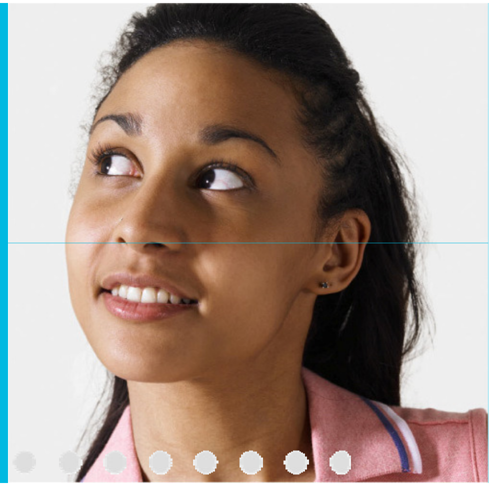
Energy Efficiency in Telecommmunication Infrastructure



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Alcatel-Lucent Bell Labs Germany

23. October 2008

Agenda

1. Broadband Access Networks
2. Wireless Access Networks
3. Wireline Transport Networks
4. Conclusions

Broadband Access Networks

Broadband Access Networks

Current situation

- Bandwidth demand = Driving force for evolution from DSL to FTTx

  Today's broadband over copper:
  VDSL2: max. 50 Mbit/s
  ADSL2+: max. 16 Mbit/s

  ➔ FTTx technology can offer 1 … 10 Gbit/s and more

  ➔ FTTx technology has high power saving potential

- Aggregation stages in the field allow for low port density at central offices

  ➔ Simple fibre management and reduced power, especially with PONs

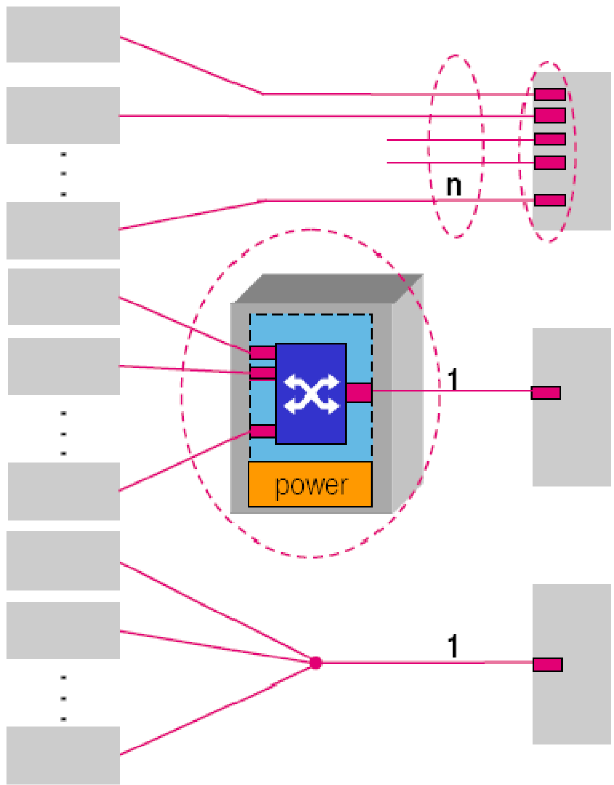
- Further power and footprint savings by reducing number of central offices

  ➔ Long optical subscriber lines (10 – 100 km)

Different Fiber Access Architectures (Operator‘s View)

Zusammenfassung der Basisstrukturen.

PtP : point-to-point
AON : Active Optical Network
PON : Passive Optical Network



- **PtP network**
  - ☹ Many Fibres through MDF and Main cable
  - ☹ Many Transceivers: Σ=2n
  - ☺ No equipment in the field
- **Aggregation with AON network**
  - ☺ Less Fibres through MDF and Main cable
  - 😐 But 2 more Transceivers: Σ=2*(n+1)
  - ☹ **Active** equipment in the field,
- **Aggregation with PON network**
  - ☺ Less Fibres through MDF and Main cable
  - ☺ Less Transceivers: Σ=n+1
  - ☺ **Passive** equipment in the field

"Aktive und passive optische Netze im Vergleich", M. Adamy, Fachtagung SächsTel 02.07.2008 14

Active Optical Networks vs. Passive Optical Networks

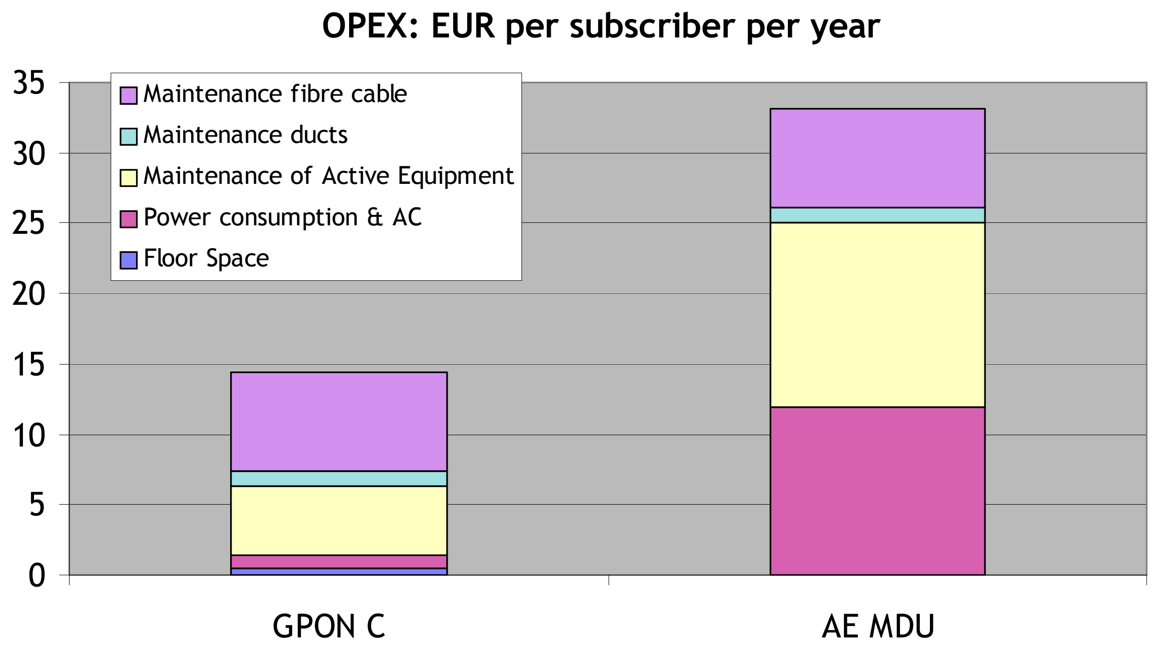
Business case for a German city : GPON vs. Active Ethernet

	GPON	Active Ethernet
Total CAPEX/subs	1.689 Euro	1.899 Euro
Total OPEX/subs	14 Euro/year	33 Euro/year

OPEX advantage >2:1 for GPON due to
- lower maintenance cost of actives
- lower power consumption

CAPEX almost identical

Network scenario
- 68% SDUs
- 32% MDUs



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Power efficiency of optical versus electronic access networks

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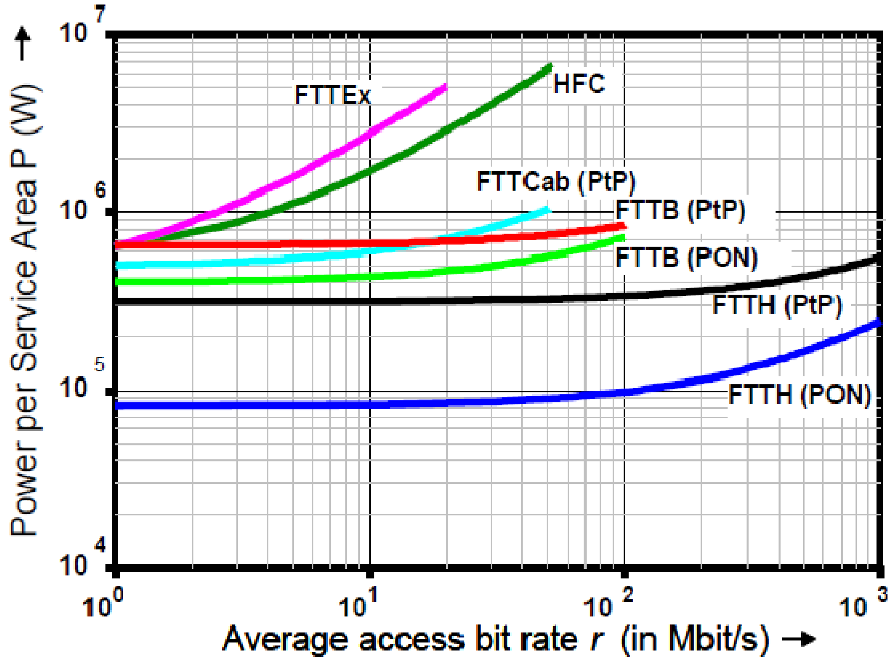

