Connecting Australian Farmers: Gateways, Gatekeepers and a Forgotten Solution

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External data connectivity is a significant choke-point for Australian producers seeking to adopt or deploy many technology-based innovations on farms. In many cases it remains a constraint on their ability to operate even with what they have. This paper discusses some of the challenges faced by producers in getting (then staying) connected, as well as those faced by emerging 'second-tier' providers of network connectivity solutions to producers. The paper also revisits a seemingly-forgotten telecommunications option – Ngara – in light of a sector-wide challenge that simply won't go away.

Background

External connectivity, and in particular digital communication, is a critical enabling or 'push factor' in realising a digital agriculture future for farmers from all socio-economic groups (Wolfert et al. 2017). This can range from enabling digital extension (Mushtaq et al. 2017) or *m-agriculture* (Gichamba & Lukandu 2012), the deployment of connected devices, namely the Internet of Things (IoT) (Taylor et al. 2013; Sundmaeker et al. 2016) through to the integration of data through an entire supply chain (Wolfert et al. 2017). Unconstrained adoption of digital agriculture in Australia is estimated to add an extra $24.6 billion to national GDP (Perrett et al. 2017). However a lack of access to reliable data connectivity is a major impediment to the adoption of digital agriculture systems (Lamb 2017a, 2017b; Leonard et al. 2017). A highly granular urban population distribution, the dispersity and size of Australian farms, the physical extent of associated supply chain operations and fixed and mobile telecommunications infrastructure which is concentrated around population centres and along transportation corridors, pose real challenges to connecting producers to the outside world and to each other.

This is the second paper looking at aspects of the recently completed 'Review of on-farm telecommunications challenges and opportunities in supporting a digital agriculture future for Australia' (Lamb 2017a). The review was produced as part of a wider investigation into enabling digital agriculture in Australia (Leonard et al. 2017). A previous paper (Lamb 2017b) examined a number of top-down initiatives at the network, industry and national strategic level to address rural and regional telecommunications challenges. In particular the paper discussed the universal services obligation, mobile domestic roaming and the recognition of access as it relates to data speeds, again in respect of agriculture. The key discussion point was whether such initiatives would make a difference to the life of producers within the farm gate, and if not, then what would be required to realise the value of such initiatives at this level. This present paper continues to look at connectivity: here we focus on external connectivity, both from the perspective of producers and also of those who seek to offer alternative connectivity solutions to producers.

Inside the farm gate, Australian producers constantly face both internal and external connectivity challenges. Here internal connectivity refers to connected devices utilising on-farm 'radio' networks. This includes the ubiquitous Wi-Fi (~2.4 gigahertz frequency band) and longer range, low power, wide area networks (LPWAN) utilising the lower frequency hence lower bandwidth (~915 megahertz frequency band). On-farm radio networks ultimately connect to the outside world through a gateway. In order for producers to access the data – be it from an automatic weather station, a remote water tank, pump monitor or other device – they invariably need to access an internet site either to view the live feeds or to access additional cloud-based analytics which hang on the back of the data. Some of these systems offer alarm functionality, such as heat load alerts for penned livestock or low water levels/pump failure alert for tank monitors. This requires external connectivity (ie connections to the outside world). In practice this means through mobile devices (phone/tablet) and fixed (office, shed etc) data access to internet or cloud based services. Alternatively, the systems may offer SMS, email and phone alerts.

Producers find it challenging to run their own networks (Lamb 2017b); more than 75% of farmers with (internal) on-farm networks rate them as moderately to extremely challenging to maintain and the majority of those producers rely upon a 'significant other' – either a tech-savvy family member or an external consultant – to keep the systems running. Moreover, many producers find external connectivity daunting with 61% not even sure where to start (Lamb 2017a). They tend to be price- and service-takers rather than price- or service-makers. Just like any business that relies heavily on internet access, producers require high speed (~10–100 megabits per second – Mbps), and **reliable** high speed; here taken to mean reliable over time.

