Network communications: spectrum changeover

PAL BUS 6.07 - Network communications spectrum changeover - Jan2020 - Public

Regulatory proposal 2021–2026

Powercor

January 2020

Contents

1 OVERVIEW 4

2 BACKGROUND 5

2.1 Communication with devices 5

3 IDENTIFIED NEED 7

3.1 Maintaining compliance 7

3.2 Asset protection and maintaining reliability 8

3.3 Maintaining safety 8

4 OPTIONS ANALYSIS 9

4.1 Option one—do nothing and lose communications 9

4.2 Option two—replace radio components to operate at new frequency 10

4.3 Option three—use fibre communications network 12

4.4 Option four—use cellular communications where possible 13

5 RECOMMENDATION 16

A POWERCOR RADIO LINKS 17

B OPTION 1 RELIABILITY IMPACT 21

C OPTION 2 COST BUILD-UP 25

D CELLULAR NETWORK RELIABILITY AND COVERAGE 27

Business	Powercor
Title	Network communications: spectrum changeover
Project ID	PAL BUS 6.07 - Network communications spectrum changeover - Jan2020 - Public
Category	Augmentation capital investment
Identified need	Maintain network reliability, compliance and safety when the Australian Communications and Media Authority requires us to cease using the 800MHz and 1.5GHz frequencies used for our microwave radio communications network.
Recommended option	Option 2 - replace radio components to operate at new frequency
Proposed start date	2021/22
Supporting documents	1. PAL MOD 6.12 - ACMA spectrum - Jan2020 - Public 2. PAL ATT109 - AEMO - Standard for power system data comms - Dec2017 - Public 3. PAL ATT115 - ACMA - Long-term strategy, 803–960 MHz - Nov2015 - Public 4. PAL ATT116 - ACMA - Band change letter - Jun2019 - Public 5. PAL ATT117 - ACMA - Spectrum reform, 803–960 MHz - Nov2015 - Public 6. PAL ATT118 - ACMA - Future use, 1.5 GHz and 3.6 GHz - Oct2016 - Public 7. PAL ATT119 - ACMA - Review of the 1.5 GHz band email - May2019 - Public

1 Overview

Remote control and monitoring the distribution network is a key part of ensuring it is operated in a safe and reliable manner. We have adopted and deployed a range of communication technologies over the last 20 years to provide critical communications to our zone substations for monitoring, data capture and remote control functions. To support communications in low customer density rural areas where optical fibre communications do not exist, we developed a private microwave radio network (**radio network**).

The radio network operates over frequency bands. The Australian Communications and Media Authority (**ACMA**) regulates the licencing of these frequency bands. To make way for new technologies that require an increase in bandwidth (such as 5G cellular), ACMA will be re-allocating frequencies over the 2021–2026 regulatory period, meaning we will lose some of our frequency licences.

We considered four options to comply with regulations, protect assets and maintain reliability, and maintain safety when the frequency bands are reallocated. The net present values (**NPV**) these options are presented in the table below. We recommend adopting Option 2, which is to replace radio components to operate at a new frequency. This option has the highest net present value and the lowest unquantified risks.

Table 1 NPV of options ($000, 2019)

Option	NPV
1—do nothing and lose communications	-34,424
2—replace radio components to operate at new frequency	-7,319
3—adopt fixed line communication technology	-46,459
4—utilise cellular communications where possible	-8,236

Source: Powercor

The capital investment for Option 2 is outlined is outlined below.

Table 2 Recommended option investment profile ($000, 2019)

Investment	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Capital investment	1,000	1,184	1,184	2,334	2,334	8,037

Source: Powercor

2 Background

2.1 Communication with devices

Our radio network was originally established to aid reliability in rural areas. While in higher density areas it is economical to deploy physical communication mediums such as optical fibre, in rural areas long haul radio networks are far more economical.

Our radio network operates on frequencies licenced by ACMA. By licencing frequencies, we guarantee no one else can use the frequency (or spectrum) and interfere with radio transmissions. This is critical where highly reliable communication is needed to operate the electricity network. ACMA allocates spectrum according to the highest value application and it has the right to revoke radio spectrum from a licensee with reasonable notice period.

Our radio network is primarily used for terminal station and zone substation communications, and supporting the integration of large-scale renewable energy generation.

2.1.1 Radio spectrum changes imposed by ACMA

Cellular mobile technology advancements have called for an increase in data speeds which in turn require higher bandwidth. With the introduction of 5G cellular technology in the coming years, ACMA is expecting a significant increase in the bandwidth requirements, driven by applications such as driverless cars and high definition video. As part of their longer term strategy to accommodate this increase, they have mandated changes to frequency allocations.

Attached PAL ATT115 is ACMA's decision paper, 'The ACMA's long-term strategy for the 803–960 MHz band' that outlines the drivers for the changes as well as the specifics of the changes to the 800 megahertz (**MHz**) bandwidth. Attachment PAL ATT116 is a letter from ACMA, 'ACMA Band change letter', which states:

> *You have been identified as the holder of apparatus licence(s) operating in the 800MHz band that will be affected by regulatory changes taking place between 2019 and 2024…Existing licensees will need to stop operating in [specified frequency] bands by the compliance end dates.*

Also indicated in ACMA's 'Future use of the 1.5 GHz and 3.6 GHz bands Initial Investigation' available at attachment PAL ATT118, the 1.5 gigahertz (**GHz**) band is under review. This investigation found:

> *Based on the outcomes of this assessment, the ACMA believes that the highest-value use of the 1.5 GHz and 3.6 GHz bands has changed, or may be changing, in some areas.*

As further outlined in attachment PAL ATT119 'Status of the ACMA's review of the 1.5 GHz band', ACMA has indicated the following about the re-allocation of the 1.5GHz band:

> *This is extremely likely to occur within the next 7 years and impact fixed links that are licensed to Powercor for operation in the band.*

The above ACMA changes will mean we cannot continue to operate our 800MHz and 1.5GHz licenced frequencies ranges.

We have a number of radio sites that communicate in the 800MHz and 1.5GHz ranges. Each radio site is designed to operate on a specific frequency range and so as a consequence of licencing changes, these sites will not operate. The following table outlines the number of radio links affected and the date at which the currently licenced frequencies will be revoked.[1]

Table 3 Radio sites affected by ACMA's radio communication licence changes

Impacted frequency	End Date	Affected Links
800 MHz Point to Point links	30 June 2024	10
800 MHz Point to Multi-point links	30 June 2024	30
1.5GHz Point to Point links	30 June 2025	23

Source: Powercor

Appendix A contains a full list of existing (and necessary new) radio sites and their frequencies.

[1] PAL ATT116: ACMA, Band change letter. PAL ATT115: ACMA , The ACMA's long-term strategy for the 803–960 MHz band, Decision paper, November 2015. PAL ATT119: ACMA representative, Status of the ACMA's review of the 1.5 GHz band email.

