Ensuring capacity for future wired and wireless access network

Capacity bottlenecks and resource management problems in (current and) future networks and how we might limit the impact

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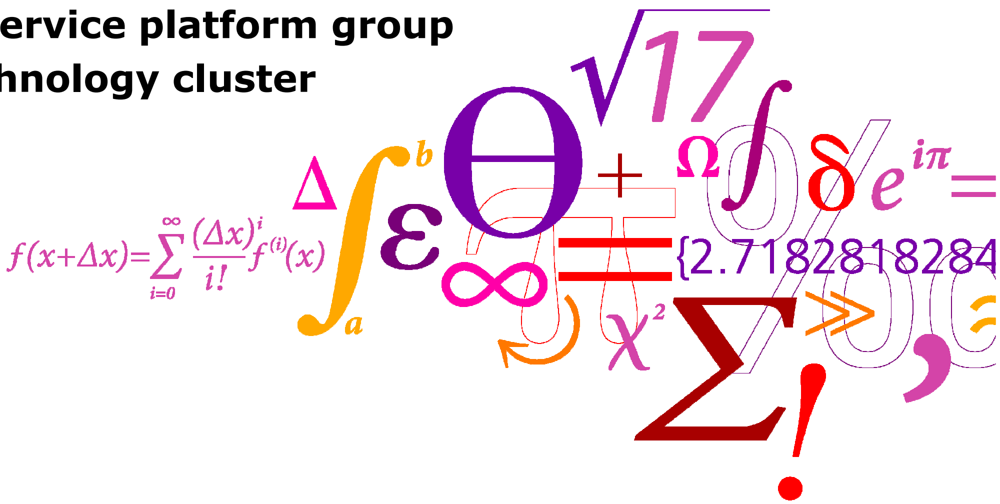

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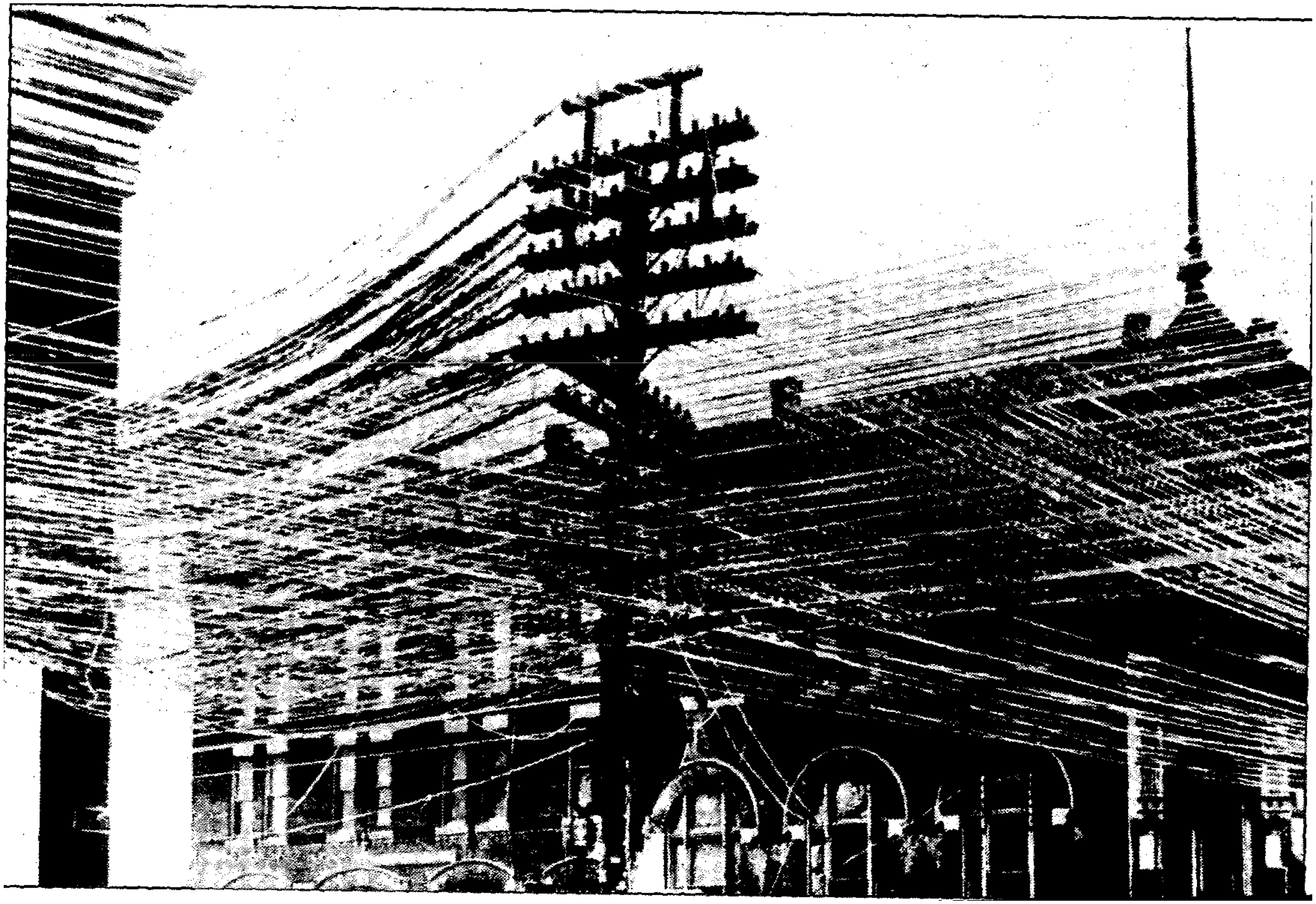
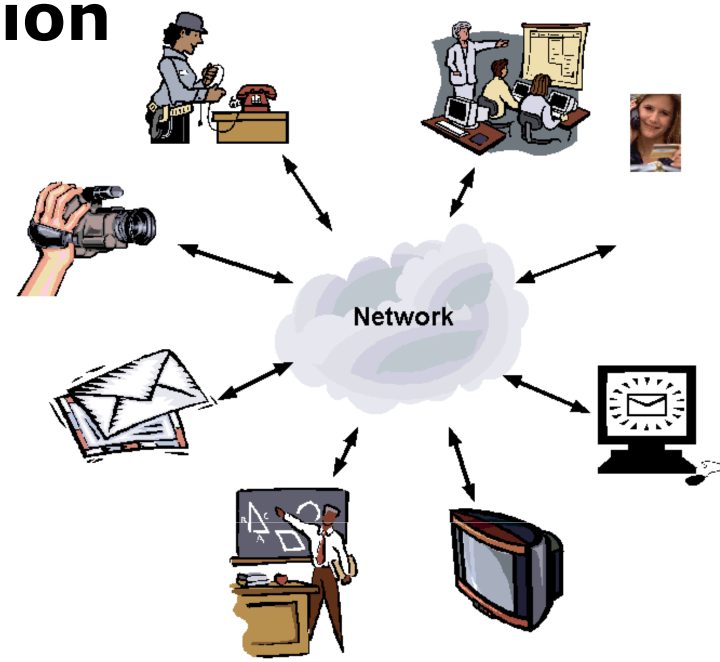
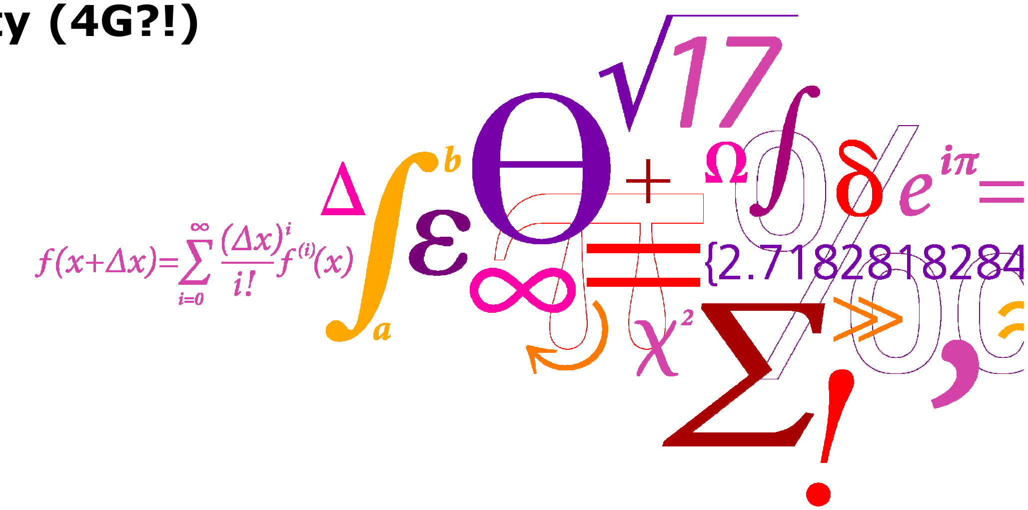
Access network of the past



