"An Offline Impairment Aware RWA Algorithm with Dedicated Path Protection Consideration"

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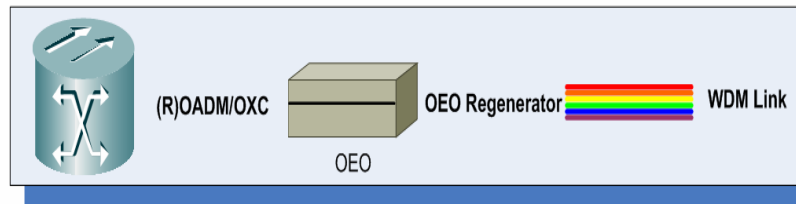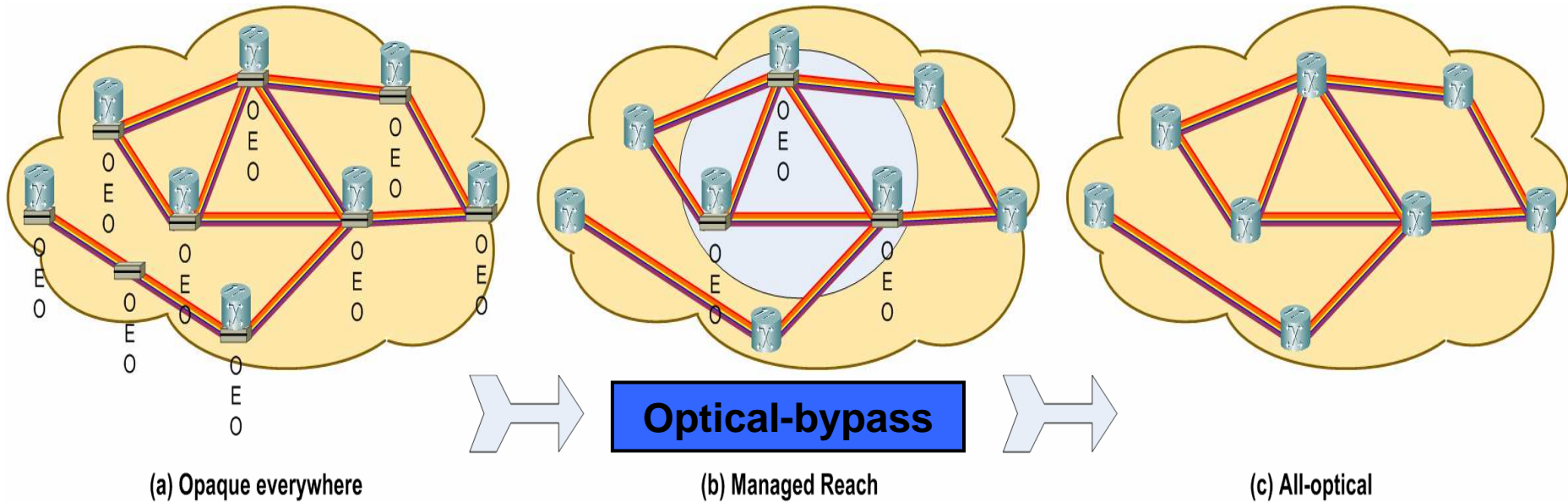[2]Athens Information Technology (AIT)

Outline

- Introduction
- Motivations
- Problem definition
- Proposed framework
- **Offline Impairment Aware RWA algorithm with Dedicated Path Protection**
- Simulation Setup
- Results
- Questions & Answers

- Evolution of core optical networks:
  - Past, Present, Future!

(a) Opaque everywhere   Optical-bypass   (b) Managed Reach   (c) All-optical

(R)OADM/OXC   OEO Regenerator   WDM Link
OEO

- **Physical Impairments accumulation**
  - Signal impairments accumulate along a transparent optical path, therefore limiting the system reach and the overall network performance
  - → *Impairment aware routing and wavelength assignment algorithms*

- **Failure localization**
  - Failure propagate in a transparent network environment and they can not be easily localized and isolated.

- **Control plane integration**
  - What to monitor and distribute?
  - What is the best control plane integration model?

Toward Future Core Optical Networks

- **The network evolution aims at:**
  - **Improved cost economics (less costly electronics)**
    - Cost savings of a transparent solution over and opaque network design of up to 50% could be achieved
      - *Source: M.Gunkel, et. al. "A Cost Model for WDM Layer", Photonics in Switching Conference, 2006.*
  - **Reduced investment and operations Efforts (CAPEX, OPEX)**
  - **Scalability (bit rate independence)**
  - **Suitability to future services (e.g. Grid computing)**

