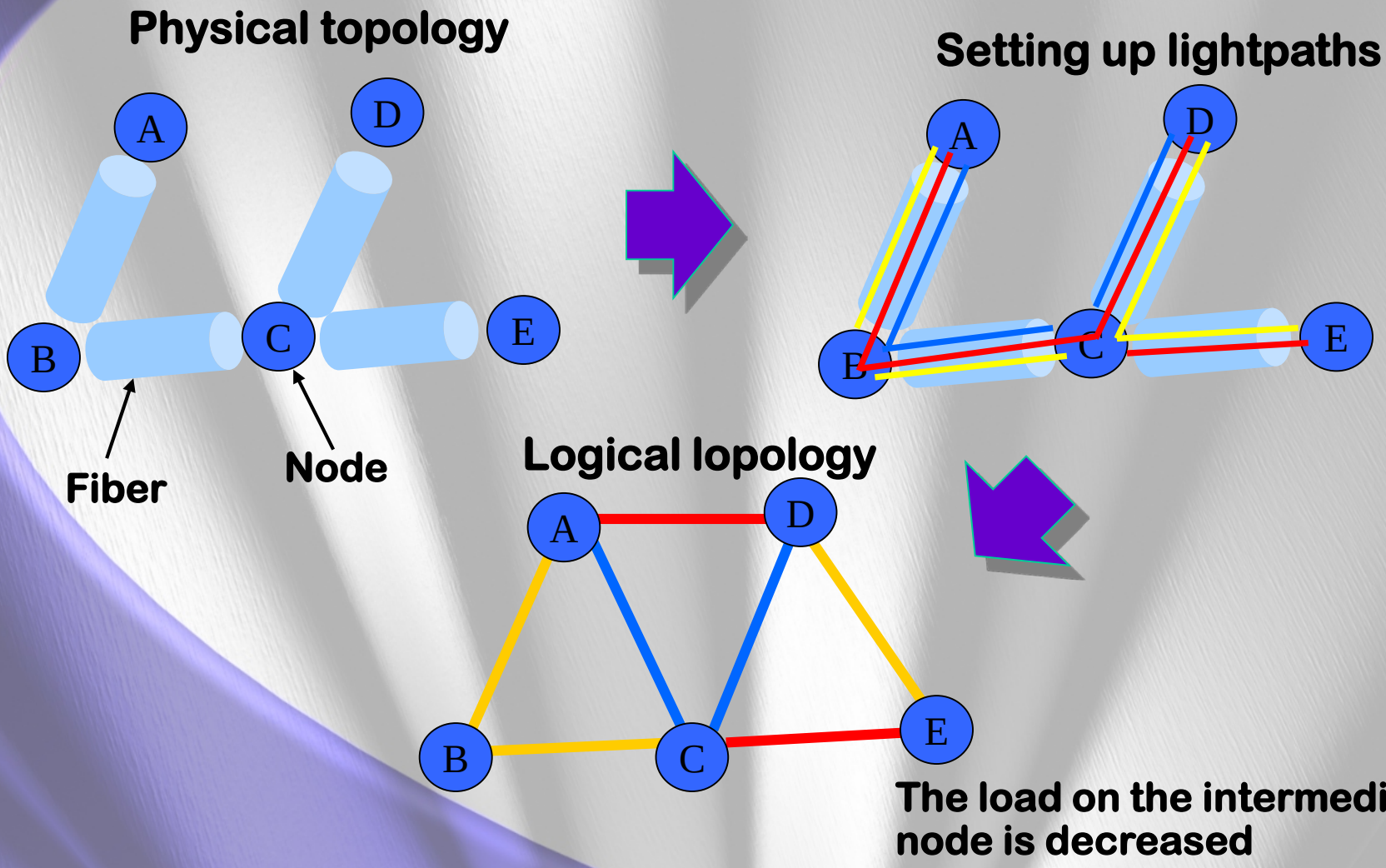
- Research background
- Logical topology design problem
- Proposal of logical topology design method
- Evaluation
- Conclusions and future Work

Background

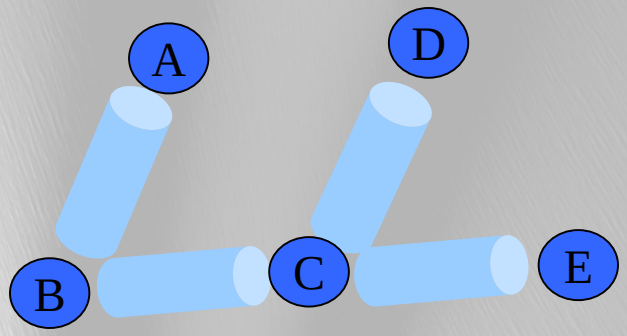
- IP over WDM network
  - Construct a logical topology
- WDM devices for multiplexing 1000 wavelengths
- Need for a new method of designing a logical topology
  - Target: WDM network with large number of wavelengths
  - Construct the cost-effective logical topology with as few WDM devices as possible

Construction of the logical topology



Logical topology design problem

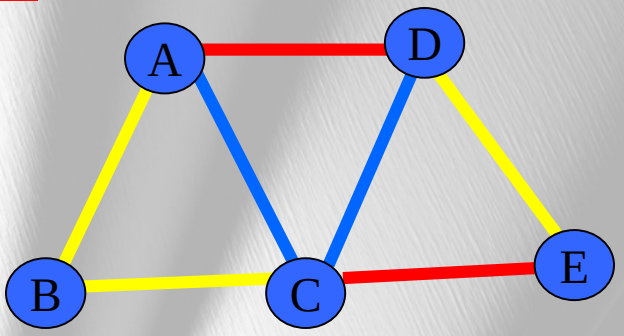
- **Input**
  - Physical topology
  - Traffic matrix
  - Available bandwidth on a wavelength
  - The number of wavelengths available on a fiber