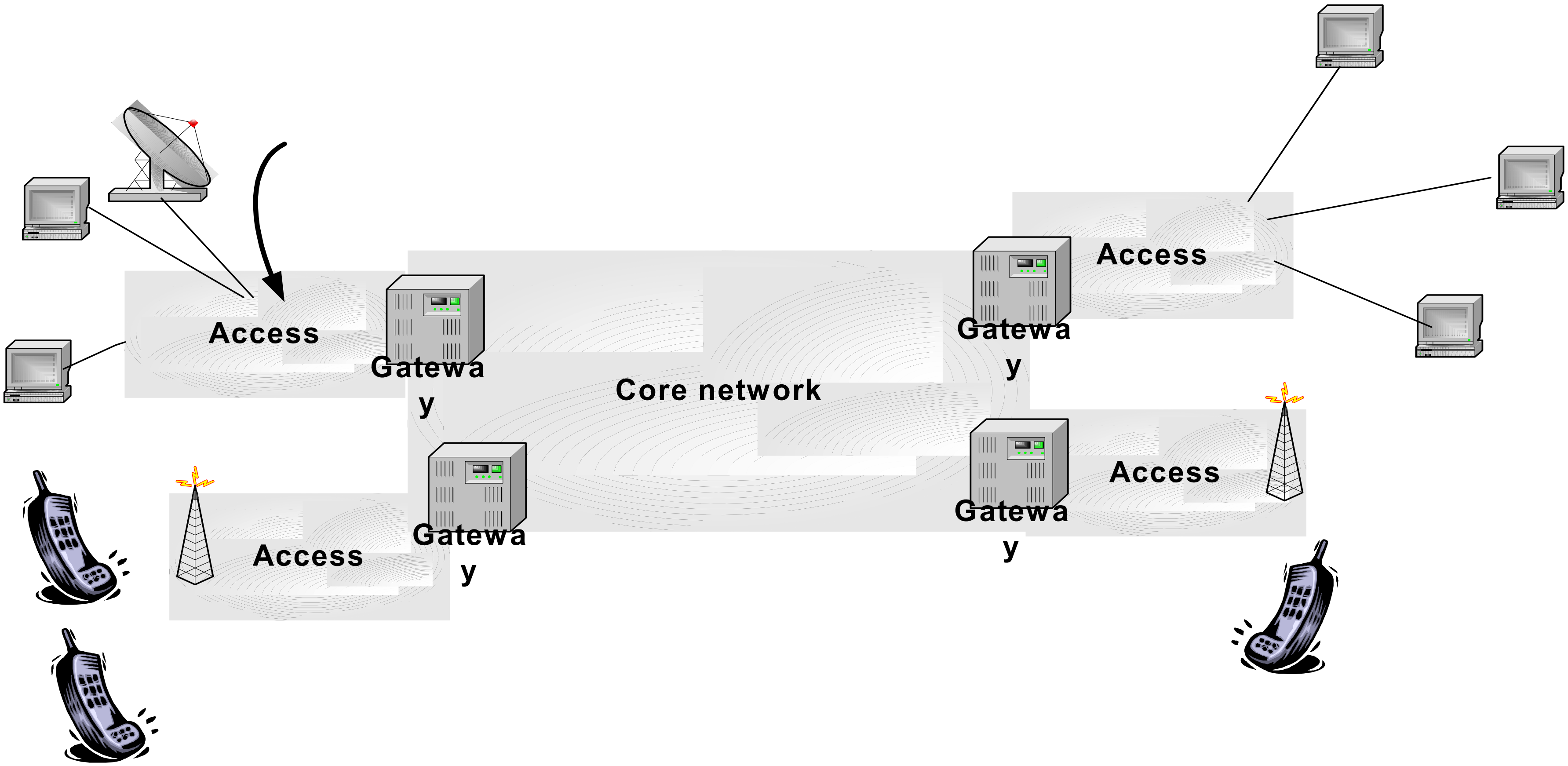
Recent trends in communcation networks

- **Migrate service intergation towards using the IP protocol family**
- **Merging of ”many” networks in to one (or fewer)**
- **Increased capacity (HSDPA, LTE, ADSL2+, VDSL, FTTx)**
- **Combine technologies to achieve higher total capacity (4G?!)**
- **Change in traffic pattern due new service architecture**

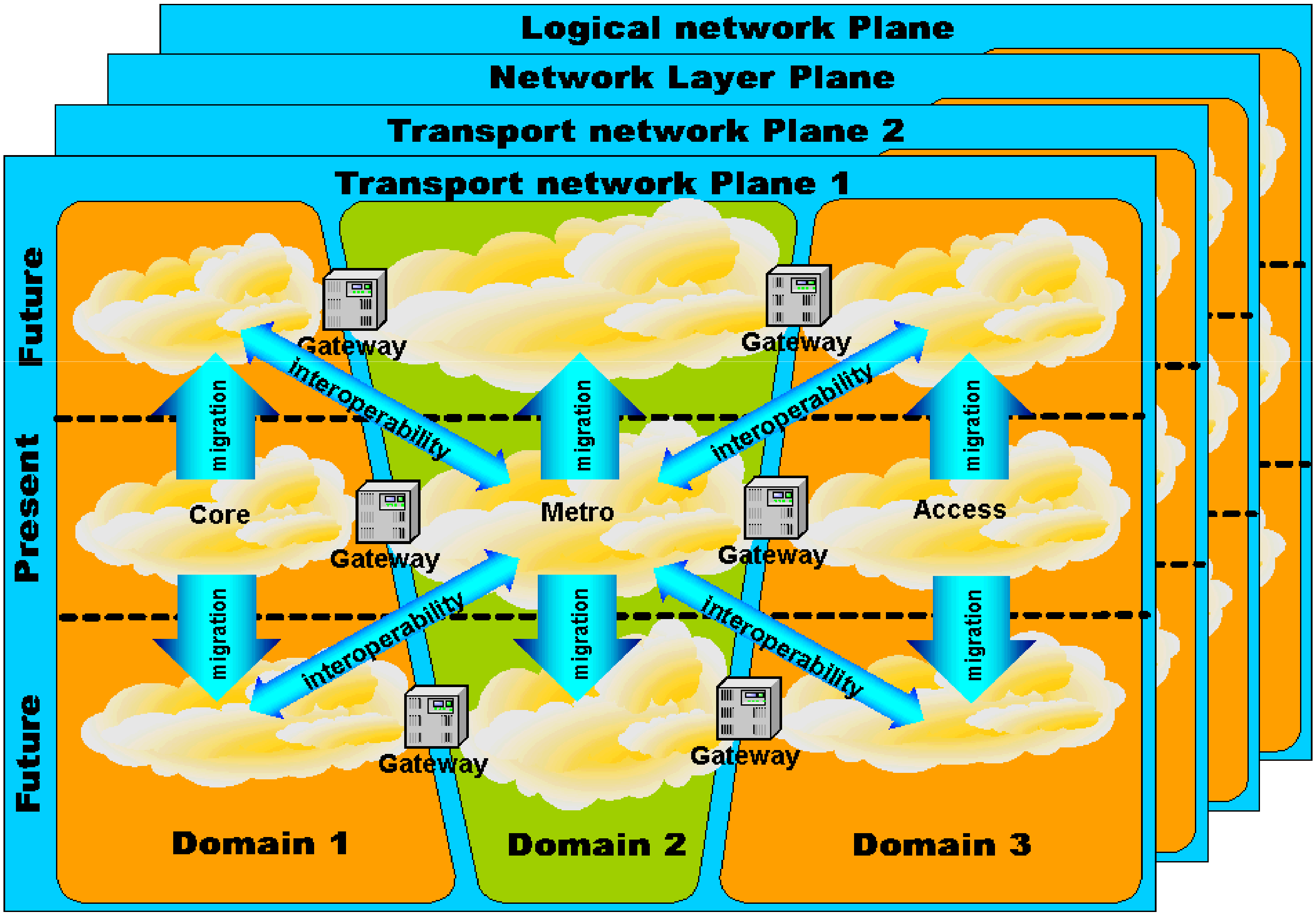




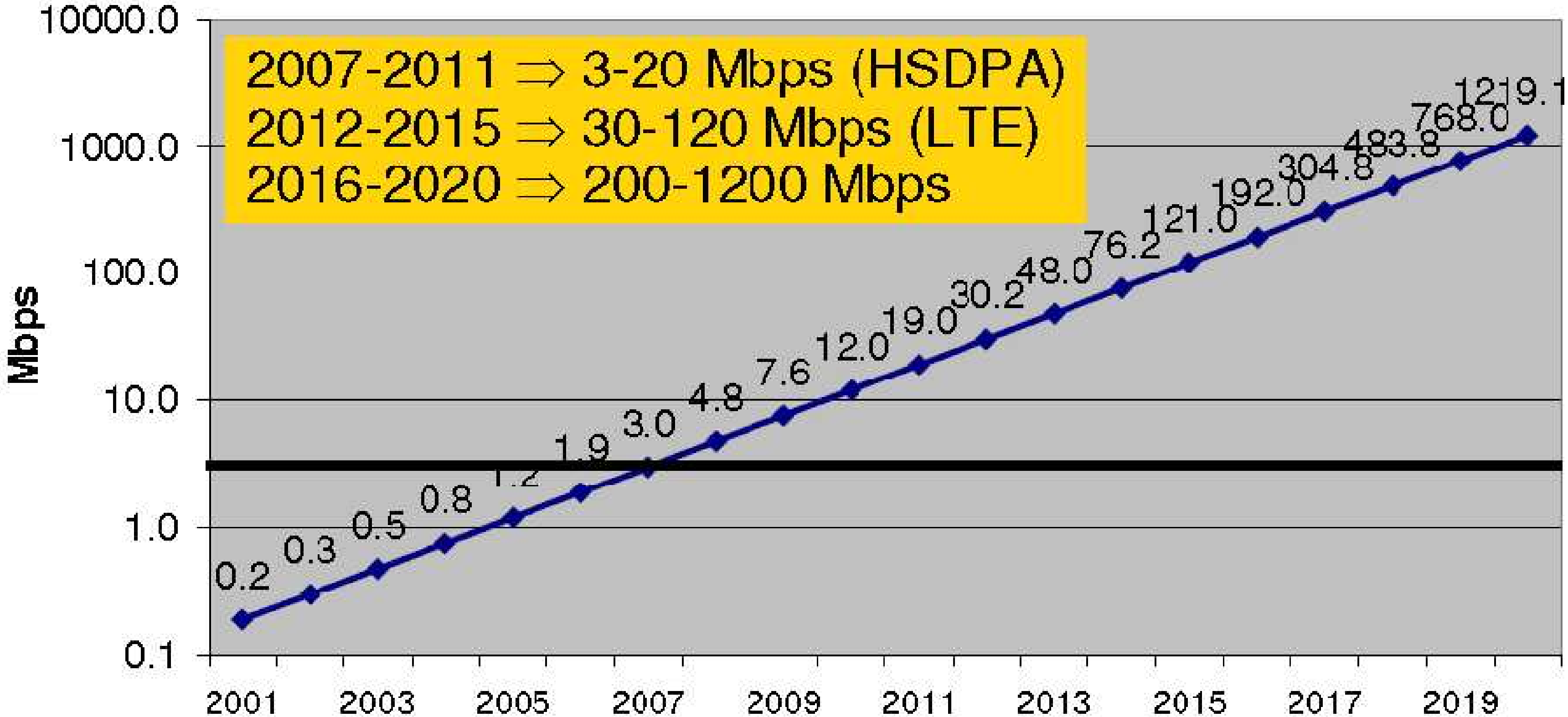
Network reference topology



Network evolution in different domains/areas



Wireless data evolution



Source: NSN

Capacity growth in access networks

- ACCESS: From a few kbit/s to several Mbit/s in about 10 years – and soon Gbit/s (grown 1000-10000 times in capacity)
- CORE: From several Mbit/s to few Gbit/s in 10 years (grown 100 times in capcity).
- IMPACT on traffic engineering: hard to plan – more sophisticated control required to ensure high utilisation.
- IMPACT on transmission techniques: Wired access first to use more advanced modulation/multiplexing techniques (and poor frequency bands) – wireless/mobile next to adopt OFDMA to increase bandwidth efficiency – and now even optical core networks is adopting OFDM and QAM coding (despite several THz of good frequency band)

- has capacity requirement grown faster than expected??

NO – capacity growth is slower than expected

- 25 years ago a strategic plan for Europe was 155/622 Mbit/s to all residential subscribers by the year 2000.
- 25 years ago broadband was a network capable of handling **services** that requires **more** than 2 Mbit/s (defined in 1984).

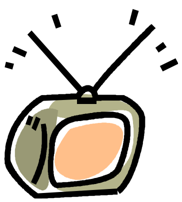
  - what happened???