Figure 2: Power P per dense urban service area as a function of the average access bit rate r

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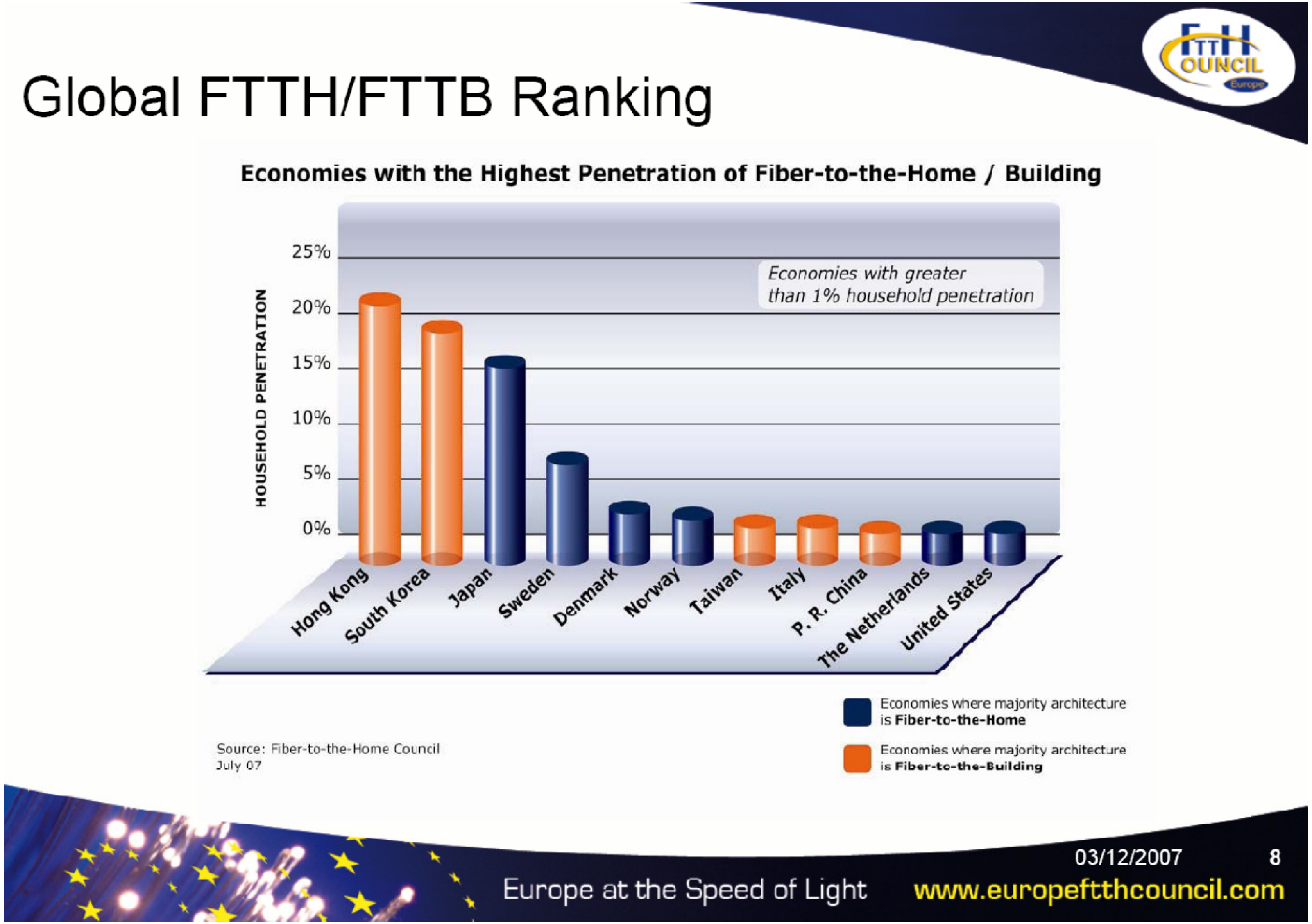
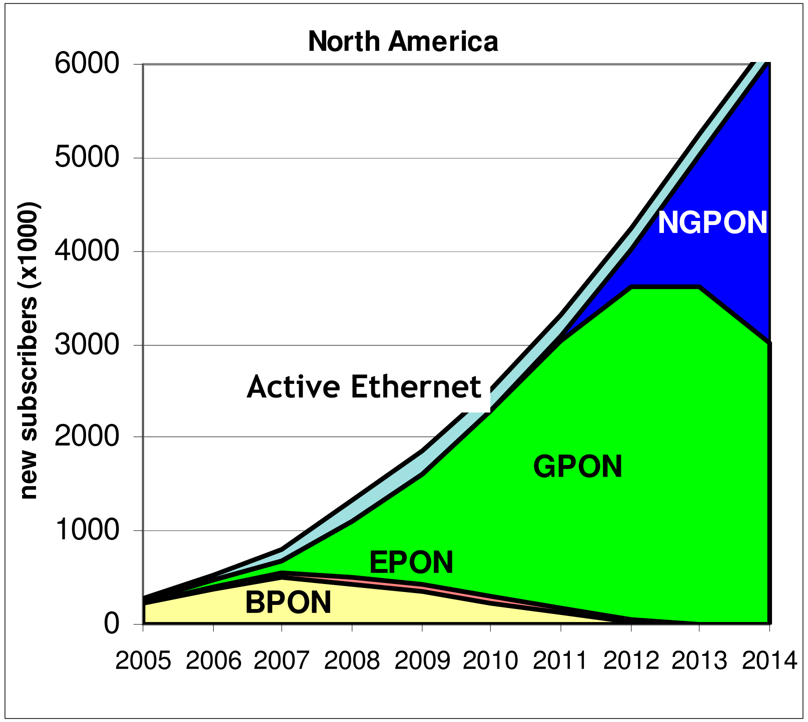
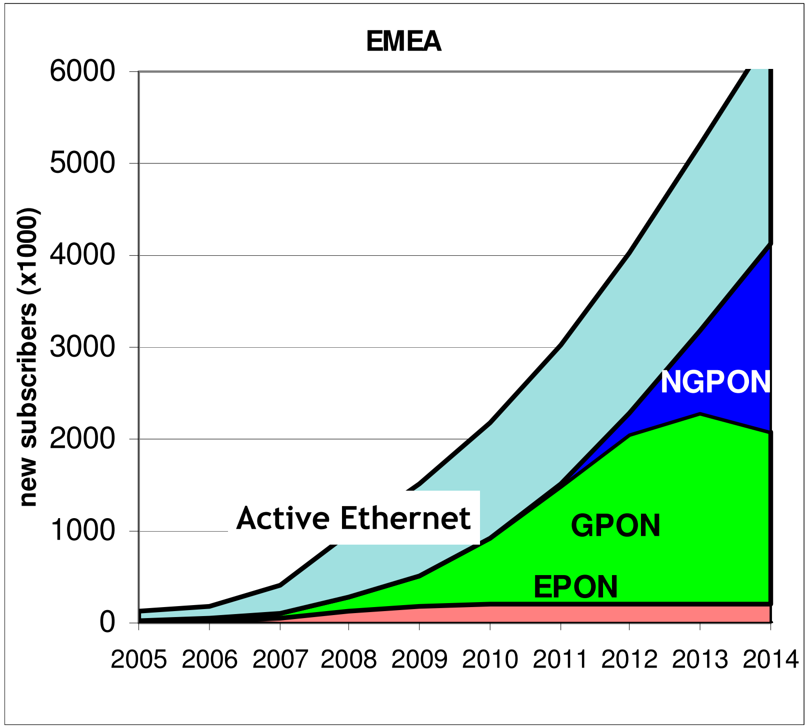
FTTx around the world



