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# Potential declaration of domestic roaming in Australia – Technical issues

## Report for Telstra

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# 1 About the authors

1. This report has been prepared by the following Aetha Consulting experts<sup>1</sup>:

**Graham Louth** (Partner) has over 25 years' experience in the telecommunications industry, originally as a leading advisor to operators and regulators on regulatory issues such as universal service, interconnect pricing, retail price control, margin squeeze analysis and market reviews; then as Director of Spectrum Policy at Ofcom, the UK's electronic communications regulator. In that role, he was responsible for many of the most significant developments in spectrum policy during that time, including the introduction of spectrum trading and liberalisation, refinement of spectrum pricing, auctioning of key spectrum bands, including the UK's 4G auction of the 800 MHz and 2.6 GHz bands, and regulatory reviews of various mobile network sharing and merger agreements. Graham also played a wider role within Ofcom as a member of the senior management group, reviewing and guiding regulatory policy across the whole of Ofcom, and playing an active role in the management of the organisation. Graham joined Aetha Consulting as a Partner in September 2014, and has since then been actively advising a range of clients worldwide on regulatory and spectrum issues. In particular, in late 2014 Graham supported the UK mobile operators (collectively) in their discussions with the UK Government over its proposal to require national roaming, helping to explain the problems that national roaming would create for end-users, and proposing an alternative solution to the problem of partial not-spots<sup>2</sup> – a 90% geographic coverage commitment by each operator.

**Steve Lewis** (Associate) is an experienced consultant, telecoms solutions architect, commercial manager and professional engineer in the mobile telecoms space. He has particular expertise in the design and implementation of wholesale service agreements between mobile network operators (MNOs), mobile virtual network operators (MVNOs) and mobile virtual network enablers (MVNEs), having negotiated and implemented a number of such agreements worldwide, including for Lycamobile in Australia and as CTO of PrimeTel in Cyprus. The technical arrangements that underpin these agreements have a lot in common with domestic roaming, and Steve is consequently well versed in the details of the practical delivery of such services.

**Prof. William Webb** (Associate) is an independent wireless technology and regulatory specialist. He is CEO of the Weightless SIG, the standards body developing a new global M2M technology, and was President of the IET, Europe's largest Professional Engineering body, during 2014/15. He was one of the founding directors of Neul, a company developing machine-to-machine technologies and networks, which was formed at the start of 2011 and subsequently sold to Huawei in 2014 for \$25m. Prior to this William was a Director at Ofcom where he managed a team providing technical advice and performing research across all areas of Ofcom's regulatory remit. He also led some of the major reviews conducted by Ofcom including the Spectrum Framework Review, the development of Spectrum Usage Rights and most recently cognitive or white space policy. Previously, William worked for a range of communications consultancies in the UK in the fields of hardware design, computer simulation, propagation modelling, spectrum management and strategy development. William also spent three years providing strategic management across Motorola's entire communications portfolio, based in Chicago.

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<sup>1</sup> More complete CVs for all three of the authors can be found in Annex B of this report.

<sup>2</sup> Areas where at least one mobile network operator has coverage, but not all mobile network operators.

## 2 Introduction

2. We have been engaged by Gilbert + Tobin on behalf of Telstra Corporation Limited (Telstra) to prepare a report, based on our expert opinion, which addresses the following question:

*What are the technical issues, if any, that would arise if wholesale domestic roaming was declared without any geographic limitations? Please consider how and to what extent your opinion would differ if the declaration was subject to geographic limitations.*

3. Gilbert + Tobin's letter of instruction to Aetha Consulting is set out in full at Annex A of this report.
4. We have each read the Harmonised Expert Witness Code of Conduct (Annexure A to Federal Court of Australia Practice Note GPN-EXPT) and agree to be bound by it.
5. Our report focusses on:
  - a) The limitations and adverse consequences, for end-users and network operators, of the wholesale domestic roaming services that are technically feasible today;
  - b) The technical means by which the availability of domestic roaming could be geographically limited today, and the extent to which the limitations and adverse consequences previously identified would continue to arise in this case;
  - c) The impact on the quality of services provided to existing end-users of Telstra's network of the increase in network traffic that would be likely to follow from the declaration of wholesale domestic roaming services (whether limited geographically or not); and
  - d) The investments and other changes that mobile network operators (Telstra in particular) would have to make in order to be able to provide wholesale domestic roaming services (whether limited geographically or not).
6. Given the extent of Telstra's existing coverage of the population and landmass of Australia, we do not expect Telstra to have much interest in acquiring wholesale domestic roaming services from other mobile network operators (MNOs). Our report therefore focusses on the provision of wholesale domestic roaming services by Telstra to other MNOs. We anticipate that much of what we say would also be applicable to Singtel Optus Pty Limited (Optus) as a potential provider of wholesale domestic roaming services to other MNOs, e.g. Vodafone Hutchison Australia Pty Limited (VHA), but we have made no attempt to analyse the specifics of that case.
7. Our analysis assumes that:
  - a) If wholesale domestic roaming services were declared, they would only need to be provided to other Australian mobile network operators (MNOs) i.e. to businesses with their own Australian mobile network code and mobile network infrastructure in Australia, including both core and radio access networks, and not to mobile virtual network operators (MVNOs)<sup>3</sup>; and

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<sup>3</sup> The provision of wholesale services to MVNOs is not roaming in our view.

- b) If wholesale domestic roaming services were declared, the services to be provided would be roaming services, and not any form of active network sharing (which would raise a completely different set of issues).
8. To determine the technical issues that would arise if a declaration of wholesale domestic roaming was made, our approach has been:
- a) To review current mobile technology standards to confirm their support for the form of domestic roaming that we set out in this report;
  - b) To draw on the analysis of technical and operational issues associated with domestic roaming which Aetha Consulting undertook for the UK mobile carriers in the UK's recent review of domestic roaming;
  - c) To obtain information from Telstra as to the capability of their current network as regards international roaming, and the manner in which they have provided domestic roaming in the past. This information was largely obtained from various discussions with Telstra employees as part of a dialogue to ensure we properly understood the relevant parameters of the Telstra network required for our analysis, and was also informed by the witness statement of Mr Michael Wright;
  - d) To assess the impact of these technical issues on end users and Telstra's network, in light of the information gathered in a), b) and c), including in circumstances where geographic limitations are placed on domestic roaming.
9. Given the detailed information required to analyse the impact of additional traffic on the quality of services provided to existing end users of the Telstra network, and time constraints, our approach to this task was to ask Telstra to undertake certain quantitative analyses using its own network modelling tools. We then undertook our own cross-check analysis to validate the Telstra modelling, and analysed the Telstra results.
10. This quantitative analysis utilised data and results from Telstra's "Devil" system<sup>4</sup>, which is a traffic and capacity monitoring system used by Telstra to forecast traffic growth and predict when capacity enhancements to the network are likely to be required. Our understanding of Devil and the data extracted from Devil was also informed by various conversations with Mr Max Downey.
11. Throughout our report, we refer to declared wholesale domestic roaming as "domestic roaming".

### 3 Summary of conclusions

12. Domestic roaming has significant limitations and adverse consequences that could potentially impact a large number of end users – not only the users of domestic roaming services, but also the existing users of Telstra's network in regional Australia and more generally. Domestic roaming users will not experience a seamless service – their calls will continue to drop when they lose coverage from their home network, and they will not be able to access mobile data services whilst their mobile device is searching for another network (which may be frequently in some situations). They may

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<sup>4</sup> Devil is comprised of two systems – Devil (which relates to Telstra's 3G network) and eDevil (which relates to Telstra's LTE network) – see the statement of Max Downey.

also experience a reduction in the battery life of their device. A number of cells in Telstra's network are likely to become congested, worsening the experience for all users, whether roaming users or existing Telstra users – increasing the chances that they will be unable to make an outgoing call, be unable to receive an incoming call, or suffer a dropped call. Mobile data speeds are also likely to fall, potentially limiting the applications that users will be able to use in future. There is also the risk that a technical problem with either Optus's or VHA's network will cause Telstra's network to become significantly overloaded and consequently also fail. None of these problems are easy to solve technically, and many may be impossible.

