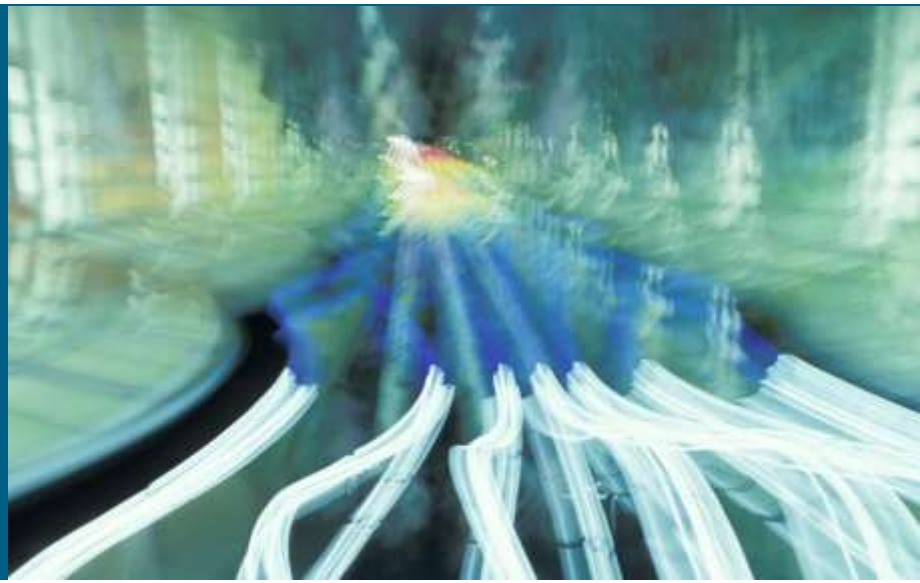
The Age of Multi-Layer Networking



Ori Gerstel, Principal Engineer

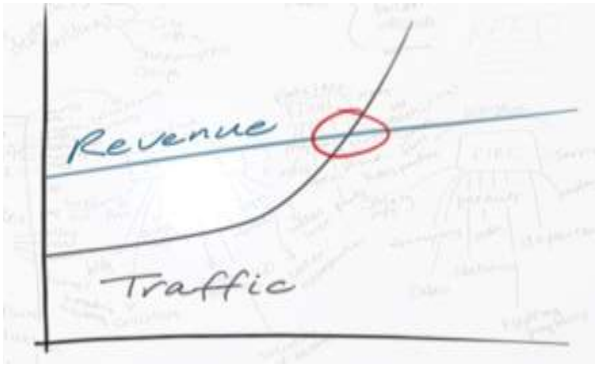
ogerstel@cisco.com

Outline

- Challenges
  - The shrinking gap between network cost and revenues
  - Are we approaching the limit of fiber capacity?
  - Cost of DWDM optics not dropping fast enough
  - The reducing accuracy of traffic forecasts
- Solution components
  - Agile and elastic optical networking
  - Multi layer coordination (control plane)
  - Multi layer optimization (SDN)
- Summary

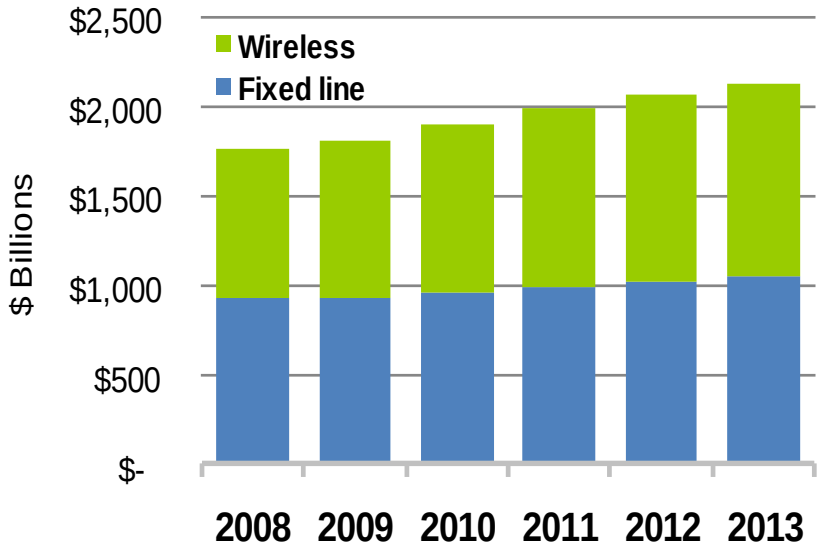
Challenge 1: Network Operator ROI

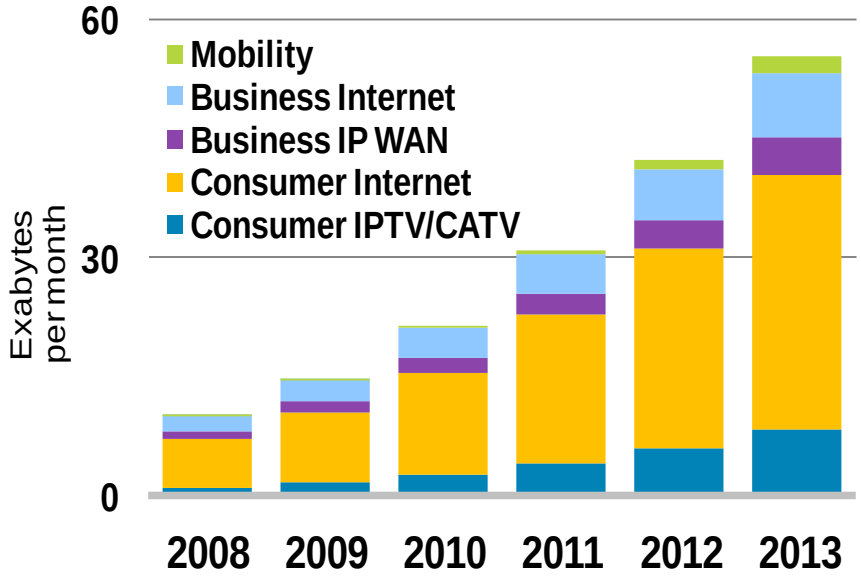
Telecom Revenue growth is limited (GDP based)



Internet traffic growth is high

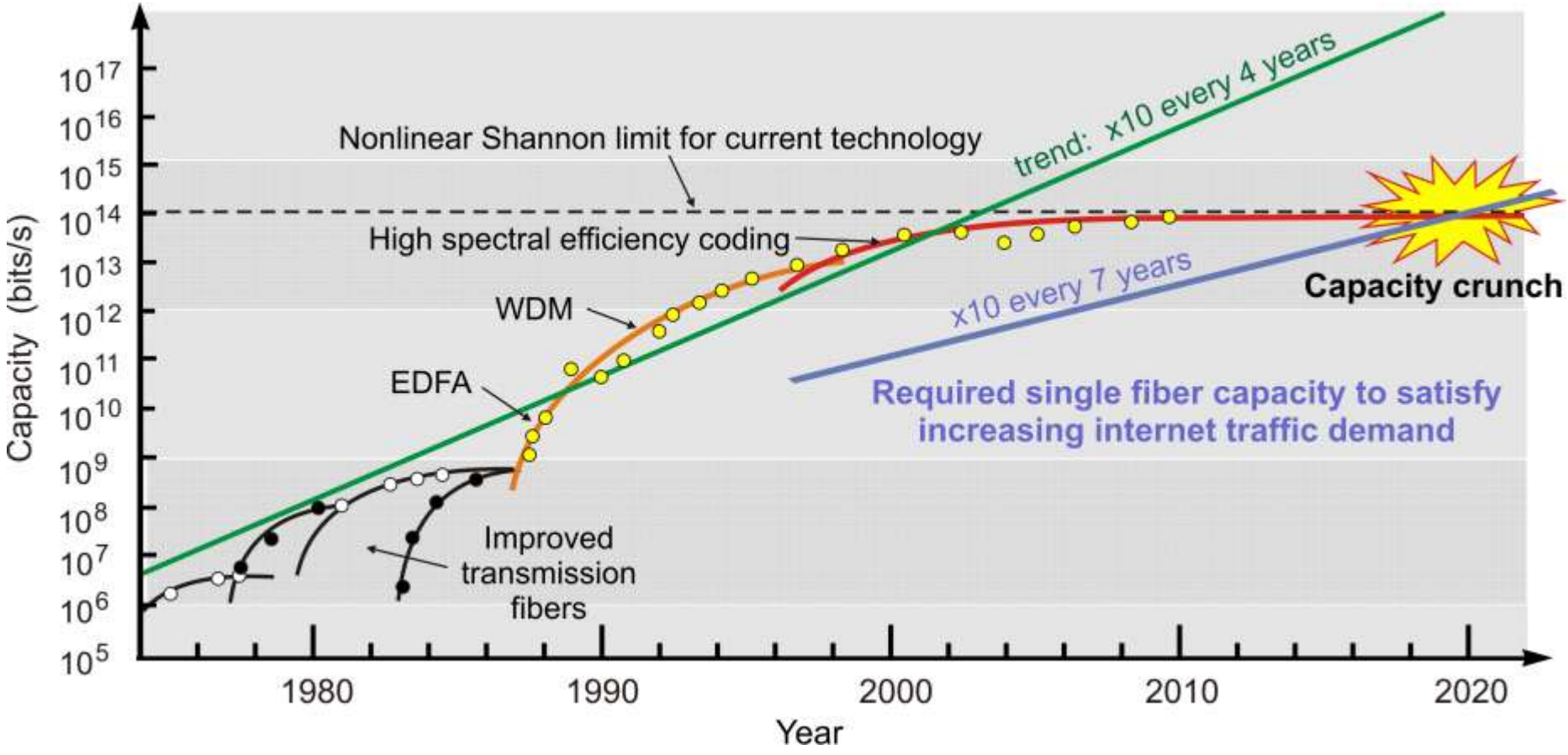
(30-100% CAGR)





Source: Independent Analyst Research and Cisco Analysis; Cisco Visual Networking Index

Challenge 2: how to achieve 10x capacity in the next 10 years?

