Network Adaptability for Incremental Traffic Fluctuation and Anomaly

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Networks Lab Group Meeting

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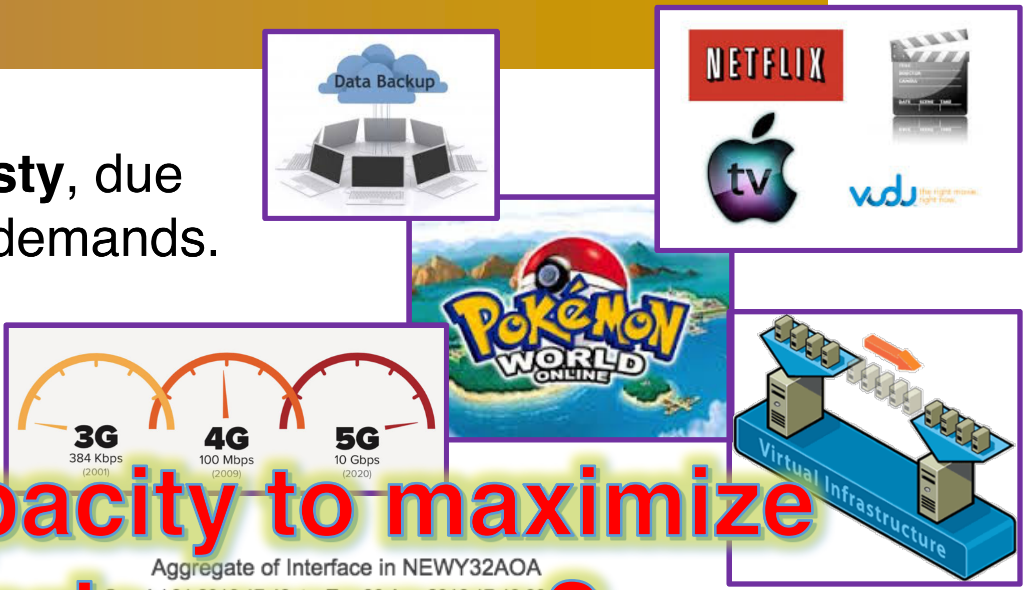
Outline

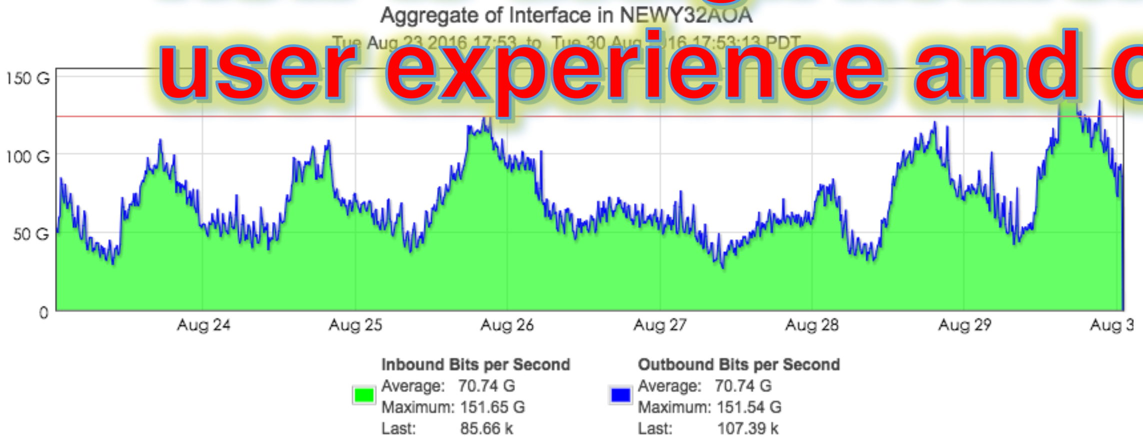
- Introduction and Problems
- Related Works and Topics, One JOCN Paper
- Our Proposal: Degraded Service Provisioning (DSP)
- Future prospects: Revenue Models, Data-Driven Methods, Machine Learning in Networking

Introduction

- Network traffic is becoming extremely **dynamic** and **bursty**, due to increase communication mobility and heterogeneous demands.
- Network **fluctuation** and **anomaly** severely impact **user experience**, as well as operator's **revenue**.



How to design networks capacity to maximize user experience and operator's revenue?



