ADVA™
Optical Networking

Cloud Computing:
The Optical Perspective

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Control Plane R&D
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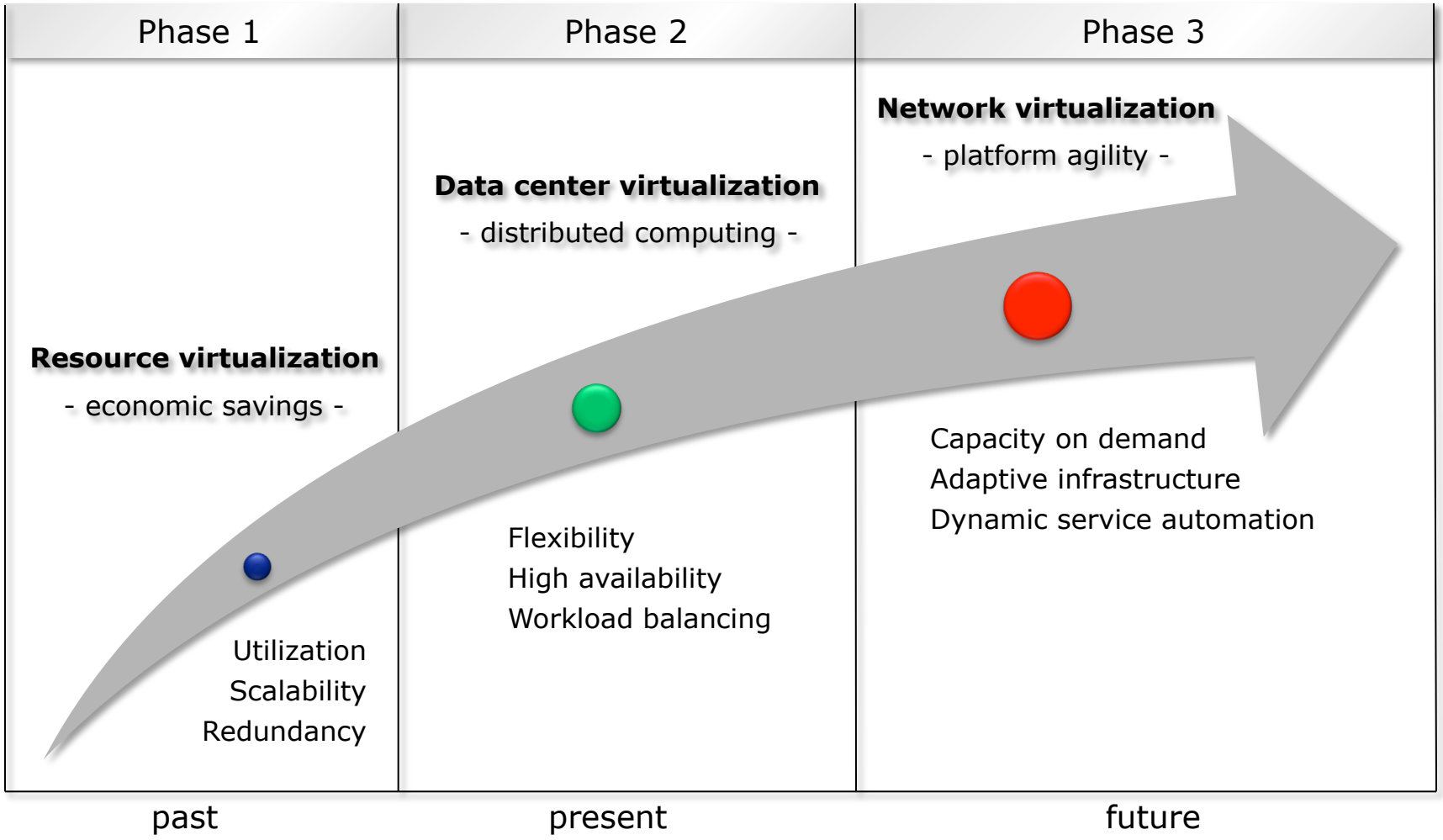
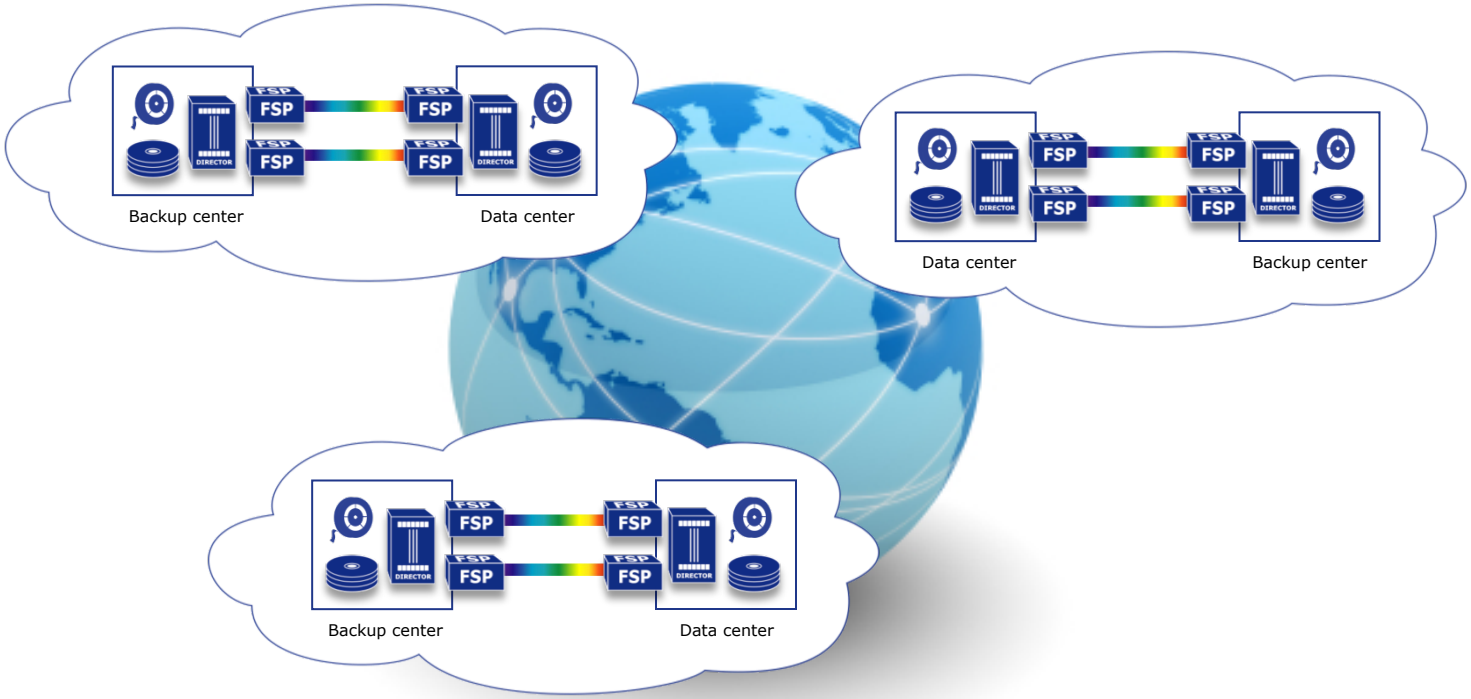
Evolution of Cloud Architectures



