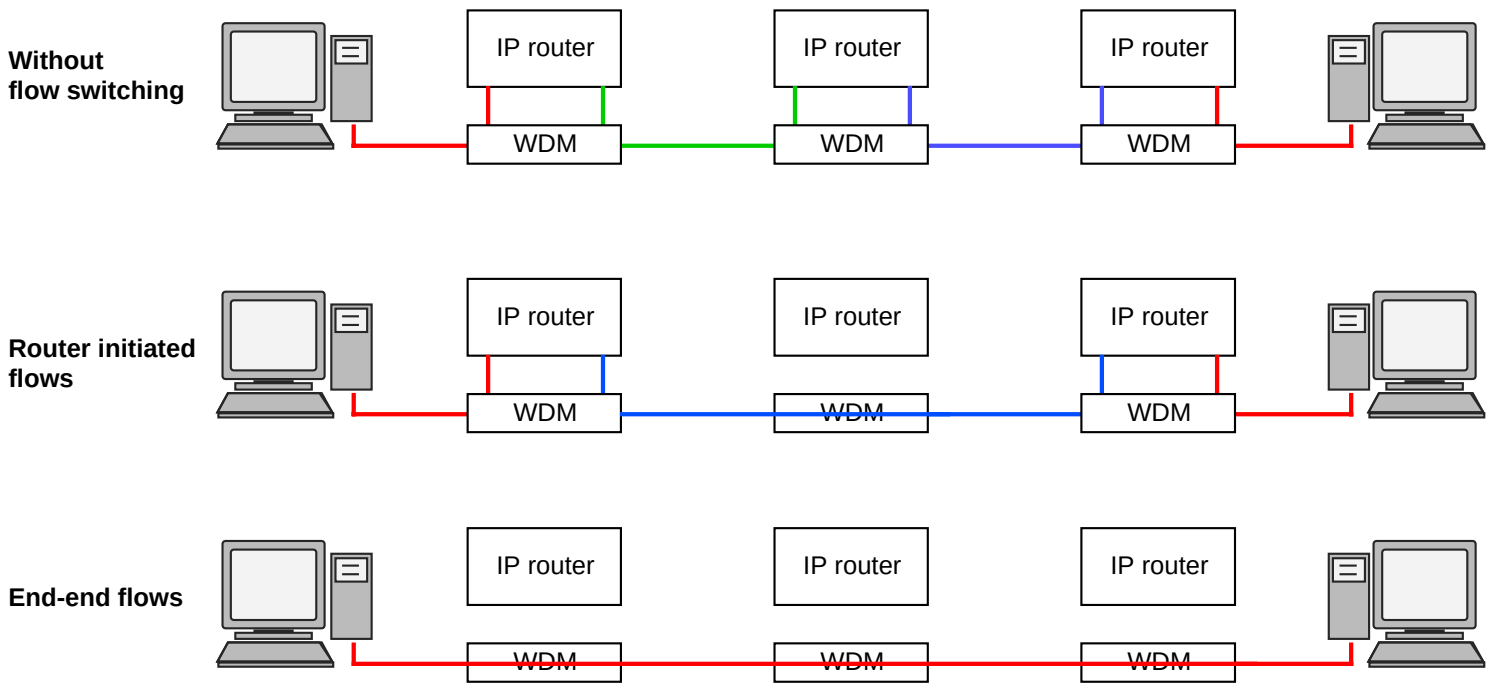
Optical Flow Switching in the NGI

Eytan Modiano
Massachusetts Institute of Technology
Laboratory for Information and Decision Systems