13. Whilst limiting the geographic availability of domestic roaming has the potential to mitigate some of these problem, it is by no means a panacea. Moreover in practice it is unlikely to be possible to limit domestic roaming solely to those areas where each access seeker does not have coverage. In practice therefore we expect geographically-limited domestic roaming to suffer all of the same limitations and adverse consequences.
14. In order for domestic roaming to work effectively and efficiently it will be necessary for the mobile network operators to share with each other highly sensitive commercial information, such as their forecasts for customers and traffic, and their plans for network upgrading and expansion. There will in practice have to be a degree of coordination between the network operators as to their network plans. The potential impact on competition of this essential coordination will need to be considered.

## 4 Assumed implementation of domestic roaming

### 4.1 Introduction

15. We have assumed that domestic roaming in Australia would be implemented in line with relevant international standards (e.g. 3GPP standards), and consequently would to a large degree mimic current implementations of international roaming. We understand that this model of roaming has been implemented in the Telstra network in the past (see paragraphs 149 to 154 of the statement of Michael Wright). For a layperson's guide to how roaming works see Annex C.
16. However, we envisage that mandatory wholesale domestic roaming in Australia would likely deviate from international roaming as it is usually implemented in one key respect, namely, the extent of Customised Applications for Mobile network Enhanced Logic (CAMEL) control. We are of the view that it would be sensible for all calls made by end users whilst roaming domestically in Australia to be CAMEL controlled by their home network, so as to ensure that the service those end users received was as similar as possible to the service that they would receive on their home network, whilst minimising the need for coordination between the operators.

### 4.2 The need for CAMEL control

17. The traditional model of call control for outgoing voice calls made by international roamers was for them to be managed solely by the visited network. This had a number of consequences, of which the most important for our discussion here was that the customer was unlikely to be able to make use of certain special short-code numbers that their home network operator had defined – to access services such as their home voicemail server or customer care centre – as the visited network would not recognise these short codes (or would route them to the visited network operator's service rather

than the home network operator's service). More generally, the services available would be those of the visited network operator rather than the user's home network operator.

18. To address these issues, standards have been developed to allow the home network a greater degree of control over calls, texts and data sessions originated by roaming subscribers on a visited network – CAMEL<sup>5</sup>. If both home and visited networks implement CAMEL, the home network can instruct the visited network to apply CAMEL control to any call, text or data session originated by a roaming subscriber when it authorises the visited network to allow the subscriber to roam. In practice this is mostly used for voice calls, as texts and data sessions can be controlled by the home network by other means.
19. When a user makes an outgoing call under CAMEL control, the call is controlled by the home network rather than the visited network. This allows the home network, for example, to instruct the visited network to route a call to a different number to the one actually dialled by the customer (number translation) – for example to route a call to the customer's home voicemail service or customer service centre when they dial the relevant short-code. CAMEL therefore allows home networks to control their own short codes, dialling plans and charging, including making changes thereto, without having to coordinate with the visited network.
20. The alternative would be for VHA and Optus to provide Telstra with details of their dialling plans and short codes, and for Telstra to hard-code those into its Mobile Switching Centres. This would be costly, and would also make it significantly more difficult for VHA and Optus to subsequently make changes – for example to add a new short-code.

## 5 Technical issues for end users and network operators if wholesale domestic roaming was declared nationwide

### 5.1 Introduction

21. In our view, if one or more MNOs in Australia were required to supply wholesale domestic roaming services, those services would necessarily be subject to a number of limitations which are inherent to the model of roaming described above. In addition, domestic roaming would have a number of adverse consequences for both end users and network operators which are also inherent to this model of roaming.
22. In this section we discuss these limitations and adverse consequences in the context of a declaration of domestic roaming on a national basis. In the next section, we discuss how these issues would play out if domestic roaming was limited geographically.

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<sup>5</sup> CAMEL can also be used to control incoming calls and texts.

23. In summary, the limitations and adverse consequences of domestic roaming would include:
- a) No seamless handover of calls between networks – If a user has a voice call in progress and then loses coverage from the network they are currently connected to, whether that be their home network or a visited network, the call will terminate (drop), even if another network is available on which the call could be continued. The user will have to redial once their device has found and connected to an available network (which may take anywhere between a few seconds and a few minutes). Mobile data sessions would also be interrupted during this process, but, depending on whether the relevant data application is sensitive to delay, it can matter less.
  - b) No managed handover of user devices between networks – If a user device loses coverage from the network to which it is currently connected it will have to look for another network to connect to itself. During this time, which may last anywhere between a few seconds and a few minutes, it will not be possible for the user to make or receive calls or texts, or use mobile data services. The manner in which the user device chooses a network to connect to also means that it will not always be connected to the network with the best signal in the area.
  - c) Reduced battery life of user devices – The battery power required to search for a new network and also to send a location update to the network are both relatively high. It is common for home network operators to require roaming devices to make frequent attempts to reconnect to their home network – this can reduce the battery life of user devices for roaming customers.
  - d) Finally, there is a need for competing MNOs to share commercially sensitive information with each other for roaming to work – To support efficient and robust network planning, operators whose customers are likely to roam onto a visited network are likely to have to share forecasts of their roaming customer numbers and traffic with the visited network on a regular basis. Visited networks may also have to share details of their planned network changes with the operators whose customers roam onto their network. The extent of information sharing required may raise competition concerns.
24. In addition to the above limitations and adverse consequences that apply to roaming in general, two additional adverse consequences can arise with domestic roaming in areas where the home network and the visited network both have coverage (areas of overlapping coverage)<sup>6</sup>. If domestic roaming was declared in Australia on a national basis, the areas of coverage overlap between Telstra's network (as access provider or visited network) and Optus or VHA's network (as access seeker or home network) would, we understand, be very extensive, encompassing practically all of the areas where Optus or VHA have coverage, since Telstra also have coverage in almost all of these areas.
25. The following adverse consequences can arise with roaming where there is overlapping coverage:
- a) 'Ping-ponging' of devices between networks – In areas of relatively poor or patchy home network coverage<sup>7</sup> where domestic roaming is also available, end user devices are likely to

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<sup>6</sup> These adverse consequences do not generally arise in the context of international roaming because there is, in general, no overlap in coverage between home and visited networks.

<sup>7</sup> Noting that such areas may exist even in areas of otherwise good home network coverage. For example a customer may receive good coverage from their home network on one side of their home, but poor coverage on the other side or in their basement. 'Ping-ponging' can therefore be a problem even in areas that might appear to have good home network coverage if wholesale domestic roaming is also available.

frequently lose coverage from their home network, roam onto a visited network, but then reconnect with their home network a few minutes later. This will further reduce the battery life of the device, lead to frequent periods when the customer is unable to make use of their device because it is looking for another network, and potentially lead to missed incoming calls. It will also create a lot of signalling traffic on the visited network which may require additional investment in capacity in the visited network.

- b) Risk of cascading network failure – If a home network suffers an outage in an area in which domestic roaming is also available, the end user devices of all of its customers in that area will almost immediately try to roam onto any other network in the area onto which they were allowed to roam. This has the potential to overload the other network with the result that it too may fail, either in the same area or more widely.
26. In practice, for many users, in particular those that frequently suffer from ‘ping ponging’ due to patchy home network coverage but who rarely go far outside the coverage of their home network, the limited benefit that they would derive from being able to access services outside the coverage of their home network may be materially outweighed by the adverse impacts of domestic roaming, such that they would be better off without it.
27. We discuss each of the issues we have identified in further detail below.