Evolution of FTTH technologies in NAR, EMEA

Source: Infonetics 2007
(plus NGPON extrapolations beyond 2010)





- Europe:
  - 350 FTTx city networks
  - 67 % run by alternatives and municipalities
- France started massive deployment of FTTH (GPON): presently the European reference market
- Deutsche Telekom recently announced GPON trial in Dresden (22000 subs)

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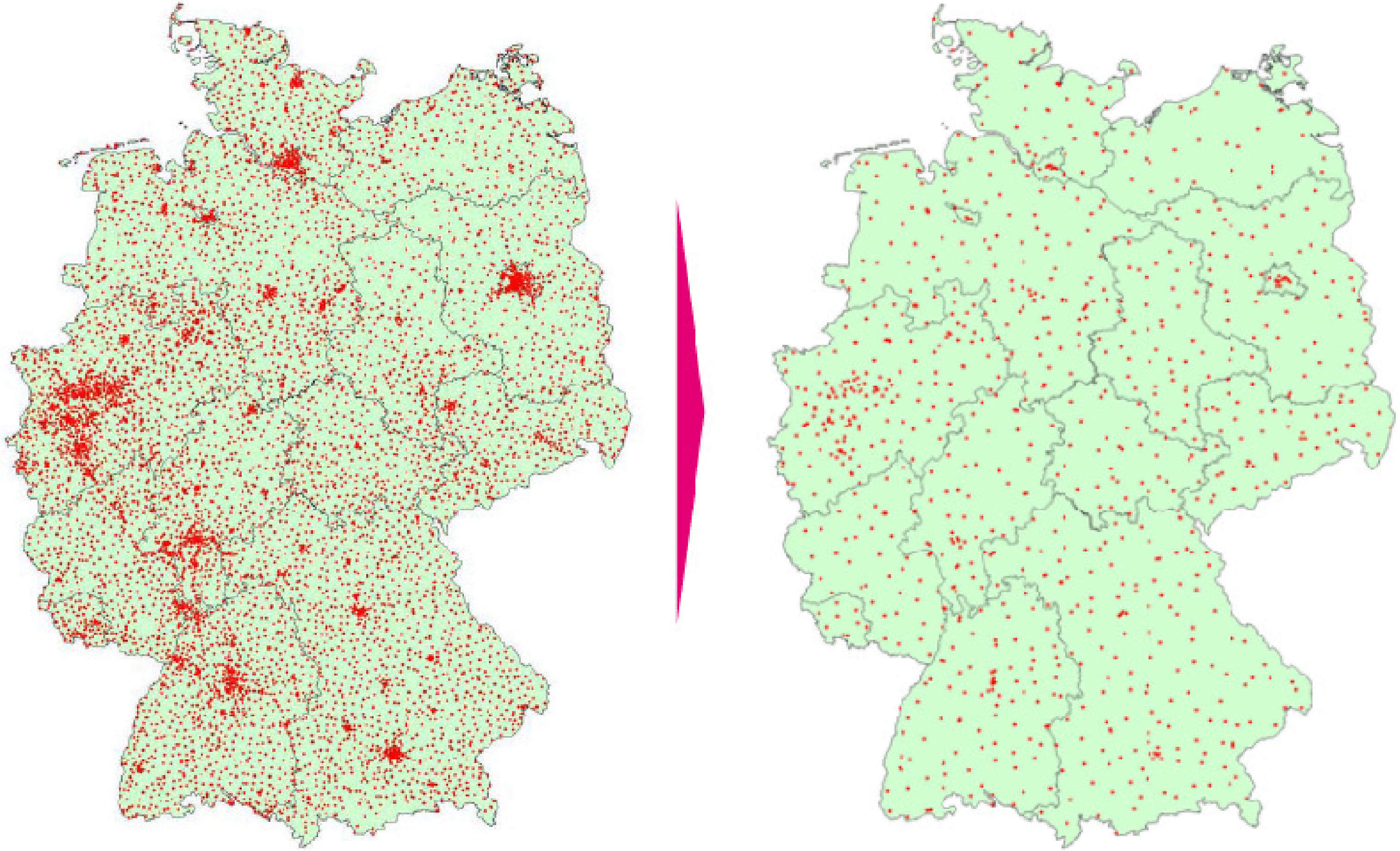
Fiber Access paves the way for Node consolidation.

Today | A Vision



C. Lange, J. Preuschaft, M. Braune, T. Monath, N. Gieschen /
Migration from current DSL-based architectures to pure optical access networks
03.07.2008
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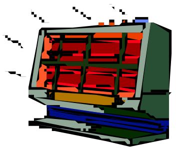
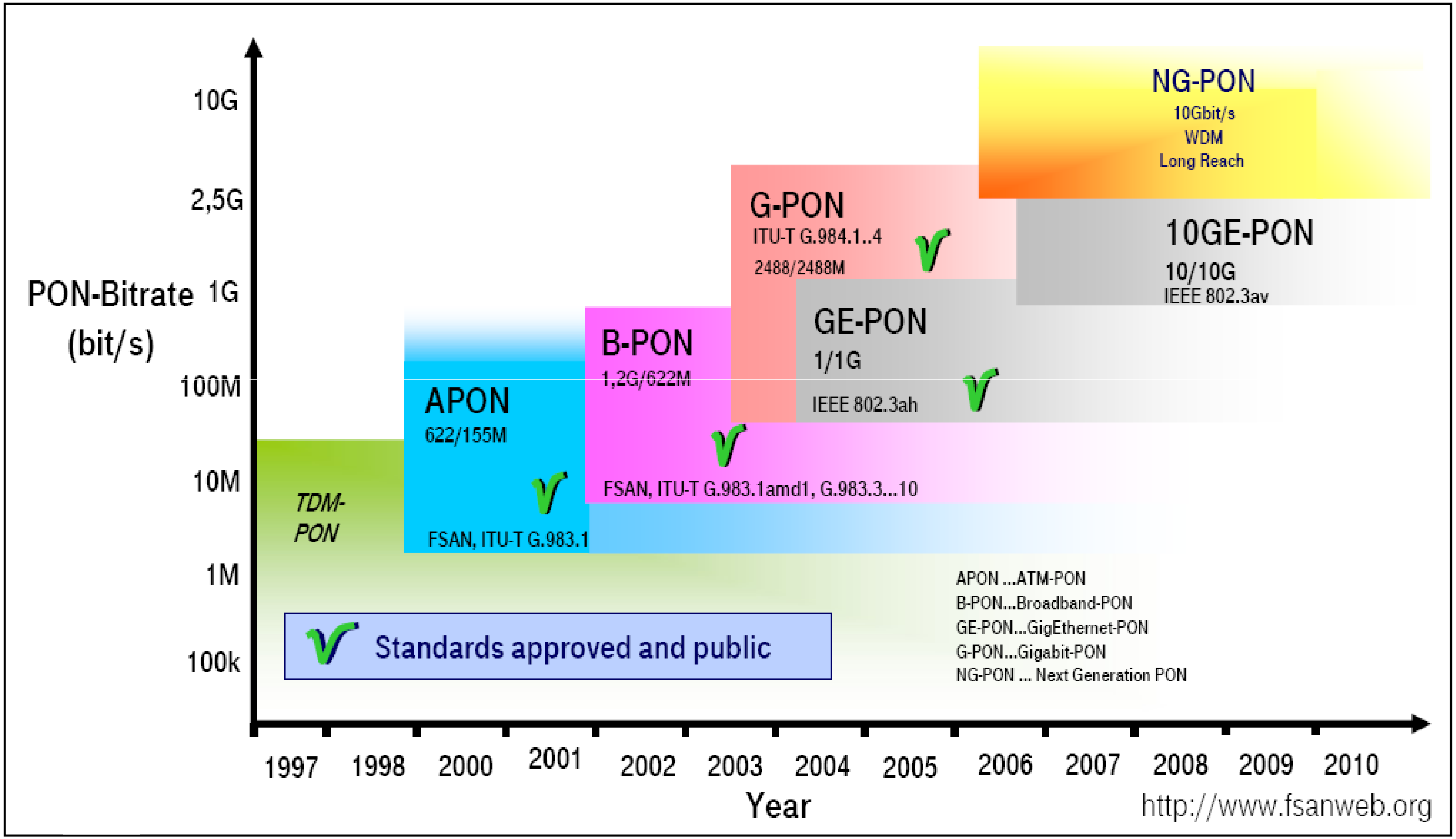
BT's Expected Benefit from Central Office Consolidation

