Optimizing Ethernet Access Network for Internet Protocol Multi-Service Architecture

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Agenda

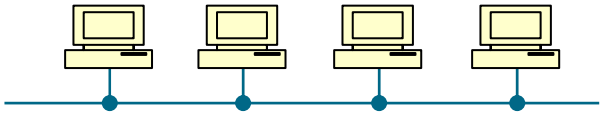
- Background and motivation for the research
- Research issues
- Comparison of solutions
- Conclusions and future views

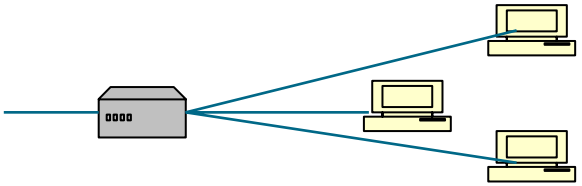
Migration from ATM to Ethernet - Drivers

- **Cost**
  - Low equipment costs of Ethernet (examples of list prices)
    16 GE mod (19995$) + 16 GBIC (à 995$) = 36000$ → 2250$ / GE
    STM1 ATM interface (155 Mbit/s) 12000$
  - Relative technical simplicity of Ethernet reduces overall infrastructure costs
- **Flexible and rapid service provisioning**
  - Wide range of speeds with fine granularity (1 Mbps … 1 Gbps)
- **Packet switching**
  - Similar with applications and suitable for IP
  - Layer 2 bridged multipoint connectivity
- **Ubiquitous adoption of Ethernet technology**
  - Standard interfaces 10M/100M/1G/10G are widely available
  - Good interoperability
- **Many of these advantages are the result of the inherent simplicity of Ethernet**

Ethernet Development Phases

- Ethernet originally designed for private Local Area Networks (LAN)
  - Coaxial cable, bus topology
  - Pair cable, star topology, full duplex
  - Hub based → switch based (bridge)



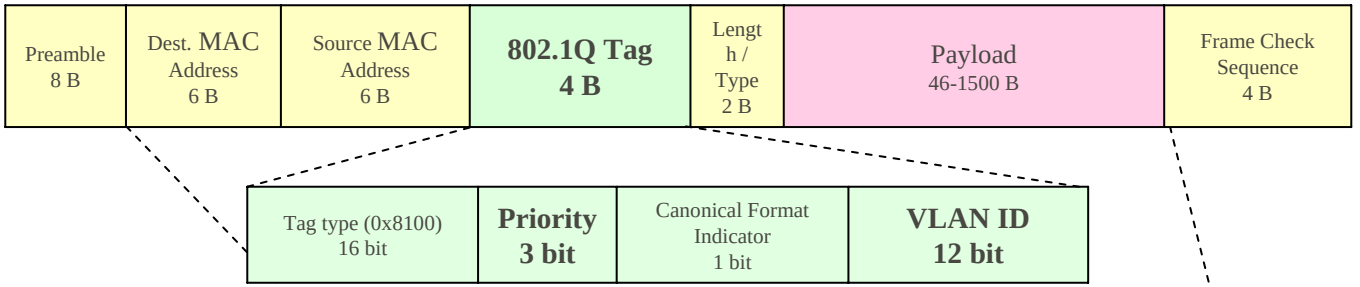


- Metropolitan Area Networks (MAN)
- Wide Area Network (WAN)