- TV was not transformed into digital format as early as possible
- ADSL was "discovered" and offloaded the phone network.
- Lack of consensus for broadband strategy (and still lacking)

Driving force: Beyond HDTV

576i

4 Mb/s

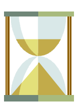


1080p

15 Mb/s

“4K”

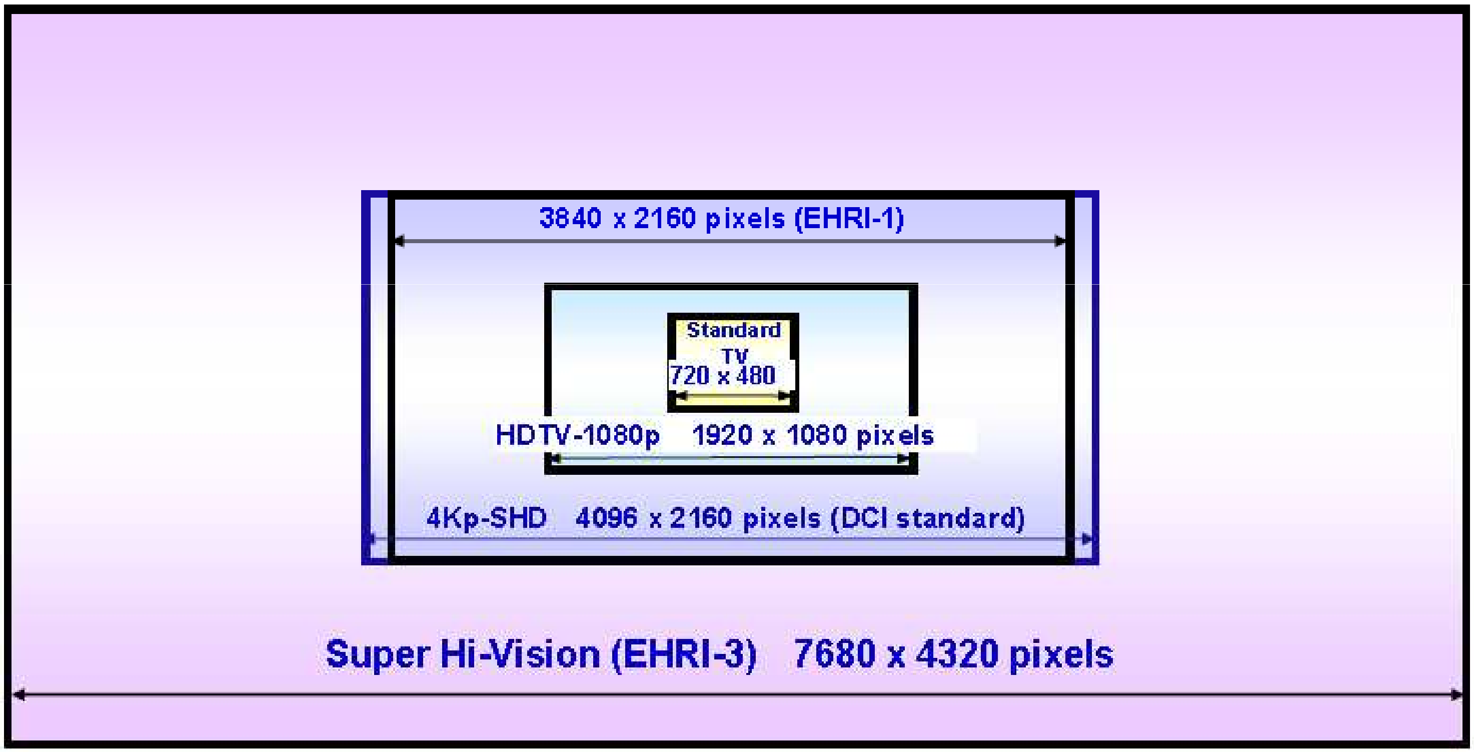
> 200 Mb/s



1960 **2005** **2025?**

“4K”= any new format with 8M+ pixel per frame

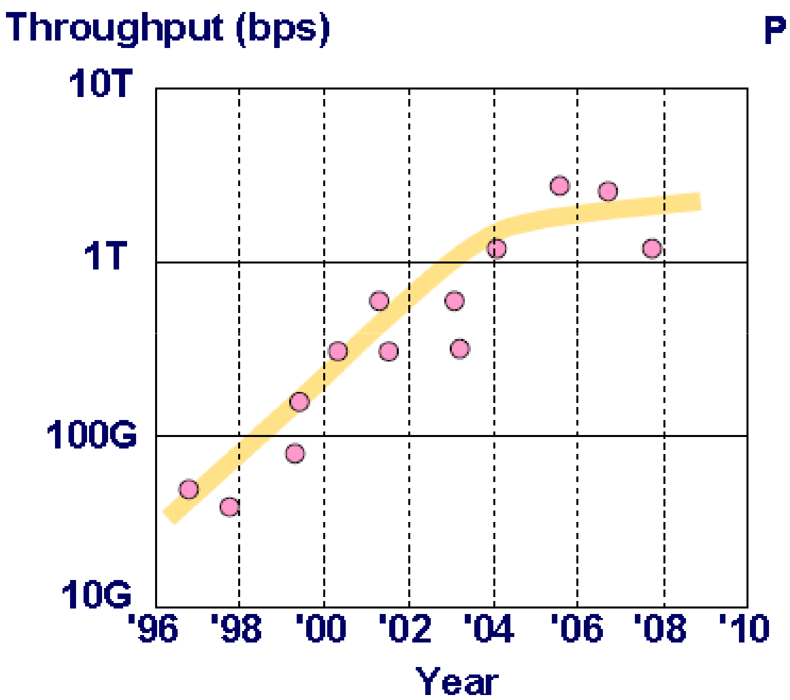
But 4k video is not the final step!

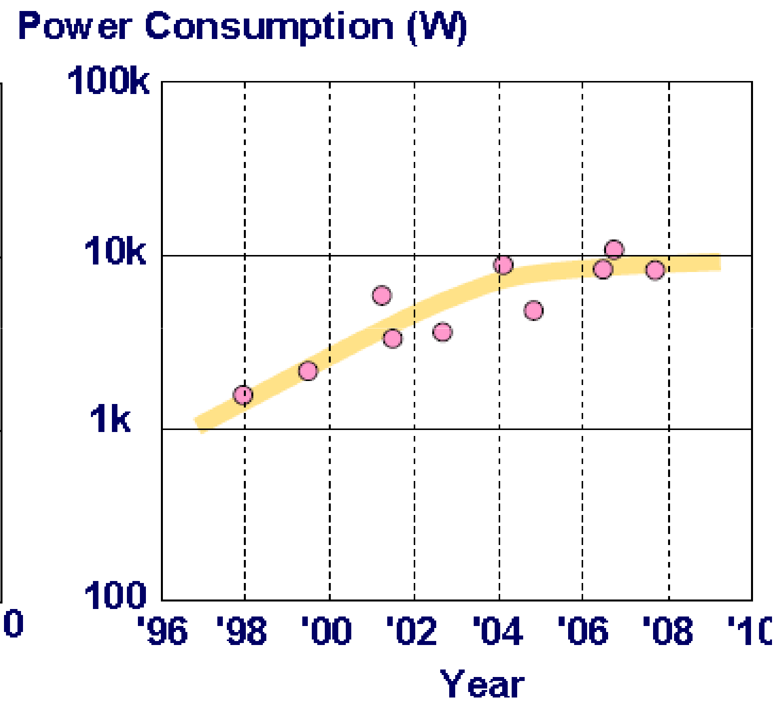


Needed consideration for future network

- We can do it the traditional way– but does it make sense?
- Resources must be used more efficient
- Network operation must be more simple (lower layer operation when possible)
- Intelligence must be more (and isolated) to the edges
- Exploit user behaviour in information retrieval and distribution (e.g. opportunistic networks)
- Power consumption must be an important design parameter

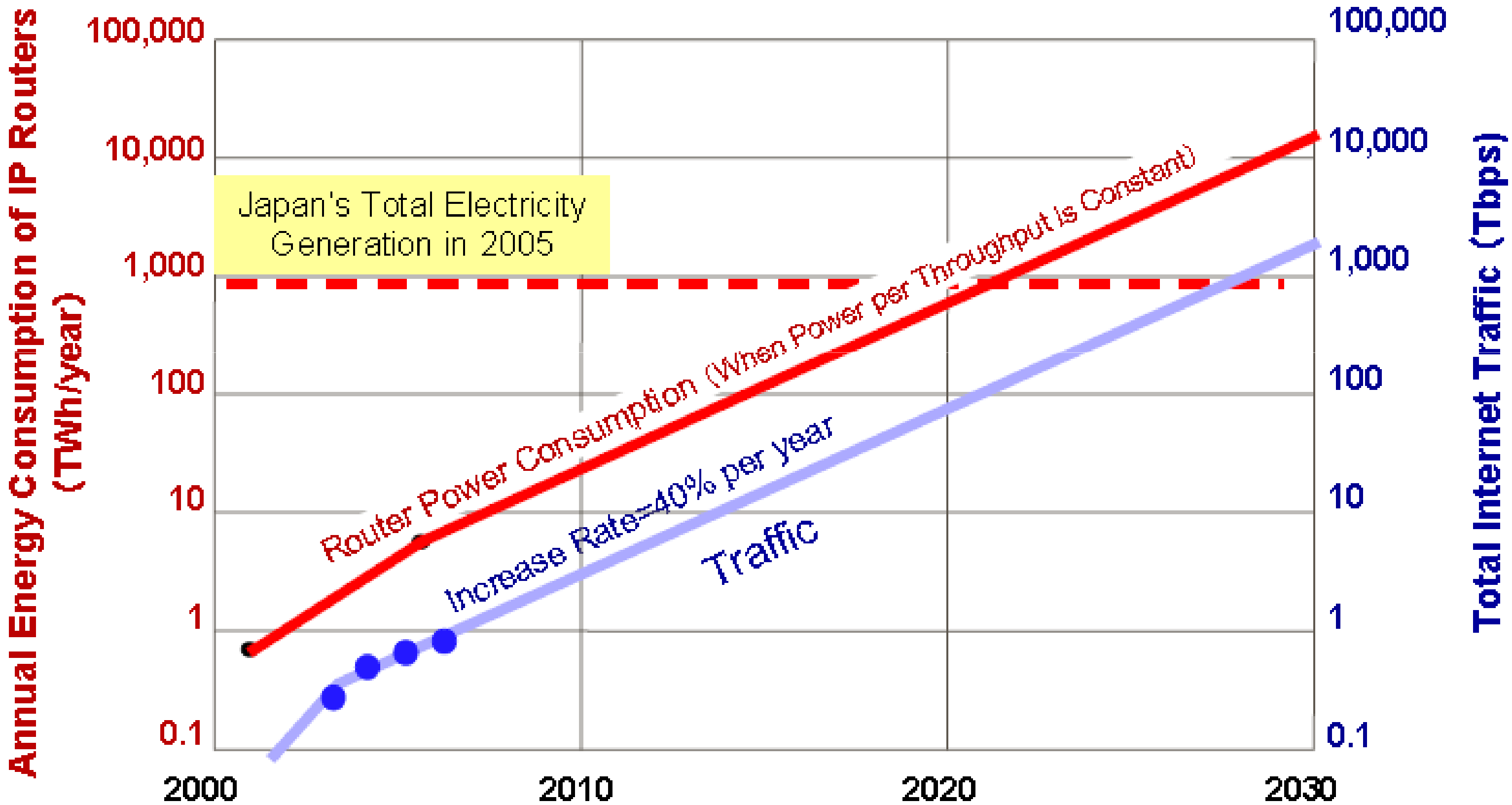
IP router power consumption vs capacity





S. Nishimura, IEICE Tokai Chapter Special Course, Nagoya, March 13, 2008

ICT power consumption might not be a problem now – but…..



