Static Lightpath Routing in IP over WDM Networks

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"IP Netzmanagement, IP Netzplanung, und Optimierung"

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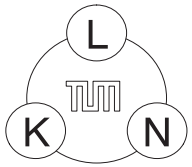
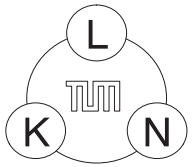
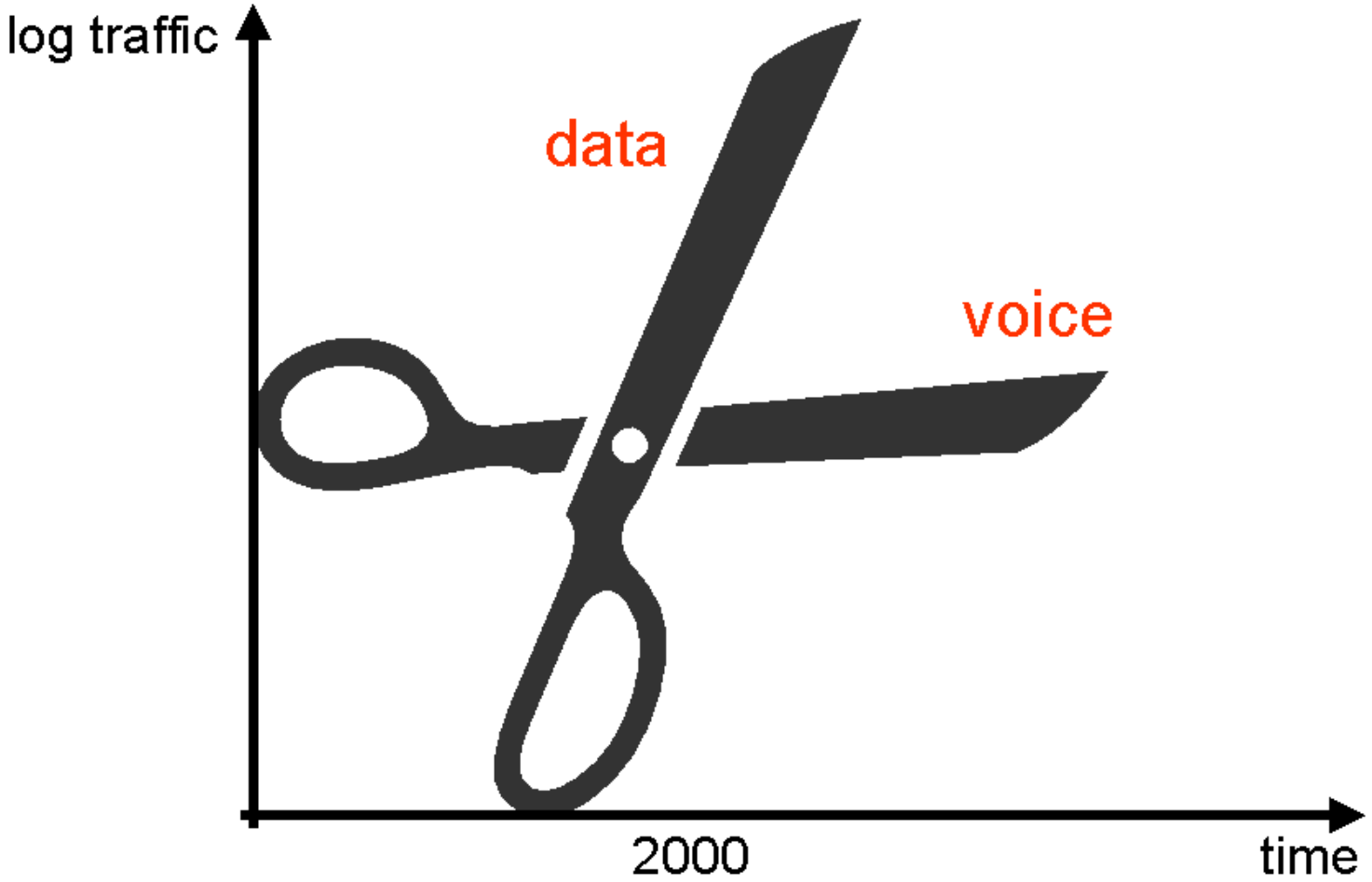


Overview

- Motivation and Introduction
- Node and Network Models
- Solution Approach
- Finding the Virtual Topology
- Wavelength Assignment
- Graph Coloring
- Case Study
- Results
- Conclusions

