

Carriers View on Challenges for Photonics.



ERLEBEN, WAS VERBINDET.

Do you know, what this is ?

Kesselmuffe für Koaxialkabelsysteme 24f und 32 c (V10800)



Do you know, what this is ?

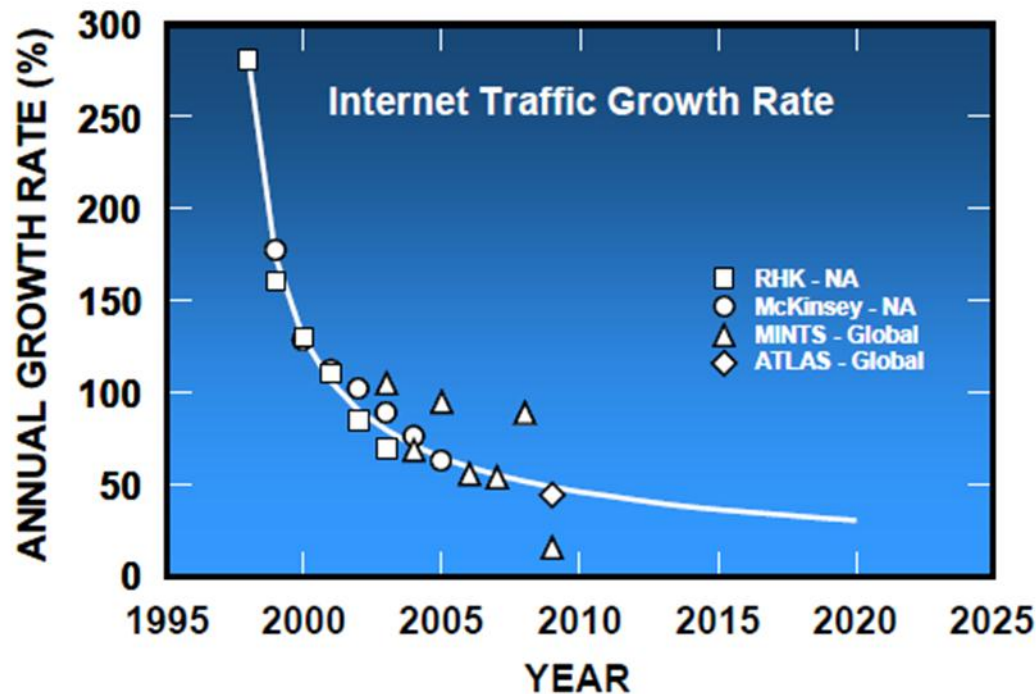


**Flickr Logs Photo Number 5 Billion
posted on September 20, 2010**



**Flickr reaches 6 billion photos uploaded
August 5, 2011**

Internet Traffic Growth.



Source Korotky OFC 2012
Bell Labs

The historical compound annual growth rates (CAGR's) of data traffic for Northern America and Global have been similar to 2010.

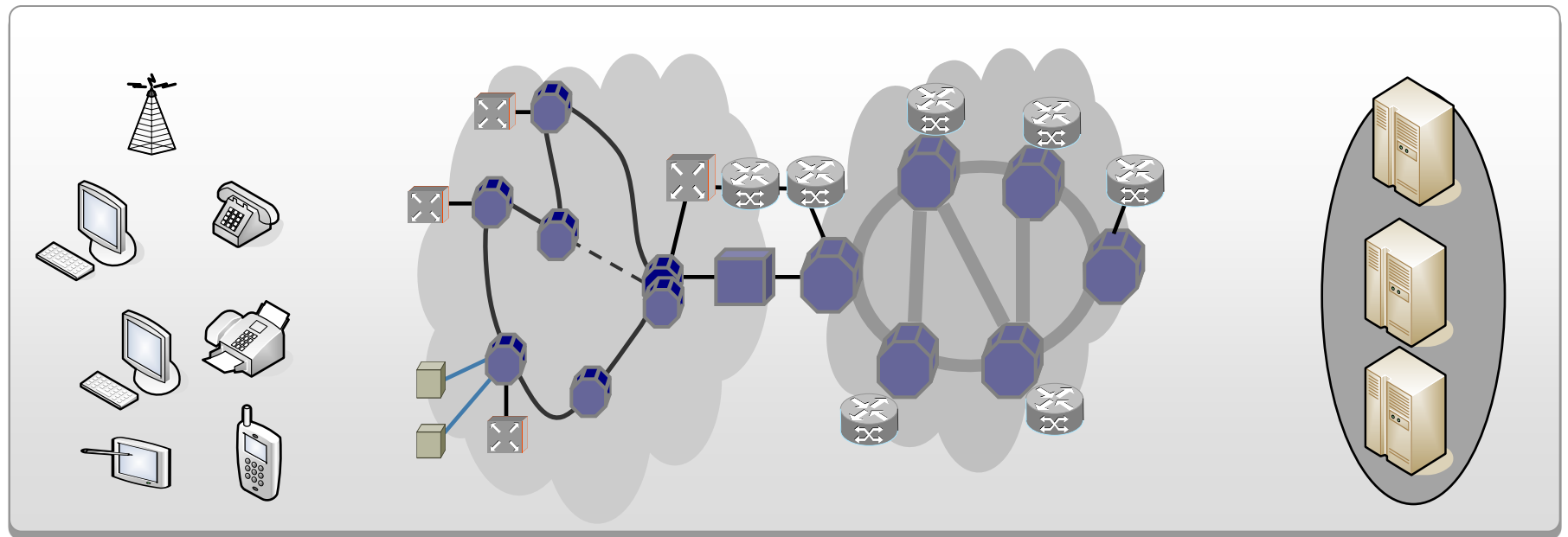
While the CAGR's have been steadily decreasing, traffic is still growing at a fast rate (2010: ~2X / 2 year).

Data Sources: RHK, 2004; McKinsey, JPMorgan, AT&T, 2001; MINTS, 2009; Arbor, 2009.
Regression Analysis and Projection: Kilper *et al.*, *JSTQE* 17, 275-284 (2011).

Challenges for next generation optics.

Increase capacity & improve efficiency

Optimize traffic structure architecture and topology

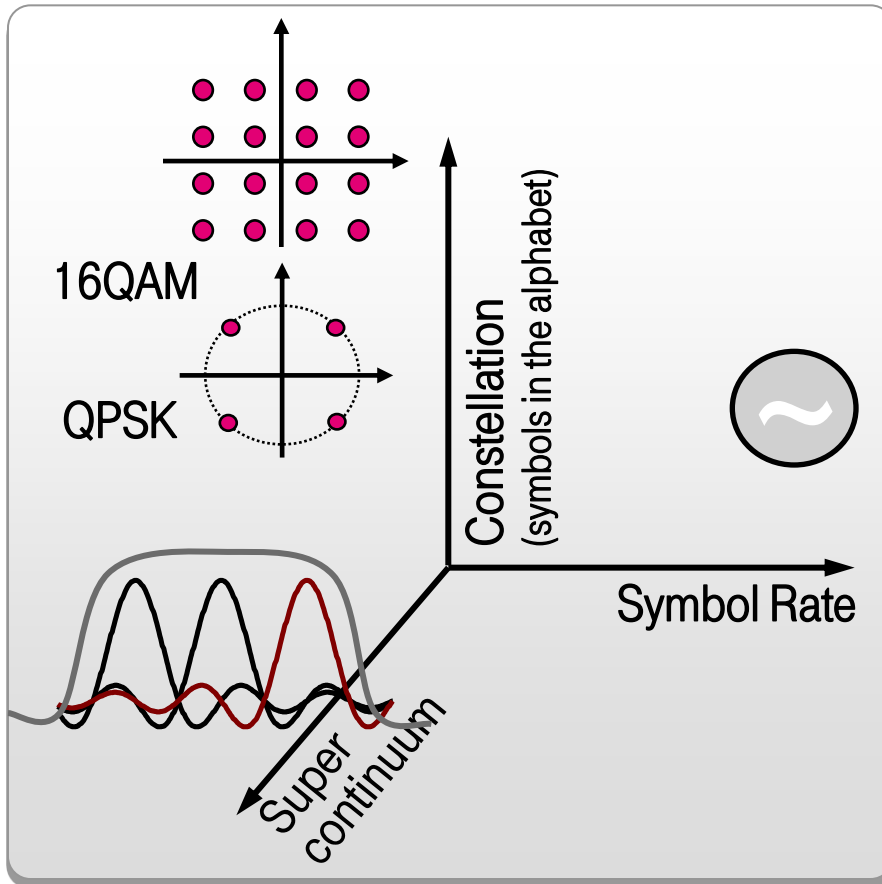


Reduce complexity and
Keep it simple

Accelerate BB access rollout
Enable convergence of networks

Improve Efficiency.