Resource Virtualization

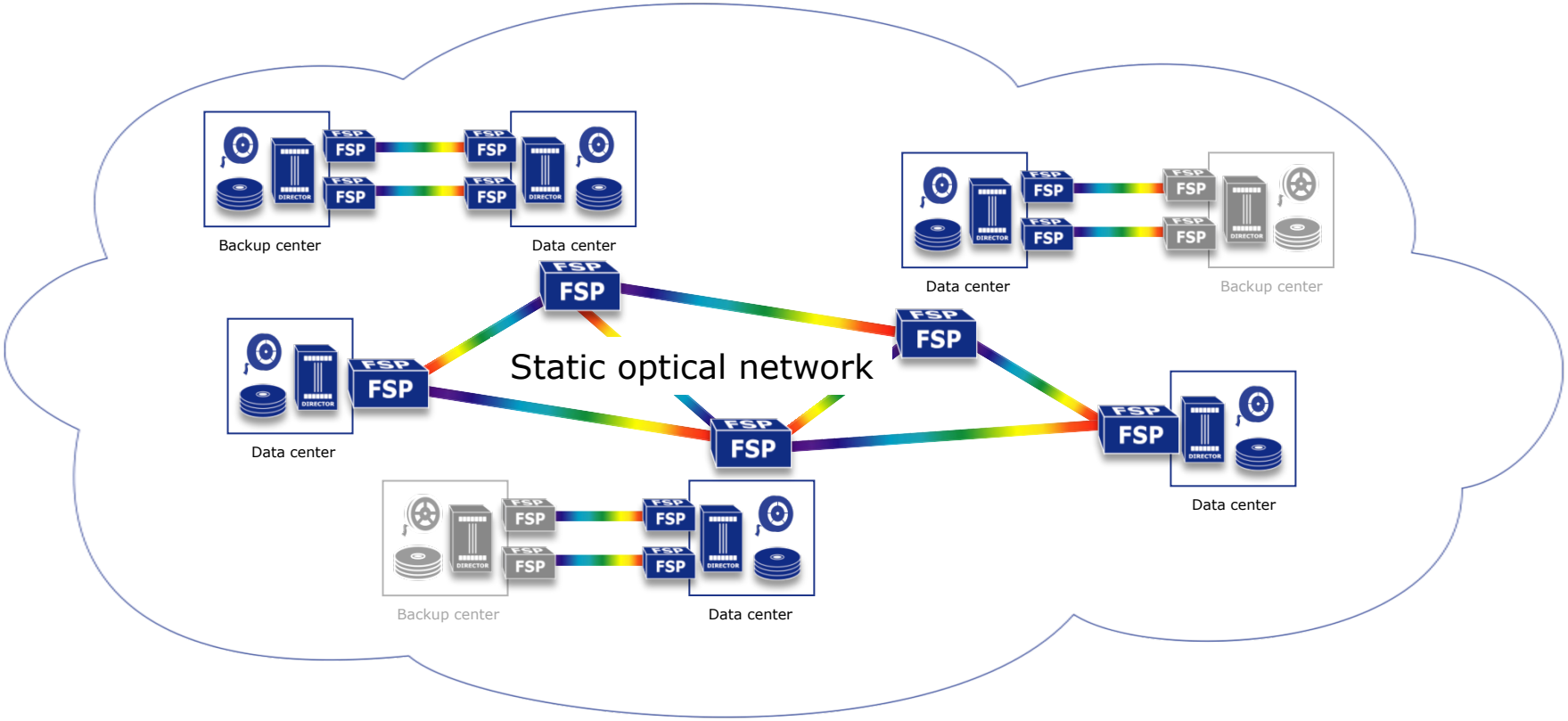


Server and storage clustering for increased efficiency inside the data center

Desired Network Attributes

- Cheapest bit/s transport
  - xWDM maximizes fiber throughput
- Protocol flexibility
  - Interfaces ranging from 10Mbit/s to 100Gbit/s
- Lowest latency
  - Transparent wavelength conversion
  - SAN: Save expensive buffer credits
- Single-span performance
  - Up to 200km without mid-span amplification
- Seamless integration
  - Full set of SAN equipment vendor qualifications

