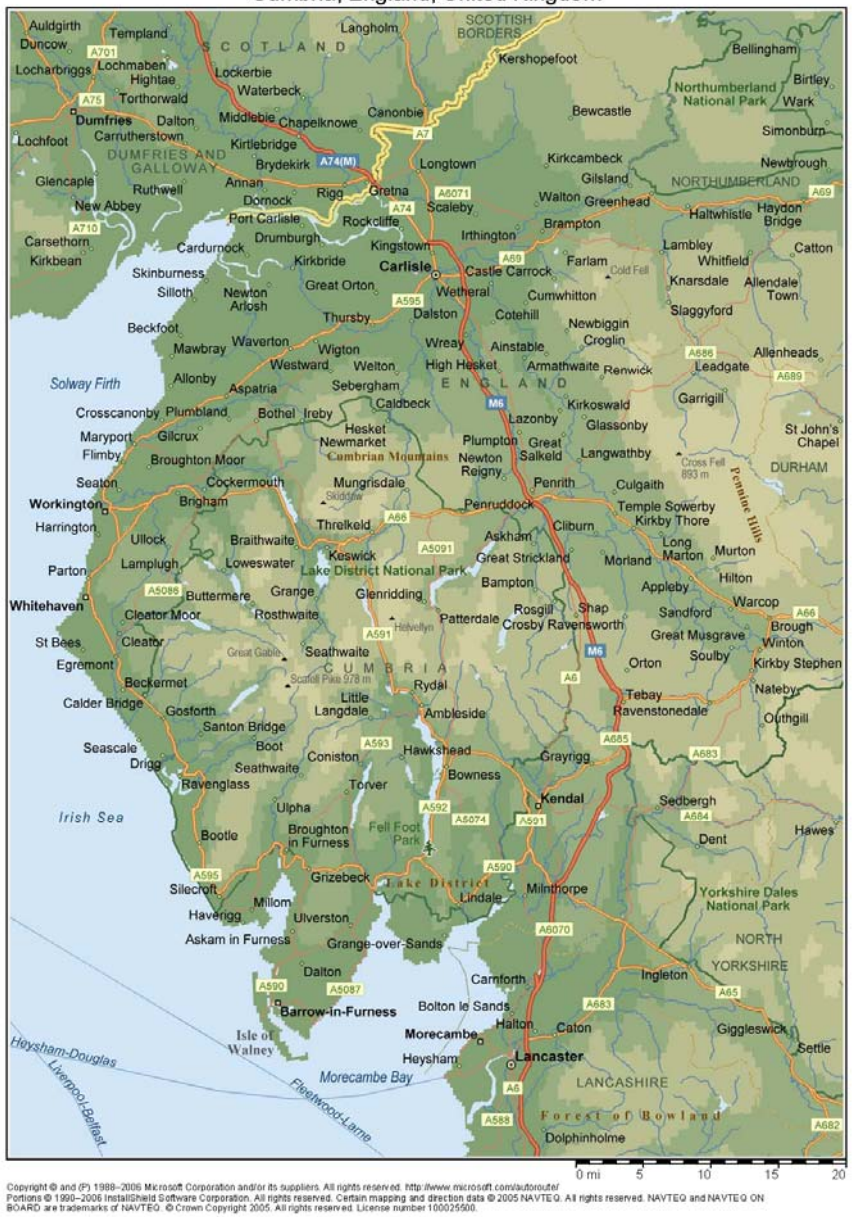
Building a regional wireless network

Barry Forde

InfoLab21

B.Forde@Lancaster.ac.uk

Cumbria, England, United Kingdom



Lancashire, England, United Kingdom