- **The main drivers for network architecture migration:**
  - High bandwidth and end-to-end QoS guaranteed services
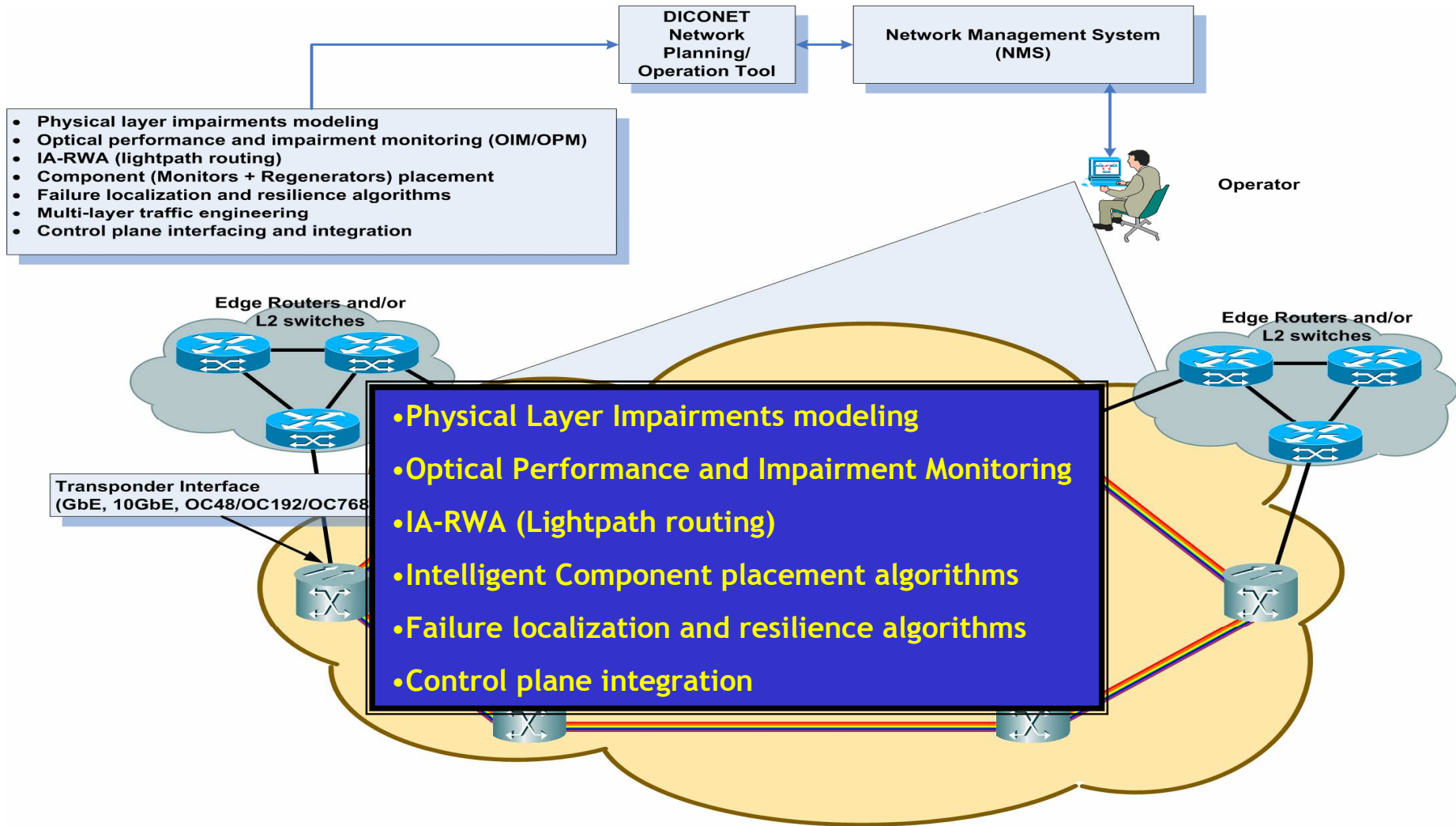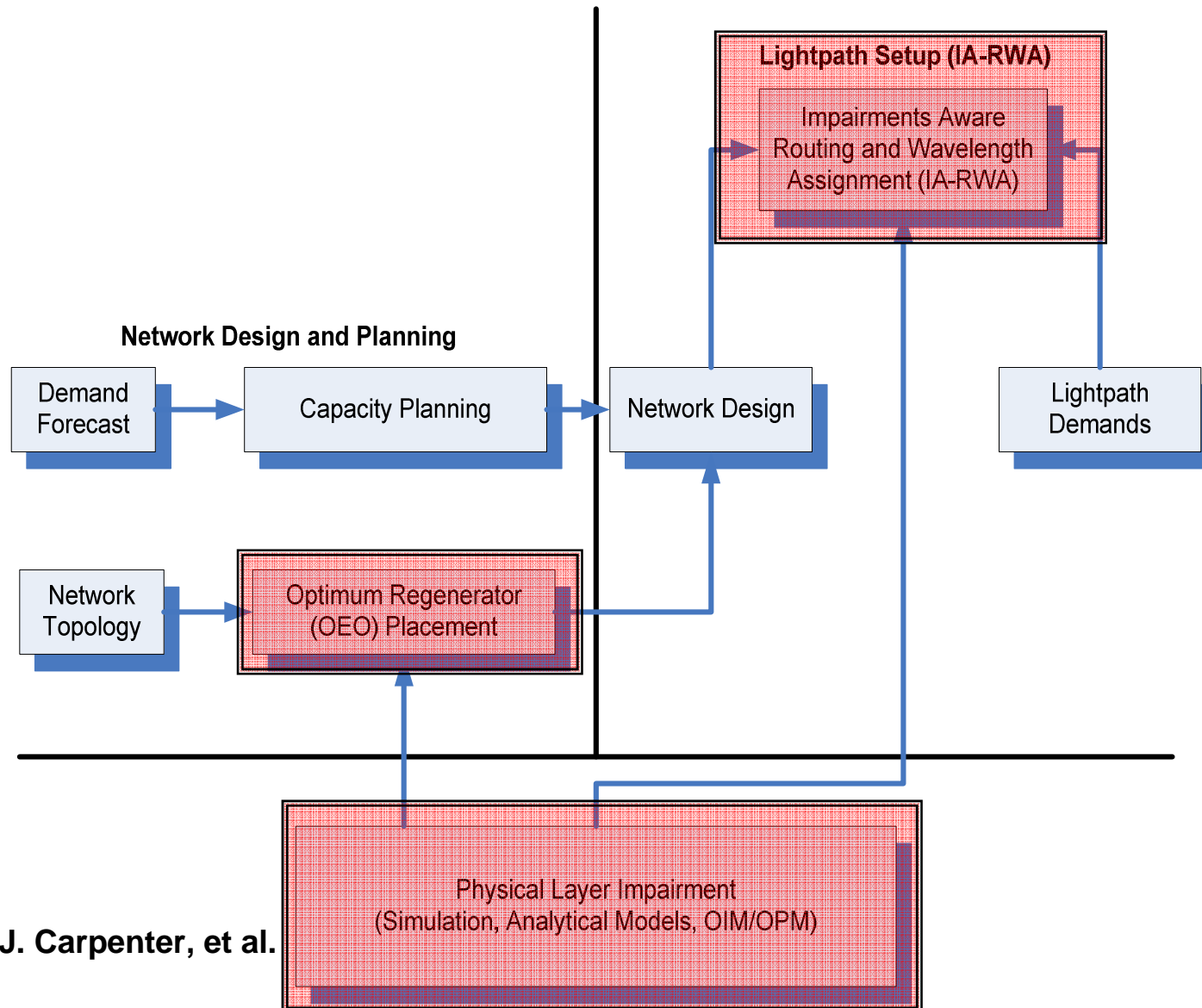 - Dynamic (on demand) technology-independent service provisioning