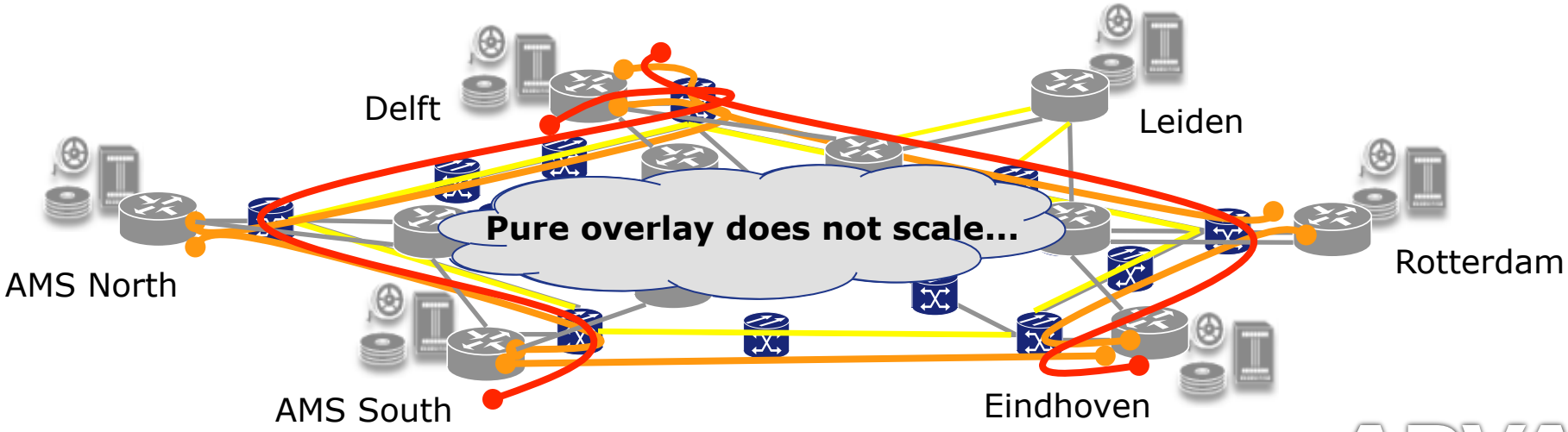
Data Center Virtualization



High-speed inter-connection of cloud facilities for infrastructure flexibility

Data Center Interconnect

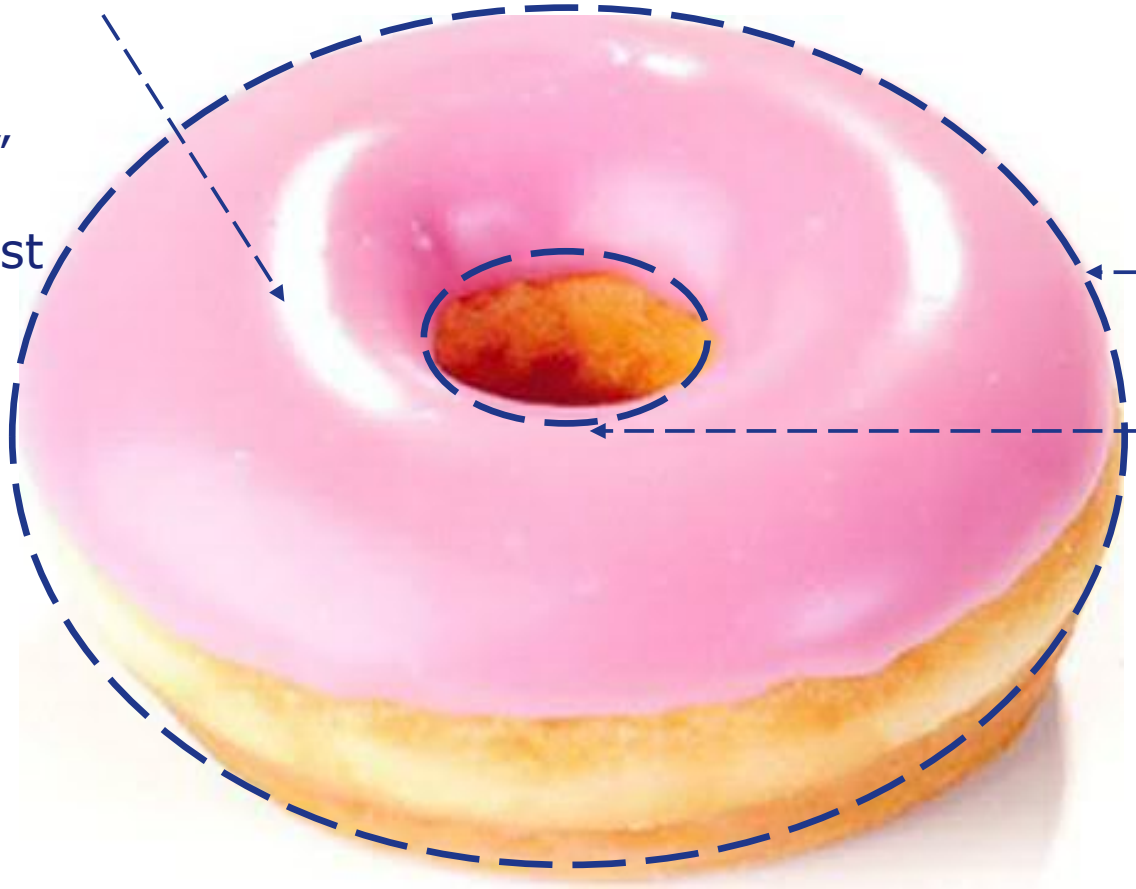
- Data Center Interconnect split into two layers: Packet & Optical
  - Packet Service Layer (L2/L3 DCI)
    - Various technologies: x-VPLS, OTV, TRILL, IP/MPLS, etc.
    - Provides various services directly to clients
    - Provides infrastructure to Cloud/CDN applications
    - Focus on client functionality (VM live migration support, virtualization, etc.)
  - Optical Transport Layer (overlay model)
    - WDM transport elements, ROADMs, regenerators, amplifiers
    - Provides point-to-point wavelength services to Packet layer
    - Enables cheap optical bypass for data center transit where needed
    - Focus on cheapest bit/s transport between 2 endpoints



Data Center Interconnect
L2/L3 + overlay VPN integration: The Donut

Optical switching:

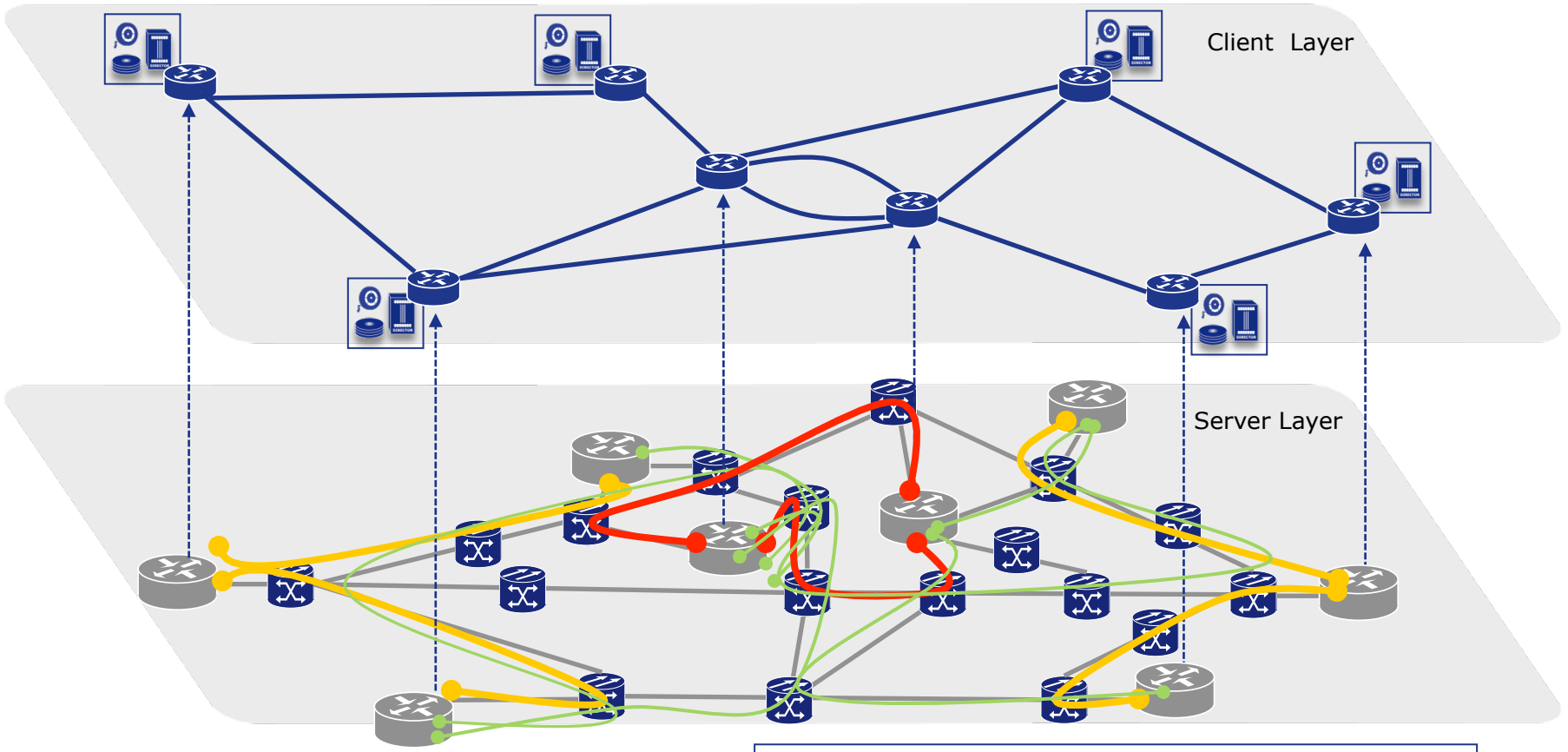
- Donut's „contents"
- Lowest cost for bit/s
- Connects rings



Electrial switching:

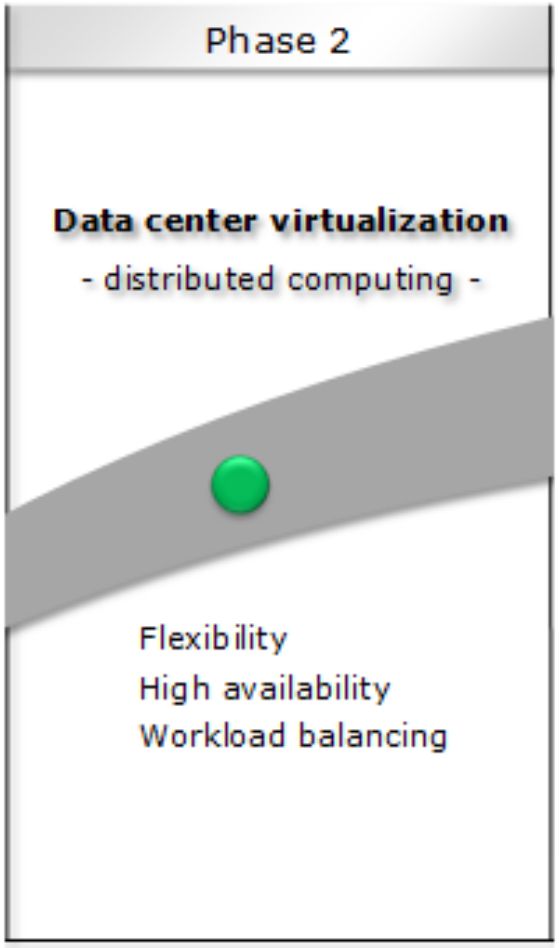
- Most flexible
- Outer ring: Data Centers (PE routers)
- Inner ring: Redistribution (P routers)
- Only at the edges