While many of the Australian producers interviewed as part of the 2016–17 Accelerating Precision to Decision Agriculture (P2D) project expressed frustration around external connectivity speeds (Leonard et al. 2017), interviews revealed that in fact the reliability of the speed is of particular concern. This is particularly the case for those producers utilising mobile broadband connections into their farm offices. We know that 66% of Australian producers rely upon the mobile network as their principle means of accessing the internet (Lamb 2017a). A significant proportion, particularly those accessing 3G towers reported unstable connections and fluctuating speeds. A typical scenario would see good speeds early in the day and then a progressive decline as the day goes on and the tower becomes congested. The use of cell boosters in offices and vehicles often provides sufficient amplification for a good quality mobile call – but in many cases users find no improvement over fluctuating (and steadily declining) data speeds during the day. Producers want guaranteed connectivity speeds 24/7 and they are now looking more widely for solutions.

A Point of Contention

Many producers interviewed during 2016–17 P2D project indicated interest in seeking solutions from so-called 'second-tier' providers, citing a desire to avoid the large network operators due to past or current frustrations with service provision. This is perhaps an unfortunate legacy of past years where interoperability and compatibility of third-party hardware for on-farm connectivity and network solutions was not as established with external network operators as it is today. It is acknowledged that the major network operators are now focusing attention on rural and farm-ready solutions, but there is some rebuilding of trust to do.

The issue of fluctuating speeds is a real point of contention for producers, both figuratively and literally. In the language of telecommunications, 'contention' refers to the relationship between the actual user demand for bandwidth compared to the available bandwidth. The lower the contention ratio the higher the quality of service. For example, a 50:1 contention ratio effectively means 50 users could be sharing the same bandwidth to the local exchange at any one time. An uncontended network connection with a 1:1 ratio is essentially a service where the provider can guarantee a fixed connection speed to a user regardless of the time of day or of how many people share the connection to the local exchange. On a single owner-single user connection, the contention ratio is of course 1:1.

Producers who experience diminishing speeds are experiencing the realities of dynamic contention ratios on their local network as more users access it. This is particularly felt on mobile broadband networks as multiple mobile users (ie travelling public) move into and out of cells. On their own, contention ratios don't tell the full story as the carrying capacity of the local network is also important. For example, a 50:1 contention ratio results from 50 users attempting to exploit their 2 Mbps capacity connection (100 Mbps in total) on a single 2 Mbps link (ie 100:2 = 50:1). During peak periods, those users could conceivably experience, as low as 40 kilobits per seconds.

During quiet times with only two active users, each would then share the link and experience 1 Mbps. Here the net capacity plays a major role in the fluctuation. The only solution is to reduce the contention ratio. In a larger capacity 40 Mbps network segment, catering for (as an example) as many as 1000 users each promised 2 Mbps (a total of 2000 Mbps) that also equates to 50:1 (ie 2000:40) contention ratio – and yes the worst case scenario is, again, 40 kbps. However, this assumes absolutely 100% peak demand from every user. The peaks and troughs are smoother, and higher. Certainly during quieter times (eg when 990 users aren't using it), 10 users could enjoy up to 4 Mbps, and 2 users would get a whopping 20 Mbps. The highest maximum speed is usually only achieved at low usage times, for example during the night, and the bandwidth capacities of the supporting network in a producer's area may have a greater impact on internet speed.

This is what really frustrates producers; contended services are quite often sold quoting the highest maximum speed but usually only guarantee a minimum data throughput speed. Producers want the gap between quoted speed and guaranteed speed closed.

A contention ratio of 50:1 is about average for a typical residential connection, and of course this too can vary in peak usage/demand times – but overall the network carrying capacity for residential users is typically much greater than for a sparse network of mobile towers, or towers in isolated regions for example. Certainly, a residential network provider promising a contention ratio better than 50:1 usually stands out. It should also be noted that contention ratios also effectively only work in plans with unlimited data; data-capped plans in which limits have been exceeded can significantly skew results.

The Rise of Second-Tier Telecommunications Providers

The last two to three years have seen the emergence of second-tier telecommunications service providers seeking to deliver end-to-end services on farms. While offering a fresh alternative to existing network operators (tapping into frustrations around perceived accessibility to service and support), what they are really selling is guaranteed performance/speed on what is, in many cases, a tailor-made uncontended (1:1) network. From a consumer perspective, this really sticks out!

