Breitbandnetze 2020 aus der Sicht der Forschung

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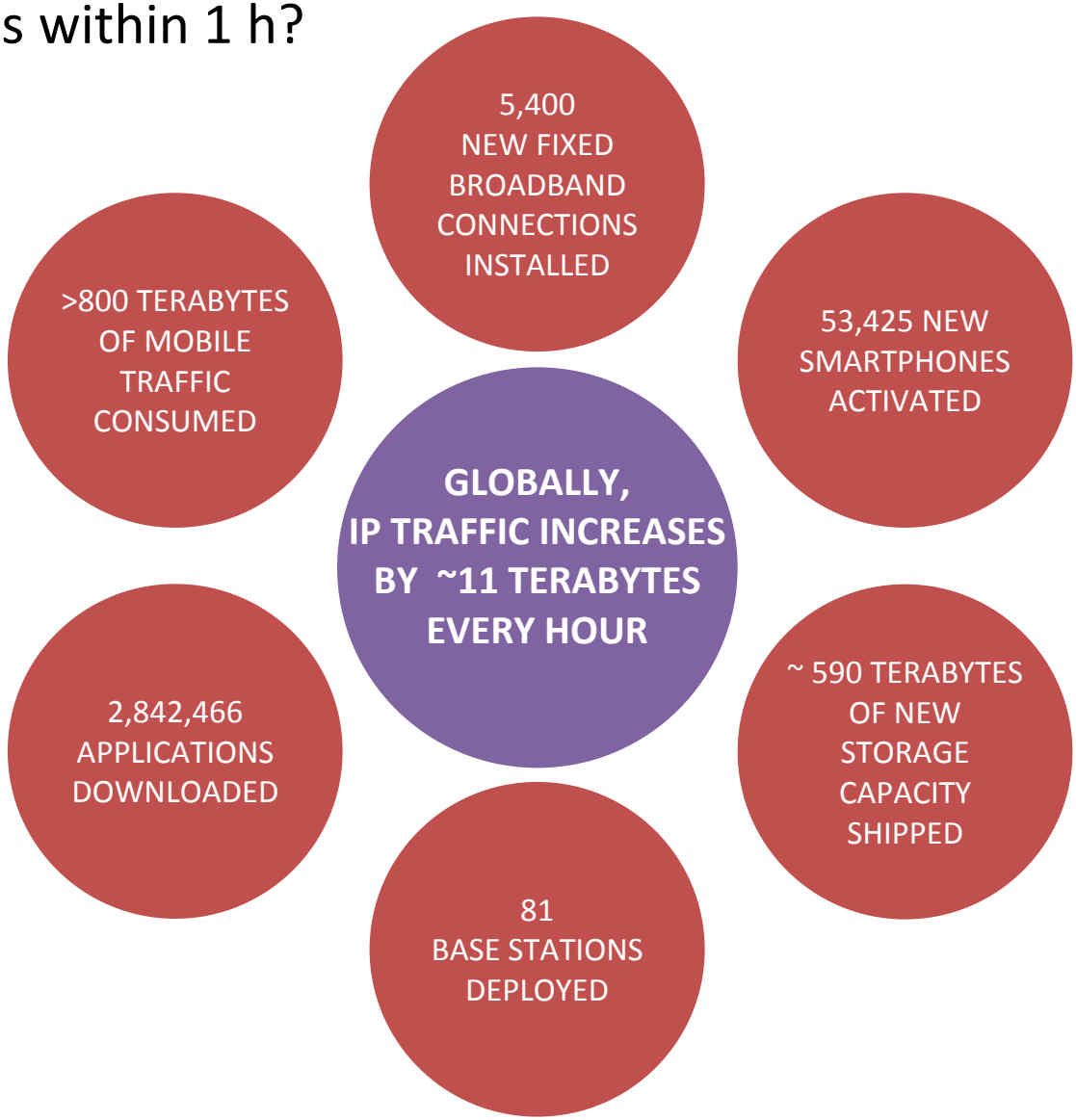
Mitglied des Vorstandes, Präsident Bell Labs DeutschlandAlcatel-Lucent Bell Labs, Stuttgart

Wissenschaftstag der Metropolregion 20.07.2012

Telecommunication Traffic Growth

What happens within 1 h?



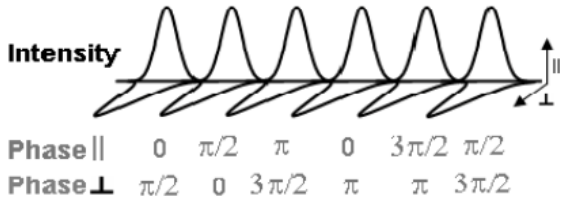
Broadband Optical Transport

Technology point on 100Gb/s

100G PDM-QPSK with Coherent Detection Overview

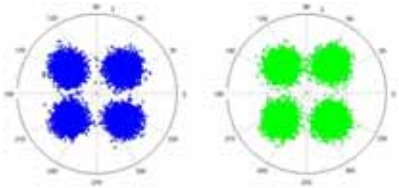
At 100G, severe fiber propagation effects (chromatic dispersion, PMD, single-channel nonlinearities) require decreasing the baud-rate

- more complex modulation formats and receiver architectures become necessary



The combined use of:

- PDM = Polarization Division Multiplexing
- QPSK = Quadrature-Phase Shift Keying



allows decreasing the baud-rate by a factor of four (from 100 to 25 Gbaud)