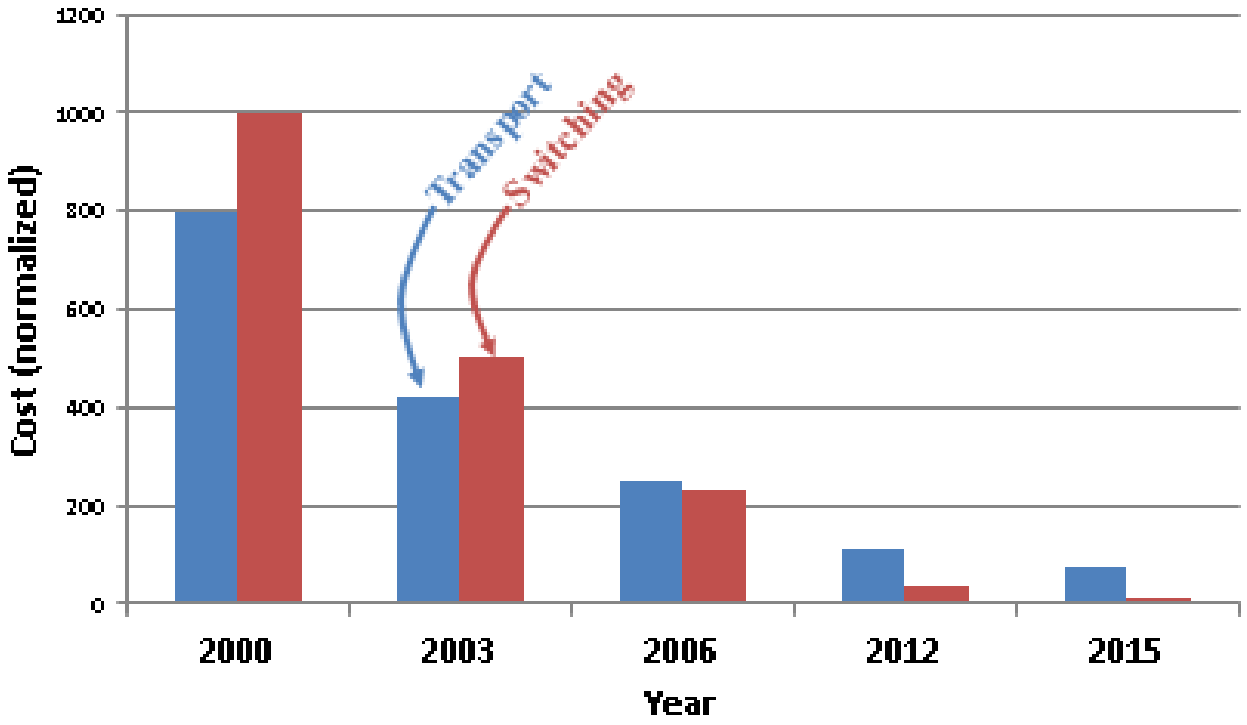


[Courtesy of David J. Richardson, adapted from “Filling the Light Pipe”, Science 15 October 2010]

Challenge 3: The cost of DWDM optics does not drop fast enough

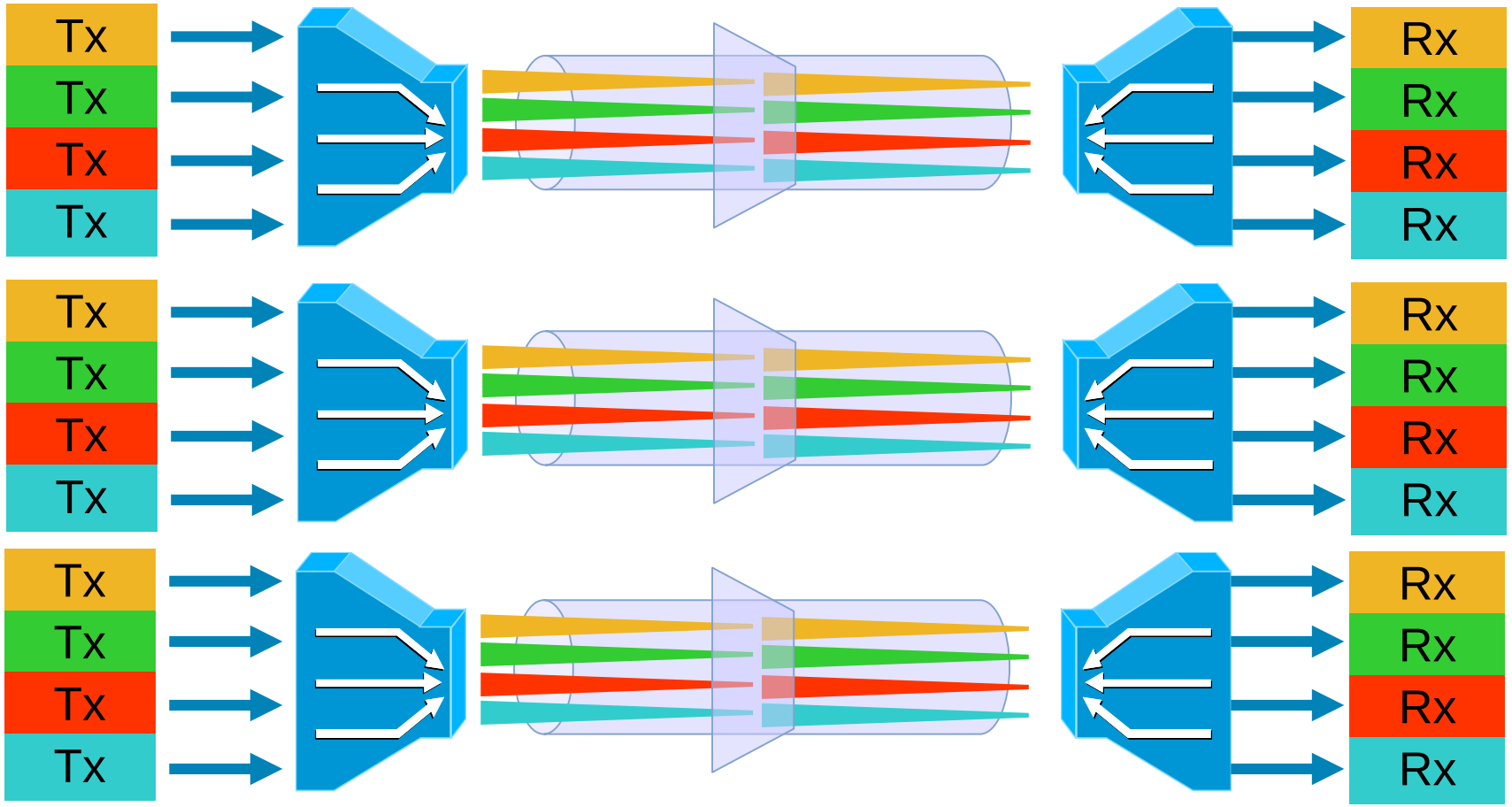
What are cost trends over the past 15 years?

Cost of 10 Gb/s-equivalent 1000km link
(two switch ports and circuit transport)



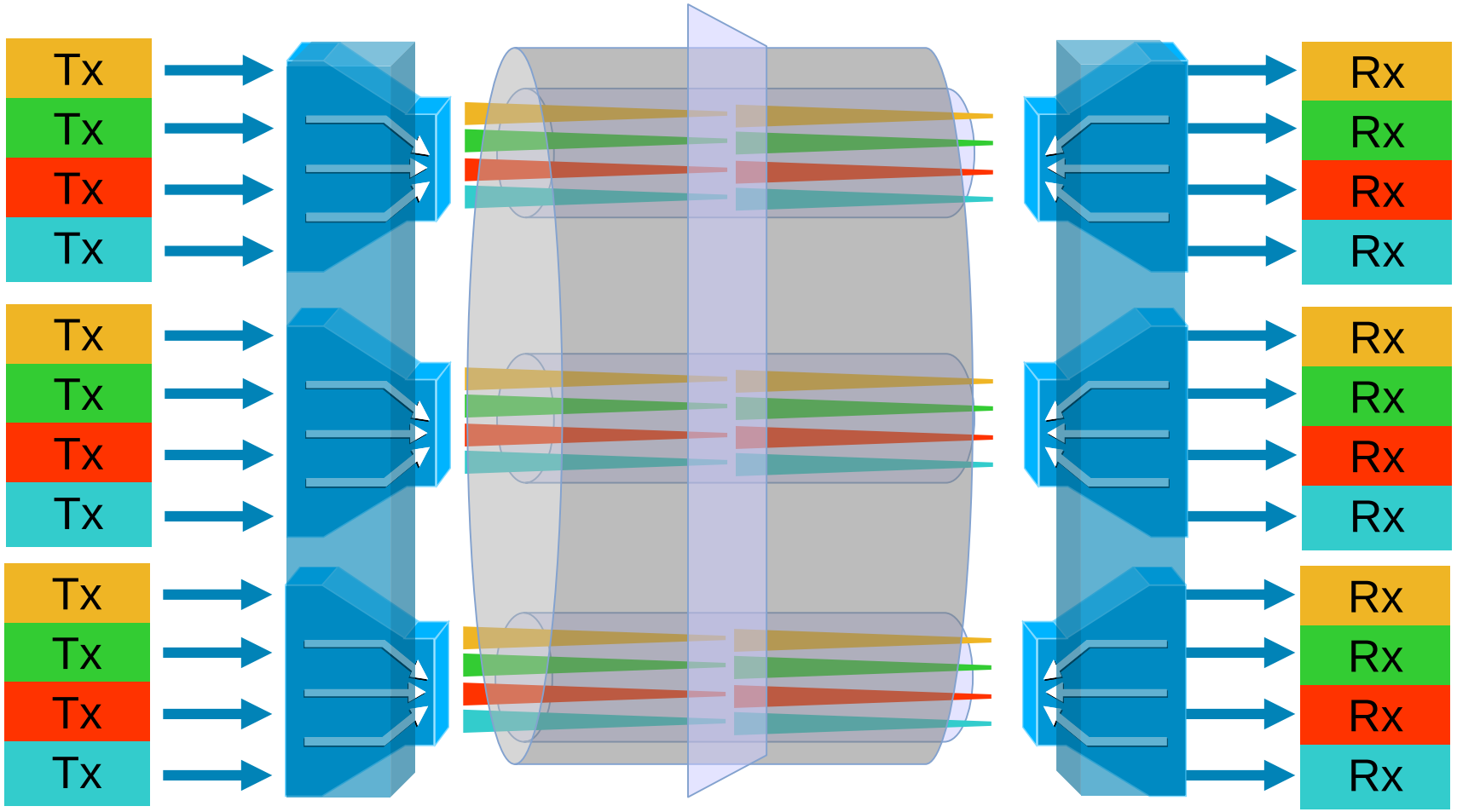
Fraction of total cost for electronic switching has been shrinking

Can SDM help?



