



## CSIRO Submission 09/348

Department of Broadband Communications and the Digital Economy

Response to the Backhaul Blackspots Initiative Stakeholder Consultation Paper

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**Enquiries should be addressed to:**

Peter King  
Executive Manager  
CSIRO Government & International  
PO BOX 225  
Dickson ACT 2602

Email: [peterg.king@csiro.au](mailto:peterg.king@csiro.au)  
Ph: (02) 6276 6361

**Main Submission Author:**

Dr Jay Guo  
CSIRO ICT Centre  
Corner Vimiera & Pembroke Roads  
MARSFIELD NSW 2122

Email: [jay.guo@csiro.au](mailto:jay.guo@csiro.au)  
Phone: (02) 9372 4291

## **Introduction**

This paper provides CSIRO's response to DBCDE's Blackhaul Blackspots Initiative Stakeholder Consultation Paper issued in April 2009.

The Consultation Paper sets out three main areas on which the views of stakeholders are being sought, namely:

1. the identification and prioritisation of regional centres to be addressed through the initiative
2. the appropriate technical parameters associated with roll-out of backhaul links, and
3. the arrangements for funding the construction of the links, the delivery of services and the ownership of the infrastructure.

Based on the expertise resident in the CSIRO ICT Centre, the CSIRO response will be limited to the second area of consultation; ie. the appropriate technical parameters associated with roll-out of backhaul links.

In terms of scoping the capacity requirements for towns of different sizes CSIRO has considered it is appropriate to evaluate towns/cities in terms of different population sizes, from 100 to 10,000.

Our analysis of this issue

- examined the characteristics of different backhaul technologies, including: optical fibre; microwave and mmWave links; and satellite; and
- concluded that whereas optical fibre is the most appropriate option to be employed for medium to large towns, microwave links can provide adequate capacity for small towns with much lower cost and within much shorter period of time.

## Backhaul Capacity Requirements

Table 1 sets out some typical backhaul scenarios for towns of small to large sizes. Assuming 100% market penetration, the average and peak backhaul data rate requirements are estimated for a variety of parameters. In particular, new 100Mbit/s peak data rate/user target for towns with populations of 100, 1,000 and 10,000 are included.

Based on 2% average usage per subscriber, it is seen that towns of 1,000 population could require backhaul data rates of 20Gbit/s if no data shaping is allowed during peak usage periods. This drops to 2Gbit/s if datashaping to the average data rate is allowed. For towns with 10,000 population, the average data rate required of backhaul is 20Gbits/s and the peak data rate goes up to 200Gbit/s.

Therefore we have concluded from our analysis that optical fibre would be the most appropriate option for major regional centres with population over 1000.

For towns with population of 100, it is seen that the required average data rate for backhaul is 200Mbit/s and the required peak data rate for backhaul is 1 or 2 gigabit/s depending on the peak to average data traffic ratio. This indicates that microwave/wireless solutions are feasible for backhauls for small to medium towns.

Case	Population	Peak Data rate Per Subscriber (Mbit/s)	Average Backhaul Data rate (Mbit/s)	Peak to Average Data Traffic Ratio	Peak Backhaul Data rate (Mbit/s)
1	100	100	200	<b>5</b>	1,000
2	100	100	200	<b>10</b>	2,000
3	1,000	100	2,000	<b>5</b>	10,000
4	1,000	100	2,000	<b>10</b>	20,000
5	10,000	100	20,000	<b>5</b>	100,000
6	10,000	100	20,000	<b>10</b>	200,000

Table 1: Typical backhaul scenarios for towns of different populations. Average usage per subscriber: 2%.

## Backhaul Technologies

### Overview

Our assessment of the various backhaul options are listed and compared in Table 2.

Technology	Pros	Cons
Optical Fibre	<ul style="list-style-type: none"> <li>• High data rates               <ul style="list-style-type: none"> <li>○ 1Gbit/s, 10Gbit/s per wavelength now (2009)</li> <li>○ 100Gbit/s per wavelength common by 2014</li> </ul> </li> <li>• Upgradeable data rates (future proof)</li> <li>• Large link range</li> </ul>	<ul style="list-style-type: none"> <li>• High cost of fibre-laying</li> <li>• High cost of terminal equipment</li> <li>• Slow to deploy</li> </ul>
Microwave Point to point Radio	<ul style="list-style-type: none"> <li>• Fast deployment</li> <li>• Lower cost of terminal equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Lower data rates: &lt;400Mbit/s per link</li> <li>• Data rate limited by channel bandwidths</li> <li>• Need multiple parallel links for higher data rates</li> <li>• High tower costs</li> </ul>
mmWave PtP Radio (eBand 70-80GHz)	<ul style="list-style-type: none"> <li>• Higher data rates (1, 2.5, 10Gbit/s)</li> <li>• Fast deployment</li> <li>• Lower cost of terminal equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Lower ranges: 3-10km</li> <li>• Ranges reduced by rain or snow</li> </ul>
Satellite	<ul style="list-style-type: none"> <li>• Cheap ground station equipment</li> <li>• No other terrestrial infrastructure needed</li> </ul>	<ul style="list-style-type: none"> <li>• Lower data rates (due to limited satellite capacity)</li> </ul>

Table 2: Backhaul technologies.

