Prospects for a Future JANET

2012/13 and beyond

David Salmon - JANET(UK)

40G & 100G slides from Rob Evans – JANET(UK)

Overview

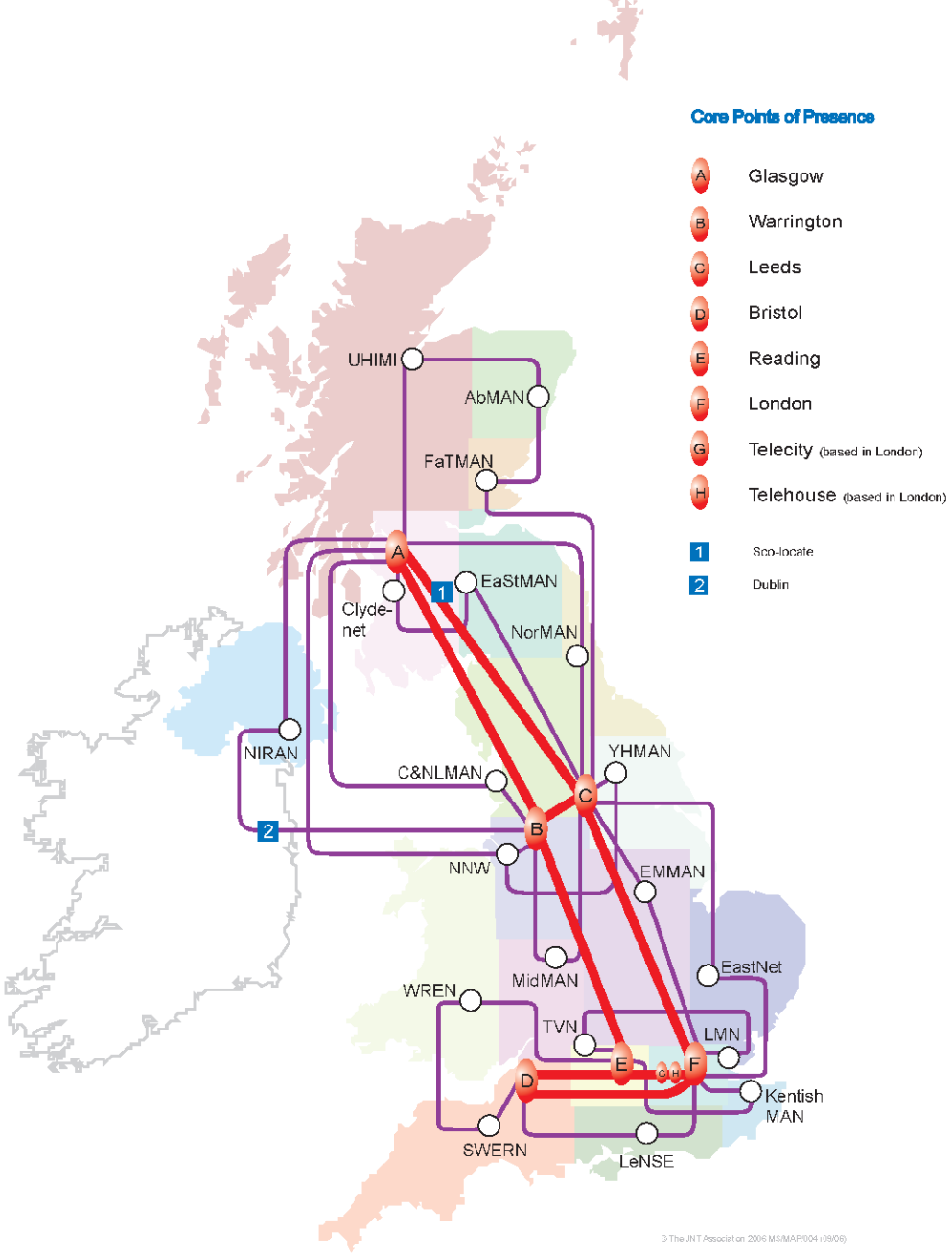
- Current JANET - SuperJANET5 backbone
  - Architecture
  - Services
  - High capacity
    - 40Gb/s service
    - 100Gb/s trial
- Research infrastructures
  - JANET Lightpath examples
  - JANET Aurora – dark fibre
- Emerging issues for a Future JANET

JANET Communities

- HE & Research
  - Since the beginning – 1984
  - 25th Anniversary of JANET 2009
  - 15th Anniversary of JANET(UK)
    - UKERNA as it was
- Further Education – age 16+
- Schools
  - Not directly connected
  - 10 additional aggregation networks
- User base potentially 18M

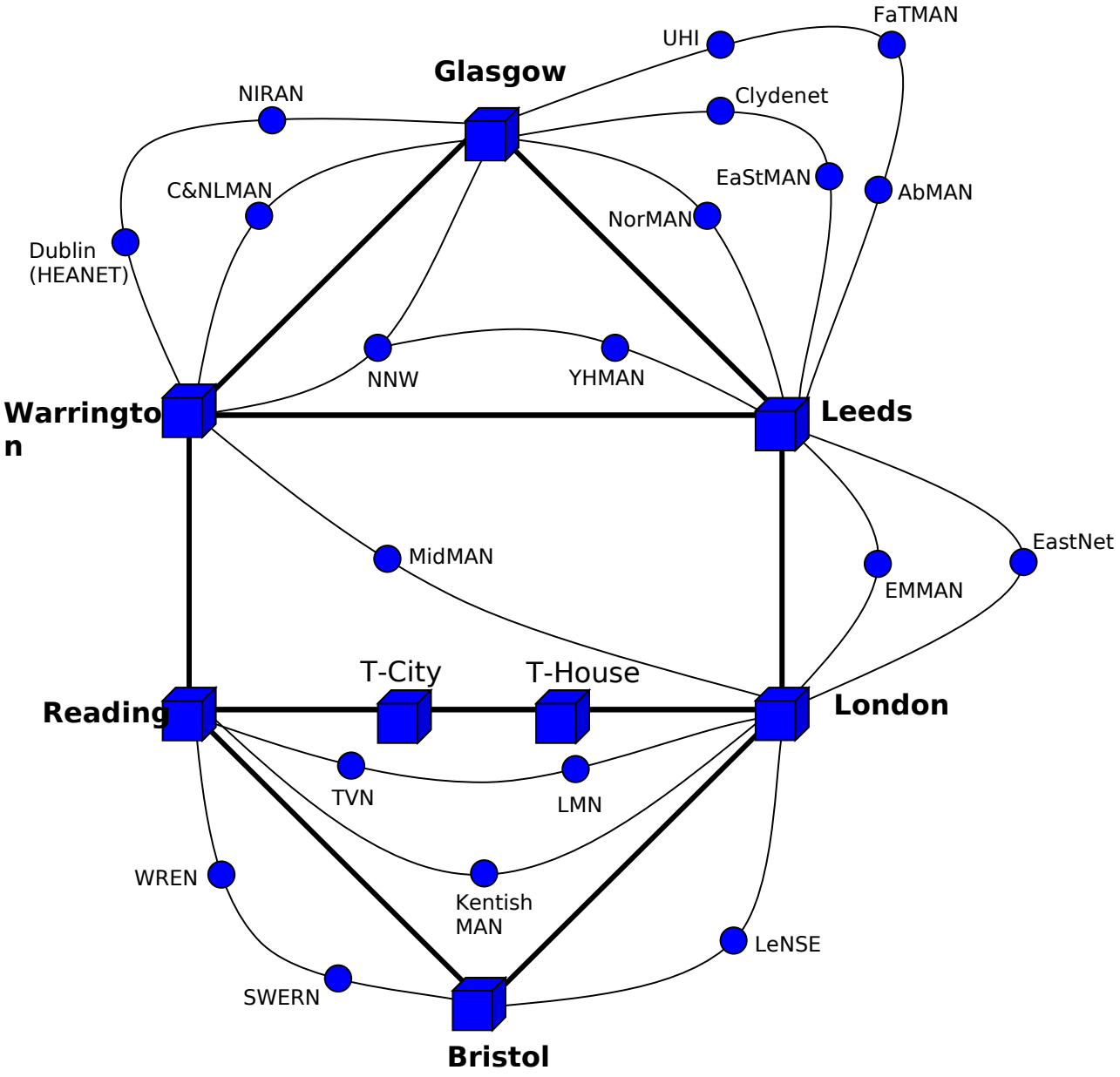
SuperJANET5

- 2006 to 2012/13
- Architecture
  - Fibre footprint
  - Regional & backbone structures
  - Service layers
  - Lightpath service implementation



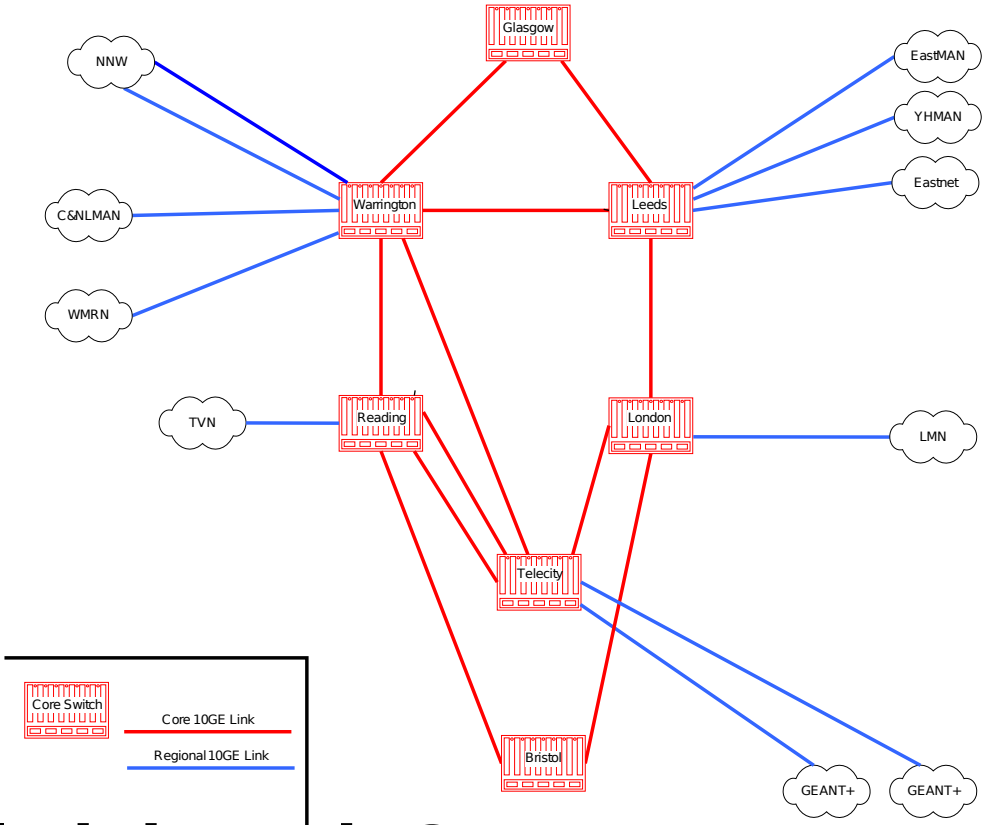
JANET Services

- JANET IP
  - High capacity
    - Core at 40Gb/s
  - High reliability & resilience
- JANET Lightpath
  - Mid to high capacity point-to-point circuits
- JANET Aurora
  - Dark fibre research platform