Data Center Interconnect:
Traditional Layering Concept



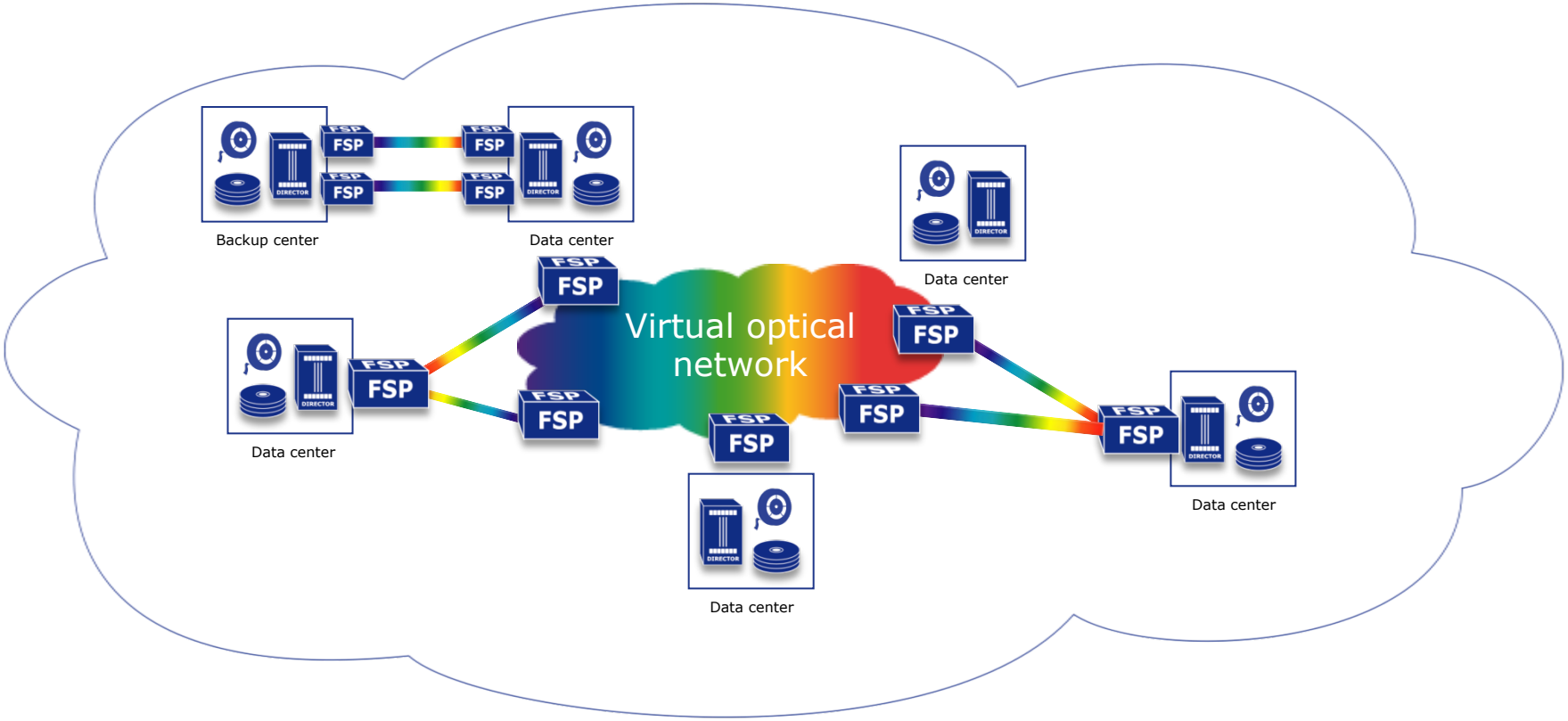
Connections in Server layer network create Links in Client layer network

Desired Network Attributes



- Long reach
  - 2000km non-regenerated transmission
- Efficient mesh networking
  - Multi-degree ROADM implementation
  - Optical switching cost is neglible
- Fast provisioning
  - Tunable optical layer and service management
  - (optional) Homogenous control plane for service activation
- Ubiquitous solution
  - Single platform for all transport applications
- High availability
  - 1+1 service protection + restoration (if CP used)
  - Protects against multiple failures