S. Namiki, ECOC 2008

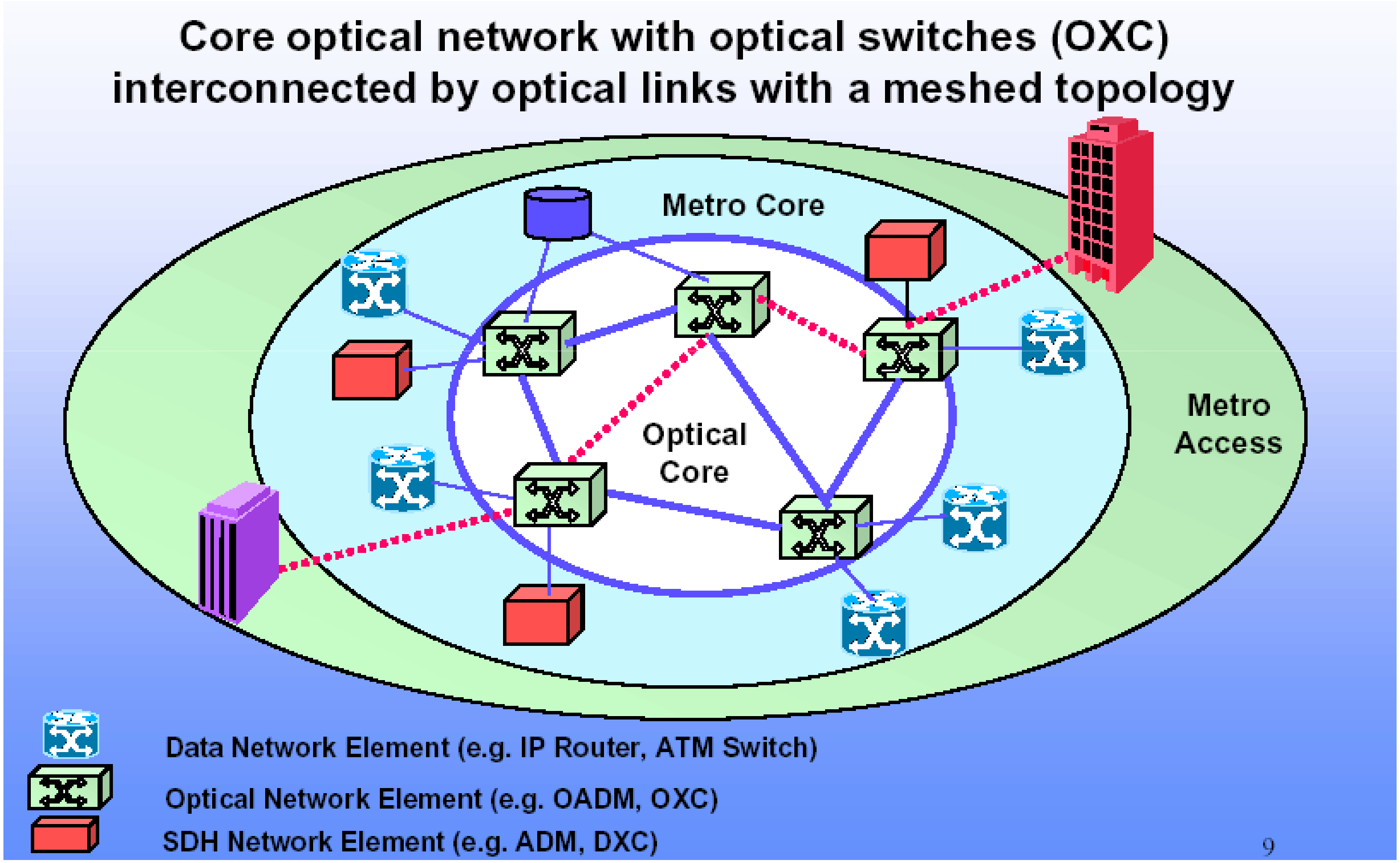
Hierarchical networks for future network services

- Vision the communication network in relation to the road network.
- Small road and highways serves different purposes depending on traffic demand and distance from end-destination.
- Road network arises from road merging and intersection.
- Intersection design depends on the amount of traffic changing direction.

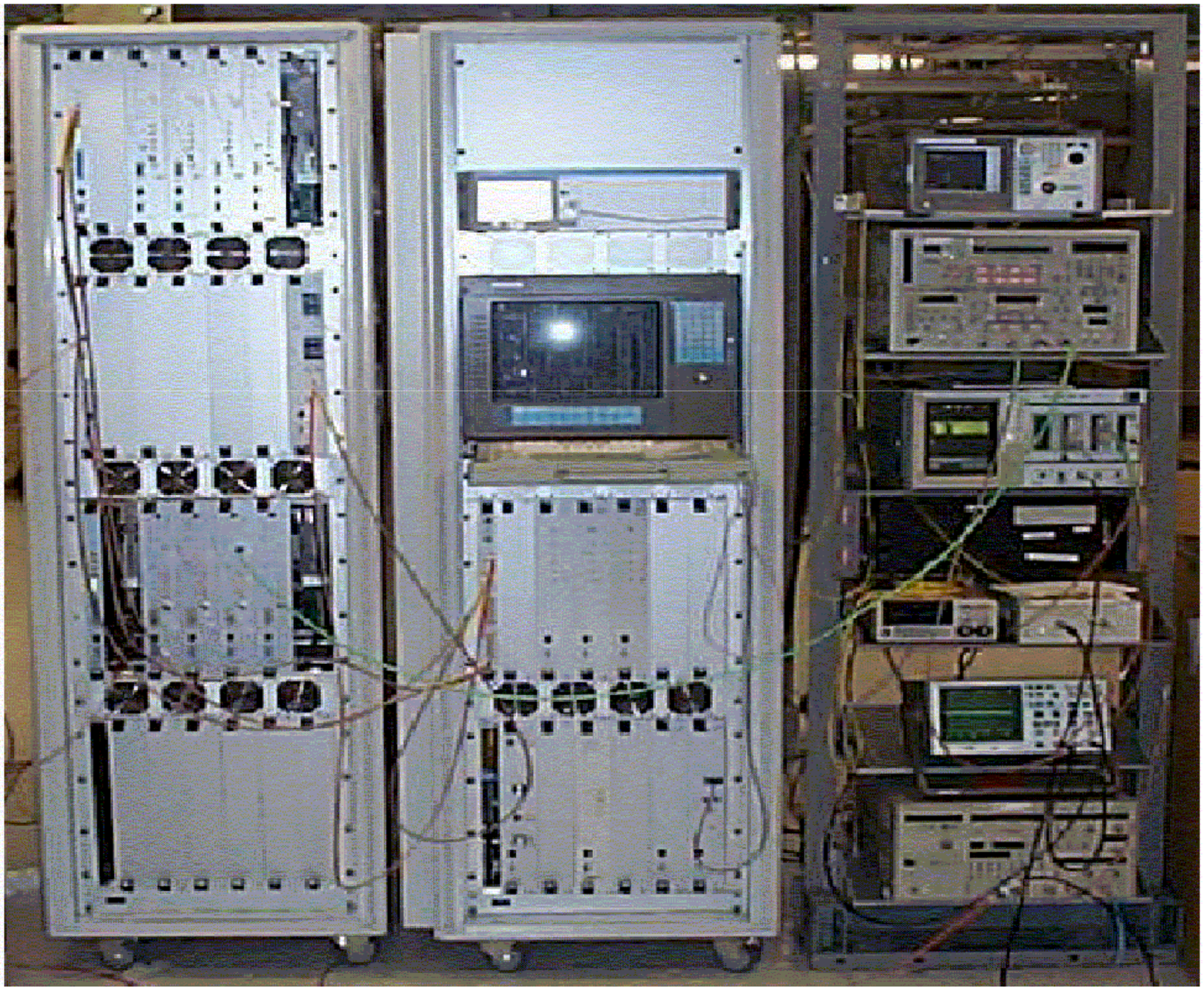
Layer 3

Layer 2

Simplified core network – intelligence only at edges



Long term goal – optical packet switching



2.5 Tbit/s

Optical

Packet switch

Power/bandwidth issues

- Around 2/3 of power consumption in routers a due to IP-header processing ->
  - Minimize number of routers passed – not the same a number of nodes.
  - Store and process at source/edges where processing is done anyhow and at lower rates.
  - Exploit intelligent storing and alternative communication channels

- Two case stories:
  - Opportunistic networking (mobile Peer2peer)
  - Increase use of layer 2 and layer 1 nodes.