FaTMAN
UHI
Glasgow
NIRAN
Clydenet
EaStMAN
AbMAN
C&NLMAN
NorMAN
Dublin
(HEANET)
NNW
YHMAN
Warrington
Leeds
MidMAN
EastNet
EMMAN
T-City
T-House
Reading
London
TVN
LMN
WREN
Kentish
MAN
LeNSE
SWERN
Bristol

JANET Lightpath Service

- Dedicated Network capacity for projects
  - Point-to-point circuits
  - Typically about 1Gb/s
- About 30 paths configured
  - Across about 15 projects
- New infrastructure
  - Reviewing provision & reinstatement with projects & US providers

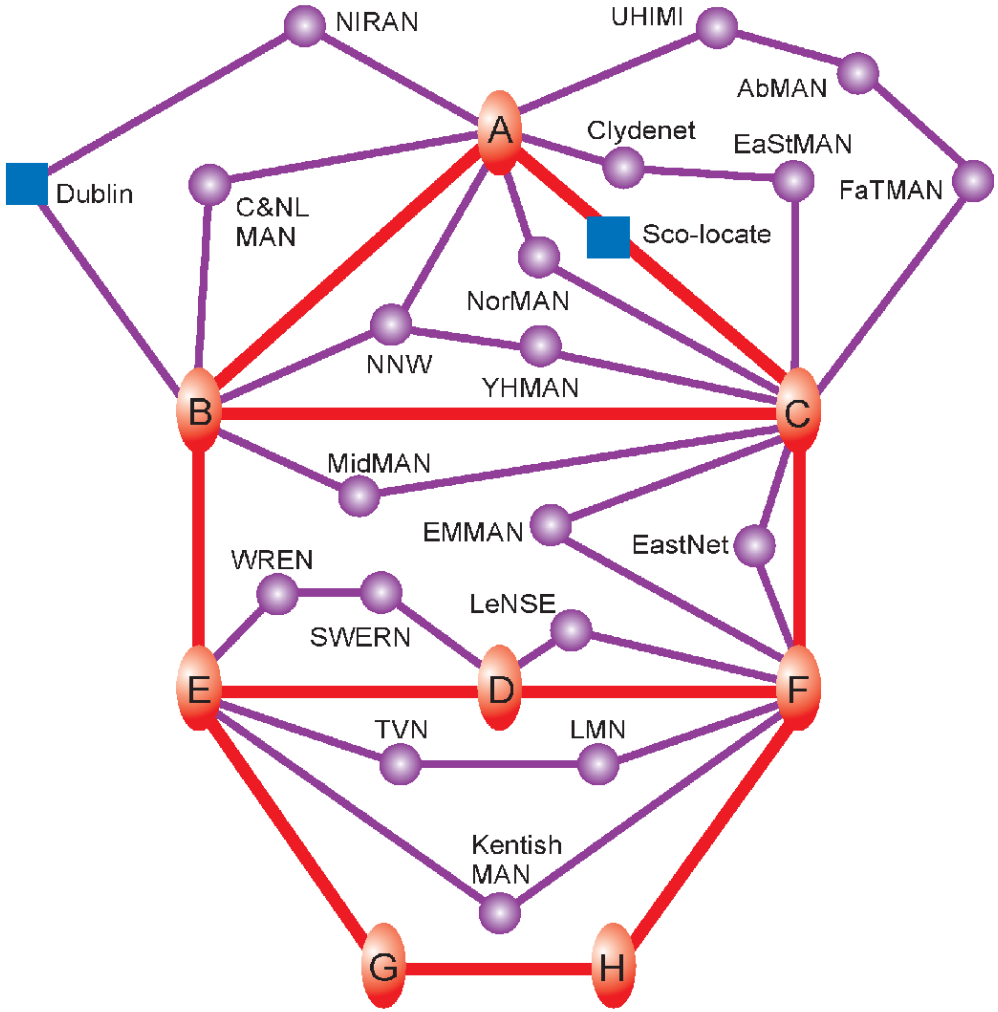


Initial Lightpath Core Topology

- Uses Existing Circuits
- Supports existing lightpaths

EoMPLS

Fine-grained capacity provisioning

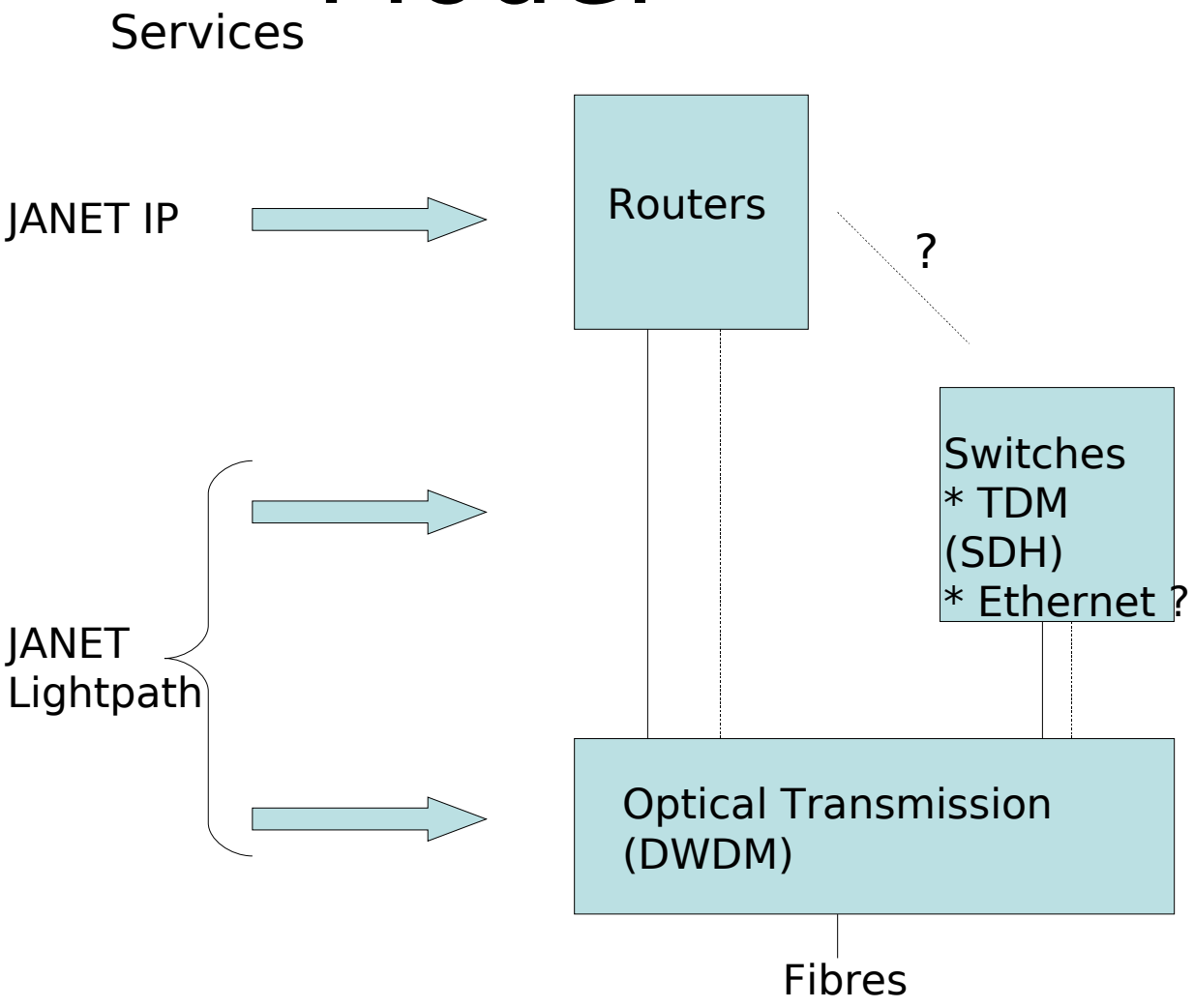


All Core links except AB and AC are 40Gb/s

A Glasgow
B Warrington
C Leeds
D Bristol
E Reading
F London
G Telecity
H Telehouse

Core Points of Presence
Regional Points of Presence
Core Path
Regional Path

Generic Service Model



Structuring Layer
Circuits
<1Gbit/s – several Gbit/s
(10 – 100+ Gbit/s) in future

Bulk Capacity
Wavelengths
1 – 10 Gbit/s
(100+ Gbit/s in future)