- ## Cross-layer optimization

  - – Physical layer impairment monitoring/management

  - – Impairment Aware Lightpath Routing (a.k.a. IA-RWA)

- ## The main Idea:

  - – The development of a *dynamic network planning/operation tool* residing in the *core network* nodes that incorporates *real-time measurements* of optical layer performance into *IA-RWA algorithms* and is integrated into a unified control plane.
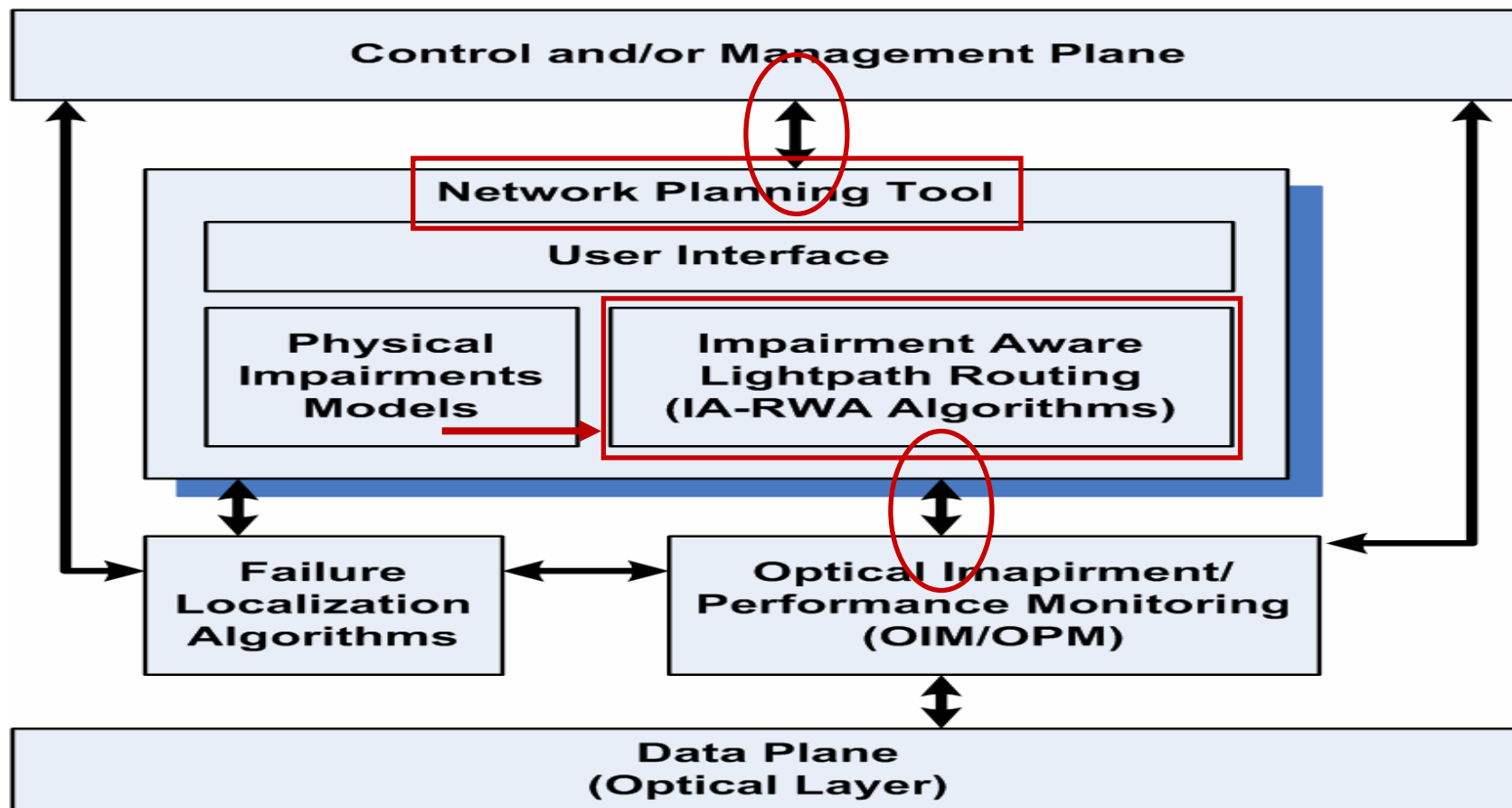
http://www.diconet.eu

DICONET Network Planning/ Operation Tool

Network Management System (NMS)

- Physical layer impairments modeling
- Optical performance and impairment monitoring (OIM/OPM)
- IA-RWA (lightpath routing)
- Component (Monitors + Regenerators) placement
- Failure localization and resilience algorithms
- Multi-layer traffic engineering
- Control plane interfacing and integration

Operator

Edge Routers and/or L2 switches

Edge Routers and/or L2 switches

Transponder Interface (GbE, 10GbE, OC48/OC192/OC768

- Physical Layer Impairments modeling
- Optical Performance and Impairment Monitoring
- IA-RWA (Lightpath routing)
- Intelligent Component placement algorithms
- Failure localization and resilience algorithms
- Control plane integration

Lightpath Setup (IA-RWA)

Impairments Aware
Routing and Wavelength
Assignment (IA-RWA)

Network Design and Planning

Demand
Forecast

Capacity Planning

Network Design

Lightpath
Demands

Network
Topology

Optimum Regenerator
(OEO) Placement

Physical Layer Impairment
(Simulation, Analytical Models, OIM/OPM)
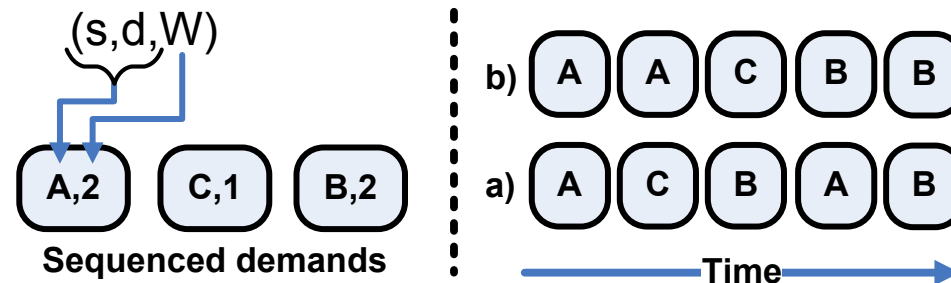
Source: T. J. Carpenter, et al.