Vision of future local exchange

Based on Ipswich Exchange serving ~15,000 customers

Today	21C MSAN	Long Reach PON
900 racks	20 racks	1 rack
826 kw	50-100 kw	100W
		

PON standards evolution



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Wireless Access Networks

Energy Efficient Wireless Access Networks

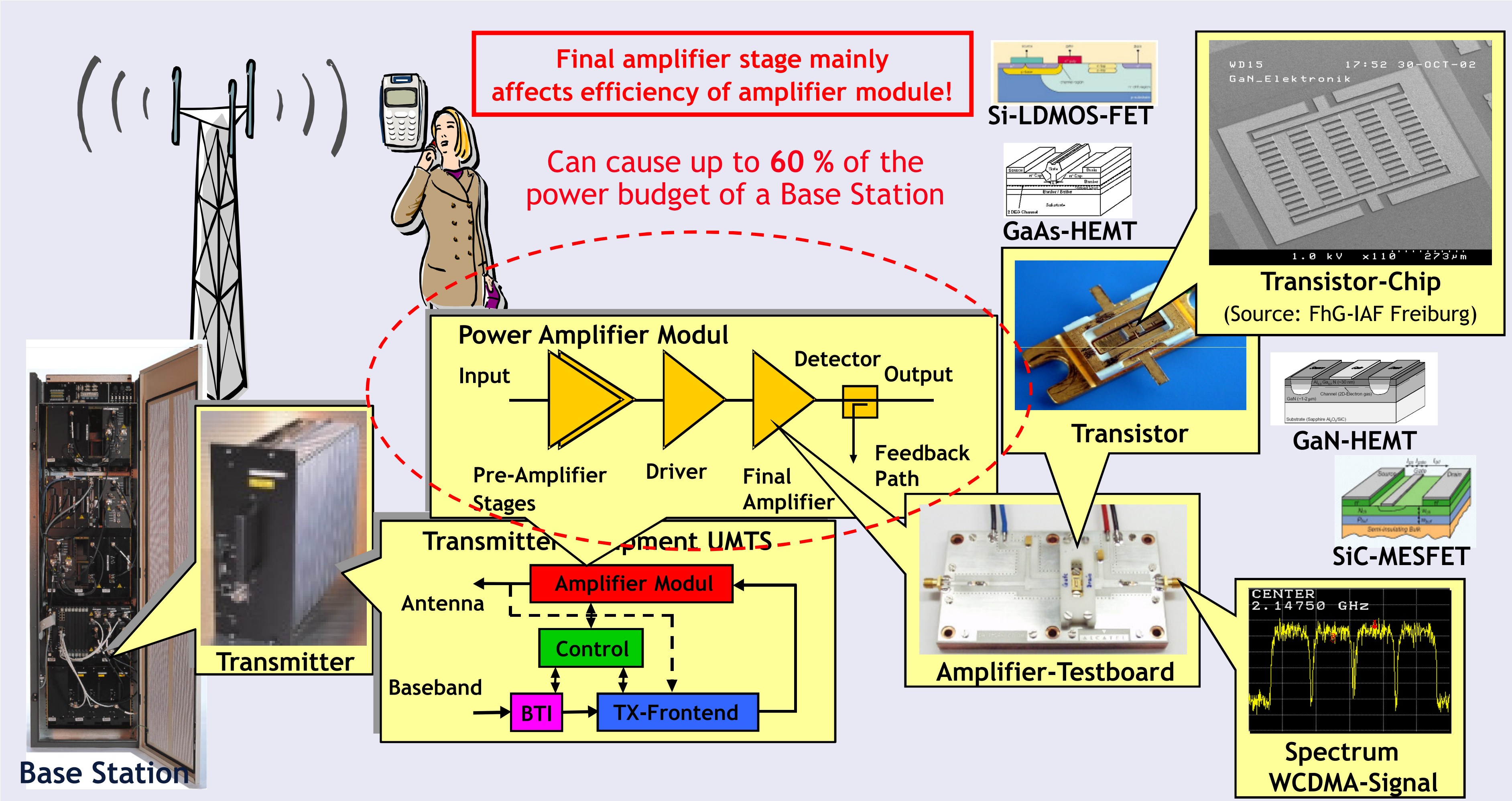
Current situation

- Mobile broadband growth and future services inducing new power requirements
  - Increasing the risk of delay in launching new technologies
  - Barrier to the deployment of renewable energy sources
  - Increasing CAPEX and OPEX to non sustainable level
- Base stations providing major contribution to overall power consumption
  - 200-500 GWh /year/operator/country = 50-80% of overall mobile network
  - In the UK, the mobile industry accounts for around 0.7% of CO_2 emissions

Research challenges

- Power amplifiers
  - Higher degree modulation schemes
  - Power amplifiers with improved efficiency - OPEX reduction by power saving
- System aspects that impact power consumption

Power Amplifier in the Base Station



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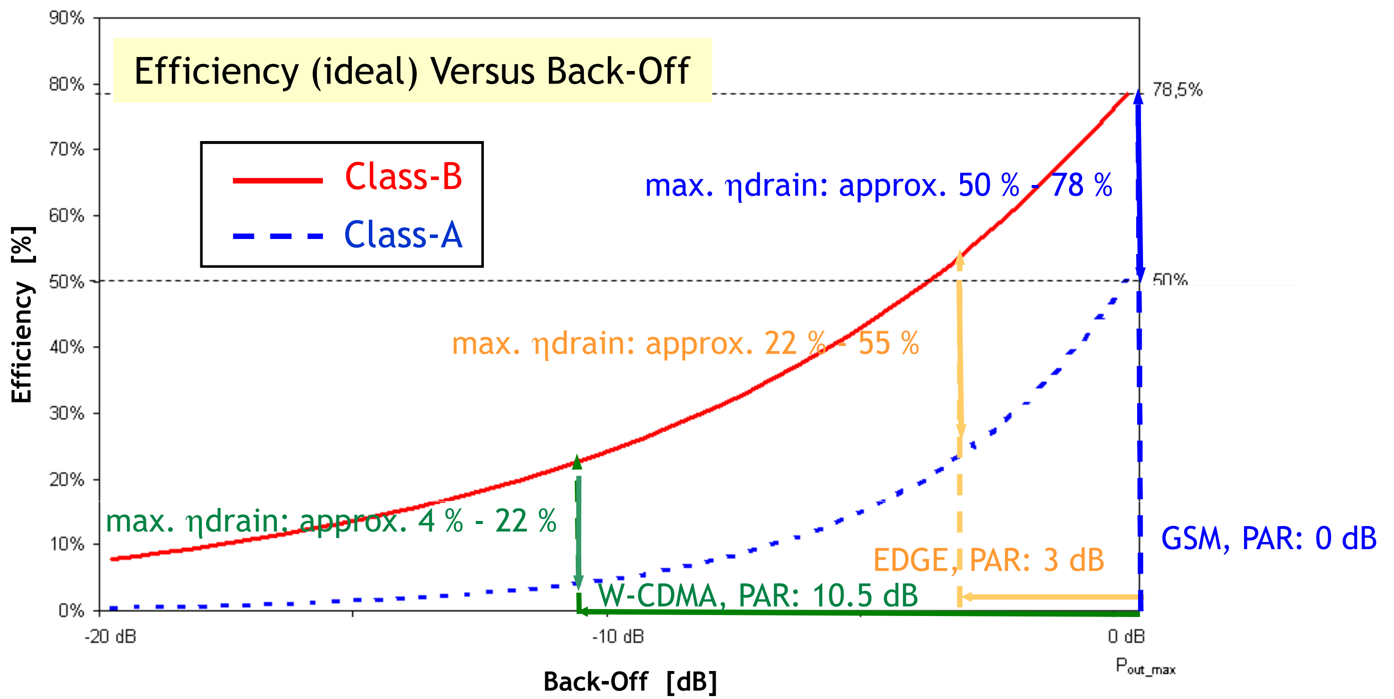
Amplifier Efficiency for Different Communication Standards



