# Optical Networking:
## What Is Its Future?

IEEE Infocom '03 Panel

## Panelists:

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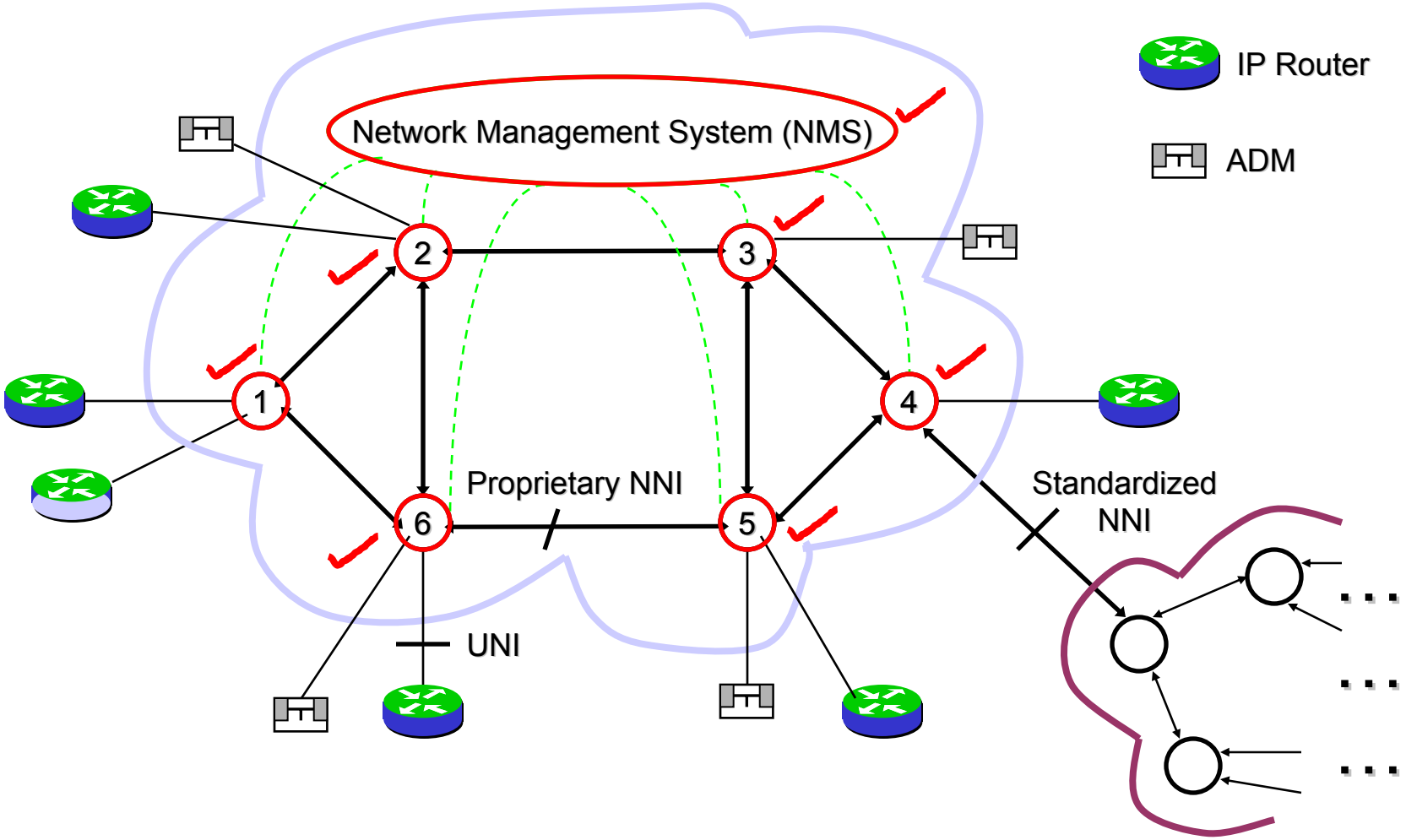
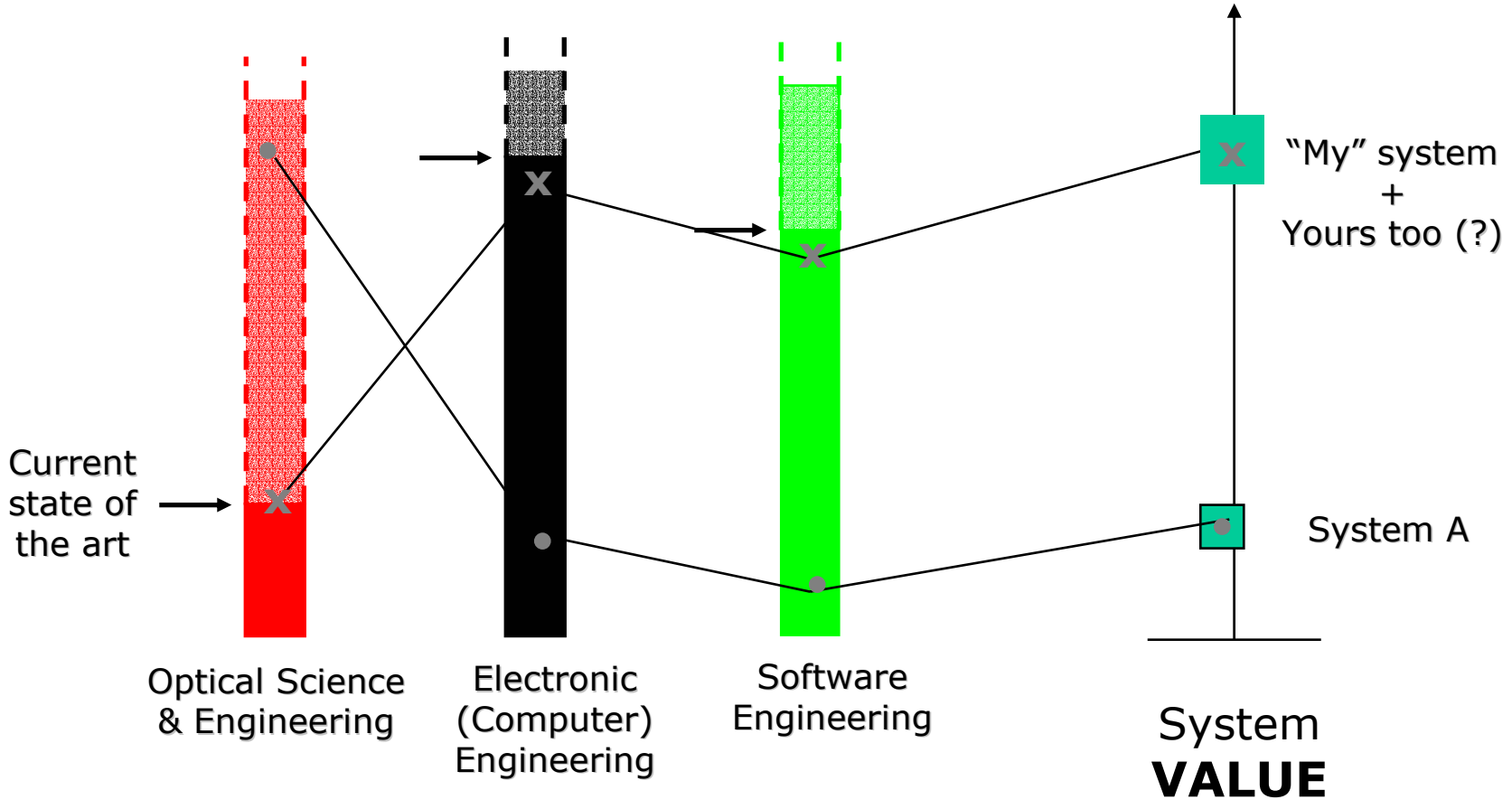
# What Is An Optical Network?