Cumbria and Lancashire Geography

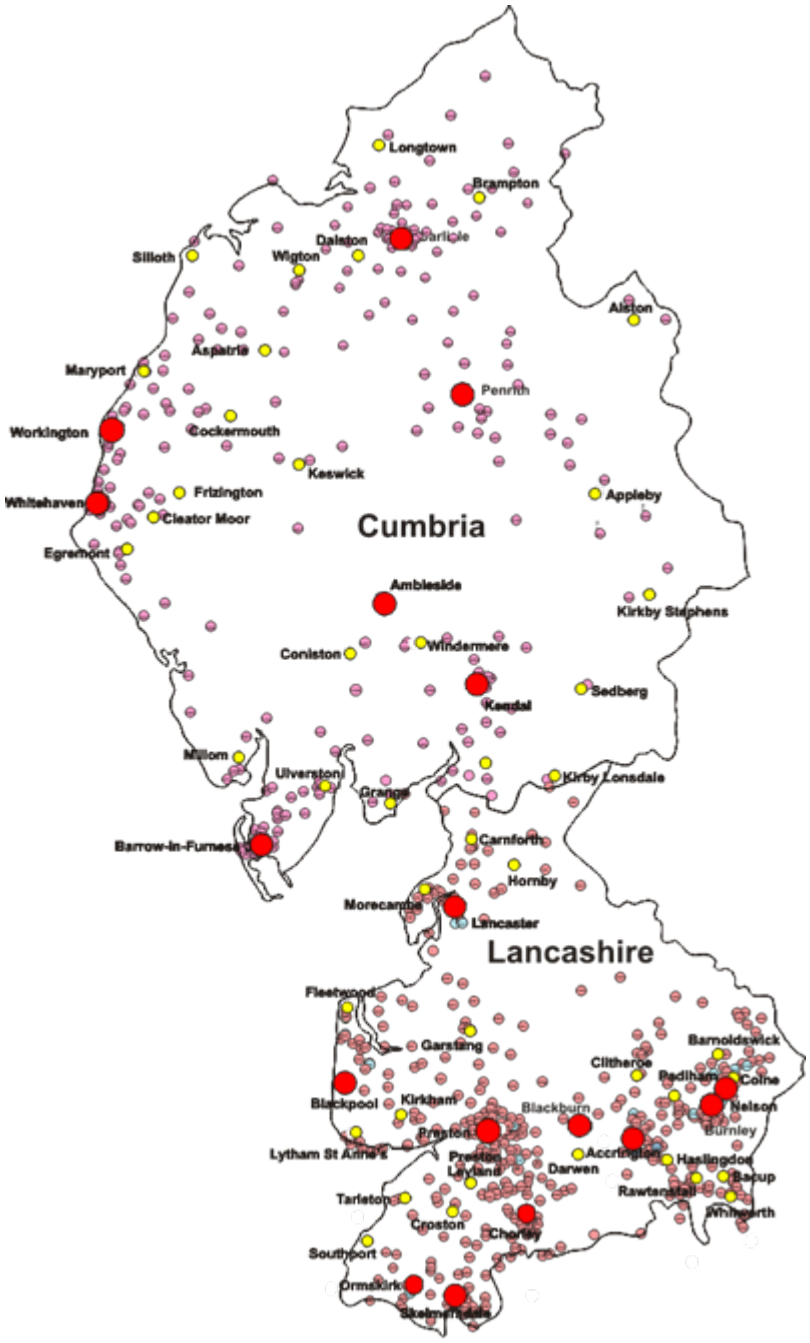
Cumbria 6810 Km²
Population ~ 496,900 (2007)

Lancashire 3063 Km²
Population ~ 1,451,500 (2007)