3 Identified need

As outlined below, the identified need in this business case is to:

- comply with regulations
- protect assets and maintain reliability
- maintain safety.

3.1 Maintaining compliance

In accordance National Electricity Rules (**Rules**), the Australian Energy Market Operator (**AEMO**) requires specific communications links to uphold market reliability. Specifically, Rules the state: [2]

Each Network Service Provider must provide and maintain…the necessary primary and, where nominated by AEMO, back-up communications facilities for control, operational metering and indication from the relevant local sites to the appropriate interfacing termination as nominated by AEMO.

It also states:[3]

…AEMO may, by notice in writing, require a Network Service Provider, a Generator or a Market Network Service Provider to: (1) install remote monitoring equipment which, in AEMO's reasonable opinion, is adequate to enable AEMO to remotely monitor the performance of a transmission system or distribution system...

Radio communications are used to meet these obligations, specifically by underpinning the operation of:

- runback schemes—to allow the integration of large-scale wind and solar power generators, power flow must be managed through 'runback' schemes. These schemes protect the electricity network by informing generators to reduce, or run back, their output when the distribution network is nearing capacity. Without runback schemes, there is a material risk our assets and terminal stations become overloaded, causing wide scale outages and the risk of fire starts.
- inter-trip systems—when network protection operates due to a fault, large generators must also be disconnected. AEMO requires inter-trip systems to ensure mass blackouts do not occur. If generators do not quickly disconnect in a fault situation then a system black outage can occur due to protection equipment tripping at the transmission level (similar to the blackout event that occurred in South Australia on 28 September 2016).
- Inter-control Centre Communications Protocol (**ICCP**)—ICCP links to zone substations and generators are required by AEMO. ICCP links allow data exchange to provide AEMO visibility of powerflow through the electricity network.

The above applications all require high reliability and speed of the communications network. AEMO and AusNet (transmission) requires greater than 99% reliability as well as low latency due to the risks involved. AEMO's Power System Data Communication Standard outlined we must transmit data in accordance with the following standards.[4]

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2 National Electricity Rules, 4.11.2 (a).

3 National Electricity Rules, 4.11.2 (d) and (e).

4 PAL ATT109: AEMO, Power System Data Communication Standard, December 2017, p. 9-10.

Figure 1 AEMOs performance requirements over 12 months

Category of RME and RCE	Total period of Critical Outages
Dispatch Data where there is no agreed substitute data	6 hours
Dispatch Data where there is agreed substitute data	12 hours
RCE	24 hours

Source: AEMO, Power Systems Data Communication Standard

Most of our substations and the generators connected to our network (for which we must operate a run back scheme) are considered as both RME (remote monitoring equipment) and RCE (remote control equipment). RCE's are required to have less than 24 hours of outages in 12 months, which equates to 99.73% availability. In the case of dispatch data (generators) greater than 99.9% is required. This availability cannot be achieved through public telecommunications networks as outlined in appendix D.

3.2 Asset protection and maintaining reliability

The radio network provides communications to zone substations in rural areas. Each of the following functions rely on communications via the radio network:

- operation of protection equipment—each zone substation contains protection equipment to ensure high value assets are not damaged when faults occur. Some of this equipment relies on the radio network to trip protection mechanisms. If this did not operate, we would face costly network damage and long outages associated with replacing high value equipment such as transformers.
- fault identification—without remote communications, our Control Centre will not know which feeder protection trip has operated or the fault type. Having this information reduces the time taken to find and isolate faults.
- switching—when a fault occurs, the protection equipment will trip at the zone substation. If there is a switchable section in the feeder then the fault can be isolated and power restored remotely, saving significant time to manually operate switches.
- automated switching programs (our Fault Detection Isolate and Restore system)—this system significantly reduces outage times for customers by automatically switching electricity to restore supply.
- demand reduction—through voltage control at the zone substations, demand can be reduced to avoid load shedding. This was demonstrated successfully on the 24th of January 2019, where load shedding was avoided due to the demand reduction achieved through managing voltage at the zone substation.
- remote sensing—communications to zone substations allows the Control Centre to understand the load on exiting feeders, enabling us to determine if shifting load during faults will overload assets (creating further outages).

The radio network is also used to perform the same functions at terminal stations and on sub transmission feeders. These have a high consequence when faults occur due to the significant number of customers connected. For this reason, remote communication is vital for managing faults effectively.

3.3 Maintaining safety

Zone substations are entered by employees that are specifically trained and entry is generally avoided due to the inherent risks of electricity. If protection has tripped inside a zone substation, upon re-energization, the asset can fail explosively. Therefore, to reduce the risk of injury this is conducted remotely, but this would not be possible without the radio network.

4 Options analysis

This section outlines options to address the identified need. In this analysis, costs are the direct expenditure required to implement the option and benefits are the quantified effects. This means benefits can be presented as negative benefits where the effects are detrimental.

A number of options and scenarios were considered before selecting four options for cost benefit analysis. These options and the reasons they were not considered further are:

- continuing to use ACMA spectrum unlicensed—when ACMA licensing is changed, the majority of our radio network will not legally be able to operate with fines of up to $300,000 per offence being be imposed. With 79 sites impacted we would incur fines up to $23.7 million. We have not considered this option further both because of the resultant non-compliance and the cost imposed by the fines.
- use other radio technology—an example of other radio technologies like eLTE that are based on cellular technologies. These have smaller propagation distances compared to radio meaning more intermediate radio towers are required and costs will be higher with no additional functionality or benefits.

4.1 Option one—do nothing and lose communications

As outlined in section 3, the radio network would be inoperable after the ACMA frequency changes are mandated, exposing the electricity network to risk and a reduction in reliability.

We have been conservative by only quantifying the impact of losing communications with zone substations and excluding the impact on terminal stations and generator communications.

The NPV of the costs and benefits of this option are outlined below.

Table 4 NPV of costs and benefits ($ 000, 2019)

Impact	Cost	Benefit
Reliability	-	-34,424
Net benefits		**-34,424**

Source: Powercor

4.1.1 Benefits

Compliance

Without communication we would be in breach of our obligations to AEMO under the Rules outlined in section 3. As such, this option is not viable.

Reliability

There is a reliability dis-benefit associated with this option. There would be negative impacts to reliability due to an inability to remotely:

- monitor zone substations and terminal stations in rural areas, resulting in increased time to determine fault causes
- switch loads at the substation level remotely, requiring manual switching taking significantly longer to perform and therefore prolonging outages.

Appendix B provides detail on the reduction in reliability associated with this option. We have forecast that this option would result in a reliability reduction shown below.

