Building the perfect R&E network.

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• Years of
  – Requirements gathering
    • Workshops
    • Capacity planning &c
  – Government engagement (funding)
  – Procurement
    • Competitive dialogue
  – Building
  – Migration
• Dark fibre
• Coherent optical
• Lots of 100GE
• Ethernet over MPLS
• No OTN switching
• Pretty good, but not the perfect NREN.

Photo from https://www.flickr.com/photos/aldaron/536362686
What do I mean by ‘perfect?’

• A network based on all user requirements, now and for the foreseeable future?
• A network built without making any compromises?
• A network that achieves the right balance between cost, management and features?

“having all the required or desirable elements, qualities, or characteristics; as good as it is possible to be”
What is a perfect NREN?

• High capacity IP provisioning
  – Flexible, statistically multiplexed packet switching
  – Cope with peaks in demand
    • Demanding users
    • Media events

• Rapidly provisioned circuits
  – No bandwidth guarantees, but not congested

• Rapid provision of dedicated bandwidth
  – Mbps, Gbps and many Gbps

• Reliable
  – Multiple failures!

• Meet the needs of production and network research
How might that network be built?

- Dark fibre
- Optical layer
- Switched layer
- Routed layer
- Network management
  - Rapid build of new bandwidth
  - Automated provisioning
  - Network intelligence
Dark fibre

• Do you need it?
  – Good for high capacity
  – Visibility of underlying network
  – Requires a long-term contract
  – Circuits allow a telco to share fibre
    • Cheaper if you don’t need capacity
  – Optical spectrum sharing alternative?

• Can you get it?
  – Fibre market in UK is fairly limited, what’s it like elsewhere?
  – ‘Fibre glut’ of early 2000s is history
    • Telcos driving existing fibre harder rather than laying new fibre

• Will you always be able to get it?
  – Unless new fibre is laid, market is unlikely to open up
    • Telcos prefer to sell services, need to be in a strong position to buy fibre.
  – Will you be able to expand a dark fibre network in five years?

Photo from https://www.flickr.com/photos/98640399@N08/9287370881
Dark fibre

- How much of a mesh?
  - Many routes creates a resilient network
  - More degrees required on ROADM
  - How do you use all the fibre?
    - Switching and protection at the optical layer?
    - Provision IP paths over all the directions?
      - Lots of router ports!
      - Complex IGP topology
  - Simpler may be better
Optical layer

• How ‘reconfigurable’ do your ROADMs need to be?
  – Less is more
  – Colourless
  – Directionless
  – Contentionless
  – Gridless
    • MEMS or LCOS
• Capacity requirements
  – Are you going to be using a large number of the 88 (96?) channels?
  – Will you want to dynamically reroute wavelengths around the network?
• Where are you building resilience?
  – Protected optical circuits, or at the IP layer?
  – WSSs won’t reroute circuits instantly.
Optical layer

• Coherent
  – Offers 40G and 100G over long distances
  – Single 10G across an uncompensated network can be expensive

• Thick or thin?
  – Transponders in the optical equipment, ‘grey’ light to the routers
  – OTN optics in the routers
    • Several years behind the optical vendors
    • Coherent requires a lot of DSP
  – Penalty of ‘grey’ light optics and OEO
    • Especially with the cost of 100GE optics
Which circuits to offer higher layers?

• 100GE is a lot of traffic to fail in one go
  – 100GBASE-LR4 optics are still expensive, but use normal single-mode fibre.
  – 100GBASE-SR10 are cheaper but require special cabling (multi-core multimode cables with MPO connectors)
  – 10x10MSA may have support issues.

• Parallel 10GE?
  – No single flow larger than 10G
  – Lots of cabling
  – If you require all the capacity, then any one of the optics failing in a bundle might mean you have to take the whole bundle down
Switched layer

- What do I mean by ‘switched layer?’
  - Something between the optical layer and the IP layer
  - Circuits
    - The things we had in X.25 before we binned them.
    - The things we had in ATM before we binned them.
    - The things we will forever reinvent.

- What will you be using it to provide?
  - Dedicated capacity circuits? How much capacity?
  - Is the fundamental statistically multiplexed aggregation layer of the network here or at IP?
    - ‘Pool of available bandwidth’

- Virtual networks
  - Network research
Switched layer

• Where should it be?
  – In the ROADMs?
    • OTN, ethernet?
  – Dedicated boxes?
    • Yet more rack space and power
  – In the routers?
    • EoMPLS

• The more places you build in switching capacity, the more layers you need a bandwidth overhead to provide it
• How many backbone routers?
  – Don’t want to carry traffic further than is necessary.
  – Don’t want to process the packet at lots of hops.
• How far out do you manage?
  – Options for collapsed CE/PE using virtualised functions?
• I don’t need to say IPv6, do I?
IP layer

- **Scaling**
  - Power, space
  - Vendors suggesting more boxes rather than always meeting demand with one box
• Content delivery
  – Lots of traffic comes from usual sources
    • Google, Akamai, Limelight, Netflix
  – House servers?
    • Netflix can serve several 30Gbps from a 1RU server
    • Can distribute them around network to reduce carrying traffic
    • Local nodes may be cheap/free, but ‘pay’ for power, rack space, time spent
      arranging broken servers to be replaced.
      – Do you need Google servers, Akamai servers, Limelight servers, Netflix servers?
      What about the next big CDN?
  – Just peer?
    • May not be available in all locations
    • Need to carry traffic around the network
    • Easy to add new peers
• ‘Cloud’ access and peering
IP layer

• QoS?
  – “You don’t need QoS if you build an adequate network” (Owen Delong commenting on “A reasonable discussion on Net Neutrality”)
  – If you’re preferring some traffic, that means you’re deprioritising everything else.
  – How do you do admission control fairly so only the VoIP traffic is prioritised, but it’s open to all VoIP providers?
  • Network neutrality
• Where does it fit in the wide-area network?
  – A tool for point-to-point circuits?
• Which layer?
• Testbed or more?
• Multi-domain SDN
  – East-west interfaces
Rapid provisioning of high bandwidth

- Capacity needs to be lit on the optical layer to use it at higher layers
  - Or at least sitting around…
  - Expensive pre-provisioning
  - May never be used
    - Who has the money?
    - Technology may be obsolete before it is used
  - Flexigrid and dynamic encoding may help here!
Automated provisioning

• **Know what you’re selling**
  – Bandwidth on demand? Or a circuit on demand?

• **Heterogeneous networks**
  – Vendor-specific solutions are bad
  – How much experience of network operations does your development team have?

• **Who is the user? How do we get to them?**
Network intelligence

• How smart should the network be?
• Historically, distributed control planes
  – BGP, LDP, OSPF, IS-IS.
• Towards more centralised control
  – SDN
  – MPLS-TE using centralised software to provision/route LSPs
• Is this a good thing?
  – Trust
  – Simplicity
Network monitoring

• Now you have your dark fibre, optical layer, switched layer, routed layer and automated circuit provisioning, how do you see what’s going on?
• Each layer may be from a different vendor.
• Expensive commercial tool
  – Does it do what you want?
• Open source
  – Will require customisation
  – Will require interface modules
    • Beware: for the optical equipment they may be expensive!
Questions, discussion…

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