Case #1
Opportunistic podcasting

Mobile P2P communication

- to exploit user behaviour and offload access network

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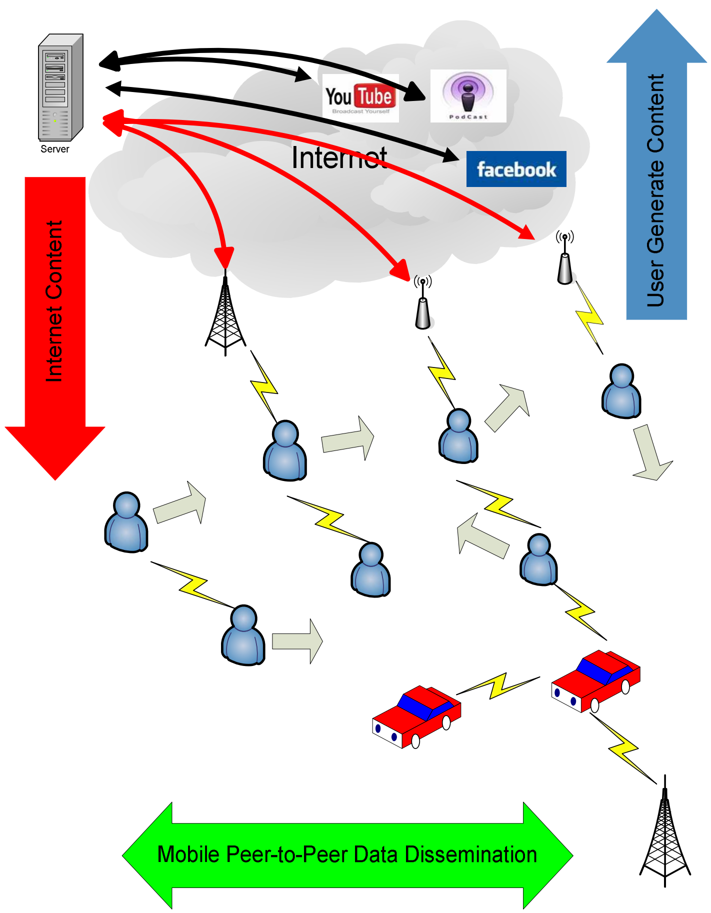
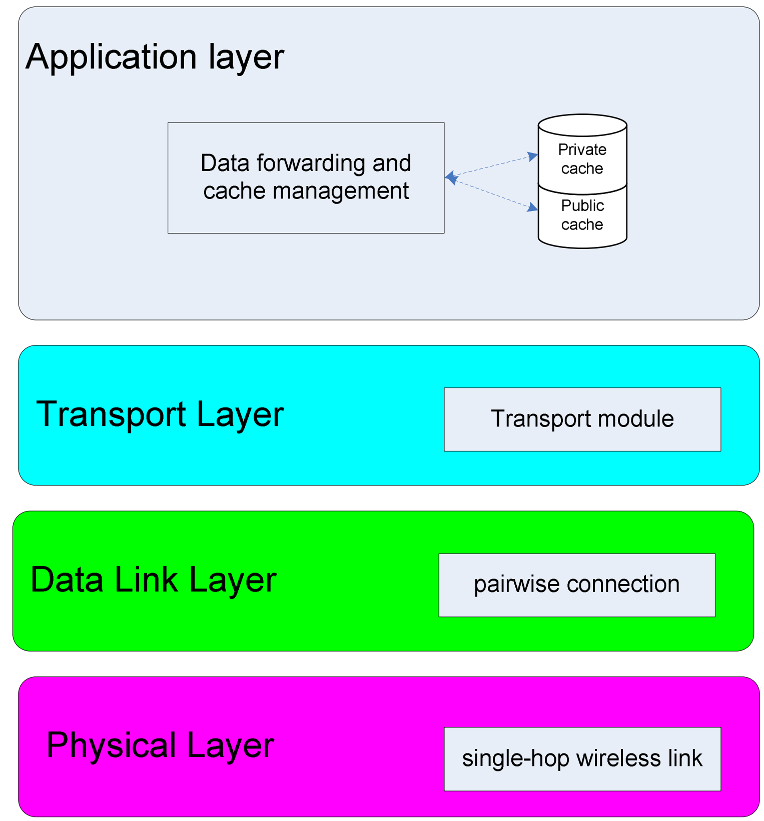
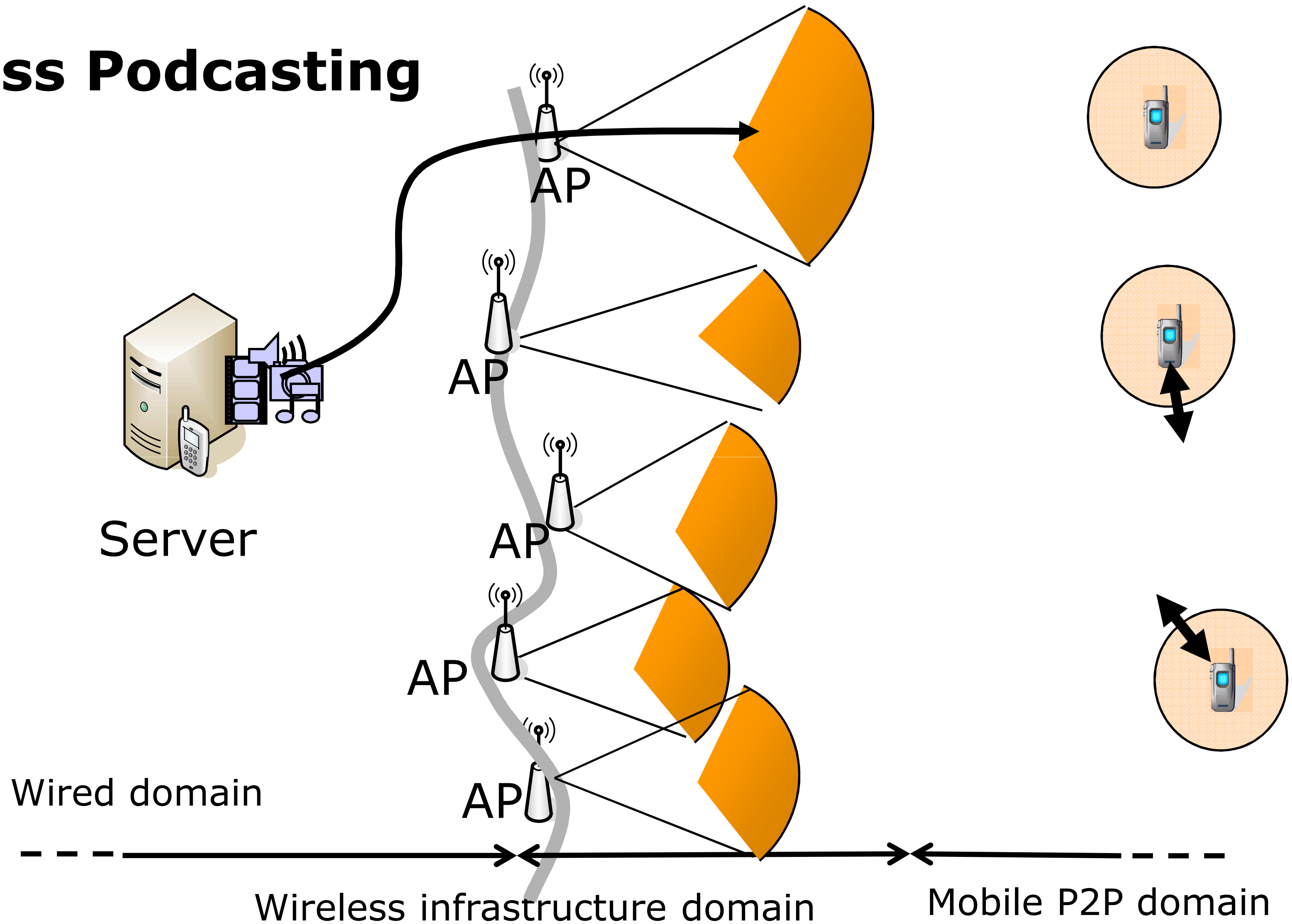
Motivation
-Mobile P2P Arcitechture





Wireless Podcasting



Case #2
Carrier Ethernet

- An approach for a simpler and differentiated network operation

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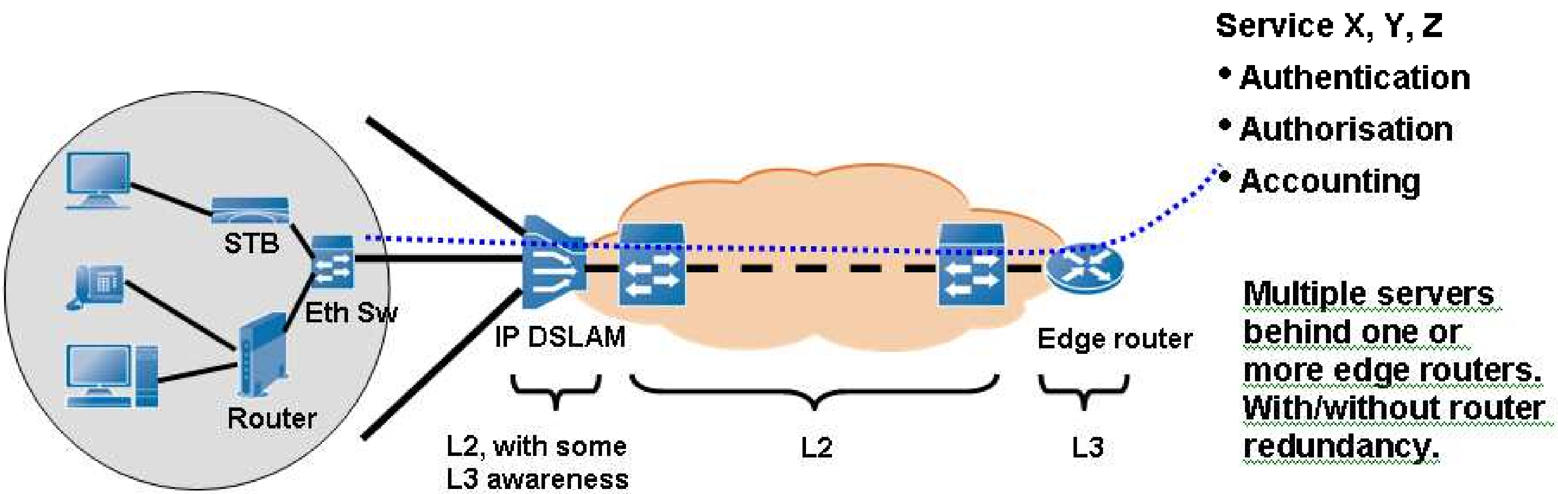
Network Architecture

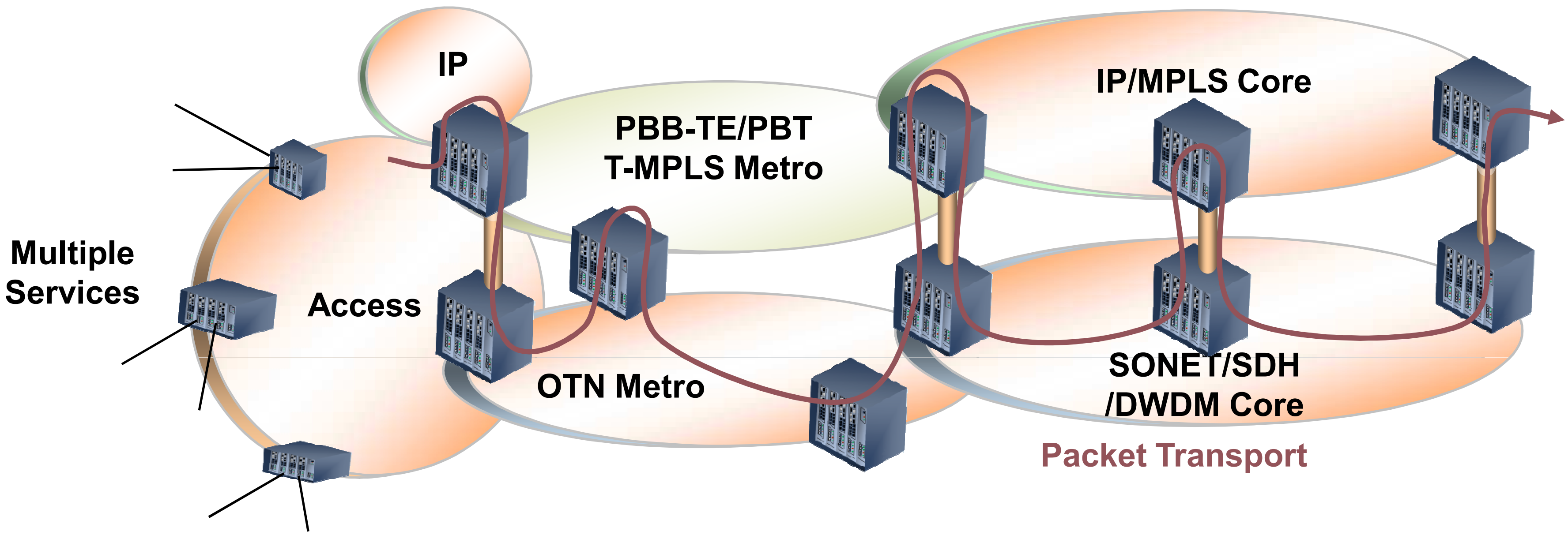
- The carrier Ethernet based network architecture is based on a Layer 2 approach with Layer 3 support in the edge routers and L3 awareness in the DSLAM