Optimize Objective Function

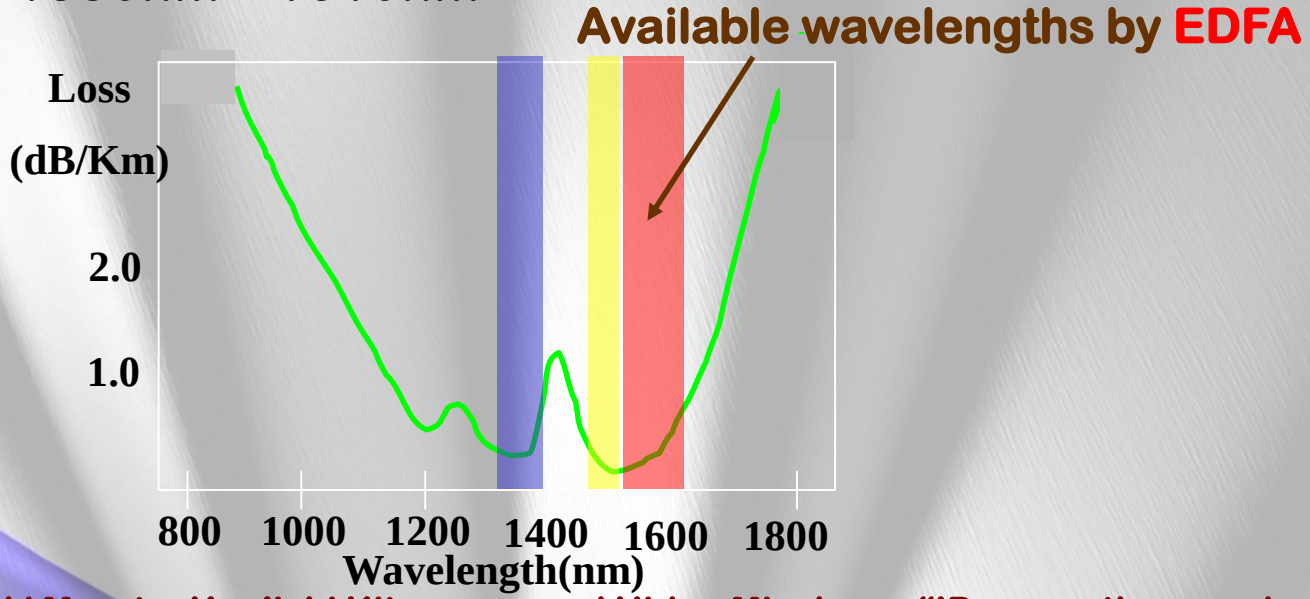
- –Number of Wavelengths
- –Throughput

- **Output**
  - Logical topology



Optical networking with a thousand wavelengths

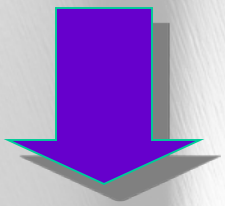
- Challenges for 1000-WDM [2]
  - Utilize wavelengths between 1290 nm and 1690 nm
- Optical fiber amplifier
  - The different kind of fiber amplifiers makes the corresponding wavelengths available
    - EDFA: 1530nm – 1610nm



Reference[2]: Masayuki Murata, Ken'ichi Kitayama, and Hideo Miyahara, "IP over a thousand-wavelength division multiplexing: Is it useful and possible for resolvingthe network bottlenecks?," *submitted to Optical Networks Magazine*,November 2000.

Approaches in conventional methods

- Utilize all the wavelengths on each fiber
- No consideration of the wavebands



- Require a lot of fiber amplifiers
- Construct high-cost logical topology

Approaches in our proposing method

- No need to utilize all the wavelengths on each fiber
  - Only Utilize the wavelengths needed to accommodate the required traffic
- Use the heuristic algorithm
  - Design of the logical topology: NP-hard Problem

Objective

Construct low-cost logical topology with fewer fiber amplifiers

Enhancement of MLDA

e-MLDA (extended-MLDA)

- Sets up multi-hop lightpaths in descending order of the traffic demand
- Enough lightpaths to accommodate the absolute volume of requested traffic are set up between each node-pair
- Does not utilize all the wavelengths

Use e-MLDA as comparison method with our proposing method

Proposal of the design method with consideration of wavebands (1/2)

- Conventional method
  - No consideration of wavebands

The number of fiber amplifiers is proportional to the number of the wavebands

We propose a method whose objective function is the number of the wavebands (fiber amplifiers)