## 5.2 No handover of voice calls between networks

28. In 2G, 3G and early 4G (pre-Voice over Long Term Evolution) networks there is no provision for inter-network handover of an active voice call (see 3GPP 23.009). Customers will not therefore enjoy a seamless voice service even in areas where both the access provider’s network (visited network) and the customer’s home network (i.e. the access seeker’s network) have coverage, because it will not be possible to perform an in-call handover between the networks. Calls that start on either network (whether outbound or inbound calls) will terminate (be dropped) if the customer loses signal from that network, even if the other network has coverage in the same area. The customer will have to wait until their device has searched for, found and connected to the other network before they will be able to redial to continue the call. Also, calls that start on a visited network will remain on the visited network until the call ends even if the customer returns to an area where their home network has coverage (i.e. they will not be handed over to the home network).
29. This limitation will be most obvious at the ‘edge’ of the home network’s coverage or where the home network’s coverage is poor. However, even in areas of supposedly good coverage and in metropolitan areas where the access seeker can be expected to have invested heavily in deep network coverage, there will in practice be places where service is not available from a particular network – micro ‘not spots’.
30. There is no technical solution within the standard model of domestic roaming for the problem of calls dropping as a result of moving out of coverage (including into micro ‘not spots’), because in-call handover between networks is not supported by the roaming standards.
31. Any solution for in-call handover for domestic roaming will be highly complex both to implement and to operate, and may require special software from network equipment vendors. In practice, in order to achieve seamless handovers, a form of radio access network (RAN) sharing would likely be required, which would be significantly more expensive and complex to implement than domestic

roaming (see 3GPP TS 23.236). This would typically involve joint investment in network assets by the sharing parties, and/or the transfer of network assets by the parties into a joint venture company.

### 5.3 No managed hand-over of user devices between networks

32. There are no mechanisms defined for 2G, 3G and early 4G networks to manage how a user device connects to different networks in a domestic roaming context. If a user device is on its home network, it will remain on that network until it loses signal from that network even if it could get a better quality signal from another network. Moreover, once it has lost signal from its home network it has to search for and register with another network itself – it will not be seamlessly handed over to the other network by the networks themselves. The same is also true in reverse – a user device that is roaming onto a visited network will not be seamlessly handed back to its home network if it loses signal from the visited network – the user device will have to search for and re-register with its home network itself.
33. The user device employs a search algorithm based on the priority that the home network assigns to different networks. If the user device finds a network that it is not explicitly blocked from trying to access, it will attempt to access it. If it finds several, it will try the highest priority network first. The user device does not give higher priority to networks with better signal quality, except in the situation where it cannot find any network with a satisfactory signal.
34. Generally speaking, if the user device cannot see a signal from the home network, it will search for a visited network that it can access. Neither the home network nor any visited network can direct the user device to use a particular network in a particular area. It is therefore unpredictable which networks the user device will seek to access (and down to the visited network and home network to block access if it is not permitted).
35. When the user device loses coverage of the network that it is registered on it will start a search for a new network that it can access. A search for a new network (on loss of coverage) typically takes between a few seconds and several minutes. While the user device is in this state it cannot make or receive calls, send or receive messages, or access data services.
36. A user device will not change networks simply because a higher quality signal is available. Nor will it choose the network with the best quality signal when it is looking for a network to attach to, unless there is no network available with satisfactory signal quality (in which case the user device will attempt to connect to the network with the best available signal quality that it can see, notwithstanding that that signal will necessarily be less than satisfactory).

### 5.4 Reduced battery life of user devices

37. When a user device is in idle mode it does not normally transmit radio signals to the network. This allows it to preserve battery life. It is able to ‘listen’ to a broadcast channel of a single base station very efficiently, so that it can respond to paging messages (for instance, for incoming calls and text messages).
38. If the user device is roaming on a visited network however, the user device will regularly search to see if its home network is available, and if it is, will try to attach. The frequency with which it does this is determined by the ‘higher priority network search period’ (as set by the home network and

stored in the user's SIM<sup>8</sup>). When an operator is relying on domestic roaming to provide coverage to its customers it is common for this period to be set as short as possible i.e. to 6 minutes, in order to get the user device back onto the home network as quickly as possible. This network search and reattach procedure is however battery intensive, and so these frequent attempts reduce the battery life of every user's device when they are roaming.

## 5.5 Need to share commercially sensitive information with competitors

39. Mobile operators dimension their voice and data networks according to the number of forecast users of their network and the anticipated usage patterns of those users. Typically, a three year quarterly rolling forecast is employed for ensuring that radio and core network capacity is available to meet the expected demands of users.
40. These forecasts need to reflect the likely demands on the network in total, not just from the MNOs own retail customers, but also from its wholesale customers (e.g. MVNOs and inbound international roamers). If wholesale domestic roaming is declared, this will also have to include the likely demand from domestic roamers.
41. In the case of international roaming the volumes involved are usually sufficiently low that MNOs do not require their international partners to provide specific forecasts – rather the MNO includes an allowance for such calls within its overall forecast.
42. In the case of domestic wholesale customers (e.g. MVNOs) however, it is common practice to require them to provide regular subscriber and subscriber usage forecasts (in a country like Australia often disaggregated geographically) so that they can be included in the overall user and traffic forecasts of the host MNO.
43. If wholesale domestic roaming is declared then it will, in our view, be essential to the proper planning and management of the networks that access seekers provide forecasts of the number of roaming users and volumes of roaming traffic that those users are likely to generate, and to do so on a geographically disaggregated basis. Given the potential volumes of roaming users and traffic, and the potential for those volumes to change in both the short and longer term as a result of unpredictable actions by the home network operator – for example marketing campaigns and retail price changes – without such information there is a very real risk of short-term network problems and under- or over-investment in the visited network in the longer term.
44. As a specific example of this latter point – in the absence of information about planned coverage expansion by VHA and Optus, Telstra may decide to invest in additional capacity in a regional town in order to cope with the growing demand, from its own customers as well as from VHA and Optus customers roaming onto its network in that area. Telstra may make that investment only for VHA and Optus to deploy a new base station of their own in the same area soon after, significantly reducing the amount of roaming traffic on Telstra's network and rendering Telstra's investment redundant.
45. The MNOs that make use of wholesale domestic roaming services will also typically have a need for information about the status and any planned changes to the network(s) of the provider(s) of wholesale domestic roaming services, for example to allow them to keep customers informed of any

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<sup>8</sup> If no value is stored then a default value of 60 minutes is used.

issues with the operation of the network (for example periods when the network in a particular area is not available due to an outage) and to ensure that customers have access to up-to-date information e.g. about changes in coverage.

46. Whilst this level of information sharing is not unusual between MVNOs and their network hosts – indeed, as noted above it is generally viewed as being essential to the effective and efficient provision of services by MVNOs – the sharing of such sensitive commercial information between competing MNOs is generally viewed as undesirable because of the potential impact on the dynamic of facilities based competition. Indeed, in our experience, when considering proposed commercial roaming or network sharing arrangements, regulators and competition authorities often pay particular attention to the degree of information sharing that is proposed, and take steps to ensure that the extent of any information sharing is as limited as possible.

## 5.6 ‘Ping ponging’ of devices between networks

47. In areas of overlapping home network and visited network coverage the user device will tend to ‘ping pong’ between the two networks – by which we mean frequently switch between the two networks – leading to frequent periods of no service while the user device searches for a visited network, and even shorter battery life because searching for a network and registering is battery intensive. Ping ponging can also impose a high level of signalling load on the visited network.
48. ‘Ping ponging’ is particularly a problem where the home network has patchy coverage, including small ‘not spots’ within its footprint. But again, ‘ping ponging’ can occur even in areas where the home network has relatively strong or deep coverage for the following reasons:
- a) There is no such thing as contiguous coverage from a single operator. There will always be small or micro ‘not spots’ e.g. inside buildings, because of the variability of radio propagation through different environments (in particular the loss in signal strength when radio waves pass through walls and floors).
  - b) The coverage of 3G cells varies with the amount of traffic being carried, and consequently if there is a surge in demand users previously at the edge of coverage may lose service.
49. The problem arises when a user device loses signal from its home network, searches for and connects to a visited network, but then when it tries to reconnect to its home network 6 minutes later (the minimum period for the higher priority network search period) it is able to do so, only for it to once again lose signal from its home network shortly thereafter. And so on.
50. ‘Ping ponging’ occurs as follows:
- a) When a user device loses contact with its home network, or when the user device is switched on and the home network is not available, it will search for and attempt to access other networks according to the rules defined in 3GPP TS 23.122. The search and registration process may take between a few seconds and several minutes. During this time the device is unable to make or receive calls, send and receive messages, and is not able to access data services. Paging messages for incoming calls may be missed altogether if they are sent via the home network while registration on the visited network is taking place.
  - b) Whilst registered on a visited network, periodically, according to the preference of the home network (see 3GPP TS 31.102), the user device will search for a higher priority network. This

takes place in the background when the mobile is in idle mode and is transparent to the user. If it finds its home network, it will move back to that network. This process typically takes less than 5 seconds. The user device will not be able to make and receive calls, send and receive messages, and is not able to access data services whilst this is taking place. Paging messages for incoming calls may be missed if they are sent via the visited network while registration on the home network is taking place.