- each symbol transports 4 bits

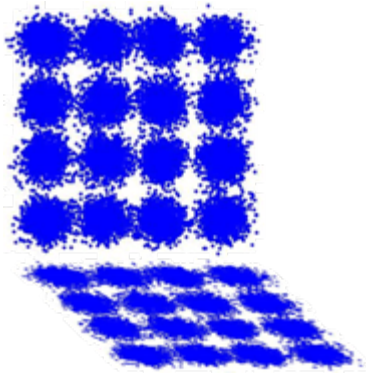
Coherent Detection + Digital Post-Processing compensate for linear impairments:

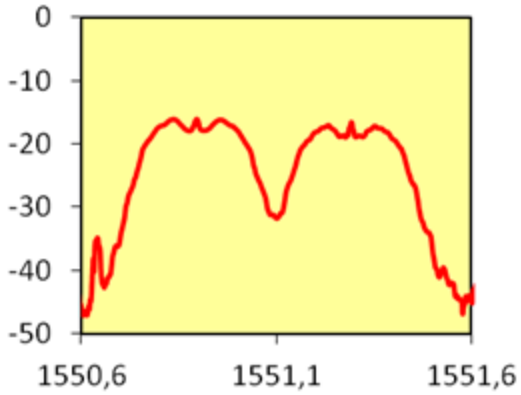
- PMD becomes an irrelevant issue (peak DGD tolerance is extended up to 90 ps)
- Chromatic Dispersion measurements and compensators are not required

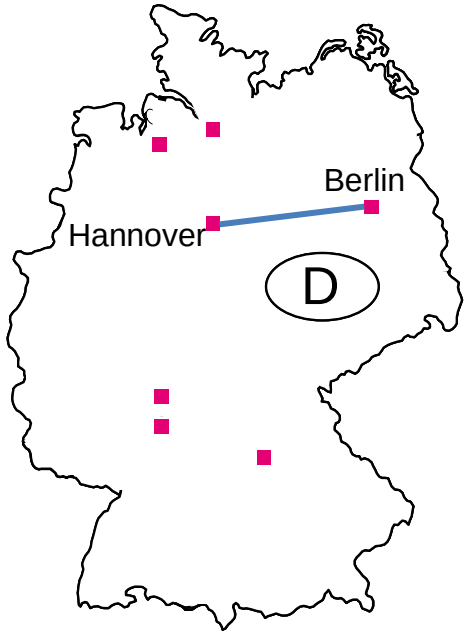
400Gb/s Trial with T-Labs

- World's first 16 QAM 400G trial on installed fiber

  - Fiber link Berlin -> Hannover -> Berlin (approx. 740 km): 16QAM, 200G
  - Fiber link Berlin -> Hannover (approx. 370 km): 16QAM, 400G







- 16 QAM
- Two polarizations
- Two carriers

- Demonstrates power of advanced FEC and Tx side DSP
- Close collaboration between T-Labs and Bell Labs

Approaches to Overcome Capacity Crunch

Physical Layer Approaches

- Improve SNR
- Novel signal processing approaches
- Improved forward error correction
- Improve spectral utilization
  - Flexible grid
  - Software-defined modulation
- Spatial multiplexing

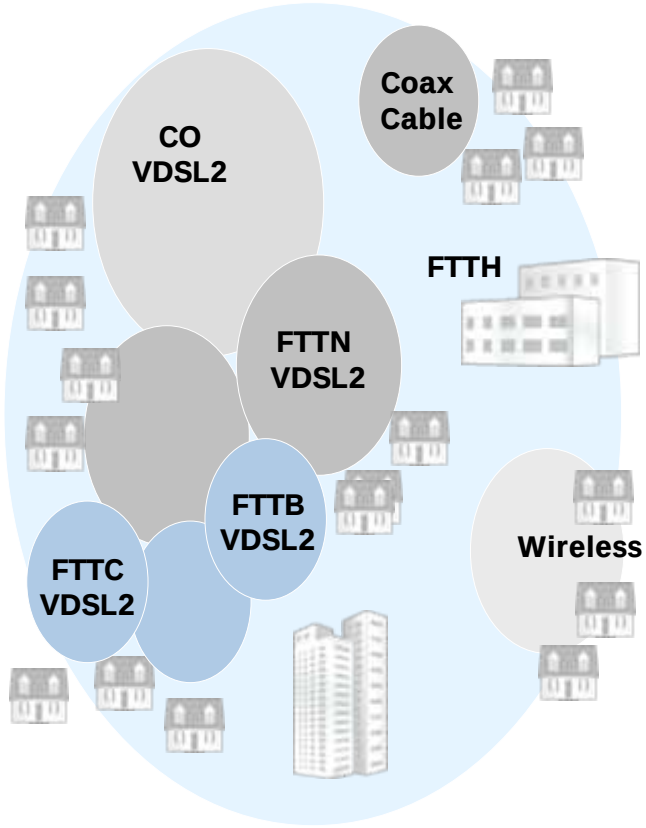
Networking Approaches

- Multilayer network optimization
- Packet-based optics

Broadband Access

Solving the Broadband Challenge

Mix of Technologies & Players



New fiber-to-the-home rollouts
- Greenfield, dense/urban areas
- New entrants (municipalities, utilities, governments)

Reuse copper infrastructure
- Brownfield, fast/cost-effective “Stop-gap” for fiber
- Existing operators (ILECs, CLECs)

