# Enhancing Restoration Performance Using Service Relocation in PCE-based Resilient Optical Clouds

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# Outline

- Optical cloud services
- Survivability options: pros and cons
- Restoration with service relocation
- Case study
- Conclusions

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# Optical cloud concept

- Grid and cloud services leveraging on high speed WDM optical transport are very popular these days
- DCs spread across different geographical areas offer storage and computing services, i.e., the cloud services
- Cloud services are provisioned over optical transport where IT and network resources assignment might be managed *independently* or *jointly*
- *Anycast* provisioning: for client not important which specific IT resources are used as long as services requirements (e.g., bandwidth, delay, reliability) are met

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# Survivability in optical clouds

- The more we rely on cloud services the more failure recovery mechanisms become essential
- Depending on the could service-type different levels of reliability might be required
  - critical vs. non-critical services
- Survivable mechanisms might work *separately* or in a *joint fashion* on the IT and network resources
- One advantage of a "joint" approach is *service relocation:* a protection path might end up at a DC different from the one the primary path was connected to

# Protection-based schemes

- Principle: dedicated redundant network resources from the source node to the destination DC
- *Sharing* can be eventually done with other protection paths, i.e., SPP
- If combined with service relocation SPP advantages (i.e., resource usage) are even greater in terms of resources
- Advantages (+): guaranteed survivability against number of pre-determined network failure scenarios
- Drawbacks (-): high resource cost (compared to restoration), low flexibility to adapt to unpredicted failure scenarios

# Restoration-based schemes

- Principle: backup network resources are allocated only after the occurrence of a failure
- Advantages (+): less stand-by resources need to sit un-used: higher resource efficiency
- Drawbacks (-): there is a risk that backup network resources are not available when needed

- Intuition: coupling dynamic restoration together with the concept of service relocation to improve service restorability

# Problem definition

- Assess the benefits of using service relocation in a centralized cloud inter-networking scenario while restoring failed cloud services
- Given: status of the cloud infrastructure at the moment the failure happens:
  - cloud services provisioned (network and IT resources in use)
  - amount and location of spare transport and IT resources
- Objective: maximize the number of restored cloud services with (possibly) minimum number of relocations
- Output: RWA result for each restored service

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# Optimal solution: ILP formulation

- Upon failure of a network element most probably a high number of disrupted cloud services asking for re-provisioning at the same time
- Complex problem to solve but also opportunity for concurrent optimization
- For the set of services disrupted by a failure (D) ILP formulation with the following objective:

**Objective 1:** $$Min\ \alpha \cdot (|D| - \sum_{\forall \lambda_c, \forall k} A_c^k) + \beta \cdot \sum_{\forall (x,y)} p_{xy}$$

**Objective 2:** $$Min\ \alpha \cdot (|D| - \sum_{\forall \lambda_c, \forall k} A_c^k) + \beta \cdot \text{Relocations} + \gamma . \sum_{\forall (x,y)} p_{xy}$$

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# Case study

- NSF network topology, 4 DC nodes
- Dynamic provisioning, only link failure considered
- Anycast services (full wavelength capacity)
- RWA computation done by an external PCE instance called by the SDN controller
- Services are initially provisioned using WLCR* heuristic adapted to solve the anycast RWA problem
- Benchmark: ILP-based solution without service relocation (ILP_PR)

*X.-W. Chu, et al., "A dynamic RWA algorithm in a wavelength-routed all optical network with wavelength converters", *in Proc. INFOCOM 2003*

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# Numerical assumptions

| | |
|---|---|
| Wavelength per fiber | 16 (in each direction) |
| Cloud service arrivals | Poisson |
| Service time | 60 time-units |
| Mean time to failure (MTTF) | 1000 time-units |
| Mean time to repair (MTTR) | 10 time-units |
| TI resources per DC | 3,000 storage units (SU) and 150 virtual machines (VM) |
| TI resources per service | [1,100] for SU and [1,5] for VM, uniformly chosen |
| Statistics | 16 experiments, with 1E6 services/ experiment |
| ILP Objective Parameters | $\alpha = 10^5$ , $\beta 1 = 10^3$, $\gamma = 10^0$ |