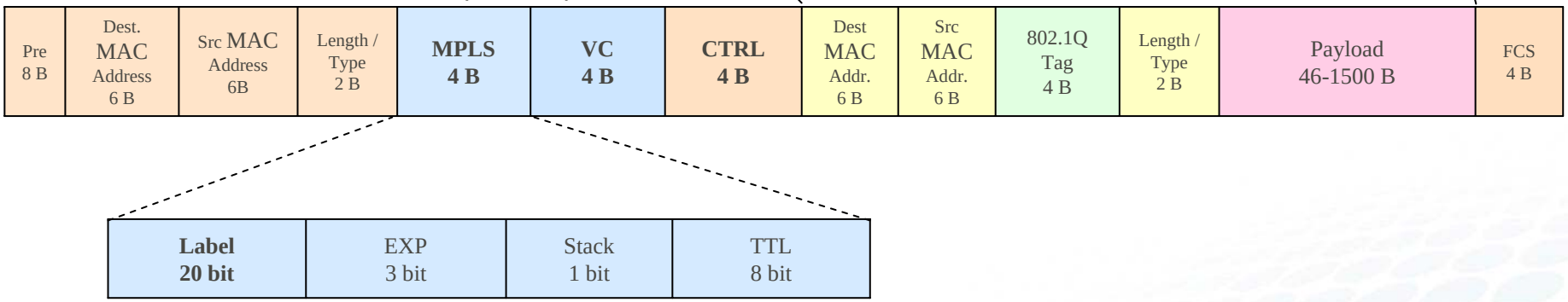
Operator Networks

Virtual Connections in Carrier Ethernet

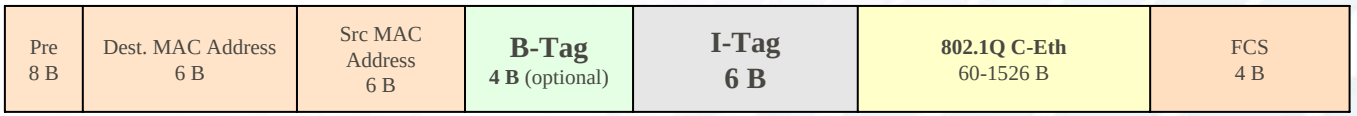
IEEE 802.1Q
VLAN tagged frame



Virtual Ethernet Emulation services
with Multi Protocol Label Switching (MPLS):
Virtual Private Wire Service (VPWS),
Virtual Private LAN Service (VPLS)



Upcoming:
IEEE 802.1ad/ah
VLAN stacking



Migration from ATM to Ethernet – Challenges (1/2)

- **Limitations in end-to-end QoS guarantees compared to ATM**
  - "Packet colouring" (to mark packets for prioritisation, scheduling, policing etc.)
  - Scheduling and policing to maintain fair access
  - Ensuring optimal path establishment trough the network
  - Connection admission for new service requests
- **Protection Mechanisms**
  - Slow failure recovery of Spanning Tree (STP): tens of secs (50 ms in SDH)
  - Lack of fault isolation capability
    - No in-built alarms like LOS etc. found in SDH
    - No "Ethernet ping"

Migration from ATM to Ethernet – Challenges (2/2)

- **In-service OAM**
  - No overhead capability, e.g. to monitor bit-error-rate (BER)
  - Some management standards are being developed (e.g. 802.1ag - Connectivity Fault Management)
- **Scalability and network resource utilization**
  - Limited standard Virtual LAN tag space, max. 4096 VLAN IDs
  - Issues with large Spanning Trees
  - MAC tables size (tens of thousands hosts in an operator network)
- **Security**
  - Customer integrity
  - Address spoofing
  - Other malicious behaviour

Possible solutions to limitations & shortcomings (1/2)

- **QoS performance – Per Hop**
  - VLAN tag Priority Field (3 bits →8 priority classes)
  - MPLS emulated Ethernet, a more versatile solution
- **Protection mechanisms**
  - Rapid Reconfiguration of Spanning Tree, IEEE 802.1D RSTP (≈ 1 s convergence time)
  - Multiple Spanning Trees, IEEE 802.1Q
  - Resilient Packet Ring, IEEE 802.17
  - MPLS

Possible solutions to limitations & shortcomings (2/2)

- **OAM issues**
  - Fault isolation and in-service OAM addressed by
    - ITU-T Q3/SG13: Y.1730 + drafts Y.17ethprot, Y.17ethoam
    - IEEE: 802.3ah EFM (Ethernet First Mile), 802.3ag CFM (Connectivity Fault Mgmt)
    - Metro Ethernet Forum
- **Scalability and network resource utilization**
  - VLAN tag stacking (double tag) IEEE 802.1ad (draft), IEEE 802.1ah (draft, over 20 bit tag)
  - MPLS techniques
- **Security**
  - Customer VLAN
  - Vendor's proprietary solutions
  - IETF draft RFC: draft-melsen-mac-forced-fwd-03.txt