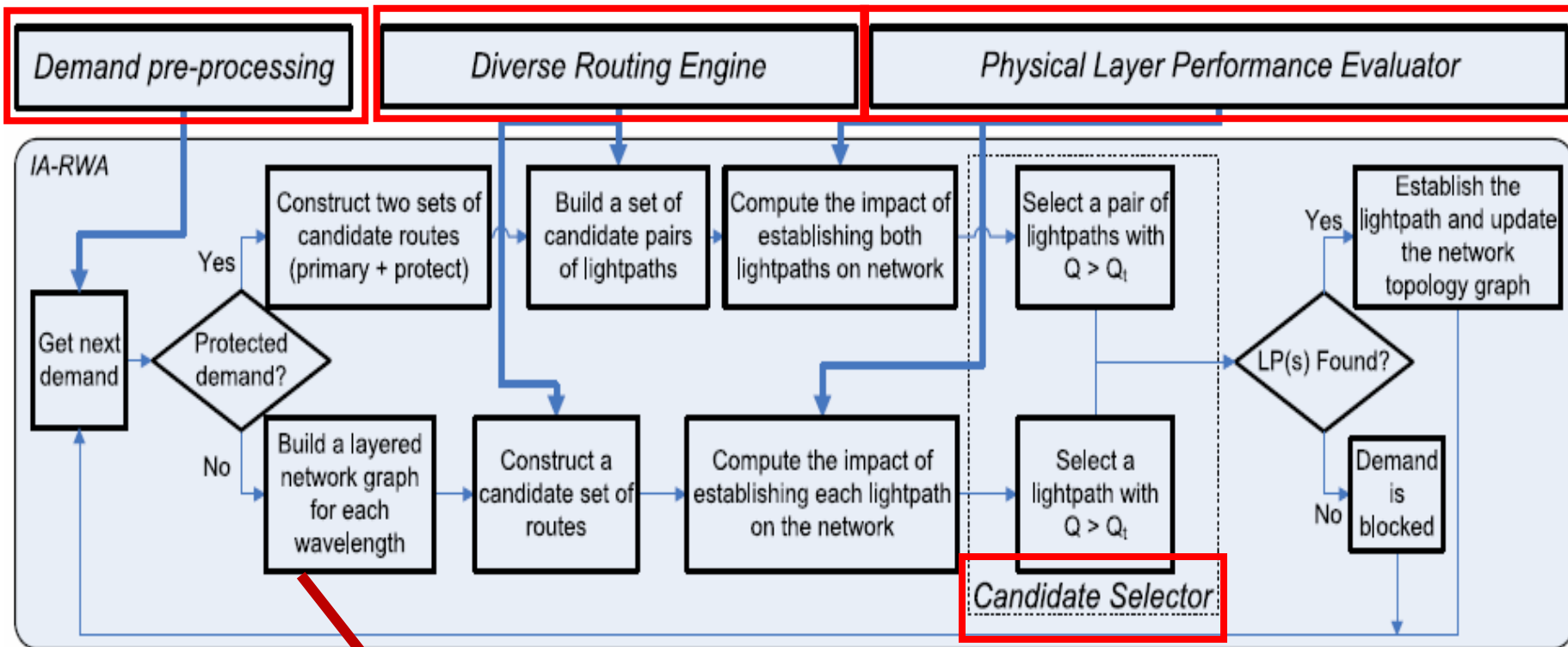- Network Planning and Operation Tool (NPOT)

Network Planner/Architect/Manager

Control and/or Management Plane

Network Planning Tool

User Interface

Physical Impairments Models

Impairment Aware Lightpath Routing (IA-RWA Algorithms)

Failure Localization Algorithms

Optical Imapirment/ Performance Monitoring (OIM/OPM)

Data Plane (Optical Layer)

Offline IA-RWA algorithm flowchart showing Demand pre-processing, Diverse Routing Engine, and Physical Layer Performance Evaluator stages.

IA-RWA

- Get next demand
- Protected demand?
  - Yes → Construct two sets of candidate routes (primary + protect) → Build a set of candidate pairs of lightpaths → Compute the impact of establishing both lightpaths on network → Select a pair of lightpaths with $Q > Q_t$
  - No → Build a layered network graph for each wavelength → Construct a candidate set of routes → Compute the impact of establishing each lightpath on the network → Select a lightpath with $Q > Q_t$

Candidate Selector

- LP(s) Found?
  - Yes → Establish the lightpath and update the network topology graph
  - No → Demand is blocked

(s,d,W)

A,2   C,1   B,2

Sequenced demands

b) A A C B B

a) A C B A B

Time

- Demand Pre-processing

- Diverse routing engine
  - Breadth-First Search (BFS)
  - K-Shortest path
  - Bhandari algorithm for demands with protection request