### Optical Fibre

Currently (2009), optical fibre links with data rates of up to 400Gbit/s (with 40 DWDM wavelengths each supplying 10Gbit/s) and link distances of 100km are commonly available. The data rate per wavelength will increase by a factor of 10 to 100Gbit/s within 5 years (2014).

### Microwave & mmWave Point to Point Radio

The performance and capital expenditure costs of various radio link backhauls are summarised in Table 3. It is seen that single microwave links can achieve a data rate of 200-300Mbits/s. The link data rates can be increased to nearly 4Gbit/s by using multiple parallel channels. It should be noted however, that the use of multiple bands is expensive using existing technologies and may also need regulatory approvals.

For short distances up to 7km single hop distance, mmWave technologies can be used to achieve tens of gigabits/s data rate

Backhaul Classification	Australian Frequency Band (GHz)	Channel Bandwidth (MHz)	Total Available Channel Bandwidth (MHz)	Number of Used Channels in Link	Dish Antenna Diameter (m)	Typical Maximal Link Distance for 256QAM (km)	Typical Link Radio & Ant Equipment Cost (\$)	Maximum Data rate in Mbit/s (256QAM)
Long-haul	6	29.65	237	1	3.6	40	65,000	237
Long-haul	6	29.65	237	8	3.6	40	240,000	1,898
Long-haul	6.7	40	320	1	3.6	40	65,000	320
Long-haul	6.7	40	320	8	3.6	40	240,000	2,560
Long-haul	8	29.65	237	1	3.6	40	65,000	237
Long-haul	8	29.65	237	8	3.6	40	240,000	1,898
Medium-haul	11	40	480	1	2.4	30	65,000	320
Medium-haul	11	40	480	12	2.4	30	360,000	3,840
Short-haul	80	5,000	5,000	1	0.6	2.5	70,000	40,000

Table 3: Radio link distances, equipment costs, & maximal link data rates for various frequency bands.

Figure 1 below sets out the link data rates and link distances which can be expected if using 100% of various Australian radio frequency bands. It is seen that the 11GHz band allows the highest data rate (3.84Gbit/s) and the 6, 6.7, and 8GHz bands allow the largest link distances (40km).

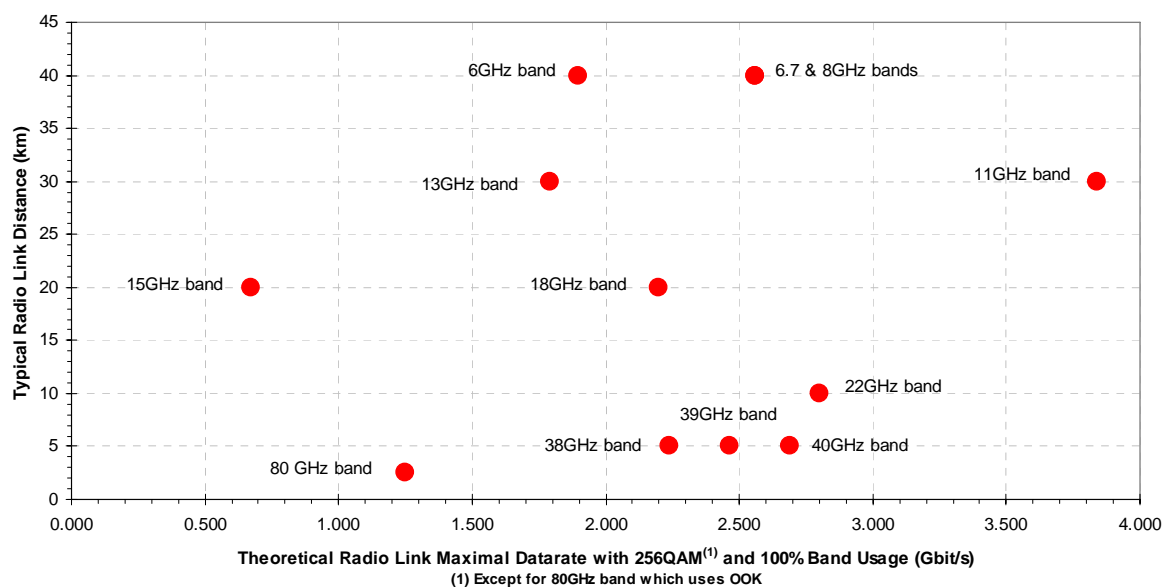


Figure 1: Radio link performances at various Australian radio frequency bands.