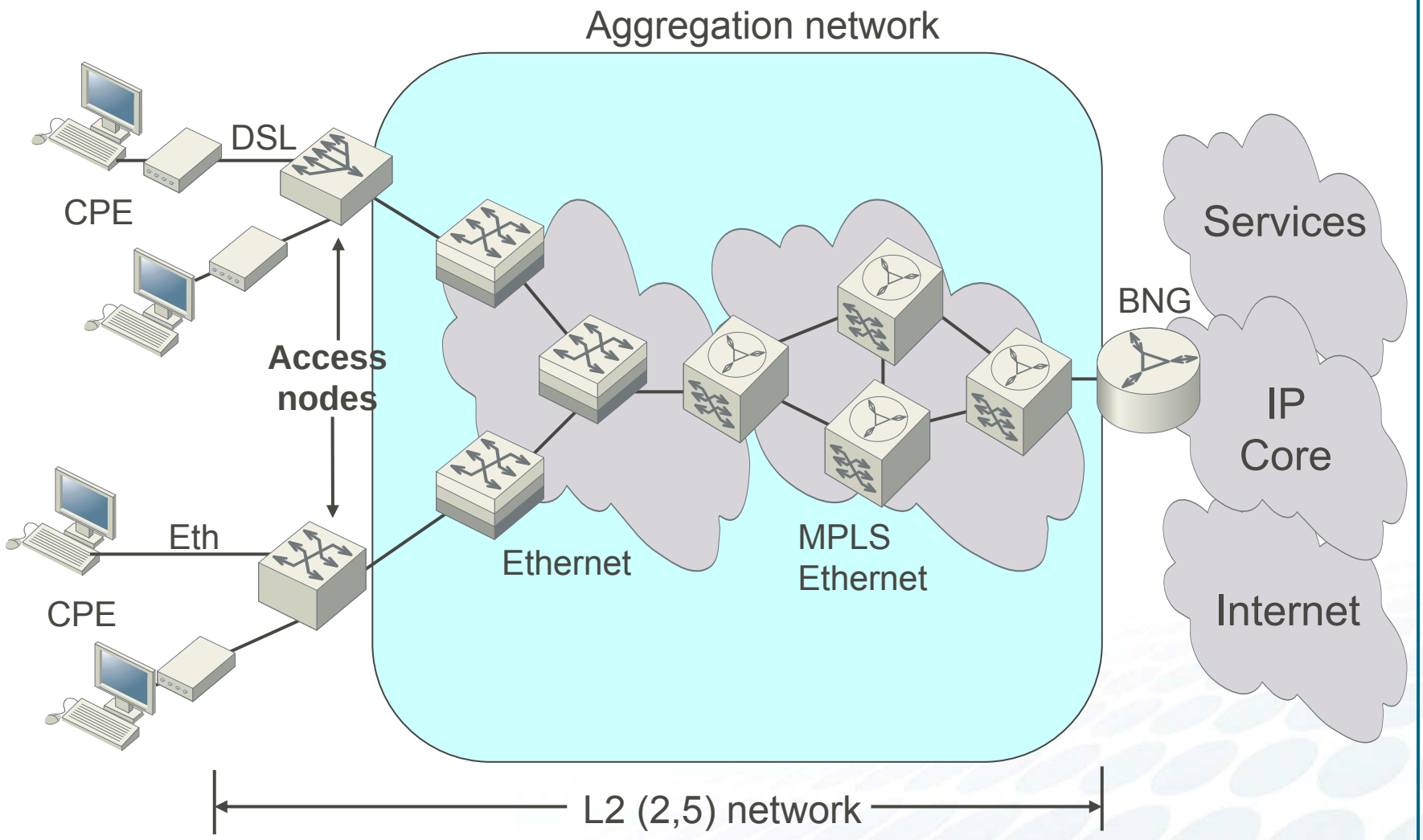
Research motivation

- **Study the possible Ethernet service solutions and the state of standardization**
- **Comparison of solutions**
- **Give recommendations**

Carrier Class Ethernet – Metro Ethernet Forum

- **Scalability**
  - Number of virtual connections in the range of tens of thousands
  - x10 Gbps bandwidths
- **Protection**
  - 50 ms protection time (convergence)
  - End-to-end path protection (resiliency)
  - Aggregated line and node protection
- **Hard Quality of Service**
  - Guaranteed end-to-end service level agreement
  - End-to-end CIR and EIR
  - Business, residential and mobile
- **Service management**
  - Fast service creation
  - Carrier-class OAM capabilities
  - Customer Network Management
- **Time Division Multiplexing support**
  - Seamless integration of TDM
  - Circuit emulation services
  - Support for existing voice applications