Layer 3 -> Layer 2

- Layer 3 and IP have proven useful in addressing Internet and other best effort data applications. This is because this type of data can tolerate delays in transmission and buffering. These mechanisms are necessary to manage the transfer of data at this layer in the network.
- The difficulty with this approach is that it is not well suited to high-bandwidth, critical services, such as IPTV, which, in general, cannot tolerate delays in the network.
- More intelligent layer 2 and layer 1 networks can be used to alleviate problems anticipated in current IP networks with demanding applications.
- Using PBB-TE/PBT and T-MPLS (MPLS TP), autonomous network decision making is removed and more traffic engineering is performed.
- This ensures control over exactly where traffic is being transported in the network with the further ability to monitor individual traffic flows (which is not easy to accomplish in layer 3 networks).
- This approach has the further advantage of being able to support layer 3. Rather than replace layer 3, the solution is intended to supplement it reducing the need for costly nodes supporting services.

Carrier Ethernet Transport network



- Use PBB-TE/PBT or T-MPLS as alternative to MPLS
- Reduce complexity (switching vs. routing, no signaling)
- Switch at layer that’s appropriate ((sub-)wavelength or packet)
- Basis for common control plane based on GMPLS

Transport Networks Characteristics (I)

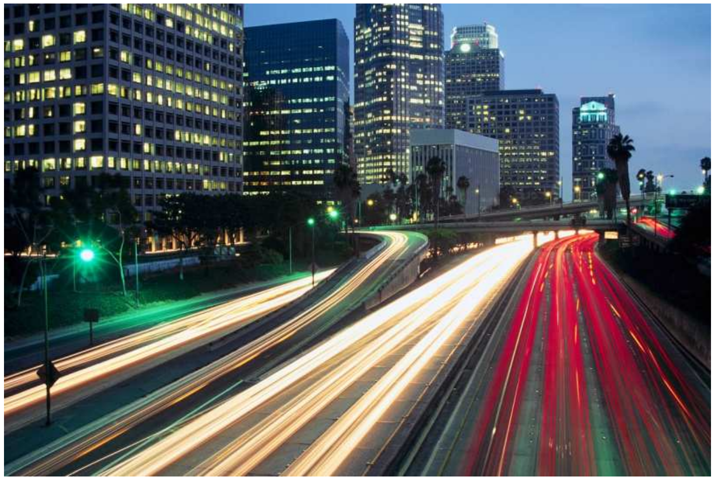
- **High scalability**
  - Since the network is expected to last many years
- **Cost efficiency**
  - Lowest cost-per-bit and per-km
  - To enable widest deployment footprint
- **Transparency**
  - To handle any end-user or other carrier's service requirements unaltered
- **Strong security**
  - To support any customer's data with confidence

Transport Networks Characteristics (2)

- **High availability**
  - With low failure rate, fast protection and optional restoration schemes
- **High QoS**
  - Predictable latency, low errors and deterministic service delivery
- **Multi-service support**
  - So that costs are shared across multiple business lines
- **Service aggregation**
  - To maximize efficiency of installed network plant and facilities

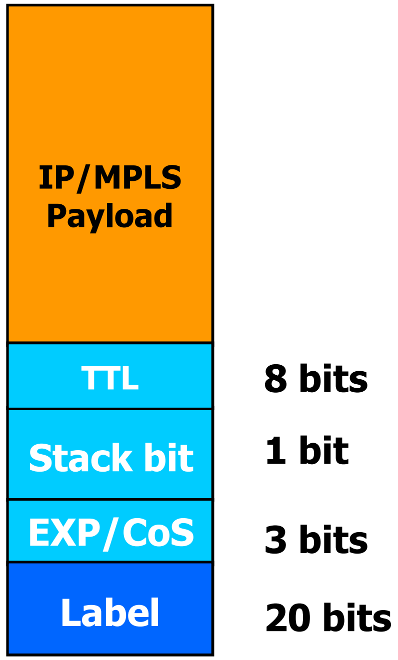
Transport Networks Characteristics (3)

- **Long holding times**
  - Customer bandwidth provision does not change very quickly
- **Remote management**
  - To eliminate expensive and slow manual intervention
- **Simple management**
  - So that staff can be readily obtained and trained
- **Interoperability**
  - Enabling an effective multi-vendor and multi-operator environment



Transport MPLS (T-MPLS)

- Driven by concerns on expansion of MPLS into metro
  - Complexity, cost, organizational and operational impact
  - Difficult to debug problems (requires time and expertise)
- Interest in an “MPLS-lite” focused on transport
  - Same characteristics as existing SONET/SDH, but based on MPLS
- IETF maintain that existing MPLS RFCs sufficient
- MPLS-lite supporters approached ITU-T
  - Create “profile” of MPLS in-line with ITU-T G.805 transport architecture
- Result: New ITU-T based standards for T-MPLS
- Now: Taken over by IETF as MPLS TP



MPLS Frame Format

OAM Requirements (G.8113)

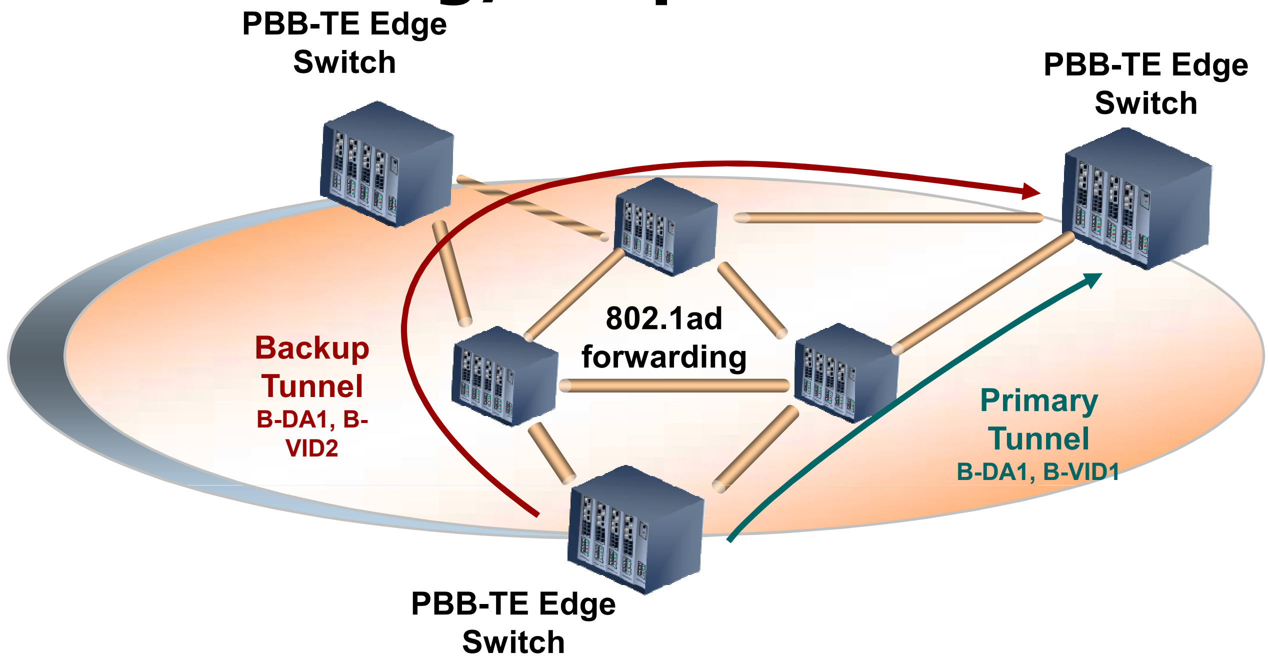
Bidirectional point-to-point T-MPLS connections

- ***Pro-active*** **OAM functions for** ***fault management r*****equired :**
  - connectivity check (CC)
  - alarm suppression
  - lock indication
  - dual–ended frame loss measurement;
  - remote defect indication.
- ***On demand*** **OAM functions for** ***fault management*** **required:**
  - non-intrusive Loopback
  - unidirectional and bidirectional diagnostic test
  - Traceroute
- ***pro-active*** **OAM functions for** ***performance management*** **required:**
  - connectivity check (CC)
  - remote defect indication
  - dual-ended frame loss measurements.
- ***On demand*** **OAM functions for** ***performance management*** **required:**
  - Single-ended frame loss measurements
  - One-way and two-way frame delay measurements

OAM functions (G.8114)

- OAM functions for fault management
  - Continuity Check (CC)
  - Alarm Indication Signal (AIS)
  - Remote Defect Indication (RDI)
  - LinkTrace (LT)
  - LoopBack (LB)
  - Lock (LCK)
  - Test (TST)
  - Client Signal Fail (CSF)
- OAM functions for performance management:
  - Frame Loss Measurement (LM)
  - Frame Delay Measurement (DM)
  - Frame delay variation
- Other OAM functions
  - Automatic Protection Switching (APS) function
  - Management Communication Channel (MCC) function
  - Synchronisation Status Message (SSM) function
  - EXperimental (EX) function
  - Vendor Specific (VS) function