- c) Where a user device is in limited home network coverage it is likely that it will start to search for visited network radio coverage and attach on a visited network. Every so often it will search for the home network and switch back, thereby alternating between networks. This is battery intensive and leads to periods where the mobile is not attached to any network (affecting the user's ability to make and receive calls, send and receive messages and access data services). However, if there were an active call or data session in progress the user device would delay searching for the home network until it was idle.
51. Frequent access registrations on the home network and visited network also create a high level of radio and core network signalling load on both the home and visited network. The base station that the mobile connects to must process the access requests, using up radio resources, and the fixed part of the network must carry these signalling messages from the base station to the servers in the network which process them.
52. Where radio or core network capacity on the visited network is already limited, this is likely to cause congestion for the visited network's customers as well as for in-bound roamers, leading to failed calls and poor data throughput.

## 5.7 Risk of cascading network failure

53. If either Optus or VHA suffers an outage in an area where roaming access to Telstra's network is permitted, it will result in all of their active customers attempting to access Telstra's network in a short time. This will place a very significant signalling demand on Telstra's network as these customers attempt to register, leading to a risk to the stability of Telstra's network and potential for it to also suffer a catastrophic outage. Such an outage would affect all of the users of Telstra's network in the relevant area, its own customers as well as any inbound roamers, and may even affect its ability to provide service to the emergency services.
54. To avoid such an outage in Telstra's network, Telstra might have to provide sufficient capacity to cope with all potential users from other MNOs accessing its network simultaneously and potentially doing so very suddenly. This would be very costly to provide and at the same time this capacity may be rarely if ever used. It seems to us unlikely that this would be economically efficient and in the best interests of mobile users in Australia – not least because the cost of this additional capacity may ultimately be passed on to consumers.
55. In the event that domestic roaming were limited geographically (as discussed below), there would nevertheless still be a risk of cascading network failure. This risk would exist even in areas where domestic roaming was not required but a visited network had coverage, albeit the risk may be lower than in areas where domestic roaming was provided. The problem would be that whilst user devices would not be allowed to roam on to the visited network in these areas in case of home network failure, they would still be able to request access (if they had not already tried and failed to gain access to the visited network in the same location area at least once since they were most recently

switched on). A sudden flood of such access requests may overload the capacity of the visited network to deal with such requests, potentially leading to its failure.

## 6 Limiting the geographic availability of wholesale domestic roaming services

### 6.1 Introduction

56. A number of the limitations and adverse consequences of domestic roaming that we have identified will apply regardless of whether roaming is mandated on a national basis or limited geographically, including no call handover, no managed device handover, reduced battery life, and the need to share a significant level of commercially sensitive information about future traffic and rollout plans.
57. As regards ‘ping ponging’ and the risk of cascading network failure, in theory if the geographic availability of domestic roaming could be limited to those areas where there was no coverage from a home network, the problem of ‘ping ponging’ would not arise and the risk of cascading network failure would be less severe (as discussed above). In practice however, for the reasons we discuss in this section, it is very difficult to define the geographic limits of domestic roaming in ways which completely eliminate overlapping coverage. The problems of ‘ping ponging’ and risk of cascading network failure are therefore very likely still to arise even if domestic roaming was declared on a limited geographic basis.

### 6.2 Standards support


58. The 3GPP standards that would support geographically-limited wholesale domestic roaming are as follows:
- a) The cells within a network are divided between a number of location areas<sup>9</sup> – each cell belongs to exactly one location area, but each location area typically includes a number of cells.
  - b) A visited network can allow or disallow roaming in each location area independently (but not for the individual cells within a location area), and this can be done independently for each home network operator.
  - c) When a visited network receives either a registration request or a location update from a roaming device, it will check to see if the subscriber concerned is allowed to roam in the location area that the device is now located within. If the user is not allowed to roam in that location area, the network will reject the registration request or location update using the message ‘roaming not allowed in this location area’. This tells the device that it might be allowed to roam onto this network elsewhere, but it isn’t allowed to do so in the current location area. The device stores this information so that it doesn’t keep trying to register with the visited network in this location

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<sup>9</sup> Location areas can be sub-divided into Routing Areas in 3G networks and Tracking Areas in 4G networks, but the current standards do not support rejecting roaming access requests (or location updates) at the level of these smaller areas.

area (although this information is lost when the device is switched off). The device then looks for another network in the same area onto which it can roam (if any is available).

### 6.3 Definition of location areas

59. Location areas were originally designed to allow networks to track the location of customers without having to know exactly which cell each customer is in at each point in time. When designing location areas for this purpose each network operator has to balance, on the one hand, the frequency with which mobile devices have to update the network as to their location (since mobile devices only have to send the network a location update when they move from one location area to another, not from one cell to another within a location area) and, on the other hand, the number of cells that have to broadcast a paging message to a mobile device when the network wishes to communicate with that device (given that the network only knows which location area the device is in, not the individual cell within that location area).
60. Paging for mobile terminating calls is an important component of radio planning and efficient use of radio spectrum. If location areas are too large then there may be congestion on the radio network due to the number of paging messages being sent to every cell in that area. If they are too small then there can be very high levels of location updating as devices move between location areas, which can also lead to radio network congestion. This can also have an adverse impact on the battery life of user devices, as the sending of a location update by a user device is relatively battery intensive. As the location areas would be the same for all users (no distinction is made for those that are roaming), all users would be affected. Location areas are likely to be smaller in urban areas and larger in rural areas.
61. The use of location areas to define the geographic areas within which domestic roaming is and is not allowed is therefore a fairly coarse tool, generally requiring domestic roaming to be switched on or off over fairly large areas of the country. 
62. Location areas may also be used for other purposes. For example location based services (allowing calls to be routed to a local business, for example), and emergency services access (allowing the emergency services to determine the approximate location of a calling subscriber) may also depend upon location areas for determining approximately where a subscriber is physically located. Making changes to the definition of location areas can therefore also have consequences for the provision of other services, which need to be considered.

### 6.4 The challenge of minimising overlapping coverage

63. To further understand the challenge of limiting the geographic availability of domestic roaming to those areas where a home network does not have coverage, we note that the location areas in a visited network can be divided into three types according to the extent of their overlap with the coverage of the selected home network<sup>11</sup>:

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<sup>10</sup> Excluding satellite base stations and test base stations.

<sup>11</sup> Noting that different home networks may have different network coverages, and therefore this typology of location areas may be different for each home network.