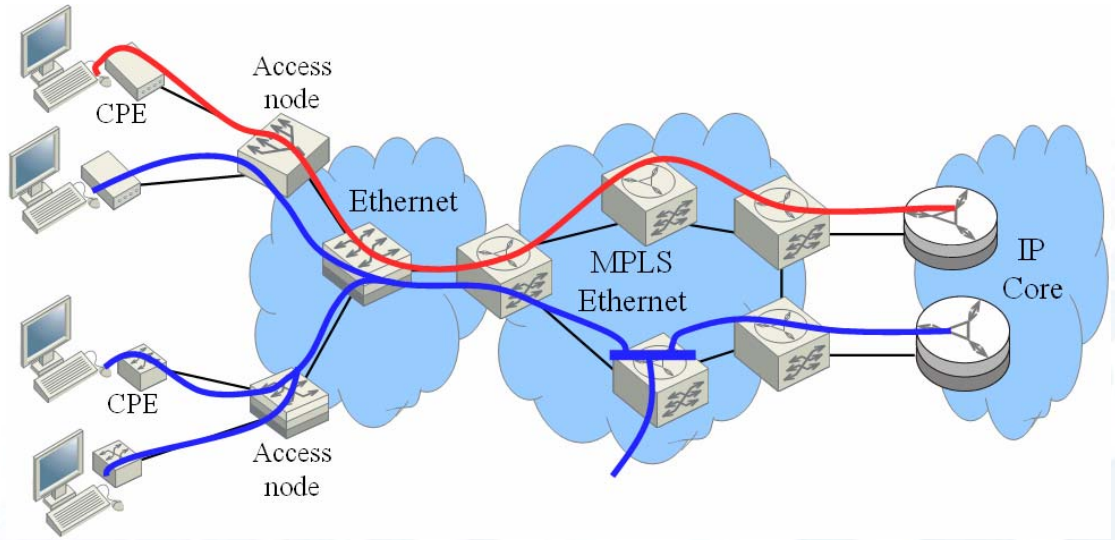
Ethernet-based Access Aggregation Network



Services in aggregation – “Triple Play”

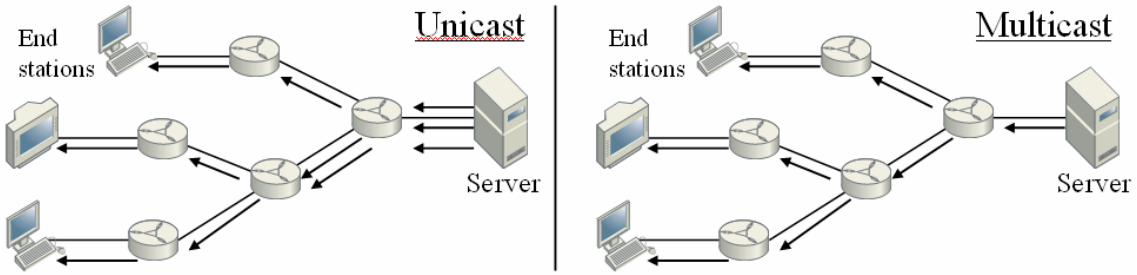
- **Internet**
- **Voice over IP**
- **Video services**
  - Multicast IPTV
  - Video on Demand
  - Near VoD (multicast)
  - Videoconferencing (multicast)
- **Virtual Private Networking**
  - Layer 2 VPN
  - Layer 3 VPN

- **Optimal aggregation network implementation?**
- **Triple play?**
- **Added IP level awareness for L2 aggregation?**
- **L3 aggregation?**

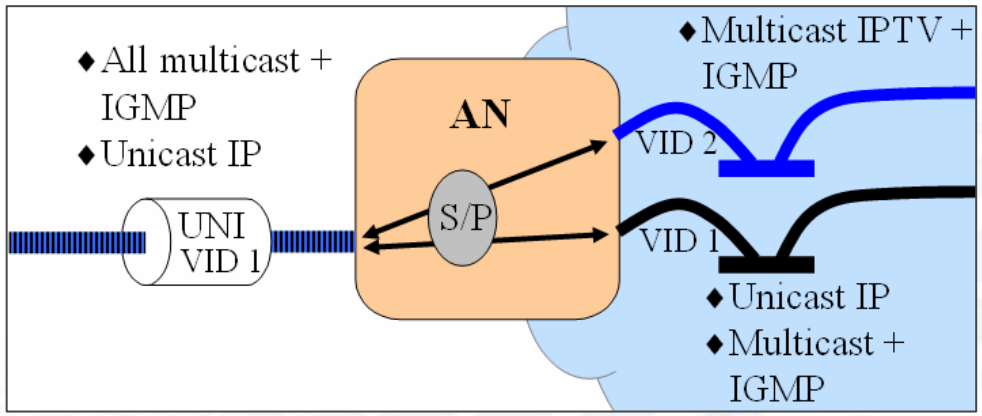


Multicast

- Packets are transmitted only once and network nodes replicate the packets into all interfaces having multicast group members