How to increase capacity per fiber (spectral efficiency)?



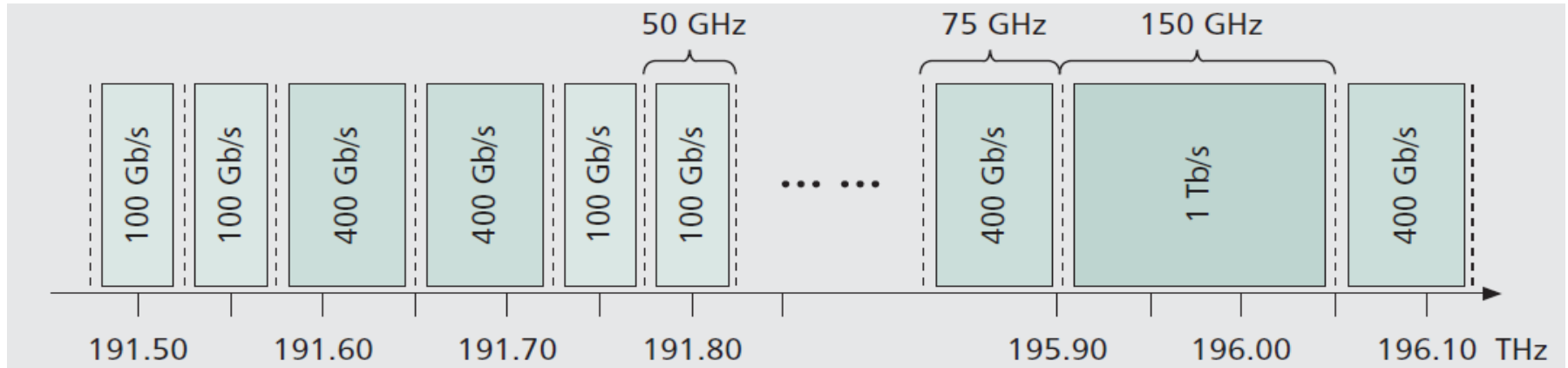
Dimensions and challenges

- Increase of capacity per fiber by
 - Higher symbol rate
 - Constellation size
 - Sub carriers (super continuum), a slice of the spectrum that is managed as one continuous super-channel
- All principles well known from DSL
- Challenges
 - Tradeoff between distance and spectral-efficiency
 - Tradeoff between complexity and spectral efficiency

Increase of spectral efficiency by the factor of 20 seems to be possible
(compared to 10G NRZ)

Improve efficiency .

How to increase capacity per fiber (spectral efficiency)?



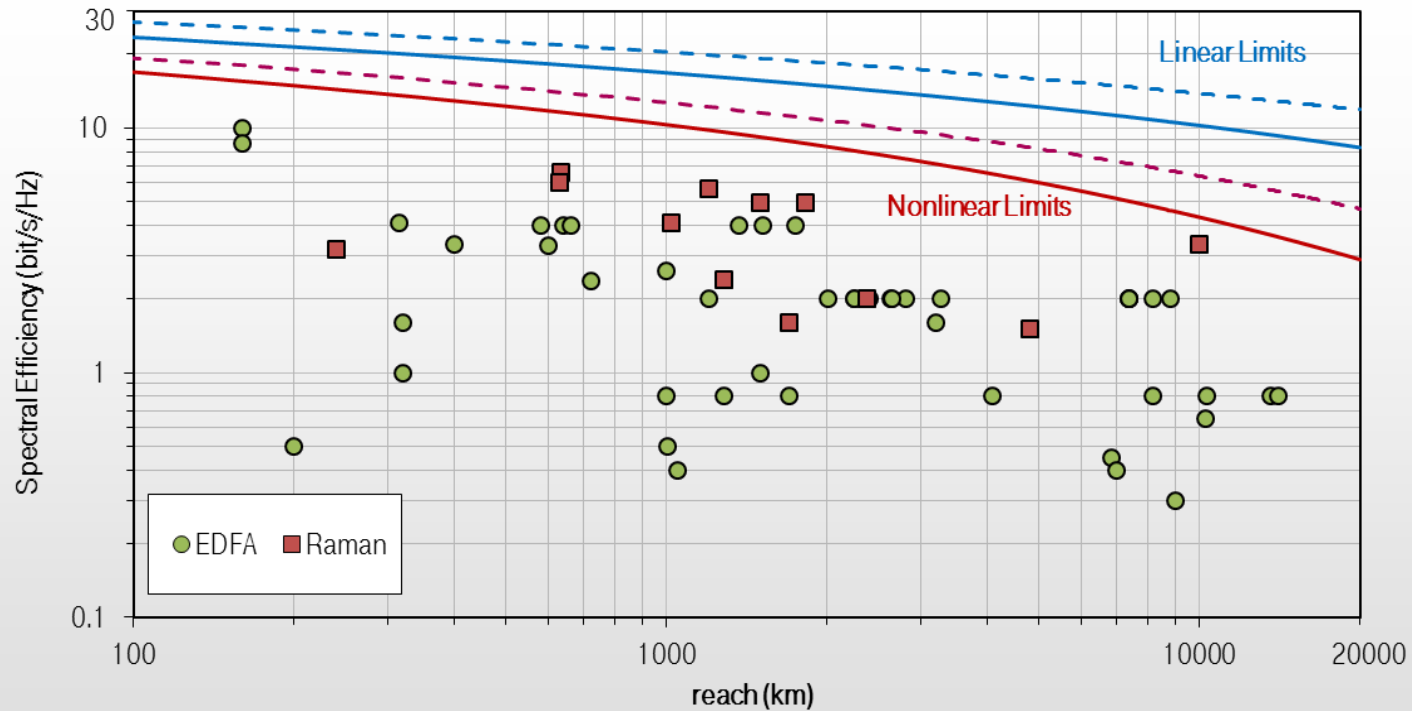
Fully configurable flex grid.

- Drastic improvement of spectral efficiency does not necessarily leads to fully configurable flex grid optical network
 - There seems to be a remarkable complexity to manage this kind of network
- Routing and wavelength assignment for each “subcarrier” + grouping of “sub-carriers”
 - Fragmentation of spectrum
 - Maintenance of single speed backbone would be much easier

Improve efficiency.

Spectral efficiency vs. reach for SMF (2 Modes).