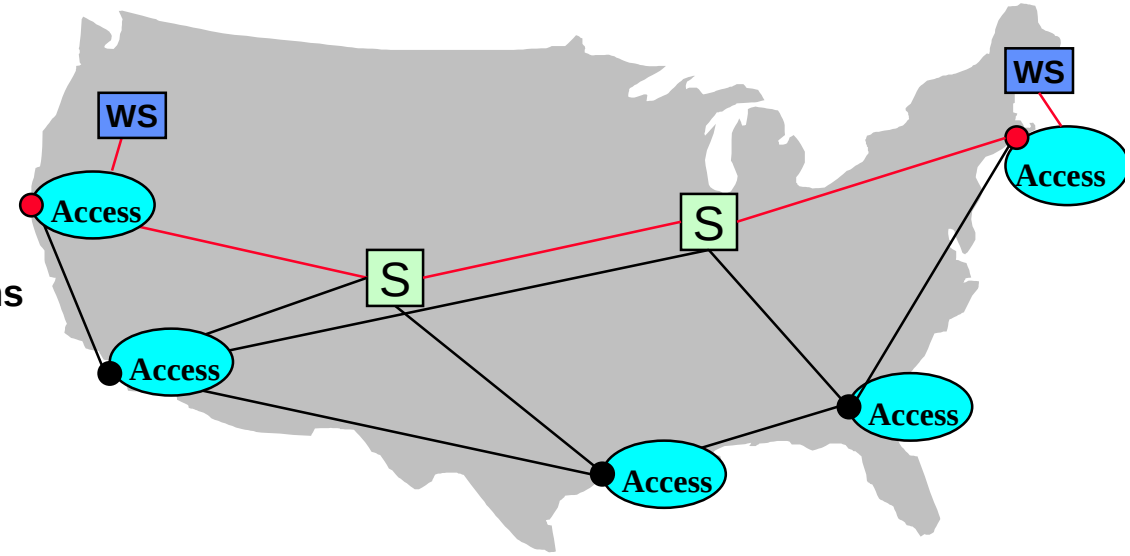
Optical flow switching

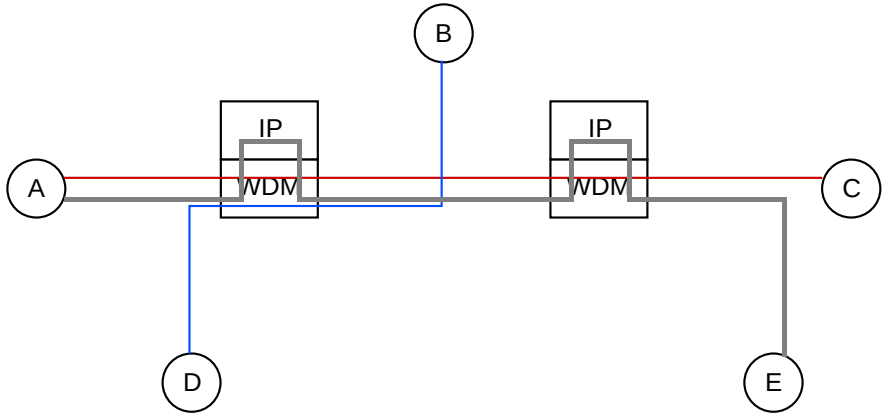


- **Optical flow switching reduces the amount of electronic processing by switching long sessions at the WDM layer**
  - **Lower costs, reduced delays, increased switch capacity**
  - **Today: IP over ATM (e.g., IP switching, tag switching)**
    - **Dynamically set-up new ATM VC's to switch a long IP session**
    - **Future: IP directly over WDM**
    - **Dynamically configure new lightpaths to optically switch a long session**

Flow Switching

- **Similar efforts**
  - Optical burst switching
  - Optical label switching
- **Key differences**
  - End-to-end optical connections
    - Electronic control network
    - No buffering
    - No optical processing
  - Large transactions only
  - Full wavelength
  - High rate (at least 2.5 Gbps)
  - No need for fast optical switching
- **Size and duration**
  - Much larger than setup time
    - E.g., 1 second or more
    - => 1 to 10 Gbits or larger
  - Efficient utilization





Why use optical flow switching

- **Reduce router costs**
  - **Bypassing routers can reduce the load on the routers**
    - **Can use smaller routers**
    - **Can support greater network load for a given router capacity**
  - **Makes sense if it is cheaper than electronic routing of the data**
  - **Makes sense if we can significantly reduce router sizes**
    - **E.g., 50% of traffic can bypass routers**

cost of switching a tera-bit

Optically:

100 λ's @ 10 Gbps

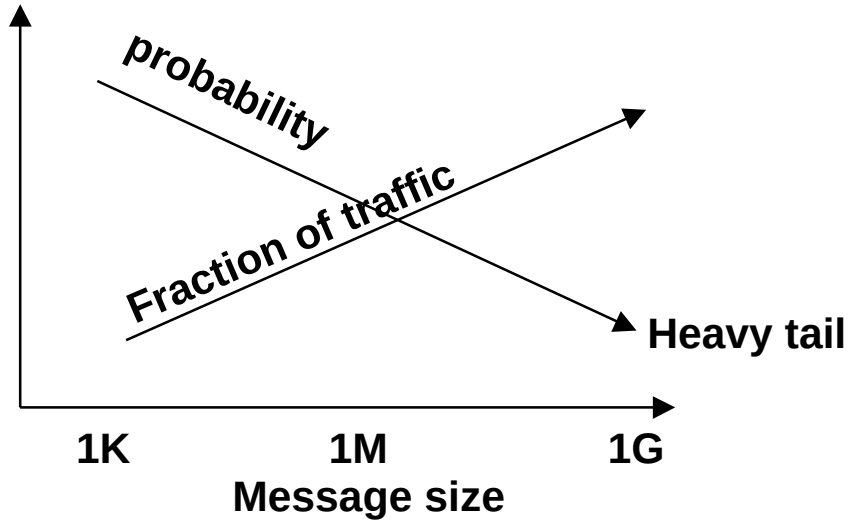
Cost ~ $250,000

Electronically:

Assume cost in line cards

100 OC-192 line cards

Cost ~ $3,000,000

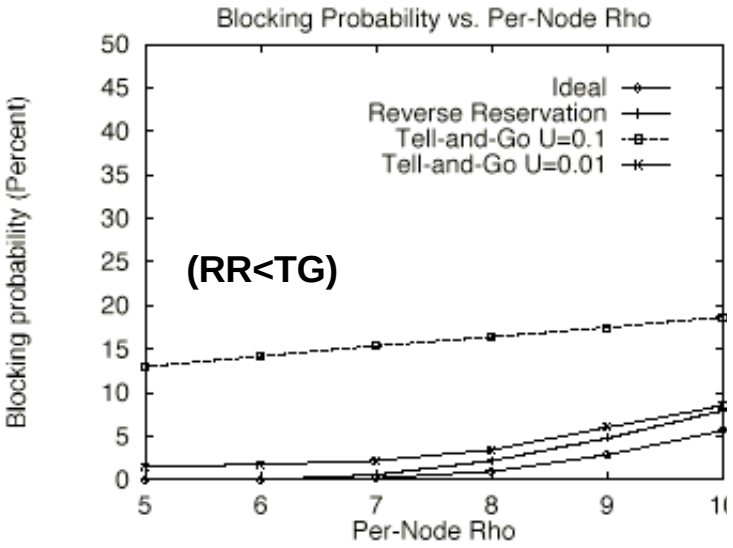


Flow switching issues

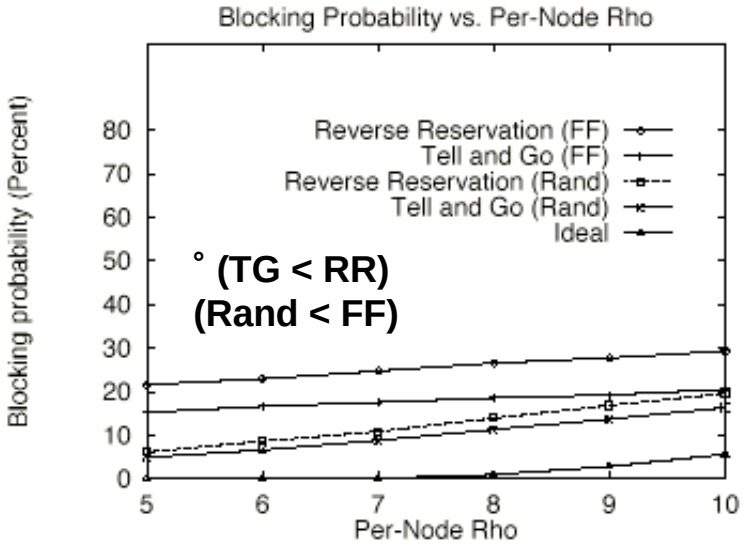
- Source of optical flow
  - End-user
    - Large transaction
  - Routers
    - Aggregation
- Flow detection
  - Explicit from application
  - Detection algorithm
    - Threshold schemes
- Route discovery
  - Pre-assigned path
  - Dynamic routing
- Connection establishment
  - Tell-and-go (TG)
  - Reservations (FR,RR)
- Dissemination of network state
  - Information distribution (TG, FR)
    - Link state updates
  - Information gathering (RR)
- Wavelength assignment
  - Use of wavelength conversion
  - Assignment algorithms
- Control network architecture
  - Impact of delays
  - MPLS framework
- TCP Performance limitations
  - Mainly processing (not protocol)
  - TCP enhancements
  - Giga-bit Ethernet experiments

Routing, λ-assignment and connection establishment (preliminary results)

- **Distributed algorithms**
  - No global state information
  - Control network delays
- **Connection establishment**
  - Tell-and-Go or Forward res.
    - Link state updates (every U sec.)
  - Reverse reservation
    - On demand exploration
- **Wavelength assignment**
  - First Fit vs. random
- **Simulation**
  - VBNS backbone
  - Markovian traffic (1 sec flows)
- **Control delays significant impact**