Wireless broadband
- Quadruple-play, or primary broadband
- Leverage FTTx network for backhaul

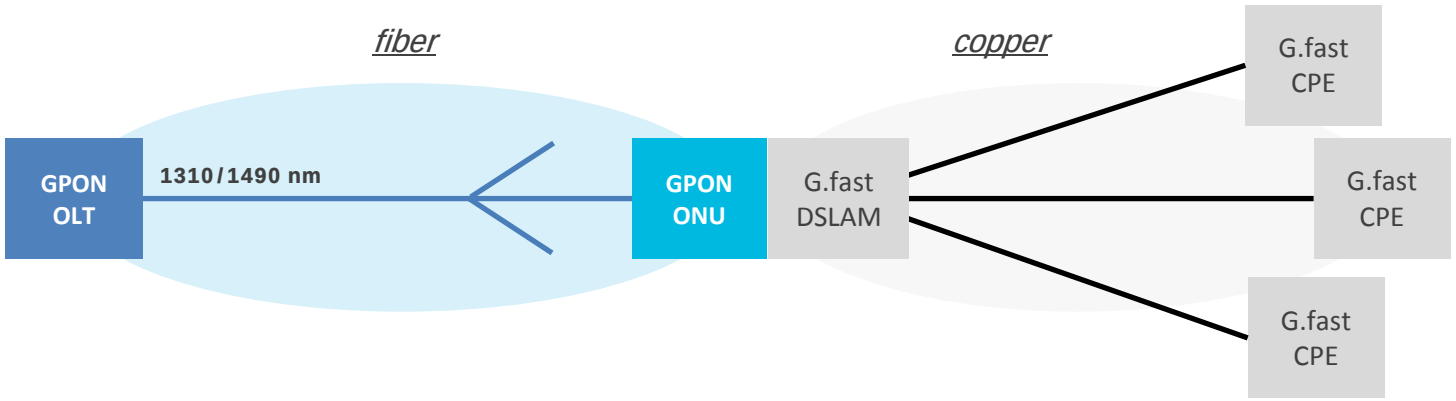
Remote areas
- Rural/remote areas, public funding
- Wireless, satellite, FTTx with microwave backhaul, FTTH

DSL is strong - and keeps accelerating : *G.fast*

Bandwidth improvements beyond *bonding*, *vectoring*, *phantom mode*

G.fast :

- ITU-T project February 2011 – end 2012 (tbc)
- **1 Gbps** on single pair, 100 ... 200 m, 100 MHz, DMT/OFDM, TDD
- strong push for tight interworking with PON
- common management, power saving modes
- improve throughput performance by linking TDD (DSL) mechanisms and TDMA (PON) mechanisms



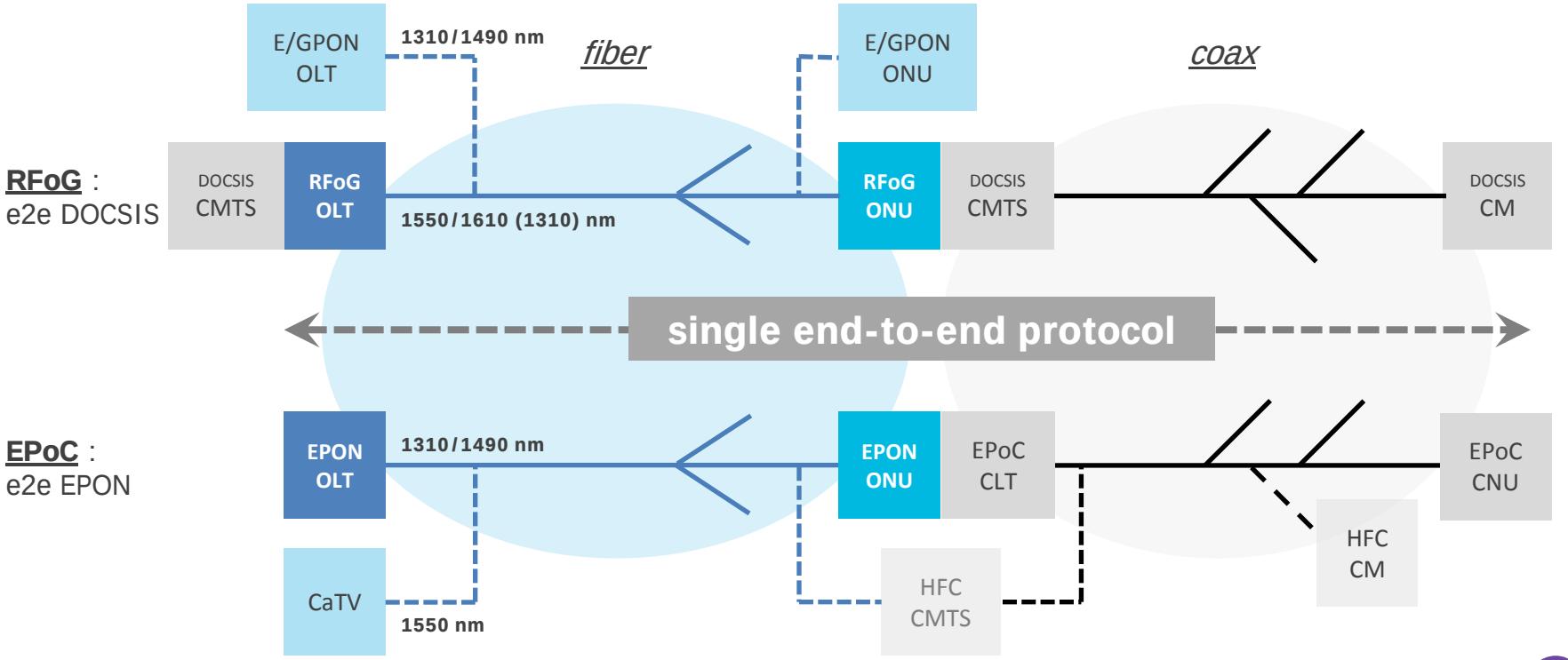
Similarly for cable : RFoG and EPoC

RFoG (RF over Glass) : SCTE/ANSI (first products available)