Table 5 Annual value of unserved energy ($ 000, 2019)

Parameter	$,000
Unserved energy (per annum)	-2,869

Source: Powercor

Risk uplift

As outlined in section 3, doing nothing will increase the risk of generators overloading assets in the electricity network resulting in bushfires and loss of life. Without communications to mitigate this risk, damage to assets is likely to occur. This risk has not been quantified due to the other dis-benefits already making this option unviable, however, the costs from an overload event occurring would be significant.

4.1.2 Costs

There is a potential one time cost from us needing to remove unused communication assets from the network. This has not been quantified given the option would already result in uneconomic outcomes.

4.2 Option two—replace radio components to operate at new frequency

Under option two, we would replace radio components at sites impacted by ACMA frequency licencing changes. This option leverages the investment already made in the radio network as well as maintaining reliability and risk levels. The table below outlines the net present value of this option.

Table 6 NPV of costs and benefits ($ 000, 2019)

Impact	Cost	Benefit
Reliability	-	-
Capital investment	7,319	-
Net benefits		**-7,319**

Source: Powercor

This option is seen as the most prudent spend because it meets current and future needs with the lowest net cost.

4.2.1 Benefits

The non-compliance, reliability and risk uplift dis-benefits outlined in Option 1 will be avoided.

4.2.2 Costs

ACMA has indicated that there are two frequency bands that are available to use:

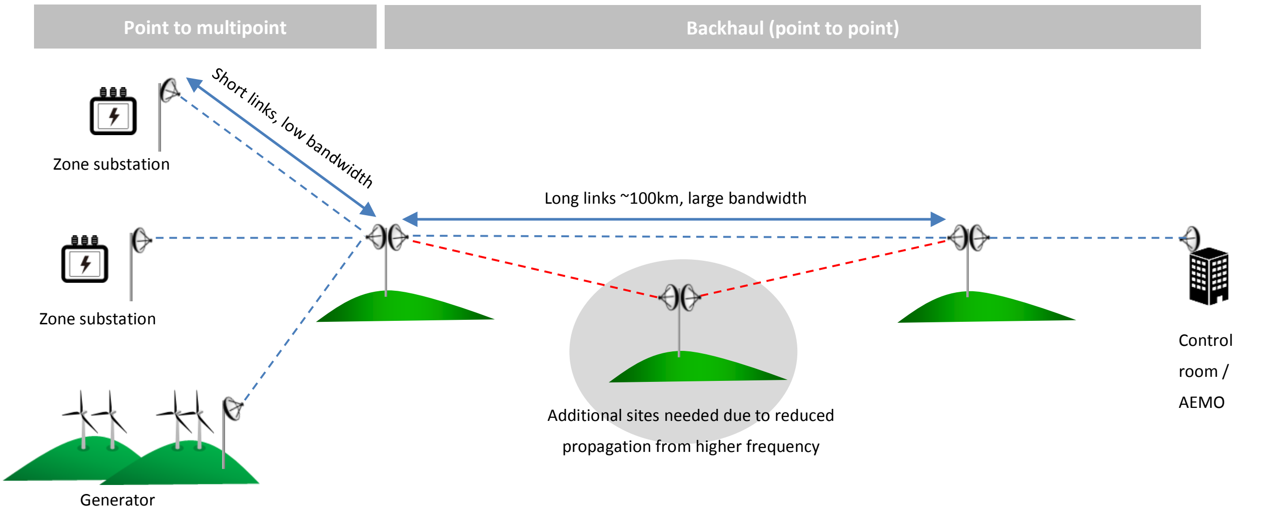
- 400MHz—this is reserved for narrowband applications (sub-25kHz). While basic information can be transferred in this band, it cannot accommodate the information we need to communicate.
- > 6 GHz—frequencies enable applications with higher bandwidth requirements.

ACMA have advised us that 8GHz would be optimal for our use as it has greater longevity for licencing and it is the only frequency available that meets our bandwidth requirements. Changing to this frequency requires:

- changes to the frequency of point to multipoint (**P2MP**) links—the low bandwidth and low distance links that provide information from multiple zone substations, terminal stations and generators
- changes to the existing point to point links (**P2P**)—once the data that has been collected from multipoint links is aggregated, high bandwidth point to point links are needed to transmit the data over long distances
- additional towers—these are needed because higher frequencies (i.e. 8GHz) do not travel as far (reduced propagation).

This is illustrated below.

Figure 2 Radio communication network



Source: Powercor

Using standard radio propagation formulas, we have determined that links greater than 58 kilometres will need a repeating site built, as outlined in model PAL MOD 6.12. As a consequence, 16 new sites will need to be developed.

Appendix A outlines our existing microwave radio links and whether additional towers are needed. Appendix C outlines the costs for upgrading P2MP links, P2P links and additional towers, which is based quotes from service providers for changing to the new frequency and previous works to establish and maintain the radio network. The following table summarises the costs associated with this option.

Table 7 Costs associated with option 2 ($ 000, 2019)

Driver	End Date	Number of radio links	Cost per link ($,000)	Total costs
Replace 800MHz P2P with 8GHz	30 June 2024	10	97	967
Replace 800MHz P2MP & P2P with 8GHz	30 June 2024	30	31	934
Additional sites due to reduced propagation distance (800MHz)	30 June 2024	6	244	1,467
Replace 1.5GHz P2P with 8GHz	30 June 2025	23	97	2,224
Additional sites due to reduced propagation distance (1.5GHz)	30 June 2025	10	244	2,445
Total				**8,037**

Source: Powercor

4.3 Option three—use fibre communications network

This option considers leasing fixed optical fibre as an alternative to radio communications. The table below outlines the net present value of this option.

Table 8 NPV of costs and benefits ($ 000, 2019)

Impact	Cost	Benefit
Reliability	-	-
Capital replacement	46,459	-
Net present value		**-46,459**

Source: Powercor

4.3.1 Benefits

The non-compliance, reliability and risk uplift dis-benefits outlined in Option 1 will be avoided.

4.3.2 Costs

We could lease optical fibre that has been rolled out by telecommunication companies between towns in Australia. However, nbnco has indicated to us that only 8 of our 22 substations currently connected with radio could be connected to the National Broadband Network (**NBN**) without additional construction and significant expense (on average optical fibre costs $20,000 per kilometre to deploy; with over 2,000 kilometres to deploy this would cost over $50 million). Additionally, to those sites where NBN is in the area, it still does not cover the 'last mile' to our zone substations and connected generators.

We have conservatively assumed that NBN is available in all areas to demonstrate that even if this were true, the leasing cost exceeds the costs of some other options considered.

Table 9 NPV of costs and benefits ($ 000, 2019)

Item	Value	Source
Optical fibre leasing cost (per kilometre per year)	1.5	Quotes from telecommunications companies (where fibre is available already)
Kilometres covered by existing radio network	2,582	Appendix A
Cost per year	3,872	
Net present value	**-46,459**	

Source: Powercor

4.4 Option four—use cellular communications where possible

Under this option we would:

- replace radio components at sites impacted by ACMA frequency licencing changes where it is needed to comply with AEMO's requirements as outlined in section 3. We have found that 42 of the 63 links fall into this category, which are listed at appendix A.
- use cellular communications (e.g. 4G) for reliability and monitoring purposes where mandated performance requirements are not in place—the remaining 21 sites.