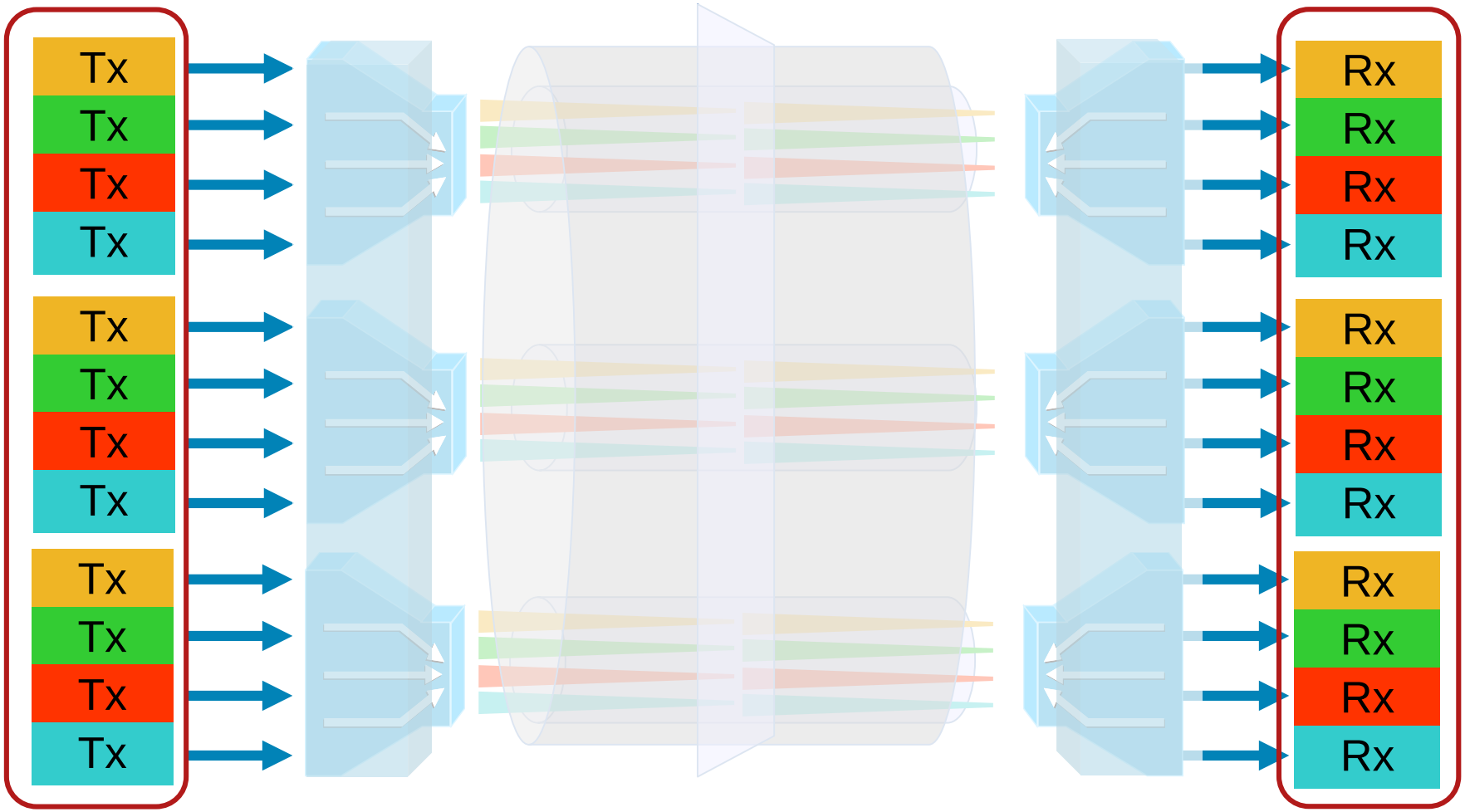
Parallel systems help challenge 2 but not challenge 3

Can SDM help?



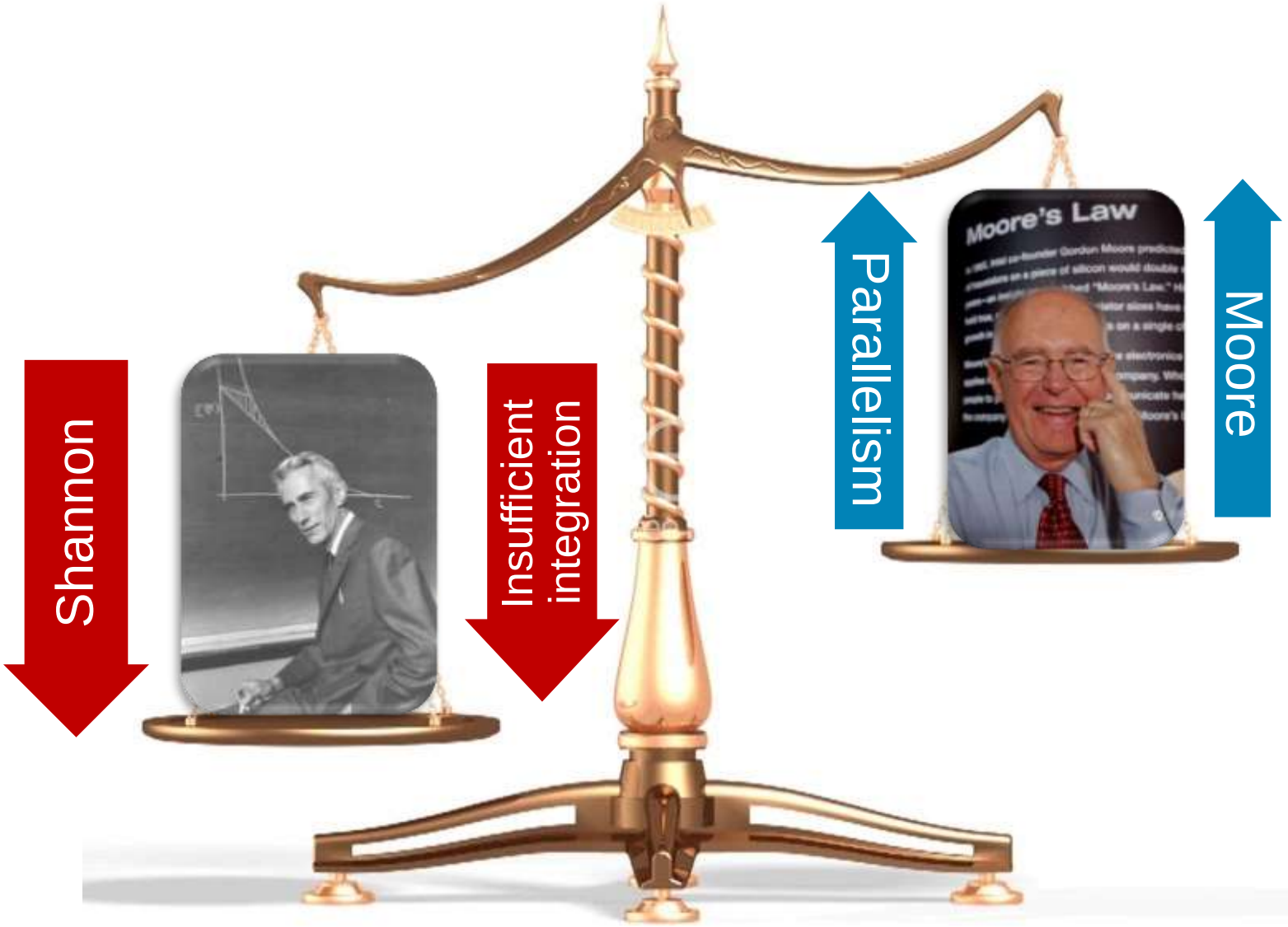
Multi-core fibers + amplifiers + ROADMs will help

Can SDM help?



But most of the power/cost is in Tx/Rx anyway…
Can they be integrated sufficiently to change the equation?

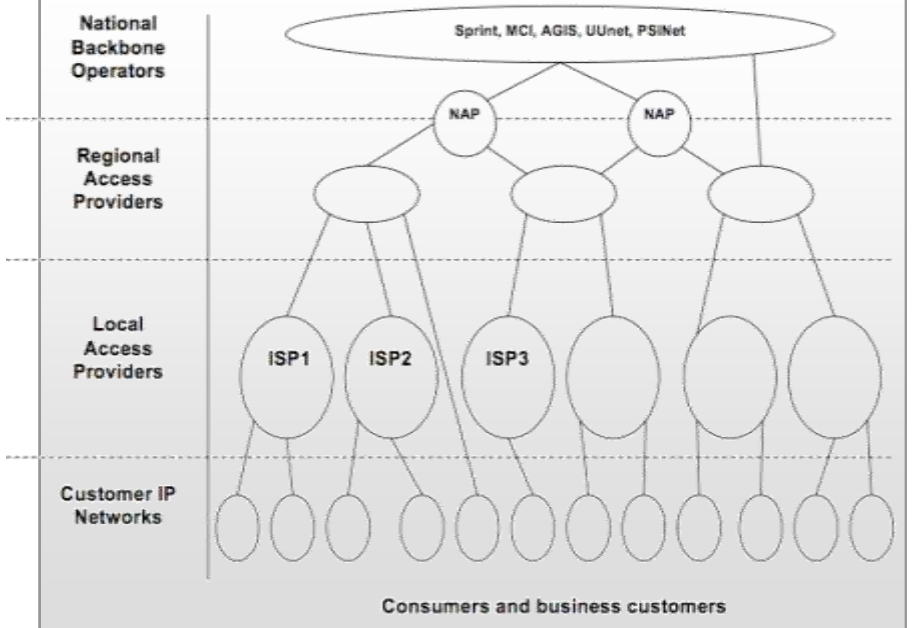
A note on Challenge 2 & Challenge 3



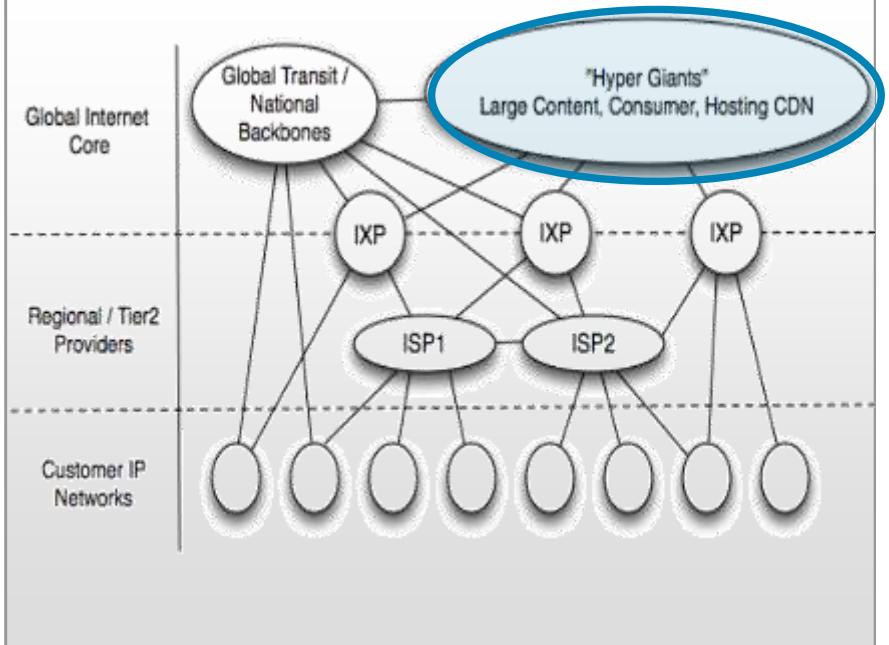
Challenge 4: Growing forecast uncertainty