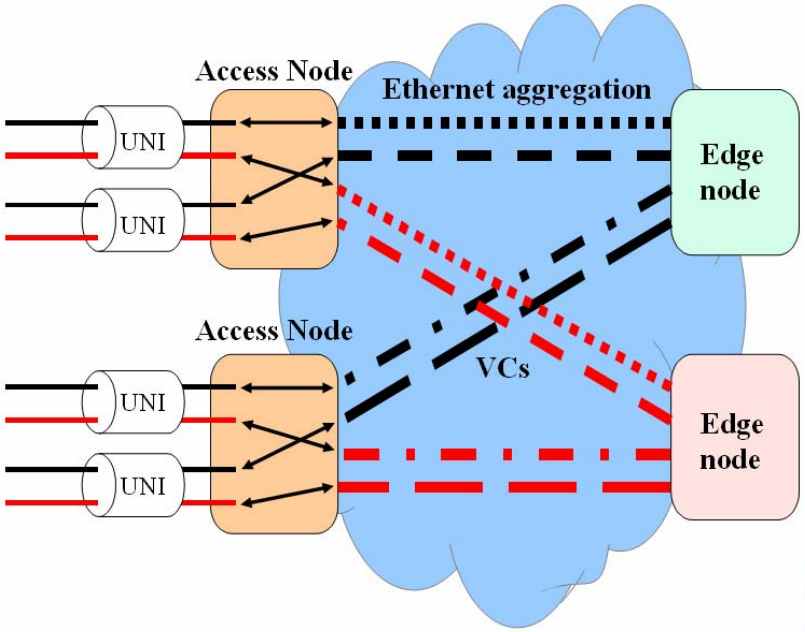
- Ethernet nodes need to support Internet Group Management Protocol
- Access node is a suitable point for L2 multicast replication
- IGMP snooping for L2 nodes
- PIM in routers

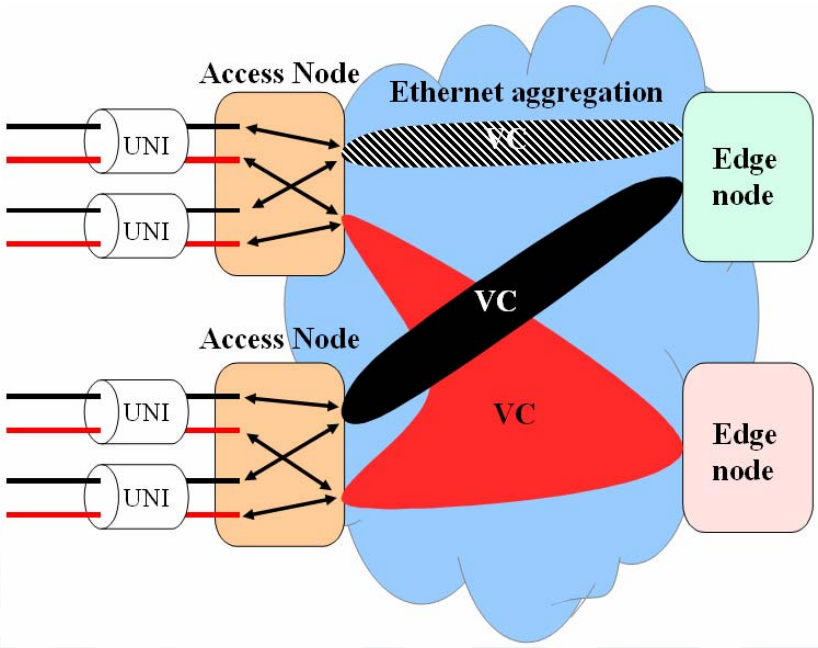


Ethernet VC implementation alternatives

- Customer unique VLANs
- Secure
- Limited and complex with conventional Ethernet
- Heavy provisioning and management workload