These providers, typically certified carriers in their own right, have access to large capacity transmission infrastructure such as dark fibre and regional points of presence (POP) from which to launch wireless connectivity. They are often offering managed fibre services, purchasing portions of spectrum for necessary point-to-point links, and are seeking physical space on existing point-to-point transmission infrastructure or negotiating access to high points such as local SES towers or grain elevators etc. At the farm

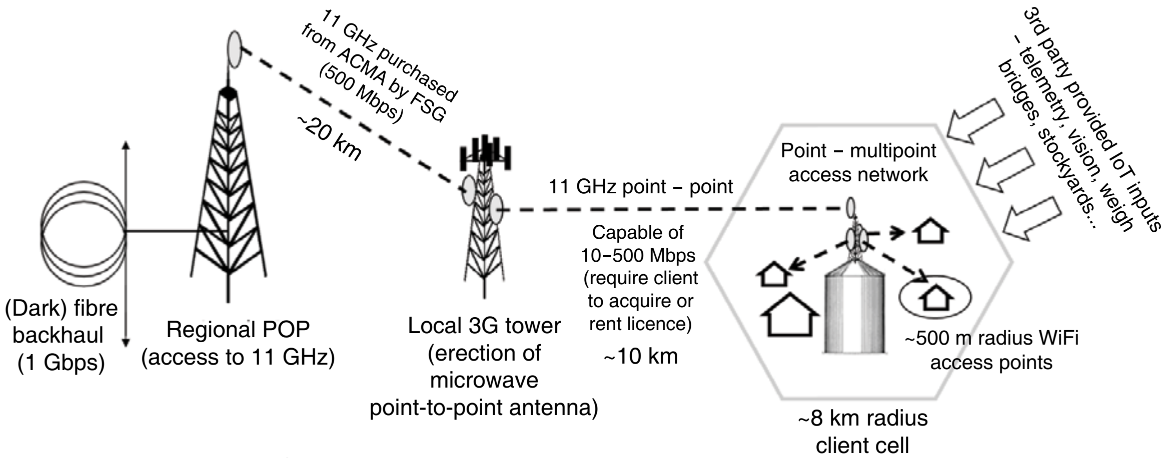

Figure 1: Example schematic of an end-to-end solution provided by a 'second-tier' telecommunications solutions provider and utilising existing backhaul infrastructure.

Source: Extracted from Lamb (2017a).

end they will have either an integral networking capability to provide ongoing point-to-point and point-to-multipoint connectivity across the farm, or will partner with local wide area network providers, and even with IoT providers to run connectivity literally into the sheds, troughs, tanks and machines (for example Figure 1, previous page).

In addition to offering the networking capability, many of these second-tier providers act as internet service providers (ISPs) and offer defining data packages that include immunity from 'shaping' (the slowing of a connection which has exceeded its allocated download allowance), for example shaping under the National Broadband Network (NBN) Fair Use Policy and competing carriage service provider (CSP)/ISP data agreements (Lamb 2017a). The defining point is that they seek to guarantee speeds of 10 MBps up to 100 MBps up AND down. For many clients (and especially the first ones connected) in a sequence, contention ratios are 1:1, and invariably the gap between quoted and guaranteed speeds in small. This is what producers want: speeds in the morning (and night) approximately equal to speeds during the afternoon.

Avoiding the Fall of Second-Tier Telecommunication Providers

Since the 2016–17 P2D project review, a small number of second-tier providers have already disappeared off the radar for a number of reasons. This is worrying given the lack of end users' digital literacy (Lamb 2017a) and the complexities of the connectivity solutions that must be supported. Even the more experienced solutions providers (those with deep experience in the telecommunications industry) acknowledge the challenges of their operating environment, including reliance upon established network operators at one or more segment in their solution chain. Experience is showing that experience counts. Here are some examples.

Many second-tier service providers cite access to existing physical infrastructure, for example telecommunications towers and backhaul networks, including fibre, as one of their biggest challenges in connecting rural properties (Lamb 2017a). In order to facilitate a connection they are exploring every possible network pathway, including accessing fibre networks utilised by local agencies and utilities. One provider described a scenario in the Riverina whereby accessing 'dark fibre' (unused fibre) to run connectivity out to a nearby farm required installing a dish on a particular tower (POP). However, the tower in question did not have the mechanical scalability to support the dish required for the onward point-to-point link. The fibre network could not be accessed unless the provider built an entirely new tower on which to mount the dish, or pay additional ~$125,000 for improving the strength of the original tower. In another scenario the producer had a private radio tower but, because they required a 3 metre (100 kilogram) antenna (1.5 m deep), it would not have been capable of supporting the dish in a storm.