- optical fiber interface for DOCSIS : **up to 1G**

EPoC (EPON Protocol over Coax) : IEEE Study Group (PAR mid 2012)

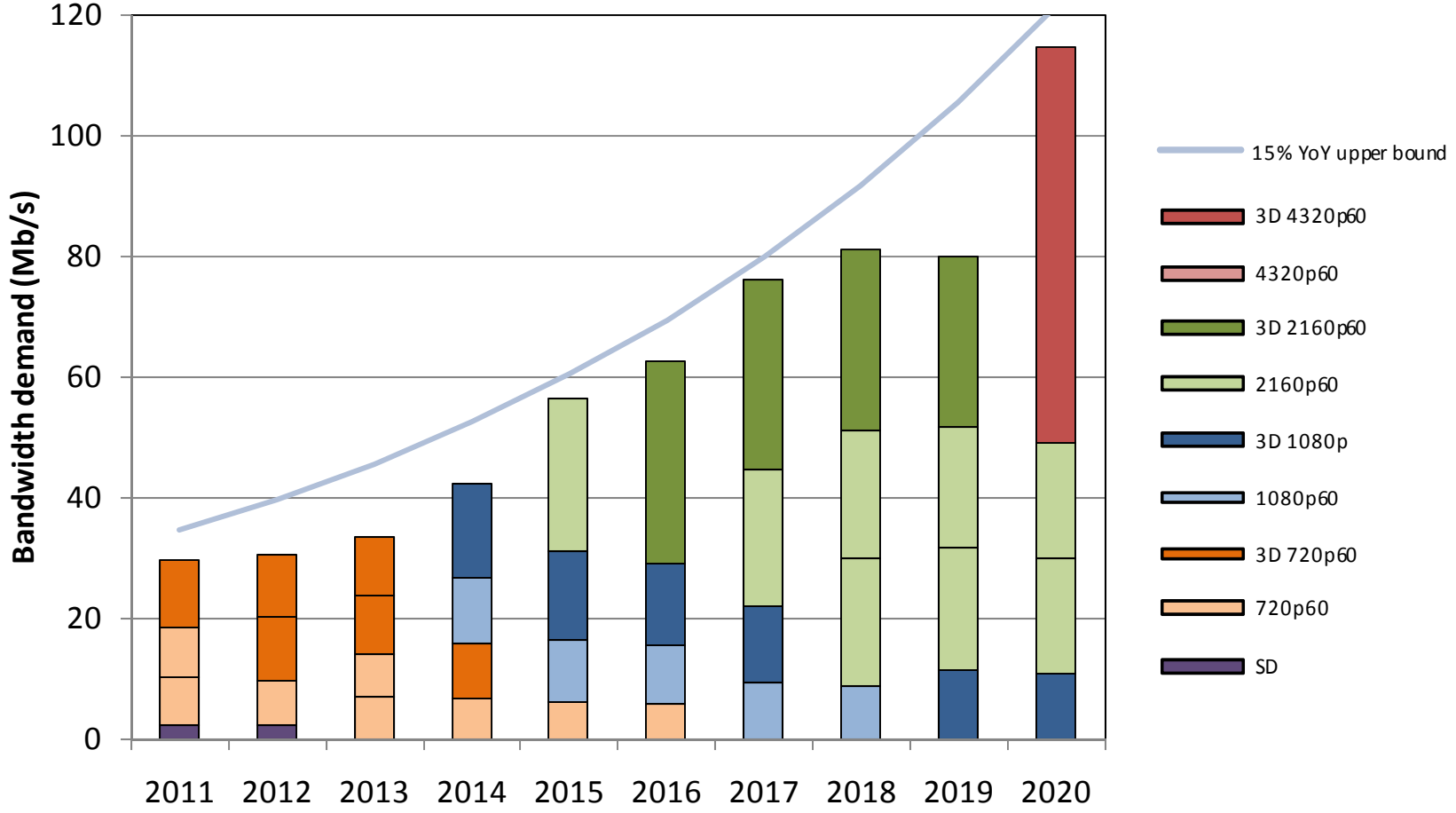
- cable interface for EPON : **up to 10G symmetrical**



Video bandwidth as the main driver for FTTH ?

upper bound of sustained bandwidth demand (per user)