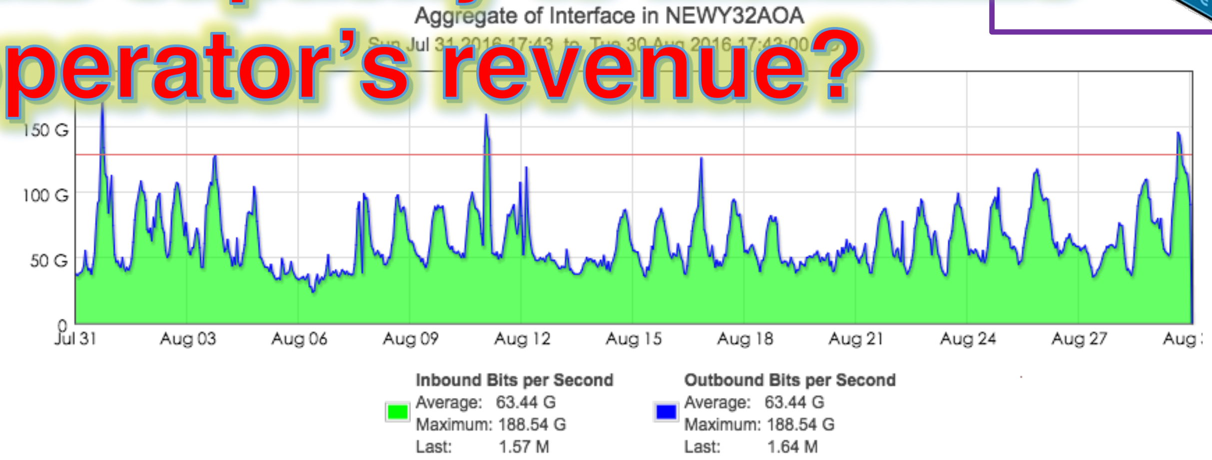


Fig. 1, Aggregated traffic variation of New York City in Internet2 network in a recent week/month by GlobalNOC (fetched on 30 Aug 2016 PDT) http://snapp2.bldc.grnoc.iu.edu/i2net/ .

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Introduction (contd.)

- **Precise** prediction is hard, while **statistical** prediction can be achieved using machine-learning (neural networks [1]) and stochastic-process [2] techniques.
- Anomaly cannot be predicted, but detection methods is mature [2], so how to cope with it?
- Implicit trade-off: peak-valley gap vs. degradation flexibility

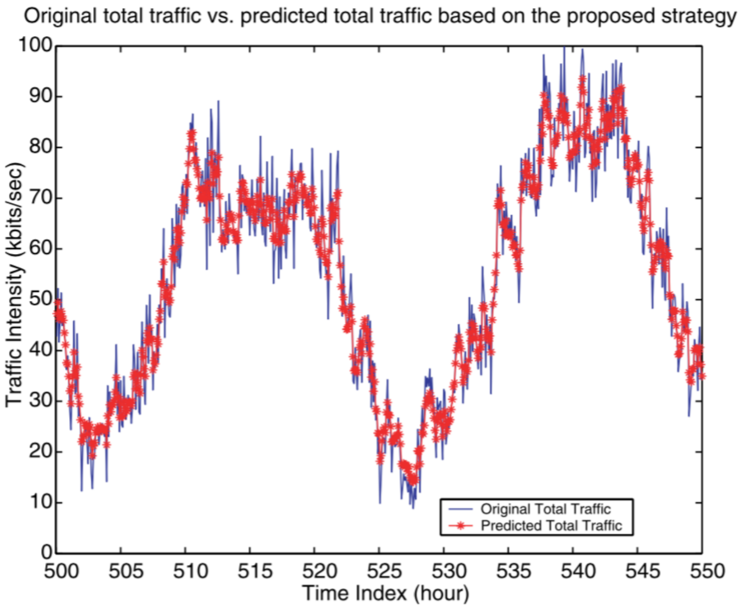

Fig. 2, normal traffic prediction [2].