Providers also expressed concerns that prices will go up; certainly as more and more users contest physical space on towers (a limited resource unless new ones are built at significantly extra cost). One provider observed that a mobile network operator that owns a tower can charge $10,000 just for a feasibility study to access that tower. The application fee itself then costs $4000–5000 – plus $900–1100 per month to rent space on tower. All of these charges are passed onto the client. The challenge of tower space could be alleviated by sharing dishes; for example by using multi-spectrum dishes.

There is also the price of spectrum. The 11 GHz spectrum supports relatively wide channels and hence lots of data throughput. This spectrum is considered affordable. For example, to run an 11 GHz link from a particular farm in northwestern NSW to a 3G tower 10 kilometres away costs $800–900 per annum. As more links go up then ultimately the available spectrum on that tower will become exhausted. In that case the alternative is to resort to the 8 or 5 GHz spectrum, with less capacity and a factor of 3–4x increase in license cost (ie thousands of dollars a year). Moreover, at the lower frequency, antenna size (and weight) also increases, placing a greater physical burden on infrastructure, and antenna are more expensive (~$7000 per dish). Alternatively there is the 'public park' spectrum (5 GHz, 2.4 GHz, 915 MHz bands), but providers worry that it is difficult to guarantee client freedom from congestion (as distinct from contention) as more and more users utilise it.

The spectrum challenge could be reduced were existing network operators to consider spectrally efficient means of operating links (eg spectrum pooling), or allow use of multi-directional antennas that operate on the same frequency. For example, a privately-owned point-to-point link is rated at milliwatts compared to the multi-watt powered links utilised by major network operators in their point-to-point links.

Providers also cited challenges in dealing with the wholesale side of network operators, mainly from the perspective that client services (at wholesale levels) are often not as mature/established as their retail arms. This makes negotiations and subsequent contracting difficult. At the end of it all, the costs of spectrum and infrastructure are passed onto the consumer – in this case, the producer. One producer (client) recently cited receiving a quotation for an end-to-end connection solution that included ~$250,000 to access nearby fibre (2018, personal communications with author). In the producer's own words: 'This stuff isn't cheap' (2018, personal communications with author).

A key ingredient for survival of these second-tier providers (and obviously for the sustainability of the connectivity solutions used by their clients) is that they must be experienced in the telecommunications industry in order to get the best possible solution for their clients. In a nutshell, when it comes to accessing spectrum, backhaul network capacity and physical infrastructure for clients, the message consistently received from second-tier telecommunications providers is simple: 'first in, best dressed, as costs may go up!' (Lamb 2017a).

The majority of second-tier network operators consulted in the P2D project agree that would-be clients' lack of knowledge of the basic concepts in telecommunications undermines both their willingness and confidence to accept solutions (Lamb 2017a); the digital literacy issue referred to earlier. Costs didn't seem to be a barrier. Costs can range from $15,000–40,000 for infrastructure plus a client's first tranche of data, but many innovative producers generally 'know their own business' and cite the value of even the simple things such internet access at workers quarters (often known as camps) to be a major driver of seeking improved/alternative connectivity solutions. Producers cited already paying thousands of dollars in mobile network operator (MNO) fees per month during peak work periods (eg harvesting, planting) to keep their workers connected at their accommodation. Many producers are seeing the cost of connecting devices on their farms as a realistic expense.

Back to the Future: Ngara

Bearing in mind some of the challenges identified by the second-tier providers in the previous section, it is useful to discuss a particular technology which was developed in Australia to augment existing and planned infrastructure capability. What makes it particularly interesting is that the technology appears to be forgotten. The CSIRO has been working on a spectrum-efficient broadband wireless technology – known as Ngara – since 2009, initially field testing the concept in Smithton, Tasmania in 2011 (CSIRO 2011, 2012). Ngara was initially conceived to meet the fixed wireless broadband needs under the then-proposed NBN and address mobile network gaps. So, where is Ngara? Ten years down the track (and with fixed wireless NBN part of the broadband technology mix today), is the technology relevant today?

The Ngara system comprises several telecommunications components: point-to-multipoint wireless access (within a cell), point-to-multipoint backhaul (sometimes referred as fronthaul), point-to-point microwave and point-to-point E-band backhaul (Figure 2, over page). E-band refers to 71–76 and 81–86 GHz bands which are used for ultra-high capacity point-to-point communications. The E-band backhaul was specifically customised for low latency, high frequency trading. The point-to-multipoint backhaul component of the 2012 and ongoing trials utilised a portion of the 3.4 GHz spectrum donated by Optus (CSIRO 2012). Spectral efficiency (measured in bps/Hz) is achieved through two means; multiple user terminals (eg households, sheds etc.) with a single antenna and a central access point comprising multiple antennas (Figure 3, over page).