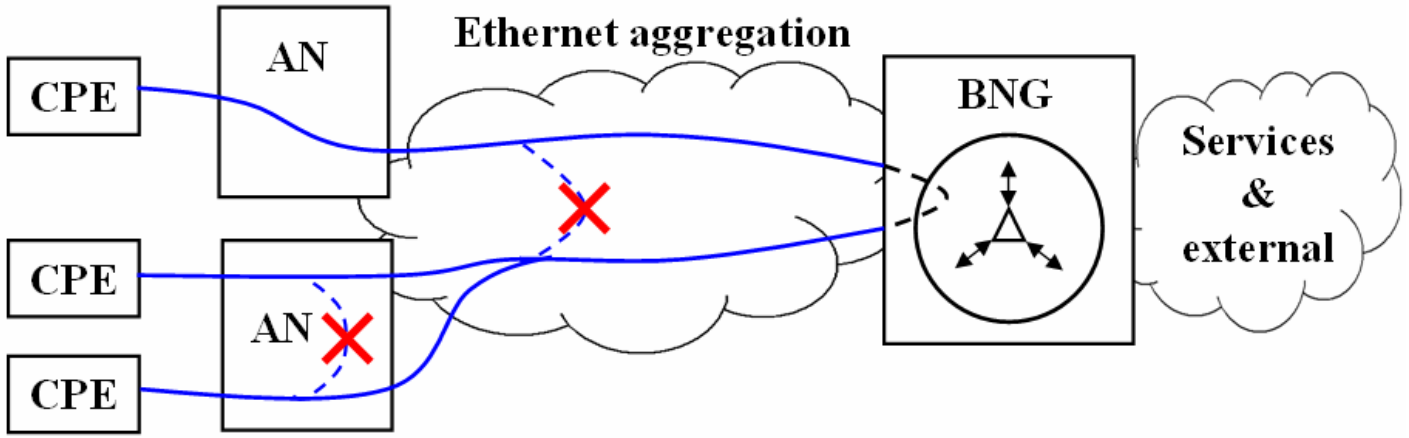
- Shared service VLANs
- Better scalability and easy provisioning task
- Problematic security issues – L2 connectivity between customers





“Peer to peer” access, L2 VPN, secure connectivity

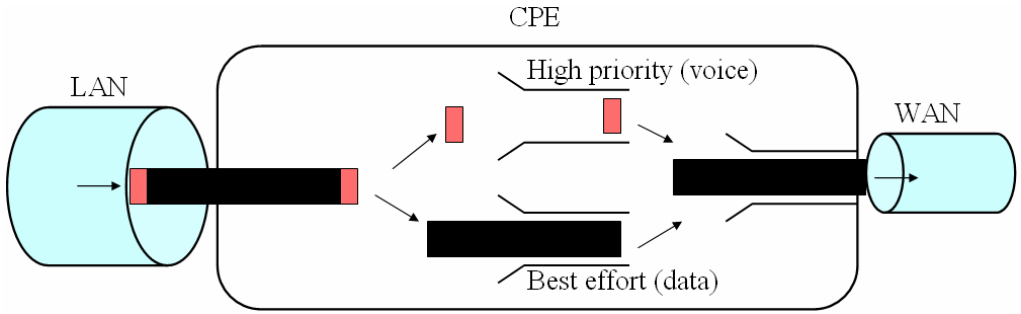
- Usually prevented with MAC/IP Forced Forwarding in shared service VLANs



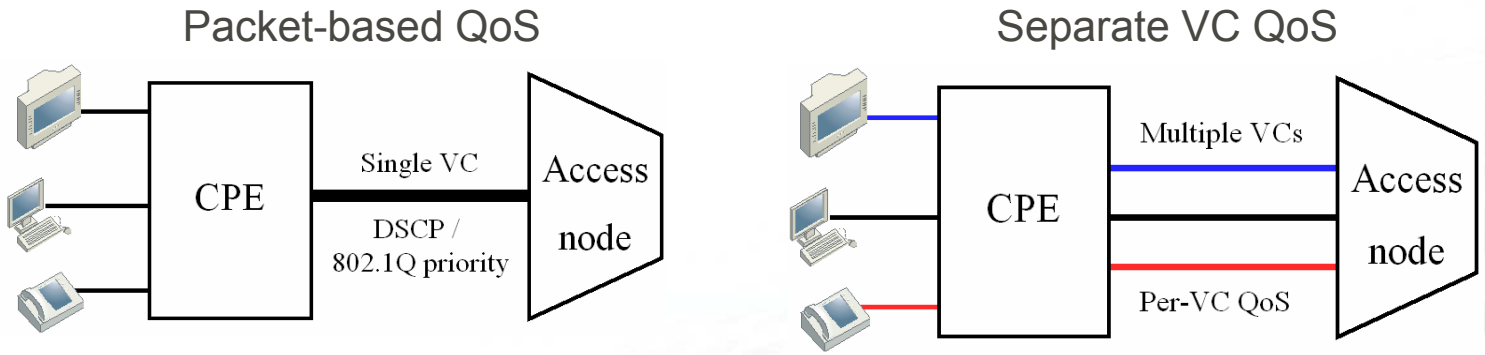
- Optimal paths within a regional aggregation network could be enabled, but it would require control, traffic counters and policing in the Access Node
- L2 VPN for organizational users allowed within a private VLAN
- MAC address spoofing prevented with Virtual MAC or IP forwarding and filters.
- IP anti-spoofing with DHCP relay and Option 82 in the Access Node