Interactions between SPs and content providers are becoming more complex and change more often

The textbook Internet (1995-2007)

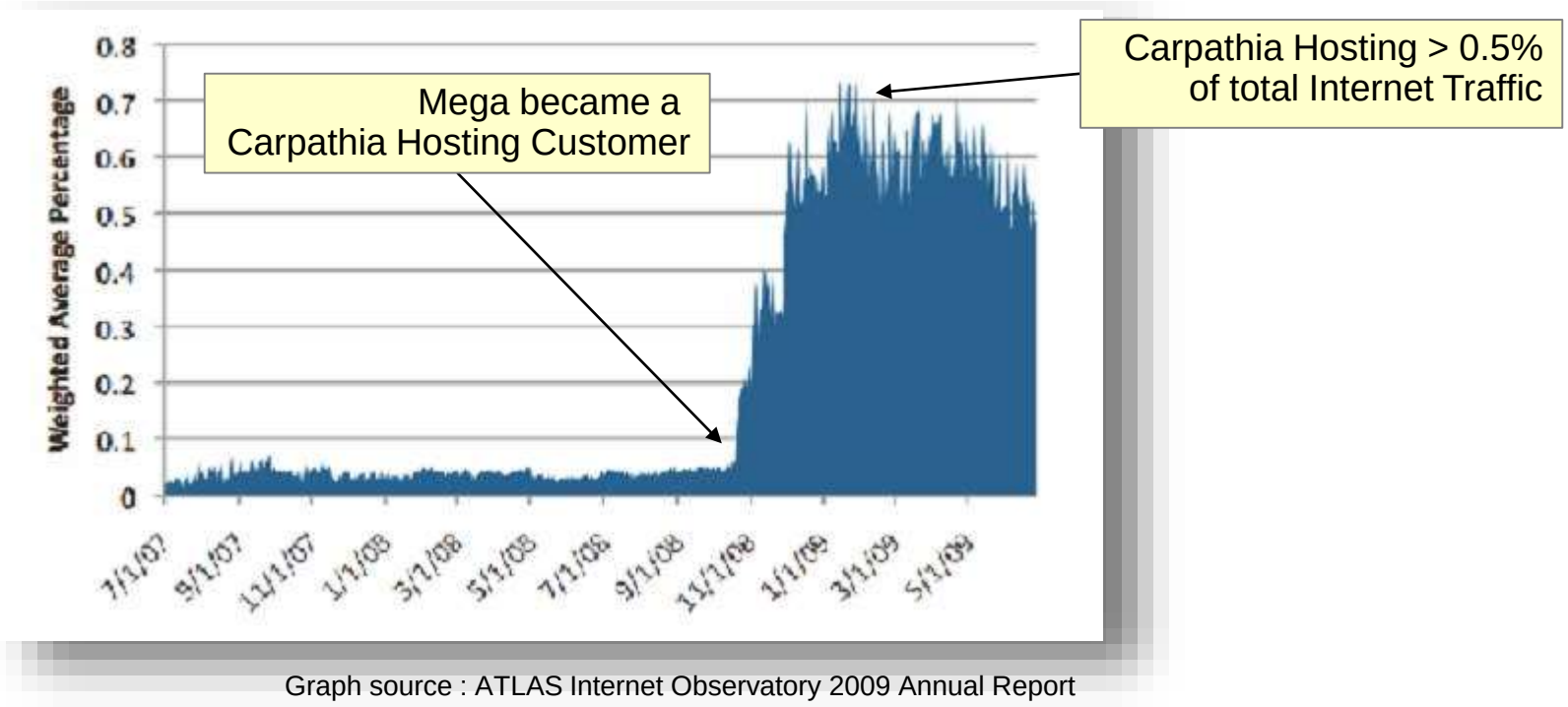


The new Internet (2009 --)



Source : ATLAS Internet Observatory 2009 Annual Report

Challenge 4: Growing forecast uncertainty



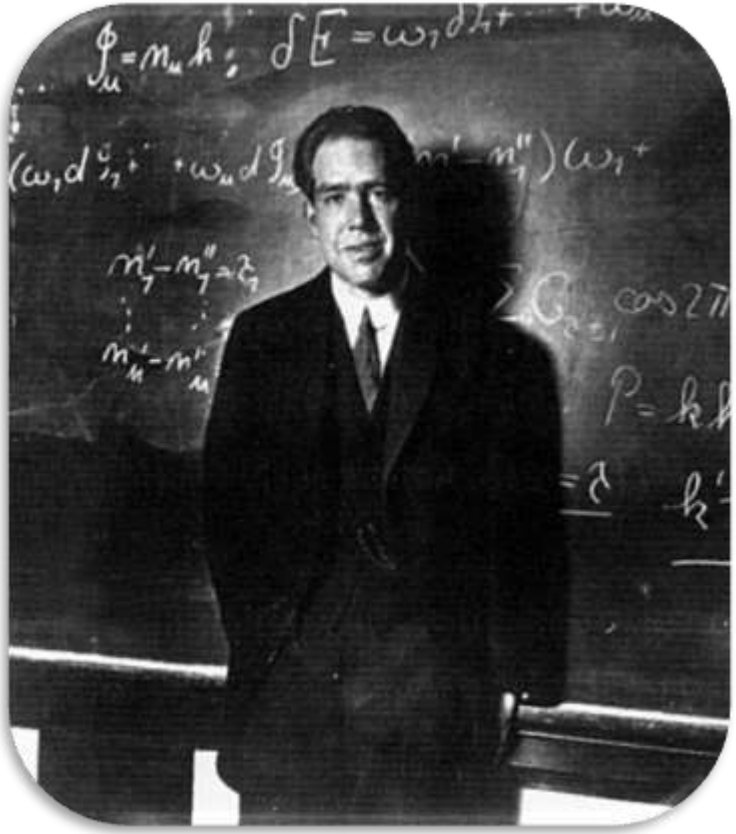
Graph source : ATLAS Internet Observatory 2009 Annual Report

- Reasons:
  - New content (who anticipated that Netflix will be 30% of the peak traffic?)
  - Changes in hosting arrangements
  - Changes in peering / transit set-up in the wider Internet
  - Failures in the wider Internet – changes entry points into SP network
  - Data Center workload shift internal / external to the Service Provider

A note on Challenge 4

Prediction is very difficult, especially about the future.

Niels Bohr



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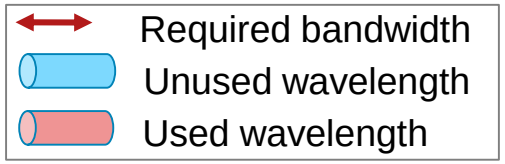
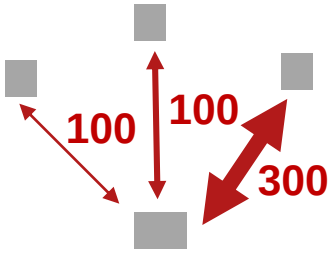
Agile optical networking

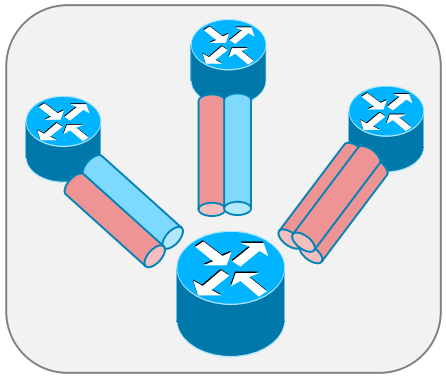


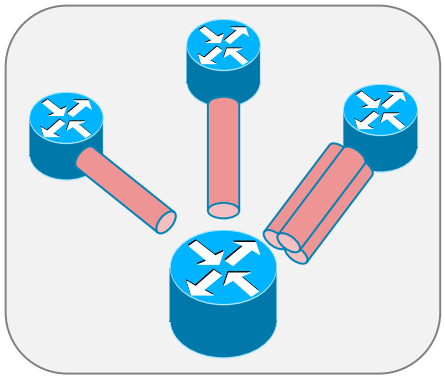
(a) non-agile solution:
7 wavelengths
=Sum(Max{Ai,Bi})

(b) agile solution:
5 wavelengths
=Max{Sum(Ai),Sum(Bi)}

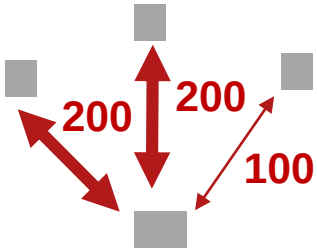
Scenario I:

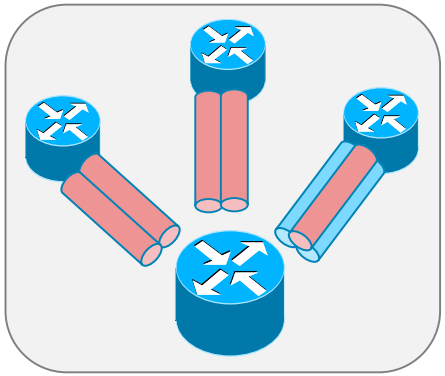


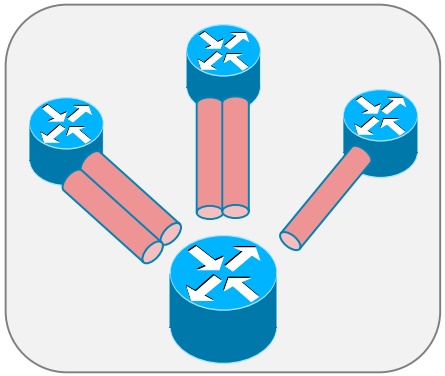




Scenario II:







Elastic Optical Networks
Flexible use of Spectrum

Rigid

40G — 50GHz slice

100G — 50GHz slice

400G — 4x50GHz slices

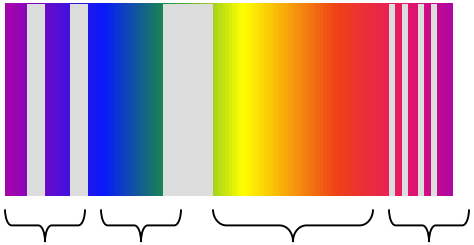
Elastic

40G — 25GHz slice

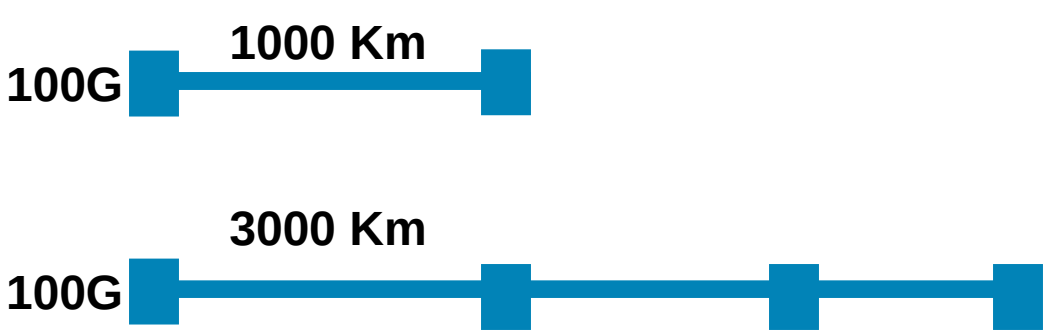
400G — 100GHz slice

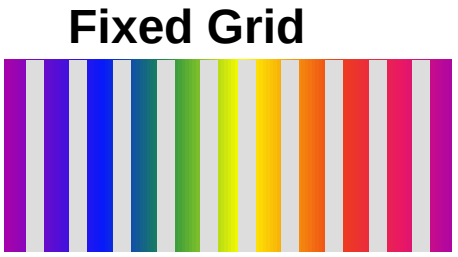
Fixed Grid

Flex Spectrum



Elastic Optical Networks
Adaptive Reach





- Current approach: the only way to extend the reach is to add regens
  - Regens → much higher CAPEX & OPEX
- What if only 30G are needed for the client layer?
  - Not only is the channel going to be under-utilized, it is also going to be unnecessarily regenerated…

Elastic Optical Networks
Adaptive Reach

Rigid

100G 1000 Km

100G 3000 Km

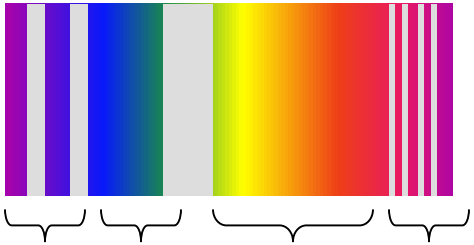
Fixed Grid

Elastic

30G 3000 Km sending less data

100G 3000 Km using more spectrum

Flex Spectrum



What this means to the IP layer?

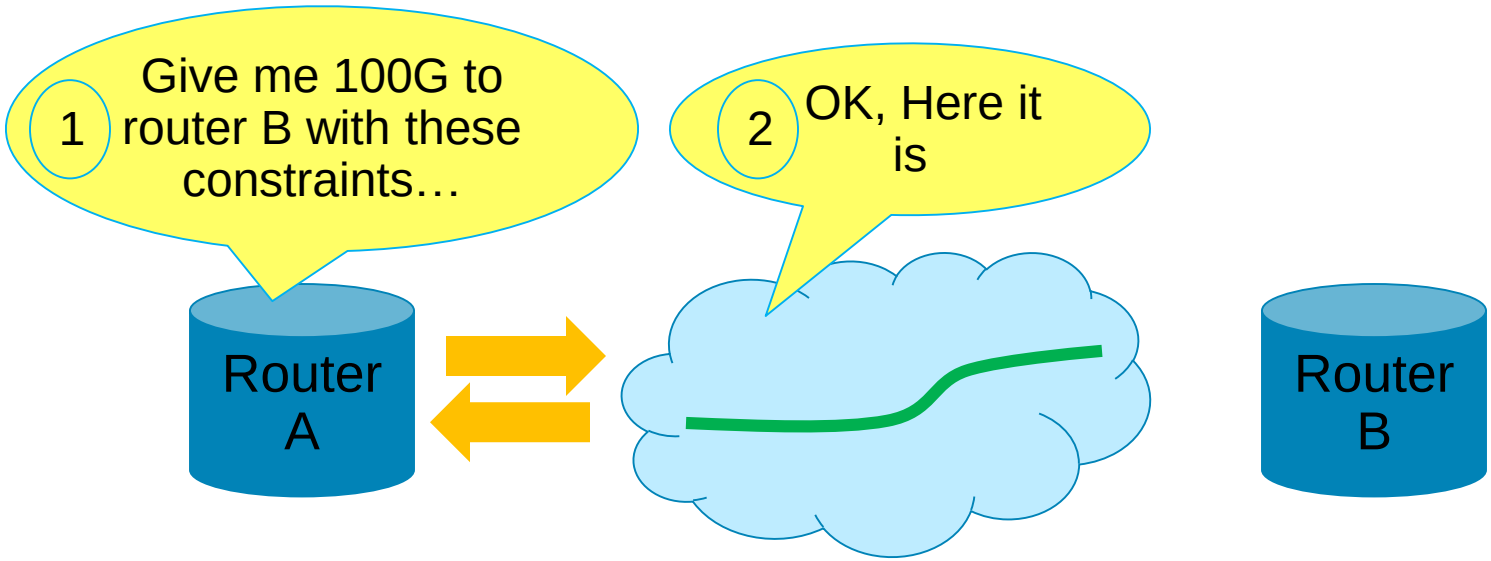
- In the past, routers focused on features, services etc.
  - Instead of managing capacity growth carefully, it was added liberally to avoid complex management
  - Optical capacity was considered nearly unlimited
- Since the optical layer is becoming the expensive and limited resource, the main optimization goal of the router may become to optimally use optical resources

What this means to the IP layer?

- Implications
  - The router must drive the requirements for optical connections
  - The optical layer will “right size” the link to the router needs
  - The router must be aware of the cost of the bandwidth on each link
  - The IP layer must add/remove optical connections based on traffic needs
  - More extensive use of traffic engineering in the IP layer, including bandwidth constraints

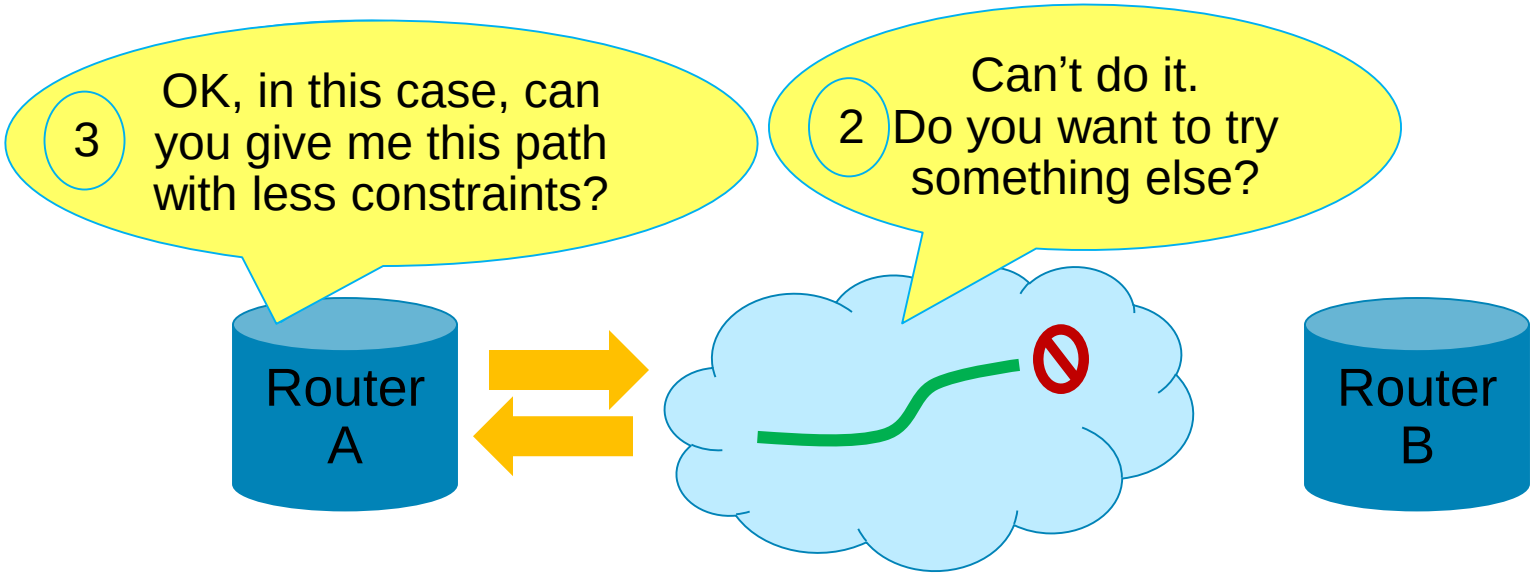
IP-optical interaction: Use case 1: “sunny day” scenario

- The routers know how much BW they need and what constraints they care about: e.g., latency, SRLGs
- The ON tries to satisfy the request at lowest cost, taking into account: TXPs used, regens used, spectrum used, distance, …
- It informs the router that the path has been established



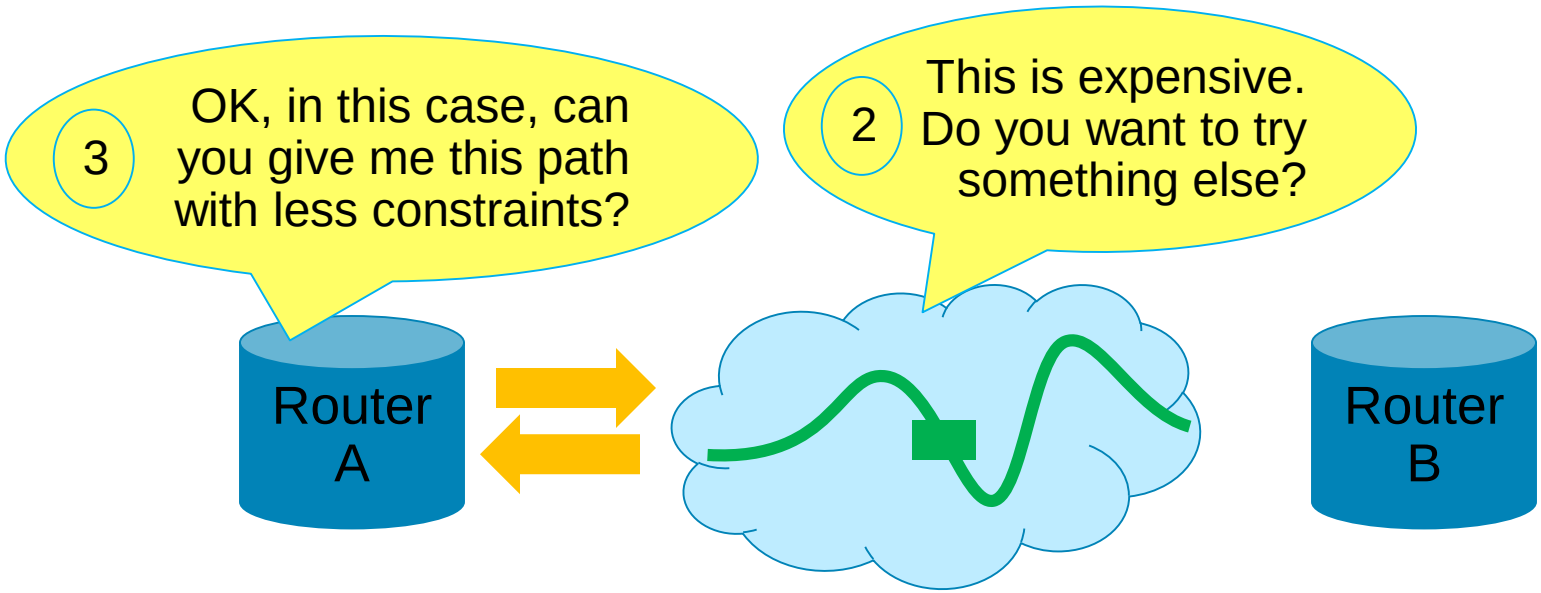
IP-optical interaction: Use case 2

- The ON cannot satisfy the request
- The ON informs the router and lets the router relax its constraints (higher latency, lower capacity,..)
- The router issues a new request, which hopefully can be satisfied