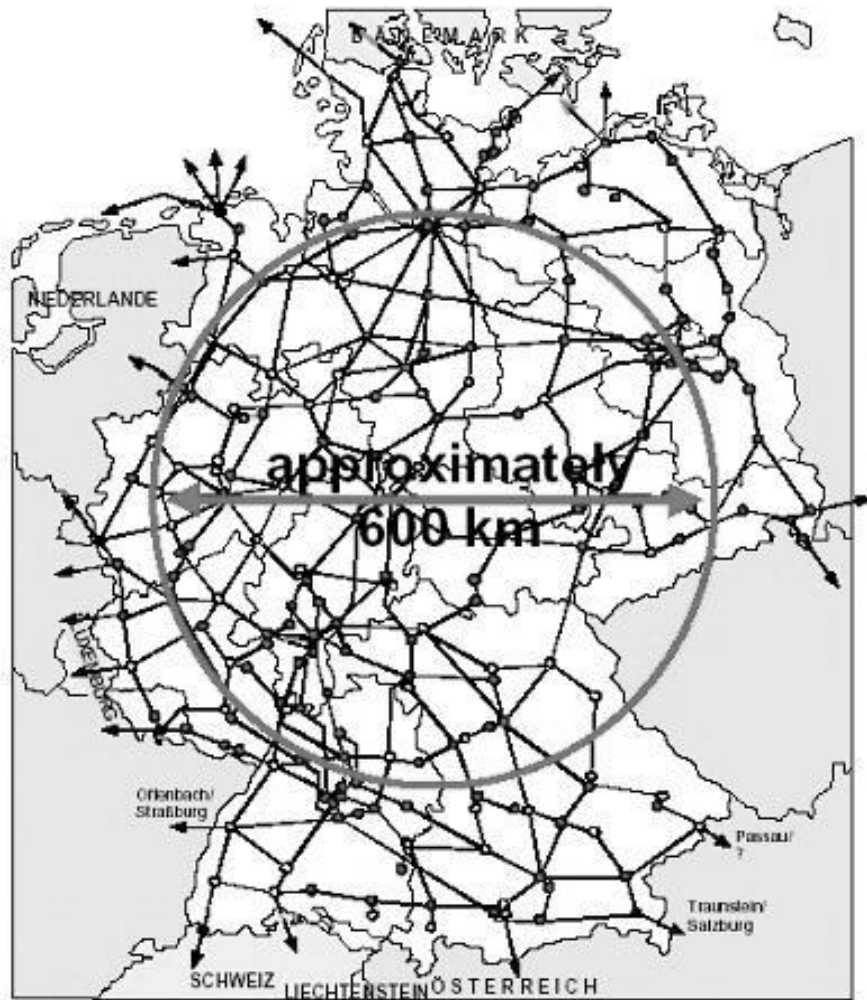
Maximum Spectral Efficiency VS Optical Reach



- Markers: “Hero”- Experiments employing WDM on an SMF link
- Solid lines: EDFA amplification ($NF = 4.5\text{dB}$)
- - - Dashed lines: Raman amplification ($NF_{\text{eff}} = -1\text{dB}$)

Some Statistics

DT-Fibre Infrastructure.



DT Fiber Infrastructure

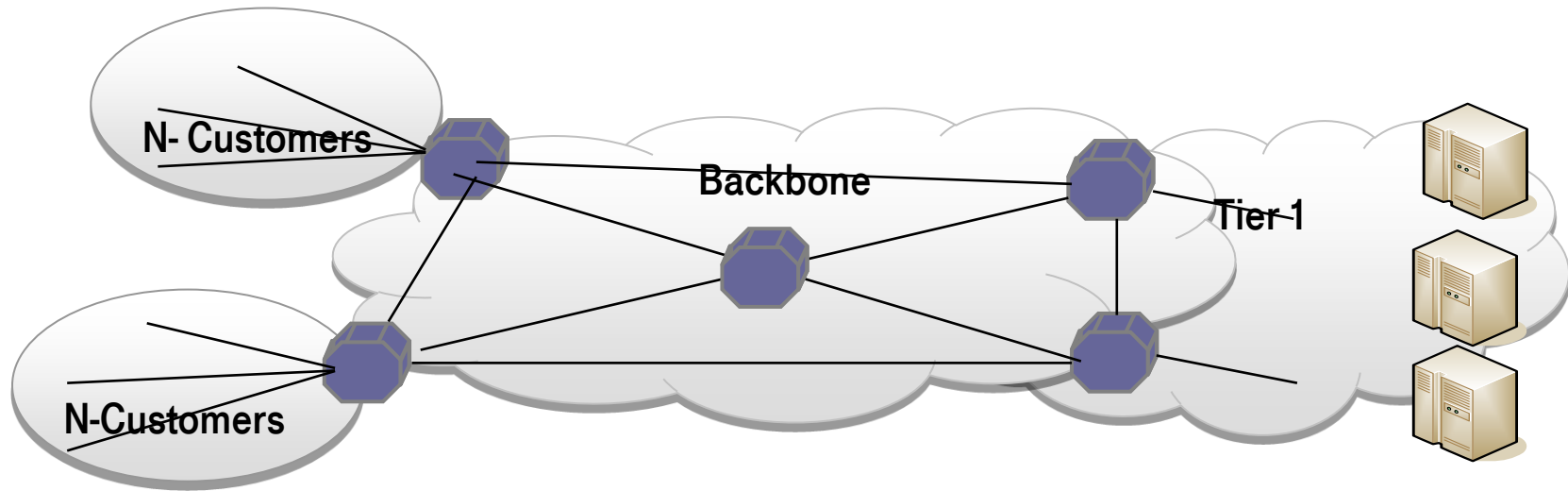
- Standard single-mode fibres
- 167700 km optical fibre cable

DT (WDM) Backbone

- Average Nodal degree 2.8
- Highest nodal degree 5
- Length of all sections (edges) are below 600km
- The average length is 215 km
- The minimum length is 51 km
- The maximum length is 556 km

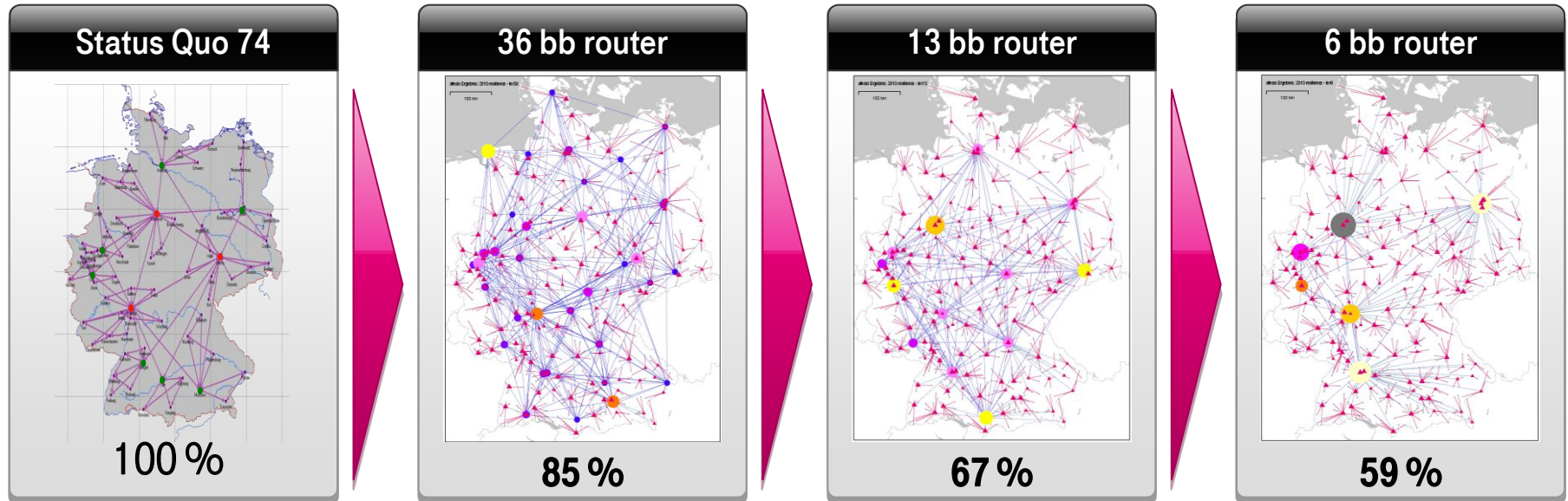
Optimize topology / Internet backbone.