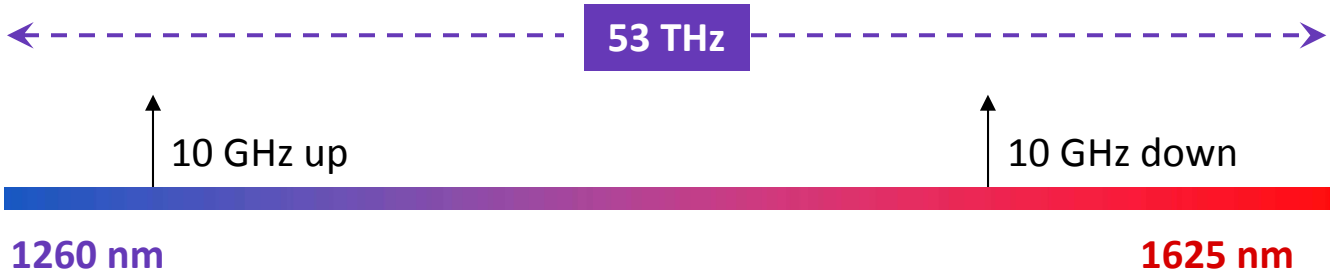
(Ed Harstead, Randy Sharpe: to appear in *IEEE Communications Magazine)*



30 Mb/s + 15% YoY bounds a high-end early adopting subscriber

What could be the real benefits from FTTH ?

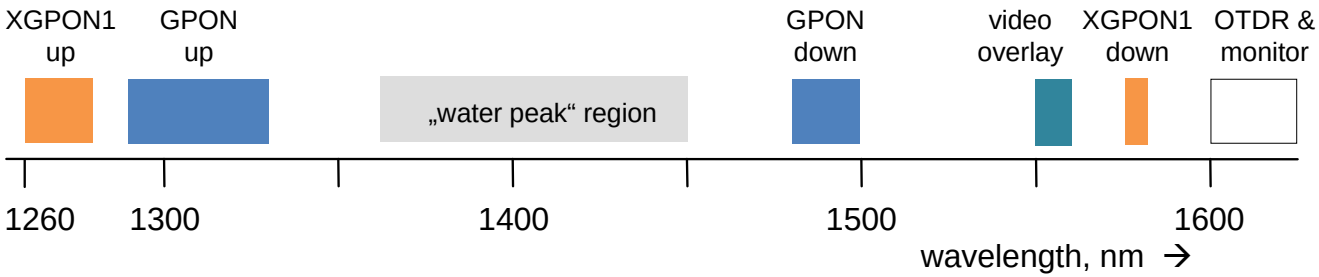
- streaming video alone does not necessarily ask for FTTH (yet)
- high speed down-/uploads are more of an argument
  - up to 10 Gbps peak per user
- but fiber just as a somewhat „faster copper cable“ ?
  - hardly justifies FTTH deployments, particularly in brownfields
- fibers offer an extremely broad optical spectrum like no other medium can do, but in access this potential is not yet adequately leveraged



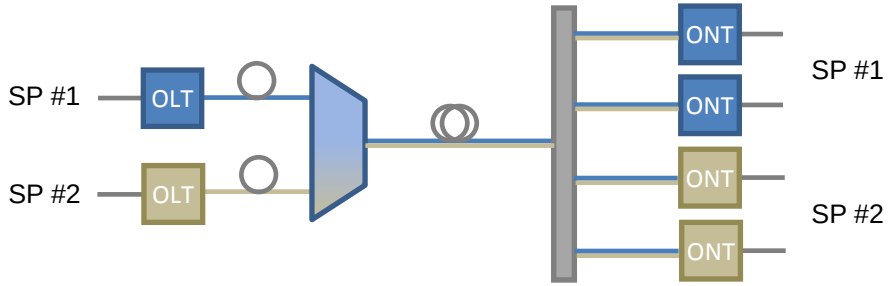
- an ever increased speed should not be the mantra in FTTH, but exploit spectrum for
  - more flexible and parallel utilization of the passive infrastructure
  - more intelligent and efficient service delivery

Spectrum is exploited already today … wasted

- Current way of using the fiber spectrum :
  - relaxed component specs *(unstabilized operation, low cost designs, manufacturing tolerances)*
  - coexistence and smooth migration of system generations



- Coming next :
  - coexistence of traditional operators via wavelength unbundling (inside xPON spectral bands)