- Physical Layer Performance Evaluator
  - Use "Q Factor" as a BER indicator
  - Account for ASE noise, PMD, node crosstalk, XPM, FWM
  - Network status dependent impairments (XPM, FWM)
    - Lengthy computations
    - Valid for 10Gbps, OOK
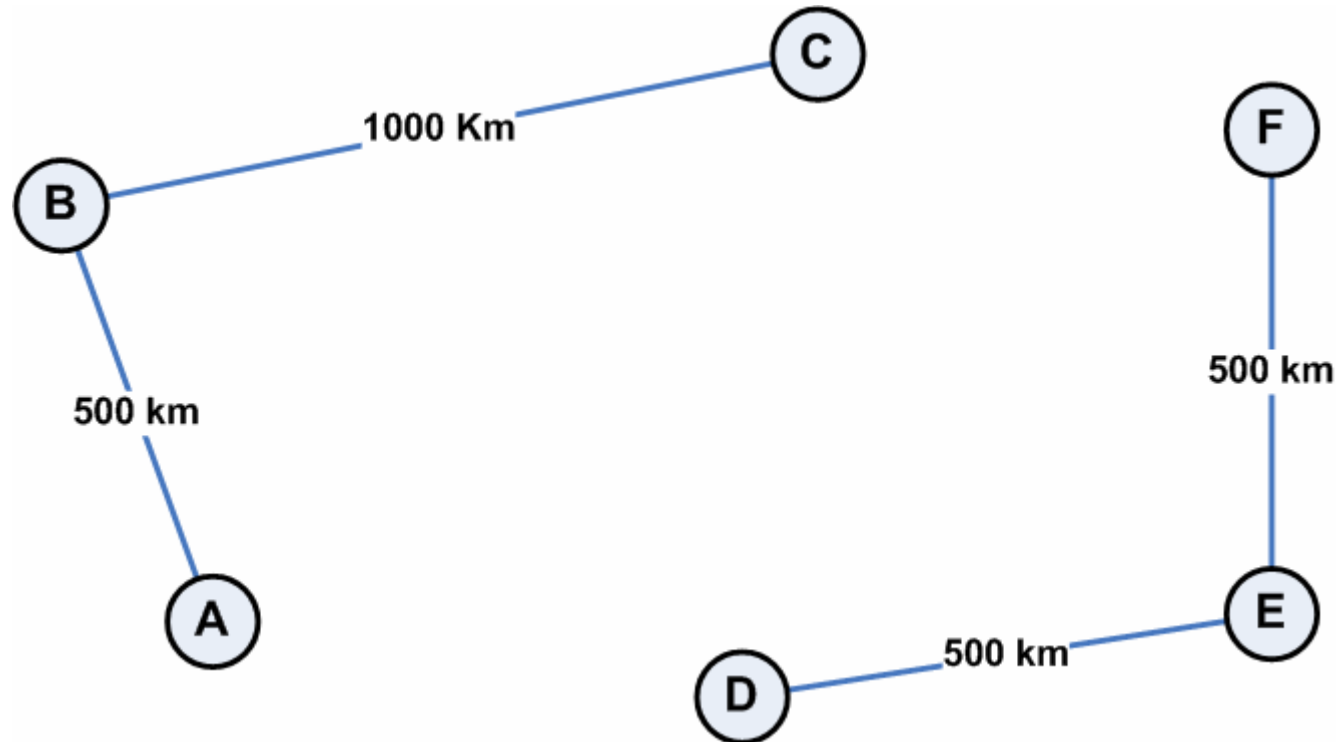
- Adaptive wavelength assignment