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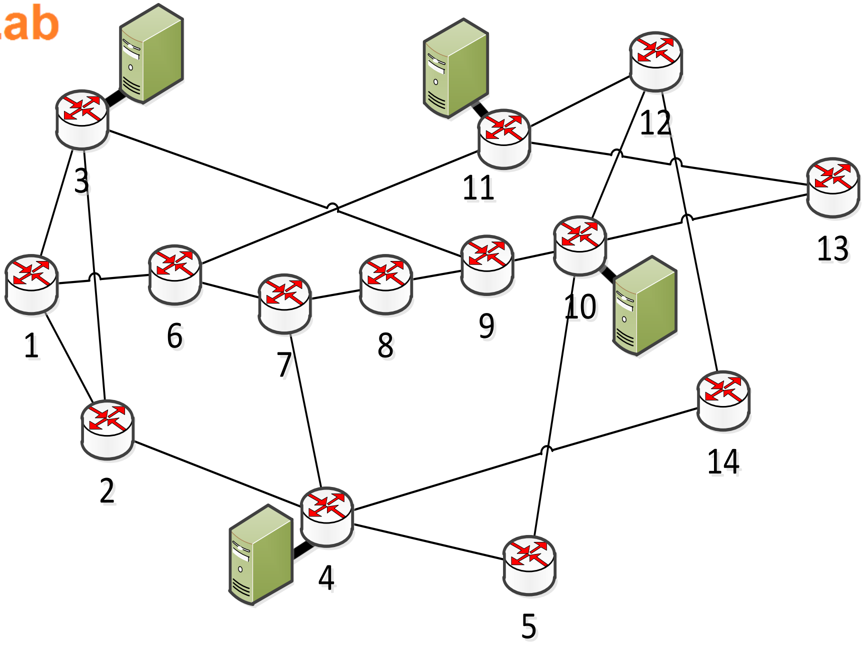
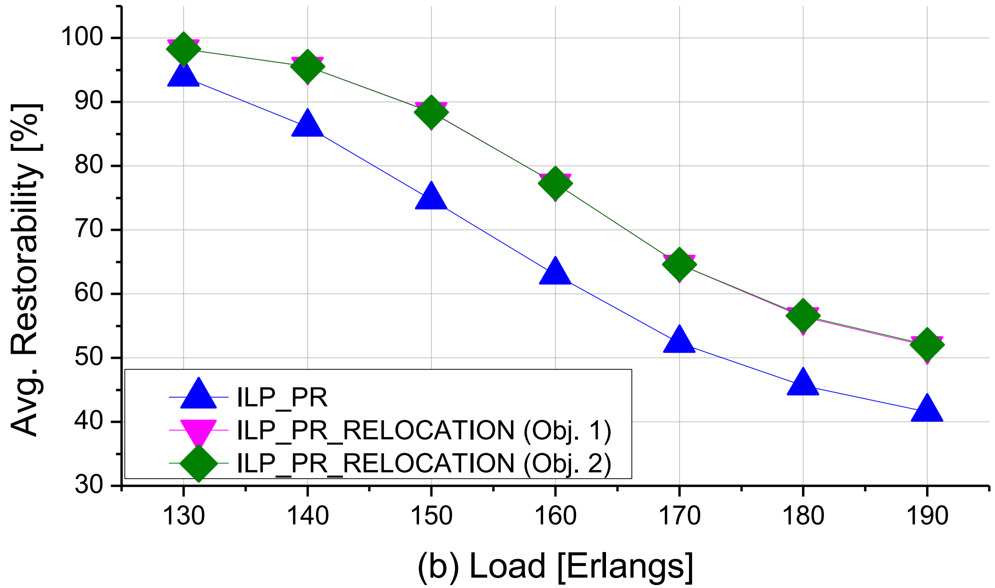
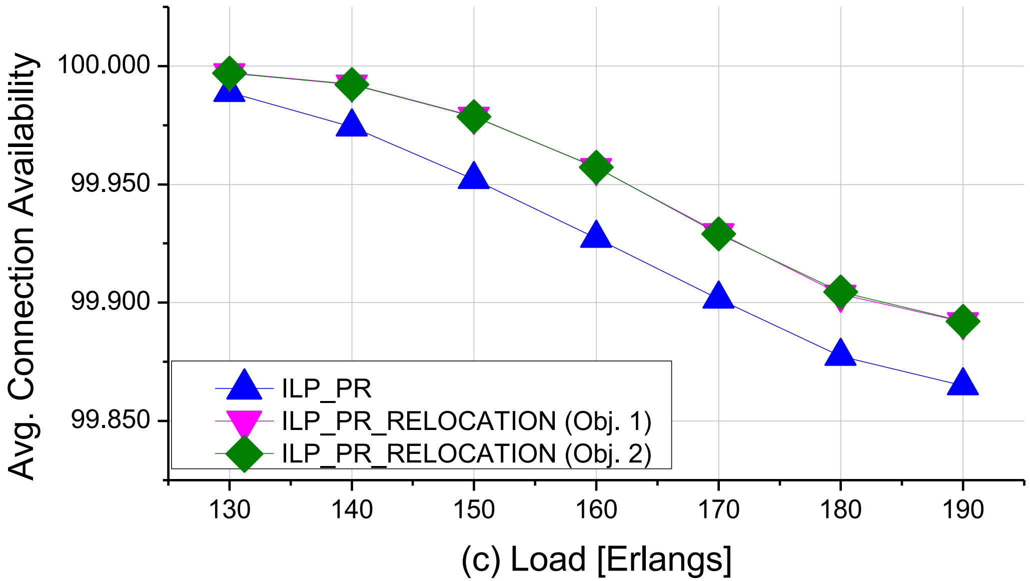
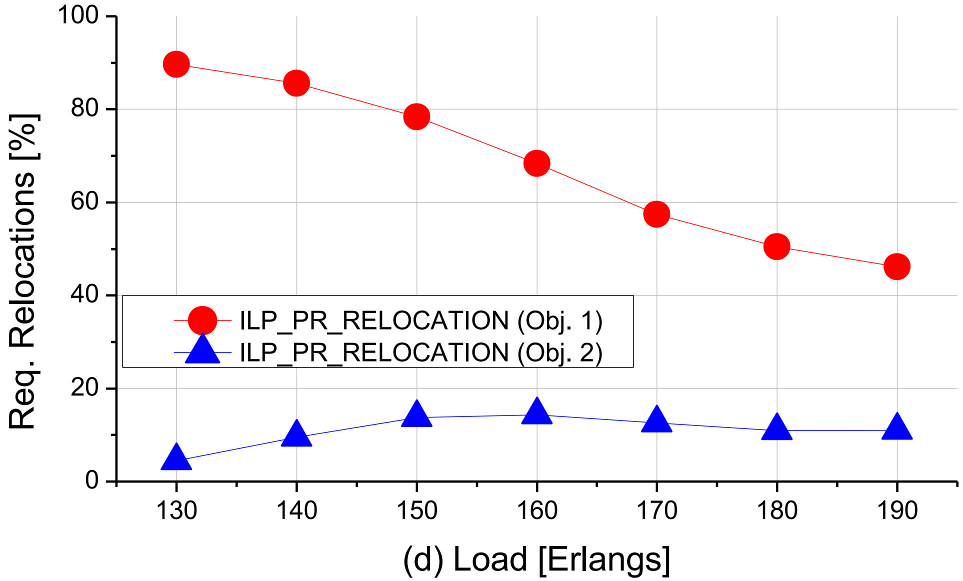
# Results



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# Conclusions

- We explore the benefits of utilizing the relocation concept while restoring optical cloud services upon the failure of a network element
- Presented an optimal solution of the problem based on ILP formulation
- It is found that service relocation is highly beneficial in improving restorability and service availability
- These benefits can be achieved requiring only a small fraction of the restored services to be relocated

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For more information

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