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Multilayer Recovery Mechanisms in Backbone Networks

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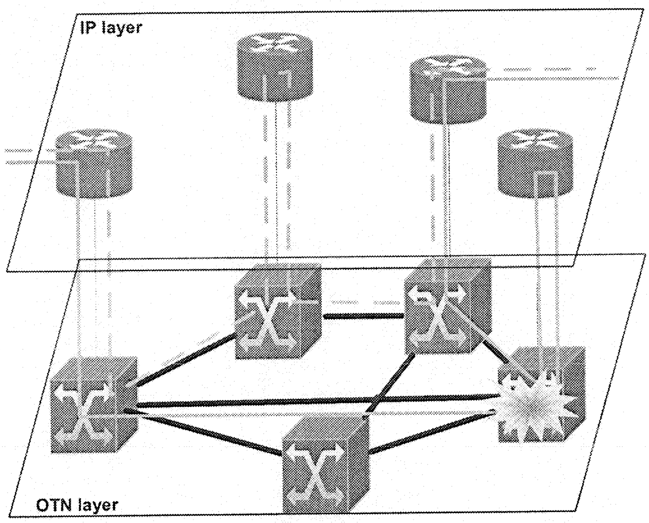
Introduction

Communications networks are subject to a wide variety of unintentional failures, caused by natural disasters, wear out and overload, software bugs, human errors, and so on, as well as intentional interruptions due to maintenance [i]. As core communication networks also play a vital military role, key telecommunication nodes were favored targets during the Gulf War, and could become a likely target for terrorist activity. For business customers, disruption of communication can suspend critical operations, which may cause a significant loss of revenue, to be reclaimed from the telecommunications provider. In fact, availability agreements now form an important component of Service Level Agreements (SLAs) between providers and customers.
In the cutthroat world of modern telecommunications, network operators need a reliable and maintainable network in order to hold a leading edge over the competition. Fast and scalable network recovery techniques are of paramount importance in order to provide the increasingly stringent levels of reliability these network operators are demanding for their future networks.

Multilayer Network Scenario

Future backbone networks will typically be carrying Internet (IP) traffic – possibly enhanced with Multi-Protocol Label Switching (MPLS) functionality – supported by Optical Transport Networks (OTNs) that provide transmission links between IP routers. A simple example is shown in the figure below, including a recovery action after the failure of optical cross-connect D.



By applying Wavelength Division Multiplexing (WDM), OTNs are capable of carrying many independent channels, carried on different wavelengths, over one single optical fiber. This allows the network to transport huge amounts of data, needed for many current and future communication services that play a very important role in many of our daily social and economical activities. For instance, strategic corporate functions show an increasing dependence on communication services.

As internet traffic is continuously shifting and changing in volume over time, for instance due to diurnal traffic fluctuation and overall traffic growth, there is ongoing research towards creating optical networks with the flexibility to reconfigure transmission according to traffic demands. This requires the possibility to set up and tear down OTN layer connections that implement logical links in the higher network layer in real-time, which has led to the concept of intelligent optical networks (IONs) ([ii], [iii], [iv]). In addition to allowing the network to adapt to changing traffic demands, this flexibility in setting up lightpaths on demand turns restoration into a viable recovery option.

Multilayer Recovery Approaches

In the tutorial, three generic approaches (and their variants) for providing recovery in multilayer networks (more specifically in IP-over-OTN networks) will be discussed:

- single-layer recovery schemes in multilayer networks with the important issue in which layer of the network to provide the recovery scheme ;
- static multilayer recovery schemes where recovery schemes at several network layers can be provided with an important issue of how to make them interwork ;
- dynamic multilayer recovery strategies that exploit logical topology adaptations for survivability purposes.

We will show that recovery at multiple layers is necessary to reach high availability. To coordinate these mechanisms at different layers, a sequential layer interworking approach with a hold-off timer or a recovery token signal is crucial.

To provide multilayer recovery, a major distinction is based on the static or dynamic nature of the optical transport network. In case of a static logical topology on one hand, several alternatives exist with respect to spare capacity provisioning: duplicated protection, logical spare unprotected and common pool. The latter alternative turns out to be quite efficient in terms of bandwidth usage, albeit with additional complexity. On the other hand, the introduction of ASON or GMPLS functionality allows for dynamic logical topology adaptations and opens new opportunities for recovery. When a failure occurs, new lightpaths can be set up or torn down to alleviate the failure repercussions. A case study on an international network reveals that this additional flexibility can highly reduce the spare capacity needed for failure recovery. Multilayer traffic engineering techniques to cope with dynamic IP traffic patterns can be used in a natural way for failure recovery as well. The MTE strategy was improved to reduce the performance impact due to traffic rerouting during failures and tested on the reference network.