Lightpath examples

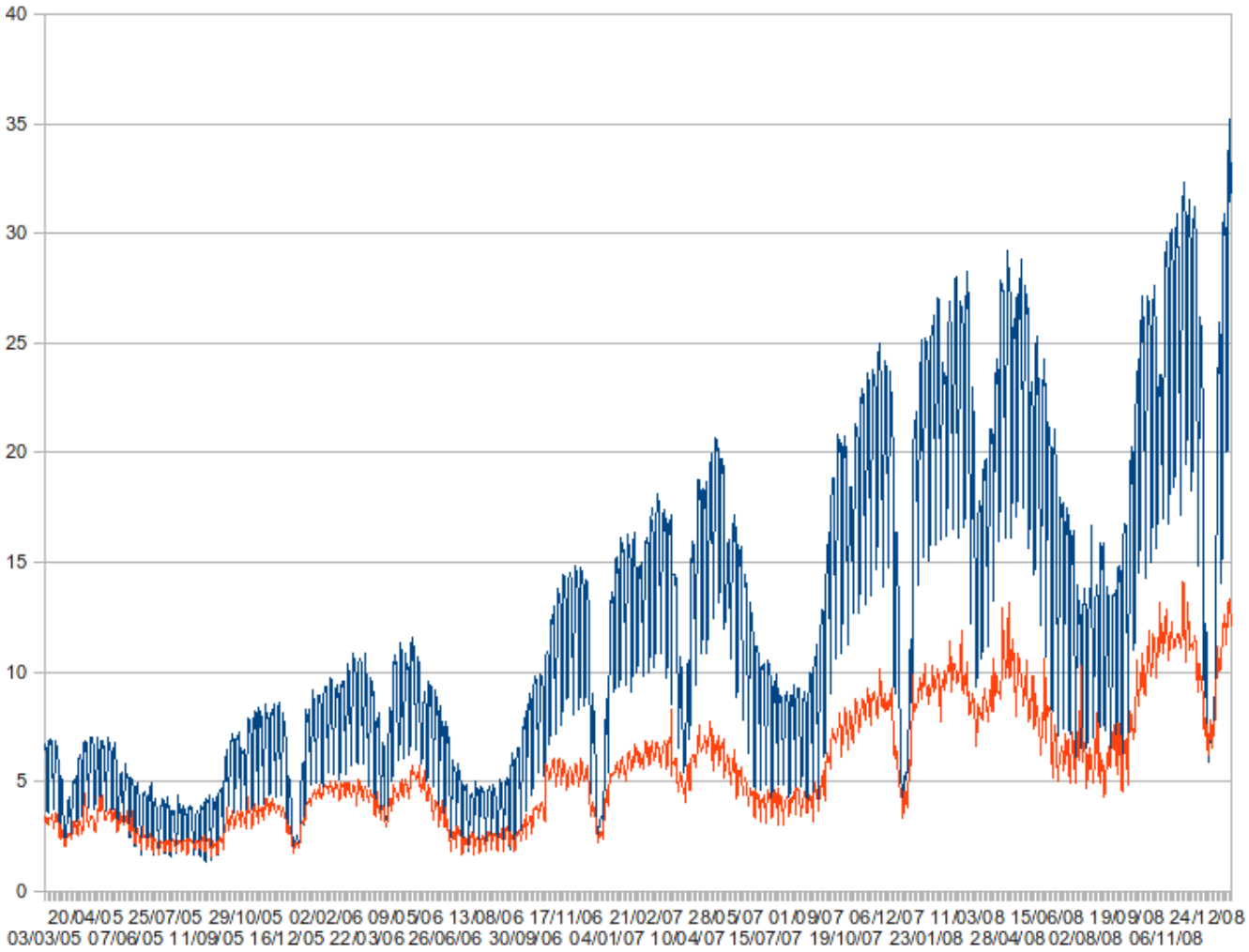
- eVLBI
- LCG
- HPC & visualisation
- Music recording…

JANET at 40Gb/s (STM256)

Slides from Rob Evans
JANET(UK)

Why increase speed?

External Traffic (Gbps)



Equipment specification

- Ciena cards made by Stratalight
- First generation card
  - PMD tolerance: 2.1ps DGD
  - Duobinary encoding
- Second generation card
  - PMD tolerance: 2.5ps DGD
    - 8ps with compensation
  - DPSK encoding

Fibre characteristics

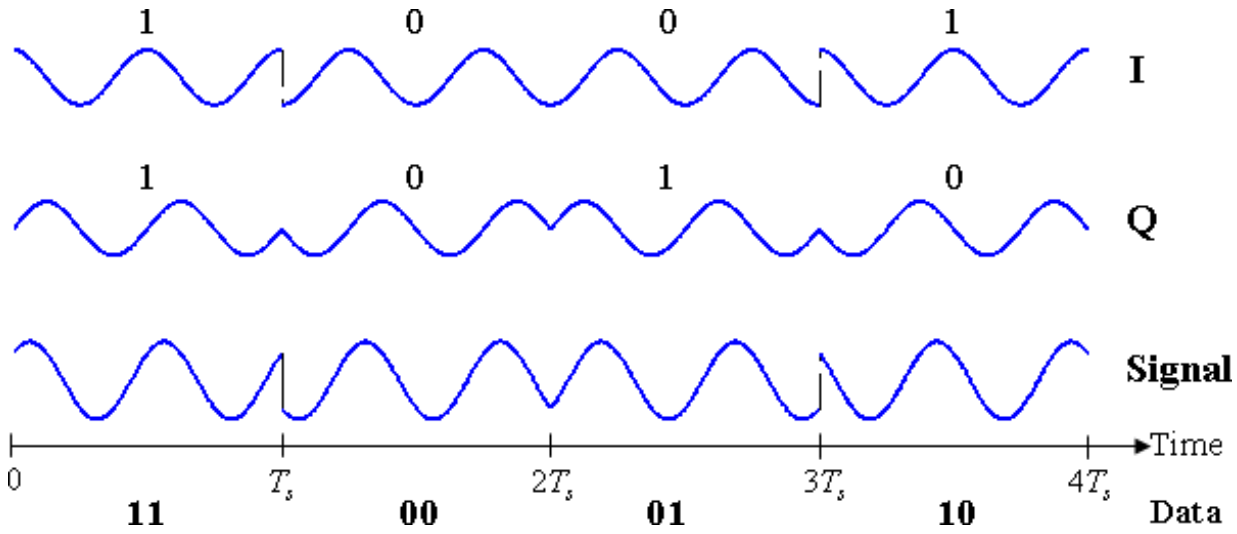
		A to B	B to A
	Length (km)	DGD (ps)	DGD (ps)
London – Telehouse	25.10	1.44	0.47
London – Telecity	28.30	1.45	0.49
Reading – Telehouse	116.50	0.75	1.64
Reading – Telecity	113.30	0.74	1.64
London – Leeds	379.68	15.46	13.66
Reading – Warrington	322.85	10.01	11.52
Warrington – Leeds	107.00	0.15	1.31
London – Bristol	252.94	2.03	1.89
Bristol – Reading	150.00	1.10	0.84

Phase 2: Nov 2008

- Outside specification for Ciena cards
  - Even with external dispersion compensation
- Alternative solution: Nortel
  - Uses Polarisation Multiplexing Differential Quadrature Phase Shift Keying (POLMUX-DQPSK)
- Carried as 'alien wavelength' on CoreStreams