Modulation	User	Average Power	Peak Power	Dissipated Power	Pk. Power/ User	Diss. Power/ User
GSM	8	40 W	80 W	40 W	10 W	5 W
EDGE	8	40 W	160 W	120 W	20 W	15 W
W-CDMA	approx. 25	40 W	400 W	360 W	16 W	14.4 W

Without linearisation or signal dynamic reduction

Dr. Richard G. Ransom, WDC2002 Workshop on High Efficiency, High Linearity Amplifiers

- **Peak Power/User**

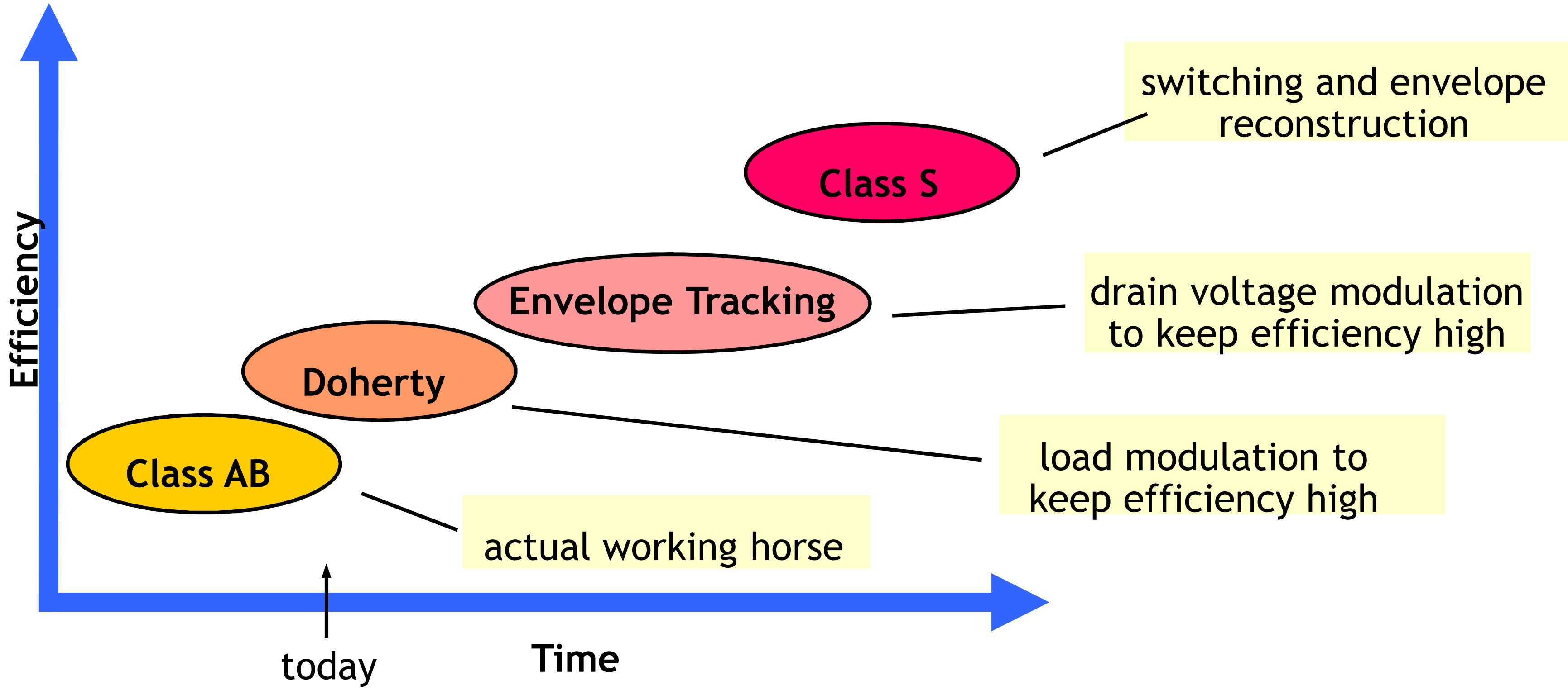
  Measure for equipment cost

- **Dissipated Power/User**

  Measure for operating cost

Amplifier Designs for Higher Efficiency

- Class AB has 40% as efficiency limit
- Target for linear amplifiers concepts is to keep peak efficiency of up to 78%



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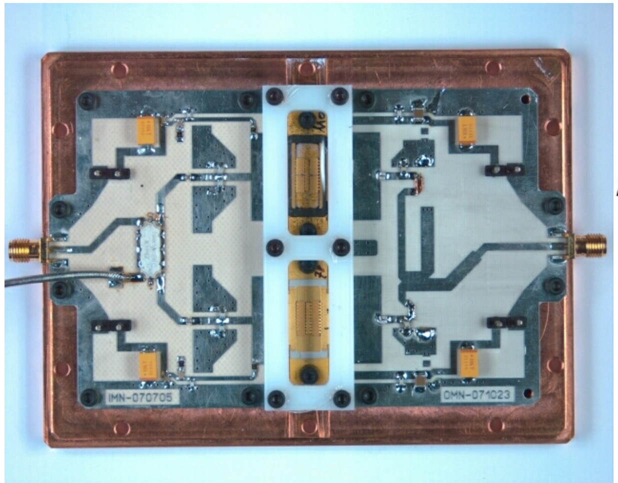
Example of Efficiency Improvement: Doherty Amplifier



Fraunhofer Institut Angewandte Festkörperphysik

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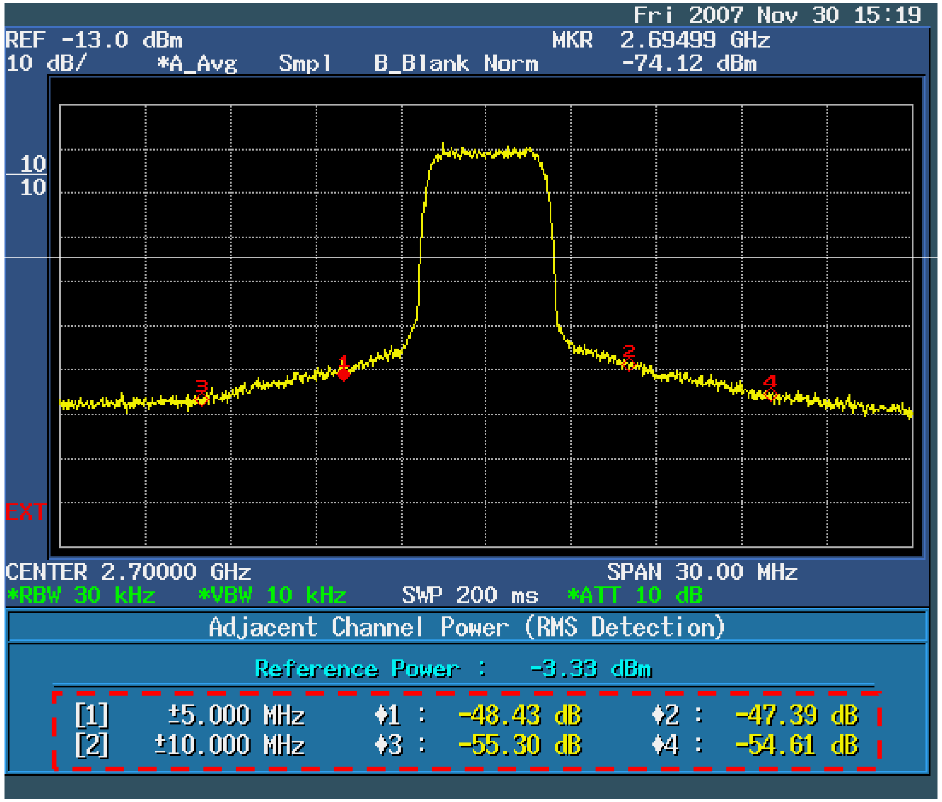
- GaN-Technology (FhG-IAF)