~4% of UK Land area
~3% of UK Population

CLEO Schools

- Secondary School
- Primary School



Cumbria
40 Secondary Schools
299 Primary Schools

Lancashire
93 Secondary Schools
554 Primary Schools

Radio Nodes

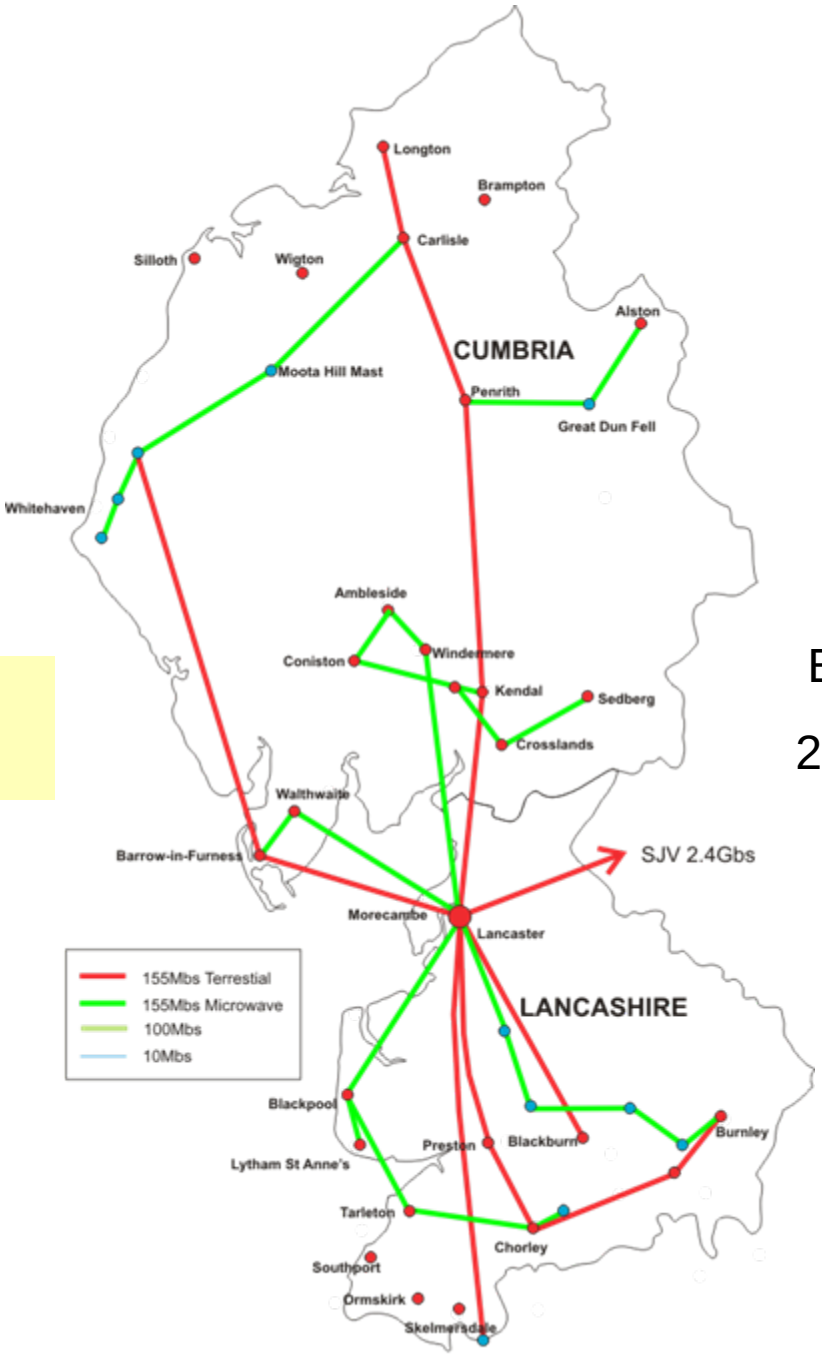
- Identified existing radio masts in area
  - No plans to build new ones
    - National Park planning rules in Lake District
    - AONB around Bowland forest
    - Time involved
    - cost
- High ground telecom masts
  - Not cellular which are short range
  - Telecom masts are part of backhaul networks
- Selected sub-set of those masts
  - with LOS to target sites
  - Good coverage of area

Typical 30m Microwave mast

Backbone

- Needed to link radio masts to core
- Each node needs resilient links
  - Access to masts can be difficult
  - In storms often have trees down blocking road
  - Long hold up time UPS systems needed
- 155Mbs selected for link speed
  - No significant gains on capital side for slower speeds
  - Can be higher licence fee for slower links

Backbone Phase 1



Backbone Design

25 links of 155Mbs linking 24 POPs

2.4Metre Microwave Dish – Langthwaite Hill

Windermere (Claiffe Heights Mast)

Aerial Clusters on Windermere mast

Claiffe Heights Costs

- Capital costs (one off) - £31,500 (€35,709)
  - Site structural survey £5,000 (€5,668)
  - Mast Stengthening £21,500 (€24,376)
  - Installation of aerials and dishes £5,000 (€5,668)
- Recurrent costs for payload
  - 1.2m dish - £4198.50 (€4760)
  - 0.6m dish - £2618.81 (€2967)
  - 2.4GHz aerials – 3 off each at £700 (€793)
    - 18dbi 450mm x 390mm x 17mm
  - Electricity £670 (€760)
  - BusinessRates £743 (€842)
- Total Annual cost for mast use £14,528 (€16,464)

Costs

- Backbone build 25 x 155Mbs
- Build out of backbone completed in summer of 2001
  - Held up by Foot and Mouth Outbreak!
  - That was not in our “Risk Assessment”
- Capital costs ~£1M
- Recurent costs ~£200K pa
  - Includes mast rentals, rates and electricity.
- Works out £40K capital + £8K pa recurrent per 155Mbs link