How to distribute optical functionalities in the network?



- Optimize the number of customer aggregated in one region
 - Related to throughput of routers and link capabilities.
 - Minimize no of hops in backbone
- Balance the traffic at the interconnection points to tier 1 and peering

Benefiting from optics by optimizing the topology. Greenfield analysis shows clear trend to fewer BB- locations.

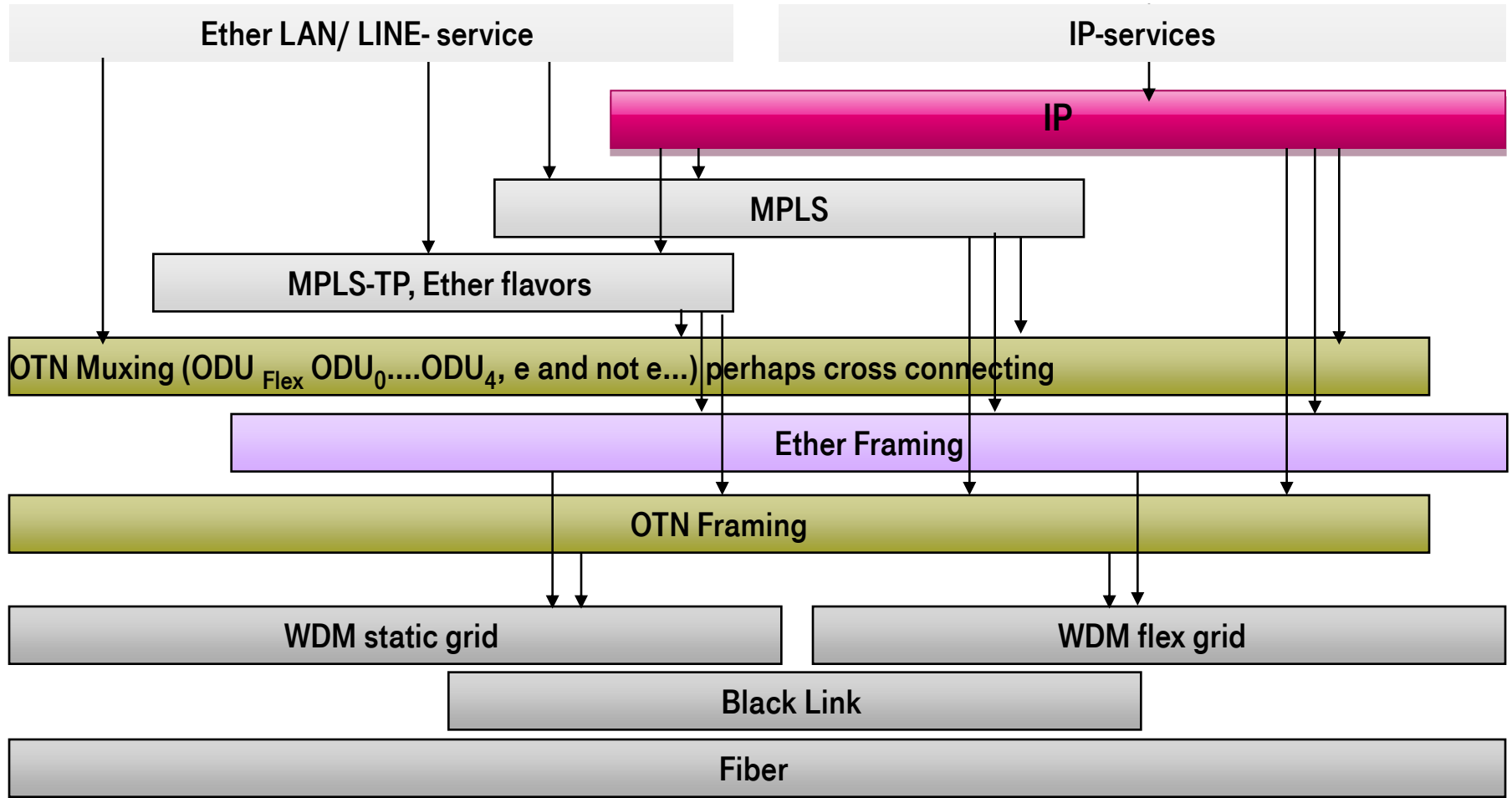


- Concentration to fewer backbone router proved to be CapEx optimal solution
- Absolute CapEx reduction with decreasing number of BB routers:
- Significant cost reduction of backbone – mainly through smaller number of links and fewer line cards

Drastic cost reduction of transport and good scalability of backbone router led to a new structure of the network, don't think about "bypassing" think about topology optimization

Reduce complexity: Keep it simple.

How to find the shortest way through the labyrinth?

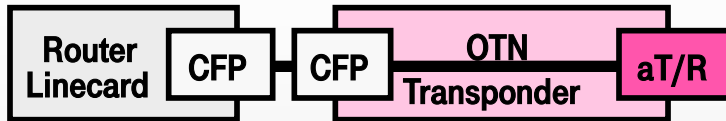


Reduce complexity: Keep it simple.

Is integration of interfaces a solution?

Interface option

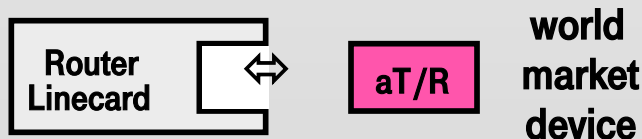
1 Today: Clear demarcation



2 Integration



3 Future Option: Modularization



Interface option

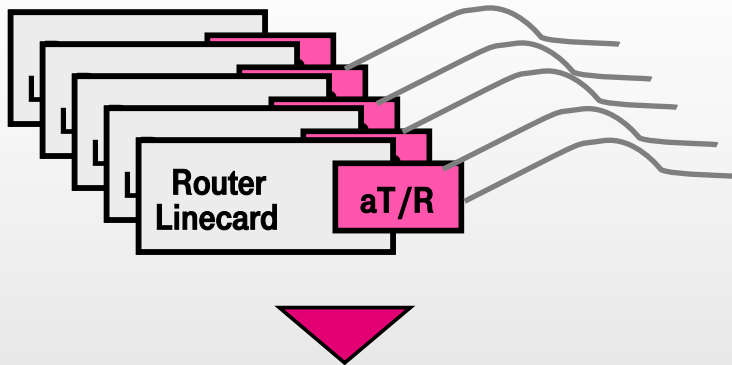
- Integration of WDM interfaces is an options to simplify the network (less O/E/O)
- Cost benefit has to be shown
- Pluggable Module is the promising solution.
- Which functions should be implemented in the module
- Integration of control functions
- Representation of link topology SRLG etc.

Reduce complexity: Keep it simple.

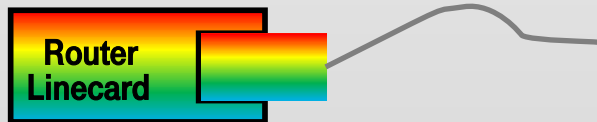
Future: Multi Channel Interfaces ?