1-Carrier W-CDMA performance:

- P_{out}: 44.9 dBm (50.5 dBm peak)
- Drain-Efficiency: **45 %**

➔ **10 % efficiency improvement**



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Energy Efficient Wireless Access Networks

System aspects that impact power consumption

- Self-organized management of Basestation operation
  - Allow temporal operation of cells (public events, stadium, …)
  - Power saving during night and low traffic hours
  - Self-learning for traffic prediction (traffic volume, time/date, load)
- Power efficient and high performance deployment scenarios with
  - Small cells, OPEX optimized cell sizes
  - Meshes, repeaters, relays, Remote Radio Heads
  - Hierarchical cell structures
- Algorithms and components that adopt power consumption on traffic situation
  - By switching off components, carriers, subcarriers
  - By radio traffic management
  - By controlling transmitter power

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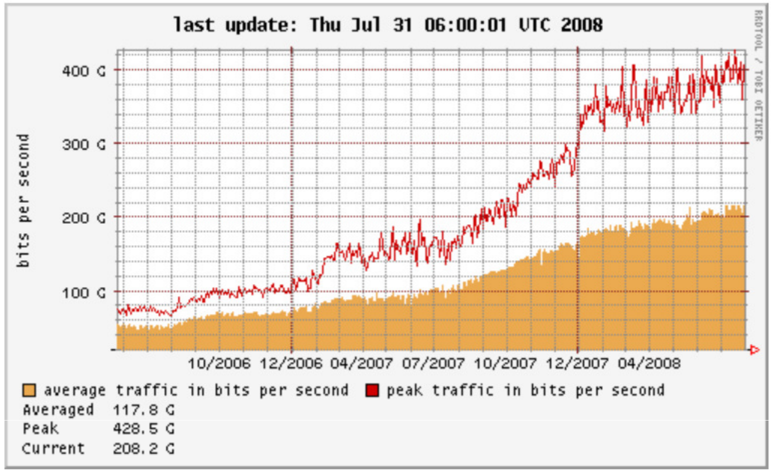
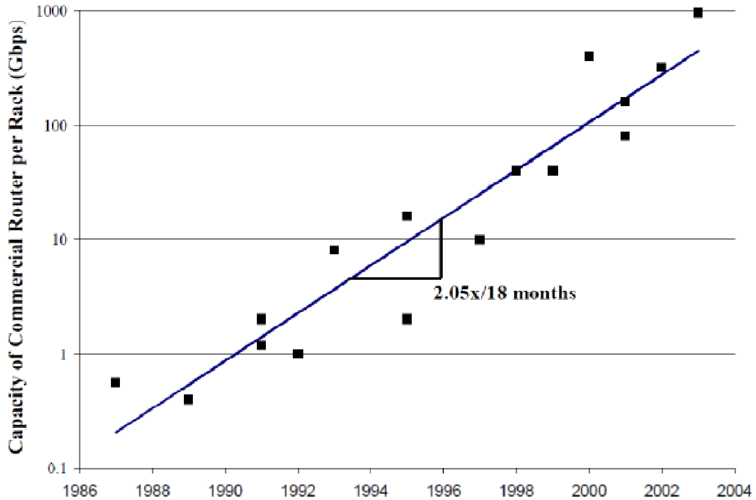
Wireline Transport Networks

Terabit Packet Transport - Challenges

German Internet Exchange, Frankfurt



Traffic is doubling every **11** months



IP Router capacity per rack is doubling every **18** months

- Traffic volume is growing much faster than the processing power (IP routers)
- Despite semiconductor technology improvements, power consumption is still growing with bitrate and volume

  ➔ total power per switch node is exploding

We can win this race only with novel architectures and technologies

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Terabit Packet Transport Networks

Vision

- A „green" packet transport network, energy/cost optimized and scalable to 100 Terabit/s throughput per node at 100 times less power

Business drivers

- Many operators starting transformation of their networks replacing legacy SDH/SONET and IP backbone networks by converged packet centric approaches
- Clear trend towards „Green IT" ➔ handle dramatic traffic increase but save power
- Offer carrier grade solutions at L1/L2, outperforming all-IP solutions in power and costs

Research challenges - Multi-Terabit network and node architectures

- Flexible, programmable Line Cards for **>100G packet processing** on multiple protocols
- Novel multi-layer switch architectures ➔ **photonic bypassing** of electronic processing
  - Achieve scalability towards 100 Tb/s throughput per node
  - At the same time reduce overall processing complexity, power and cost
- **Multi-layer optimization:** best mix of photonics and electronics at least cost and power
- **Feasibility**, footprint and cooling issues (MegaWatts power per node = feasibility issue)
- Simplified, automated/autonomous network **operation**