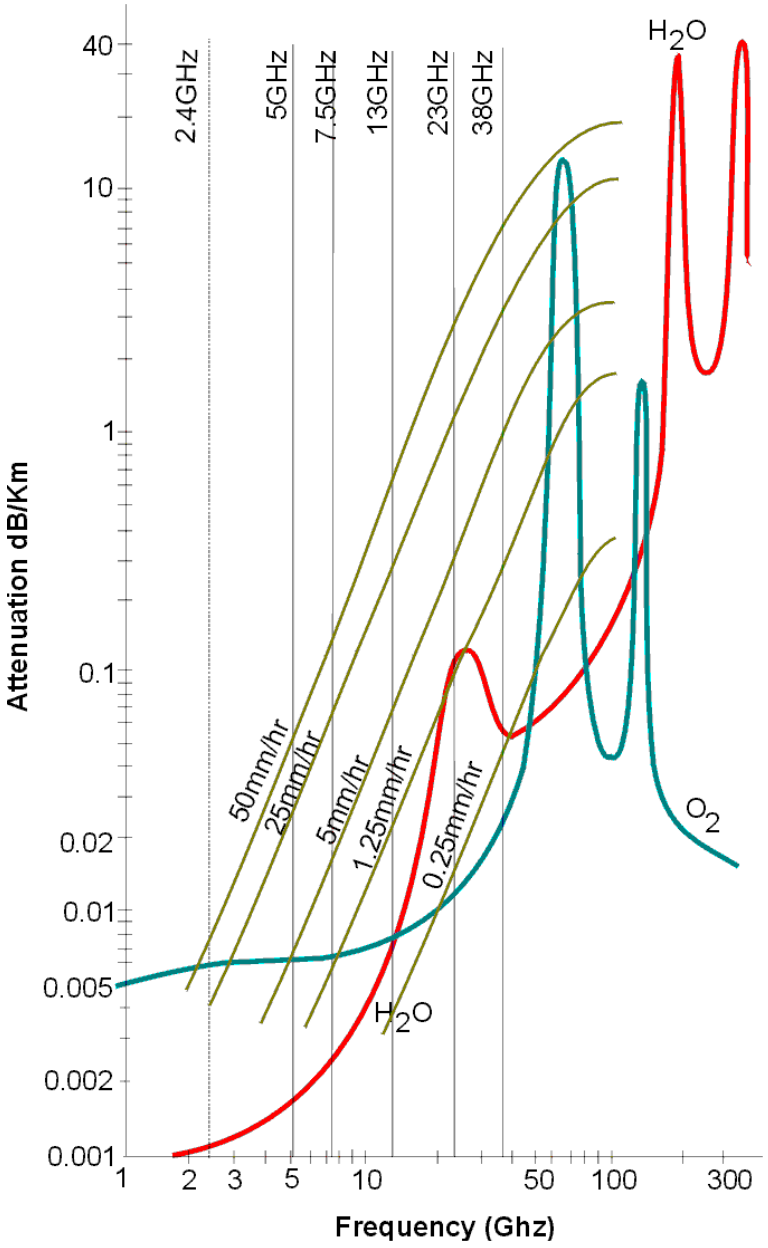
Schools connections

- 24 Core PoPs
- 30 Secondary PoPs
- Majority of targets within 15Km of a PoP
- Where possible use radio for Last Mile
- If not direct LOS then try relay
- If its in a deep hole then final fallback position is to use Telco circuit back to nearest connected school or PoP

2.4GHz Band

- 1999/2000 not many options for unlicensed links!
- 2400MHz to 2483.5MHz
  - In Europe 13 channels each of 22MHz
  - But only 3 usable without overlap
- Channel 1 2412MHz (2401-2423MHz)
- Channel 7 2442MHz (2431-2453MHz)
- Channel 13 2472MHz (2461-2483MHz)
- DSSS (Direct Sequence Spread Spectrum)
- Strictly Line of Sight

Atmospheric Absorption (Wavebands)