References

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[ii] ITU-T Recommendation G.807/Y.1302, *Requirements for automatic switched transport networks (ASTN)*, ITU-T Standardization Organization, July 2001, www.itu.int.

[iii] Wesam Alanqar et al., *Requirements for generalized MPLS (GMPLS) routing for automatically switched optical network (ASON)*, Internet draft, work in progress, December 2003, www.ietf.org.

[iv] Dimitri Papadimitriou et al., *Requirements for generalized MPLS (GMPLS) signaling usage and extension for Automatically Switched Optical Network (ASON)*, Internet draft, work in progress, November 2003, www.ietf.org.

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Program

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Thursday, March 30		Friday, March 31		Saturday, April 1	
Track A	Track B	Track A	Track B	Track A	Track B
Session 1: 8:00 - 10:45		Session 6: 8:30 - 10:00		Session 11: 8:30 - 10:00	
Workshop A: Mobile Networks	**Workshop B: Optical Networks**	**Dissertation Competition 1** Chair: S. Ragahavan	**Minimal Spanning Trees** Chair: Luis Gouveia	**Pricing and Policy** Chair: Nicolas Stier-Moses	**Survivability** Chair: Andras Farago
Network Optimization for a Mobile-network Operator, *Koster and Wessäly*	**Tutorial:** Designing DWDM Networks with Service Availability Targets, *Spiride*	Discrete models for content distribution, *Bektas*	Determining hop-constrained spanning trees with repetitive heuristics, *Fernandes, Gouveia and Voss*	Telecommunication value intermediation: A portal model, *Werner and Chakravarty*	Providing survivable interdomain connections over an optical backbone network, *Staessens et al.*
	Tutorial: Multilayer recovery mechanisms in backbone networks, *Pickavet et al.*	Dynamic scheduling in queueing systems with applications to communication networks, *Ross*	The distance constrained MST: Models and solution procedures, *Gouveia, Paias and Sharma*	Lottery-based pricing scheme for peer-to-peer networks, *Zghaibeh and Harmantzis*	Hop-constrained node survivable network design: An application to MPLS over WDM, *Gouveia, Patricio and de Sousa*
		Models and algorithms for effective traffic engineering of tunnel-based backbone networks, *Srivastava*	Hop-constrained spanning trees: The jump formulation and a relax and cut, *Gouveia, Dahl, Flatberg and Foldnes*	Network Games with Atomic Players, *Stier-Moses, Cominetti and Correa*	Survivable network design by demand-wise shared protection, *Koster, Gruber, Orlowski, Wessäly and Zymolka*
					A graph theoretic model for complex network failure scenarios, *Farago*
Coffee Break					
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Determining loss without simulation, *Van Breusegem and Pickavet*	Routing and wavelength assignment and transmission capacity allocation for all-optical networks based on wavelength groups, *Scheffel*	Selfish versus coordinated routing in network games, *Stier-Moses*	Computing minimum-cost h-independent paths with reliability considerations, *Andreas, Smith and Kucukyavuz*	Why is IP network design so difficult?, *Klinewicz*	Locating servers and dimensioning circuits to reduce delay in an enterprise data network, *Berger, Hartman and Trump*
AntNet: ACO routing algorithm in practice, *Verstraete et al.*	Regenerator location problem, *Chen and Raghavan*	Efficiency loss in market mechanisms for resource allocation, *Johari*	Meeting service availability targets using DWDM dedicated protection, *Spiride*	A study of VPN growth trends for network planning, *Ramakrishnan*	Robust tower location for CDMA networks, *Rosenberger and Olinick*
A mixed loss and delay model for mobile communication systems, *Shinohara et al.*	IP/WDM optical network testbed: Design and implementation, *Crispim, Pastor, Abdalla Jr. and Soares*	Designing capacitated survivable networks: Polyhedral analysis and algorithms, *Rajan*	Reliable W-CDMA network design with sectorization, *Cai*	On WiMax access network design, *Li, Wang, Balasaygun, Doverspike and Magill*	Simultaneous object placement and request routing in content distribution networks, *Bektas, Cordeau, Erkut and Laporte*
Large scale simulation model for PSTN and cellular phone infrastructure analysis, *Eidenbenz and Pan*	Practical integrated design and shared restoration strategies for DWDM networks, *Birkan*		Modeling the design of a converged network, *Allen*	Improved bounds for network performability evaluation algorithms, *Oikonomou*	FTTH-PON splitter location-allocation problem, *Lee, Kim and Han*