The table below outlines the net present value of this option.

Table 10 NPV of costs and benefits ($ 000, 2019)

Impact	Cost	Benefit
Reliability		-1,743
Capital replacement	6,493	-
Net present value		**-8,236**

Source: Powercor

4.4.1 Benefits

Reliability

As shown in appendix A, 21 of the 63 links impacted by the ACMA changes are not associated directly with AEMO compliance obligations and would move to cellular communications under this option.

As demonstrated in appendix D, a cellular communications reliability cannot be expected to exceed 95% in rural areas (down from 99.9% with radio networks), which will reduce network reliability.[5] By applying the reliability impact from Option 1 (outlined in appendix B) we can calculate the impact of reducing communications reliability as follows.

[5] This is a conservative estimate; reliability is likely to be less than 95%.

Figure 3 Reliability impact

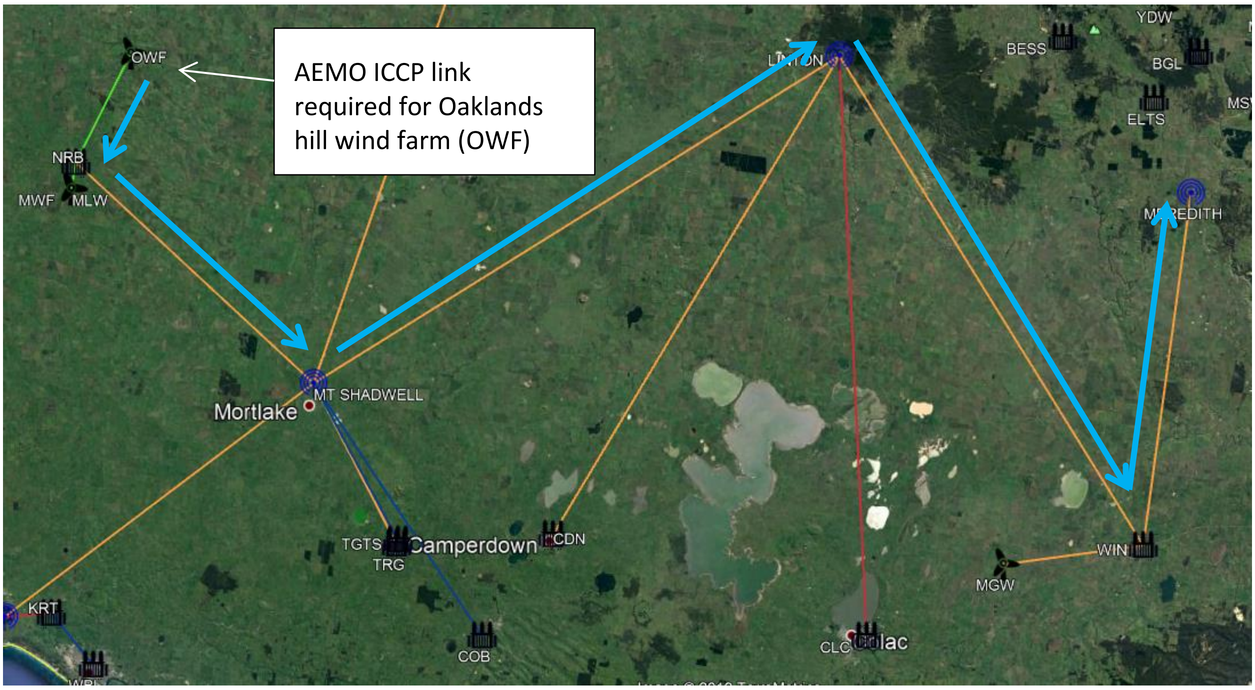
Item	Unit
Number of zone substations	21
Reliability impact of no communications to zone subs per annum (from Appendix A) ($, 000)	-2,869
Average reliability impact per zone sub ($,000)	-130
Communications reliability (%)	95
Resulting average reliability reduction per zone sub per annum ($, 000)	-6.5

Source: Powercor

4.4.2 Costs

The cost of this option is not materially less than replacing and using the radio network in full (Option 2). The reason for this is illustrated and discussed below.

Figure 4 ICCP path from Oaklands hill wind farm



Source: Powercor

The blue line shows the communication path for the required runback scheme from Oaklands hill windfarm (**OWF**) to Meredith (where an optical fibre network is located which is used to communicate the rest of the way). This requires microwave links at Nareeb (**NRB**) switching station, Mt Shadwell, Linton, Winchelsea zone substation (**WIN**) (which also has to remain on radio network for the runback scheme at Mount Gellibrand Wind Farm (**MGW**)) and Meredith.

That is, to get the signal to Meredith, a high bandwidth 'backhaul' radio network is needed. This requires changes to point to point sites and (in some cases, but not this example) additional towers due to reduced propagation from operating at a higher frequency. As illustrated and discussed in section 4.2 and appendix C, this 'backhaul' accounts for majority of the radio network cost.

Given the radio network backbone must already be established, there is a relatively low incremental cost to upgrade the remaining (low bandwidth) multi point links at Koroit zone substation, (**KRT**) Camperdown zone substation (**CDN**) and Colac zone substation (**CLC**) so that they too can operate on the radio network. Therefore, the cost of this option is not substantially lower than Option 2.

Table 11 Capital costs for option 4

Item	Cost
Costs to install cellular communications	98
800MHz to 8GHz costs for compliance	2,386
Total 1.5GHz to 8GHz costs for compliance	4,669
Total	**7,153**

Source: Powercor

5 Recommendation

We recommend adopting Option 2 to replace radio components to operate at new frequency because this has the highest NPV as shown in the table below.

Table 12 NPV of options ($000, 2019)

Option	NPV
1—do nothing and lose communications	-34,424
2—replace radio components to operate at new frequency	-7,319
3—adopt fixed line communication technology	-46,459
4—utilise cellular communications where possible	-8,236

Source: Powercor

The capital investment for this option is slightly higher than Option 4, however, a negative change to reliability is avoided. The capital investment for Option 2 is outlined is outlined below.