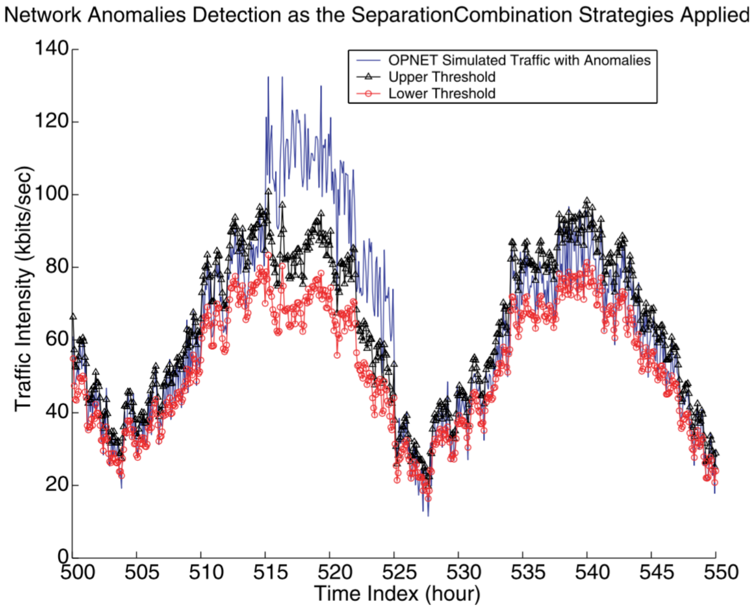

Fig. 3, anomaly detection [2].

[1] Vicente Alarcon-Aquino, and Javier A. Barria, "Multiresolution FIR neural-network-based learning algorithm applied to network traffic prediction." *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews* 36, no. 2 (2006): 208-220.

[2] Jun Jiang, Symeon Papavassiliou, "Enhancing network traffic prediction and anomaly detection via statistical network traffic separation and combination strategies," *Computer Communications*, 2006.

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Introduction (contd.): research problems

- **Given network capacity**, how to exploit network flexibility to deal with unexpected traffic peaks?
    - Increase network robustness against transient peaks.
    - Given a certain amount capacity, accommodate more traffic (achieve more revenue) than conventional.
- **Given traffic profile, how to conduct incremental network capacity planning**, how much capacity is optimal
    - Perfect prediction or statistical percentage of traffic anomaly (e.g. 95% (of time) 100G baseline, 4% 200G peaks and 1% 300G peaks)?
    - Find optimal balance between user experience and operator's revenue.
    - Network revenue model, the optimal capacity under given traffic profile.

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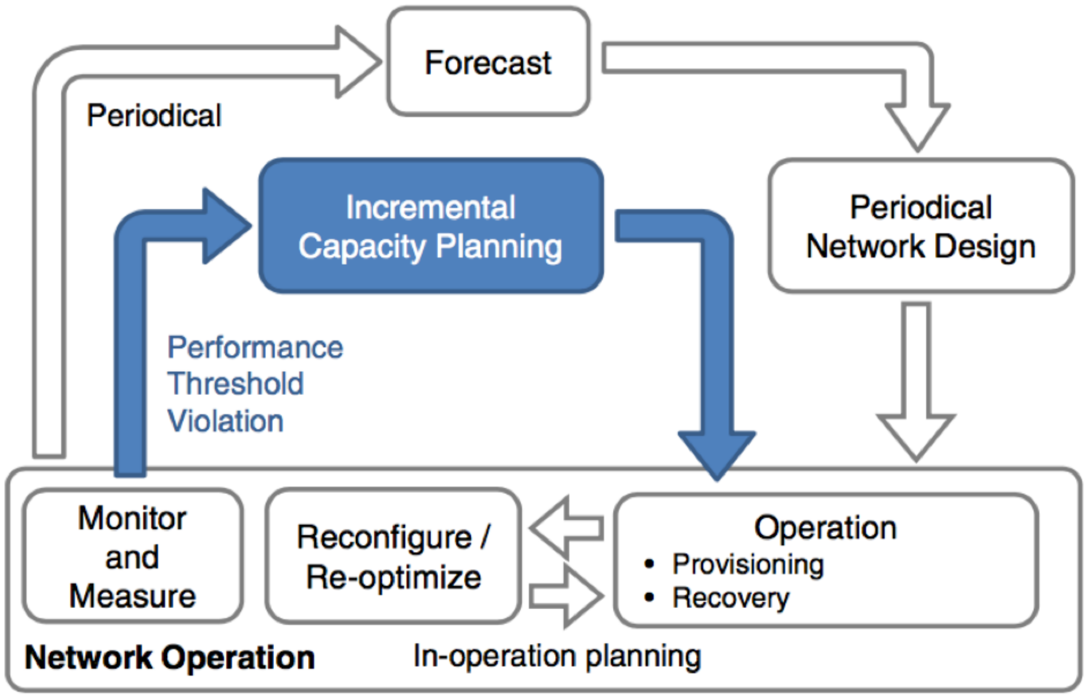
Related works