POLMUX-DQPSK

Quadrature Phase Shift Keying



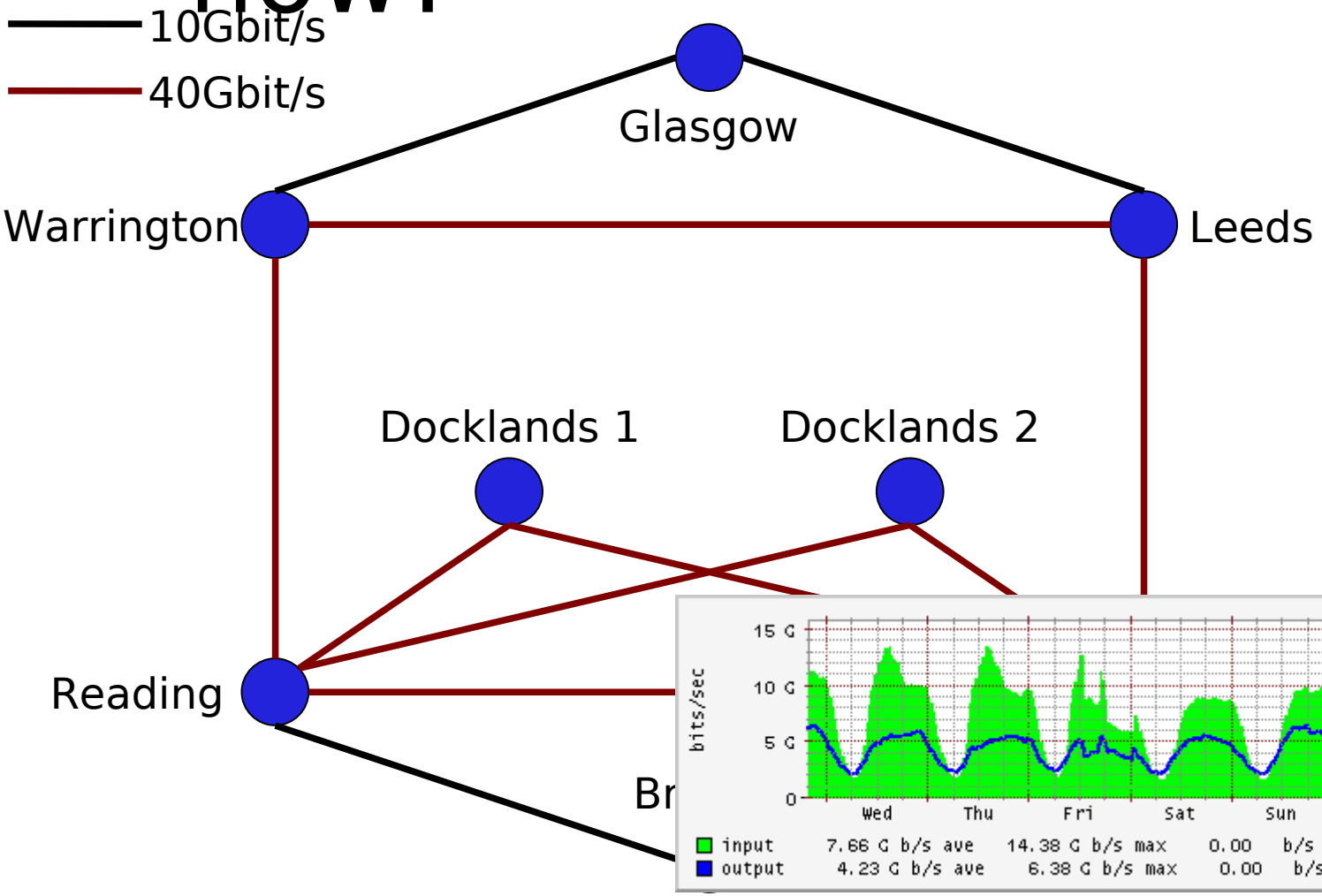
2 bits per symbol, ~ 1bit/s/Hz

Diagram by wikipedia:User:Splash

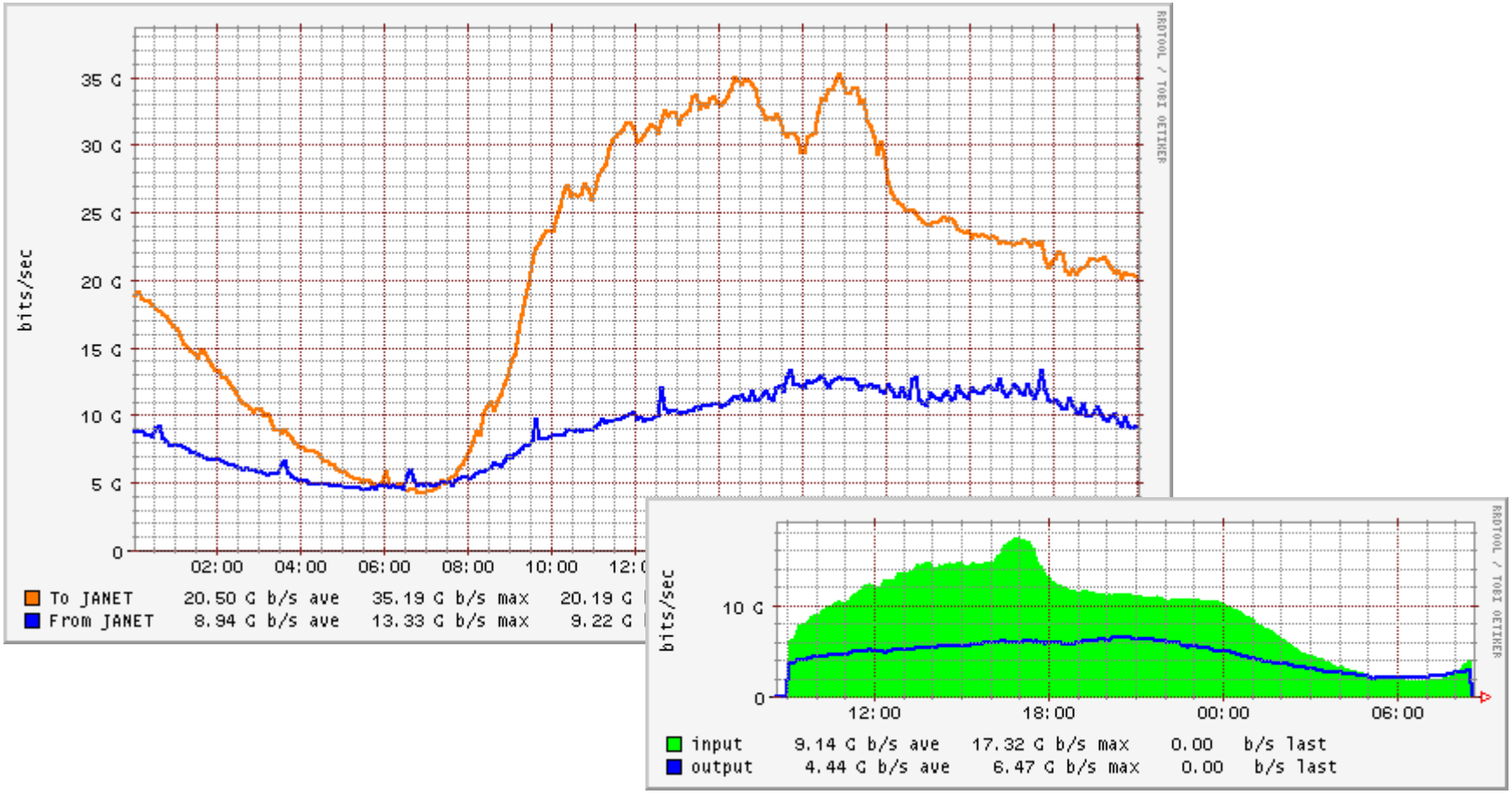
POLMUX-DQPSK

- Two DQPSK signals sent down the fibre at the same frequency with different polarisations
- 2 x 2 bits per symbol = 4 bits per symbol
  - ~2 bit/s/Hz
- Can carry 100Gbit/s signals (112Gbit/s for ODU-4) within neighbouring 50GHz ITU grid channels

What do we have now?



US Inauguration



Credits

- Verizon Business worked very hard with us to make this happen
- Ciena
- Nortel
- Alcatel-Lucent and Juniper

100Gbps Transmission Trial

Rob Evans

JANET(UK)

Credit…

- Much of the work here was performed by Verizon and Nortel
  - We were mainly observers
- Especially
  - Tom Sims at Verizon
  - Alan Beard at Nortel

100G Transmission

- At the optical layer, line side and client side are very different.
- Client side tends to be standardised
  - Ethernet, SDH
  - Connect to the users of the network
- Line side is often proprietary
  - Forward Error Correction algorithms
  - Client side encoding
  - Nortel to Nortel, Ciena to Ciena

100G Transmission

- Optical equipment vendors working on 100Gbps independently of IEEE 100Gbps ethernet standardisation
  - Still useful in the meantime to carry multiple 1/2.5/10/40Gbps signals on a single wavelength
  - Not totally in isolation, of course
    - Needs to be fast enough to carry 100GE
    - Needs to be fast enough to carry ODU-4

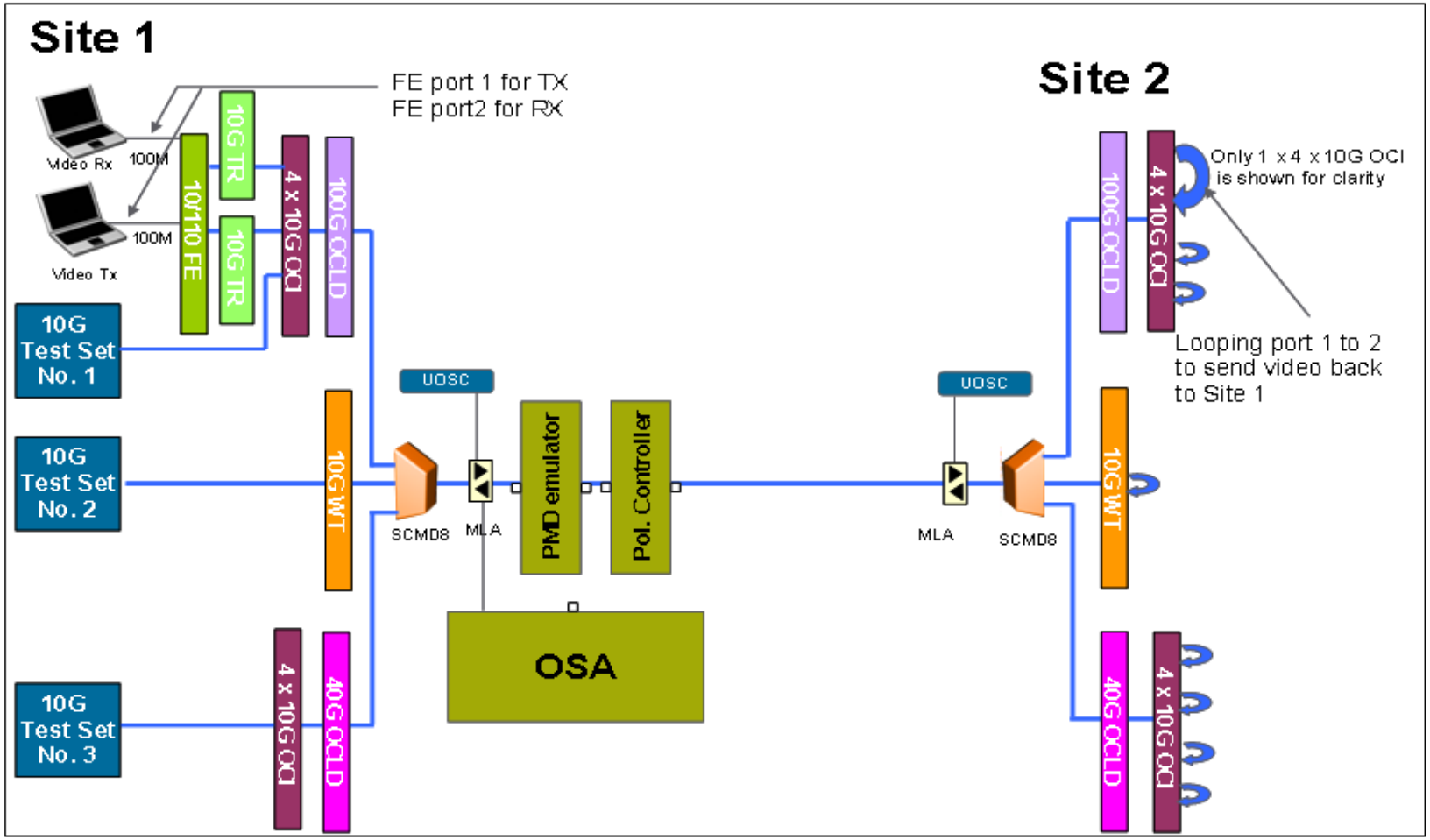
100G Transmission

- Existing DWDM systems use ITU grid
  - Wavelengths 50GHz apart
- 100G should fit in same grid
  - Too much deployed kit for anything else
- POLMUX-QPSK

100G Trial

- ~100km dark fibre
  - London to Reading
- Three neighbouring 50GHz channels
  - 100, 40 & 10Gbps
- PMD Emulator
- Ethernet & SDH test sets
- Optical Spectrum Analyser
- …and the only two 100G Nortel linecards in Europe