Table 13 Recommended option: expenditure profile ($000, 2019)

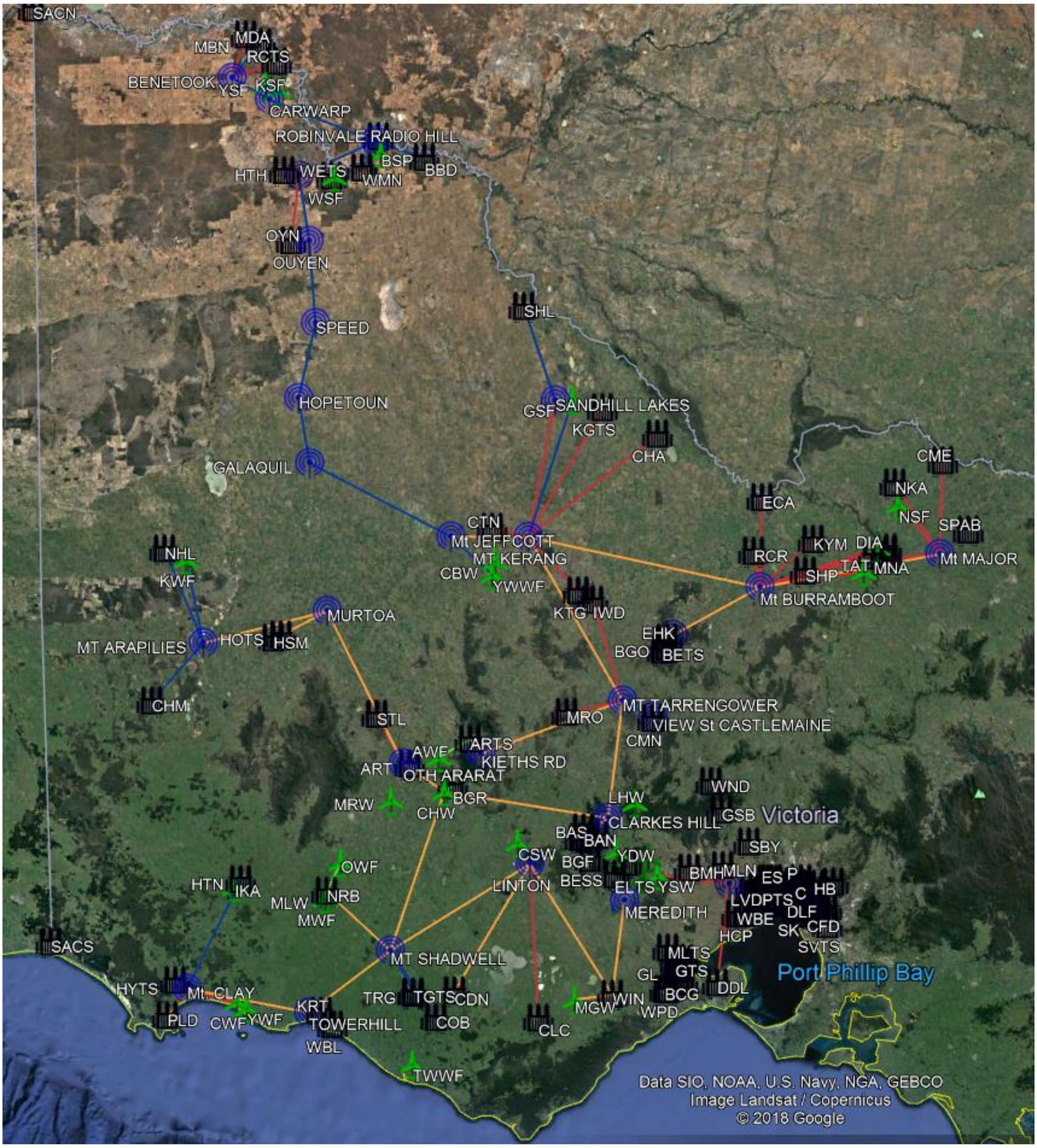
Investment	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Capital investment	1,000	1,184	1,184	2,334	2,334	8,037

Source: Powercor

A Powercor radio links

Figure 5 shows the extent of and remoteness of the areas covered by our radio network.

Figure 5 - Powercor radio network



Source: Powercor

The following table lists all of the microware radio sites in our network. It also outlines changes needed due to the ACMA frequency license changes.

From point	To point	MHz band	Distance	Intermediate site needed	Needed for compliance
CHW	OTH ARARAT	1,500	23.4	No	Yes
CHW	Mt SHADWELL	1,500	79.3	No	Yes
CLARKES HILL	CHW	1,500	77.6	No	Yes
CLARKES HILL	Mt TARRENGOWER	1,500	55.2	No	Yes
EPSOM	MT BURRAMBOOT	1,500	46.1	No	Yes
Mt BURRAMBOOT	MT KERANG	1,500	110.5	No	Yes
MT TARRENGOWER	MT KERANG	1,500	88.1	No	Yes
Mt SHADWELL	NRB	1,500	40.8	Yes	Yes
Mt SHADWELL	TOWERHILL	1,500	49.0	No	Yes
MURTOA	HOTS	1,500	24.7	No	Yes
OTH ARARAT	MURTOA	1,500	79.7	No	Yes
TOWERHILL	Mt. CLAY	1,500	58.7	No	Yes
Mt BURRAMBOOT	MT MAJOR	1,500	85.2	No	Yes
MT KERANG	Mt JEFFCOTT	1,500	36.2	No	Yes
MT TARRENGOWER	KIETHS RD	1,500	70.8	No	Yes
KIETHS RD	ARTS	1,500	8.4	No	Yes
MT ARAPILIES	MURTOA	1,500	60.7	No	Yes
MT SHADWELL	LINTON	1,500	77.7	Yes	Yes
LINTON	WIN	1,500	72.3	No	Yes
WIN	MGW	1,500	17.7	No	Yes
WIN	MEREDITH	1,500	44.6	No	Yes
MT SHADWELL	TRG	1,500	22.7	No	Yes
BAS	CLARKES HILL	1,500	16.1	No	Yes
Mt. CLAY	CWF	800	24.4	No	Yes
Mt. CLAY	PLD	800	16.4	No	No

Mt. CLAY	YWF	800	29.7	No	Yes
OTH ARARAT	ART	800	3.0	No	Yes
OTH ARARAT	STL	800	26.0	No	Yes
TOWERHILL	KRT	800	6.0	No	No
Mt. CLAY	HYTS	800	6.9	Yes	Yes
Mt BURRAMBOOT	SHN	800	60.9	Yes	No
Mt BURRAMBOOT	MNA	800	54.9	Yes	Yes
Mt BURRAMBOOT	TAT	800	48.9	Yes	Yes
Mt BURRAMBOOT	RCR	800	16.9	Yes	No
Mt BURRAMBOOT	SHTS	800	61.6	Yes	Yes
Mt KERANG	CHA	800	76.9	Yes	No
Mt KERANG	KGTS	800	69.3	Yes	Yes
Mt KERANG	CTN	800	17.5	Yes	Yes
Mt KERANG	KTG	800	34.4	Yes	No
Mt KERANG	SANDHILL LAKES	800	64.9	No	No
BENETOOK	MBN	800	21.2	Yes	No
BENETOOK	RCTS	800	22.3	Yes	Yes
HATTAH	HTH	800	7.6	Yes	No
HATTAH	OYN	800	31.1	Yes	Yes
HATTAH	WSF	800	16.7	Yes	Yes
Mt BURRAMBOOT	ECA	800	41.6	Yes	No
Mt BURRAMBOOT	KYM	800	33.2	Yes	No
Mt BURRAMBOOT	SHP	800	22.3	Yes	No
Mt COTTRELL	BMH	800	20.1	Yes	No
Mt COTTRELL	YSW	800	33.7	Yes	Yes
Mt COTTRELL	DDL	800	47.0	Yes	No