Interface option

1 IP-Supplier Proposal: Integration



2 Multi Color Interface

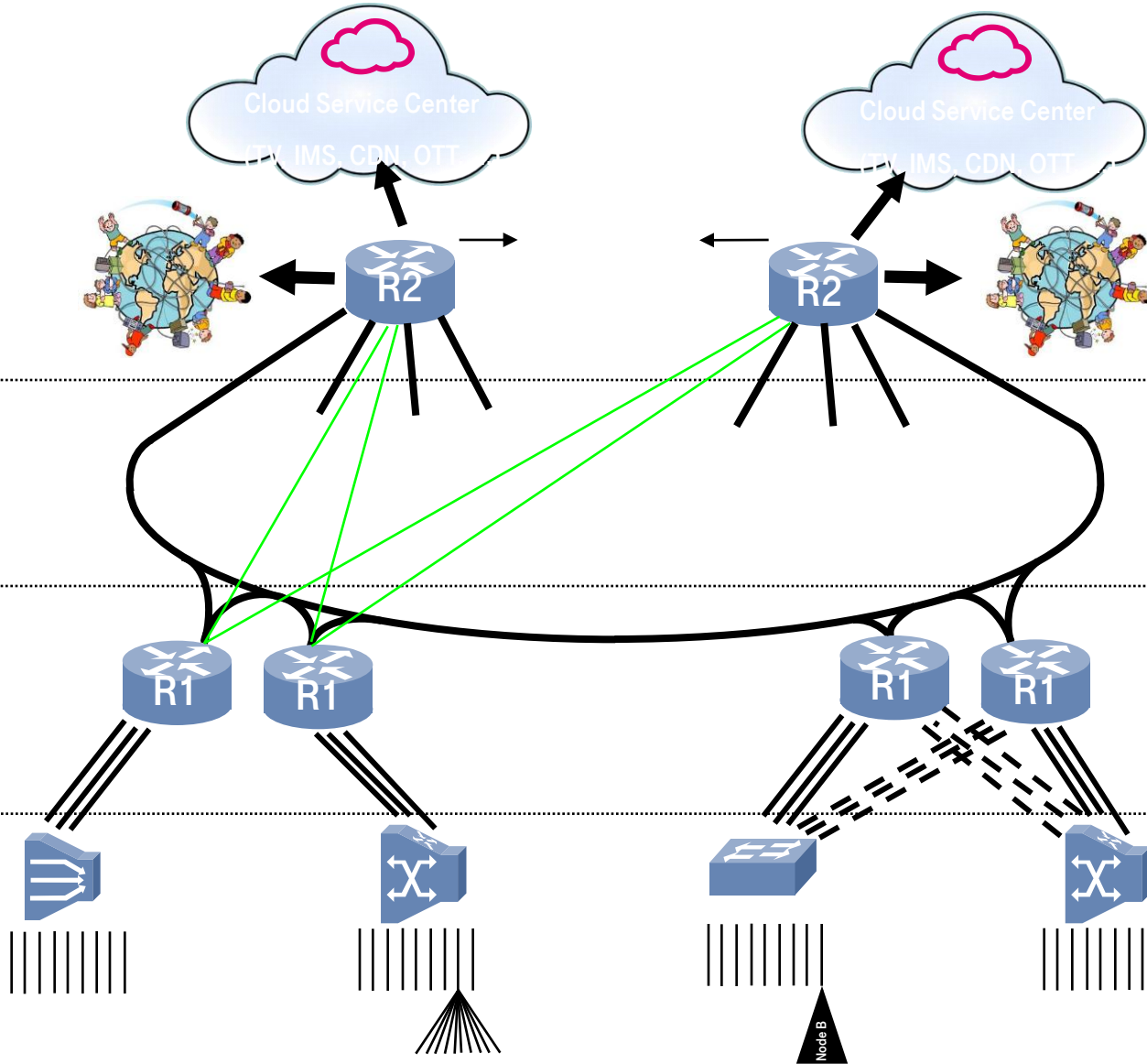


Interface option

- Multi color interface simplifies the patch cabling a lot
- ROADM can be used to configure the virtual link topology
- Multi Path Interface slicing would require adequate integration of optical systems into IP control

Represented as link or,
Represented as MPLS path

The TeraStream Architecture.



How does a datacenter look like?

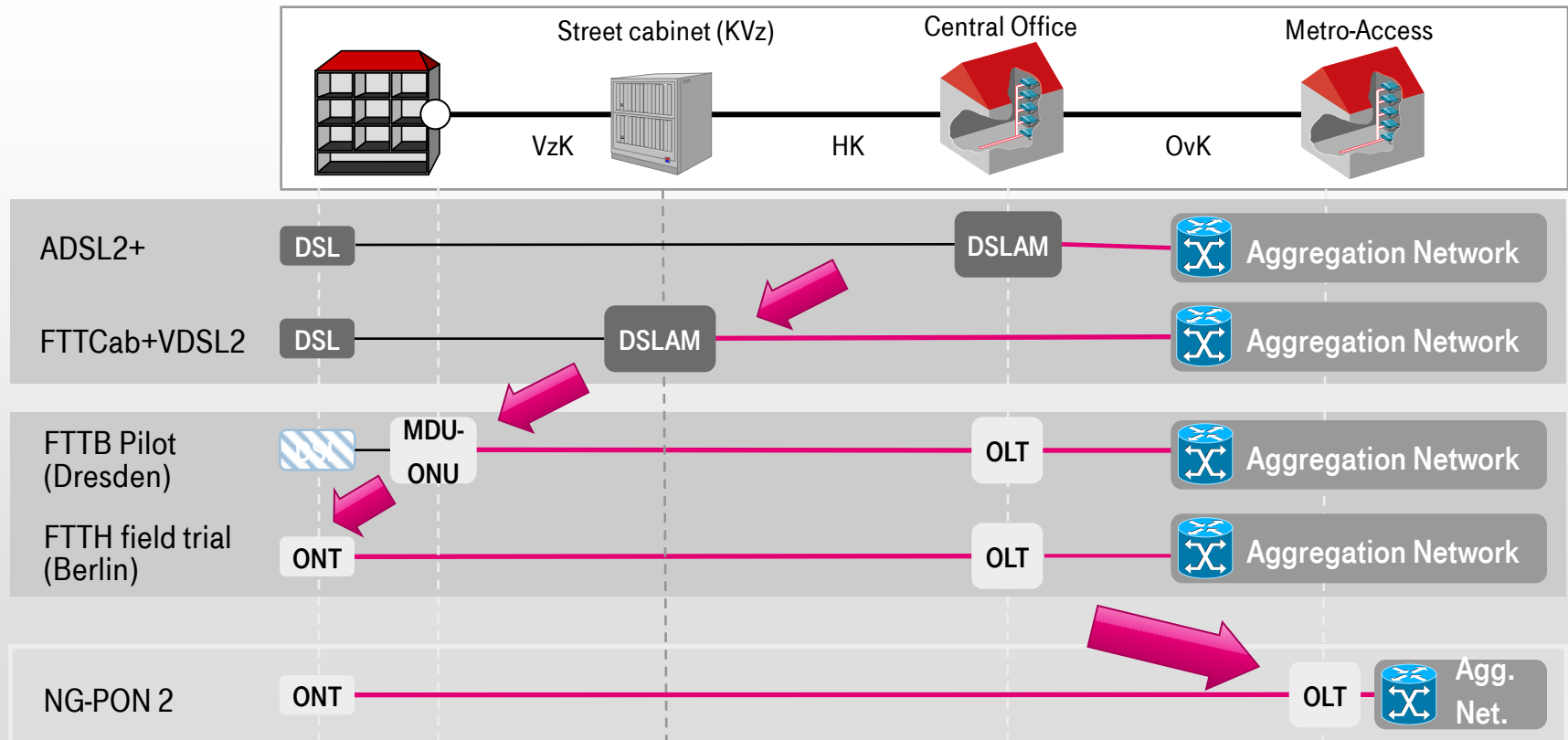
More than 10.000 Server.

A size of 1.000.000 will come soon ?



Transforming the optical access network into the structure of the Gigabit Society.

Access / aggregation network migration path



Optics in access / aggregation.