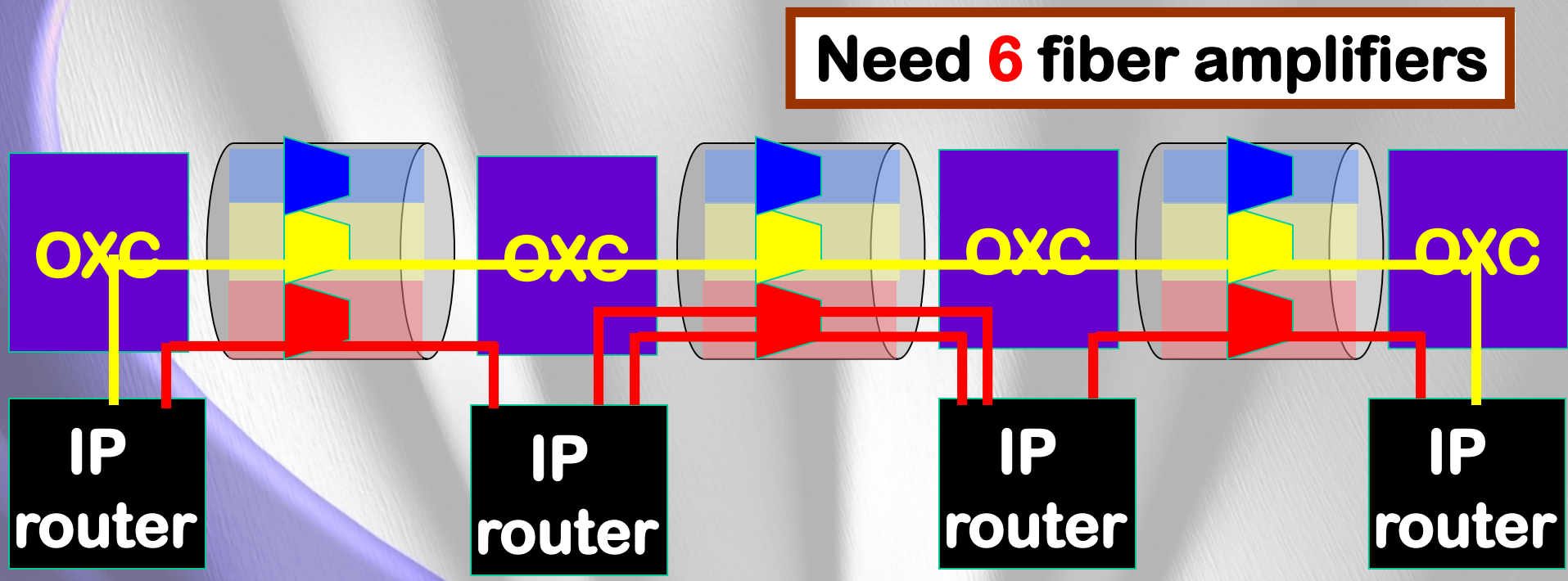
Proposal of the design method with consideration of wavebands (2/2)

MALDA (Minimum number of fiber Amplifiers Logical topology Design Algorithm)

- Objective function : The number of wavebands (i.e.,fiber amplifiers)
- Sets up the lightpaths with the wavelengths belonging to the same wavebands
  - Order and route of setting lightpaths: same as e-MLDA
- Decreases the load on the IP router
  - Make the input packet rate of all the IP routers below those processing capacities

Setting up lightpaths in conventional method

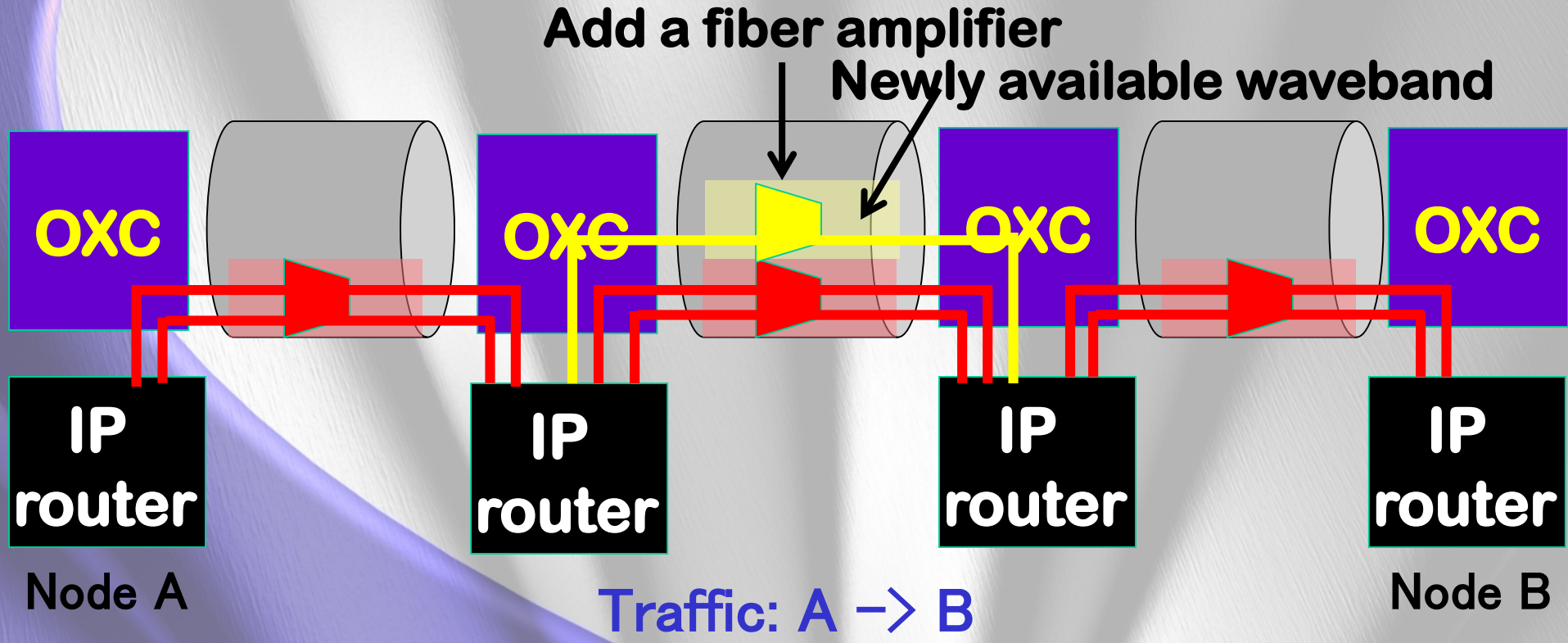
- Set up a lightpath with new wavelength
  - That wavelength may require a new fiber amplifier