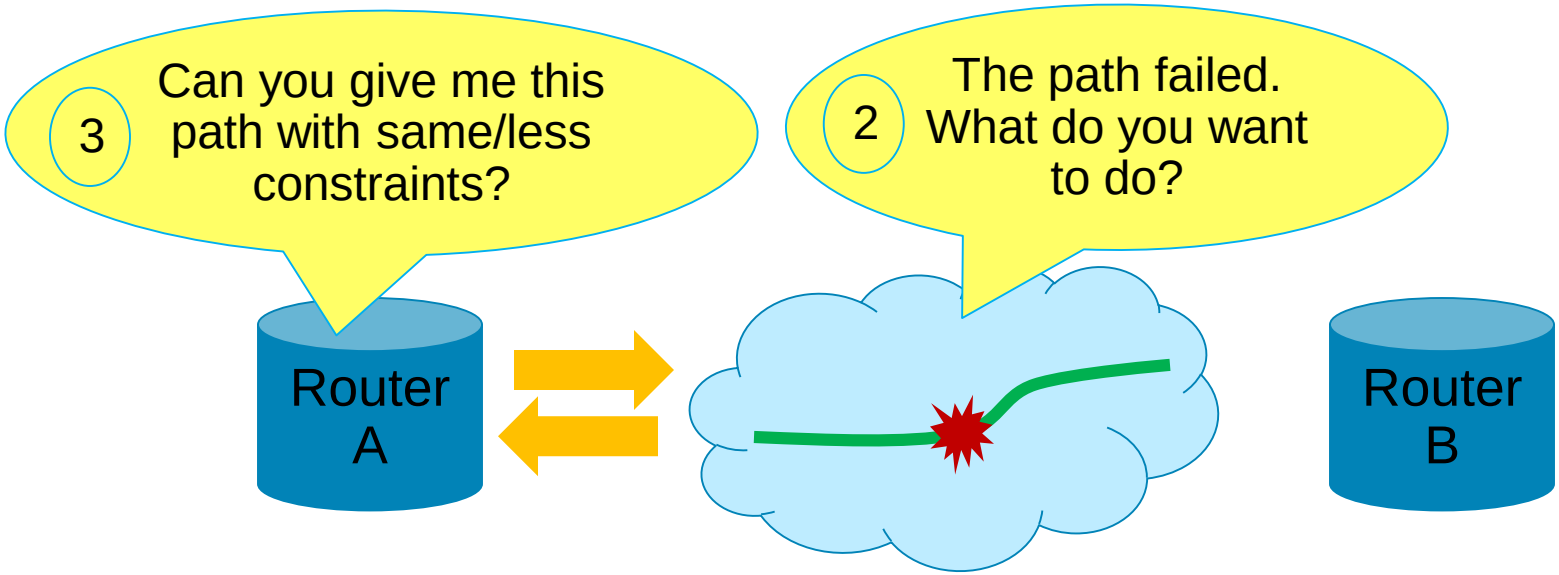
IP-optical interaction: Use case 3

- The ON can satisfy the request, but the cost is high (e.g., need regens)
- Should the ON inform the router and let the router relax its constraints?
- How does the ON know that there is a cheaper option? Or is this a blind search?



IP-optical interaction: Use case 4: restoration

- The original path failed. ON informs the router and receives a new path request from the router
- The new request can have the same constraints as the old request
- Or it may have a relaxed set of constraints (even less capacity)
- Or it may be unconstrained
- Or the IP layer may choose not to restore the path



Striking the right balance between distributed and centralized control

Striking the right balance between distributed and centralized control

Distributed control sweet-spot

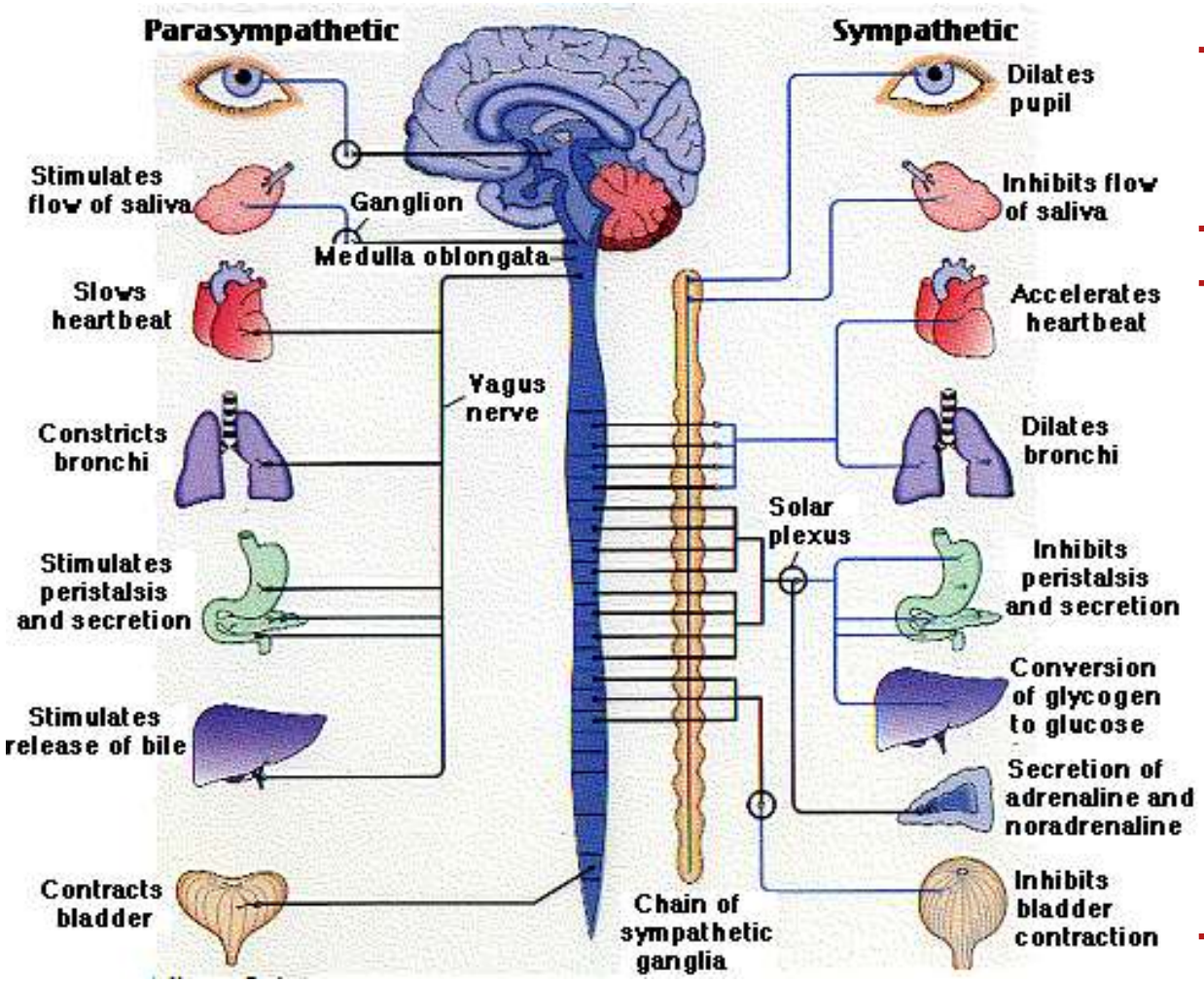
- Optimized for restoration
- Localized changes
- Good enough for customers with basic agility needs
- Highly survivable – even during large scale disasters
- Harder to extend

Centralized control sweet-spot

- Optimized for network optimization
- Global network changes
- Adds value for customers expecting advanced features
- Less available – unless significant complexity is added
- Ease of extending the code

A combination of both is needed for an optimal solution

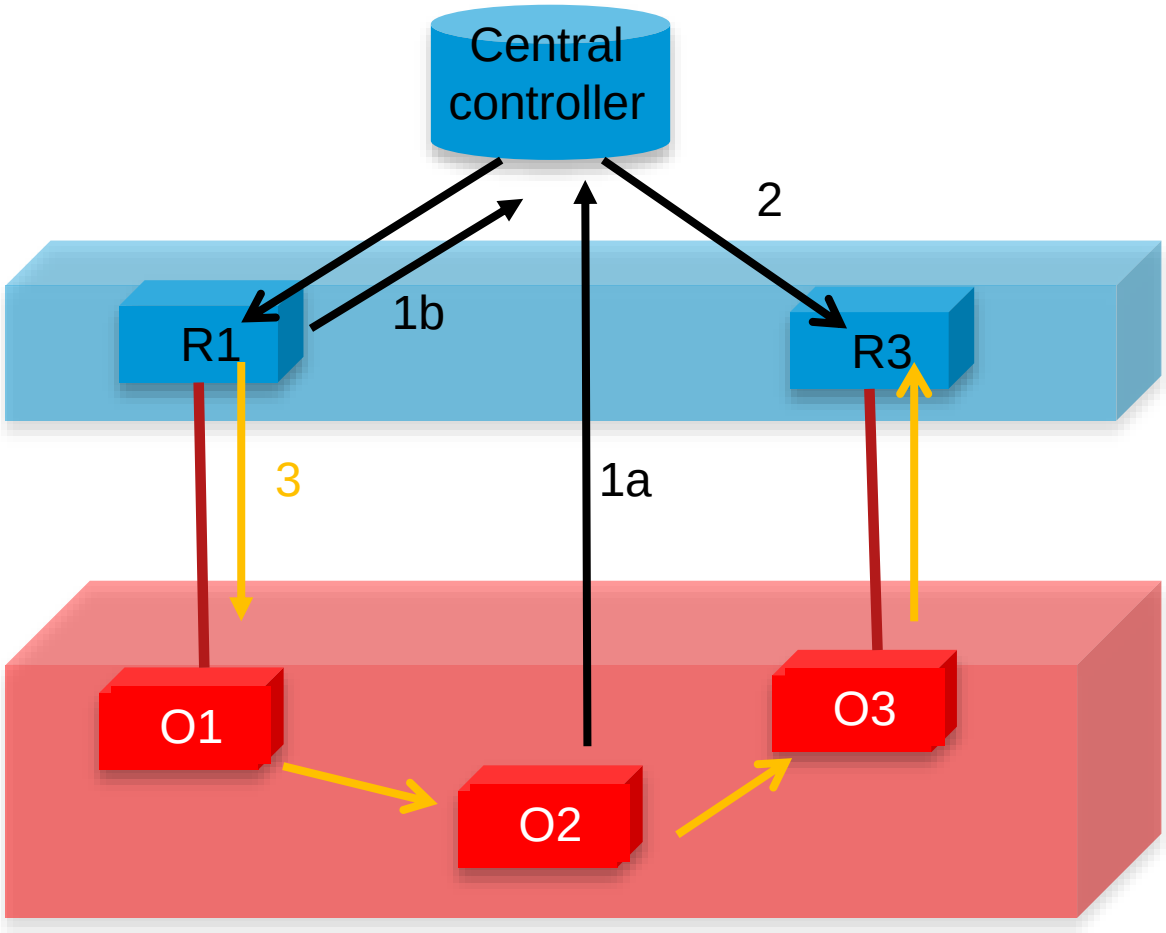
Striking the balance between distributed and centralized intelligence – not our invention…