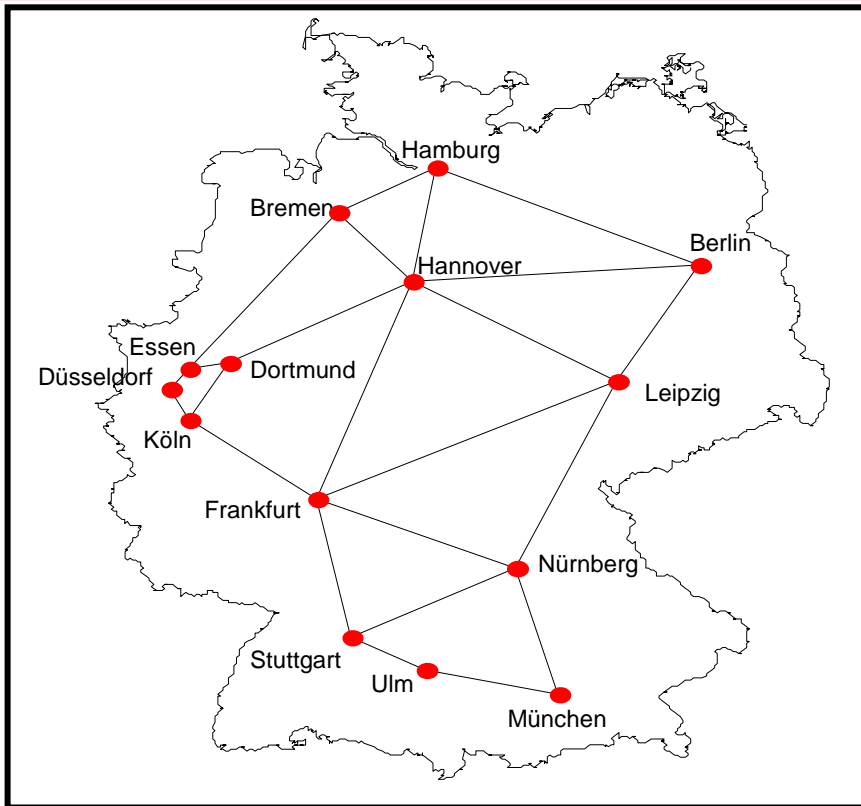- Find two routes (link and node disjoint) from "A" to "F" (1+1 protection)
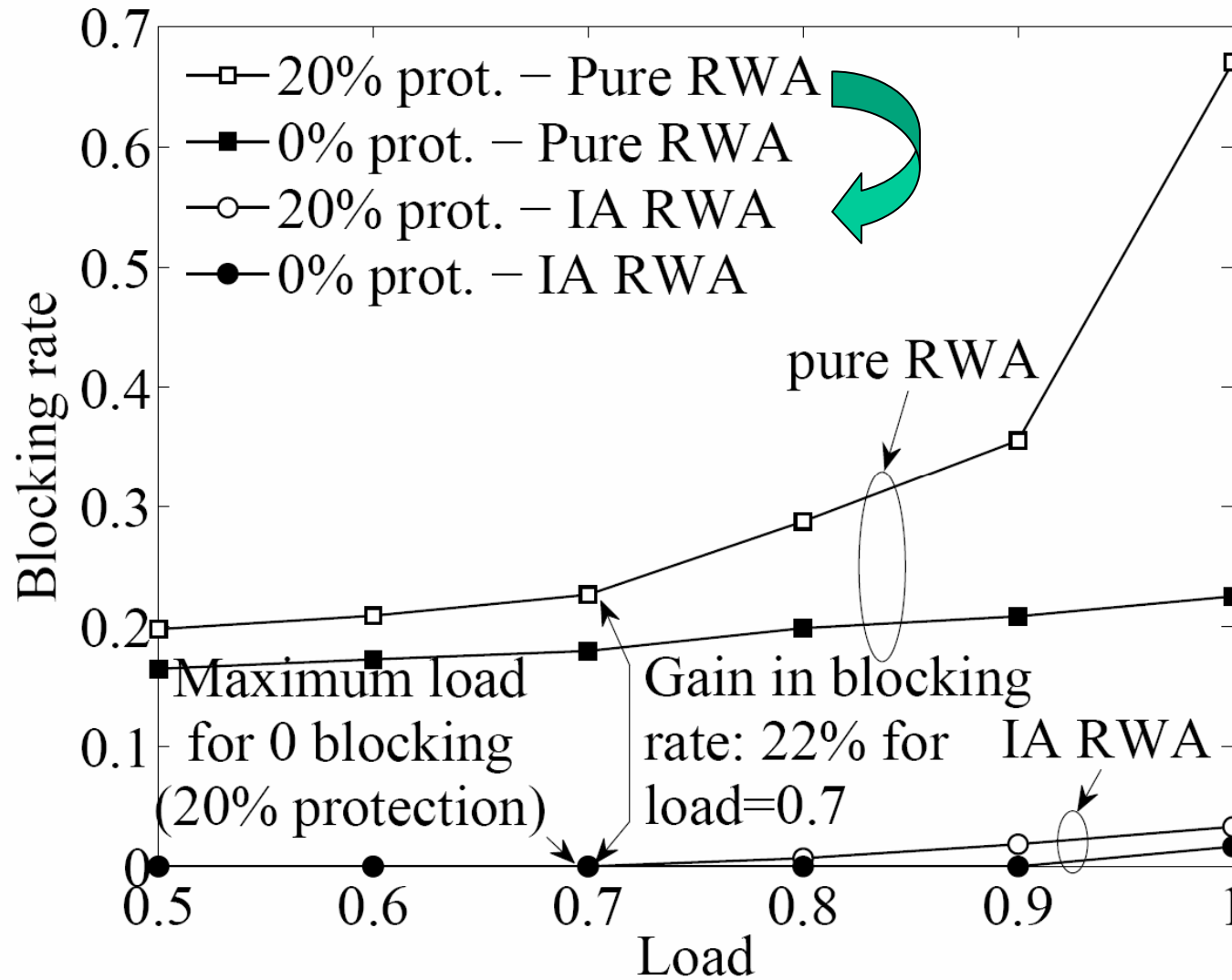
- How to generate diverse path?
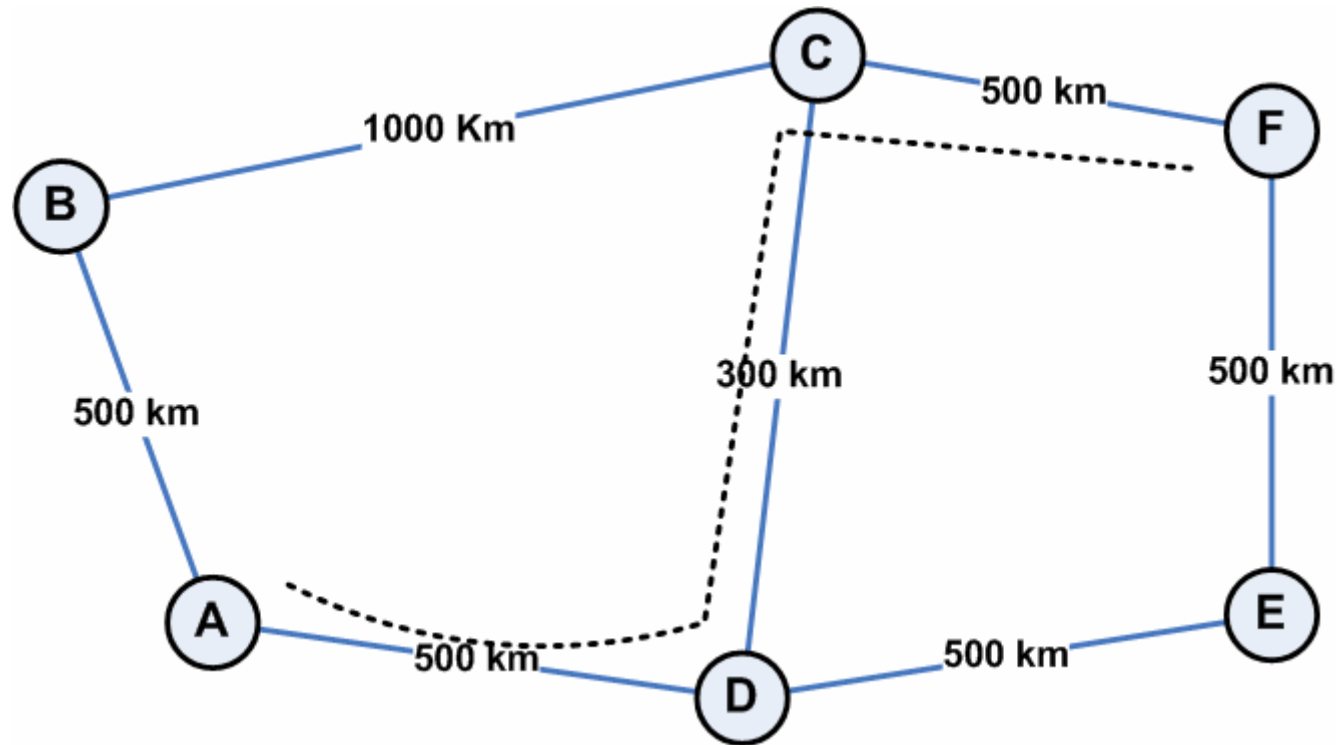
Diverse Routing Challenge (3/3)