1 Fiber amplifier makes 2 wavelengths available

Setting up lightpaths in MALDA

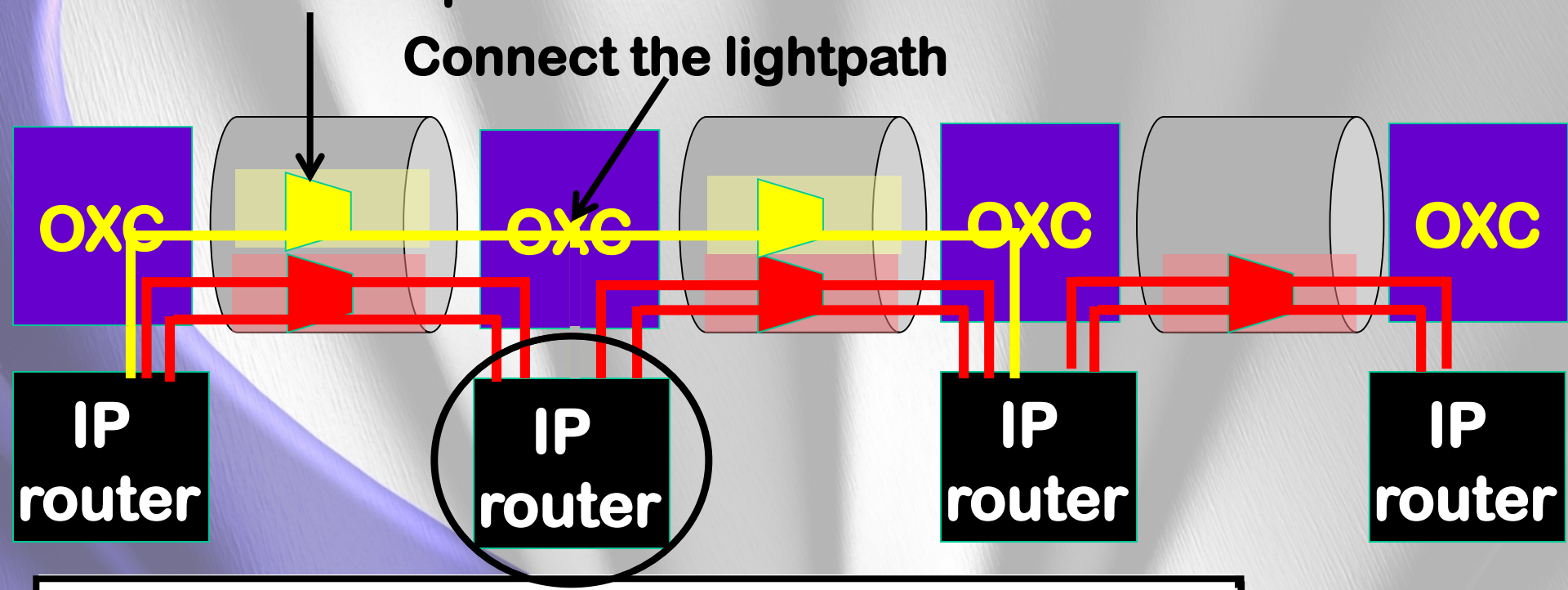
- Utilize the wavelength available by the already deployed fiber amplifier
- Add a fiber amplifier on fiber which lacks of wavelength



Decreasing the load on the IP router in MALDA

- Add the fiber amplifier
- Then, connect lightpath so that the load on the IP router is decreased

Need 5 fiber amplifiers



Input packet rate < Processing capacity

Evaluation model (1/2)

- Japan Backbone Network of NTT
  - 49 nodes and 91 links
- Traffic model
  - Based on an amount of telephone calls
  - Introduce a scale-up factor α
    - Actual requested traffic between node i and j: α ×64 kbps ×[number of telephone calls]

Evaluation model (2/2)

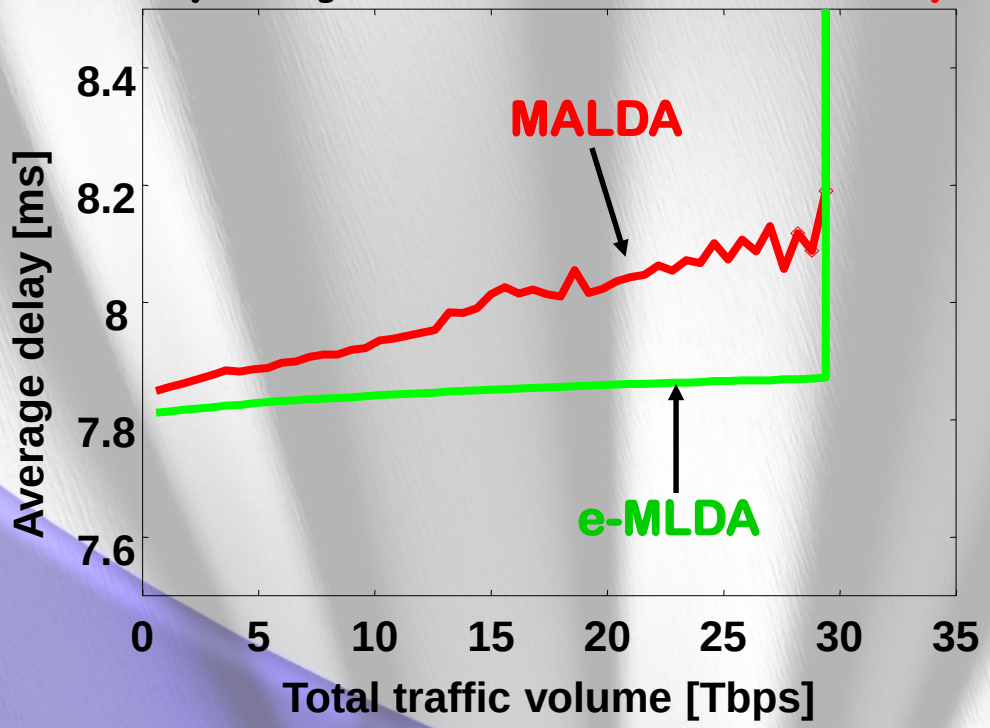
- Wavelength model
  - Number of wavelengths: Up to 1000
  - The number of available wavelengths
    - e-MLDA
      - Initial: 1000 wavelengths
    - MALDA
      - Initial: 200 wavelengths
      - If we add a fiber amplifier, 100 wavelengths are available
  - The bandwidth of a single wavelength: 10 Gbps
- Performance metric
  - Throughput
  - Required number of fiber amplifiers