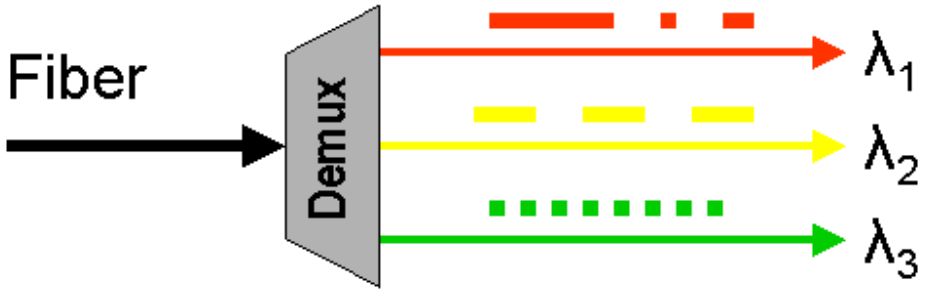


Exponential growth of IP backbones



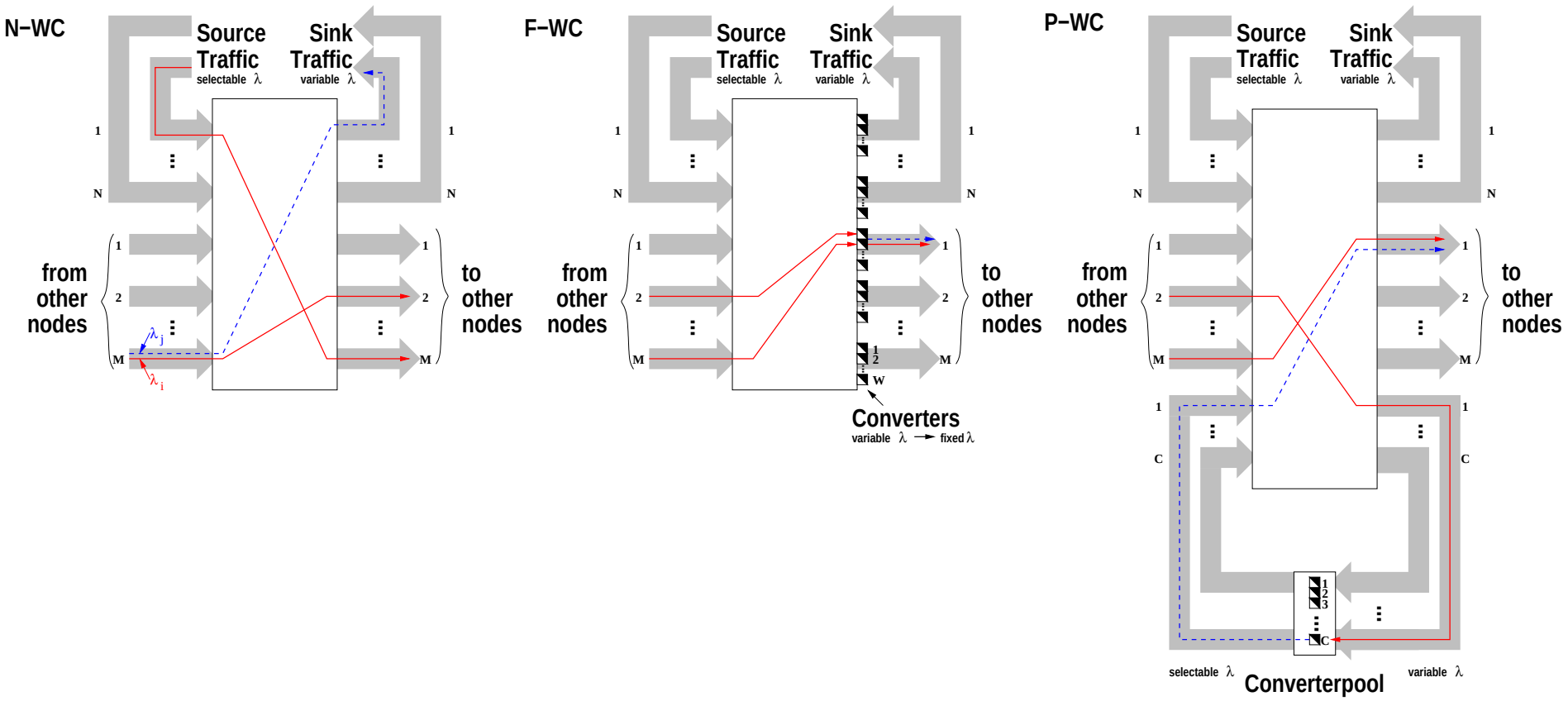
Motivation

- IP fiber backbones - usage of WDM:



- Optical crossconnects (OXCs) interconnect IP routers by lightpaths
- No intermediate multiplexing layers (e.g., SDH, ATM) ⇒ less administration, fixed capacities per lightpath
- Aim: determine efficient (static) configuration of the lightpaths for IP router demands, i.e. find an optimal
  - virtual topology for IP and
  - a routing and wavelength assignment (RWA)