- Diverse Routing Engine (Two routes from "A" to "F")
- Bhandari Algorithm
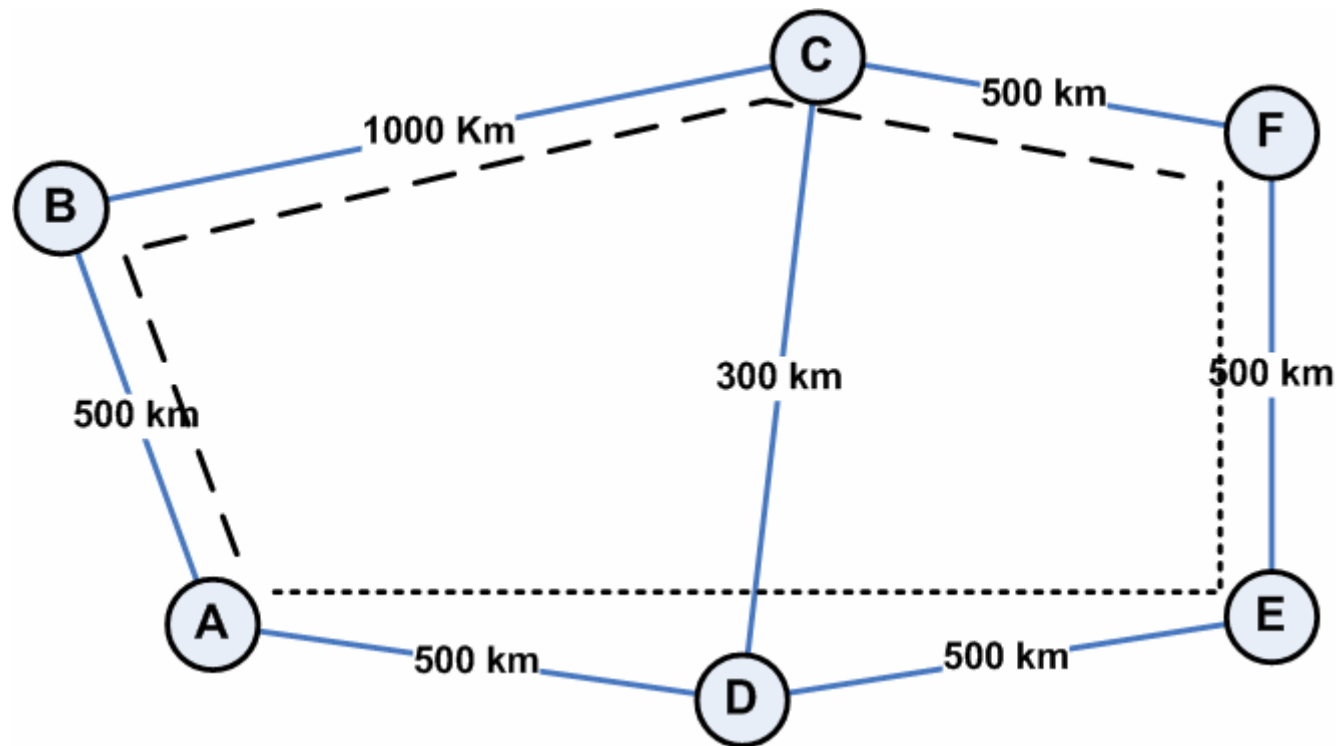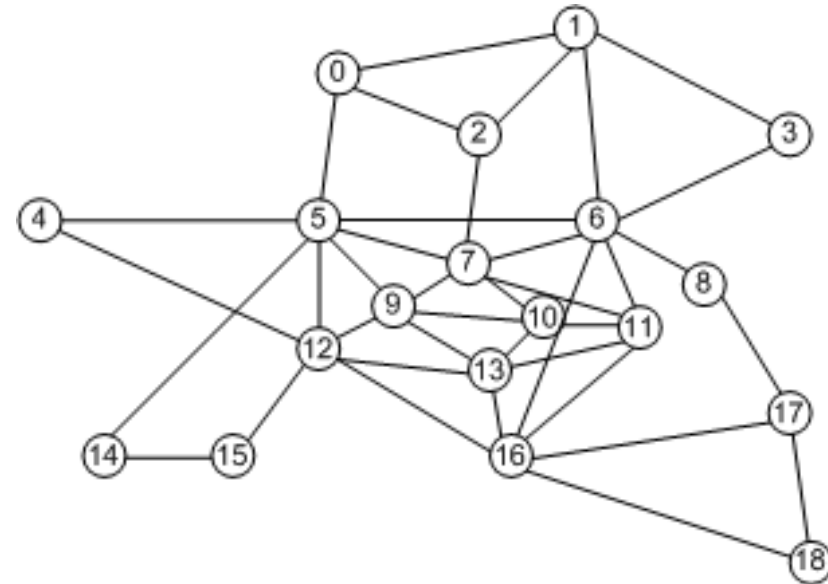
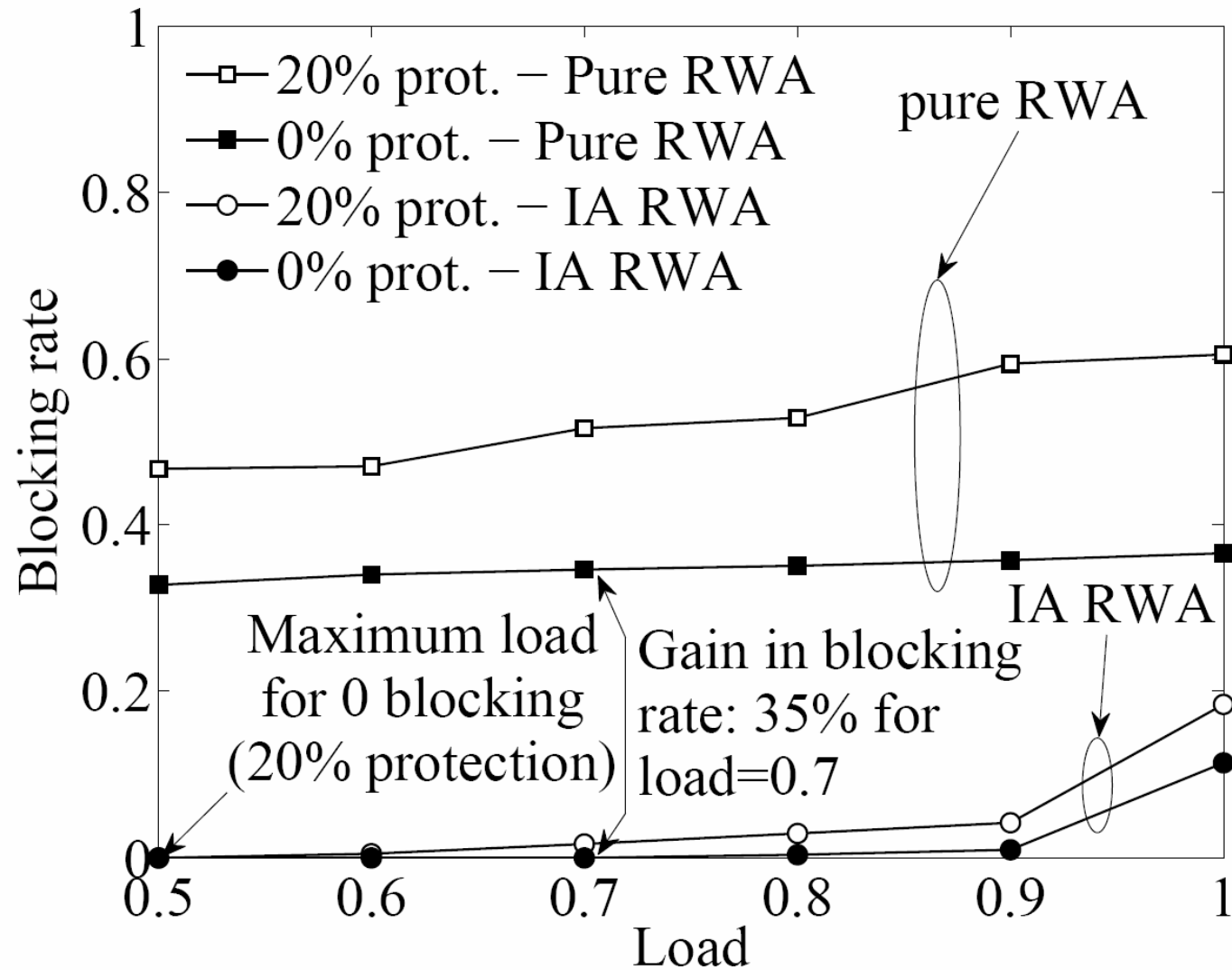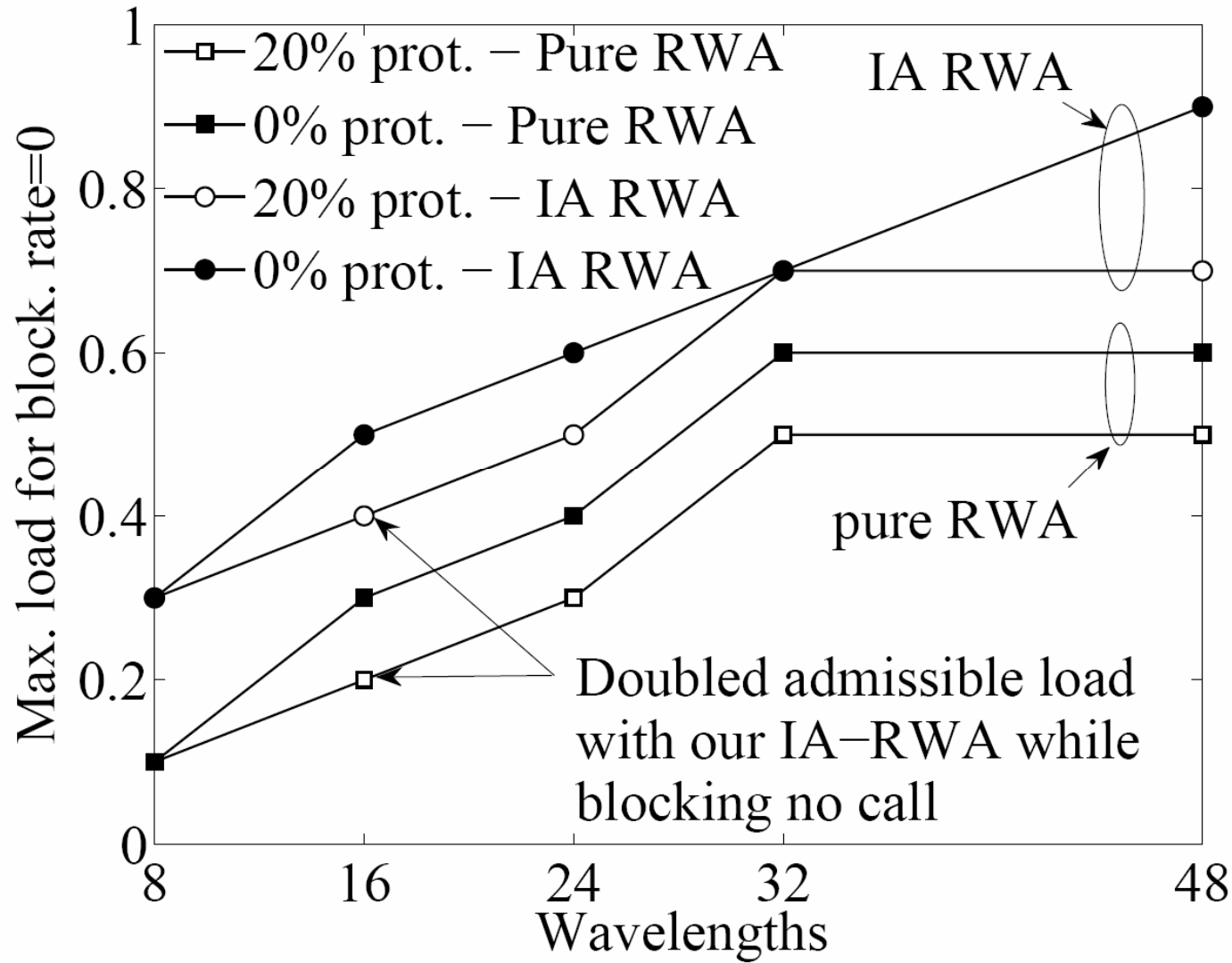| Topo-logy	Scaling factor	Largest shortest path (after scaling)	Nodes	Bidirectio--nal link	Average node degree
DTNet	1.3	1162 km	14	23	3.29
EON	0.4	1658 km	19	74	3.85

Conclusions

- **Next Generation Core Optical Networks**
  - Many studies around
  - Many problem addressed
  - Not many integrated and comprehensive works

- **DICONET → Integrated Network Planning and Operation Tool**
  - Presented here: Planning Mode/Offline IA-RWA with dedicated path protection

- **Future work/Work in progress:**
  - Online IA-RWA multi-constraint algorithms
  - Fault management
  - Control plane design and implementation
  - Integrated Network Planning and operation tool
  - FPGA acceleration
  - Validation with testbed

Thank you!

- ## Question & Answers

- ## Acknowledgements

  – This work is partially funded by the European Commission (FP7)

Dynamic Impairment Constraint Networking for Transparent Mesh Optical Networks

Building the Future Optical Network in Europe

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