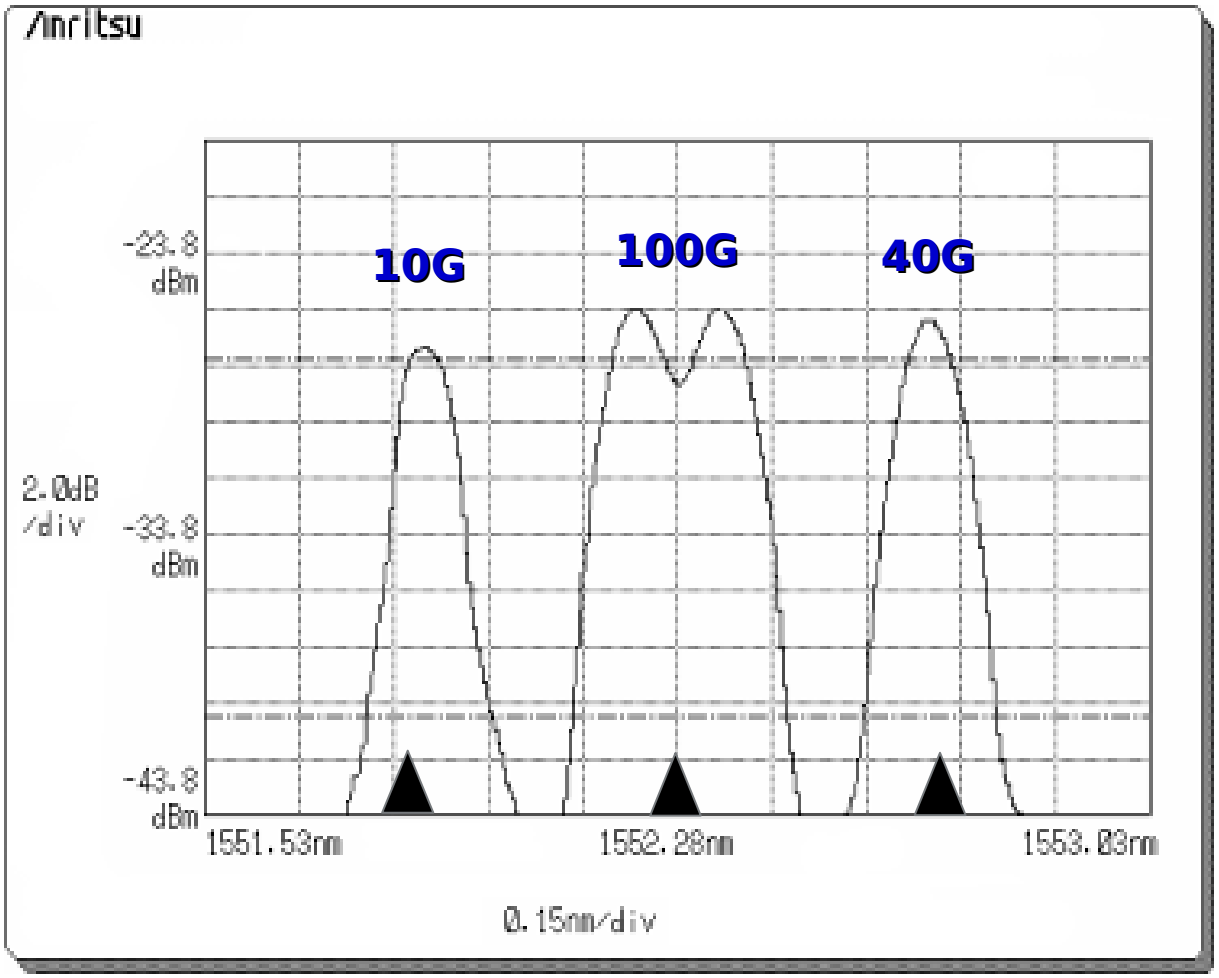
100G Trial


Site 1
FE port 1 for TX
FE port2 for RX
Video Rx
100M
Video Tx
100M
10/110 FE
10G TR
10G TR
4 x 10G OCI
100G OCLD
10G Test Set No. 1
10G Test Set No. 2
10G Test Set No. 3
10G WT
4 x 10G OCI
40G OCLD
UOSC
SCMD8
MLA
PMD emulator
Pol. Controller
OSA
Site 2
Only 1 x 4 x 10G OCI is shown for clarity
100G OCLD
4 x 10G OCI
Looping port 1 to 2 to send video back to Site 1
UOSC
MLA
SCMD8
10G WT
40G OCLD
4 x 10G OCI

100G Trial

- 100Gbps signal in centre grid position
  - POLMUX-QPSK
  - Some of the D/A & A/D circuitry isn't working at 100Gbps yet
    - Two POLMUX-QPSK carriers of ~50Gbps within same 50GHz grid spacing
- 10Gbps signal one side
  - Duobinary
- 40Gbps signal other side
  - POLMUX-QPSK

100G Trial


Anritsu
10G
100G
40G
-23.8 dBm
2.0dB /div
-33.8 dBm
-43.8 dBm
1551.53nm
1552.28nm
1553.03nm
0.15nm/div

100G Trial

- PMD simulator increased 'instantaneous' PMD from 0 to 150ps
  - Equivalent to ~50ps DGD
- 10G SDH test set started recording errors at ~21ps mean DGD
- 40 & 100Gbps FEC started having to work at ~40ps mean DGD
- Started to get client side errors at ~50ps mean DGD

In context

- Worst mean DGD we've seen on our fibre is ~15ps.
- On trial link, 100G transmission was working fine with much worse simulated PMD.
- Encouraging for rolling out 100G on installed fibre.

JANET Aurora

A Dark Fibre Facility for Photonics and Optical Networks and Systems Research

Aurora

What is JANET Aurora ?

- A dark fibre facility to support research on Photonics and Optical Networks and systems
  - Not a “production” network
  - Not a “production” testbed
  - A flexible platform to support University Research

Background

- Early discussions in 2001-2002
- 2003-2004 UKLight case made & funding secured
- Circuit oriented network (Lightpaths)
  - Implemented with TDM technology (SDH)
- A small dark-fibre facility
  - Initially lower priority, then many additional funding & committee delays
  - Eventually procured in 2005, and first phase in service Dec 2007 – 3 universities
  - Second phase completing in May 2009 – 2 more universities
- Total about £4M over about 3.5 years
  - Funded with five sites until May 2011 (2 years operating)
  - FROM HEFCE via JISC

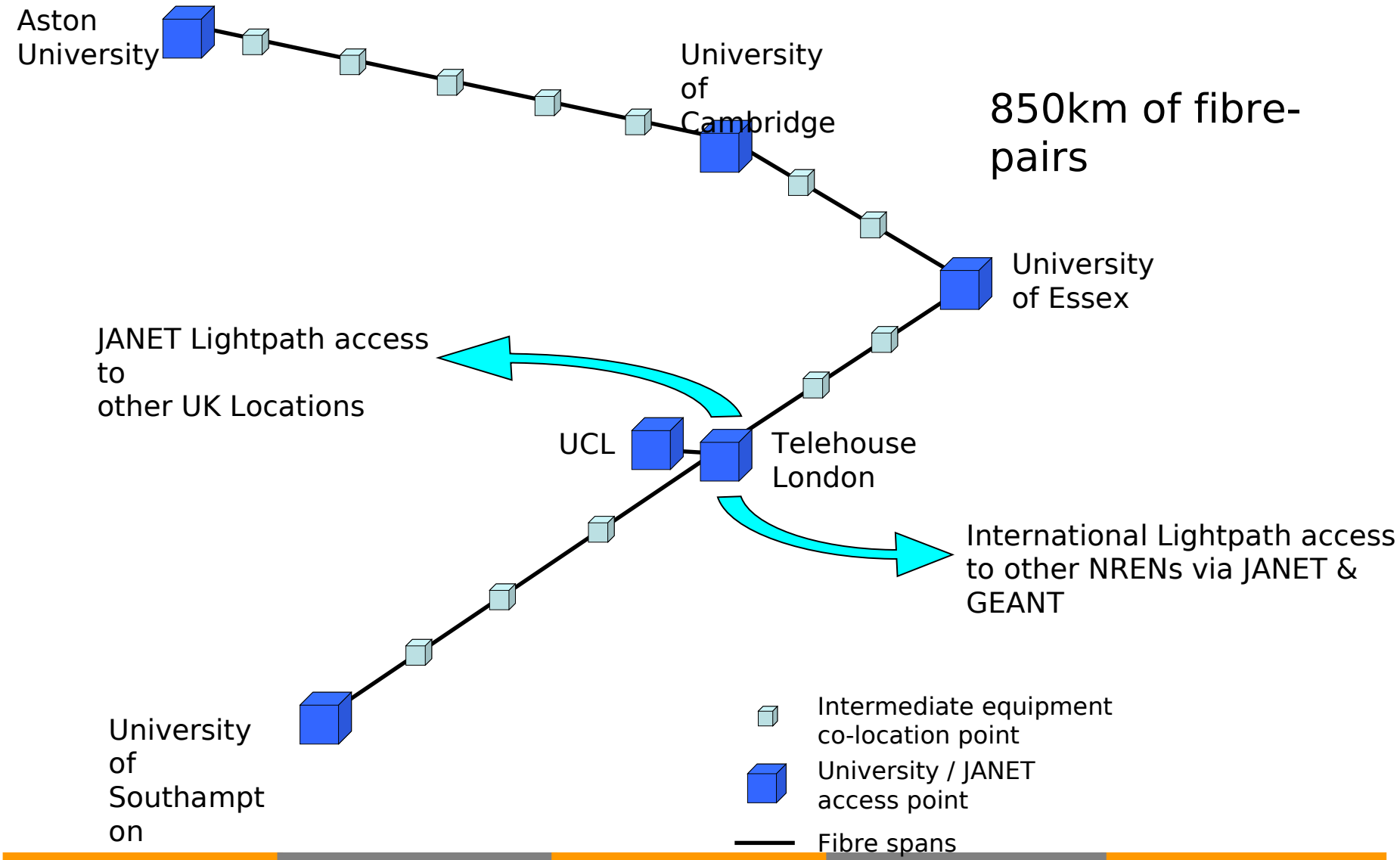
Why dark fibre ?

- Photonics Work at this level needs a dedicated fibre network
  - Researchers can put their own equipment on the fibres
  - Possibly equipment they have built themselves
- Investigate new devices & components
  - Lasers, Amplifiers, Modulators…
  - All the elements to make communication systems work
- New transmission techniques
  - Higher capacity (more bits/s) on each wavelength
  - More wavelengths
- Avoid disrupting other users
  - This kind of work can’t possible be done on shared fibres (eg JANET !)

What have we procured ?

- Access (lease) a pair of fibres
  - linking Research groups at five Universities
- Access to intermediate locations for installing equipment
  - Researchers will put Optical Amplifiers and Dispersion Compensators in these locations
  - possibly ROADMS/WSS in future

JANET Aurora



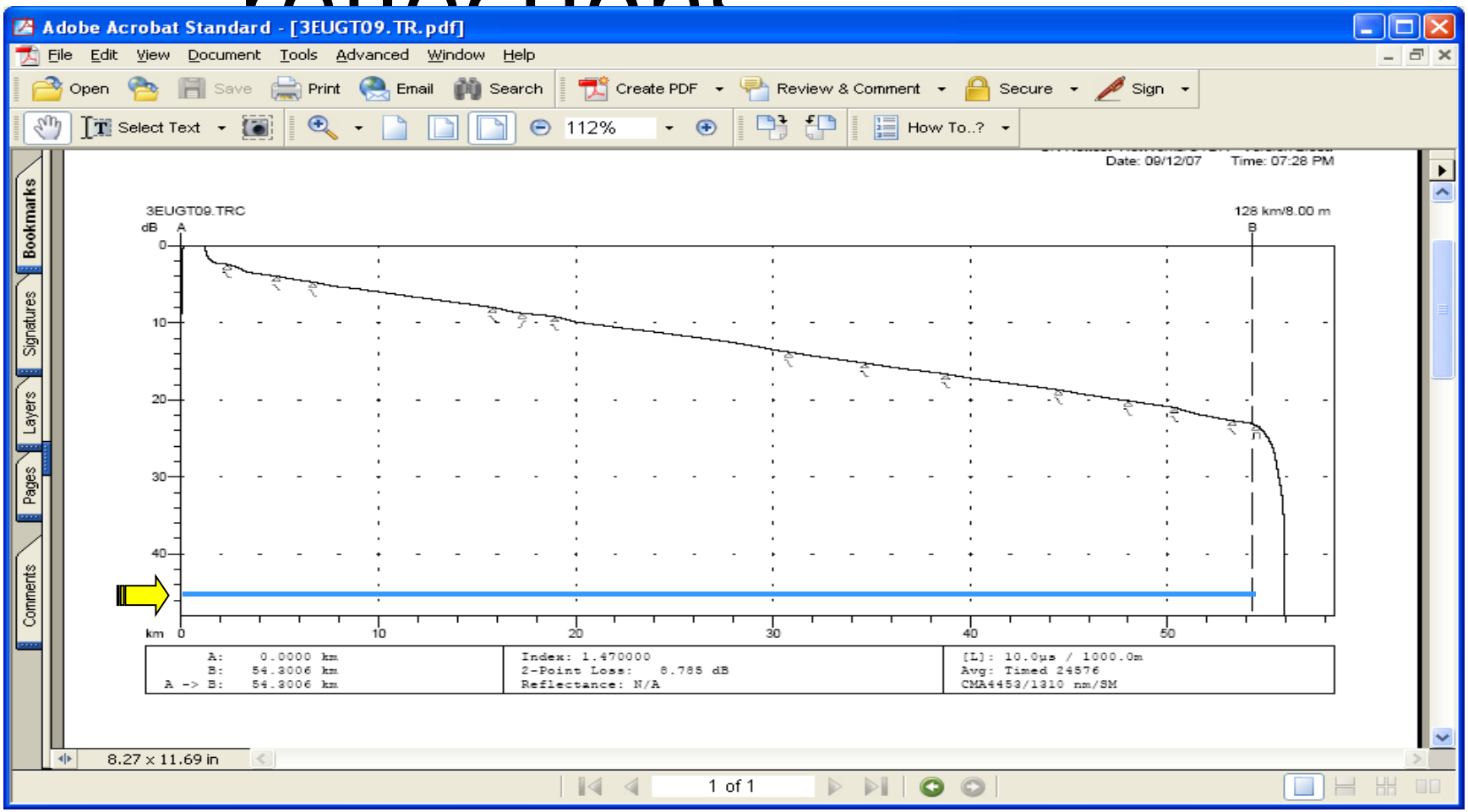
Deployment

- Virgin Media (ntl:Telewest Business) are approaching the end of the deployment
- Much iteration on testing and accepting fibres to meet the specifications
- Access policy agreed
  - Accompanied access – no extra cost (within reason)
  - Three days notice (faster in