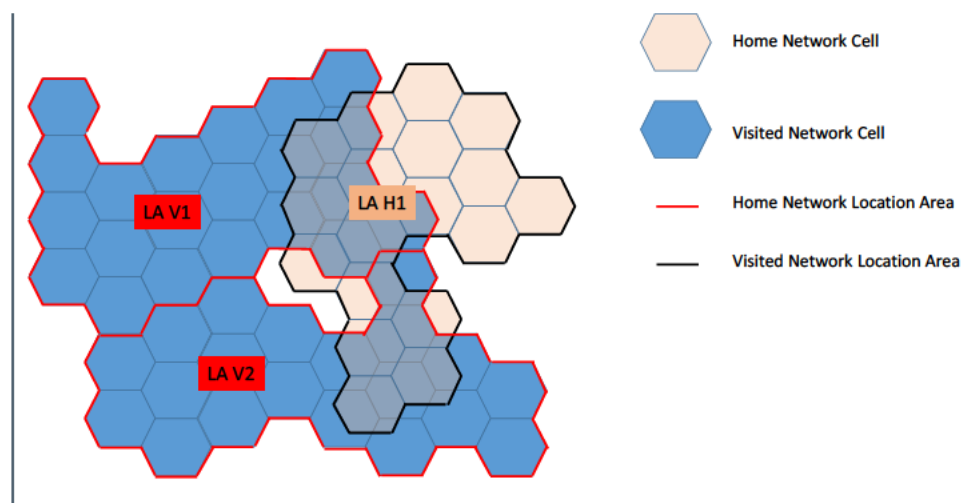
- a) Location areas where the home network has coverage across the whole of the location area<sup>12</sup>.
  - b) Location areas where the home network has no coverage in any part of the location area.
  - c) Location areas where the home network has some coverage, but not complete coverage.
64. The implications of each type of location area are as follows.
65. If the objective is to limit the overlap in coverage between the home network and where roaming is available from the visited network then roaming should not be available in type a) areas. This will remove the problem of ‘ping-ponging’ and reduce the risk of cascading network failure in these areas of complete overlap (but not completely eliminate it, for the reasons explained in paragraph 55 above).
66. Roaming can safely be made available in type b) areas without the risks of ‘ping-ponging’ and cascading network failure that we discussed in Section 5, since there is no overlap of coverage (but there will still need to be sufficient capacity available in the visited network for it not to become overloaded). As discussed below, the difficulty is defining the limits of the domestic roaming area to include only type b) areas.
67. The problem is type c) areas. On the one hand it may be thought desirable for these areas to be included in domestic roaming in order to ensure contiguous coverage. On the other hand, if there is significant coverage overlap, then there may be a serious problem of ‘ping-ponging’ and risk of cascading network failure.
68. In theory it might be possible to mitigate the problem of type c) areas (and limit domestic roaming to type b) areas) by redefining location areas in the visited network to better mesh with the coverage of the home network. However, there are a number of problems with this in practice:
- a) For a start the cell plans of the two networks are unlikely to perfectly mesh, so even at a cellular level there may well be areas of partial overlap (or gaps).
  - b) Secondly, the coverage of the home network may change over time – for example as they roll-out new base stations, including for example ‘islands of coverage’ in areas where the home network otherwise relies on domestic roaming – creating new areas of coverage overlap that would require a redefinition of location areas to minimise them.
  - c) Thirdly, there may be two or more home networks that wish to access wholesale domestic roaming services on the same visited network, with differing home network coverages, potentially requiring location areas to be further sub-divided so as to be able to join them together in different ways to match the differing coverages of the different home networks.
  - d) Finally, as noted above, changing (and continuing to change) location area design and size to exclude coverage of the home network has a number of important consequent effects for the visited network.
69. As a result, there will be overlap problems at the boundaries of the roaming areas but also possibly within the roaming area as network rollout by the home network continues.

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<sup>12</sup> Noting our previous comment that even in areas of apparently good coverage there will in practice be locations where it is not possible to get a mobile signal.

70. Turning first to the issues in defining the outer boundaries of the roaming area, Figure 6-1 shows two location areas in the visited network (LA V1 and LA V2) and one in the home network (LA H1) – for the purposes of this illustration assumed to be the total extent of the coverage of the home network. Each location area (outlined in black for the home network and red for the visited network) is a collection of cells (shown here as hexagons for simplicity). Here it can be seen that there is significant overlap between LA H1 and both LA V1 and LA V2, but also a large proportion of both LA V1 and LA V2 which lie outside the coverage of the home network (assumed not to extend beyond LA H1). If domestic roaming is required in those areas where there is coverage from the visited network but not from the home network, LA V1 and LA V2 will need to be included within the area where domestic roaming is provided. But in that case there will also be a significant area of overlap in coverage between the two networks – where LA H1 overlaps with LA V1 and LA V2.

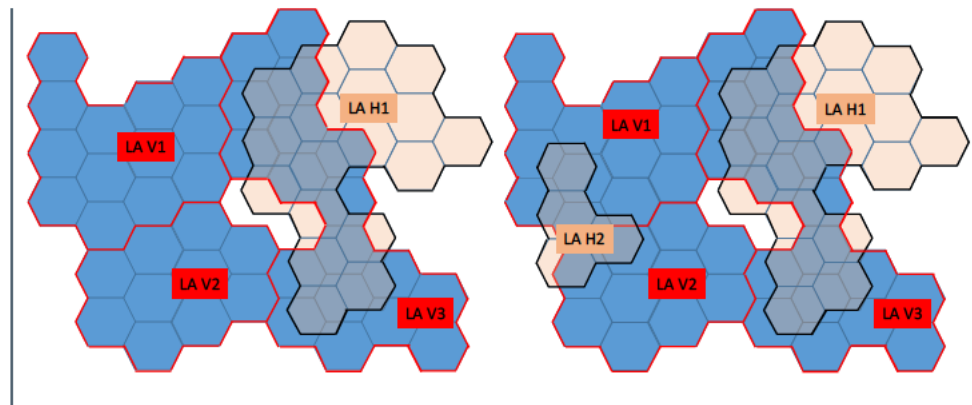
**Figure 6-1:**  
**Problem of overlapping coverage**  
[Source: Aetha Consulting]



71. The left-hand side of Figure 6-2 shows how this problem might be reduced to some extent, by changing the definitions of LA V1 and LA V2, and creating a new LA V3 – removing the cells that overlap with LA H1 from LA V1 and LA V2 and putting them into a new LA V3. Subscribers from the home network could now be permitted to roam in LA V1 and LA V2, but not in LA V3, thereby providing them with roaming service outside the coverage of their home network, but without any overlap between the area in which roaming was available and the coverage of their home network<sup>13</sup>. As noted above however, this would have other consequences for the home network that would have to be considered.
72. In the event that location areas were optimised in this way to minimise overlap between the network operators, this would however introduce significant challenges for new network rollout since any change by either network in an area where domestic roaming is permitted would imply the need for a further redesign of the location areas in the visited network in that area.

<sup>13</sup> As drawn however there would be a gap between the coverage of the home network and the area in which roaming was available. In practice there is always likely to be either a gap or an overlap in this situation, because the cell edges of the two networks are very unlikely to perfectly align.

**Figure 6-2:**  
**Optimisation of**  
**location areas and**  
**problem of new**  
**network rollout**  
 [Source: Aetha  
 Consulting]



73. If the home network rolled out further network coverage, it is likely that they would attempt to cover populated areas first, because this would generate a faster return on investment. In the example on the right-hand side of Figure 6-2, the home network has built four new cells, identified by LA H2, in an area where their customers have been permitted to roam. There is consequently a new area of overlapping coverage between the home network and where domestic roaming is available from the visited network, with the potential for this to give rise to ping-ponging and cascading network failure. To reduce these problems, the visited network would once again have to change the definition of its location areas, removing the areas of overlap from LA V1 and V2, and creating yet another new location area (e.g. LA V4 – not shown) in the area of overlapping coverage. And so on.
74. In an environment where network operators are continually improving network coverage, minimising overlapping location areas becomes operationally very complex and difficult to manage. The situation is compounded where there are more than two parties, for instance, where there are two home networks and one visited network. In our view, it is unlikely to be feasible in practice to continuously update location areas to minimise coverage overlaps in this situation.
75. A further complication is that the variability of radio signal propagation means that it isn't even possible to predict with certainty where the coverage of a mobile operator starts and ends. Even in areas where an operator might have generally good coverage there will still be locations where an end user will be unable to obtain service.
76. For all of these reasons we consider it impractical to limit the geographic availability of wholesale domestic roaming solely to those areas where an access seeker does not have coverage.

## 7 Impact on the quality of services provided to existing end users of Telstra's network

### 7.1 Introduction

77. In this section we consider whether any increase in end users and traffic on Telstra's mobile services network as a result of domestic roaming will cause a worsening of the quality of service provided by Telstra to its own customers, absent a corresponding increase in capacity.