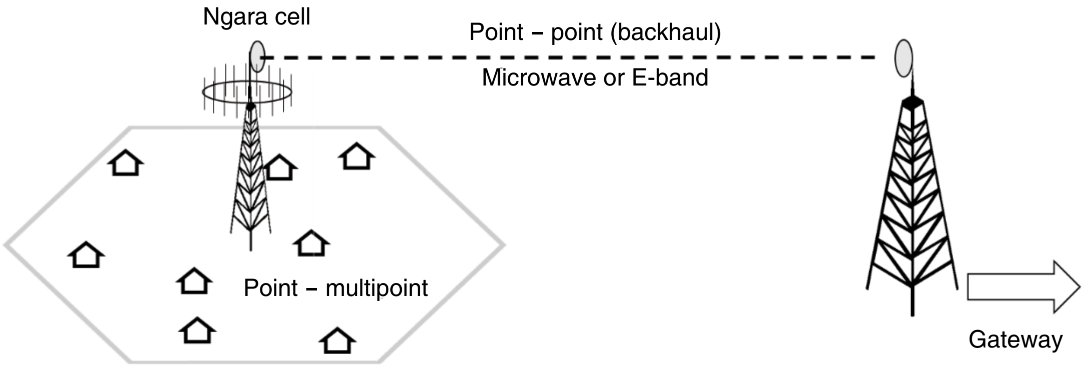

Figure 2: The basic telecommunications components of the Ngara system.

Source: Extracted from Lamb (2017a).

(a) (b)

Figure 3: **(a)** A UHF (641 MHz) user terminal (with directional Yagi antenna), in this case located in an open paddock 8.4 km from the receiver tower during the 2011 Smithton Tasmania trial. (Photo extracted from CSIRO 2011.)

(b) The heart of a Ngara cell is the receiver tower, comprising multiple receiver antennas; this one used for the Macquarie University point-multipoint backhaul trial (3.4 GHz).

Source: https://www.csiro.au/en/Research/Technology/Telecommunications/NgaraMQtrial-2015.

Within the Ngara cell (Figure 2), the multipoint connections utilise orthogonal frequency division multiplexing (OFDM) which allows multiple data streams to be transmitted in a single slice of spectrum (CSIRO 2011). OFDM uses as a multi-carrier modulation method. Here a large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Orthogonal means 'at right angles'; in telecommunications this refers to two simultaneous signals that are both detectable. Hence orthogonality refers to detecting multiple data streams in the same channel and at the same time.

A second means, which capitalises on the sparse nature of user terminals within the cell, is a space division multiple access (SDMA) method called Multi-User MIMO (MU-MIMO). Effectively this means that users in different directions from the receiver can transmit on the same frequency. The 2011 trial demonstrated data rates of 12 Mbps 'up and down' (24 Mbps aggregate) for six simultaneous users in only a single 7 MHz (TV) channel, using two-way video streaming as the means of demonstration. This represented a spectral efficiency of 20 bps/Hz, compared to typical values ranging from 0.5–4 bps/Hz for a single digital TV channel. A second trial in

Figure 4: A group of six of the 12 laptop computers each streaming four high-definition videos via a Ngara point-multipoint link.

Source: Photo extracted from Lamb (2017a).

2012 demonstrated 50 Mbps symmetrical (ie 50 Mbps each way, or 100 Mbps aggregate) to 12 simultaneous users in only 28 MHz of spectrum, yielding a spectral efficiency of 40 bps/Hz (Figure 4). Subsequent efficiencies up to ~67 bps/Hz have been reported. By using frequency multiplexing techniques this system would be capable of providing 12 Mbps symmetric (ie up AND down) to a community of up to 1000 residences.

Demonstrations of the completed integrated system consisting of the 50 Mbps symmetrical access and a 10 Gbps microwave backhaul technology using a point-to-point link over 50 km (simulated) were conducted in 2012 (CSIRO 2012) and continue today.