Mt COTTRELL	BHP	800	15.7	Yes	Yes
LINTON	CLC	800	72.9	Yes	No
Mt MAJOR	STN	800	25.1	Yes	No
Mt MAJOR	NKA	800	39.1	Yes	No
Mt MAJOR	CME	800	43.5	Yes	Yes
MT TARRENGOWER	MRO	800	26.8	Yes	No
MT TARRENGOWER	IWD	800	48.6	Yes	No
CLARKES HILL	BGF	800	14.4	No	No
Mt MAJOR	NSF	800	30.0	Yes	Yes
Mt BURRAMBOOT	DIA	800	57.8	Yes	Yes
IKA	HTN	800	4.2	No	Yes
LINTON	CDN	800	42.5	No	No
Totals			**2,581.5**		**21**

Source: Powercor

B Option 1 reliability impact

When a fault occurs at a zone substation or terminal station, the initial notification is received over a communications link in the Control Centre via the Distribution Management System (**DMS**). In the rural areas of Powercor, microwave radio links are used for communications. The network controller reviews the data and dispatches crews to investigate. In some situations, the network controller is able to restore healthy sections of the affected feeder using remote switching equipment before the field crew gets onsite.

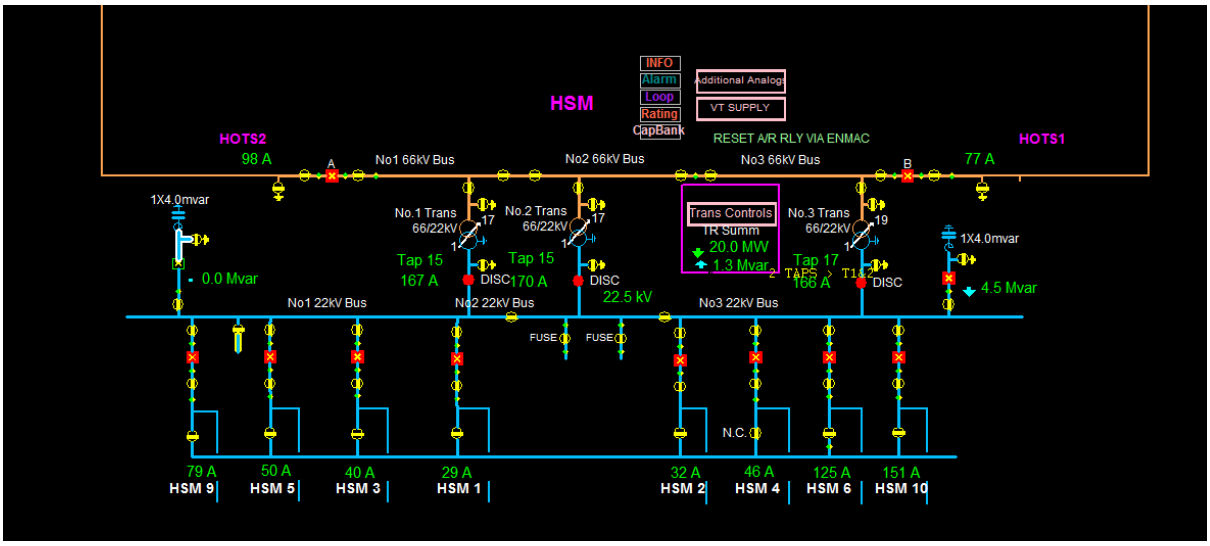
During the fault finding and restoration process the Control Centre will open and close Feeder Circuit Breakers (**CB**), automatic circuit reclosers (**ACR**) and Remote switches. They utilise the field crews to further refine outage areas using manual switching devices.

If the radio network failed to function or was shutdown, the information currently received for many zone substations and terminal stations via the DMS would have to be completed by crews in the field.

B.1 Outage example

The diagram below shows how the Horsham zone substation is seen from the Control Centre. The green values show the amount of current following through the substation. In a fault situation, the Control Centre will be alerted that protection has tripped and this will be displayed on the screen. A faults crew will be dispatched.

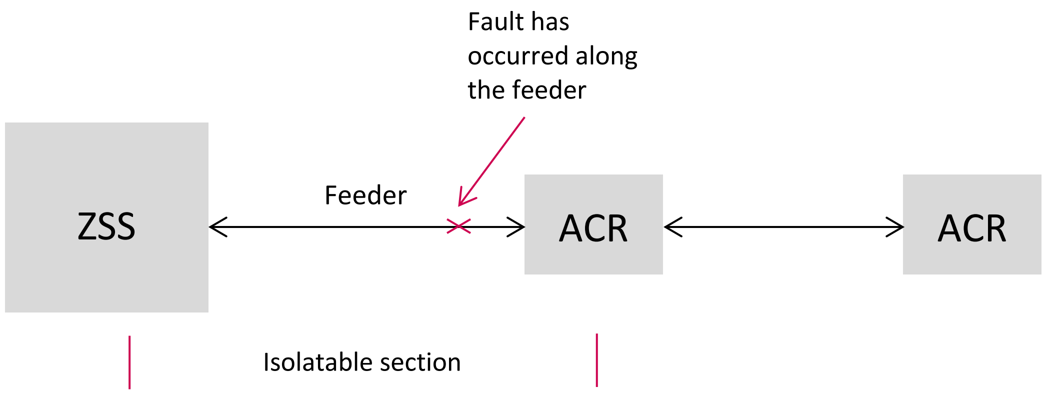
Figure 6 Control Centre view of network



Source: Powercor

Zone substation switching allows the restoration of faults that occur between the zone substation and the next protection device such as ACR. The diagram below demonstrates the structure of a typical feeder that has isolatable sections due to remote switching devices.

Figure 7 Feeder with isolatable sections



Source: Powercor

If a fault occurs within the first isolatable section coming out of a zone substation, then the protection within the zone substation will operate, turning the whole feeder off. Without remote communications, the Control Centre would not be aware of the outage and where in the feeder the outage occurred. Once the outage is detected through other means (AMI or customer notification) the field crew would be dispatched to the substation.