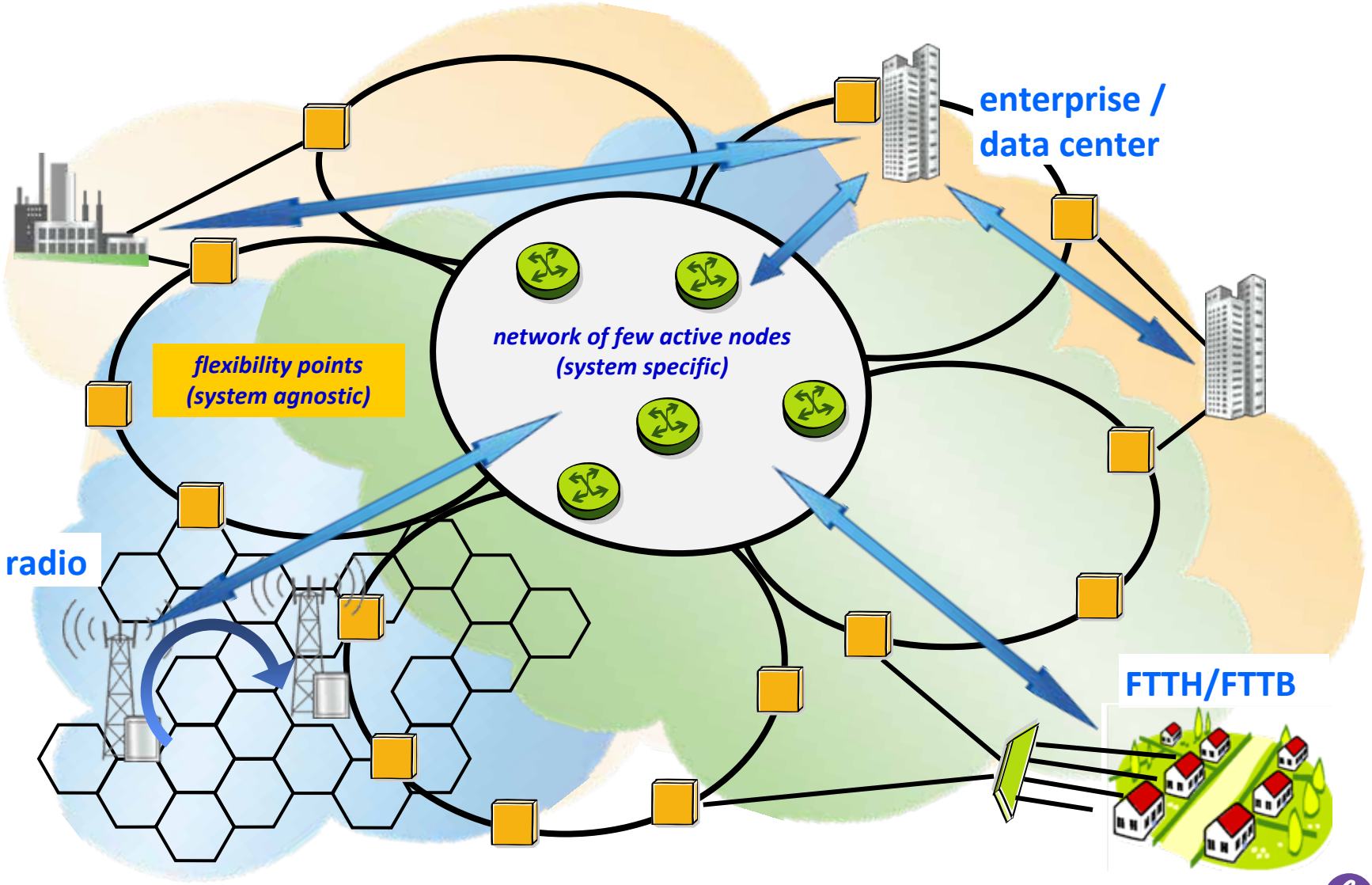
→ in both cases end users are just being moved around the spectrum