Evaluation of the throughput (1/2)

- **Throughput**: Minimum requested traffic volume such that the average delay reaches saturation

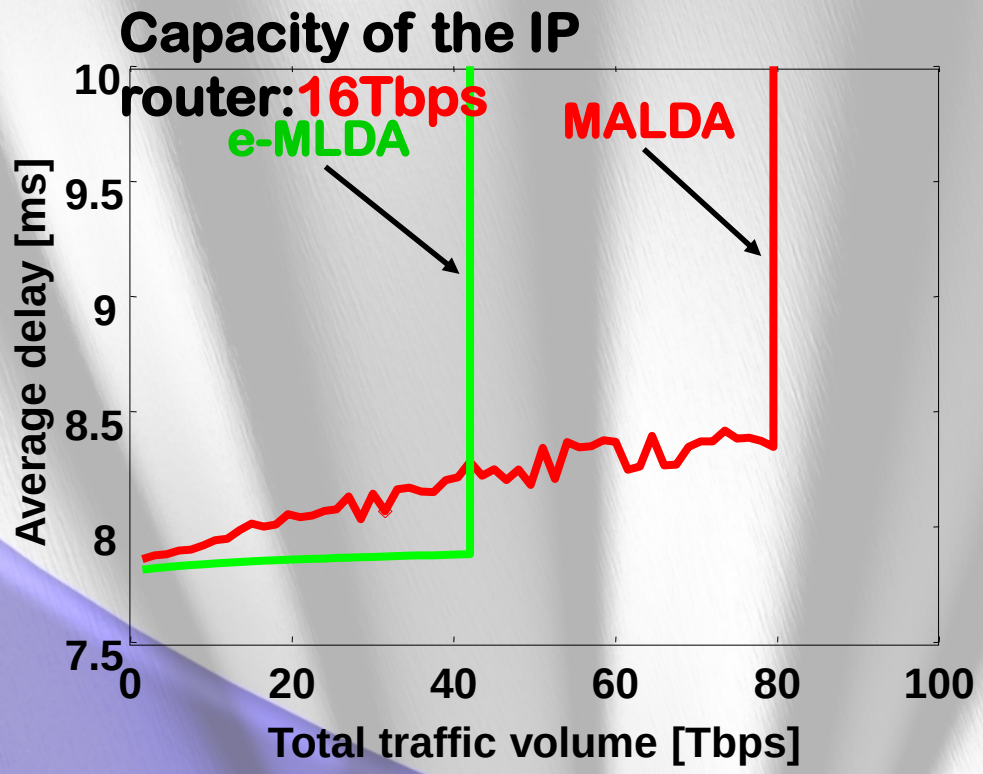
- The load on source and destination node limits the throughput
- e-MLDA and MALDA show the same throughput since that load can not be relieved by construction of the logical topology

Capacity of the IP router: 5.6Tbps



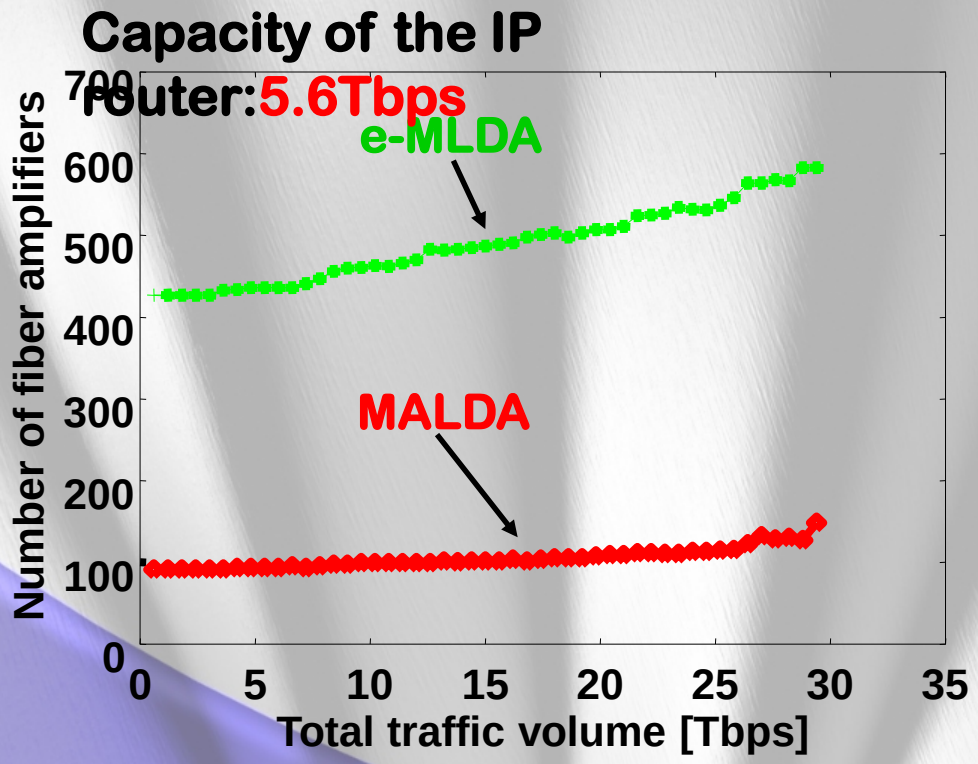
Evaluation of the throughput (2/2)

- The lack of available wavelengths limits the throughput
- MALDA accommodates more traffic volume since MALDA utilizes the wavelengths effectively by sharing the wavelengths