Ultimately the Ngara systems, both point-to-multipoint and point-to-point, have performance characteristics that are worth revisiting in light of potentially augmenting the wireless networks currently servicing Australian producers, and some of the challenges discussed earlier. For example, Ngara does not exhibit the limitations experienced by mobile network clients on sector boundaries within a cell. Ngara has a greater data capacity for the same available spectral bands. In supporting point-to-multipoint links, and compared to a similar configuration involving single radio microwave links, Ngara requires smaller (lighter) antennae (omni-directional antenna at the cell hub and directional antennae at the access points). The latency of a Ngara point-to-multipoint link is considerably less than satellite-direct links. In the case of point-to-point transmission links, the Ngara E-band link achieved the highest E-band transmission rate (5 Gbps), provided the longest E-band range (12 km, no rain) and produced unprecedented (low) latency. CSIRO have E-band designs capable of supporting up to 40 Gbps. Ngara point-to-point microwave transmission links, designed for the 30–50 km ranges, are capable of providing multi-Gbps transmission rates at a cost comparable to the present ~300 Mbps (single channel) links.

Through software-defined radio (SDR), a single Ngara radio uses all available channels, both adjacent and non-adjacent, with no performance compromises. Effectively SDR is a radio communication system where components traditionally implemented in hardware are implemented by means of software on an embedded system. SDR can avoid the typical limited spectrum conditions of networks by dynamic selection of multiple channels, spread spectrum and ultra-wideband techniques that allow several transmitters to transmit in the same place on the same frequency with very little interference, and software defined antennas which adaptively lock onto a directional signal, so that receivers can better reject interference from other directions and hence detect fainter transmissions.

Importantly, a single Ngara point-to-point link dish could potentially replace a multitude of dishes operated by different network operators that are tailored to their fixed bands. Ngara point-to-point technology could reduce the physical infrastructure demand on existing point-to-point transmission towers and provide more efficient use of available spectrum.

Ngara technology has the potential to augment existing and planned network expansion in rural and regional Australia (namely mobile networks, NBN fixed wireless and NBN Sky Muster),

ultimately providing options for end users such as producers and connectivity solutions providers alike. It is important to note that the underlying Ngara technologies are largely frequency independent. For example the Macquarie University point-to-multipoint backhaul system was a version of the point-to-multipoint access technology used in the earlier Smithton trial but at a higher frequency. In that case a Ngara user terminal was co-located with a Wi-Fi access point on the distributed end user buildings and end users used standard Wi-Fi technology as a means of accessing the system. Ultimately Ngara offers an alternative network solution rather than a telecommunications solution. Ngara point-to-multipoint technology could offer a spectrally-efficient networking solution to complement existing telecommunications developments.

At present Ngara point-to-multipoint technologies lack a manufacturing partner (bearing in mind that Ngara has significant market opportunities overseas). The Ngara E-band backhaul technology has been licensed to Brisbane-based company EMClarity Pty Ltd.

Looking Ahead

Thanks to producer demands for reliable external connectivity on their farms, a new service provision market is evolving; so-called second-tier telecommunications providers, offering end-to-end solutions that includes hardware and ongoing service provision. However, challenges in getting connected at the network end remain. An opportunity also exists to draft in Australian network technology and knowhow, already developed but seemingly forgotten, to complement network improvements and expansion, ultimately benefiting farmers. Gaps in mobile network coverage remain.

Producers are excited about the ongoing evolution of mobile network technologies; for example 5G, which offers Gbps download and ~100 Mbps upload speeds, and the type of connectivity capable of supporting cloud-based, vision-based analytics capability.

Moreover, planned 5G trials and rollout plans are likely to place Australia at the leading edge of 5G roll-out worldwide, but again reality kicks in. Producers hope that the ongoing mobile black spot program won't be distracted into focusing on improving mobile network capacity (ie upgrading 3G and 4G to 5G) in urban centres (and at sporting events) and stay focused instead on filling real black spots where there is little or no 3G or 4G available at all. Is that likely?

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David established the University of New England's Precision Agriculture Research Group (www.une.edu.au/parg) in 2002 and leads the university's SMART Farm project (www.une.edu.au/smartfarm); a 2900 ha, 'highly-connected', predominantly grazing property serving as an education, outreach and R&D farm showcasing the latest innovations in digital agriculture.

David has co-authored more than 100 peer-reviewed scientific publications, a book and numerous book chapters in the area of precision agriculture. He currently serves as a Science Director in the Cooperative Research Centre for Spatial information and is a member of the National Positioning Infrastructure Advisory Board.