High Speed E-Band Backhaul: Applications and Challenges

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Outline

- Wireless Backhaul and Applications
- Challenges for High Speed E-band Backhaul
- CSIRO E-band Solutions
- Conclusions

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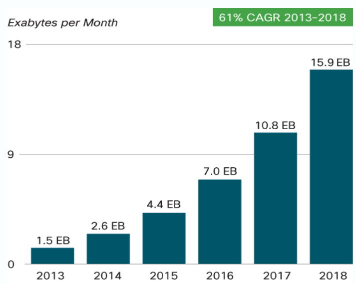
Backhaul Challenge

High speed wireless broadband has placed huge pressure on backhaul infrastructure

- Cisco forecasts 15.9 Exabytes per Month of mobile data traffic by 2018 (Exa = 10^{18}).

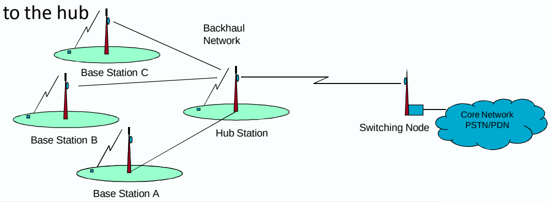
Source: Cisco Visual Network Index, February 2014



What Is Backhaul

In cellular and wireless broadband networks, backhaul is the communication link (wireline and/or wireless) between a base station and the associated switching node

A number of base stations can be connected to a switching node via hub station, where each base station has at least one backhaul link to the hub

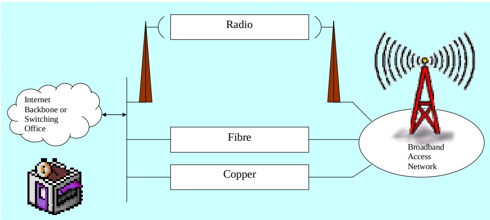


Other Backhaul Networks

Backhaul can also refer to other high speed transmission links and networks which connect distributed sites and centralized points, such as network backbone, enterprise connection, fibre extension, etc.

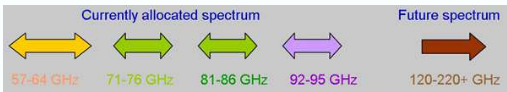
Primary Physical Media for Backhaul

There are currently three primary physical media used for backhaul: copper, fibre and wireless radio



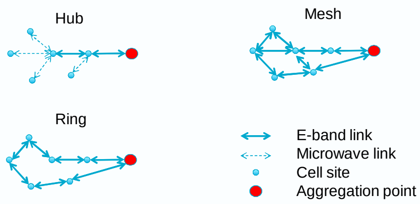
Spectrum for Gigabits Wireless Transmission

- Multi-gigabit data rate millimetre wave networks are becoming viable due to the spectrum allocation and cost reduction in semiconductor devices
- Available bands at mm-wave frequencies
  - 60 GHz
  - 70/80 GHz (E-band)
  - 90 GHz



E-band Backhaul Applications (1)

- Cellular and broadband wireless access backhaul
  - IP-based networks require increasingly higher capacity backhaul
  - E-band backhauls can be used to connect cell sites to aggregation points
- Various topologies

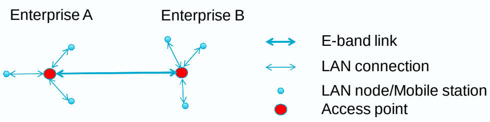


E-band Backhaul Applications (2)

- Distributed antenna system (DAS)
  - With DAS, cellular coverage can be improved by relacing a single antenna at a base station with a number of smaller spatially distributed antennas
  - A radio header (RF transceiver) in DAS is traditionally connected back to base station by fibre optic cable
- There is an opportunity for high speed E-band backhaul to replace the fibre connection

E-band Backhaul Applications (3)