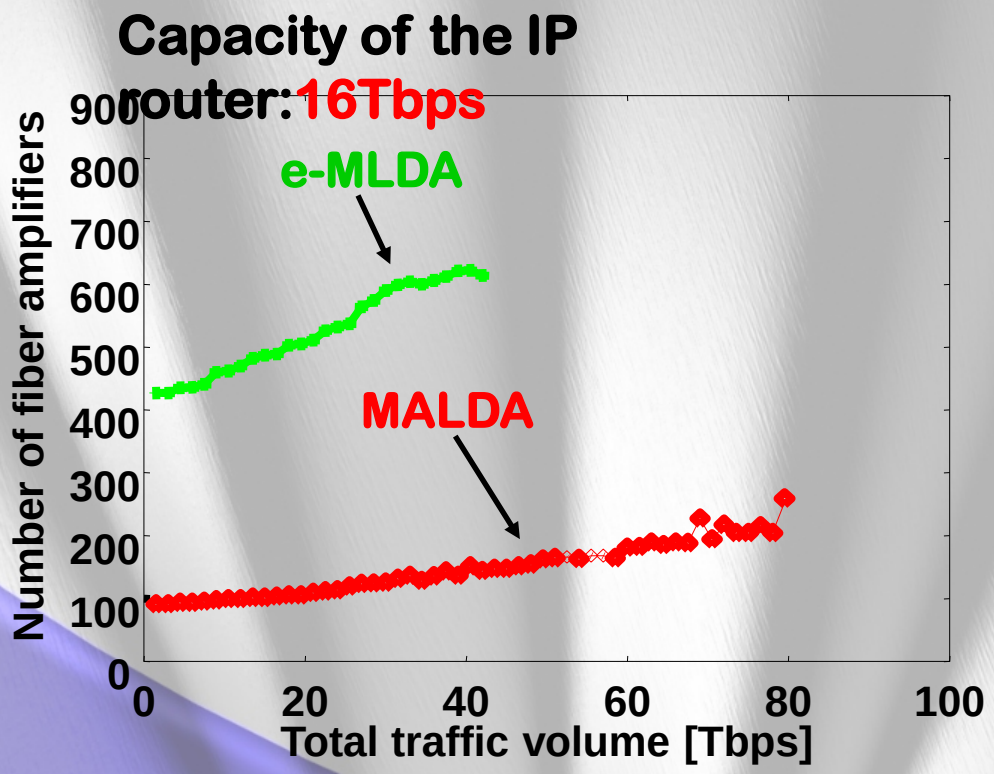


Evaluation of the required number of fiber amplifiers(1/2)

MALDA needs less number of fiber amplifiers since it **limits the number of wavelengths initially available** and gives priority to the wavelengths **belonging to the same wavebands**



Evaluation of the required number of fiber amplifiers(2/2)



Conclusion and future Work

- Conclusion
  - Propose the design method of the logical topology whose objective function is the number of fiber amplifiers (MALDA)
  - MALDA shows higher throughput than e-MLDA when the lack of wavelengths limits the throughput
  - MALDA requires less number of fiber amplifiers than e-MLDA

- Future work
  - Consider how IP routing affects the performance of the logical topology
    - In our research, it is assumed that traffic flow is placed on the path with the lowest propagation delay, which is different from the situation for actual IP routing

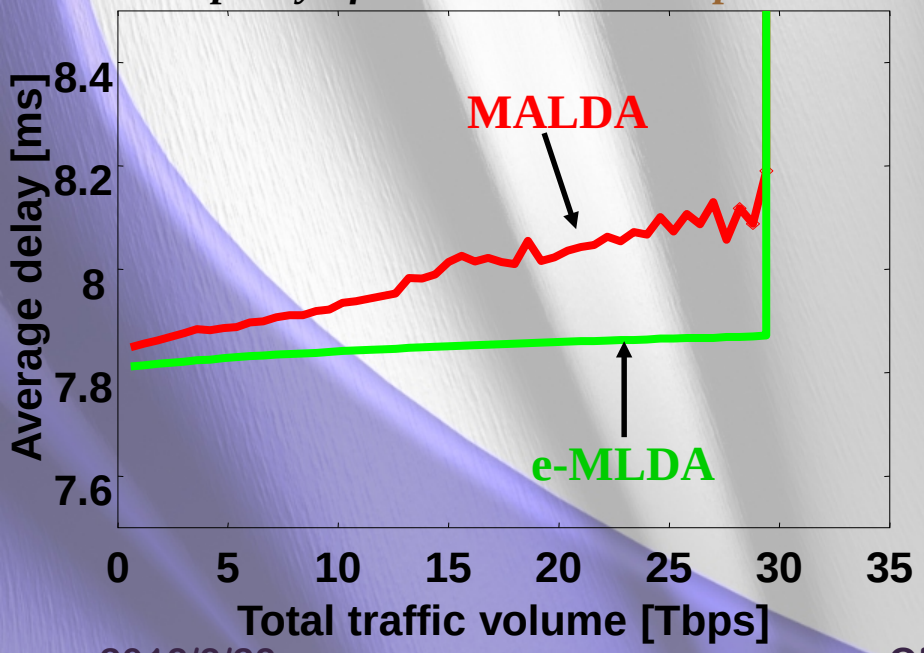
Evaluation of the throughput of each logical topology

•*Throughput* :*The minimum requested traffic volume such that the average delay goes satuation*