The faults crew would need to travel to the zone substation and then down the feeder to find the fault. In many cases there can be very long distances down the feeder until the cause of the fault is found. Once the fault is found, the field crew will notify the Control Centre and the feeder will be remotely switched on.

B.2 Outage impact

To understand the effect of not having radio communications to zone substations, a three year average of customer minutes off supply (**CMOS**) has been compiled for the zone substations with radio communications. The CMOS average is only for outages that occurred at the zone substation level. The following table contains this average and the number of customers connected by type.

Table 14 CMOS impact by zone substation and customer sectors

Zone Sub	Industrial	Residential	Agricultural	Commercial	Customer minutes off supply (3 year average)
			Customer numbers		
ART	159	4,461	1,649	737	77,405
CDN	136	2,931	2,313	616	234,674
CHA	199	1,908	1,974	541	218,595
CLC	356	12,018	2,779	1,521	2,243,597
CME	241	7,576	915	896	1,611,370
CTN	248	4,911	2,128	1,200	2,657,043
ECA	280	6,839	1,459	1,082	430,676
HTN	255	7,697	4,380	1,499	391,055
KRT	228	5,326	2,022	824	174,259
KYM	278	4,580	2,477	776	399,085
MBN	182	8,292	1,531	538	220,534
MNA	284	7,489	1,522	812	946,636
NKA	329	4,194	2,842	822	479,920
OYN	101	1,638	1,206	481	172,241
PLD	147	7,211	1,140	988	166,797
RVL	124	1,016	544	256	10,451
SHL	278	5,928	1,771	1,079	595,335
SHN	212	8,543	1,255	826	297,926
STL	206	4,502	1,296	778	72,606
STN	274	8,440	1,169	1,614	285,930
TRG	177	3,230	2,974	745	723,723
WBL	226	14,458	1,172	1,543	414,238
Total	**4,920**	**133,188**	**40,518**	**20,174**	**12,824,096**

Source: Powercor

The above table shows that there was a total of 12,824,096 customer minutes across the listed zone substations.

B.3 Valuing the impact on network reliability

Using the customer type information from Table 14, the following table outlines the composite calculation of Value of Customer Reliability (**VCR**) for our network.

Table 15 VCR calculation ($, 2019)

Sector	Average daily consumption (kWH)	$/MWh	Sector weighting (%)	Customer days off supply per sector	MWh for outage time	VCR
Residential	12	26,450	67	5,851	70	1,841,632
Agricultural	38	50,930	20	1,873	72	3,656,764
Commercial	237	47,770	10	949	225	10,740,568
Industrial	98	47,070	2	233	23	1,075,789
Value of unserved energy						**17,314,752**

Source: Powercor

On average, outage durations on these substations is 78 minutes. We have conservatively estimated that not having communications to these zone substations would increase outage times by 13 minutes (based on the time for crews to arrive at the zone substation and excluding further time to locate the outage). This represents an increase of 17% which results the additional unserved energy as a result of not having communications as shown below.

Table 16 Value of not having communications ($ 000, 2019)

Item	Value
Value of unserved energy from not having communication	2,869

Source: Powercor

C Option 2 cost build-up

This appendix provides detail on the forecast for replacing radio equipment as outlined in Option 2. Costs are based on quotes from service providers and previous works for establishing and maintaining the radio network.

The table below outlines the costs to covert from the 800MHz and 1.5GHz for point to multi point sites to the 8GHz frequency.

Table 17 Costs to rework 800MHz / 1500MHz multipoint sites to 8 GHz ($ 000, 2019)

Item	Cost
Testing	0.4
Drafting and design	1.2
Materials	16.5
Specialist labour	13
Total	**31.1**

Source: Powercor

The table below outline the costs to covert from the 800MHz frequency to 8GHz for point to point links.

Table 18 Costs to rework 800MHz point to point links to 8 GHz ($ 000, 2019)

Item	Cost
Testing	2.0
Drafting and design	5.0
Materials	64.7
Specialist labour	25.0
Total	**96.7**

Source: Powercor

The table below outline the costs to for additional towers due to lower propagation.

Table 19 Additional towers due to propagation limits at 8GHz ($ 000, 2019)

Item	Cost
Testing	3.0
Drafting and design	9.0
Materials	143.5
Specialist labour	89.0
Total	**244.5**

Source: Powercor

D Cellular network reliability and coverage

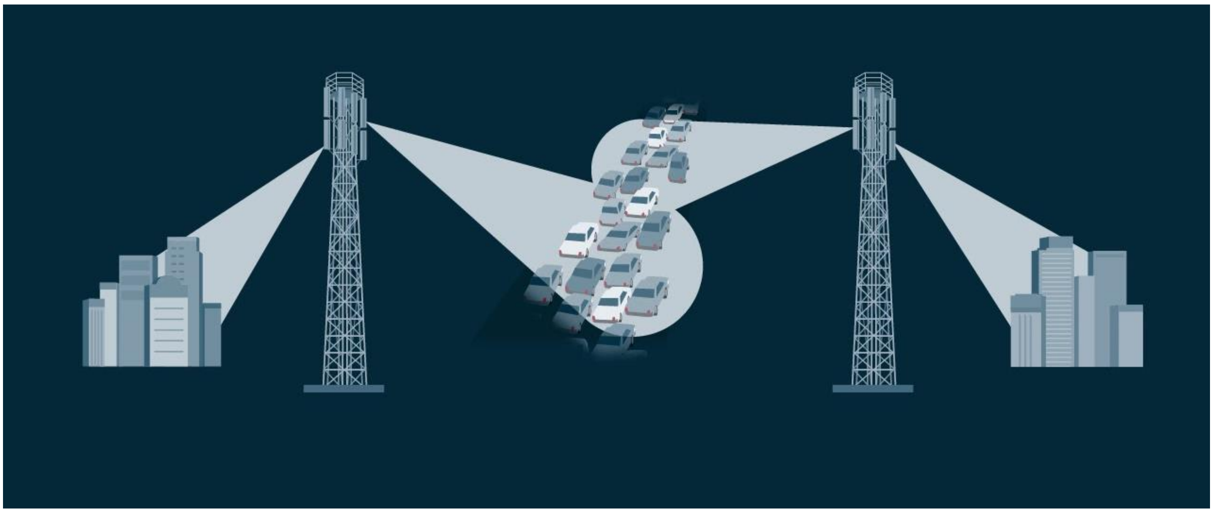
This appendix considers the reliability and coverage issues associated with cellular network. We have estimated that cellular network could provide 95% reliability and full coverage. We have been very conservative in using 95% reliability as the cellular communications network in rural areas is likely to have less reliability and we know full coverage is not available as discussed below.