QoS for Customer Premises and Upstream

- A level of packet-based QoS functions reguired for Customer Premises Equipment

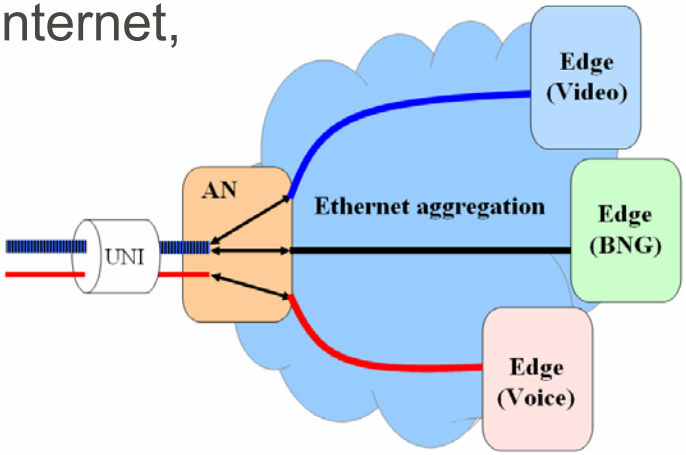


- VC-based QoS leads to restricted service access when separate interfaces are required for all services



Ethernet VC (VLAN) separation for services

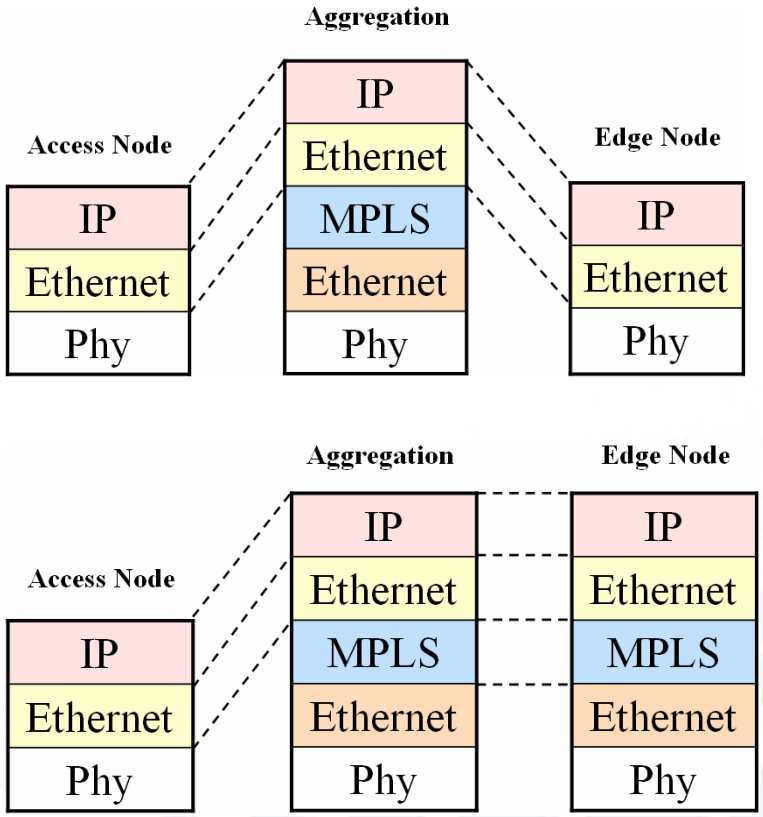
- Delivering services within separate or shared VLANs gives different alternatives
- An example for Internet, VoIP and IPTV:



- Using QoS for upstream VoIP is problematic for VoIP services used over public Internet VC
  - Cannot trust upstream packet priority
  - Rate limiting and quota could be used for VoIP class if enabled in Internet VC
  - Separate VC for VoIP gateway access – a controlled VoIP solution