- It is **NOT NECESSARILY** all optical
  " " " " packet switched
- **Characteristics of an optical network**
  - **Transmission: optical**
  - **Switching:** could be optical, could be electronic, could be hybrid
    could be circuit, could be packet, could be burst
- **Most Promising Approach Today**
  - Electronic circuit switching with sub-lambda granularity (STS-1, OC-3, …)
- **Example Utility for IP Networking**
  - Connect any two IP routers (geographically far apart) with a direct ("virtual") bandwidth pipe… of whatever capacity (STS-1, … OC-192)
  - Increase (or decrease or delete) the capacity on demand
  - Dynamically control the "topology" connecting the IP routers
  - Create a "separated control network" (of whatever bandwidth)
  - …

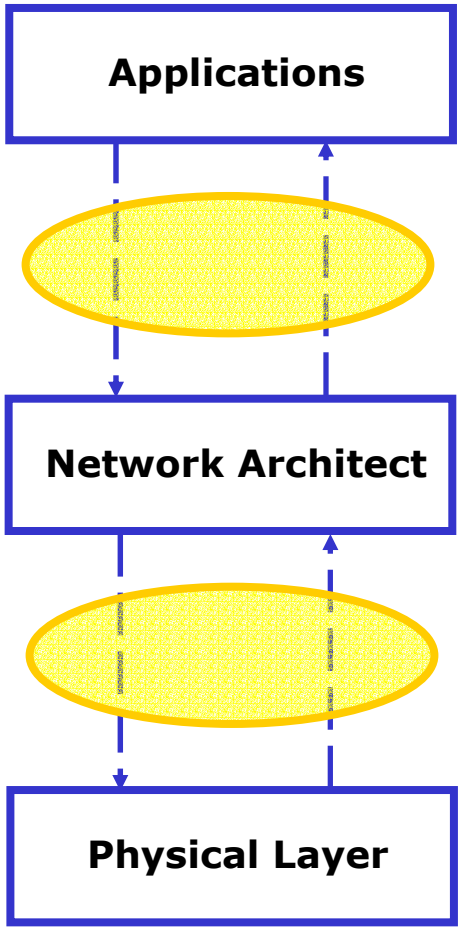
# An Example Network



# System/Network : Value Proposition



# Optical Network Architecture:
## Extending Our "Boundaries"




("Customer" needs)

**Differentiated Services:**
**Bandwidth:** OC-192, OC-48, … , STS-1, VT1.5, …
**Failure-Recovery Delay:** The "50-ms myth!"
**Network Economics:** Pricing, SLA, …

(you and I)

+ routing protocols to combat optical channel impairments
+ breakthroughs needed in device technologies?
- optical RAM, ultra-wideband amp, "tunable" AWG, …

(optical comm. channel) -- materials, devices, subsystems

# Emerging Business Paradigms

- "Wave Services"
  - "transparent" lambdas: run whatever you like (OC-48, OC-192, OC-768, GigE, 10GigE, …)
- Carrier-Neutral Internet-Exchange Points
  - "Carrier Hotels"
- Fast Bandwidth Provisioning
  - With a variety of user-configurable features
  - GMPLS for control plane?
- Bandwidth Brokers
  - Sell sub-lambda services as well (e.g., STS-1, OC-3, …)

# Some Thoughts…

- Optical networking:
  - Three “pillars” for optical network architecture
    - Optics, electronics, software
  - All-optical networking
    - (When) will it happen?
    - Is it needed?
  - Circuit vs. packet vs. “burst”
  - Dynamic bandwidth management
  - Access vs. metro vs. long haul
    - Optical access: free-space optics
  - What revolutions/breakthroughs are needed in device technologies?
    - Optical RAM, ultra-wideband amplifier, “tunable” AWG, …

# R&D Priorities

- **Access:** ***EPON architectures, Free-space optics***
- **Metro:** ***ROADM-based architectures***
- **Long-Haul:**
  - ***Provisioning Connections of Different Bandwidth Granularities***
    - Hierarchical Optical Switch (Crossconnect) Architectures
    - Traffic Grooming in WDM Mesh Networks
  - ***Fault Monitoring and Restoration***
    - Provisioning with Guaranteed SLA
    - "X-ms" guaranteed protection-switching time
  - ***Dynamic Network Planning, Topology Engineering***

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  - Network Architectures and Algorithms to Combat Optical Signal-Quality Impairments
  - Optical Multicasting and "Light-Trees"
  - Optical Packet Switching (OPS) and Optical Burst Switching (OBS)