D.1 Reliability

Reliability issues on public cellular networks occur at multiple levels of the network, as outlined below:

- network level—Telstra's network wide cellular outages are well documented. In 2018 alone there were 4 nationwide outages that affected Powercor communications for greater than 3 hours at a time. These outages combined represented more than 24 hours of outage time, demonstrating that it does not meet AEMOs reliability standard. References to these outages are as follows:
  - 1/5/2018 - https://www.abc.net.au/news/2018-05-01/telstra-outage-affecting-customers-nationwide/9716166
  - 21 May 2018 - https://www.itnews.com.au/news/telstras-4g-network-goes-down-again-491360
  - 19 June 2018 - https://www.gizmodo.com.au/2018/06/telstra-is-down-again/
  - 2 November 2018 - https://www.techguide.com.au/news/mobiles-news/telstras-3g-outage-knocks-eftpos-atms-disconnects-tesla-cars/
- customer level—there have also been outages during 2018–19 that have affected Powercor only due to issues such as configuration changes made by Telstra.
- local level—cellular communications coverage can be unpredictable and dynamic. Cellular technologies use what is called 'beamforming' to increase coverage by dynamically concentrating on areas with the highest concentration of uses. The following illustration demonstrates how beamforming focuses signal on areas of population.

Figure 8 - Beamforming



Although beamforming works well for higher concentrations of customers, it can have the effect of ignoring devices that are away from the population and are relatively infrequently communicating. Zone substations and generators are generally located outside of towns, away from the population making communications less reliable.

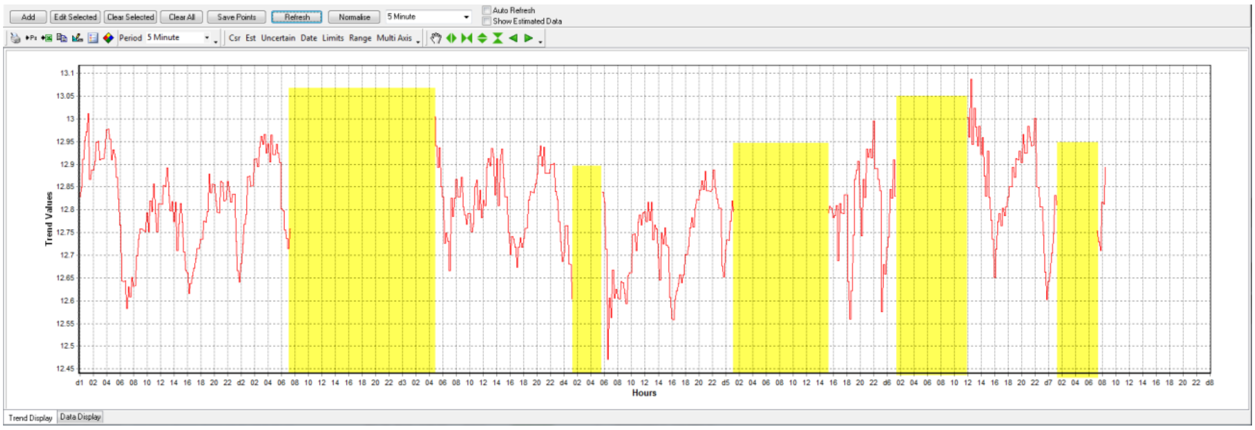
Further, telecommunication companies do not offer minimum guaranteed service levels, but rather use a 'best endeavours' approach to fixing outages.

The following case study demonstrates unreliable communications within cellular coverage.

D.1.1 Case study: Kerang terminal station

The figure below shows data collected from a metering device located at Kerang terminal station via the cellular network. Highlighted in yellow are the areas that are missing due to communication issues.

Figure 9 Metering device at Kerang terminal station



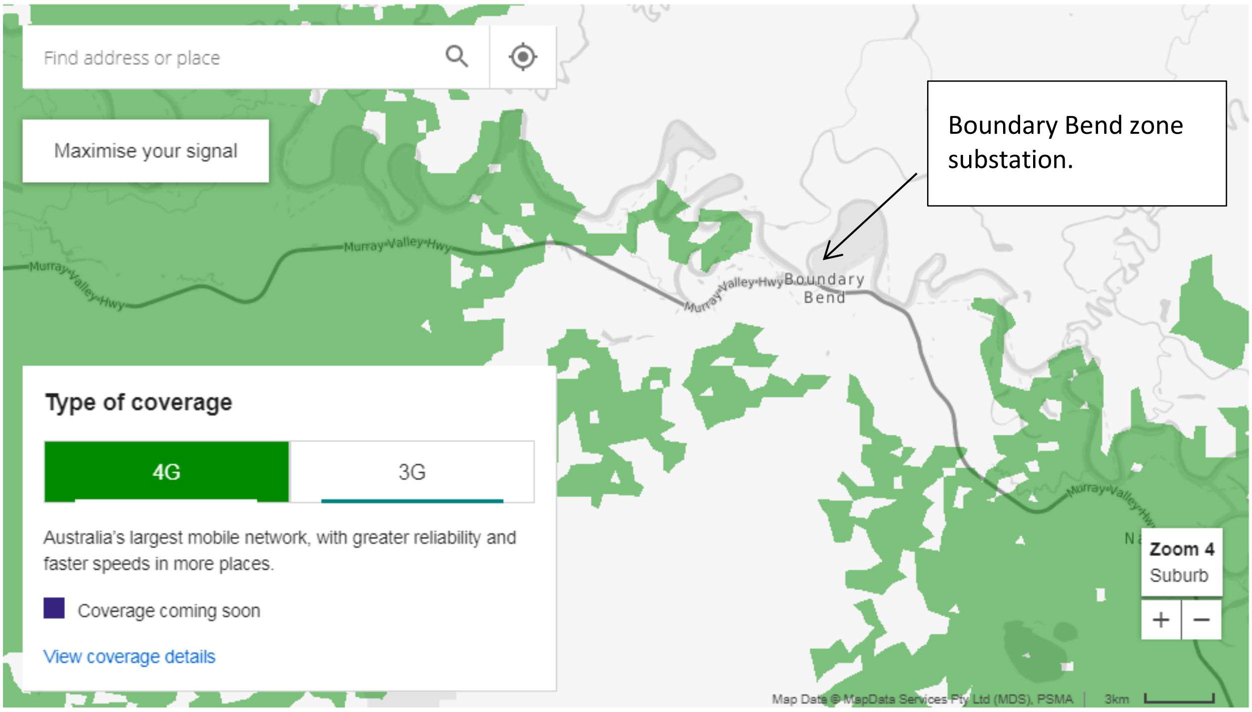
Source: Powercor

This zone substation is located outside of Kerang and away from the main population means that reliability was less than 80%. This is a common issue in rural areas.

D.2 Coverage

In many cases, cellular coverage is not available for zone substations. Figure 10 shows the Telstra coverage map and the location of Boundary Bend zone substation, which shows there is no coverage available.

Figure 10 - Boundary bend zone substation coverage



Source: Telstra