Zero control latency



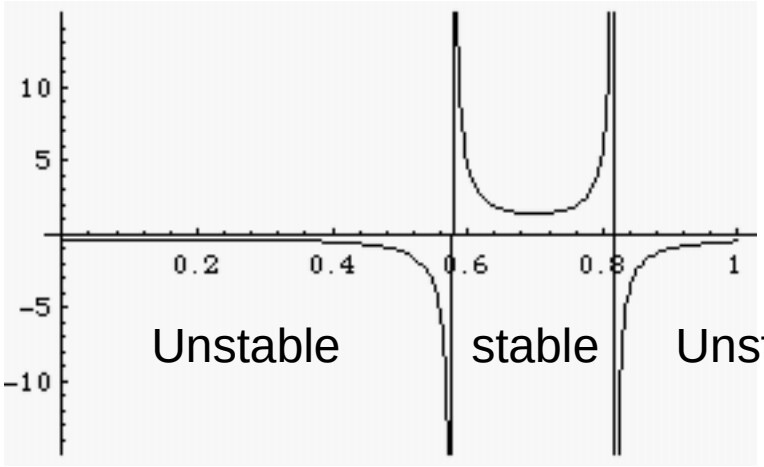
Control prop. delay

Threshold decision scheme

- **Given flow of size L, how do we decide if to switch it optically or electronically?**
  - **Simple threshold scheme**
    - **L < T electronically**
    - **L > T optically**
  - **Choose threshold to minimize delay in the network**

- **Example**
  - **Flow setup time = 0.1 second**
  - **Messages between 0 and 1 second in duration**
  - **Capacity equally divided between optical and Electronic networks**
- **Optimal threshold**
  - **Static vs. dynamic**

Delay vs Threshold

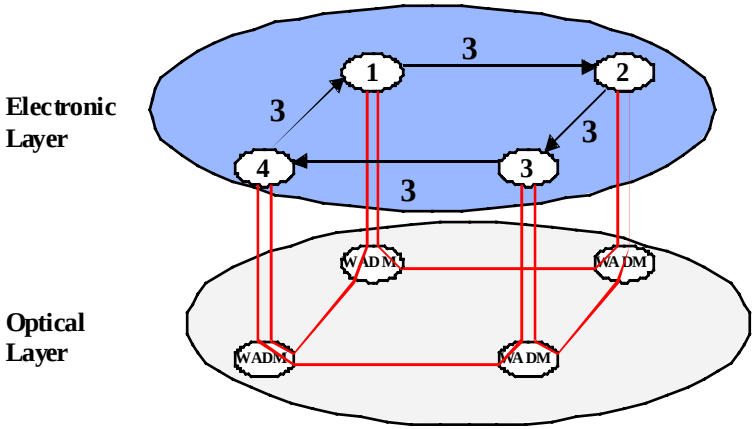


Load Balancing

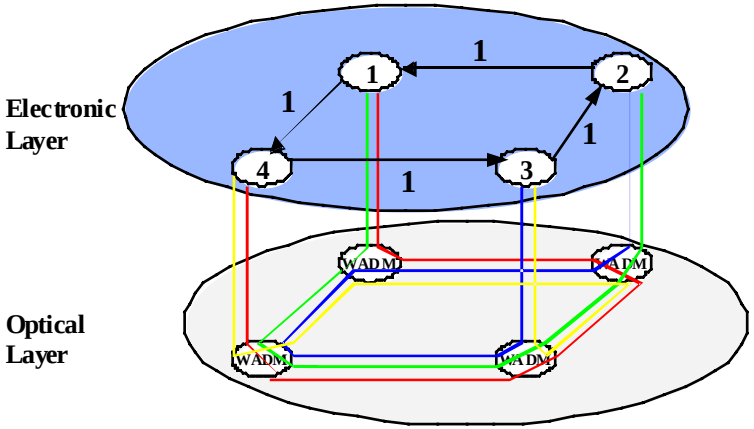
- **Reconfigure the logical topology of the network in order to reduce the load on links and routers ⇒ reduce delays, increase capacity**
  - **Router-router flows**
  - **Aggregation of traffic**
- **Example: WDM ring network**

Traffic matrix

$$T = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$



Fixed Topology



Reconfigured Topology

Dynamic Load Balancing for WDM-based Packet Networks, Aradhana Narula-Tam and Eytan Modiano
Optical Networks Session, Wednesday, 3:30