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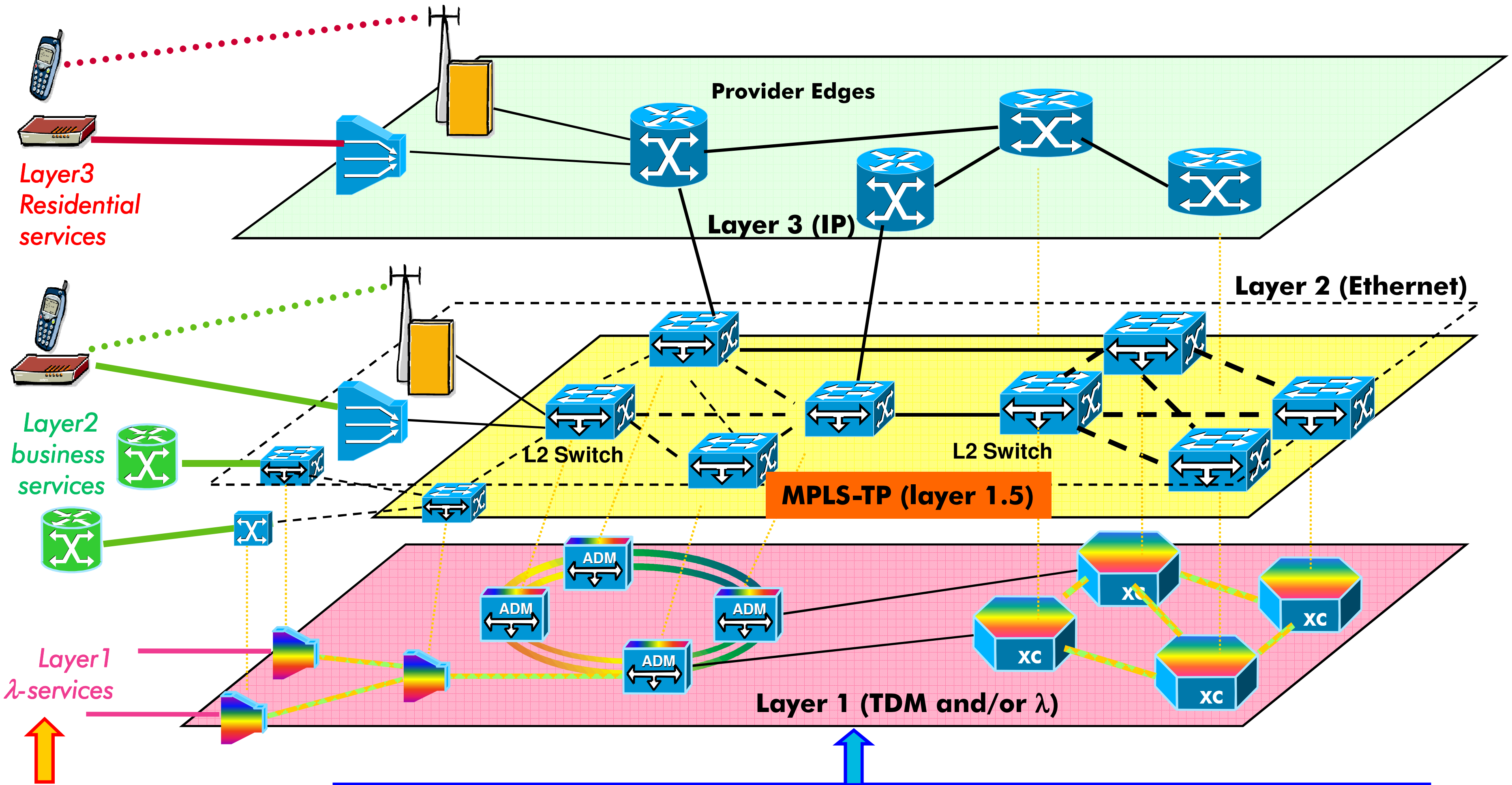
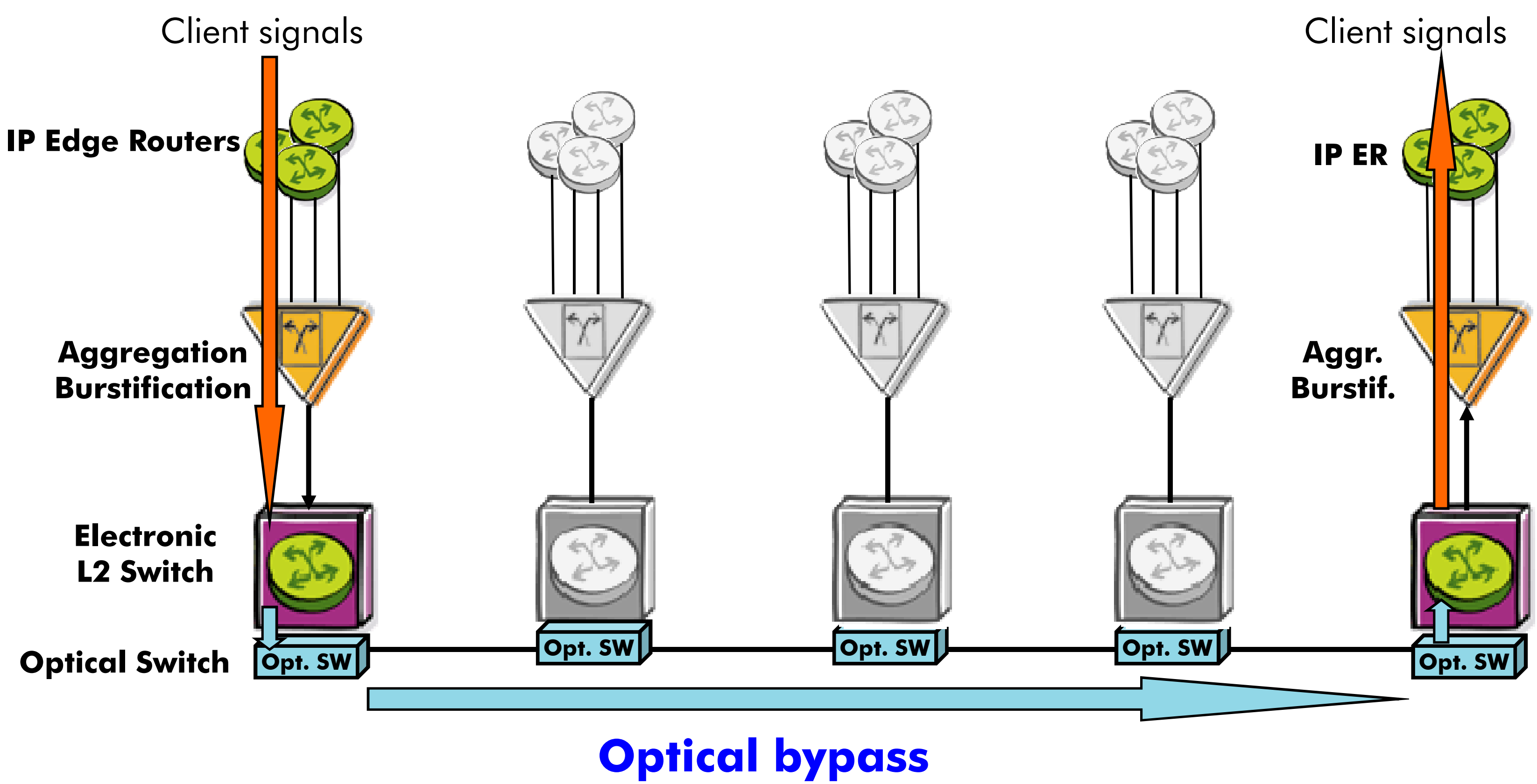
Multi-Layer Terabit Packet Transport Network



Multiple service access

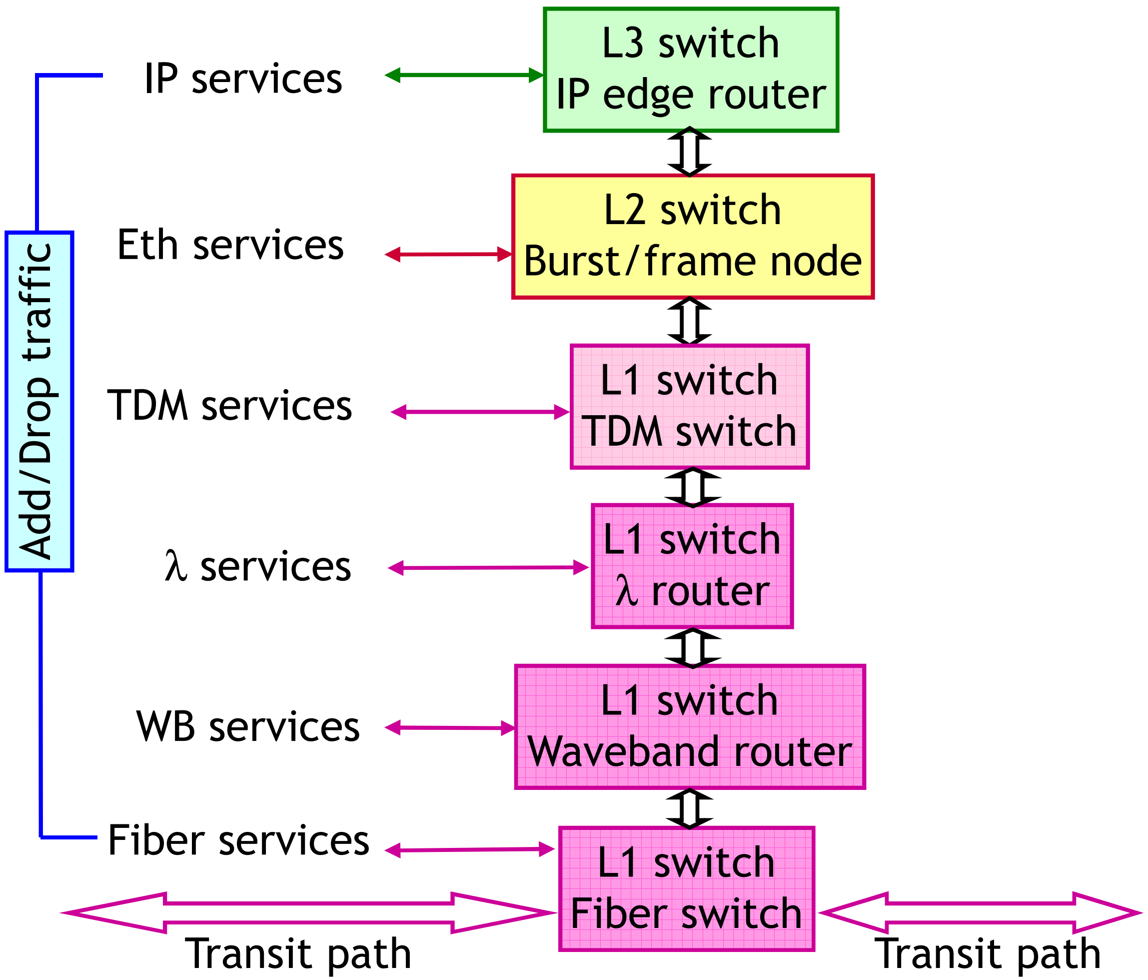
Switching at lowest possible layer and lowest granularities
➔ Reduce bit/packet processing and power

Bypass Switching in the Optical Domain



- Optical bypass: low complexity circuit switching
- Transparency domains are limited by signal impairments in nodes and on transmission links
  ➔ Signal regeneration is mandatory