Optical Crossconnect Models



{N,F,P}-WC = {Non,Full,Partial}-Wavelength Converting

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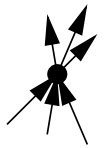
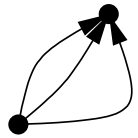
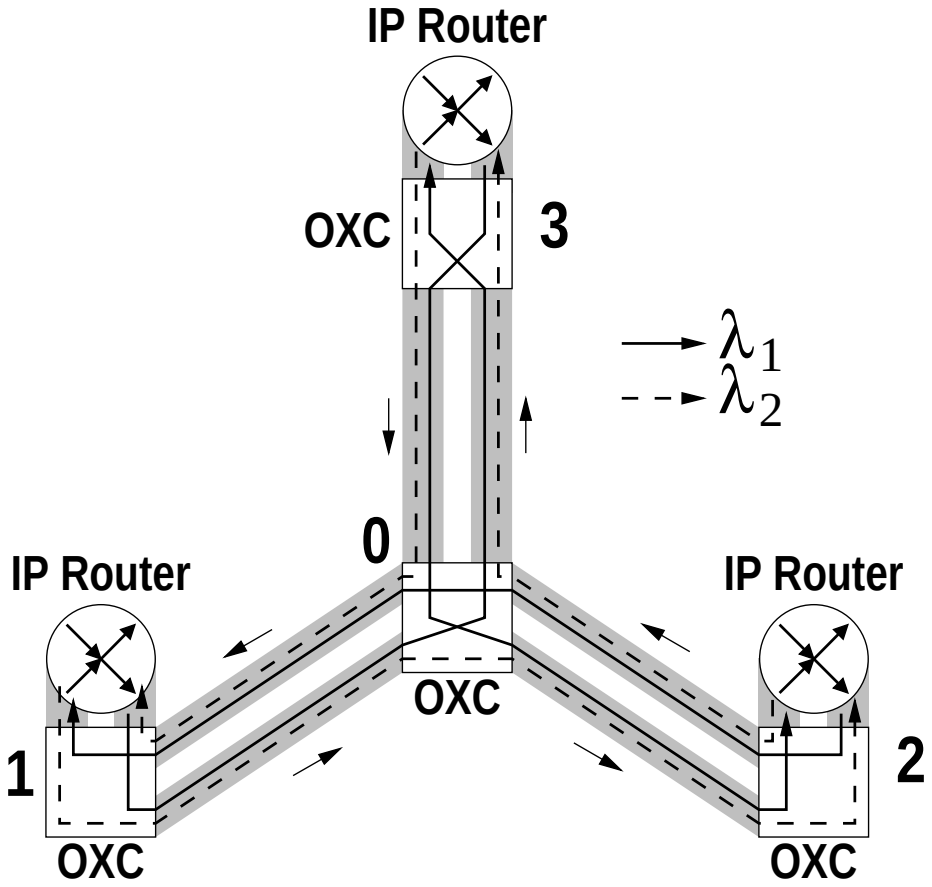
The Entire Problem

Main Characteristics	Flow Formulation 	Route Formulation 
IP Layer	+ Unknown virtual topology – Metric assignment	+ Path constraints – Path pre–selection
WDM Layer	+ Partial conversion – Long computation time	+ Path constraints – Wavelength constraint

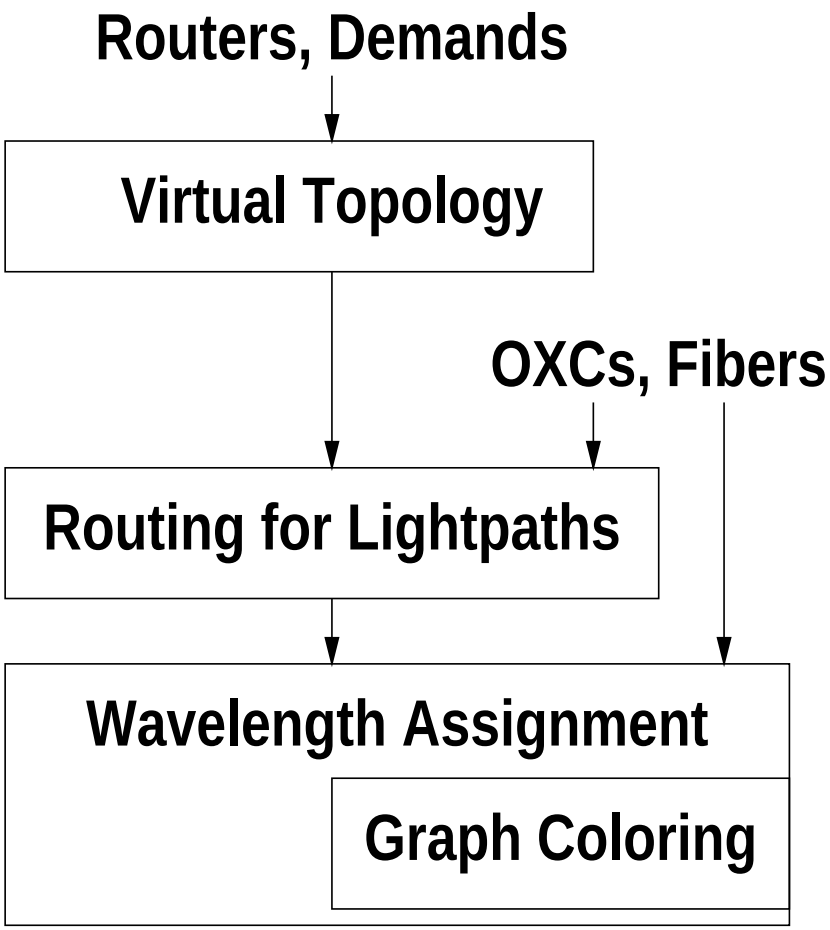
Large problem $\Rightarrow$ approach: consider subproblems