Benefits of site reduction.

Site reduction



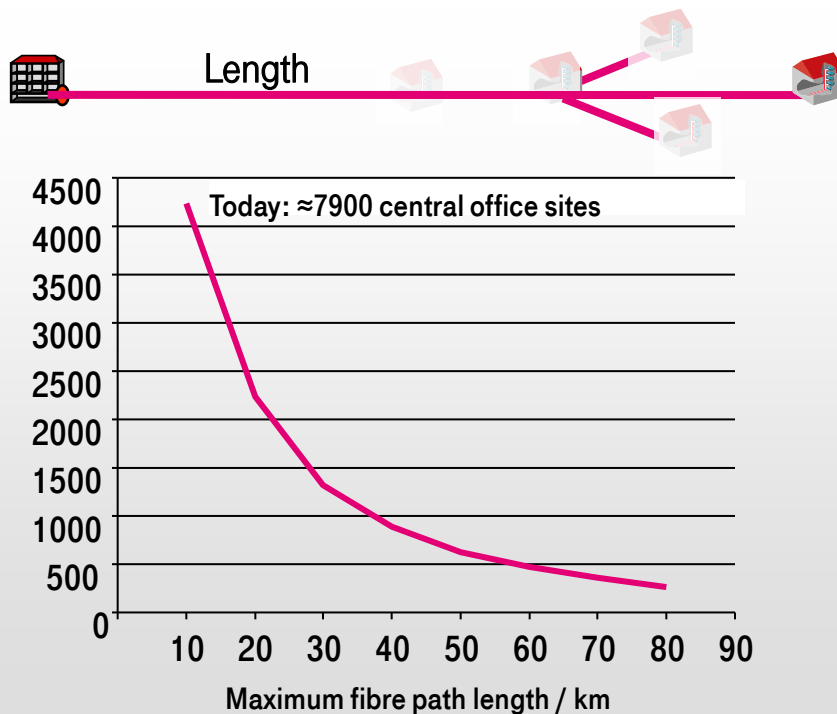
Benefits of site reduction

- Reduced CapEx
 - Reduced overall costs for buildings, compared to cost of new deployed cable basic indicator
- Lower OpEx
 - Sites with higher concentration can be operated more efficiently
 - Reduced cost for maintenance
 - Simplified Power supply / HVAC; Line extenders & amps require simple additional powers supply

Optics enables site reduction, but other parameters have to be taken into account too

Calculation from pure distance / reach perspective. How many sites could be closed?

Dependency # of sites – path length



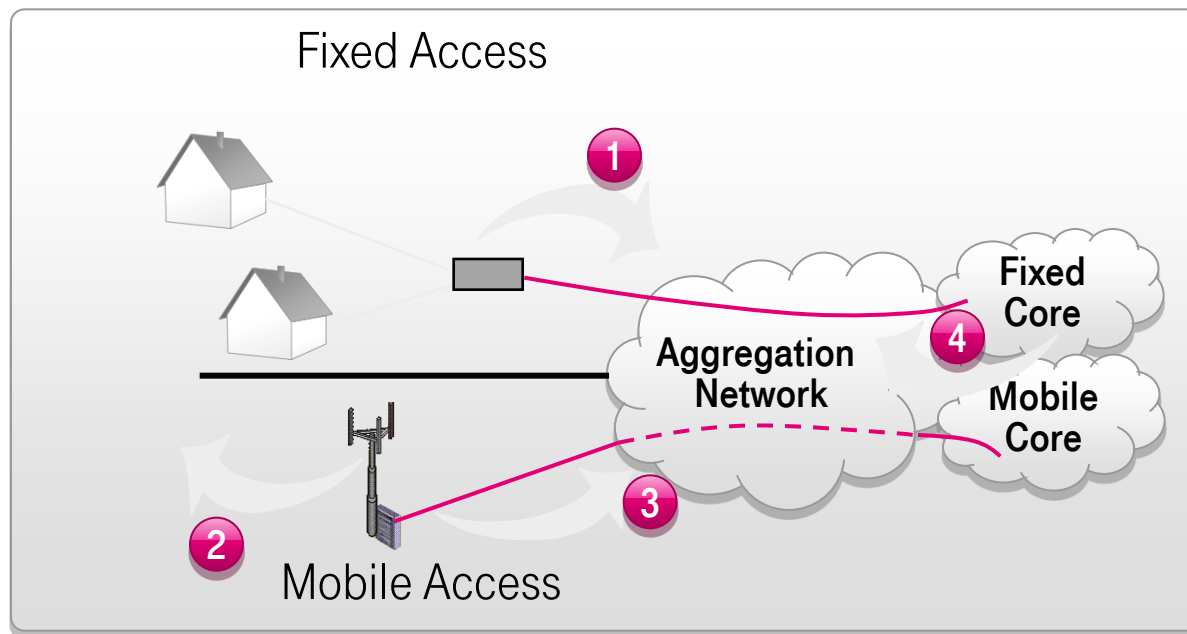
Number of metro access nodes

- Current structure with ≈ 7900 exchange / multiplexer sites given by copper based access infrastructure
- Optical Technology
 - less than 500 nodes if optics would allow to achieve 70 km distance
 - more realistic today: 40 km would allow for approx. 1000 nodes
- However, there is no free lunch ...
- Extra cost for additional cable between former sites to be required

Maximum distance enables drastic site reduction subject to practical considerations

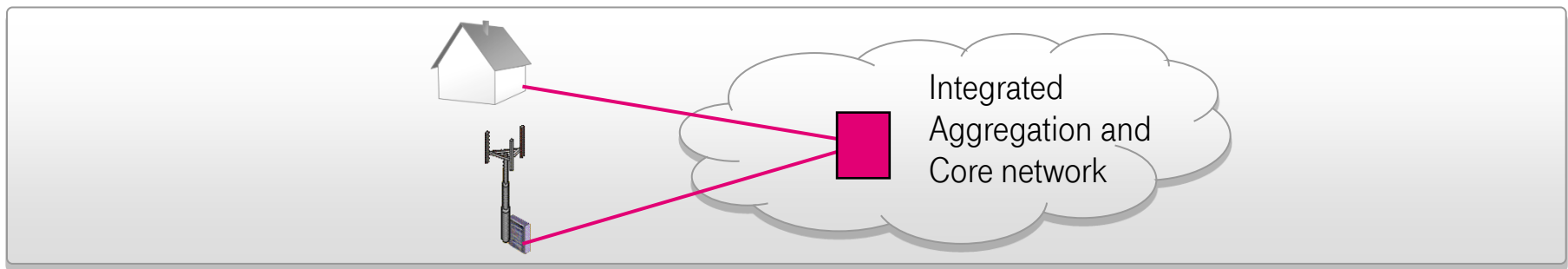
Solutions for future converged infrastructures.

Consolidate and integrate fixed and mobile networks.