78. Any increase in end users and traffic as a result of domestic roaming could result in:
- Dropped calls, especially at handover.
  - The inability to make calls.
  - The inability to receive calls.
  - The inability to stream video or use video-related services.
  - A poor experience when using data services, with slow or very slow responses.
  - A reduction in cell size, resulting in those towards the edge of the cell no longer having coverage.
79. The underlying effect which causes the degradations listed above is often termed “congestion”. Congestion in radio networks has a similar meaning to that in, say, road networks. It indicates that the volume of traffic is greater than the system can manage without some degradation of service. In this section we firstly consider how congestion can occur in general and the various ways that this can be resolved. We then look at the sites where Telstra is the only MNO to provide coverage in the area (Telstra-only sites) and assess the extent to which congestion will occur both without roaming traffic and with roaming traffic.
80. We understand that if a geographic limitation was applied to a declaration, it would likely include Telstra-only sites (which are generally in less densely populated geographic areas). As such, our analysis in this section applies regardless of whether the declaration is limited geographically to such areas.

## 7.2 Cell capacity

81. The capacity of a cell depends on many variables. These include:
- The technology deployed (eg 3G or 4G).
  - Whether the cell is divided into sectors (which adds capacity).
  - The amount of radio spectrum in use in the cell.
  - The range of the cell (longer range cells tend to have lower capacity as more users have weak signals).
82. If a cell does experience congestion, there are various options that might be available to alleviate this. In approximate order of cost, starting with the lowest, these are:
- Add more radio spectrum if available. However, for long-range rural cells, only lower frequency spectrum will be fully effective as higher frequencies such as 2.6GHz would only provide coverage for a small fraction of the cell.
  - Sectorise the cell if this has not already been done.
  - Re-farm any older 2G or 3G spectrum to 4G spectrum. However, there may be a need to retain some 2G or 3G carriers to support any non-4G devices and to provide voice fall-back where needed.

d) Split the cell into multiple smaller cells.<sup>14</sup>

83. Here we are specifically interested in the cells in areas where Telstra has coverage but its competitors do not (and so domestic roaming will be the sole means of network access for non-Telstra customers).

**Figure 7-1: Location of Telstra-only sites [Source: Telstra]**

84. In general, across Telstra-only sites, in those cells likely to suffer congestion Telstra has already sectorised the cells. If these cells become congested it might:

- a) Add 4G at 700MHz to those sites that are currently 3G-only.
- b) Deploy higher frequency carriers such as 2.6GHz and hand over users near the cell centre onto these frequencies, providing some capacity relief to the lower frequencies. However, the users

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<sup>14</sup> See also paras 140-145 of the witness statement by M Wright that aligns with this.

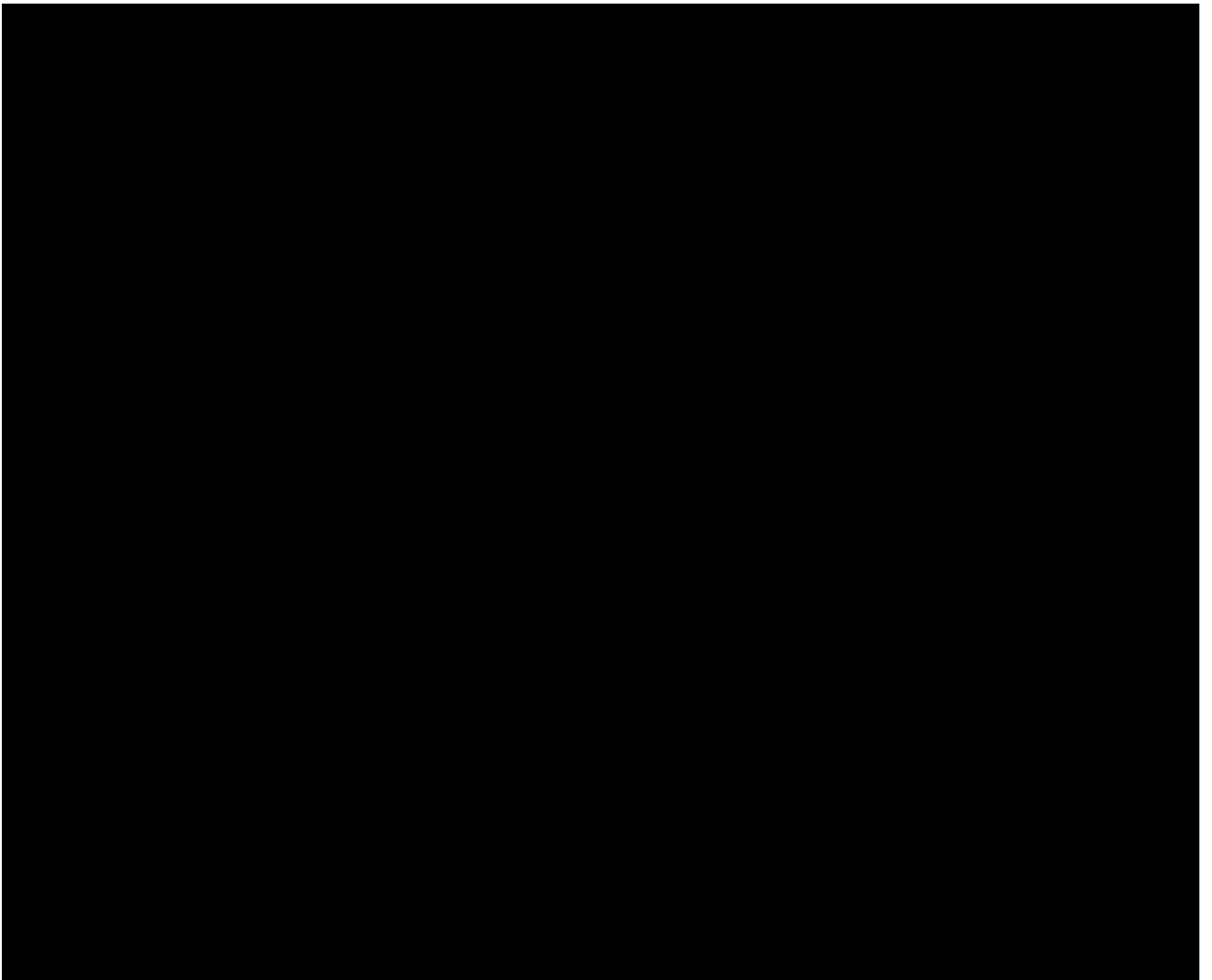
near the cell centre do not load the cell significantly as they have a good signal strength and so can transmit at a high rate, so the effect of this is limited.