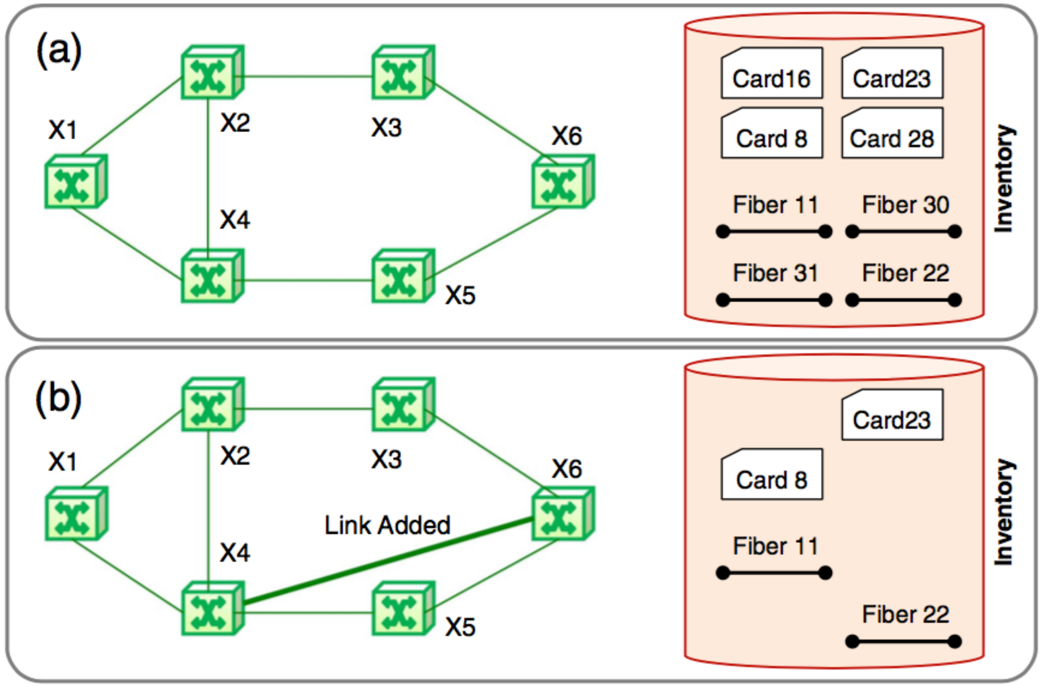
- **On incremental network capacity design, an interesting JOCN Paper from *UPC Spain*:**
  - Luis Velasco, Fernando Morales, Lluís Gifre, Alberto Castro, Oscar González de Dios, and Marc Ruiz, "**On-demand incremental capacity planning in optical transport networks**," IEEE/OSA *Journal of Optical Communications and Networking,* vol. 8, no. 1 pp. 11-22, 2016.
- **Problems solved**: exact prediction is not usually available. This leads to the installation of more capacity than required, thus increasing network expenditures. In this paper, we propose to reduce expenses by incrementing the capacity of the network as soon as it is required to meet the target performance. Performance metrics are monitored and the incremental capacity (INCA) planning problem is solved on-demand when some metrics drop under a threshold.

Incremental capacity planning

- Augmented network lifecycle.



- Incremental network capacity (INCA) planning



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INCA problem statement and formulation

- INCA problem: deciding which resources need to be added to the network to ensure some performance metrics.
  - **Grade of service** (i.e., blocking probability).
  - **Restorability** (defined as the ratio between the number of LSPs that are successfully re- stored and the total number of LSPs to restore) under single-link failure scenarios.
- They propose a Integer Linear Program to solve the incremental capacity planning problem.

- The augmented network topology represented by graph $G_x(N, E_x)$, where N represents the set of optical nodes and E_x the set of links. The subset $L \subseteq E_x$ contains inactive links ready to be installed.
- A set of available line cards and the card-slot compatibility.
- The physical layout of each node in terms of card slots.
- The cost structure of adding new links.
- The blocking probability and restorability thresholds to be ensured, based on operators' policies.

Objective: Minimize the cost of extending the network topology, considering the cost of activating new links and installing new line cards.