- Enterprise connection
  - Enterprise connectivity refers to the connecting together of businesses, schools, hospitals, campus buildings, and any other enterprise
  - This applications is often called local area network (LAN) extension
- E-band backhaul can be used to provide high speed enterprise connections



E-band Backhaul Applications (4)

- Fibre extensions/backup
  - Fibre optic networks have been the national and international backbone infrastructure
  - However, access to fibre connection may not be available for some locations
  - There is need for short-haul wireless connectivity in the last mile
- E-band backhaul network may provide shorter end-to-end latency than fibre network since radio propagation is faster in the air than in the fibre!
  - Light travels slower in fibre due to its refractive index, with latency approximately 5 µs/km
  - However, radio travels at 3x10^5 km/s and this is equivalent to a latency of 3.33 µs/km

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Spectral Efficiency and Distance

- Higher spectral efficiency requires higher-order modulation
- However, there are system penalties
  - Design and implementation cost
  - Reduced receiver sensitivity (higher SNR required)
  - Reduced output power due to linearity in the power amplifier
- The reduction in both transmit power and receiver sensitivity leads to reduced link distance

Spectral Efficiency and Data Rate

- Higher spectral efficiency does not necessarily mean higher data rate
  - It also depends on signal bandwidth
- With higher order modulation, the digital modem needs to be implemented by digital signal processing device such as ASIC or FPGA
- However, due to the availability of high speed digital signal processor and mixed signal devices (A/D and D/A), the signal bandwidth cannot be very high
- As a result, the achievable data rate is still low

Data Rate and System Complexity

- To achieve high data rate, channel aggregation is necessary
- However, it adds to system complexity and cost
  - More digital data streams
  - More IF/RF chains
  - Multiplexing and de-multiplexing

Other Practical Limitations

- Antenna alignment and mounting (towers sway in wind and twist in heat)
- Limited output power (currently 24 dBm at P1dB)
- Analogue filter
  - Narrow Bandwidth and frequency response ripple
- I/Q imbalance
- Phase noise
- Component tolerance and manufacturing fluctuations
- …

Technology Trends

- Employing higher order modulation
  - 1024QAM has been seen in commercial microwave product
  - Such higher order modulation can only be possible for narrow bandwidth systems (<100MHz)
  - The highest modulation used so far is only 64QAM with 250 MHz bandwidth (Huawei)
- Using line-of-sight (LOS) MIMO
  - 2x2 (Ericsson) and 4x4 (MIMOtech) LOS MIMO have been demonstrated in microwave systems
  - LOS MIMO has been proposed by DARPA in its 100G program for E-band RF backbone
- Improving link availability: ATPC, ACM, AR,…
- Increasing transmit power: adaptive array with beamforming,…
- Allowing more available links and more efficient spectrum usage

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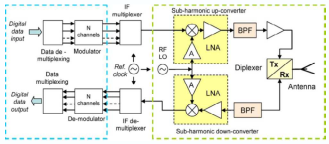
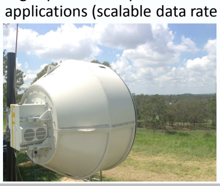
CSIRO 6 Gbps E-band System

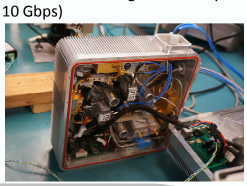
- CSIRO developed and demonstrated a 6 Gbps E-band system in 2007
- The 5 GHz spectrum is divided into 8 channels, each having 625 MHz bandwidth
- 2.4 b/s/Hz spectral efficiency was achieved using patented frequency domain multiplexing technique



High Speed Low Latency E-band System

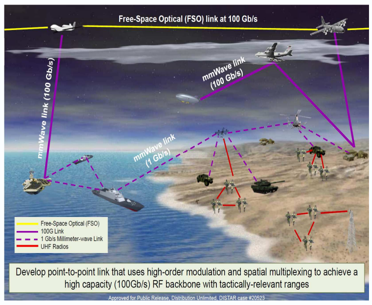
- CSIRO is currently developing E-band systems which can provide higher data rate and lower latency for multiple purposes
  - Low latency full duplex relay for long distance fast than fibre applications (5 and 10 Gbps) (jointly developed with our industry partner EM Solutions)
    - Field trialled in December 2013 over 16km distance
  - High speed full duplex link for short distance low cost high availability applications (scalable data rate up to 10 Gbps)