throughput- / coverage- / service-wise only little will change

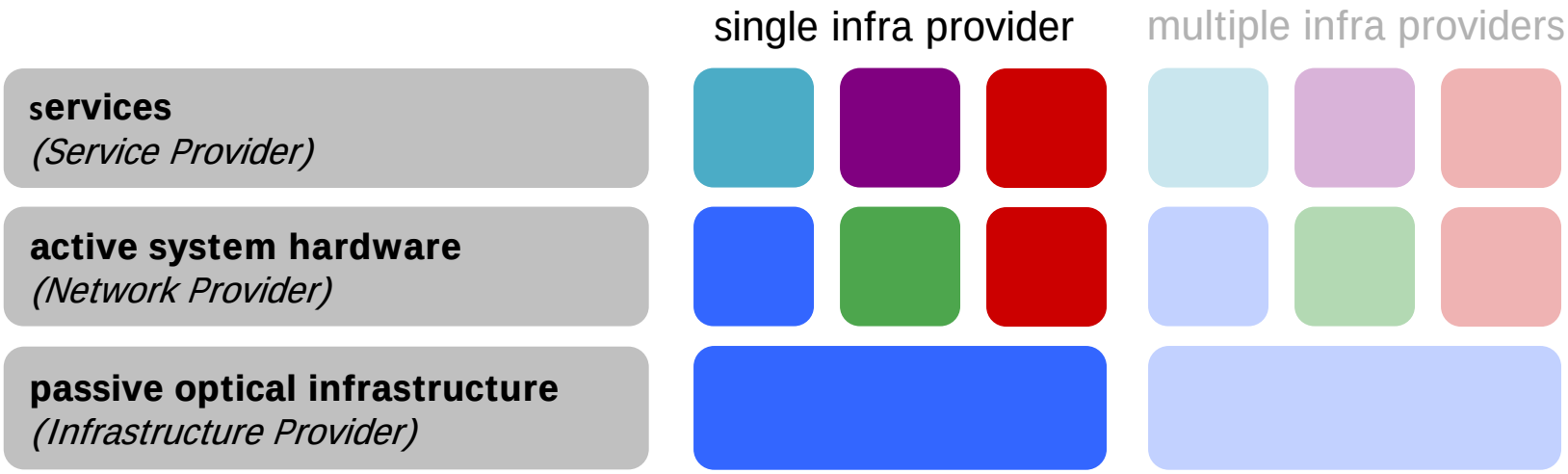
Open Metro-Access Concept

Converged Metro-Access Fiber Network

Example configuration showing basic services



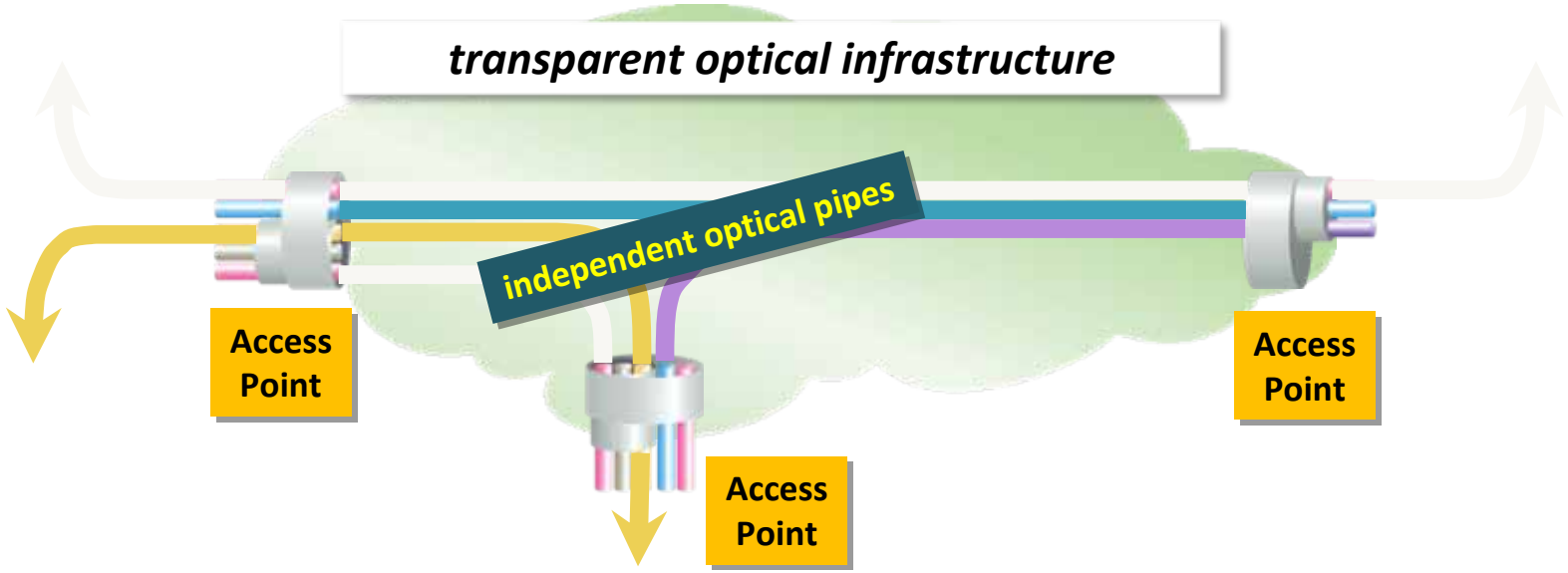
Sharing Network Resources in Open Access Model



Some major challenges :

- independent operation of multiple parallel optical channels
- monitoring and management of non-vertically integrated network
- protection for independent optical channels on the same fiber
- resource allocation and management across metro-access network domain
- transition between multiple infrastructures (in case there are any)

Infrastructure Sharing via Optical Pipes



Design target :

- pipes are transparent for different signal modulation and multiplexing formats
  - may contain active elements, but no system specific elements
  - no interworking with the systems protocols
- pipes can be reconfigured for establishing a variety of connectivity patterns
  - not just ptp, but as well multipoint patterns like ptmp, mesh, ring
- system operation in one particular pipe is entirely independent from any other pipe

The Nature of Pipes

which granularity ?