Network Model IP over N-WC WDM



- OXCs are interconnected by fiber pairs (wavelength constraint)
- OXC are connected to at most one IP router (source and sink for least one lightpath)
- Transponders or colored interfaces
- No wavelength converters present (wavelength continuity constraint)
- Shortest path based IP routing protocols (e.g., OSPF)
- Equal IP routing metrics (e.g., all 1)

Solution Approach

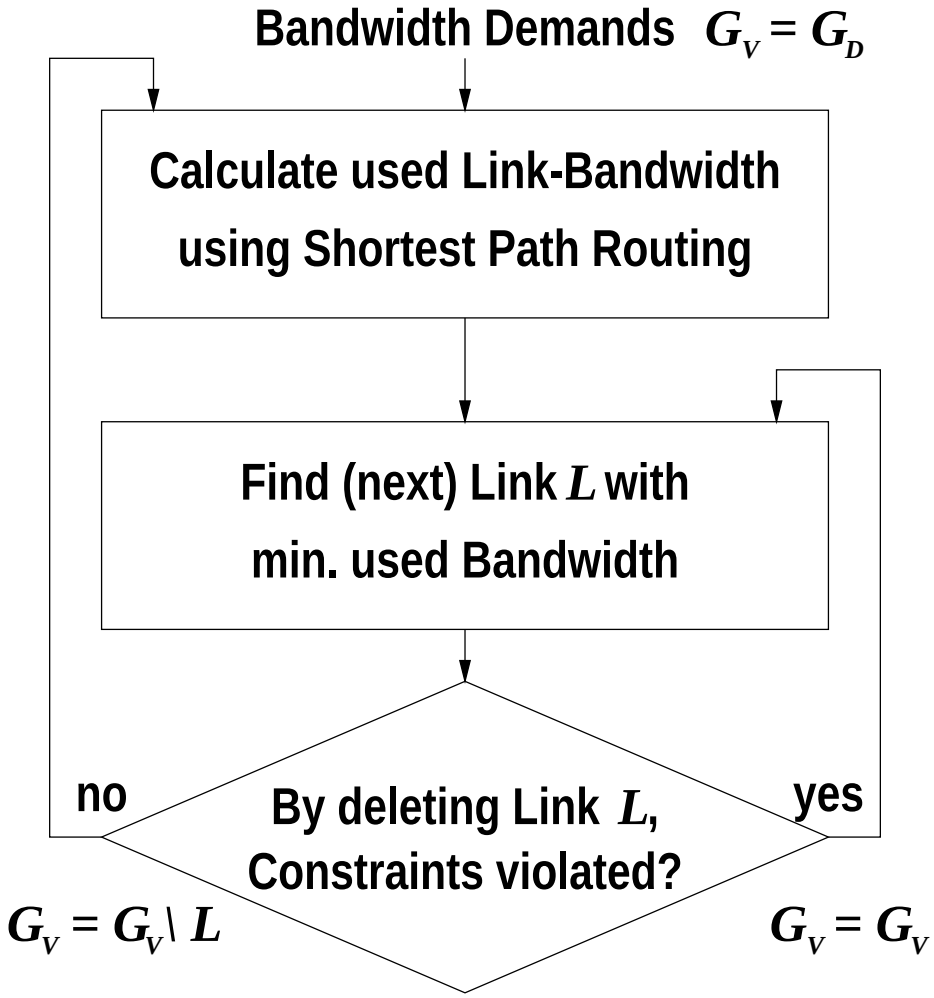


Whole problem becomes too complex (let alone RWA)

$\Rightarrow$ subproblems solved each by heuristic algorithms:

- Objective: minimize laser sources (significant cost factor)
- Virtual topology: minimize virtual links (and thus laser sources)
- Routing of lightpath demands: shortest path (keeps fiber usage and lightpath lengths low)
- Assignment of wavelengths: graph coloring problem (even minimization of number of wavelengths)

Finding the Virtual Topology



Aim:

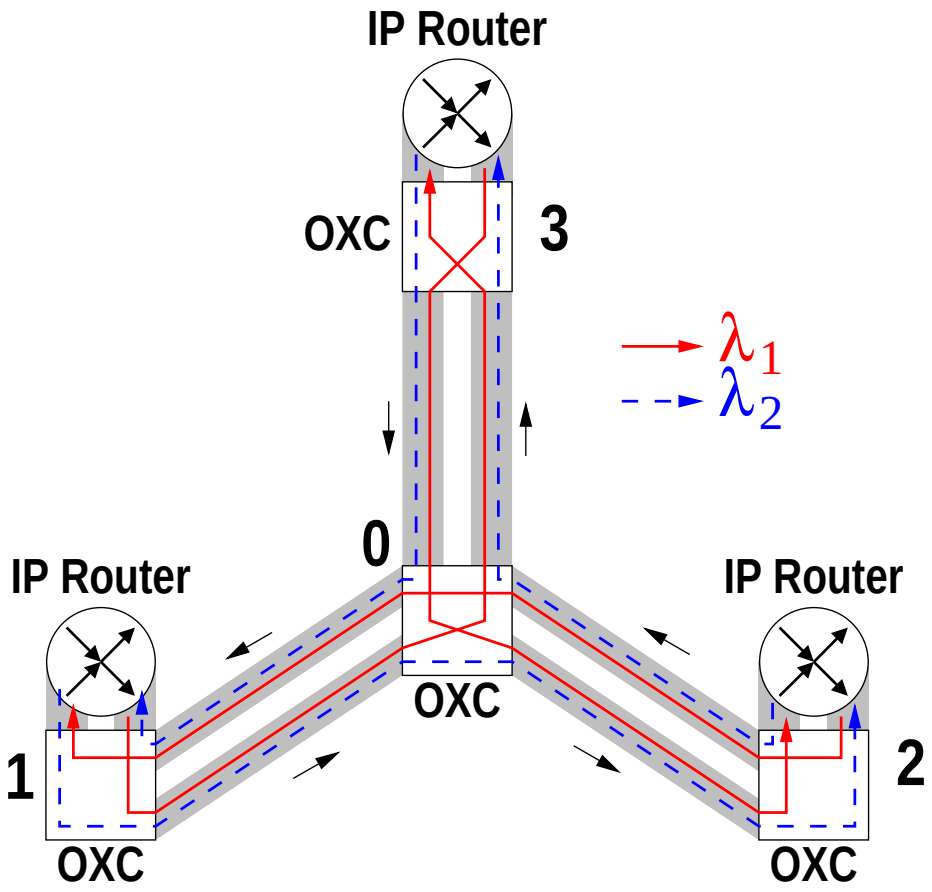
find virtual topology with minimum number of links such that bandwidth demand is carried

Further constraints:

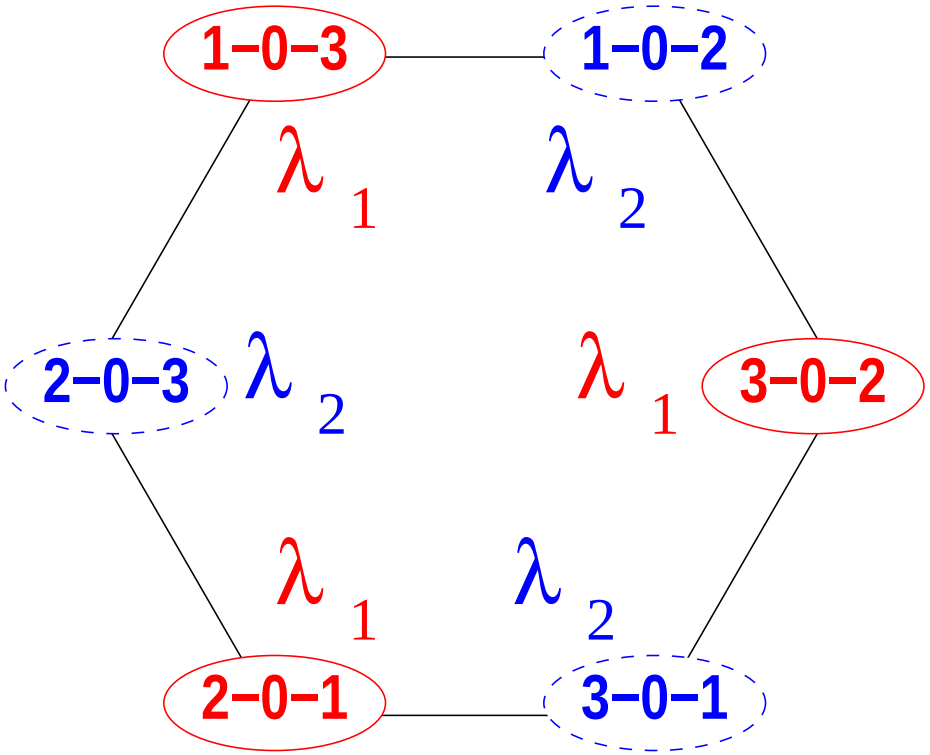
- link capacity
- maximum number of hops (keeps IP packet delay low)
- maximum amount of transit traffic through an IP router (avoids over-whelming of routers and reduces IP packet delay)

Wavelength Assignment and Graph Coloring

Network example:



Corresponding path graph:



Graph Coloring Algorithm

Aim: assign colors to the path graph nodes such that

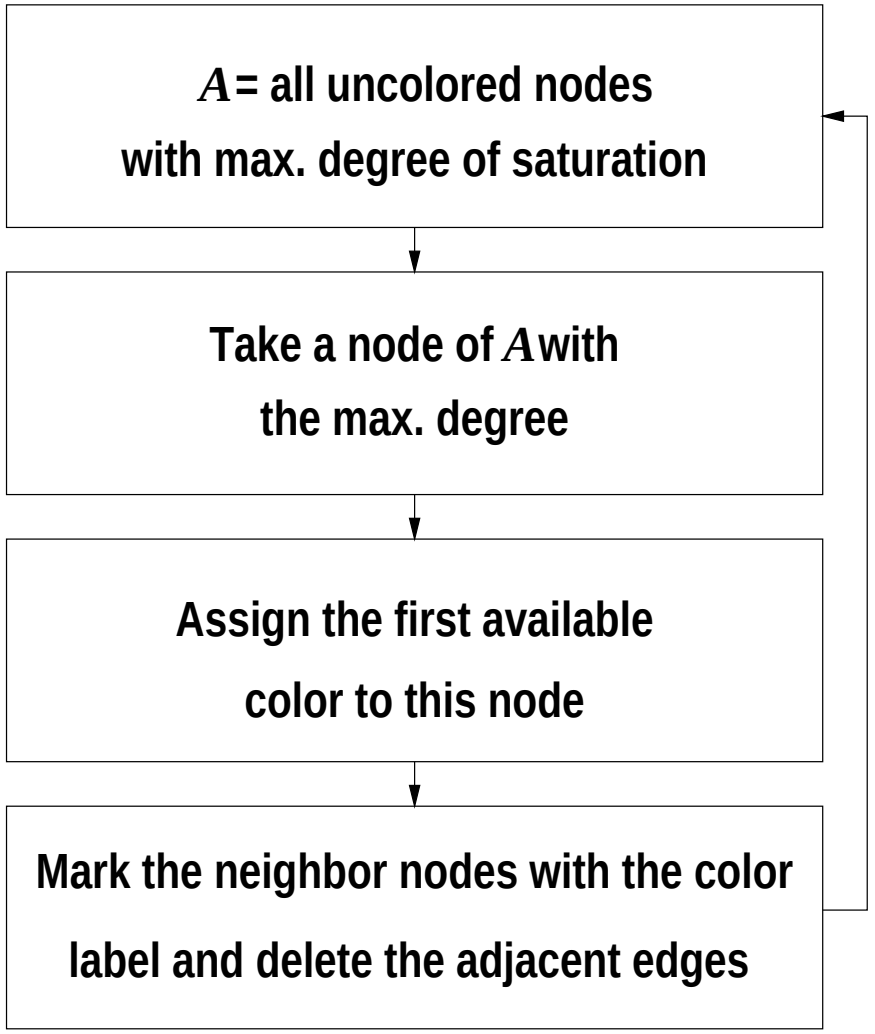
- adjacent nodes do not have the same color
- the number of used colors is minimized

Algorithm:

Degree of Saturation (DSATUR) heuristic

“Degree of saturation:”

the number of colors that are not allowed for a node (adjacent nodes have already obtained these colors)