Further High Capacity E-band Solutions

- Improve spectral efficiency using higher-order modulation
- Remove guard band/roll-off between sub-channels
- Use dual polarisation
- Target:
  - 50 Gbps symmetric full duplex link
  - 100 Gbps using LOS MIMO



Conclusions

As cost-effective alternatives to fibre backhauls, high speed E-band backhauls are becoming increasingly attractive

However, there are significant technical challenges such as how to achieve higher spectral efficiency and extend operating range

CSIRO has solutions to tackle these challenges and is developing the most advanced E-band systems for high capacity wireless backhaul applications

Thank you

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E-Band Spectrum and Channel Sizes

In the United States, the 71-76 and 81-86 GHz bands are allocated as two pairs of 5 GHz blocks

No subchannel is defined

In Europe, 19 250MHz channels are allocated (ITU-R F.2006, March 2012)

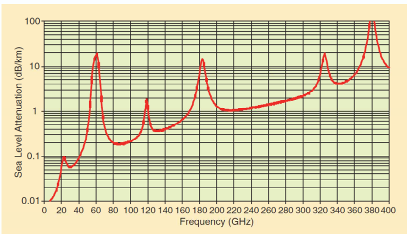
- 125 MHz guard band at two ends of each 5 GHz band
- Several channel pairing methods are allowed for FDD operation

In Australia, a band plan similar to United Kingdom is adopted (71.125-75.875 GHz and 81.125-85.875GHz)

In New Zealand, only 250 MHz, 1.25 GHz, 1.75 GHz, and 2.25 GH channels are permited

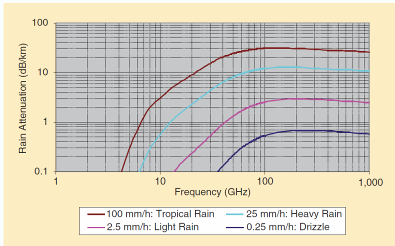
Atmospheric Propagation

Within so-called atmospheric windows (35, 90, 140, 220 GHz and upwards), attenuation is minimized, allowing superior wireless transmission



Rain Attenuation

The main factor that limits available communication range at the upper microwave and mm-wave frequencies is the rain attenuation



60 GHz Wireless Systems

60 GHz systems operate at an oxygen absorption peak, reaching a maximum of 15 dB/km absorption at sea level

Only useful for short-distance transmission

- 1 Gbps over distances of 400-800 m (outdoor)
- Up to 4 Gbps over distances of 10 m (indoor) WPAN – WirelessHD, IEEE 802.15.3c
- Up to 7 Gbps over a short range using approximately 2 GHz spectrum – IEEE802.11ad

Key benefits of 60 GHz wireless versus other mm-wave technologies

- Low cost CMOS
- Radio building blocks such as transceivers, power amplifiers, low noise amplifier, mixers, etc. are more readily available at 60 GHz than the higher mm-wave frequencies

70/80 GHz Wireless Systems

70/80 GHz E-bands operate in an atmospheric window where clear air absorption is less than 0.5 dB/km

However, practical links are much shorter due to rain attenuation (up to 30 dB/km for rainfalls <100 mm/hr)

Currently available 70/80 GHz equipment can achieve 1 Gbps connectivity with 99.999% weather availability (carrier class performance, equivalent to only 5 min of weather outage per year) over distances of 2-3 km

Key benefits of 70/80 GHz wireless

- Unaffected by most other transmission deteriorations (water particles, sand, dust, etc.)
- Antennas are smaller, portable and can have higher gain
- Increased frequency reuse and security due to the narrow communication beam and limited radio range