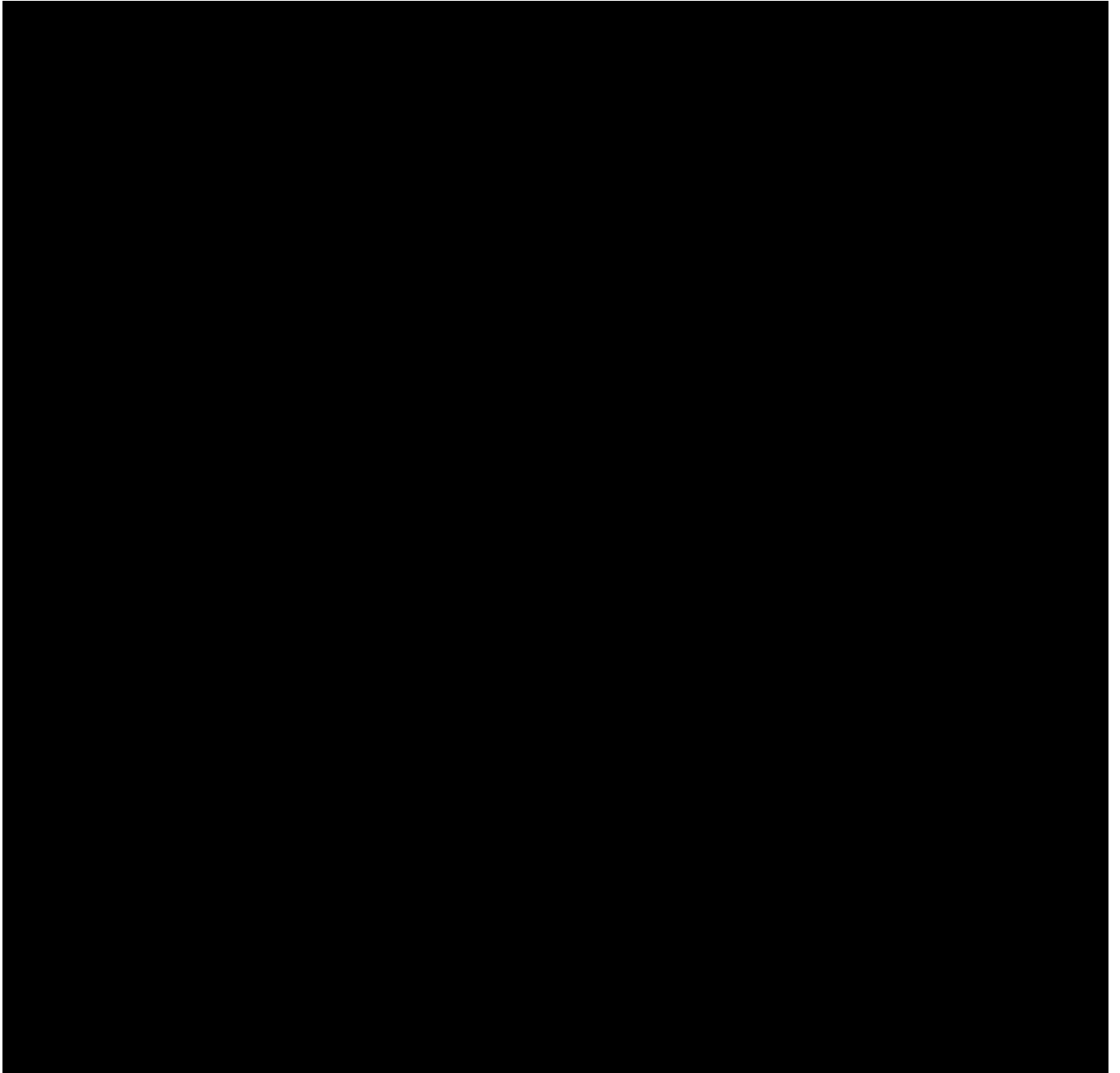
- c) Split the cell into multiple smaller cells. This would significantly increase capacity, but at a substantial cost of acquiring multiple new sites, installing equipment, arranging backhaul and power and paying site rental. It also often takes years to find suitable sites and negotiate over their availability.<sup>15</sup>