2.4GHz radio Unit

18dBi Aerial

39x45cm

15Km Range

ODU Below

Range Limitations

Spreading

$$L_{dB} = 20Log(d) + 20Log(F) + 32.4$$

Where LdB = Loss in decibels

d = Path length in Kilometers

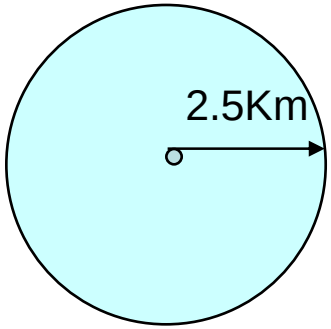
F = Frequency in Megahertz

Attenuation

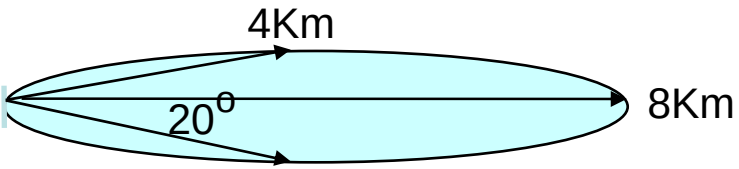
Function of atmospheric gases and weather

Propagation Pattern

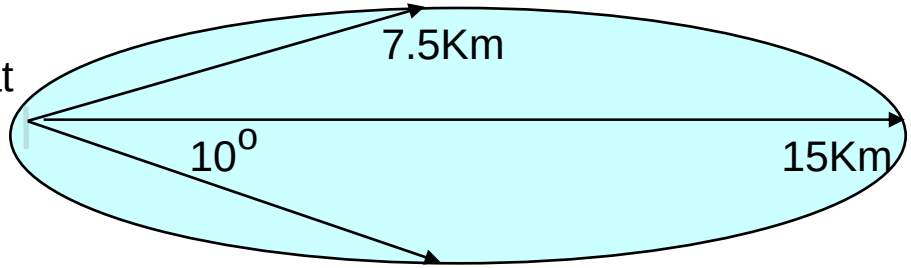
Omni Aerial gives 360 degree coverage



14dB Directional Aerial give max range at 0 degrees azimuth falling to 50% range at 20 degrees offset



18dB Directional Aerial give max range at 0 degrees azimuth falling to 50% range at 10 degrees offset