Lunch

Session 3: 13:30 - 15:00		Session 8: 13:00 - 14:30	Session 13: 13:00 - 14:30
Simulation and Queueing Chair: Natarajan Gautam	**Grooming and Protection in Networks** Chair: Thomas Stidsen	**Plenary Talk**	**Plenary Talk**
First exceed level theory application for networked server management, *Kim*	Optimization of resilient networks with column generation, *Gruber and Kiese*	Advances in Modeling and Solving Network Design Problems, *Anantaram Balakrishnan*	Creating New Services and Service-Level Agreements (SLAs) in Telecom Networks, *Biswanath Mukherjee*
Performance analysis of a heterogenous mobile network based on "wrap-up" cell structure, *Luo and Alfa*	Enhancing traffic grooming in WDM networks through λ-monitoring, *Solano, Caro, Fabregat, Marzo and Stidsen*		
On using fluid flow models for performance analysis of computer networks, *Goel and Gautam*	Shortcut span protection, *Stidsen and Ruepp*		

Coffee Break

Session 4: 15:15 - 16:45	Session 9: 14:45 - 16:15	Session 14: 14:45 - 16:15

Multimedia Distribution Chair: Neil Keon	**Multi-Layer Networks** Chair: Stefan Voss	**Mobile Communication Networks** Chair: Neil Keon	**Novel Optimization Models and Solutions in Communications** Chair: Iraj Saniee	**Ad Hoc Mobile Networks** Chair: Clayton Commander	**OSPF** Chair: Bernard Fortz
Distributed algorithms for optimal rate adaptation of streaming media, *Veeraraghavan, Singhal and Weber*	**Heuristics for the multi-layer design of MPLS/SDH/ WDM networks,** *Holler and Voss*	**Pricing and competition in the mobile telecommunications,** *Cricelli, DiPillo, Gastaldi and Ghiron*	**RWA decomposition for optimal throughput in reconfigurable optical networks,** *Brzezinski and Modiano*	**A greedy randomized algorithm for the cooperative communication problem on ad hoc networks,** *Commander et al.*	**Survivable composite-link IP network design with OSPF routing,** *Resende, Andrade, Buriol, and Thorup*
Auction algorithms for capacity allocation in video on demand service, *Keon and Kalvenes*	**Iterative design of two layer networks to achieve throughput maximization,** *Kublinskas and Pioro*	**Optimal design of next-generation wireless base station subsystems: Models and algorithms,** *Kalvenes*	**Projective cone scheduling algorithms for maximal throughput in packet switch networks,** *Ross*	**Node-independent multipath routing algorithm for mobil ad hoc networks,** *Pasaogullari, Harmononsky and Joshi*	**Comparison of objective functions of the unique shortest path routing problem,** *Zhang*
	A cut-and-branch-and-price approach to two-layer network design, *Koster, Belotti and Orlowski*	**Revenue management and user behavior in mobile communications,** *Keon and Kalvenes*	**Cooperative data-optical InterNetworking: Distributed multi-layer optimization,** *Mitra, Walid and Wang*	**Total energy optimal multicasting in wireless ad hoc networks,** *Min and Pardalos*	**An arc-path model for the OSPF weight setting problem,** *Madhavan*
		BitTorrent and incentive to collaborate, *Jin, Shu and Kesidis*	**An equitable bandwidth allocation model for video-on-demand networks,** *Luss*	**A class of approximation algorithms for the minimum energy broadcast routing problem,** *Bauer, Haugland and Yuan*	**A primal-dual approach for the IGP weight setting problem,** *Fortz and Thorup*
				Schedule algorithms for data extraction in energy limited wireless sensor networks, *Ye*	

Coffee Break

Session 5: 17:00 - 18:00

Keynote Address

Delivering Multimedia Home Entertainment: Services and Technologies, *Michael Grasso (assistant vice president, Consumer Marketing, AT&T U-verse),* bio

Reception: 18:00-19:30

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Session 10: 16:30 - 18:00

Market Analysis Chair: John Hopkins	**Optimization Models for Network Design and Management** Chair: Mauricio Resende
Digital multimedia broadcasting market analysis: S-DMB vs. T-DMB, *Shin*	**Partition inequalities for survivable network design using p-cycles,** *Atamturk and Rajan*
Economic effects of the indirect access regime in the ML communications market in Korea, *Kim, Seol and Kim*	**Fair capacity provision for multiclass processor sharing queue with average service time,** *Cao*