Output: The subset of links in L to be activated and line cards to be installed in every node.

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Planning schemes and traffic profile

- **Introduce two schemes**
  - provisioning-wise INCA (Pw-INCA) the scheme that focuses on blocking probability, ensures that probability of accepting new incoming requests is higher than the threshold.
  - recovery-wise INCA (Rw-INCA) the scheme that centers on restorability, guarantee that the restorability after the single failure of every active link is higher than the given threshold.
- **Traffic profile**
  - simulate for 10 years, traffic load is increased 25% per year (in monthly intervals).

Results for the Pw-INCA algorithm

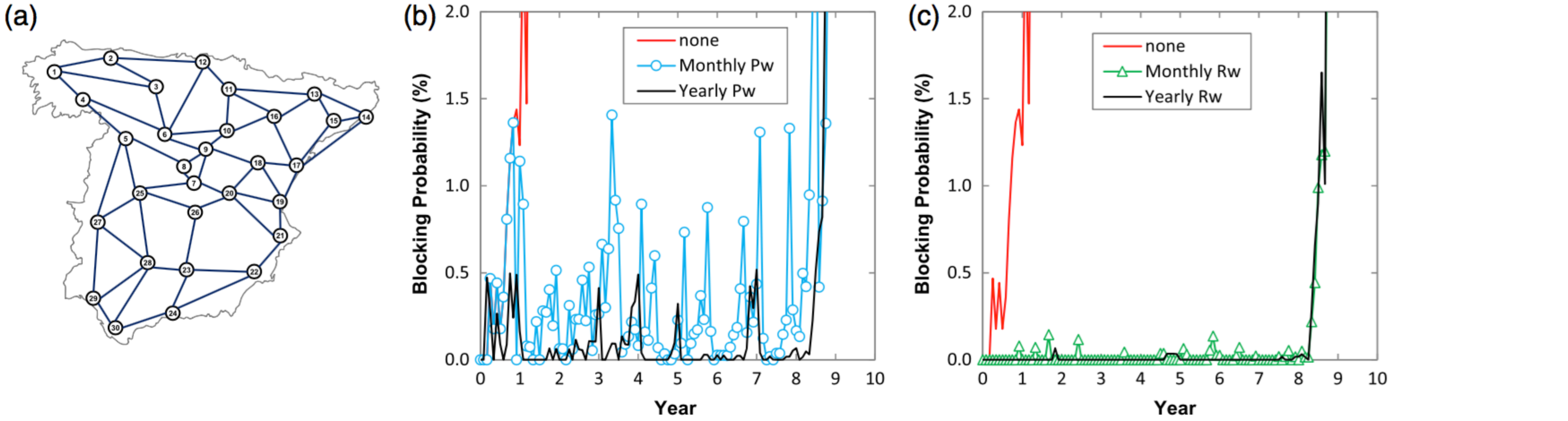

Fig. 6. (a) Telefonica national network and blocking probability against time, (b) provisioning-wise, and (c) recovery-wise.

Results for the Pw-INCA algorithm, when it was run monthly after monitoring traffic and when it was run at the beginning of each year, based on perfect traffic estimations.

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Results for the Rw-INCA algorithm

