



# Transmission Findings

- › New low loss fibre and improved modulation techniques promise longer transmission distances (up to 150 km without amplification)
- › New G.656 fibre standard supports CWDM and additional DWDM channels.
- › Newer fibre may be obtainable, but most routes will likely be mix of older fibre types. May therefore be difficult to take advantage of recent advances in transmission capabilities.
- › No obvious path for SDH beyond OC-768 (40 Gbps), and likely to become legacy technology in coming years.
- › All manufacturers developing 40 and/or 100 Gigabit Ethernet because of cost advantages (an OC-192 port is 10 times that of a 10 GE port). Carrier-grade OAM&P and virtual circuit functionality is currently being added (e.g. PBBTE, CFM)
- › 100 GE implementations expected by 2010, although may be later. Initially likely to be 4 x 25 Gbps and restricted to short-haul applications. Full serial implementations not expected until 2012.



## Transmission Findings

- › 40 GE may be interim solution as implementations expected by 2009 (expected to be 40% the cost of OC-768). Supposedly for data centre applications, but some vendors talking about WAN capabilities (80 km before amplification/2000 km before regeneration).
- › Most manufacturers focusing on 50 GHz spacing for DWDM channels (i.e. ~80 channels per fibre). This has been found to provide good performance trade-off with respect to faster line rates and longer reaches.
- › Tunable lasers, VOAs, EDCMs, multi-degree ROADMs technology, and PIC-based OEOs promise easier-to-facilitate (and potentially cheaper) WDM systems. Also make meshed optical networks possible.
- › True all-optical PXC's under development.
- › Passive Optical Networks (PONs) being trialled.



# Control Plane and Routing Findings

- › Routing scalability becoming problematic (again).
  - › Huge rise in number of hosts, fragmentation of service provider hierarchy, increase in multihoming, and amount of traffic.
  - › Global routing table now >230,000 entries, which generates around 400,000 BGP updates per day.
  - › Concern that growth is starting to outstrip router chipset and memory developments, but more specifically the cost of provisioning these.
  - › Not immediate cause for concern, but IAB/IETF looking for efficiencies. Proposed to split IP addresses into identifiers and locators. [Possible implications for AAA as well]
- › IPv6 growth has been slow, but new predictions now suggest IPv4 address space could be exhausted in 3-5 years.
- › IPTV may (finally) provide impetus for IP multicast.
- › MPLS widely adopted, but GMPLS less popular.



# Network Virtualisation Findings

- › Virtualisation concepts starting to be used across all networking layers.
- › Basic virtualisation already implemented in certain modern routers to enable upgrades and troubleshooting of specific interfaces.
- › NRENs (e.g. CANARIE, CESNET) pioneered customer-empowered network concept, where multiple virtual networks can be defined and managed by customers over NREN-provisioned infrastructure.
- › Deployment of UCLP and similar technologies are first step towards full network virtualisation.
- › GENI and FEDERICA initiatives aim to develop network virtualisation to allow disruptive technologies to be tested over production infrastructure.



## Operations and Performance Findings

- › Limited tools for managing Network Layers 0-2, and very expensive.
- › Management of Layers 0-2 currently labour intensive and relies heavily on documentation.
- › Core networks likely to continue to be overprovisioned as bandwidth is cheap, although should support QoS information so QoS can be applied on edge networks if necessary.
- › Increasing availability of dark fibre allows R&E networks to operate hybrid networks, enabling dedicated links to be provisioned for demanding customers using C/DWDM.
- › Middleboxes such as firewalls, NATs, rate shapers and other 'black box' solutions are responsible for many network problems. They also encourage workarounds that circumvent what the box is trying to achieve in the first place. More careful use and management needed.
- › Most end-to-end performance issues are due to problems at customer sites.
- › 10 Gbps+ network monitoring is currently expensive, but cost should reduce with specialist multi-core appliances.
- › Recommend extending scope of PERT (possibly integrating with NOCs).



## Middleware Findings

- › Identity federations are solution for supporting user access to remote services.
- › Most NRENs have identity federation or are establishing one. Others should plan to do so within next couple of years.
- › NRENs are natural candidates for supporting technical organisation within their countries, as well as representing national federations.
- › User-centric identity (e.g. OpenId) management also growing, and abstract identity framework also being worked on. NRENs should monitor developments.
  - › Already integrations of identity federation and OpenId



# Middleware findings

- › Inter-operability of identity federation happening:
  - › SAML 2.0 is today choice for exchanging identity data for web-based applications.
  - › All the identity federations technologies are SAML2.0-compatible or they migrating to be SAML2.0-compatible.
  - › Schemas such as eduPerson or SCHAC becoming more important to facilitate inter-operability.
- › In order to be able to handle different AAs it is recommended that NRENs support multiple trust infrastructures:
  - › X.509 certificates used quite a lot.
  - › SAML signed tokens, coming up.
- › It is recommended that NRENs try to minimise number necessary (e.g. by reusing existing PKIs).
- › Still open issue: No well established standard for communicating identity data to applications.
  - › NRENs should be proactive about this (possible TF?)