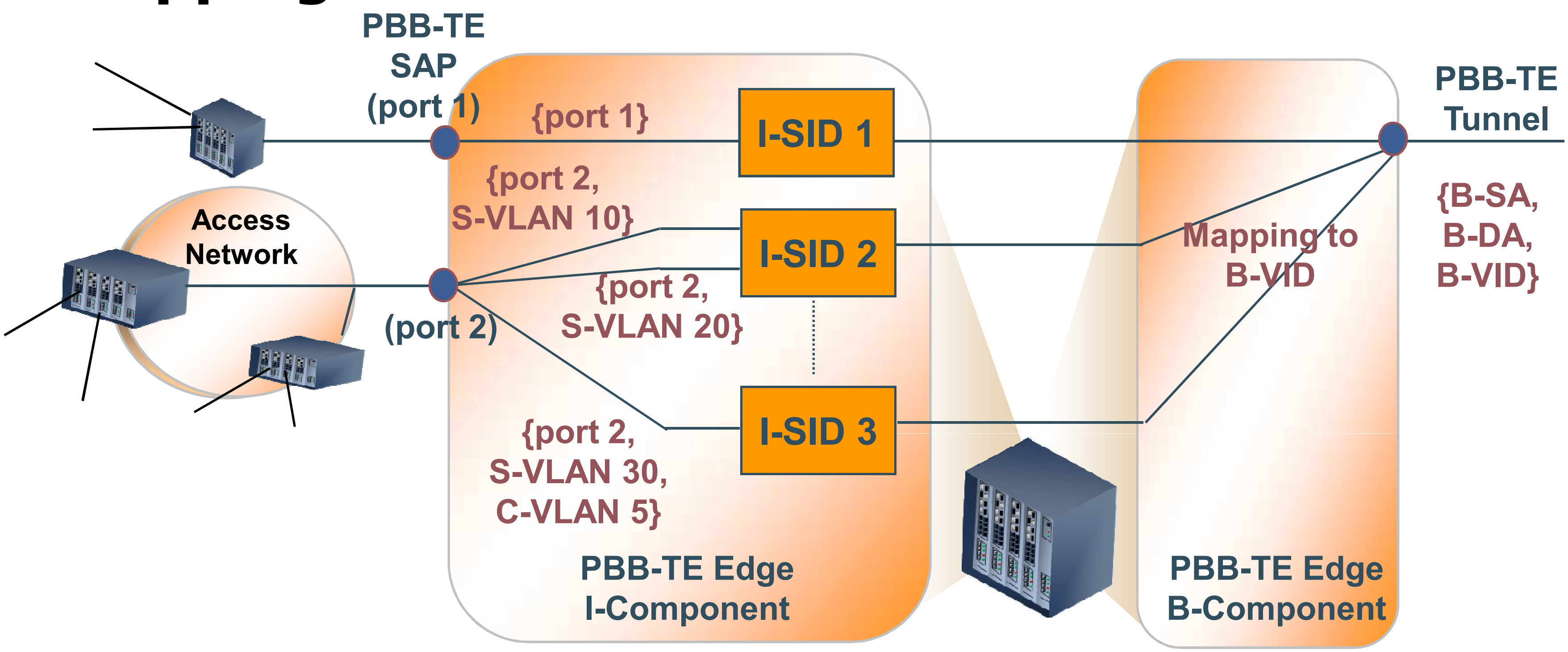
Re-use of existing/simpler switches



- Internal Ethernet Switch does not need to support PBT
  - B-TAG resembles S-TAG and can be forwarded
  - Only OAM MIP points internally (just forward*)
  - APS from Edge Switch, not internally
- PBT ports can co-exist with PB and PBB STP ports
  - Ports can be designated as PBT ports using MSTPID

*Exception is LBM

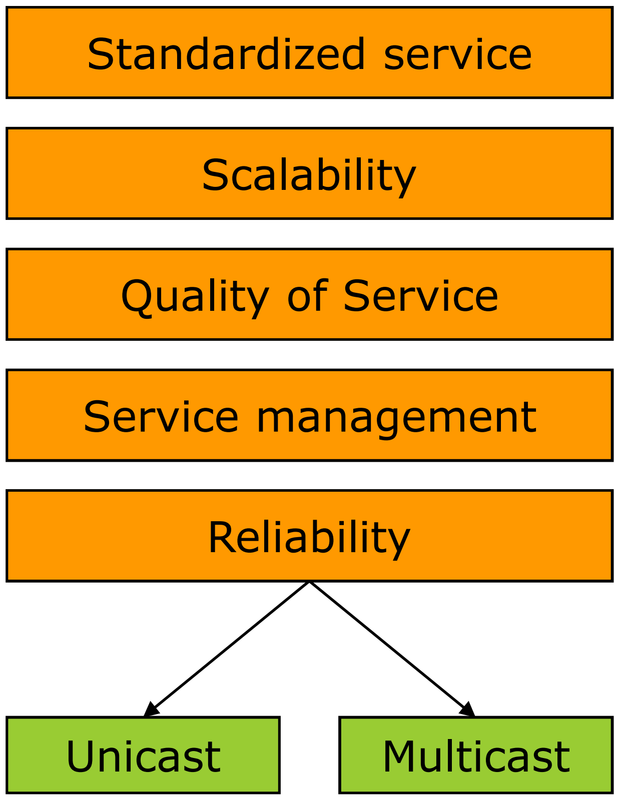
Mapping of services to I-SIDs



Service Access Point (SAP) at the UNI port is defined as:

- Entire Ethernet port = I-SID 1
- Ethernet port + S-VLAN = I-SID 2
- Ethernet port + S-VLAN + C-VLAN = I-SID 3

Requirements for Carrier Ethernet



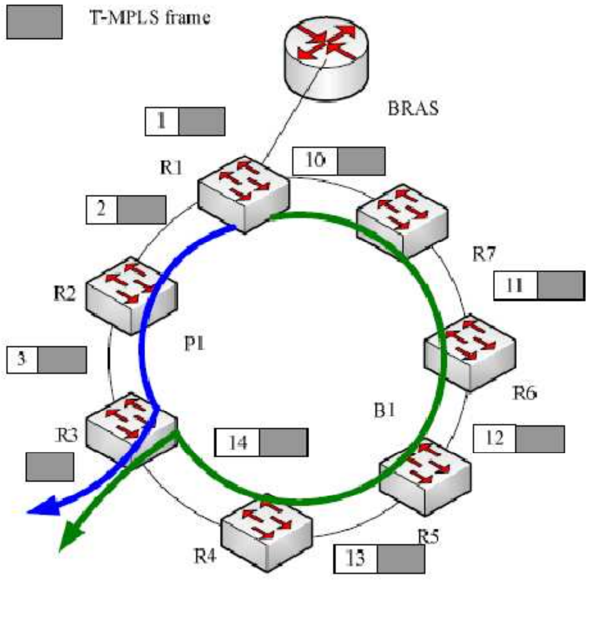
Recovery in Carrier Ethernet

- Can we reuse some concepts of other resililiency techniques: e.g. Ethernet or MPLS?
- Ethernet uses (Rapid) Spanning Tree: Too Slow
- MPLS uses Fast Reroute: T-MPLS does not allow label merging
- MPLS uses global path protection: no conflict with T-MPLS

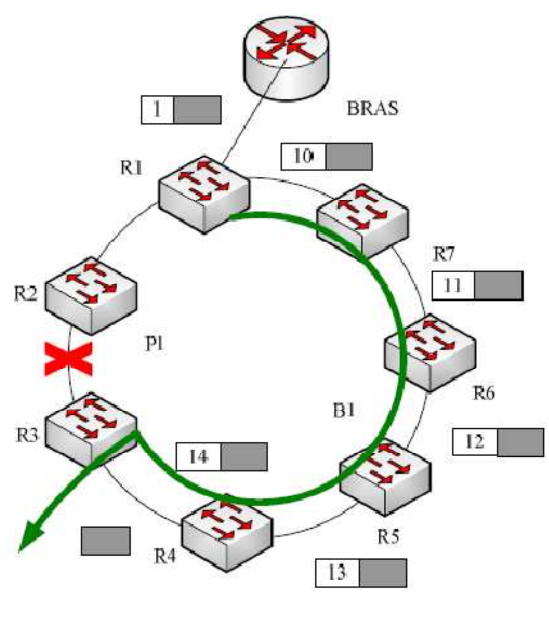
- Linear protection switching for T-MPLS
  - Trail or SNC: entire/portion of connection, resp.
  - Specified in G.8131
  - Very similar to global end-to-end path protection for MPLS as defined in Y.1720
- Ring protection
  - Draft G.8132
  - Concepts borrowed from SONET

Label operation of 1+1 trail protection

- OAM protocol used to detect defects on working and protection LSP
- Connection continuity is probed with Connection Verification (CV) packets
- Default transmission period for protection: 3.33 ms
- If no CV packets received for 3.5 times the transmission period we assume a failure (Y.17TOM)



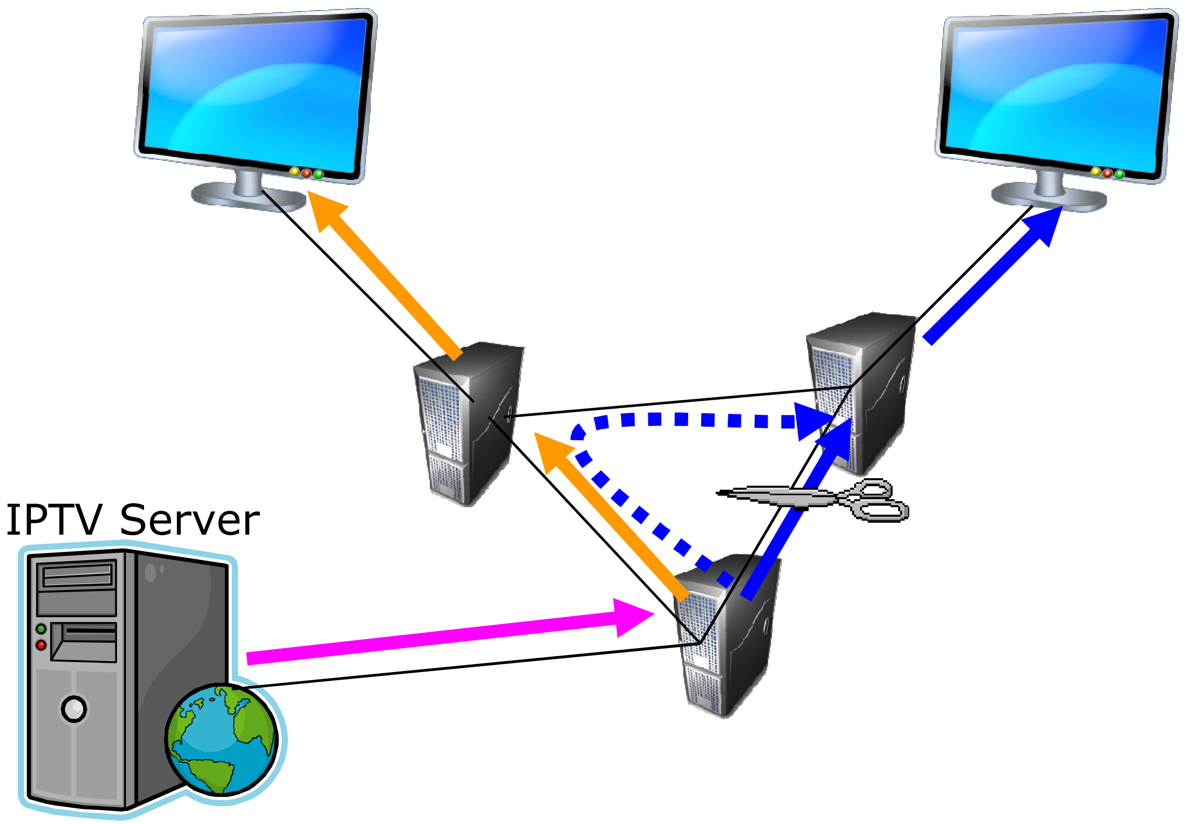
(a). Normal condition



(b). Failure condition

- BRAS translates IP packet into T-MPLS frame
- R1 replicates frame, assigns two diff. labels, sends them on both paths
- R3 is selector