Idea: Hybrid Multi-Layer Switch Node Architecture



PPC	Function	Time	Traffic
4	max	ns	5%
3	high	µs	15%
1	medium	sec… min	30%
0,3	low	min	35%
0,3	low	hours… days	10%
0,2	min	days… weeks	5%

PPC= Processing, Power, Cost

- Processing complexity, power and cost is considerably lower in the optical layers
- All-IP electronic Terabit router: 1 kW per port ⇔ optical switch: <25 W per port

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Multi-Layer Network Dimensioning/Optimization

Aim: To define an optimal network design at lowest cost benefiting from the multi-layer capabilities

Real multi-layer planning, dimensioning and optimization platform

- Integrated approach for IP/MPLS, L2 and subjacent DWDM/OTH layers
- Modeling
  - Network topology and traffic matrix generation
  - Protection/Restoration (single/double failure elements, linear protection, SRLG)
  - Statistical multiplexing schemes (core link dimensioning)
- Planning
  - Detailed multi-layer **CAPEX** calculation and analysis
  - **OPEX** calculation and analysis under development
  - Analysis of "what…if" restoration scenarios of several failure classes
- Optimization
  - Cost optimization heuristics tailored for customer needs
  - Single and multi-layer optimization

Multi-Layer Dimensioning/Optimization for Terabit Networks
CAPEX/OPEX and Power Optimization

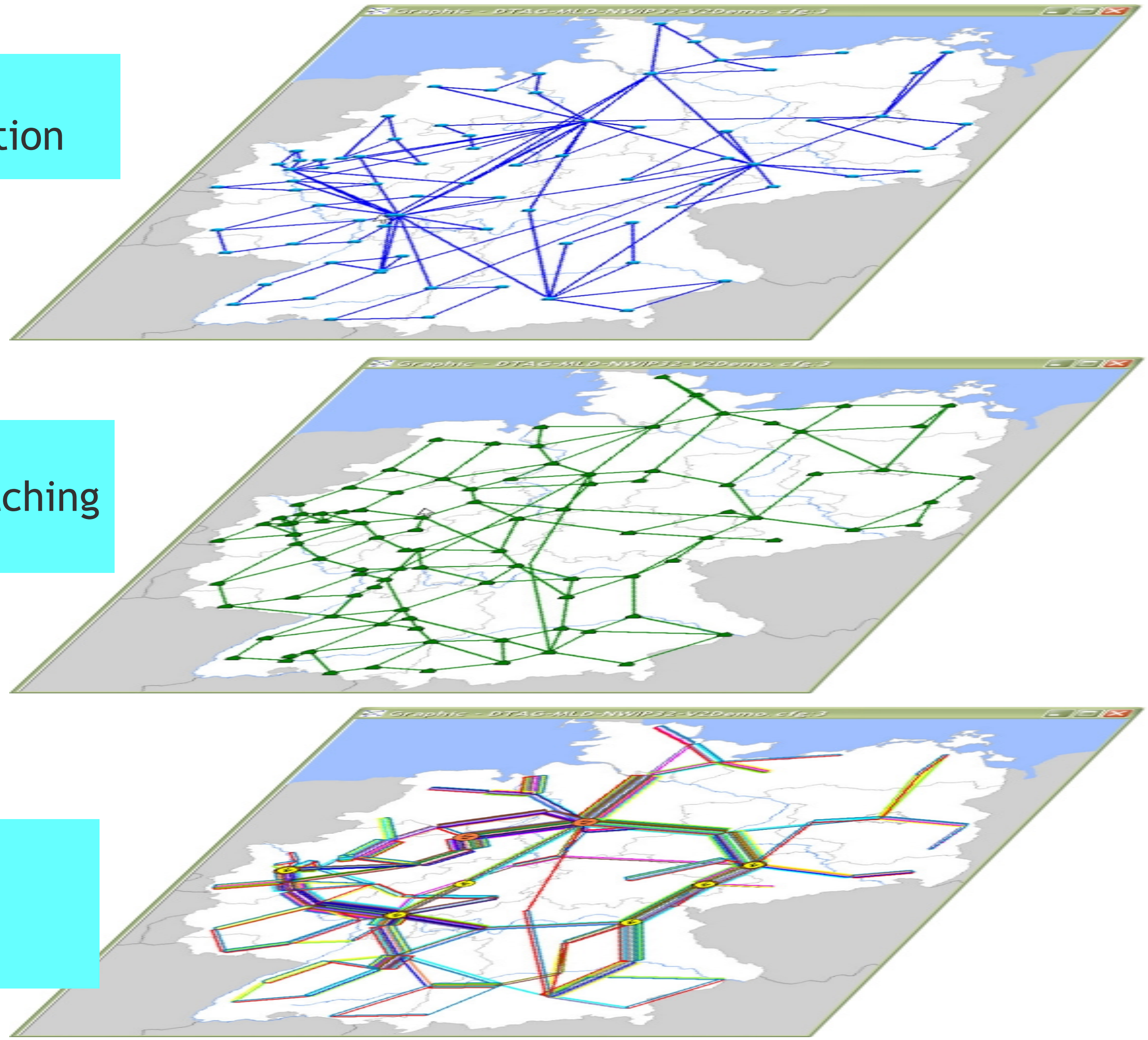
IP layer
IP/flow switching, traffic aggregation

Client-Server relations

Transport layer
SONET/SDH circuits, packet switching (MPLS-TP, PBB-TE, etc.)

Client-Server relations

Optical layer
Fiber, waveband, wavelength switching, ROADMs

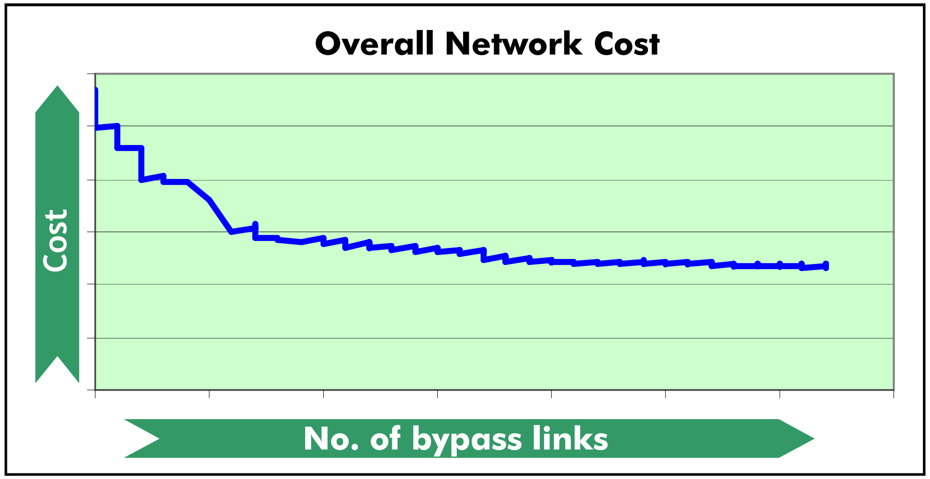


New Terabit Core Networks

Benefits of novel architecture in today's networks

- Optimized hybrid multi-layer architecture with photonic bypass
  - Off-loading traffic from IP core routers
- Multi-layer cost optimization heuristic developed by Bell Labs
  - Example: European backbone reference network in 2007
  - Result: overall network cost reduction by >30% (CAPEX) deploying photonic bypass
  - OPEX cost savings also expected

Significant cost reduction possible by introduction of multi-layer nodes with photonic technologies



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Conclusions

Conclusions

- Internet traffic keeps growing dramatically
  - Fuelled by increasing bandwidth in wireline and wireless access networks
- Evolution of telecommunication infrastructure
  - Cost of transported bit (CAPEX & OPEX) to be reduced
  - Power dissipation as major cost driver, feasibility and environmental issue
- Wireline access networks
  - Passive optical networks will reduce OPEX, in particular power dissipation
- Wireless access networks
  - Power amplifier efficiency
  - Intelligent, traffic dependent self-management to save power
- Wireline packet transport networks
  - New architectures and technologies to simplify processing and operation
  - Optical bypassing of electronic processing to save power, complexity and cost

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