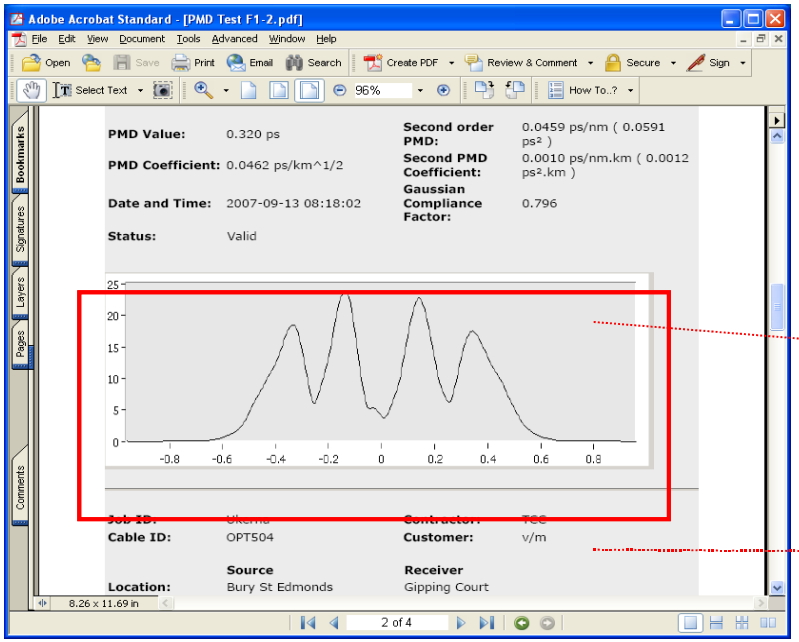
Target Fibre parameters

- Maximum span loss 17dB
  - Standard splice losses apply (<0.2 dB)
  - All spans fully spliced (no connectors except terminal ODFs)
- Chromatic dispersion < 1100ps/nm
  - Per span
  - except longest links ~> 65km where 1200ps/nm is the limit
- Maximum PMD 2.5ps
  - University to University – NOT per span
- Aimed for spans of <50km
  - in practice there are several between 60 and 70km, and one at 73km

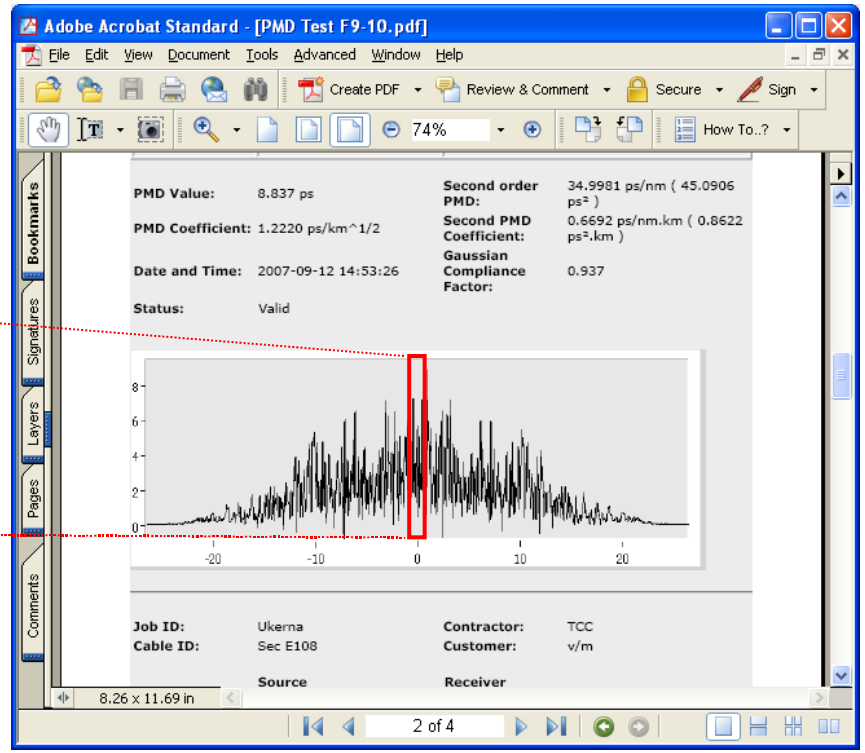
Looking for reflections



Dispersion (PMD) Tests



Good – very little spreading



Bad – 25 times as much spreading

What will JANET Aurora be used for ?

Photonics Examples

- Phosphorus Project – EU FP6 funding
  - End-to-end lightpath provisioning
  - Co-scheduling with GRID resources
- Photonics Device research
  - Install bespoke optical equipment on fibres (lasers/modulators/compensators)
  - Ultra-fast photonics research
- Optical Burst Switching
  - Flow triggered switched lightpaths (genuine lambdas/wavelengths) 160Gb/s trials undertaken
- OTDM – see following slides

University of Essex

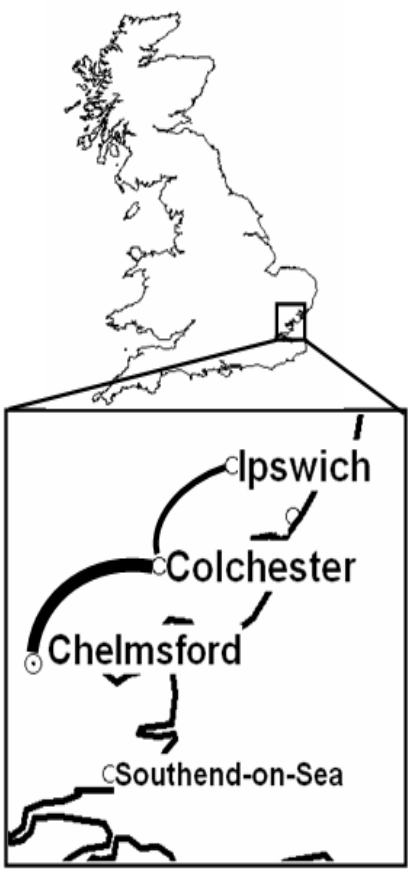
School of Computer Science and Electronic Engineering

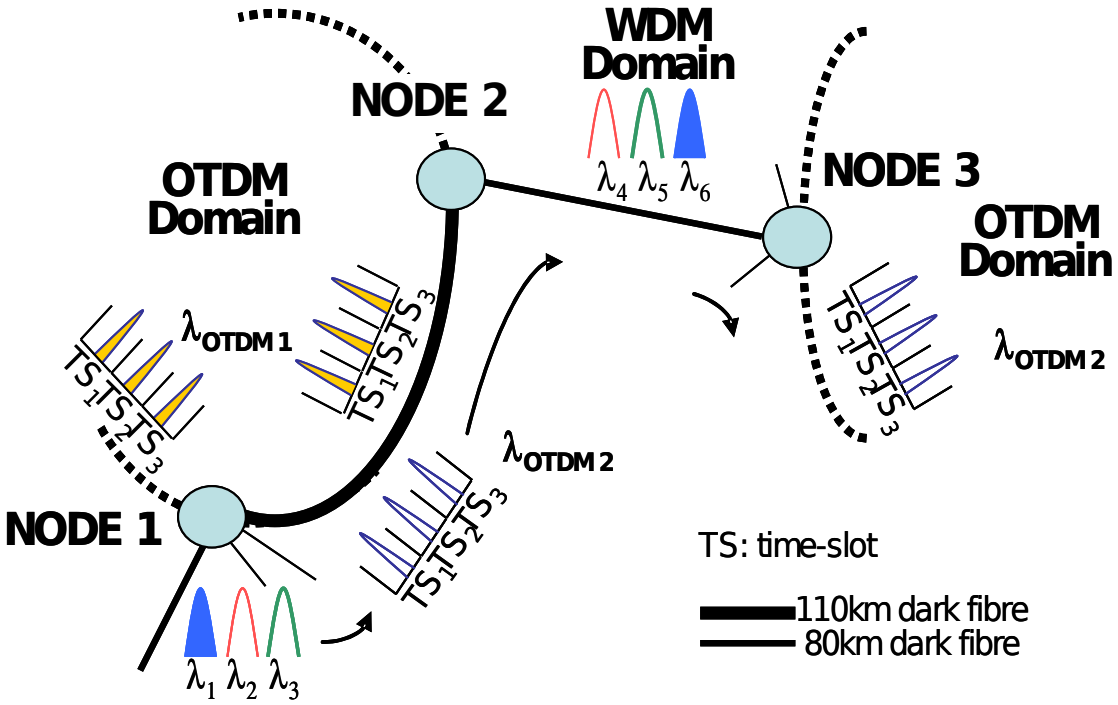
Field Trial of WDM-OTDM Transmultiplexing employing Photonic Switch Fabric-based Buffer-less Bit-interleaved Data Grooming and All-Optical Regeneration

G. Zarris[1], F. Parmigiani[2], E. Hugues-Salas[1], R. Weerasuriya[3], D. Hillerkuss[4], N. Amaya Gonzalez[1], M. Spyropoulou[5], P. Vorreau[4], R. Morais[6], S.K. Ibrahim[3], D. Klonidis[5], P. Petropoulos[2], A.D. Ellis[3], P. Monteiro[6], A. Tzanakaki[5], D. Richardson[2], I. Tomkos[5], R. Bonk[4], W. Freude[4], J. Leuthold[4], and D. Simeonidou[1]