Centralized control

Distributed control

Hybrid solution: Central decision + distributed execution



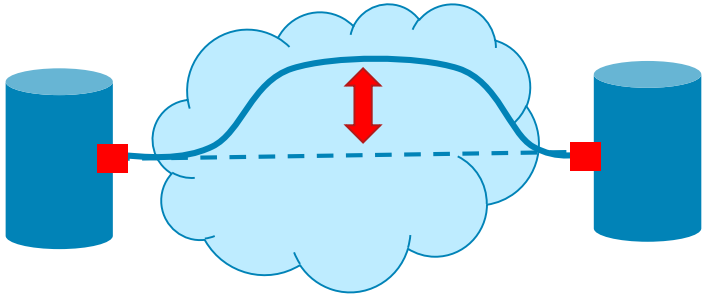
1. Central controller learns optical network from (a) Optical layer, (b) Routed Layer

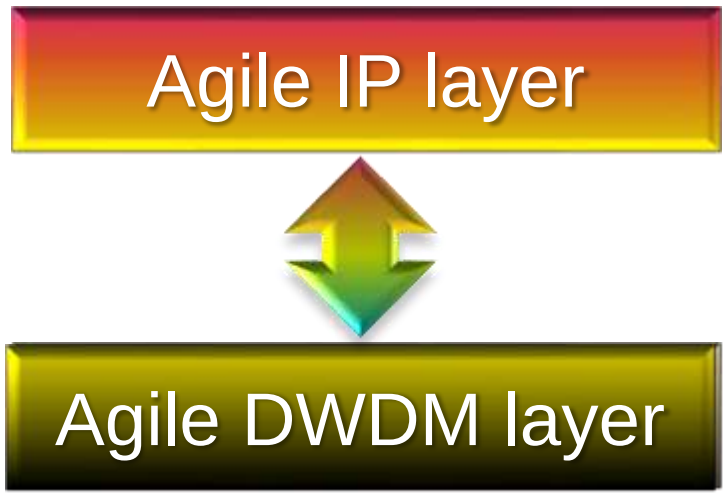
2. Central controller triggers creation of new link by provisioning the router with policies

3. GMPLS-UNI creates the optical circuit leveraging WSON

Basic multi-layer optimization

- The ability to hitlessly reroute optical paths helps both IP layer and optical layer



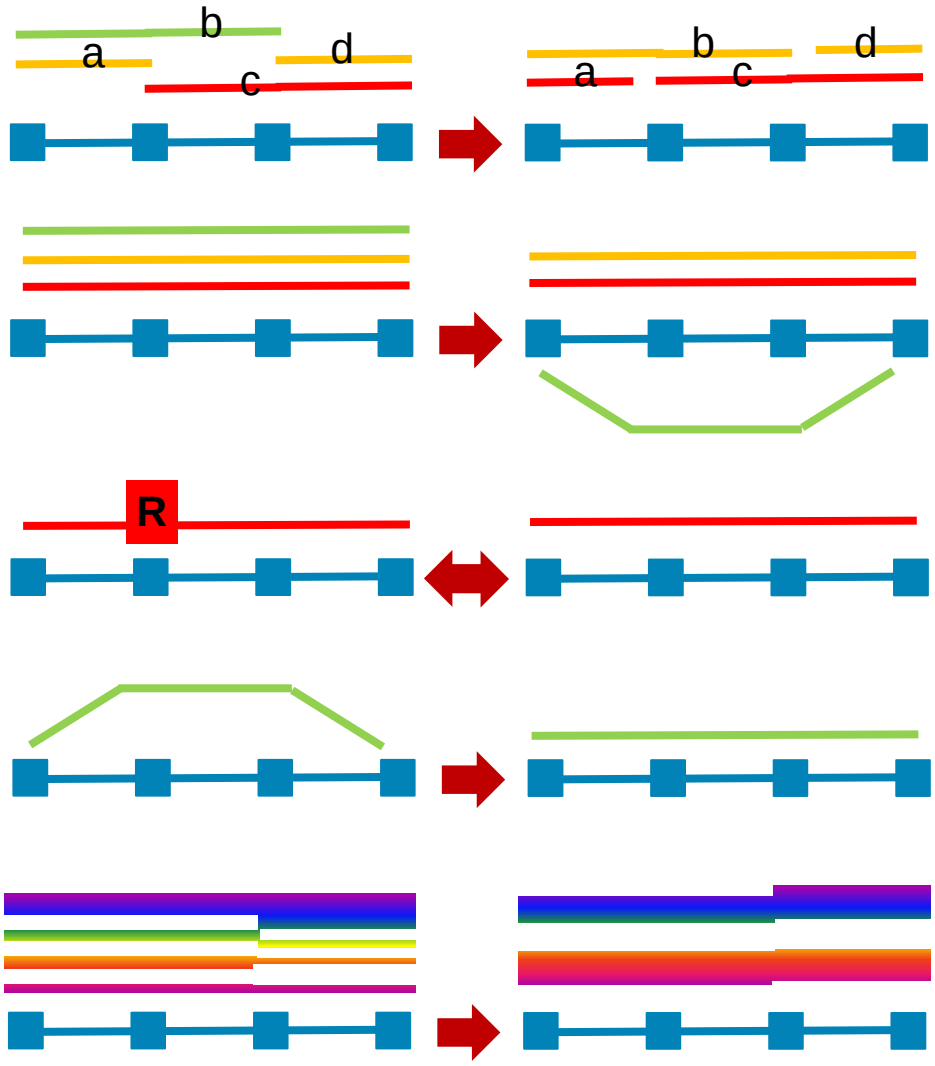


Improving the IP layer:
- Reduce link latency
- Improve link diversity

Improving the optical layer:
- Reduce path distance
- Reduce regens
- Reduce congestion

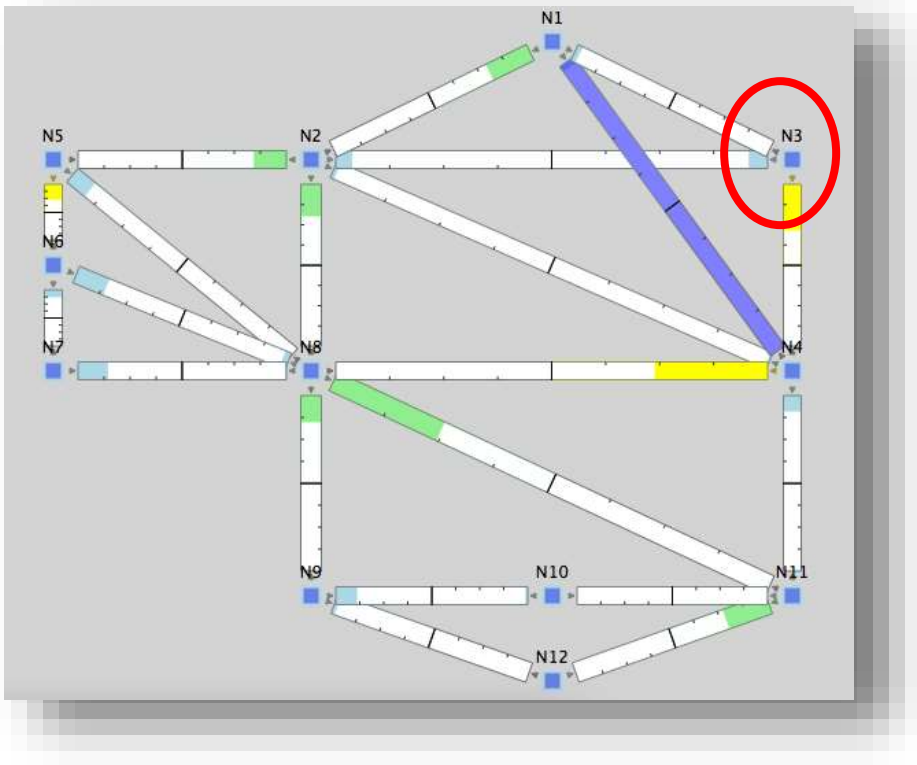
What can be re-optimized in the optical layer?

- Reduce stranded BW
- Reduce congestion on opitcal link
- Remove regen
- Reduce path length to improve latency, combat aging
- Redistribute spectrum (critical for FlexSpectrum)



How can the IP layer be reoptimized?