Network Virtualization

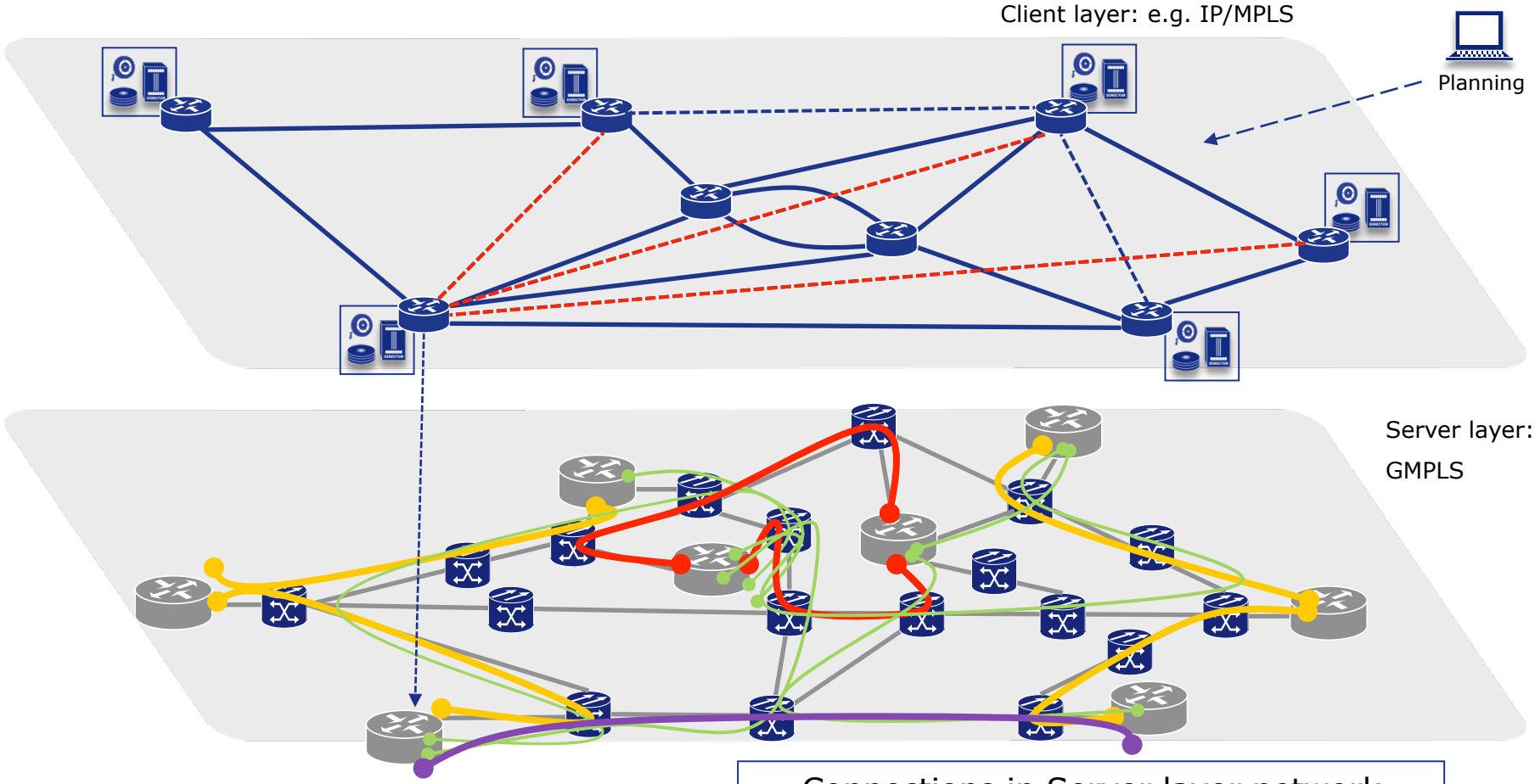


Dynamic network resource allocation for cloud services agility

Virtual Network Topologies

- Abstract representation of a real network
  - Built from virtual components – virtual links, virtual nodes
- Purpose: Abstraction
  - Represent multiple real components as a single virtual component
    - Example: represent domain A as single virtual node in domain B
- Purpose: Adaptation
  - Represent server layer network capabilities in client layer network
    - Example: expose a lambda connection as a link in a packet topology
- Purpose: Activation
  - Coordination activation of capabilities across layers, domains
    - Example: server layer connection activated during client layer signaling
- Virtual Topologies are generally planned
  - VNTs created during application planning process
    - Prior to service provisioning, ongoing over lifetime of network
  - Represent "potentialities" of the real network
    - E.g. what real connectivity "can" be, when requested

Data Center Interconnect:
Virtual Topology Concept



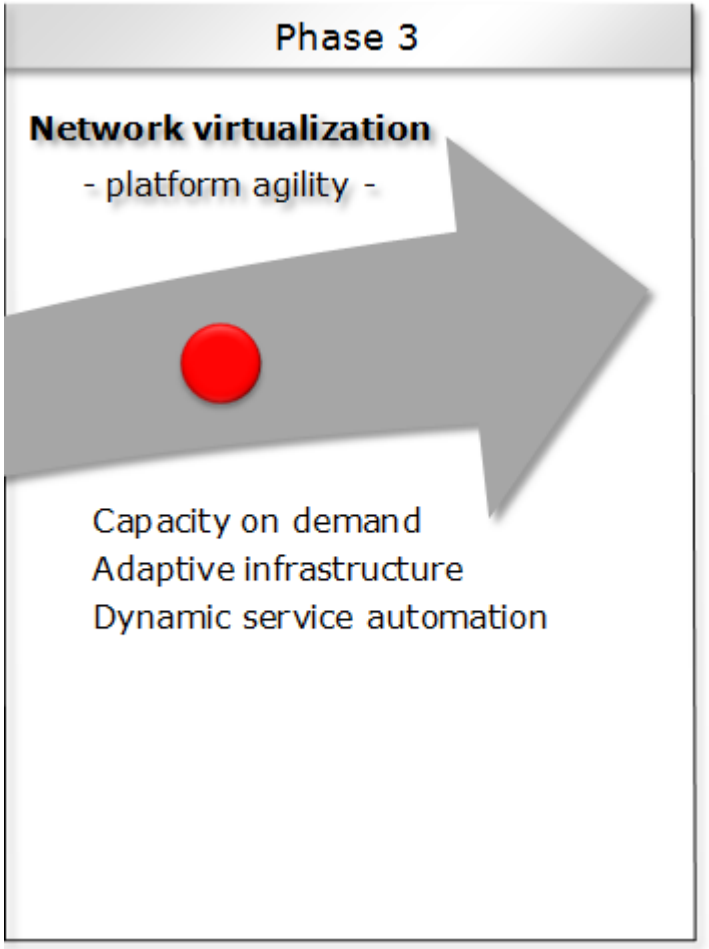
Virtual Links

- Represent "potential" connectivity in a topology
  - Entered into standard Traffic Engineering databases (TEDB)
    - Standardized TE extensions to regular IGP routing
    - Advertised into client TE routing, standard LSA formats/TLVs
    - Annotated with standard TE attributes (metric, bandwidth, etc)
    - Essentially indistinguishable from normal "real" TE links
  - Server network resources not committed to virtual link
    - E.g. bandwidth/wavelength not committed until link is used
  - Made available to path computers in the client network
    - PCE computes paths using links in TEDB, real or virtual
- When link is used …
  - E.g. when signaling in client network traverses a virtual link
    - Server network control plane is activated
    - Server network connections provisioned to commit resources
    - If successful, signaling in client network allowed to proceed
- Virtual links coordinate information, activation across networks

GMPLS Overlay

- GMPLS UNI/ENNI
  - Interoperable service activation across layers and domains
- Precursor: RFC4208
  - Defines the overlay network model, concepts
  - Outlines multiple scenarios, options, mechanisms
  - Initially issued in 2005, considerable experience since then
- Update: draft-beeram-ccamp-gmpls-uni-bcp
  - Presents "best current practice" for utilizing RFC4208
  - Derived from specific experiences, lessons learned
    - Multi-layer activation, use of virtual topologies
    - Label signaling across technologies
    - Coordinating administrative status
    - Routing updates to support virtual nodes
    - Handling of generic constraints
    - Macro SRLGs, MELGs
    - L1VPNs
- Alternative: OIF UNI2.0

Desired Network Attributes



- Fast provisioning
  - Tunable optical layer and service management
- Highest capacity
  - 50GHz grid with up to 100Gbit/s per wavelength
- Enhanced flexibility
  - Directionless and colorless optical switching
  - (optional) gridless optics
  - 2000km non-regenerated transmission
- Automated configuration
  - mature GMPLS control plane implementation
  - The difference in provisioning time
  - Furthetrenhances flexibility of the optical network
- Virtual bandwidth
  - Inter-layer intergration mechanisms: e.g GMPLS UNI, OIF UNI
  - Multi-layer service recovery: SRLGs, MELGs
  - Virtualization of optics: L1VPNs