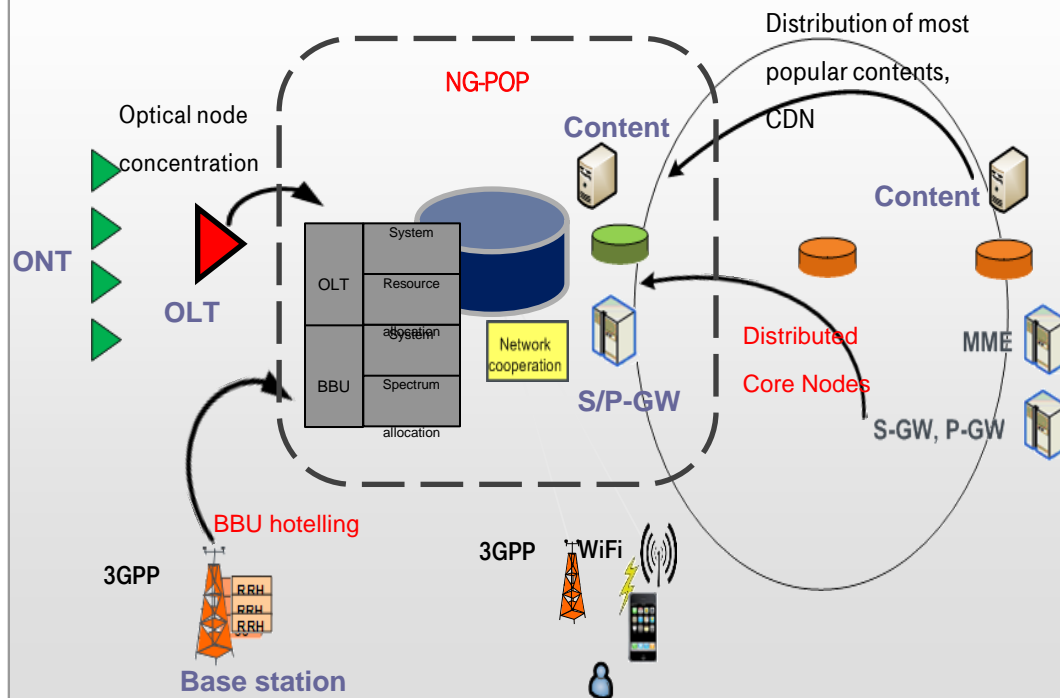
Trend for network changes

- 1 Site consolidation
- 2 Densification of radio cells (small cells, heterogeneous networks)
- 3 Centralization of base-band processing for mobile base stations (C-RAN)
- 4 Shift of core network functions closer to the customer



Example: High-level concept for converged “NG-POP”. EU Project COMBO

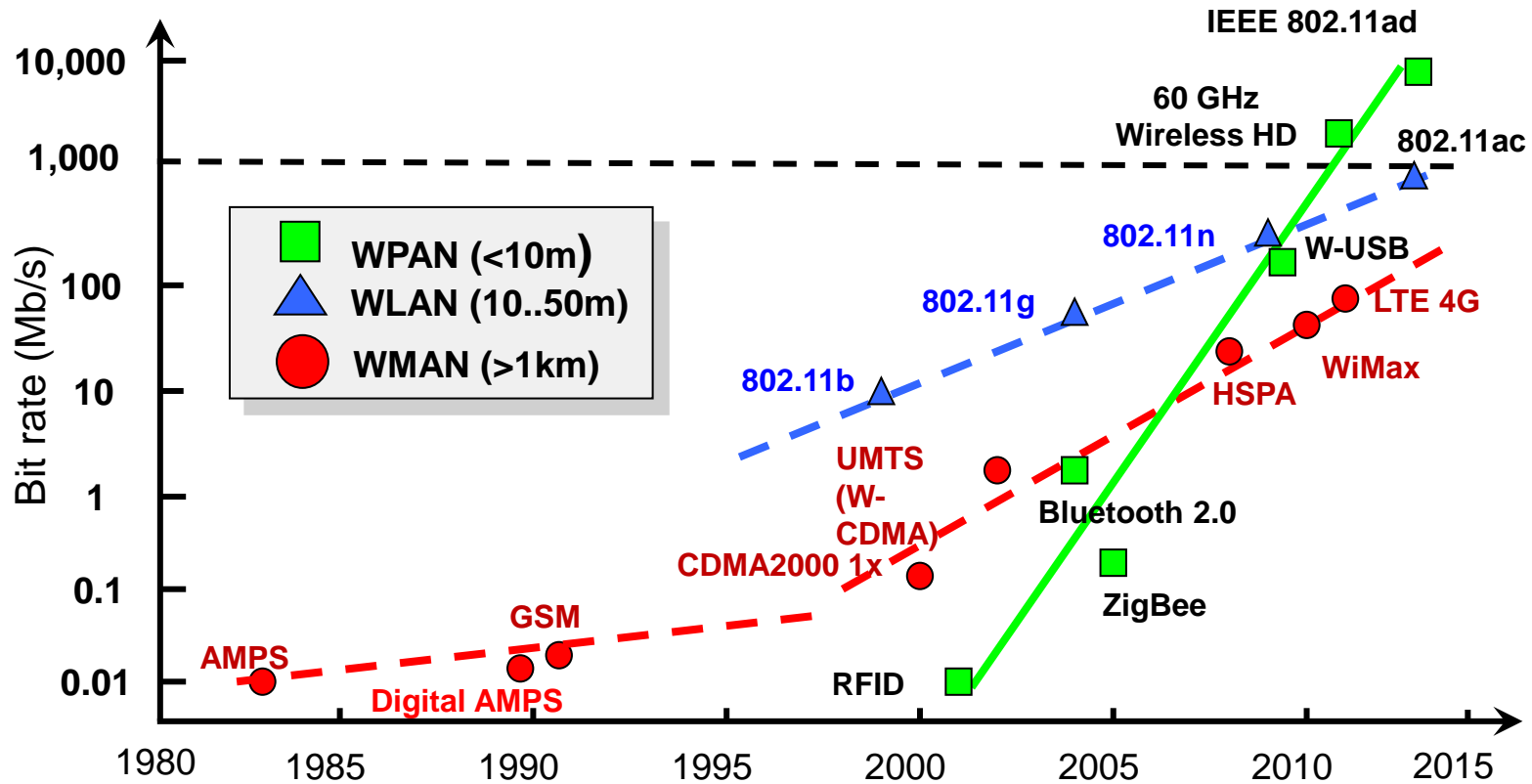
Which functions need to be integrated in an NG-POP ?



- Future access domains (reach of Central Offices) may be enlarged up to 100 km.
- Next Generation PoP may include
 - Optical nodes (OLT)
 - Central mobile baseband processing (BBU)
 - Elements for coordination at network layer
 - Mobile and fixed network core elements
 - Functionalities of content delivery networks

Wireless Capacity.

Roadmap of wireless technologies



Importance of 60Ghz and Short Range Wireless is increasing

Mm-Wave and THz-Wave Communication.

THz Standardization at the IEEE 802.

IEEE 802.15 WPAN™ Terahertz Interest Group (IGthz)

IEEE802.15 IG THz - Study Group proposal

„Beam switchable wireless point-to-point 40/100 Gbps links“

(with limited antenna beam-steering requirements)

Fixed Outdoor

- Static link; < 1km
- atmospheric influences
- beam alignment: configuration / pole sway



Use case: Wireless backhaul

Fixed Indoor

- Static link; few m to tens of m
- beam alignment: re-/configuration



Use case: Wireless server

Connectivity

- dynam. wireless cable apps
- few cm to m
- automatic beam steering
- manual alignment may possible