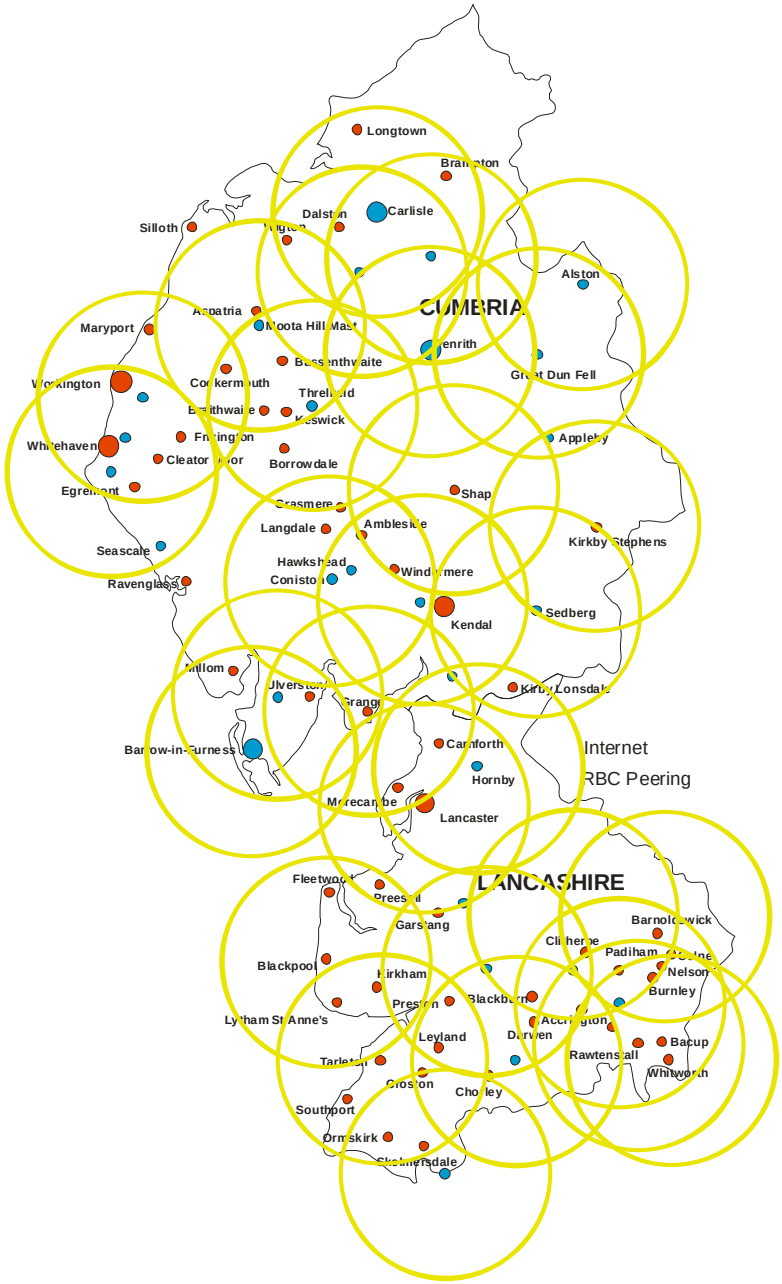


Phase 1
2.4GHz Cells

54 Base Stations Sites

108 Sectors

15Km Radius Circles



Rollout

- Started 2001
- Completed 2003
- ~800 radio links operational
- Ranges out to 30Km
  - Using 24dB high gain aerial
  - But with Transmit power reduced to keep EIRP within 100mw limit
  - Relying on +6dB gain on RX side for range (+6dB improvement in link budget =2x range)

First Generation

- Last Secondary school connected end of 2001
  - Most via 2.4GHz radio links
- Last Primary school connected end of 2003
  - Many via 2.4GHz radio
  - Several hundred using EPS9/8 with SDSL on top
  - Around 50 using LES2 and LES10 circuits
  - Patterdale for instance would need three radio relays

Problems

- Only 3 channels
- Lots of 802.11b/g kit in use
- Many deployments totally illegal!
  - Omni aerials with much higher power than 100mW EIRP, external amplifiers
  - Highly directional aerials
- Having to spend time channel hopping to get out of the way of others
- Needed to exit 2.4GHz band

5GHz Band

- 5150MHz to 5350 MHz Band “A”
  - Indoor use only, EIRP 200mW
- 5470MHz to 5725 MHz Band “B”
  - Mobile/nomadic use only, indoor or outdoor, EIRP 1W
- 5725MHz to 5850 MHz Band “C”
  - External Fixed point to point links
  - EIRP 2W
  - DFS and TPC a requirement

5GHz Band

- 2002 some affordable radios beginning to appear
- C slot channels, 4 in total
  - 5745MHz, 5765MHz, 5785MHz, 5805MHz
  - Each link needs registration £1 annual fee
- 2W EIRP, big improvement on 100mW
- OFDM rather than DSSS opens up Non LOS options (multipath effects)
- C slot reserved for external PtP/PtmP links
- 802.11a uses frequencies in “A” band and limited to 200mW so no interference issues