Thank you

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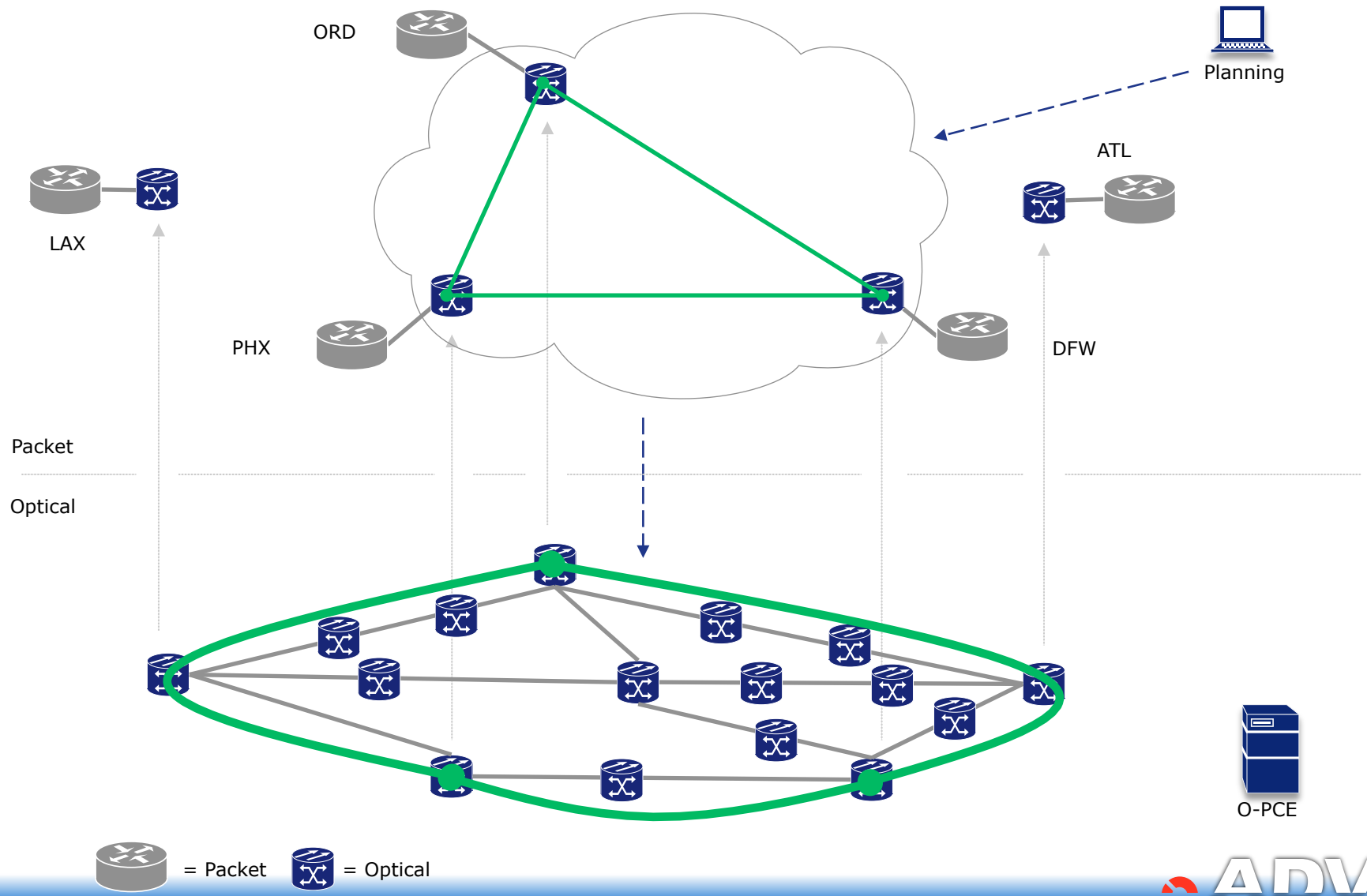
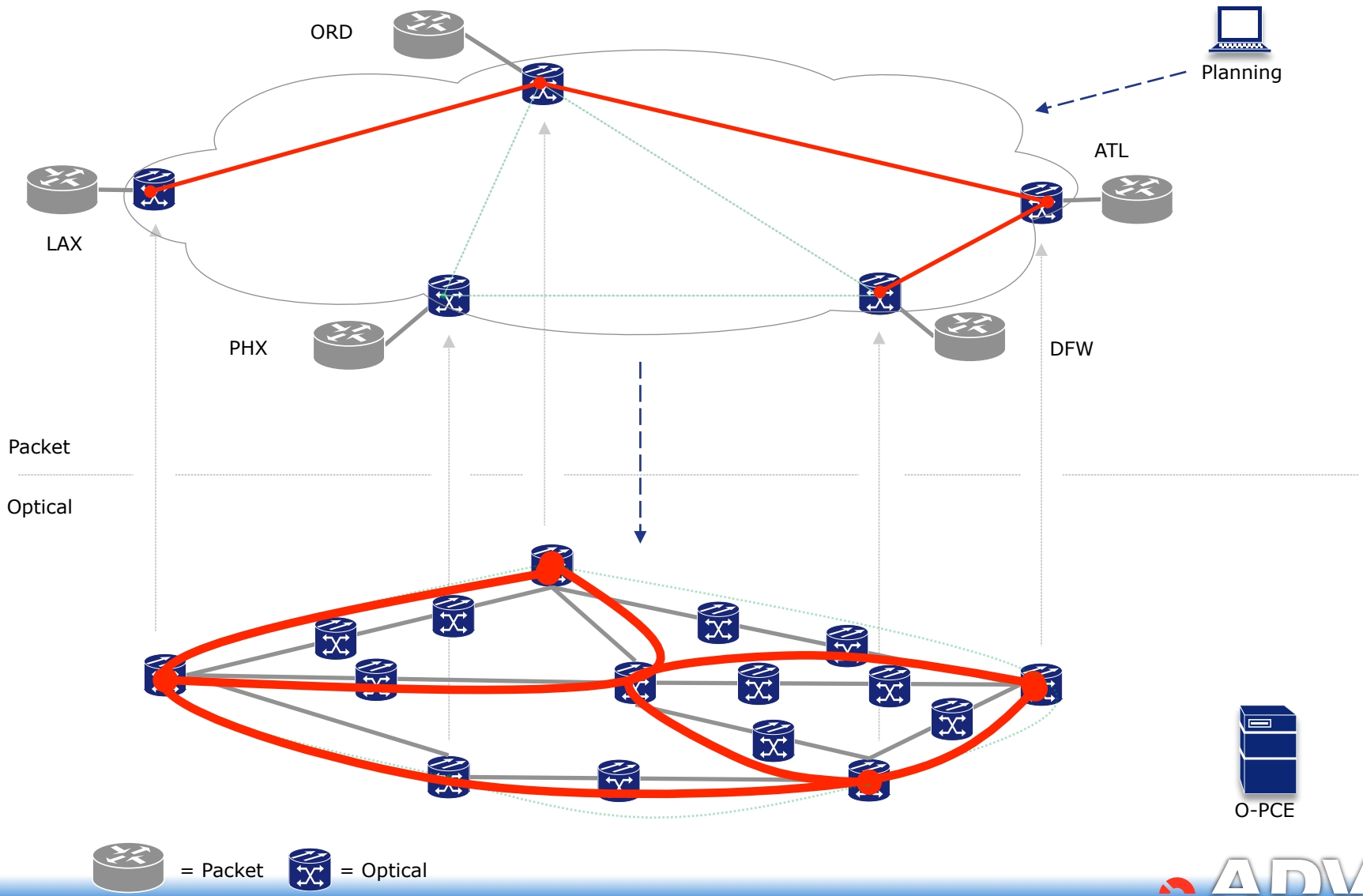
Backup slides