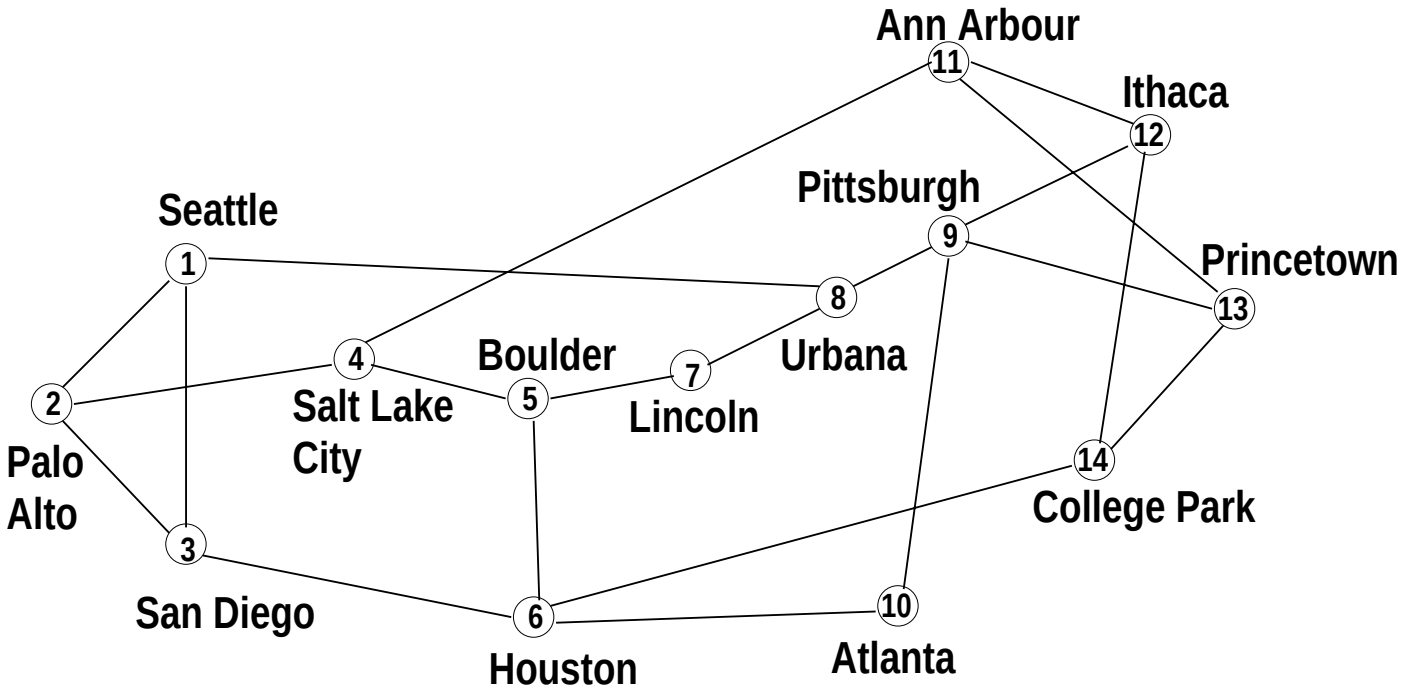


Case Study

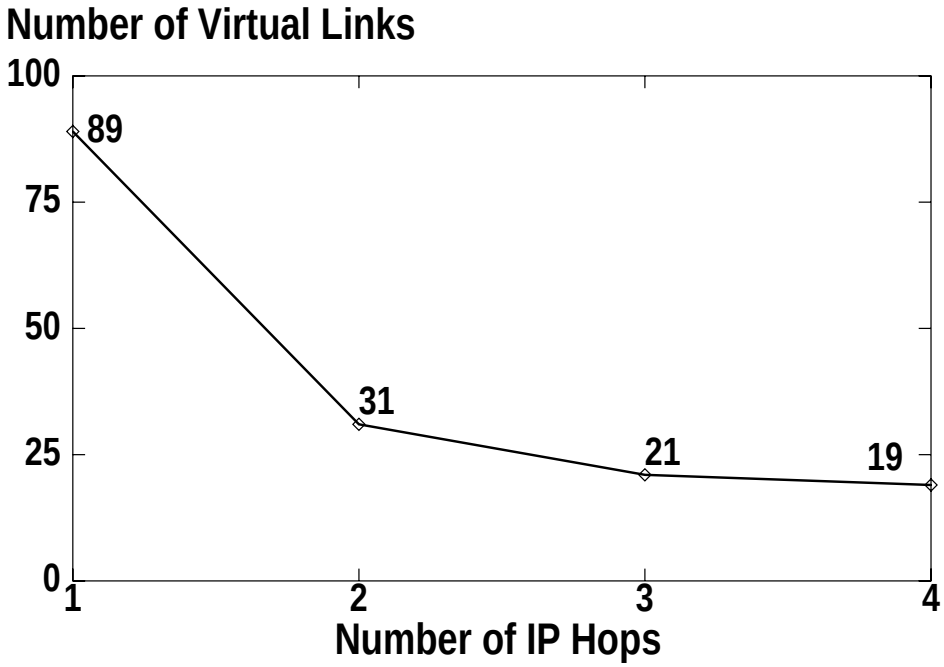
NSF network with 14 nodes (node: IP router plus OXC) and 21 links (fiber pairs)

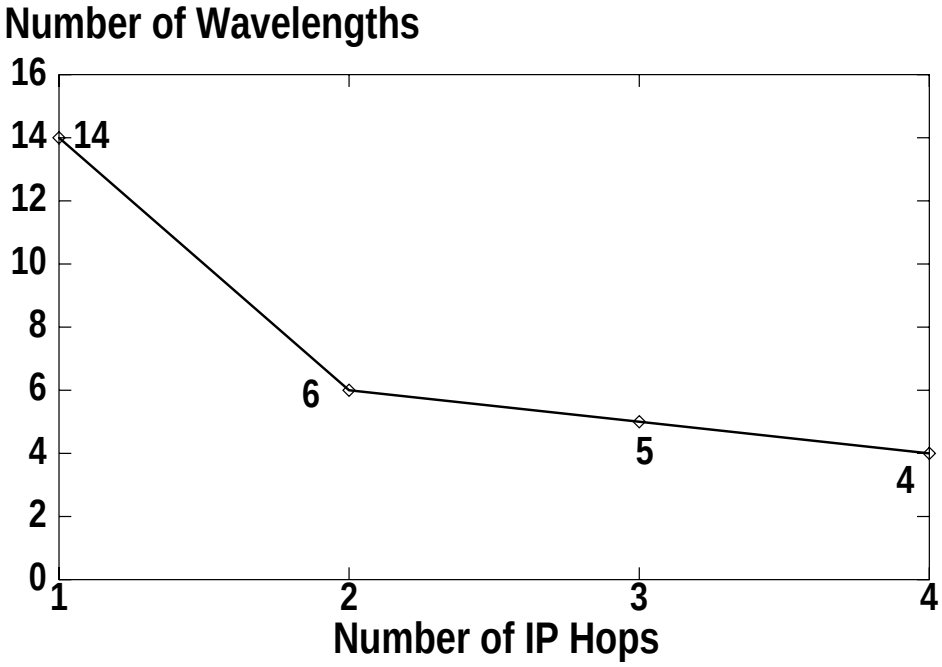
Bit rate capacity of a wavelength: 10 Gb/s

Traffic matrix: scaled such that entry with maximum value equals 10 Gb/s (total network load: 120 Gb/s)