Session 15: 16:30 - 18:00

Satellite Networks Chair: Olivier Goldschmidt	**Local Access and Tree Networks** Chair: Luis Gouveia
Opportunities for network designa nd revenue management in satellite communication networks, *Fromont, Gamvros, Ragahvan and Srikar*	**Flow models for local access network expansion problem,** *Corte-Real and Gouveia*
Traffic routing and onboard configuration planning in satellite networks, *Gamvros and Raghavan*	**Cross decomposition of the capacitated minimum spanning tree problem,** *Sohn and Bricker*
An integer programming model for optimizing	**Traffic engineering of Ethernet carries networks based**

The value distribution of the telecommunications supply network in Ireland, *Hopkins and Fynes*	**A new state generation algorithm for evaluating performability of networks with multi-mode components,** *Oikonomou and Sinha*	**satellite and terrestrial network configuration and routing,** *Chandran, Fromont and Srikar*	**on multiple spanning trees,** *de Sousa and Soares*
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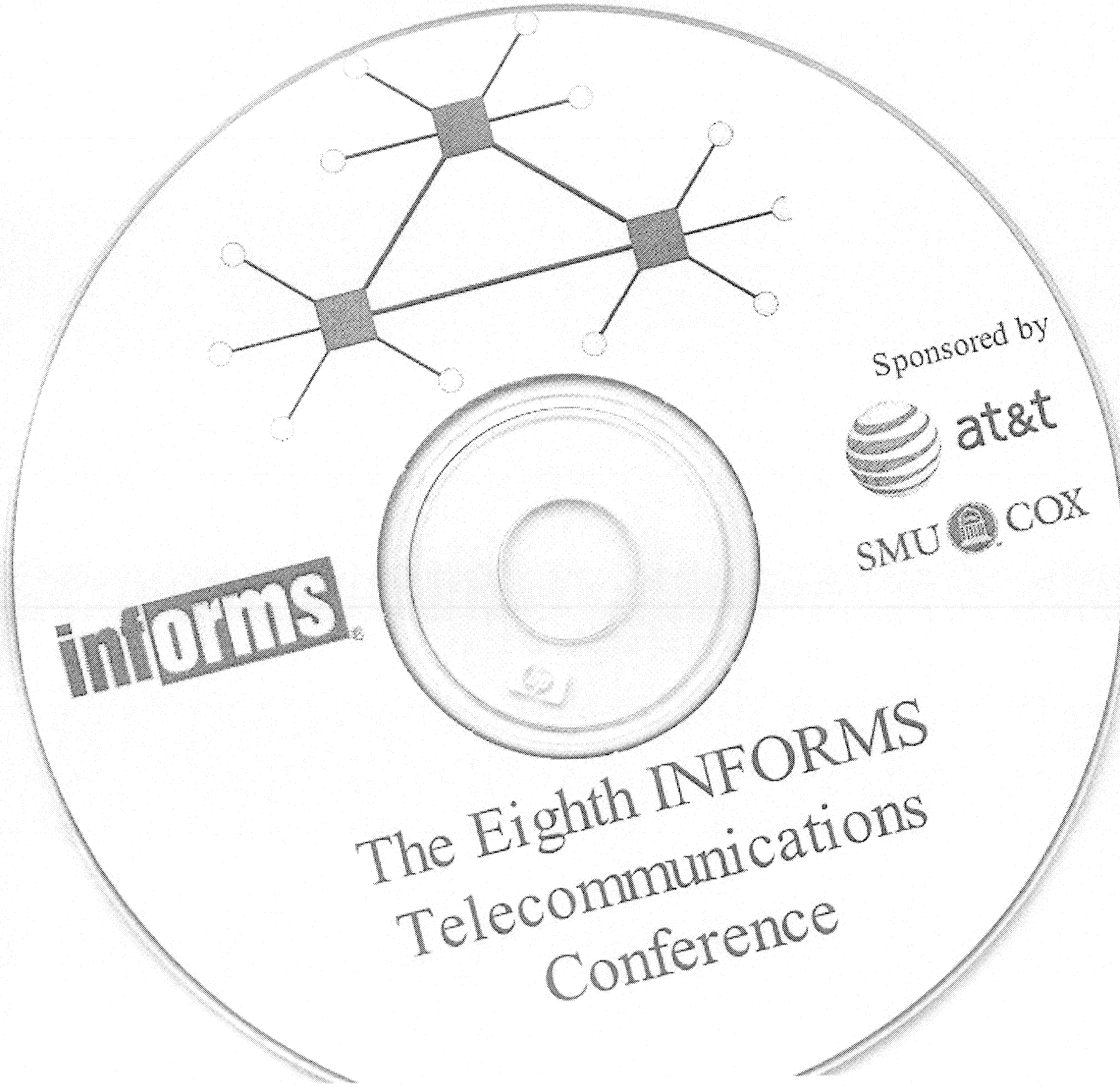
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