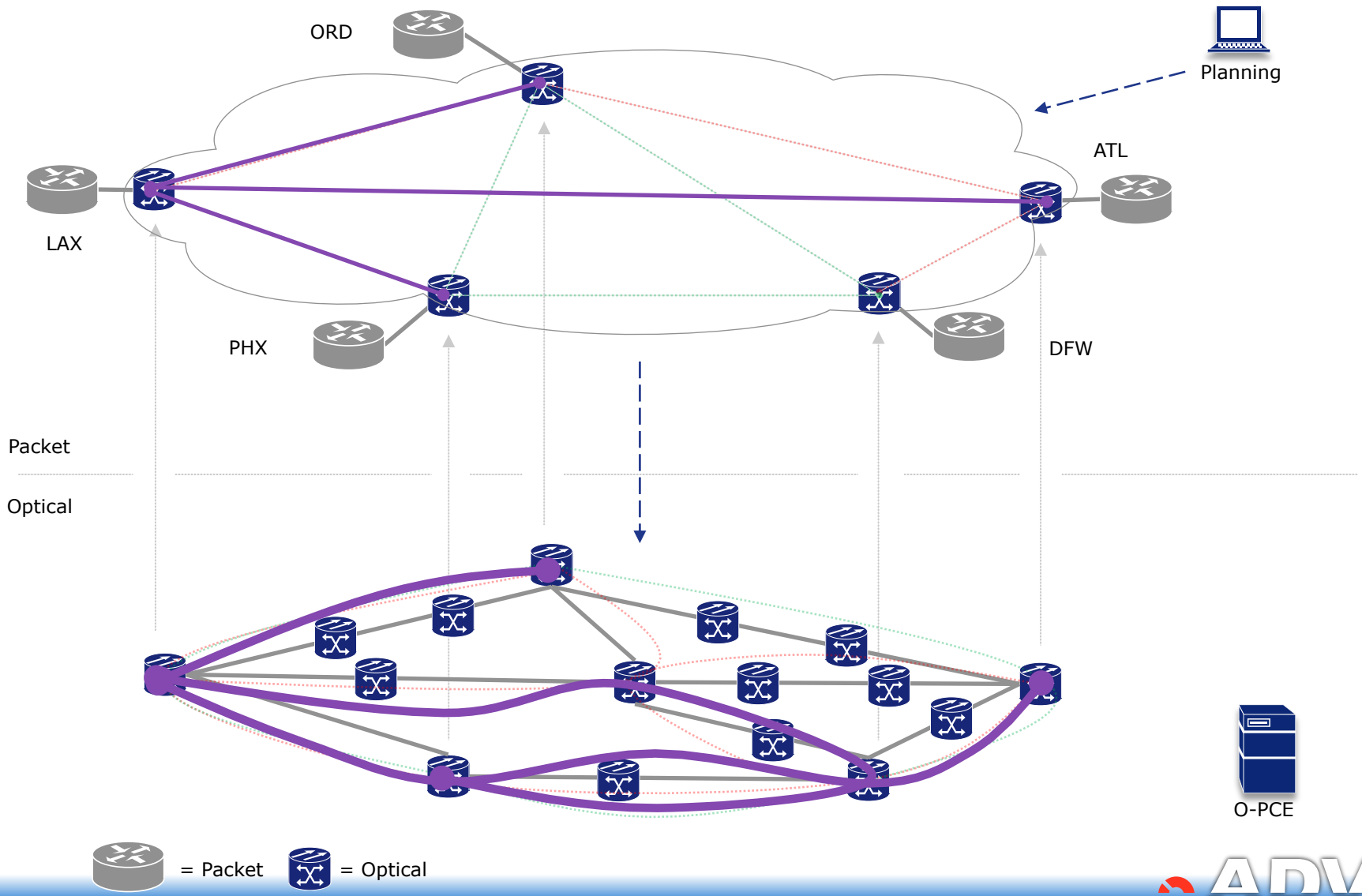
L1VPNs: User #1



L1VPNs: User #2



L1VPNs: User #3



Link Activation