Results: Dependence of Allowed IP Hops

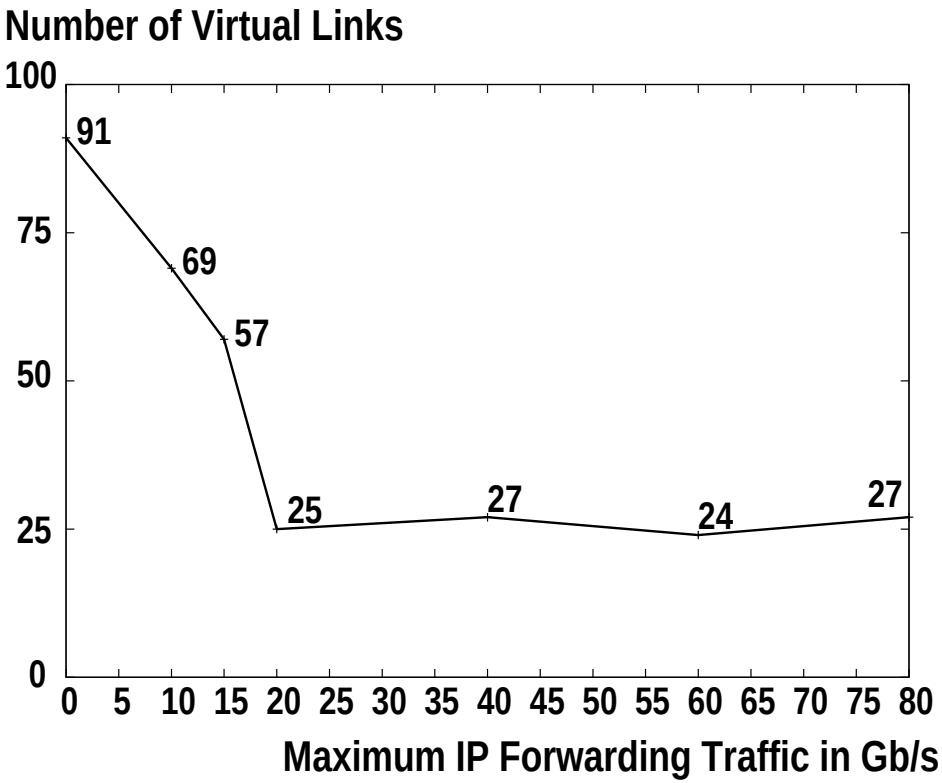


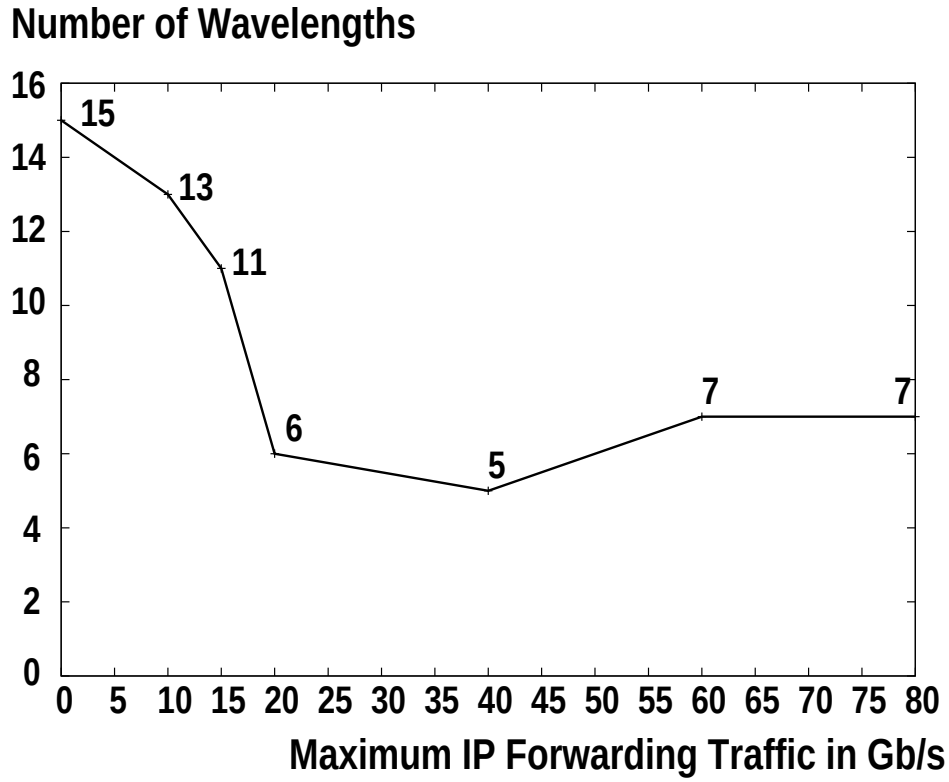


$\Rightarrow$ 2-3 hops: already reasonable results

Results: Dependence of Allowed Transit Traffic

Traffic matrix: full mesh demand with demand-pairs of 1 Gb/s





$\Rightarrow$ heuristic nature of the virtual topology algorithm

Restrictions can be used to obtain result alternatives.

Conclusions

Static lightpath routing in IP over WDM networks:

- Finding a virtual topology for the IP layer
- Routing and wavelength assignment on the WDM layer

The results of the heuristic algorithm approach show:

- The simple heuristic for virtual topology produced already reasonable results
- DSATUR algorithm for the graph coloring performed well
- Due to heuristic approach: short execution time

Further information: `http://www.transinet.de/`