## Costings

### *Capital Expenditure*

Typical capital expenditure requirements from industry sources for various backhaul components are listed in Table 4. The table shows land type (desert, farmland, city) and the required data rate effects on fibre optic backhaul costings. Also, for radio links, the topology (land flatness, presence of hills/mountains/existing towers) affects the required height of radio towers which consequently affects costings. The costings of Table 4 have been used to generate the comparison of capital expenditure costings for various selected examples of the backhaul technologies shown in Figure 2.

<b>Description</b>	<b>Capex Cost</b>	<b>Unit</b>
Optical Terminal Equipment - DWDM, 1 Wavelength, 10Gbit/s	150	\$k
Optical Terminal Equipment - DWDM, 10 Wavelengths, 100Gbit/s	510	\$k
Optical Terminal Equipment - DWDM, 40 Wavelengths, 400Gbit/s, 400km	1,710	\$k
Optical Repeater - DWDM, up to 40 wavelengths, 100km	40	\$k
Optical Repeater Hut (including Power Supplies, etc)	200	\$k
Optical fibre-laying - Desert	18	\$k/km
Optical fibre-laying - Farmland	38	\$k/km
Optical fibre-laying - City	200	\$k/km
Radio Terminal Equipment - Microwave Link, 40km, 256QAM, 0.949Gbit/s, 6GHz	120	\$k
Radio Terminal Equipment - Microwave Link, 40km, 256QAM, 1.898Gbit/s, 6GHz	240	\$k
Radio Terminal Equipment -Microwave Link, 40km, 256QAM, 2.560Gbit/s, 6.7GHz	240	\$k
Radio Terminal Equipment - Microwave Link, 40km, 256QAM, 3.840Gbit/s, 11GHz	360	\$k
Radio Terminal Equipment - mmWave Link, 2.5km, OOK, 1.250Gbit/s, 80GHz	70	\$k
Radio Tower - 9m	3	\$k
Radio Tower - 12m	4	\$k
Radio Tower - 20m	40	\$k
Radio Tower - 50m	300	\$k
Satellite Groundstation, LEO, 620Mbit/s	350	\$k

Table 4: Capital Expenditure costs for backhaul components.