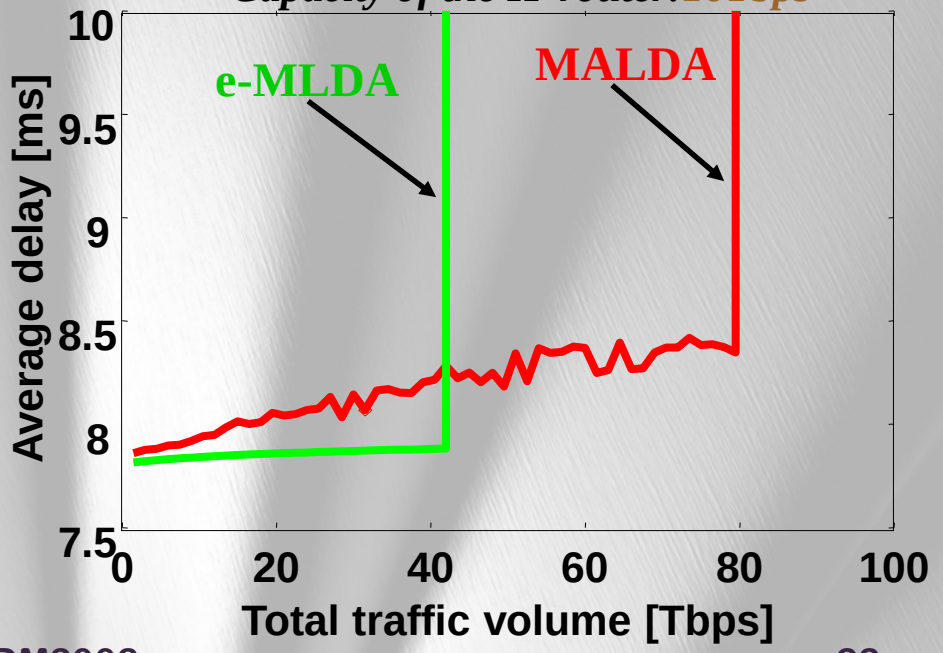
- *The load on source and destination node* limits the throughput
- *e-MLDA* and *MALDA* show the same throughput since that load can not be relieved by construction of the logical topology

- *The lack of available wavelengths* limits the throughput
- *MALDA* accommodates more traffic volume since *MALDA utilizes the wavelengths effectively* by sharing the wavelengths

Capacity of the IP router:5.6Tbps



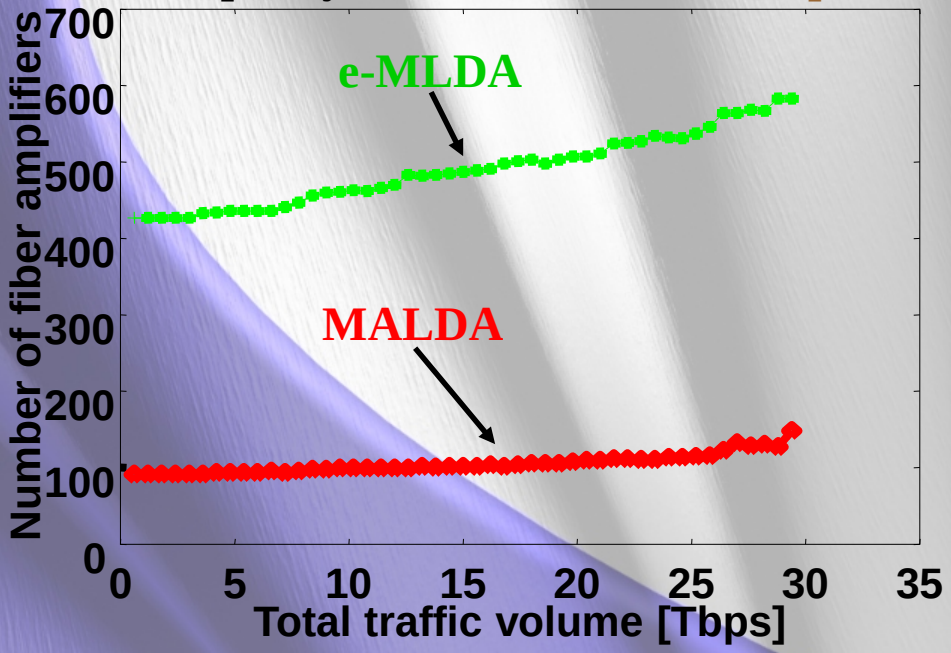
Capacity of the IP router:16Tbps



Evaluation of the required number of fiber amplifiers

MALDA needs less number of fiber amplifiers since it limits the number of wavelengths initially available and takes the priority in utilizing the wavelengths belonging to the same wavebands

Capacity of the IP router:5.6Tbps



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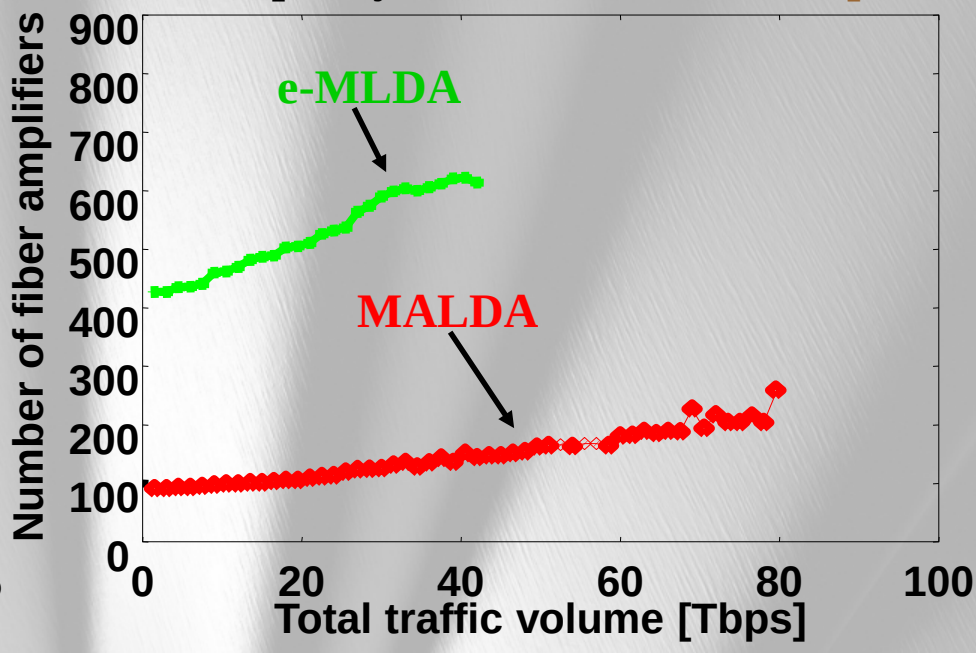