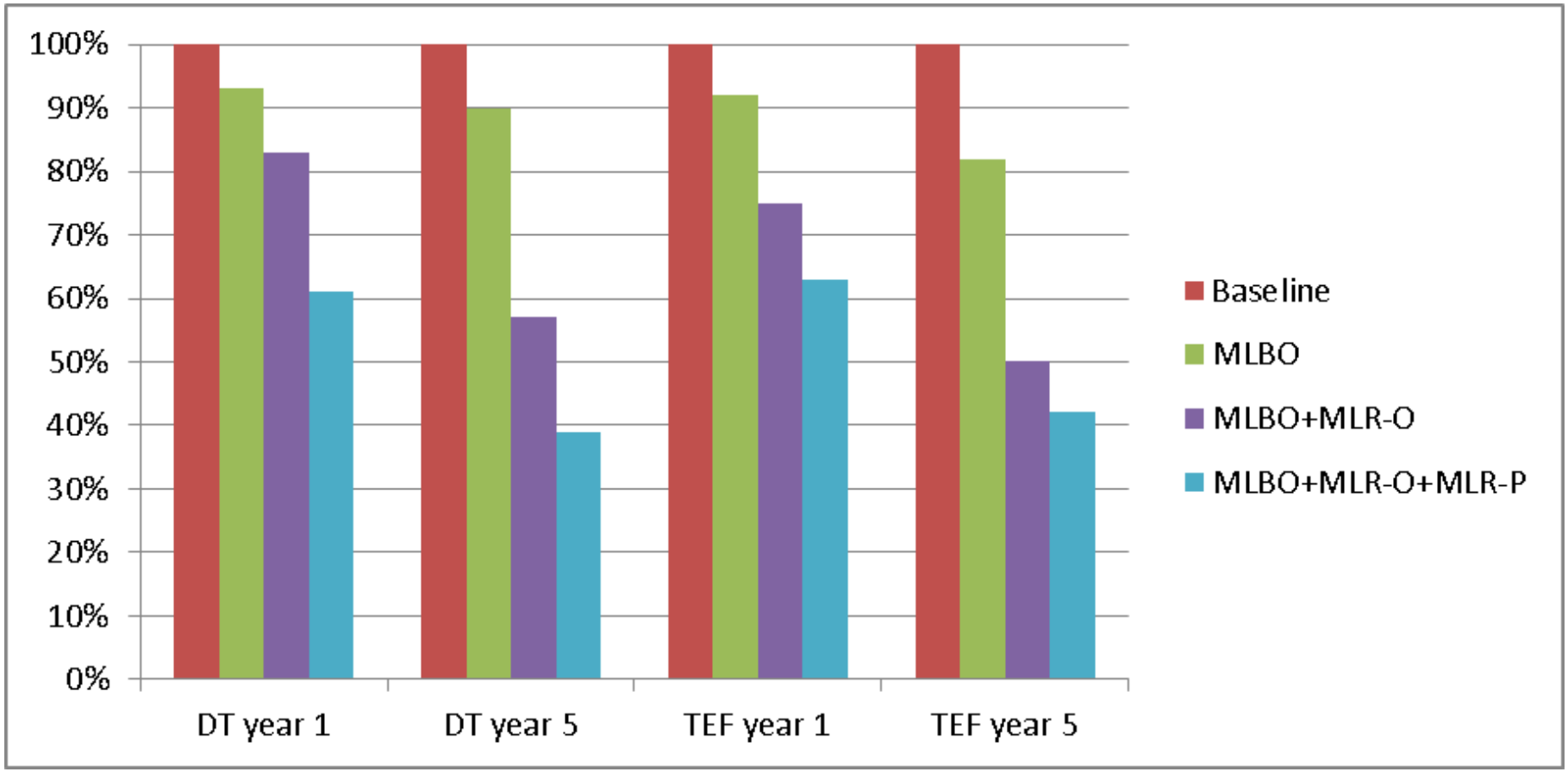
- Should the purple link be added to bypass router N3?
- Not simple to answer – it depends…
  - On the end to end IP traffic
  - On the routing metric assigned to the link
  - On use of IP load balancing
  - On share risks between the new link and existing ones
  - On protection capacity elsewhere



This requires centralized ML SDN that know the entire network

Striking the right balance between distributed and centralized control

Quantifying the savings



[To be published in IEEE Comm. Mag., 1-2/2014]

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Summary

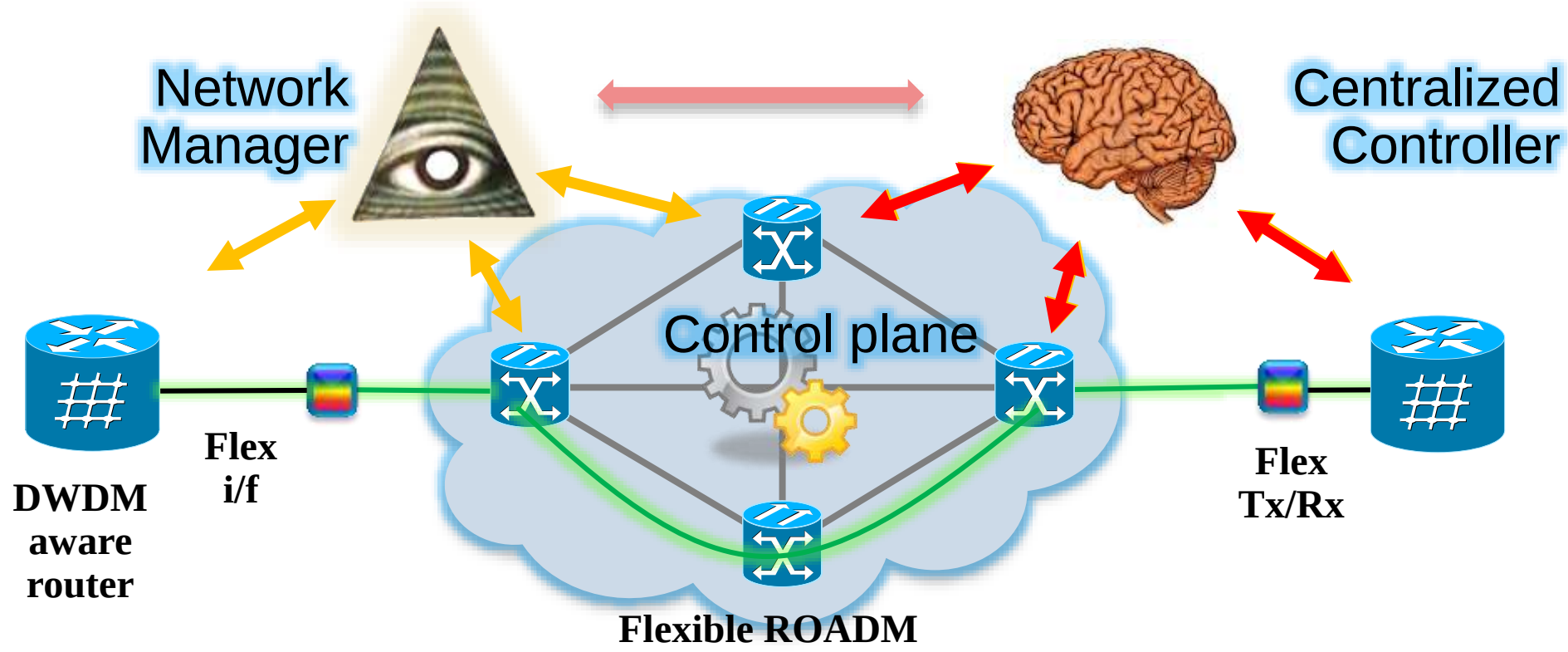
In the past

- Fixed optical layer design
- Network flexibility achieved thru IP layer
- Distributed control in IP layer
- No optical control plane
- Decoupled operation between layers

In the future

- Agile and elastic optical layer
- Both layers collaborate to achieve required flexibility
- Both distributed and central control for IP layer
- Both distributed and central control for optical layer
- Strong multi-layer networking via distributed and centralized control

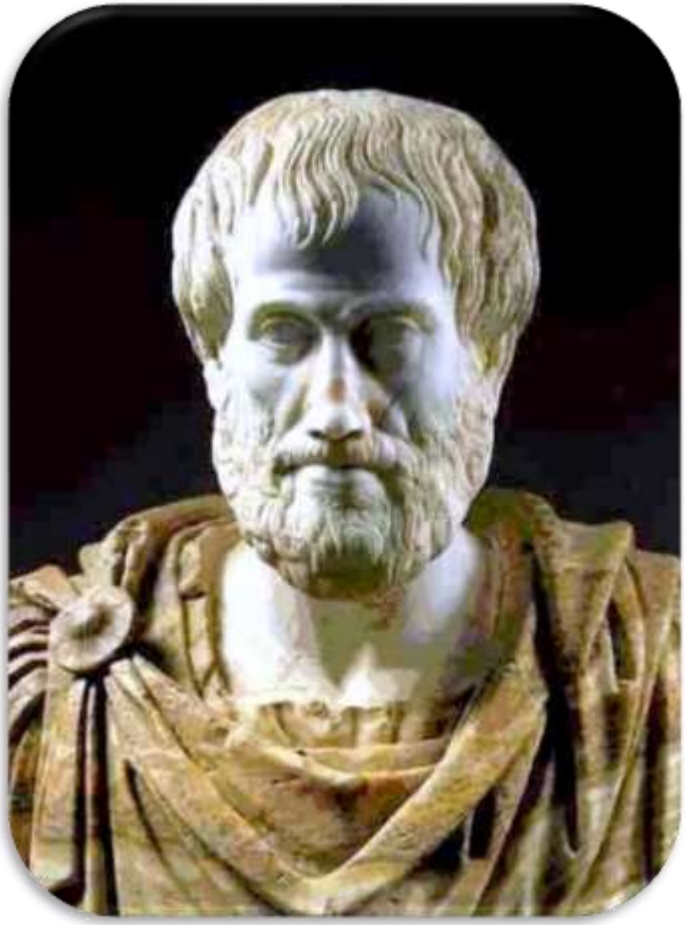
The ideal converged network of the future



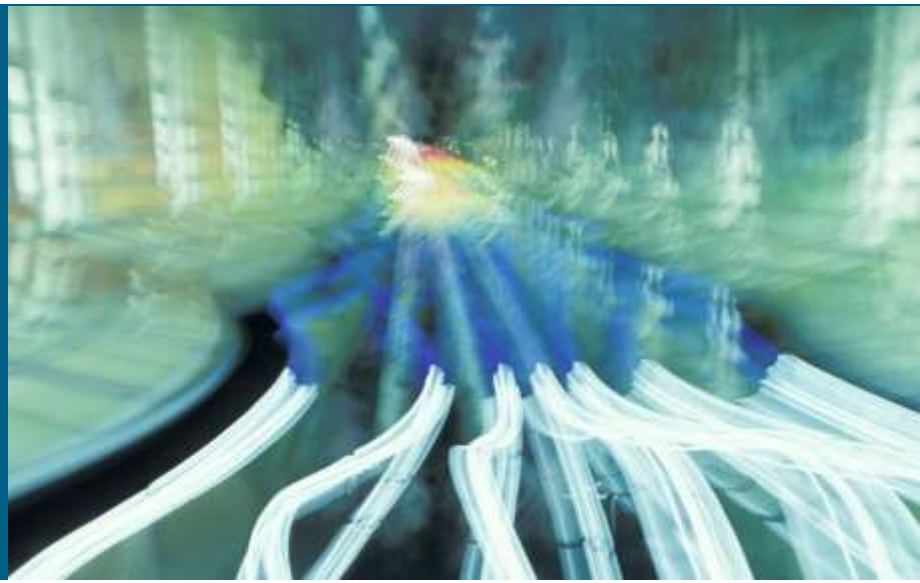
A final note on IP-optical collaboration

The whole is greater than the sum of its parts

Aristotle



Thank You!



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