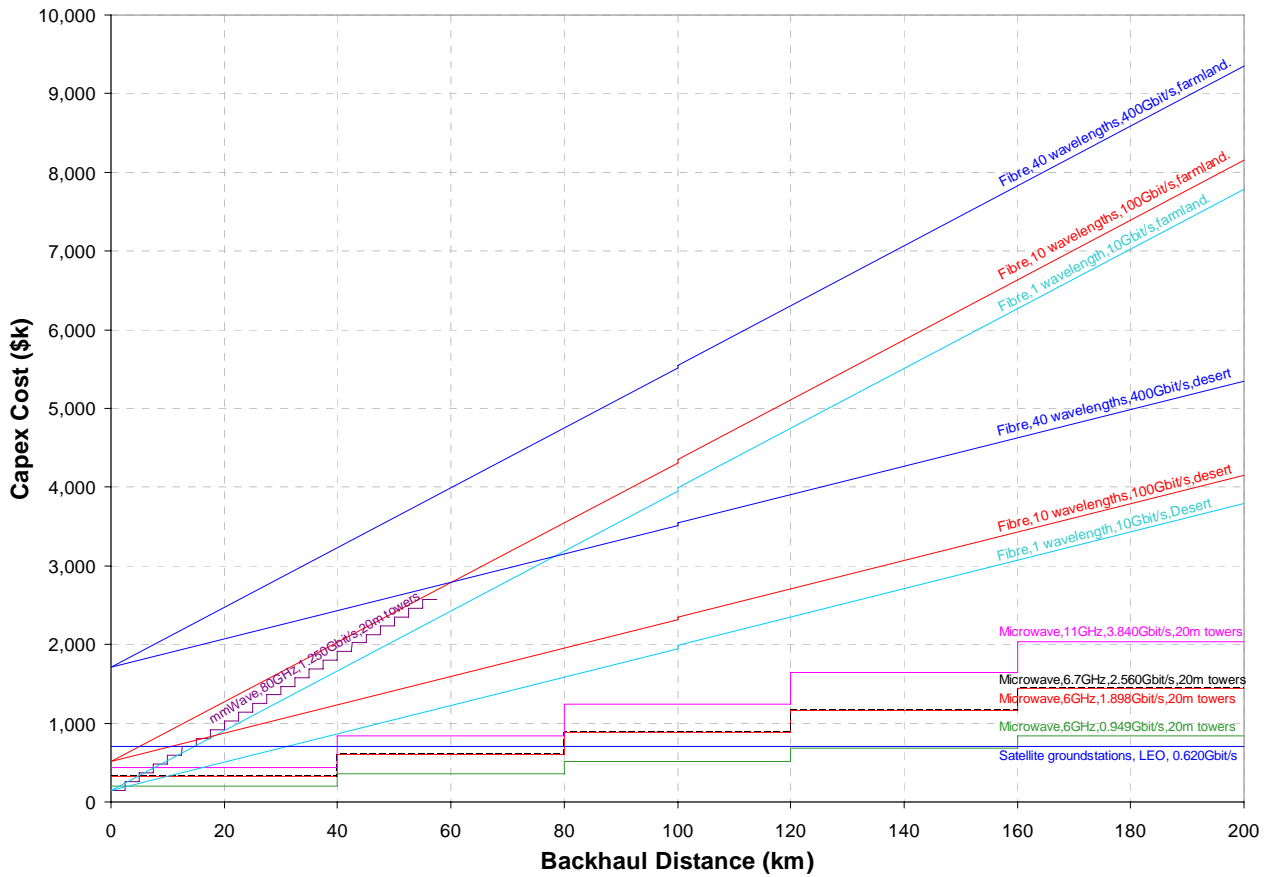


Figure 2: Capital expenditure costs for various backhaul scenarios. Discontinuities in the curves indicate the addition of another link hop.

From Figure 2, it can be seen that optical fibre backhails are more costly than microwave backhails but provide much higher data rates. The land type has a significant effect on optical fibre backhaul costing.

For microwave links, the cost per hop increases with data rate due to the requirement for additional radios when extra parallel channels are used to achieve the data rate.

mmWave links may be suitable for short haul (~7km max subject to the frequency selected), however, these links are seen to be inappropriate for long-haul backhaul due to the large number of link hops required to achieve significant backhaul distances. This is evident in the fine-pitch sawtooth appearance of the “mmWave, 80GHz” curve.

Satellite backhaul is less expensive than microwave backhaul in many cases but its data rate is limited to 620Mbit/s.

### ***Operational Expenditure***

The operating expenditure for the various backhaul technologies have not been considered in detail here. The main operating expenditure contributors include the following:

- Electricity
- Maintenance
- Tower rental
- Land rights leasing (fibre trenches, towers)
- Performance monitoring / adjusting
- Monthly/yearly service fees (satellite usage).

### **Conclusions**

From CSIRO's analysis, optical fibre is the premium backhaul technology with its high data rates and upgradeability. It is the technology of choice if digging and deployment time is not an issue.

Microwave & mmWave point to point radio backhails offer lower capital expenditure costs than optical fibre, but offer lower data rates for long-haul backhails. mmWave radios are appropriate only for very short-haul backhails. Microwave radios should be used where low cost is a requirement and high data rates > 3.8Gbit/s are not required.

Satellite should only be chosen when only relatively low backhaul data rates <620Mbit/s are required. For multiple backhails, the entire satellite capacity would be used up very quickly. Satellite operating costs (service fees) may be prohibitive.

When choosing a backhaul technology, the main factors to consider include the following:

- Required peak data rate
- Backhaul distance
- Capital expenditure
- Operating expenditure
- Reliability
- Upgradeability

Radio backhaul data rates are limited mainly by spectrum availability in the "long-haul" frequency bands. This situation could be improved by the allocation by ACMA of, say, 500MHz or 1GHz of spectrum for long-haul radio links.

### **Future CSIRO Contributions to Backhaul Technologies**

It is concluded that, for small towns with a few hundreds or less population, employing microwave links for backhails can be much faster and cheaper (by the order of up to 80% in capex) than optical fibre. To this end, new and green wireless backhaul technologies are being developed at CSIRO. CSIRO is currently negotiating with stakeholders to establish a sustainable research investment model for this technology. CSIRO's track record in the field includes the development of world-first 6Gigabit/s link at 80GHz, most spectrally efficient multiple-input and multiple-output antenna technologies, and world leading satellite communications systems.