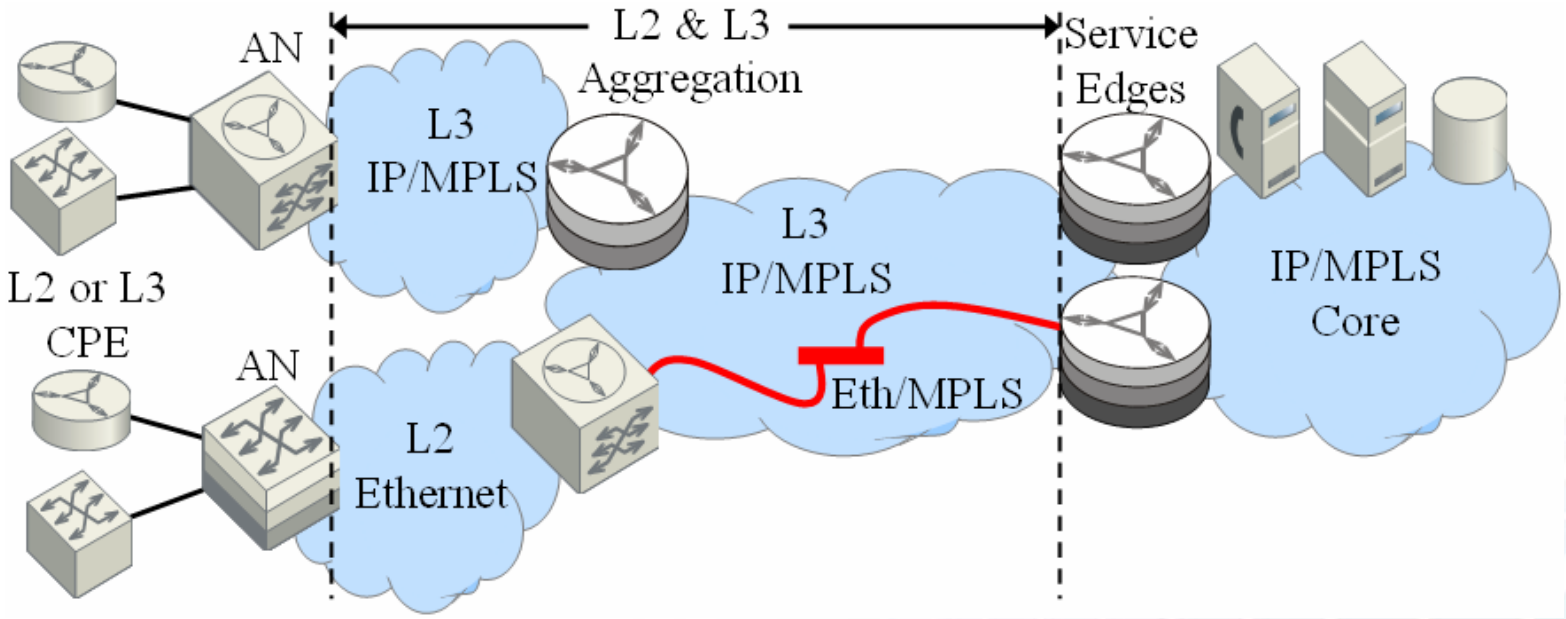
Emulated Ethernet with MPLS

- Better than multitagging VLANs
  - MPLS replaces STP in failure recovery
  - Enables 50 ms convergence time
  - Flexible and easy service provisioning
- May be used transparent to the Access Node and Edge
- Adds scalability with 20 bit VC label
- Separate VLAN domains for each physical Interface at the Edge
- The use of MPLS in the Egde allows separate VLAN domains for each MPLS VC and thus 4096 802.1Q VLANs for each 20-bit MPLS vc label = highly scalable



Layer 3 aggregation

- It seems that layer 2 aggregation is somewhat complex a solution and requires a lot of higher layer functionality in addition.
- Layer 3 aggregation with routers may provide better implementation for the future if router cost is reduced and IPv6 is utilized.



Conclusions

- Service models for the future require a lot of extra functionality compared to a traditional network.
- Some of the additional requirements for the CPEs and ANs are results of the use of Ethernet, but the major factor clearly is the new, better multipoint service infrastructure.
- Ethernet is certainly beginning to have competent performance and features for carrier network implementations, but standards are required to be finished.
- Bridged Layer 2 Ethernet access network model may still be an intermediate step from ATM evolving to a fully routed Layer 3 IP aggregation network model and IPv6.
- Ethernet emulation with MPLS-based services is the most flexible and reliable solution for Carrier Class Ethernet implementation

Recommendations

- Customer unique VLAN model is suitable for organizational customers
- Shared service VLAN model is suitable for masses consumers
- Virtual MAC, forced forwarding and IP layer awareness required in the Access Node
- DHCP relay with Option 82, ARP proxy and IGMP proxy reporting required in the Access Node
- Multicast IPTV implemented in separate VLAN
- MPLS should be used for large aggregation networks

- Seven-OSI-layer-aware switches are recommended for further study

Thank you!