Developments

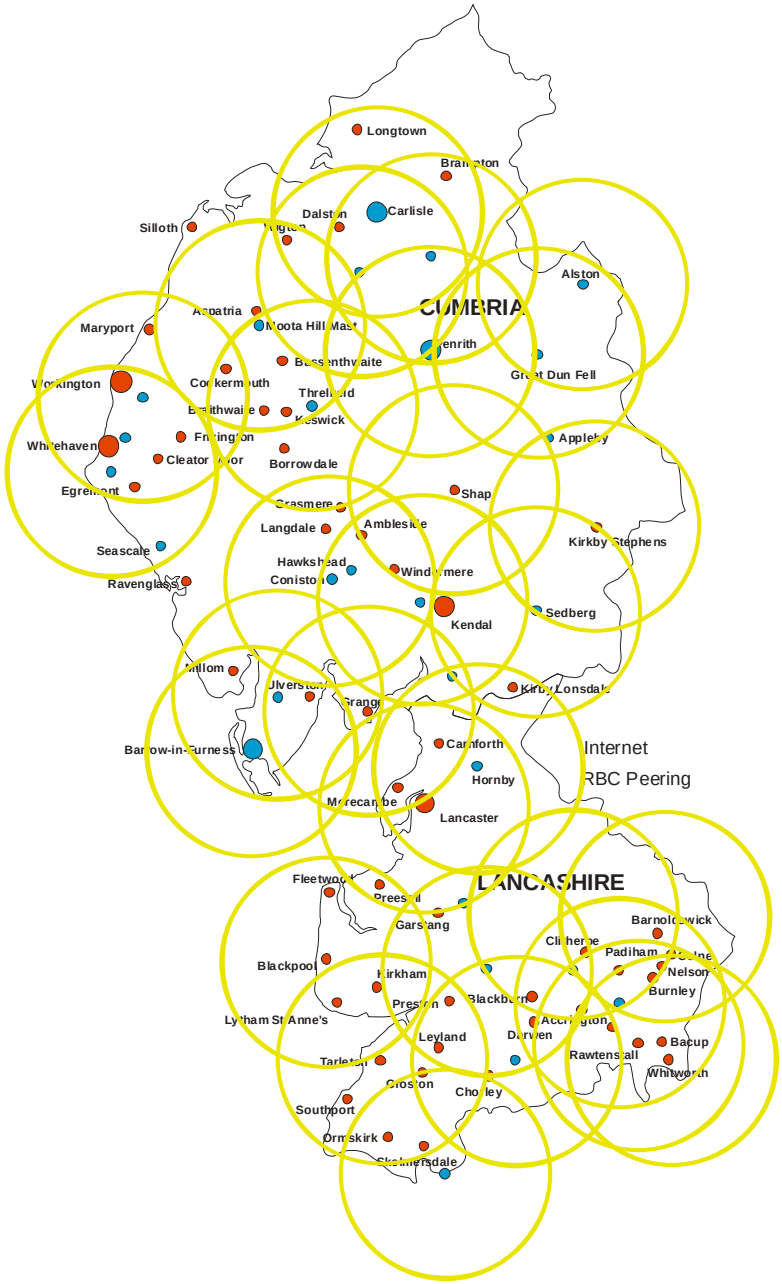
- Radio upgraded to NERA Netlink III 5.8GHz
- Higher bandwidth 34Mbs v 8-10Mbs at data layer
  - OFDM better able to withstand interference
  - Some, but marginal, NLOS capability
  - Higher power 2W v 0.1W
  - Still only 4 non-overlapping channels
  - Ranges very good ~ 30Km
  - Wide beam aerials 90 or 120 deg are effective
- Migration significantly improved performance
- 95% geographic coverage @ >2Mbs, 90% >10Mbs
- 98% population coverage