1 – Photonic Networks Laboratory, University of Essex, U.K.
2 – Optoelectronics Research Centre, University of Southampton, U.K.
3 – Photonic Systems Group, Department of Physics and Tyndall National Institute, University College Cork, Ireland
4 – Institute of Photonics and Quantum Electronics, University of Karlsruhe, Germany
5 – Athens Information Technology Centre, Greece
6 – Nokia Siemens Networks Portugal S.A., Portugal

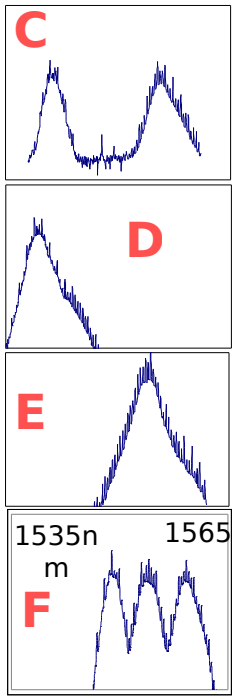
Field Trial

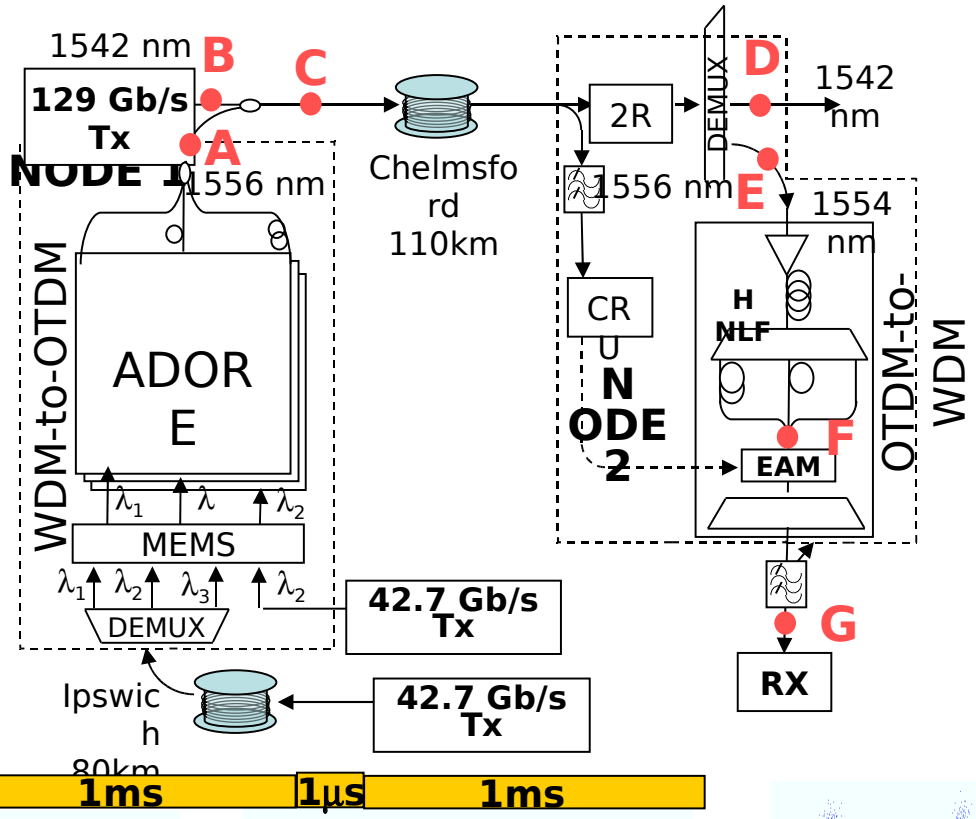

Ipswich
Colchester
Chelmsford
Southend-on-Sea

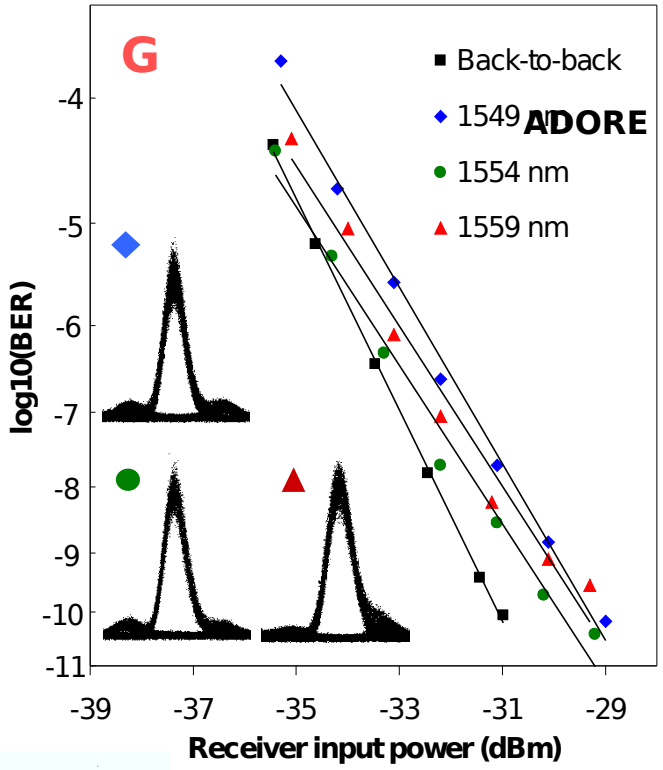

WDM Domain
NODE 2
NODE 3
OTDM Domain
OTDM Domain
NODE 1
λ4 λ5 λ6
λOTDM 1
λOTDM 2
λOTDM 2
TS1TS2TS3
TS1TS2TS3
TS1TS2TS3
TS1TS2TS3
λ1 λ2 λ3
TS: time-slot
110km dark fibre
80km dark fibre

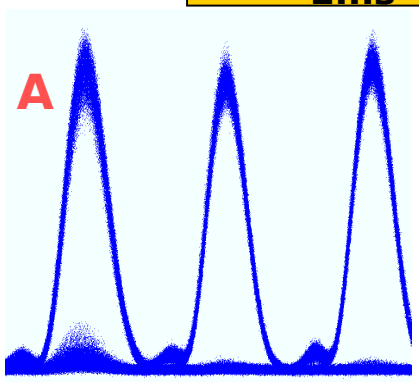
University of Essex

First Experimen

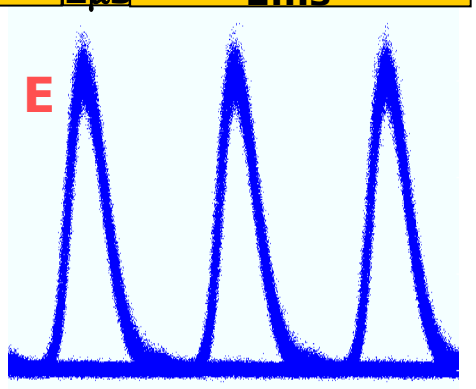




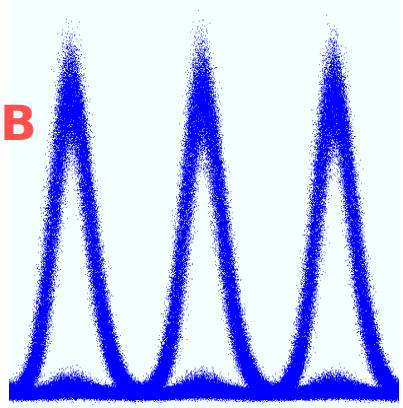




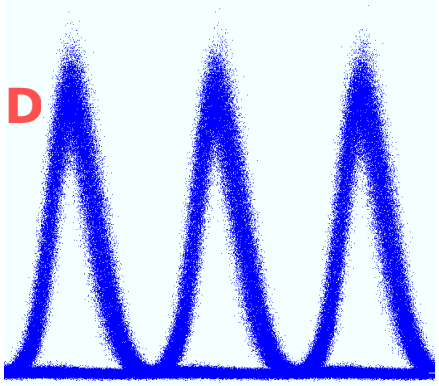
Q^2 = 20dB



Q^2 = 24.5dB



Q^2 = 19.5dB



Q^2 = 19.5dB

Issues for a Future JANET

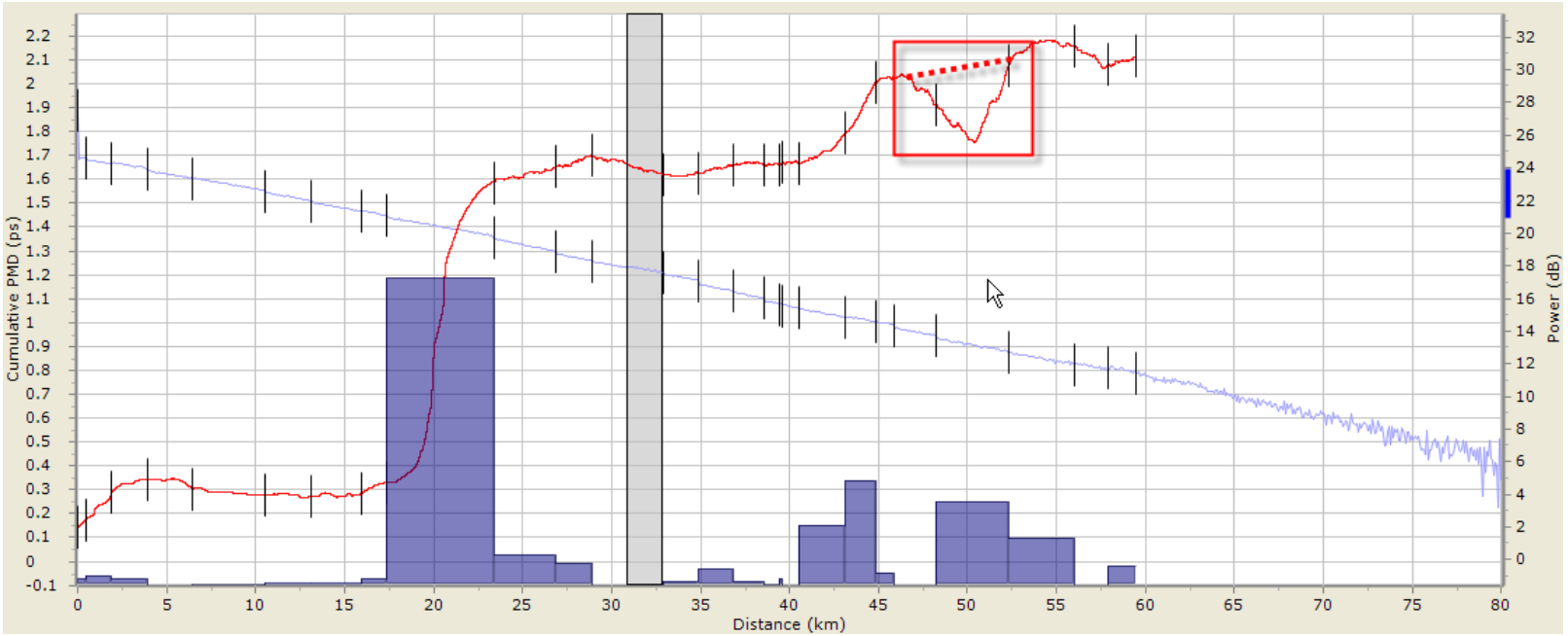
Contract structures

- JANET Backbone
  - Core
  - Arcs
- Current cost model has multiple components
- Better if this was simpler