Use case: Kiosk Download

Intra-Device

- cm
- beam alignment: implementation design

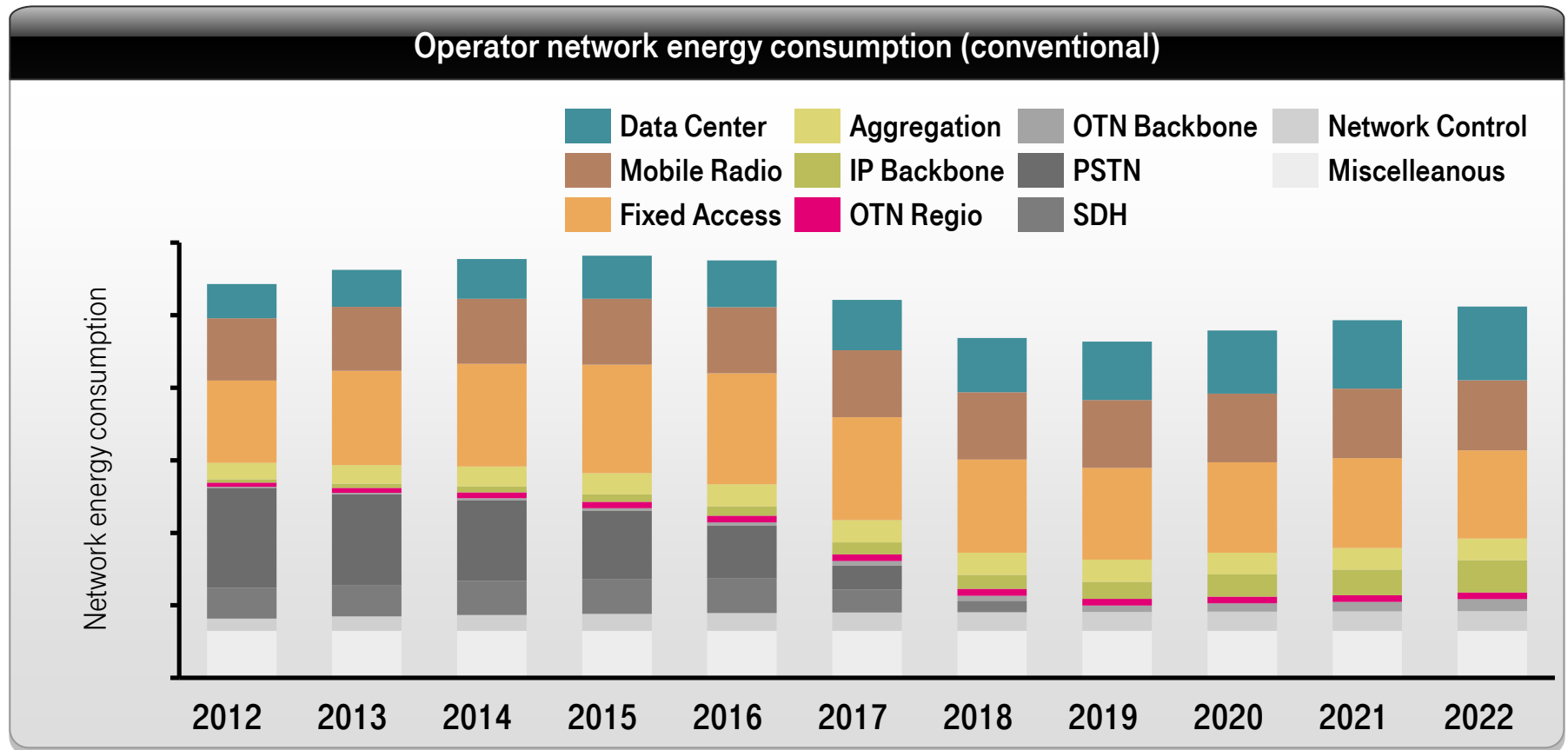


Use case: Chip-to-chip

Source: IEEE802.15 IG THz

Network Energy Consumption Forecast.

Fixed & mobile operator network energy consumption.

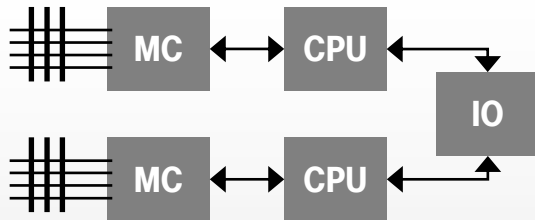


Large energy consumption shares in access and legacy network equipment, IP backbone and data center growing fast.

Detailed power consumption of servers.

Appr. 50 % of this power consumption is needed for blade internal communication.

Current blade server

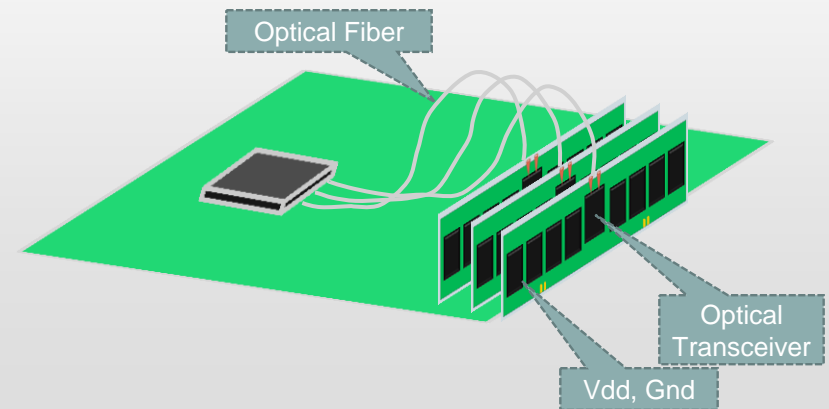


Bin	Watts	% of power for communication	absolut
Processor	210	33-50	69-105
Chipset	50	90	45
Memory	30	50	15
Other	50	40	20
Total	340	43-54	149-185

Appr. 50 % of this power consumption is needed for blade internal communication.

Emerging technologies

- Internal optical communication may help
 - On board communication, on chip communication
- Reduction of power consumption by more than 90% is forecasted



Blade internal communication is app. 50% of the over all power consumption for servers.
Optics for internal communication is the most promising approach to improve situation.

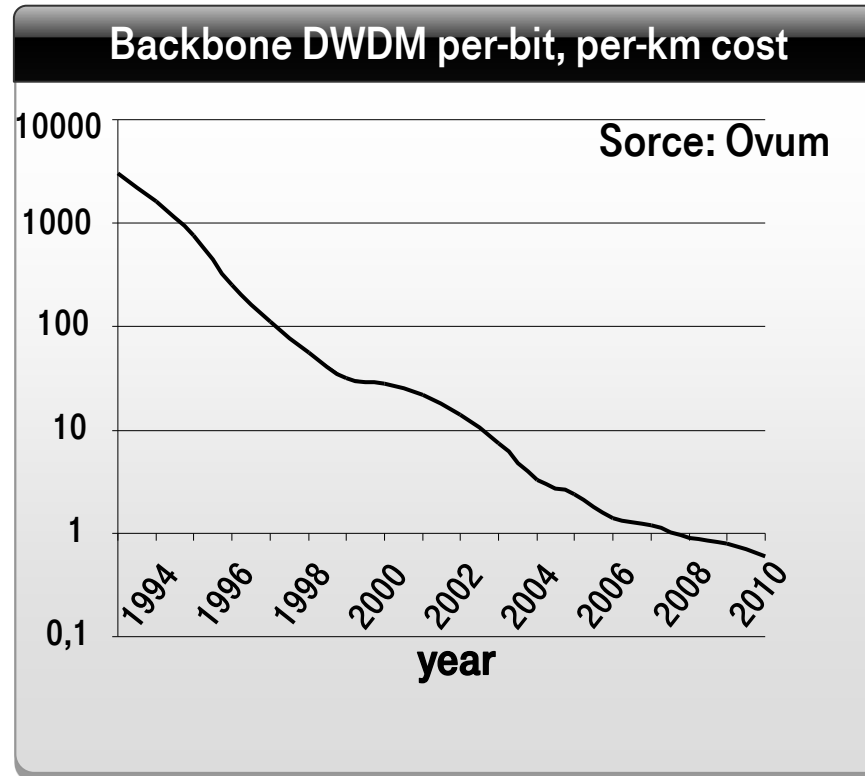
Source: Greg Astfalk Why optical data communications and why now? Appl Phys A (2009) 95: 933-940 DOI 10.1007/s00339-009-5115-4

Summary.

Challenges of next generation optical transport networking.

Increase capacity &
Improve efficiency

Reduce complexity
and
Keep it simple



Optimize traffic
structure
architecture and
topology

Accelerate BB
access rollout
Enable convergence
of networks