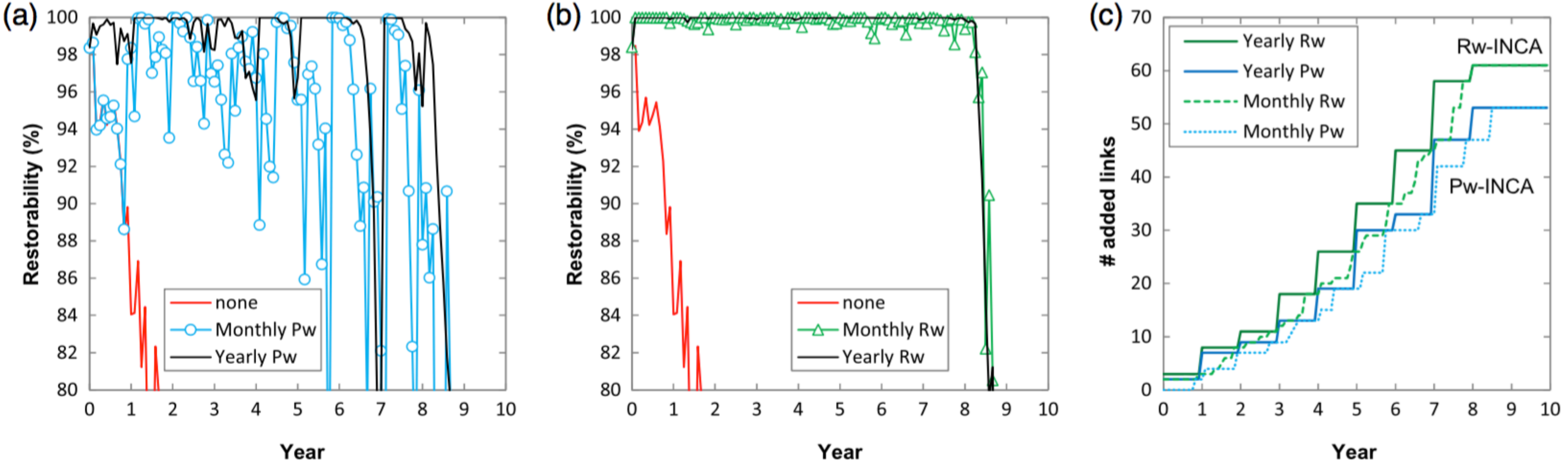

Fig. 7. Restorability against time (a) provisioning-wise and (b) recovery-wise. (c) Added links versus year.

TABLE VI
CARDS-YEAR INCREMENTS

	Year No.									
	1	2	3	4	5	6	7	8	9	10
Pw-INCA	3.3	5.8	3.0	3.0	3.7	13	4	9.8	6	0
Rw-INCA	1.8	6.2	2.8	6.7	10	11	11	14	0	0

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Paper Conclusion

- Periodic planning needs predictions as exact as possible for the expected traffic volume and distribution—which, although feasible for static traffic scenarios, is unreal when dynamic traffic is considered. So on-demand incremental planning is needed.
- Pw-INCA provides peaks of high blocking and low restorability, even when the capacity is added beforehand.
- Rw-INCA scheme showed a close-to-zero blocking probability and virtually full restorability.
- Rw-INCA scheme installed more capacity than the Pw-INCA one.
- Implementation feasibility is also discussed, a architecture with NMS, PCE containing the operation databases, a planning tool where algorithms run, and the inventory system is proposed. The proposed architecture was experimentally validated on our SYNERGY test bed.

Review remarks

- This paper solves an important problem of on-demand incremental network capacity planning.
- The way that they treat incremental traffic is worth learning from.
- Implementation is tested, which adds the feasibility to the paper.

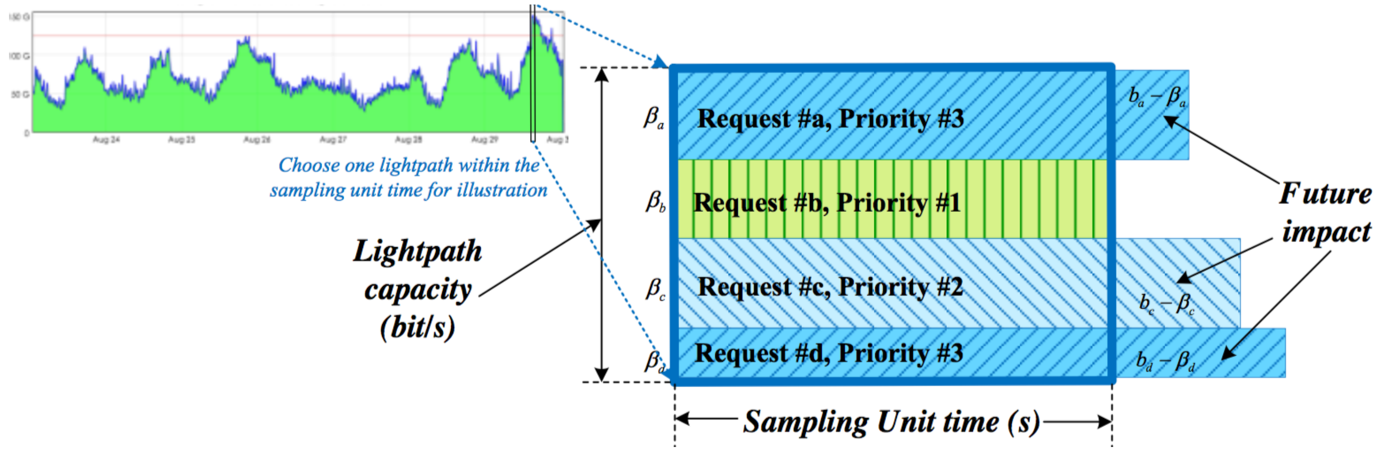
- This paper is based on the assumption that PERFECT traffic prediction is provided. However, when it is not perfect, which is a more normal case, what should we do?
- In other words, this paper solves the problem on a monthly basis. What about tidal traffic within the time range of a typical day, or other short-term period where transient peaks may occur.