cable ? **fiber ?**

inefficient utilization
→ high CAPEX

wavebands

wavelength ? **subcarrier ?**

many comps., complex management
→ high CAPEX + OPEX

Waveband characteristics

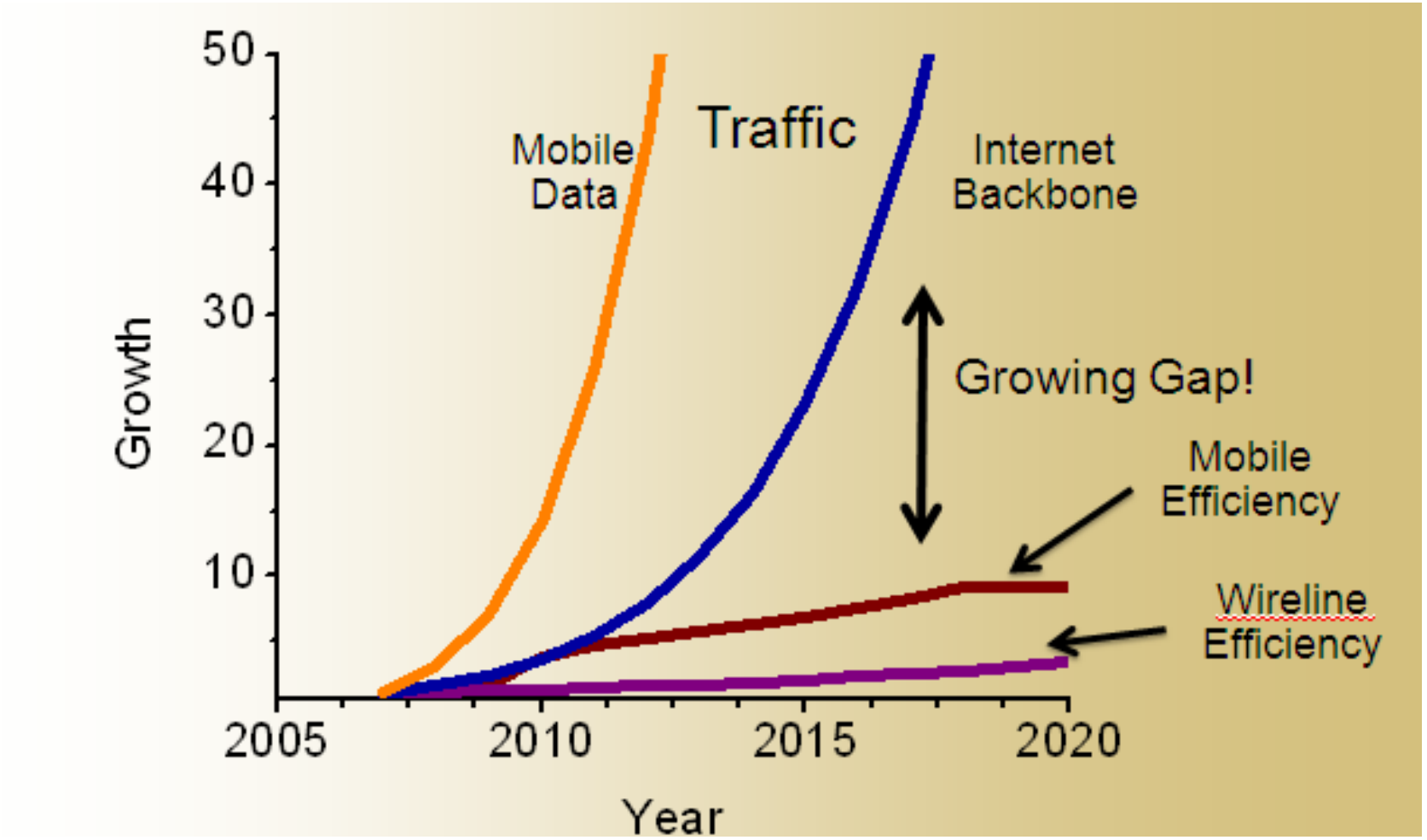
- fixed bandwidth in the range 5 - 20 nm
- on any individual fiber the wavebands may have different size
  - few different waveband patterns in an infrastructure (on different fibers in a cable)
- inside the wavebands no spectral structure is defined, leaving them open for use with
  - DWDM systems, coherent detection systems
  - uncontrolled single channel (GPON)
  - wavelength stacked XGPON
  - broadband sources (FP laser, LED)
  - OFDM systems
  - ...

The way of using of the spectrum inside the waveband is entirely up to the client system

BMBF Project CONDOR: Cooperation with KIT, HHI, JDSU, Leoni Fiber Optics

Network Efficiency

The Network Energy Gap

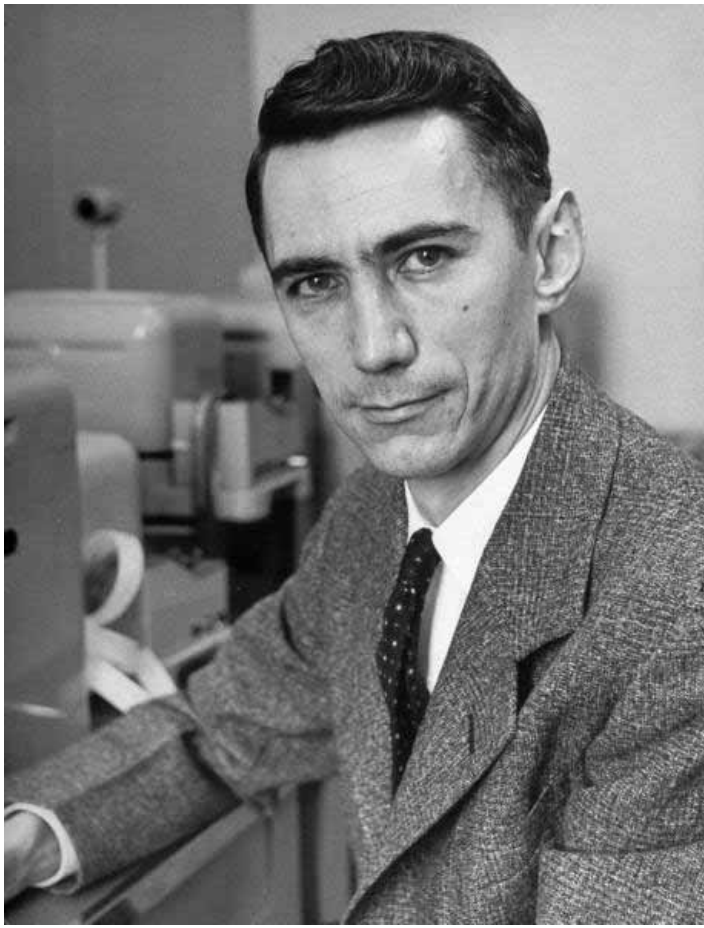


GreenTouch[TM] Consortium

How far can we go?

"Communications networks could be **10,000 times** more energy-efficient than they are today."

— Bell Labs research study



Claude Shannon

Source: GreenTouch

It Takes an Ecosystem …

By 2015, the GreenTouch goal is to deliver the architecture, specifications and roadmap — and demonstrate key components and technologies —needed to increase network energy efficiency by a factor of 1000 from current levels.

- Global research consortium representing industry, government and academic organizations
- Launched in May 2010
- 50+ member organizations
- 300 individual participants from 19 countries
- 25+ projects across wireless, wireline, routing, networking and optical transmission