Phase 1
5.8GHz Cells

54 Base Stations Sites

108 Sectors

20Km Radius Circles



5.8GHz Moota Hill

12 sites

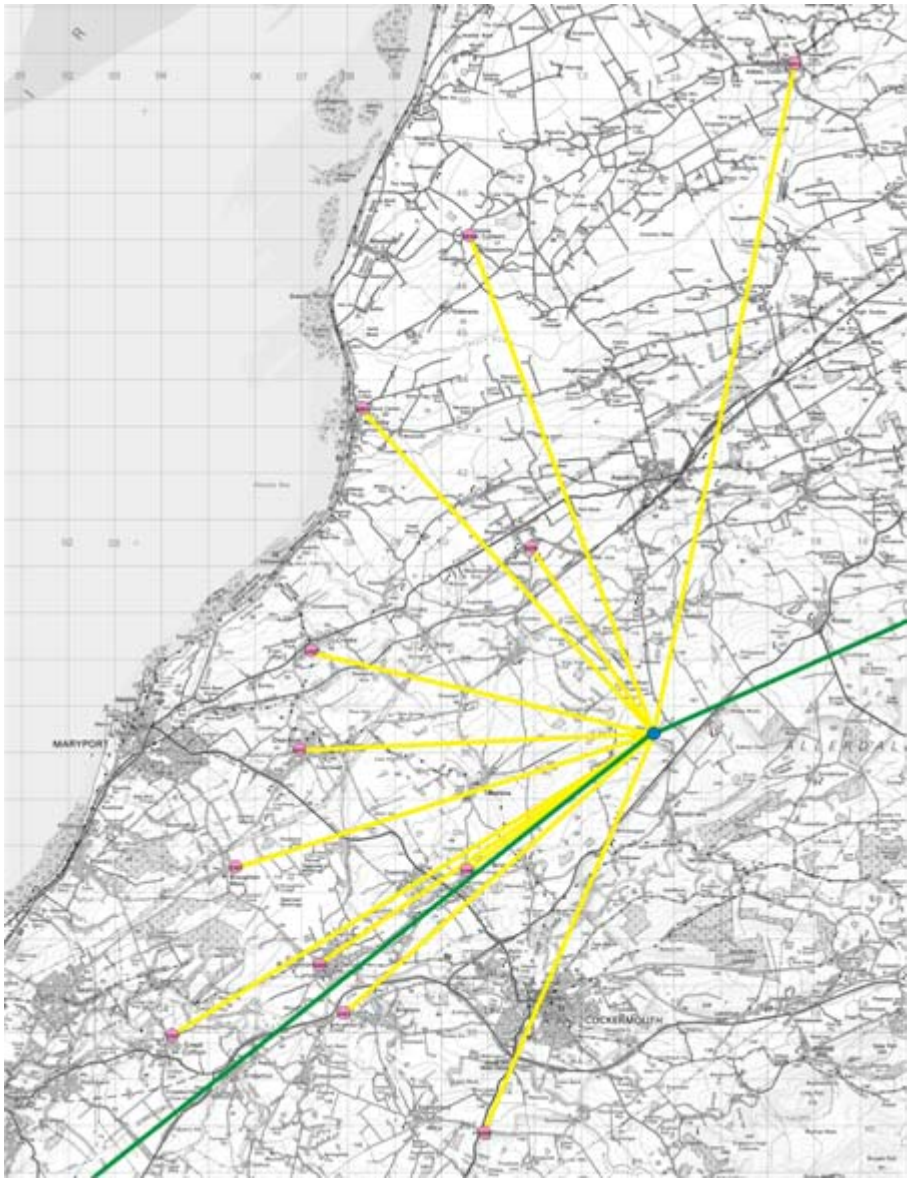
Ranges to 15Km

4 x sectors

(overlapping)

3 sites per sector

~10Mbs/Site



Flexible Working

Problems

- Regional Telco rolled out new 5.8GHz network
- Used exactly the same equipment
- Copied our network design, same masts same payloads
- 6 sectors+backhauls does not fit into 4 available channels
- Co-interference

5GHz Band "B" Group

- OFCOM changed use restriction on "B" slot channels in 2006
- Previously had to be used for mobile/nomadic links only
- Now removed that restriction so can be used for fixed PtP and PtmP links
- B slot channels, 11 in total
  - 5500MHz, 5520MHz, 5540MHz, 5560MHz, 5580MHz, 5600MHz, 5620MHz, 5640MHz, 5660MHz, 5680MHz, 5700MHz
- So another 11 channels became available to add to the 4 channels in the "C" group
- At the same time the "C" group had its power limits increased to 4W but "B" group held at 1W

New Radios

- If we going to replace radios again then it would be nice to get some future proofing
- WiMAX 802.16-2004 and 802.16e not really suitable
- Schools already expecting minimum of 10Mbs (existing radios give 32-33Mbs of throughput in real life use)
- Existing WiMax designed for narrow channel use to service large numbers of users with modest bandwidth,10Mbs difficult to achieve in real life deployments.
- 802.16m would be where we want to go
  - But all vendors we spoke to are holding off developments due to lack of radio spectrum availability
- Couldn't identify any kit on market that lifts the bandwidth available to our schools and/or has upgrade path to 802.16m
- Decided to stay with existing kit but shift into "B"group channels

Reconfiguration

- Deploy 5.4GHz “B” channel units where possible.
- On some long range links keep 5.8GHz which are 4W units compared with 1W for “B” channel units.
- This is small number and never more than 1 per mast so interference reduced.
- At same time upgrading backhauls
  - At a number of key masts we are digging dark fibre, several kilometres. Then run 1GbE links to core routers
  - Other minor masts where originally backhaul was using 5.8GHz PtP links we replacing them with licensed band 15GHz 155Mbs radios.
  - This will reduce requirements for channels and hopefully minimise interference issues

Things to consider

- Unlicensed bands will become congested again
  - As kit becomes cheaper and demand for broadband grows more and more operators will deploy it.
- Radio spectrum is a precious thing
  - 2.6GHz being auctioned in UK (205MHz bandwidth)
  - 2.1GHz earned government ~£26Billion when auction to 3G operators
  - Telephone operators hungry for bandwidth for LTE/LTE-Advanced for 4G services, including mobile broadband.
    - LTE-Advanced 4G with 1Gbs capacity requires 100MHz channel!
  - Who is most likely to win the 2.6GHz spectrum?
  - Digital Dividend 800MHz band (72MHz bandwidth)?
- WiMax needs bandwidth where to get it?

Barry Forde

InfoLab21

B.Forde@Lancaster.ac.uk