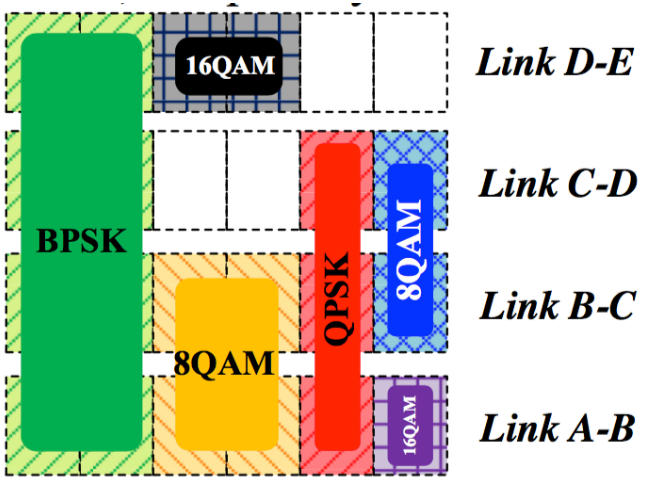
Degraded service provisioning [3] to address unexpected traffic peaks.

[3] Zhizhen Zhong, Jipu Li, Nan Hua, Gustavo. B Figueiredo, Yanhe Li, Xiaoping Zheng, and Biswanath Mukherjee, "On QoS-Assured Degraded Provisioning in Service-Differentiated Multi-Layer Elastic Optical Networks," in GLOBECOM 2016, to appear.

Our Proposal: Degraded Service Provisioning (DSP)

- **Degraded Service Provisioning (DSP)** refers to providing a degraded level of service when network congestion occurs instead of no service at all.
- Degraded service provisioning needs network flexibility.
    - On service (electric) layer, the flexibility can be achieved by adjusting transmission rates.
    - On optical layer, the flexibility can be achieve by adjusting modulation levels.





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Motivation

- **Problem to solve**: Given network capacity, how to deal with transient traffic peaks.
- **Scenario**: Network capacity is sufficient for baseline traffic accommodation, but insufficient for peak traffic.
- **Problem formation**: Traffic-fluctuation-robust bandwidth failure minimization problem by degraded provisioning with service prolongation in elastic optical networks.
- **Methodology**: Do degradation on existing baseline requests (also lightpaths)
- **Information to get**:
  - 1. how much peak/baseline ratio can be achieved with no blocking? (conventional: 1.2, ours: 3), and how bandwidth blocking ratio line goes in conventional's and ours?
  - 2. how request degradability affects the effect of our method? (90%, 30% degrade ddl)

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Traffic-Fluctuation-Robust Failure Minimization Problem with DSP

- When traffic peak arrives, baseline traffic is already provisioned. So we should plan the incremental peak traffic on the basis of existing baseline traffic.
- Two-stage network planning:
- **Integer Linear Programming** formation for baseline traffic planning
  - *Normal routing and spectrum modulation level allocation problem.*
- **Constraint Programming** formation for incremental peak traffic accommodation
  - *Use ILP results as input, degradation with service prolongation on electric layer, and modulation level adjustment on optical layer.*
  - *Routes of baseline traffic (on both electric and optical layers) cannot be changed, while it is only the transmission rate on electric layer and the modulation level along with spectrum allocation on optical layer that can be reconfigured.*

Extensions

- Change the optimization criteria, see what happens.
  - Minimize bandwidth failure=maximize accepted bandwidth
  - But ≠maximize revenue, it depends on network revenue models (e.g. power-law by Kleinrock, and penalty-included revenue)
  - Information may get: different goals results in different result sets, if the operator focuses on performance (Max accepted bandwidth), there is one sort of results, and if the operator focuses on revenue (Max revenue), there may be other results.

Thanks!
Any comments or questions?

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