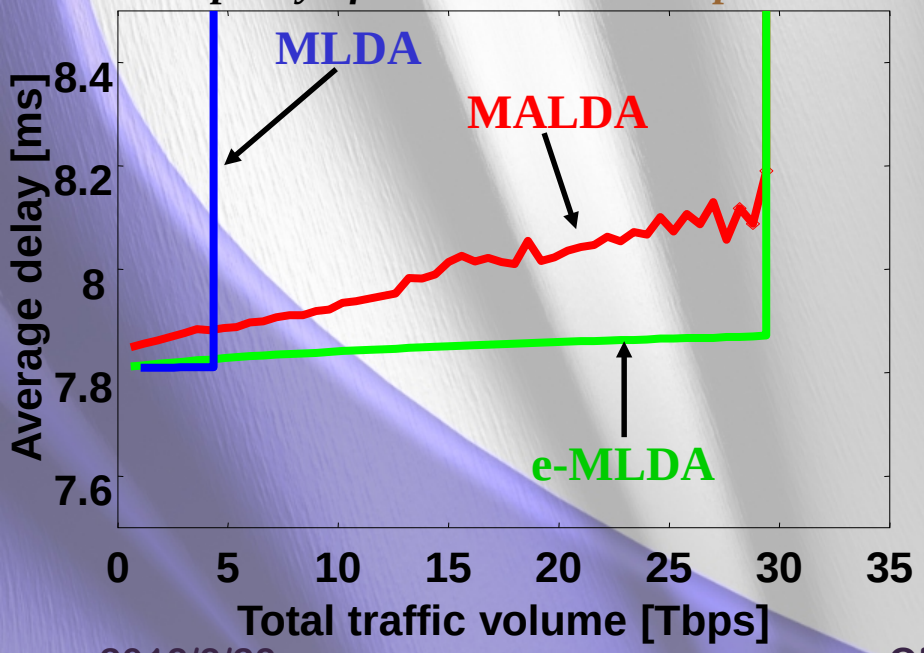
Evaluation of the throughput of each logical topology

•*Throughput* :*The minimum requested traffic volume such that the average delay goes satuation*

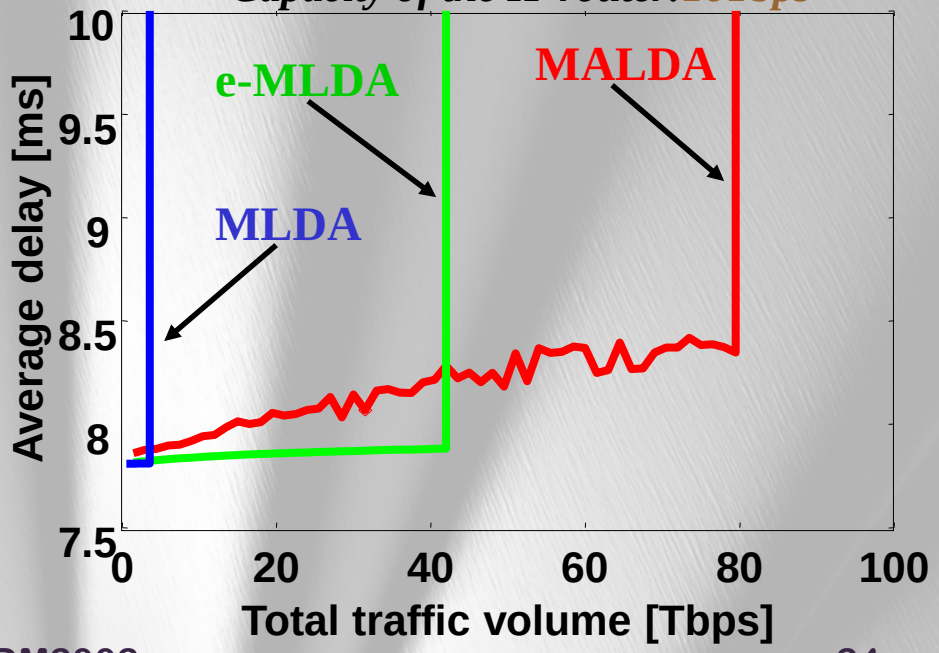
- *The load of source and destination node limits the throughput*
- *e-MLDA and MALDA show the same throughput since that load can not be relieved by construction of the logical topology*

- *The lack of available wavelengths limits the throughput*
- *MALDA accommodates more traffic volume since it utilizes the wavelengths effectively by sharing the wavelengths*

Capacity of the IP router:5.6Tbps



Capacity of the IP router:16Tbps



Enhancement of MLDA(1/2)

MLDA (Minimum delay Logical topology design Algorithm)

- A heuristic method to design the logical topology
- Order of setting lightpaths between node-pairs
  - In descending order of the required traffic demand
- Route of the lightpaths
  - shortest path in terms of the propagation delay

Problem of MLDA

- Utilize all the wavelengths

Approaches in our proposing method

- Only utilize the wavelengths needed to accommodate the required traffic
- Design the logical topology with as few fiber amplifiers as possible

- Require fewer fiber amplifiers
- Construct low-cost logical topology

NP hard problem

We use the heuristic algorithm to design the logical topology