IPTV Resilience Demo



- Stream (multicast) a video to two users
- See the effect of a cable cut when different OAM update intervals are used

Quality of IPTV

Subjective evaluations

- Mean Opinion Score (MOS)
- Perceptual Evaluation of Video Quality (PEVQ)

Mathematical or network evaluations

- Media Delivery Index (MDI)
- Peak Signal to Noise Ratio (PSNR)
- Czenakowski Distance (CZD)
- Structural Similarity (SSIM)

Mostly focused on encoding an compression quality

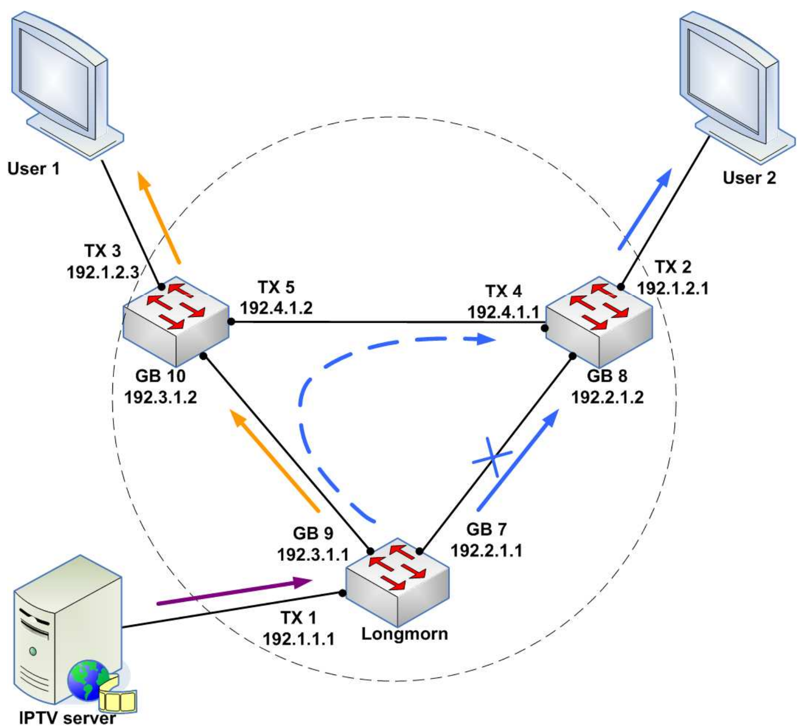
Media Delivery Index (MDI)

- Monitoring quality of video stream
- Indicate system margins for IPTV solution – Buffer length
- Acurate measure of jitter and delay at Network level
- Two measures
  - Delay Factor (DF)
  - Media Loss Rate (MLR)
- MDI expressed as DF : MLR
- Delay Factor
  - Indicates the needed length of receiver buffer
  - Acceptable values depending on setup (9 – 50 ms)
- MLR
  - Measure of lost media packets over time period
  - Acceptable value for HDTV typically 0.0005 packets pr. second
- MDI values as measure for restoration performance

Experimental evaluation

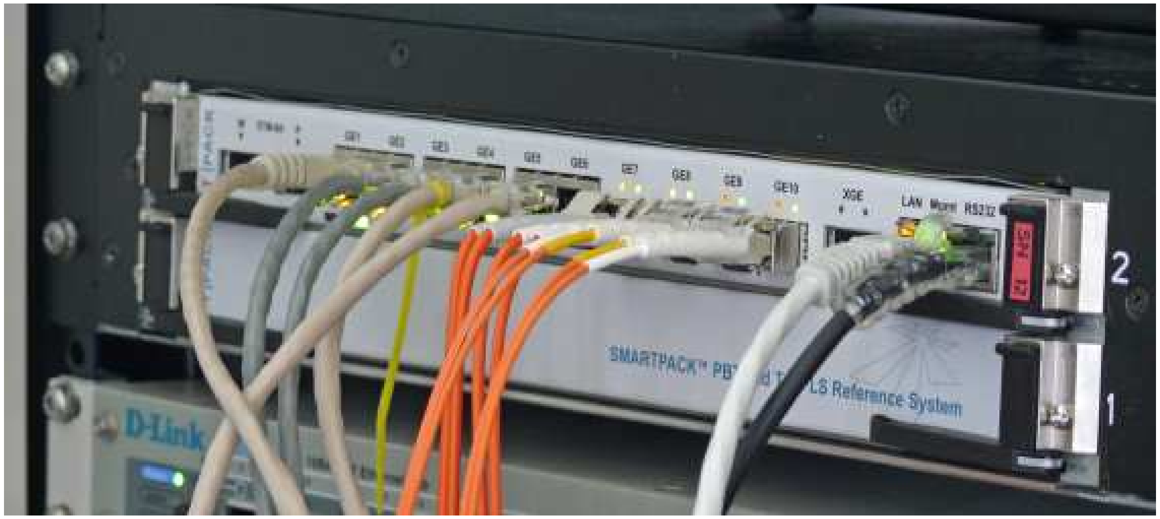
- **Objectives**
  - What is the effect of the Carrier Ethernet OAM signalling/monitoring?
  - User perceived Quality of Experience (QoE)?
  - Relation to MDI measure
  - Only interested in the second(s) after the failure (cable break)
- **Methodology**
  - Establishing three node Carrier Ethernet setup
  - Adjusting OAM update frequency in network
  - Introduce point of failure same time in HDTV clips
  - Note and evaluate artifacts on HDTV clip when failure occur
  - MDI measurements for the failure situation

Experimental setup



Carrier Ethernet Swicthes

- From collaboration partner TPACK
- Longmorn SmartPack PBT Carrier Ethernet Switch
- 6 electrical GE ports
- 4 optical GE ports
- 1 10 GE port
- Partioned into isolated virtual switches
- Provides full implementation of a PBT/PBB-TE solution
- FPGA based design as standards continously updated



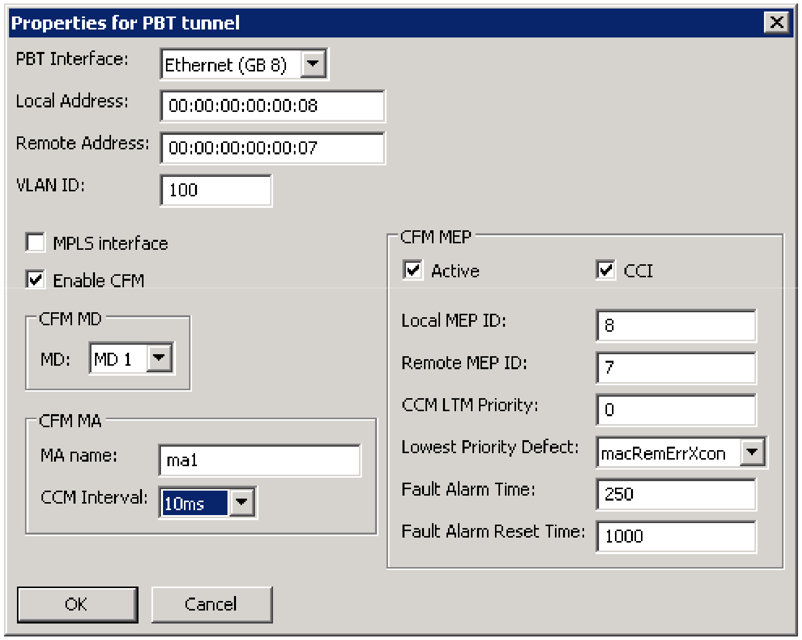
Test equipment

- Agilent N2X test solution
- Flexible reprogrammable FPGA based platform
- High end equipment to emulate thousands of triple play users
- Measuring loss, signal power, delay, jitter etc.
- From services to fibres
- Used to exactly measure MDI values

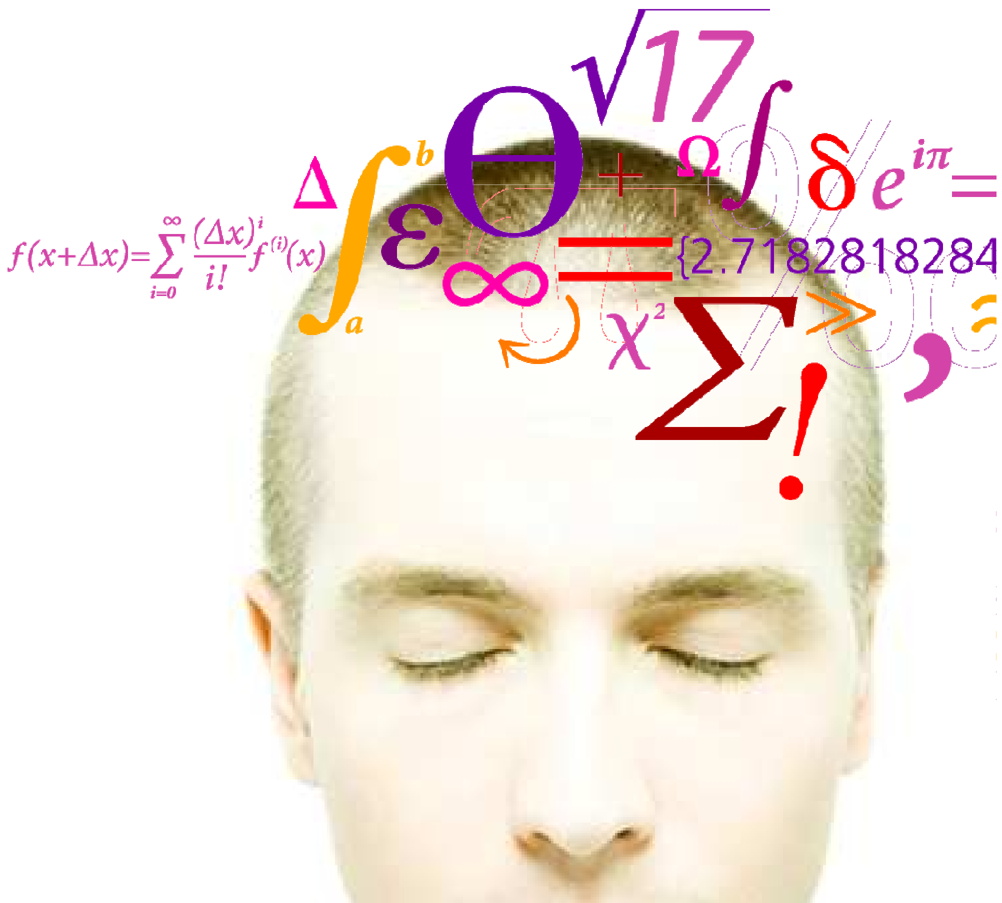
OAM update frequencies

- Possible values:
  - 300 Hz ~ 3 ms
  - 10 ms
  - 100 ms
  - 1 s
- Restoration if 3 OAM frames lost

- Conclusion : OAM update has to be below 50 ms to ensure quality durring a fault recovery session.



Thank you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$\sqrt{17}$
$e^{i\pi}=$
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χ^2