Fibre Options

- Contracts
  - Continue to lease ?
  - Would IRUs be better value?
  - Look into advantages/differences
- Fibre characteristics
  - Learn from Aurora experiences
  - Mandate full characterisation ?
  - What specifications to set ?
  - Also developments in fibre testing…

Distributed PMD testing



Layer 2 transmission

- Technology options
  - EoMPLS – in service
  - PBB-TE – trials over next 2 years
  - MPLS-TP – watching closely
- Maintain a rapid deployment service
  - Much quicker than contractual response at optical layer
  - Need to acquire and install new transponders

IP Layer

- Not expecting much evolution here
- Probably more Organisations (Universities…) implementing dual connections for resilience

Capacity

- Currently 40G
- Trials at 100G
- Broadly OK here – technical roadmap is clear to 100Gb/s
- Funding may be interesting in current climate
  - NRENs
  - And projects

Operational issues

- Do we manage the optical layer ourselves
- Do we continue to sub-contract ?
- JANET as an NREN needs to keep close enough to the infrastructure to make sure we can deliver what our communities need

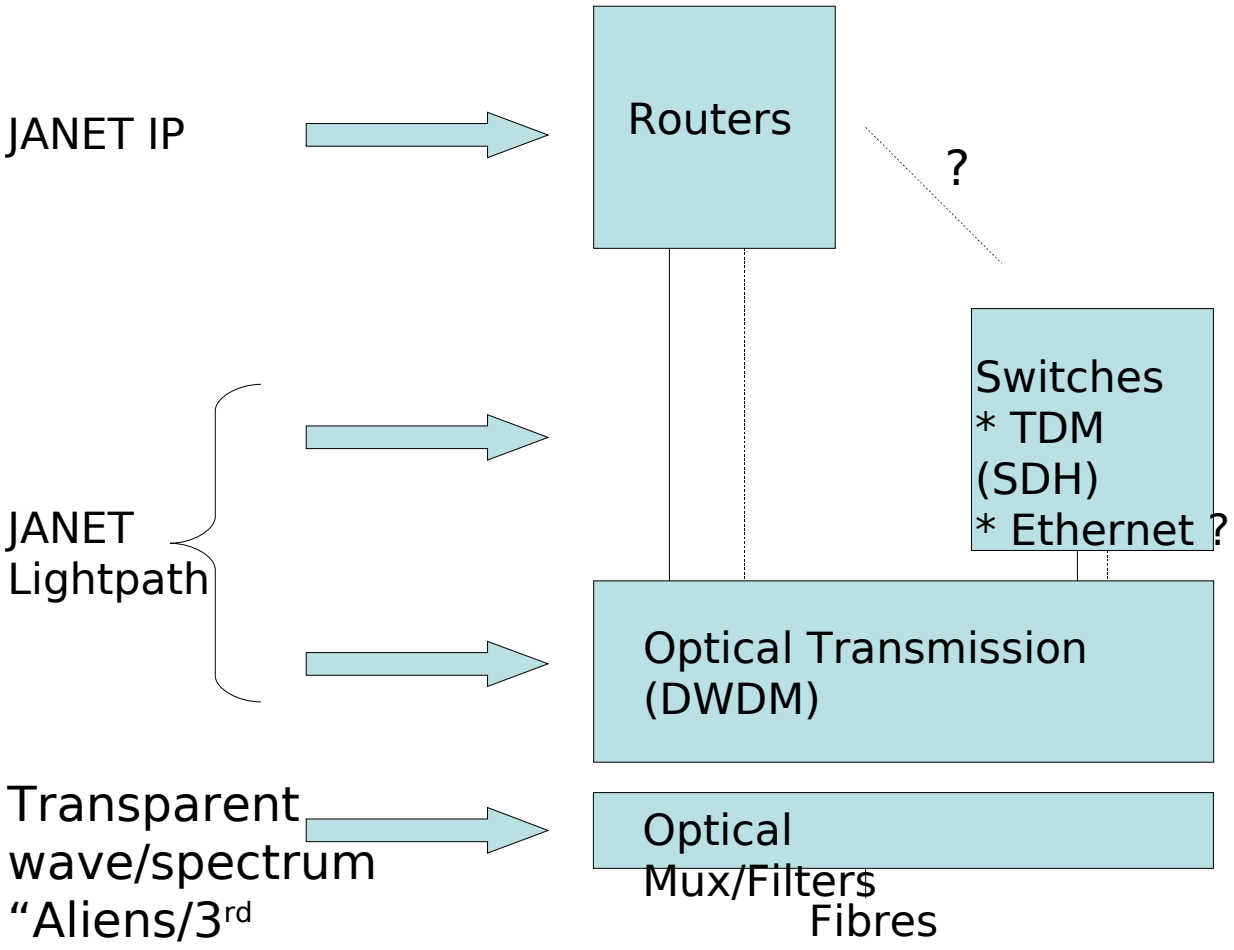
Transmission layer options

- Optics
- ROADMS – WSS
- Fully flexible optics
- Tuneable
- “Colourless” switching
  - wavelength agnostic
  - any port to any port

Transparent Optical Cloud ?

- Alien wave admission
  - Power levels
  - Conformance to ITU grid & spacing
- Transmission
  - Range – short vs. long
  - Dispersion compensation
    - Chromatic, PMD (2nd order PMD??)
- Is it technically feasible to operate a network of this nature
- Is it affordable ?
- How would we monitor it
  - Operationally – SLAs etc
  - Traffic – deep packet inspection ?

Future Service Model ?



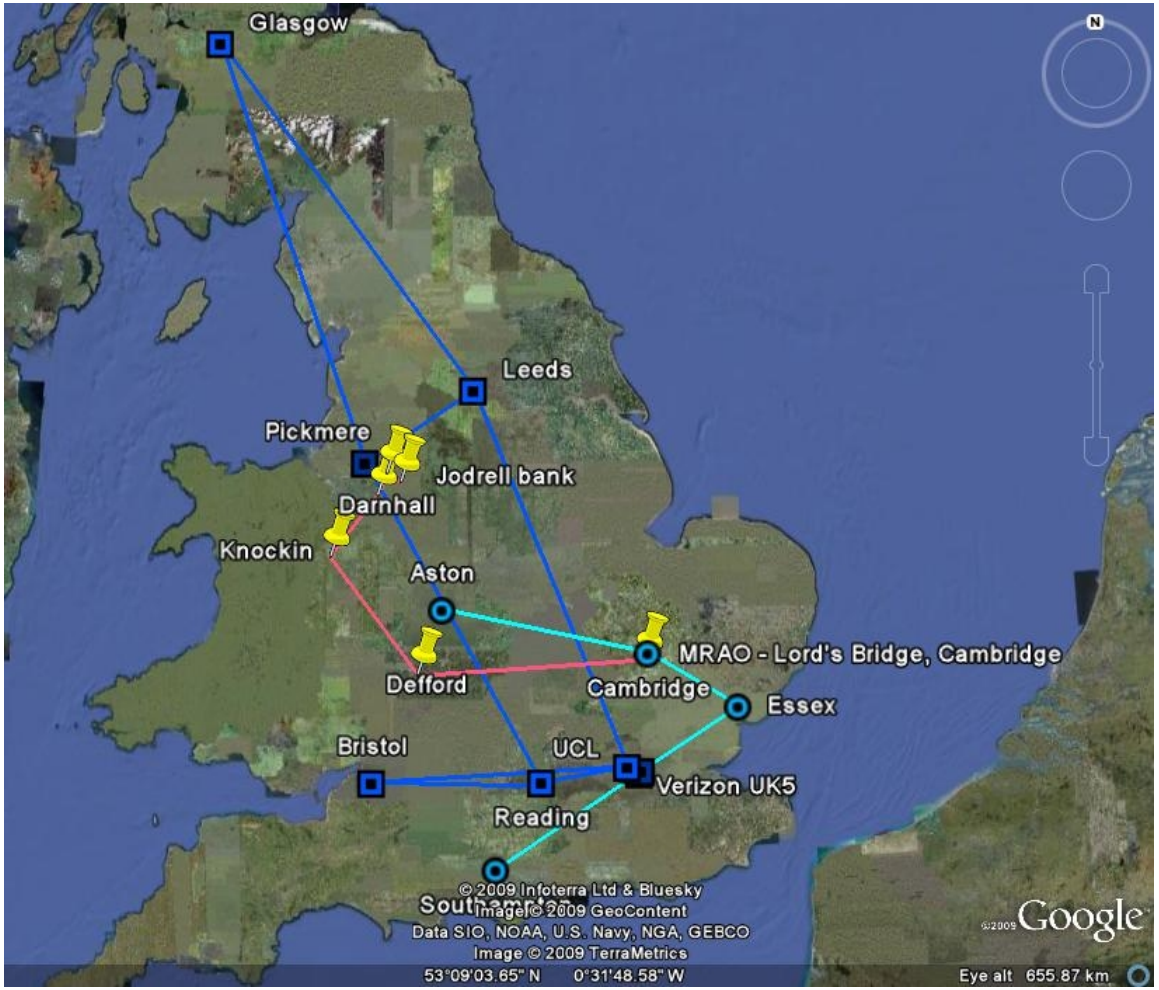
Structuring Layer
Circuits
<1Gbit/s – several Gbit/s
(10 – 100+ Gbit/s) in future

Bulk Capacity
Wavelengths
1 – 10 Gbit/s
(100+ Gbit/s in future)

Support for eVLBI

- Lightpaths
  - Technology roadmap to 100Gb/s seems secure
  - Policy & Funding will need to be addressed
    - High capacity services will be expensive, particularly in the early years
- Aliens transparent wave service in future ?
- Shared Fibres ?
  - Could Aurora & e-Merlin type requirement be integrated into the JANET fibre footprint in any way ?
- LOFAR

Infrastructures



Summary

- JANET services in good shape for supporting research requirements
- High capacity for eVLBI should not present any fundamental technical problems
  - Funding will need to be discussed & planned
- JANET(UK) has 1.5 to 2yrs to plan for the next procurement
- Most evolution expected at the optical level
- “Future JANET” will need to meet all research requirements from 2013 to

End