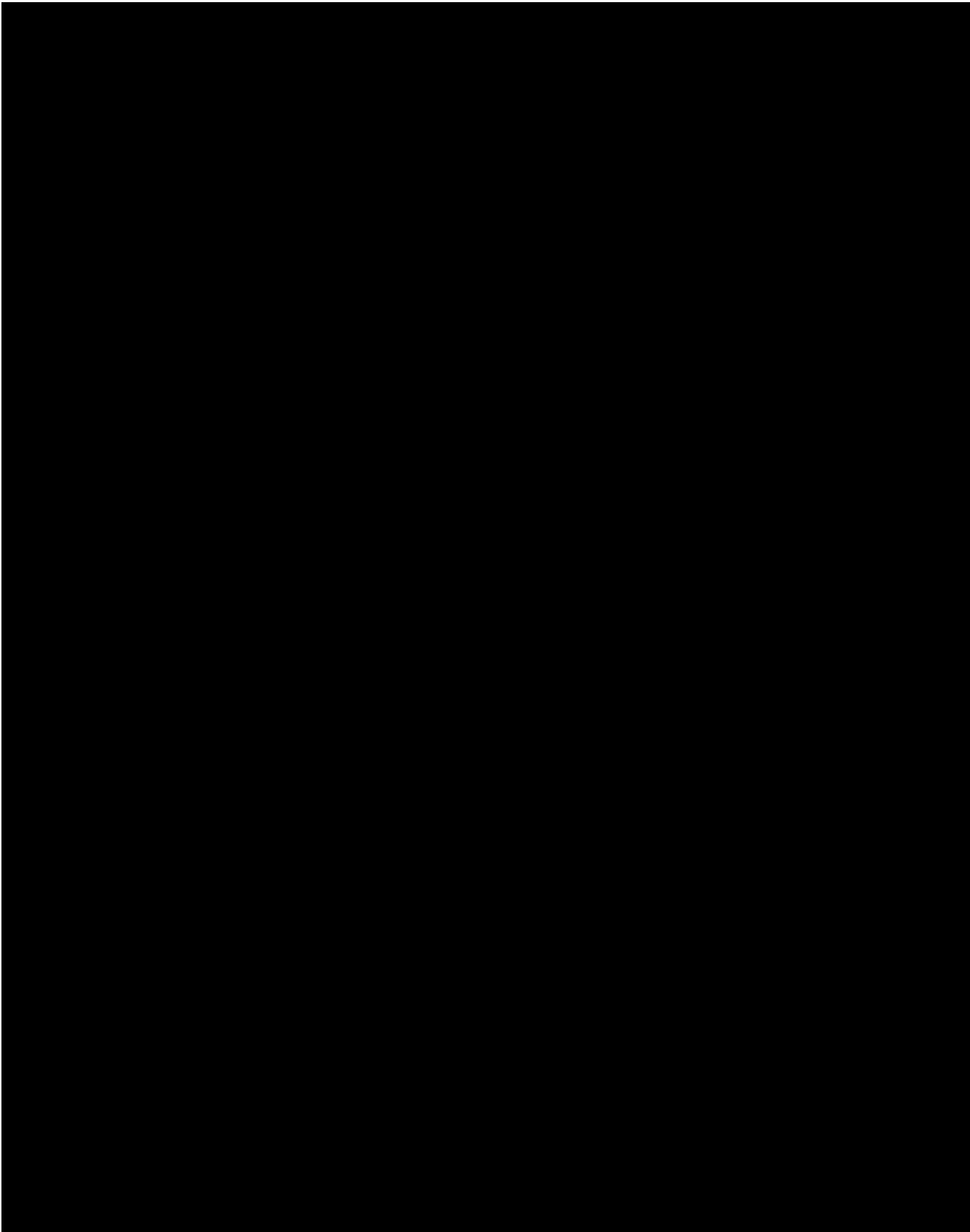
### 7.3 Reduction in coverage

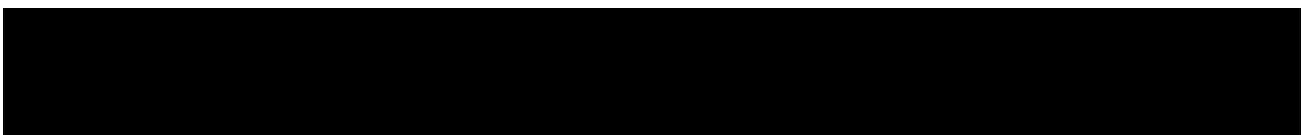
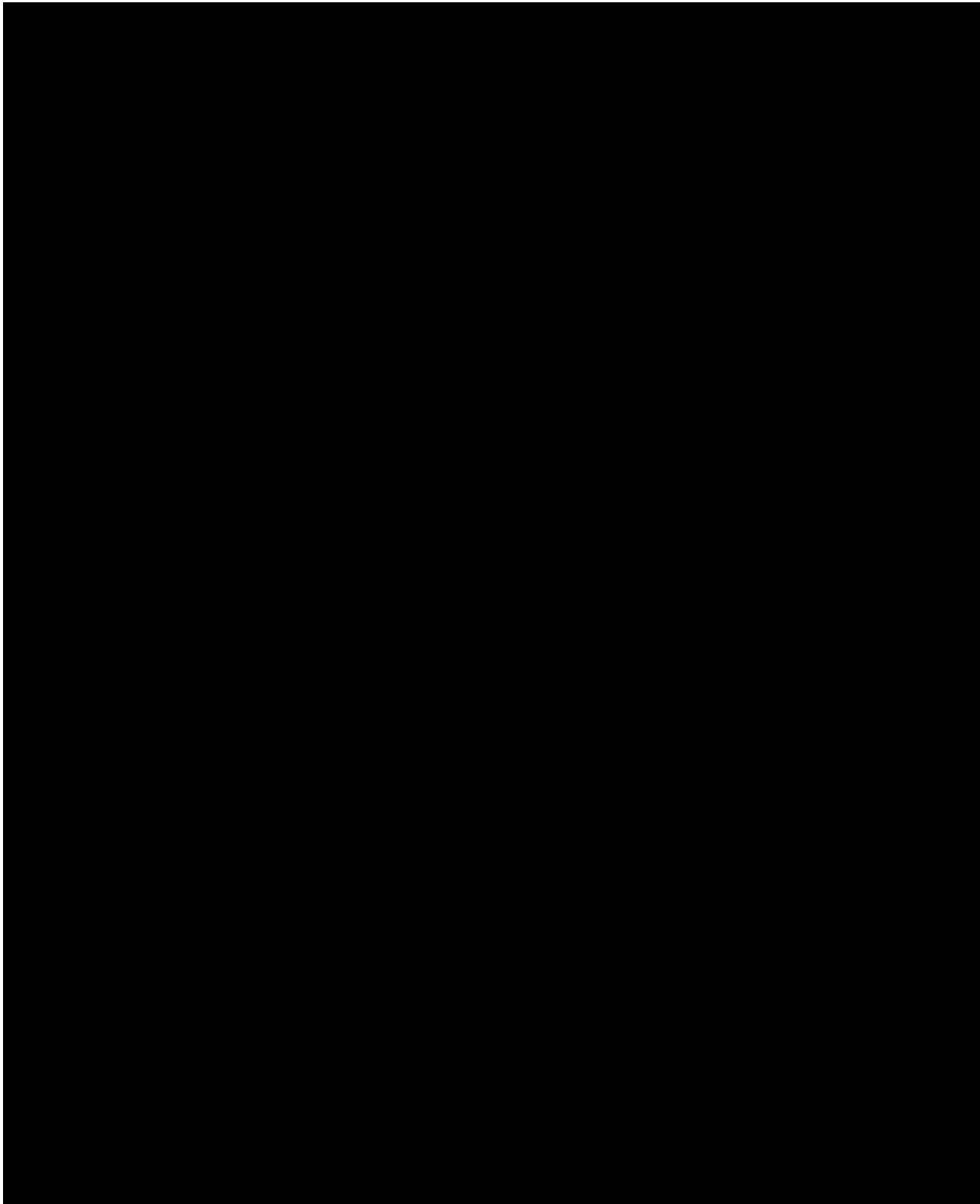
- 85. For 3G-only cells, an effect known as “cell breathing” can occur as the cell loading increases. This results in a reduction in cell size such that a cell loaded at 50% of maximum capacity will have its range reduced by around 15%, increasing rapidly to a 75% reduction in range at full capacity. Since these cells provide important rural coverage, any reduction in range might lead to users falling outside the effective coverage area. As a result, there is an argument that 3G-only sites should have their capacity upgraded at around 50% loading, rather than the more usual 100%. We have not modelled this effect here but note that it would result in more cells needing to be upgraded to accommodate domestic roaming without congestion and service degradation than we suggest below.

### 7.4 Telstra-only site capacity analysis









## 8 Additional capacity required on Telstra’s network (as access provider)

105. As explained in section 7 above, if Telstra is required to supply wholesale domestic roaming services, we expect the load on its network to increase (regardless as to whether domestic roaming is limited geographically). This will increase the demand for capacity on its network in a number of regards:
- a) An increase in the number of devices requesting access to its network and updating their location on the network (increased signalling) – including failed attempts to access Telstra’s network in areas where roaming is not allowed if domestic roaming is geographically limited.<sup>17</sup>
  - b) An increase in end user voice, text and data traffic on its network, both originating and terminating, as a result of the additional devices attached to its network.
  - c) A greater proportion of voice calls needing to be CAMEL controlled.
106. To meet the increase in signalling traffic required to support wholesale domestic roaming (including failed roaming access requests in areas where domestic roaming is not available), Telstra will likely have to increase the signalling capacity of its network in some or all of the following areas:
- a) Additional Mobile Switching Centre and Signal Transfer Point capacity.
  - b) Additional inter-Mobile Switching Centre capacity.
  - c) Additional signalling interconnect capacity with VHA and Optus.
  - d) Additional base station capacity at existing sites.
107. To meet the increase in user traffic on Telstra’s network arising from wholesale domestic roaming, some or all of the following items are likely to be necessary:
- a) Increased hardware and software licencing for Mobile Switching Centres, Serving GPRS Support Nodes, Signal Transfer Points.
  - b) Additional inter-Mobile Switching Centre capacity.
  - c) Additional IP routing capacity.
  - d) Additional interconnect capacity (circuit and IP) with other Australian operators.
  - e) Additional base station capacity at existing sites, and potentially the deployment of new sites – discussed in more detail in Section 7 above.

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<sup>17</sup> User devices do not know if they are or are not allowed to roam in a particular area until they try to do so. If they try and are refused – message “Roaming not allowed in this location area” – they save this information for as long as they remain switched on, but forget it when they are switched off, and will therefore try again in the same area the next time they lose coverage from their home network in that area. The capacity of Telstra’s network will need to be increased to cope with these failed roaming access requests.

108. Supporting the use of CAMEL to control all outgoing calls made by domestic end users roaming on Telstra's network is likely to require some or all of the following:
- a) Additional Mobile Switching Centre and Signal Transfer Point capacity.
  - b) Additional inter- Mobile Switching Centre circuits.
  - c) Additional signalling interconnect capacity with VHA and Optus.

## Annex A Letter of instruction

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**30 November 2016**

**By email**

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Confidential

Dear Mr Louth

**Response to the Australian Competition and Consumer Commission regarding potential declaration of a wholesale domestic roaming service on behalf of Telstra Corporation Limited**

**1 Background**

- 1.1 We act for Telstra Corporation Limited (**Telstra**).
- 1.2 On 5 September 2016, the Australian Competition and Consumer Commission (**ACCC**) commenced an inquiry into whether to declare a wholesale domestic mobile roaming service (**ACCC Inquiry**). As part of that inquiry, on 26 October 2016, the ACCC released a Discussion Paper seeking views on a range of issues it considers relevant to whether such a declaration should be made.
- 1.3 The ACCC has invited submissions to the Discussion Paper from mobile network operators, including Telstra. Set out in the ACCC's Discussion is a description of the legal framework and the assessment approach.
- 1.4 In accordance with section 152AL under Part XIC of the *Competition and Consumer Act 2010* (Cth) (**CCA**), the ACCC may only declare a telecommunications services if (among other things) it is satisfied that doing so will be in the long-term interests of end-users (LTIE). Under section 152AB of the CCA, in deciding whether the declaration will promote the LTIE, the ACCC must consider whether declaration is likely to result in the achievement of the following three objectives:
  - (a) the objective of promoting competition in markets for telecommunications services;
  - (b) the objective of achieving any-to-any connectivity in markets for telecommunications services; and

- (c) the objective of encouraging the economically efficient use of, and investment in, telecommunications infrastructure.
- 1.5 In determining the likelihood to which a particular thing is likely to result in the achievement of promoting competition in markets for telecommunication services, regard must be had to the extent to which the thing will remove obstacles to ensure users of telecommunications services gain access to those telecommunications services.<sup>1</sup>
- 1.6 In determining the likelihood to which a particular thing is likely to result in the achievement of encouraging the economically efficient use of, and investment in, telecommunications infrastructure, regard must be had to the following matters:<sup>2</sup>
- (a) whether it is, or is likely to become, technically feasible for the services to be supplied and charged for, having regard to:
    - (i) the technology that is in use, available or likely to become available; and
    - (ii) whether the costs that would be involved in supplying, and charging for, the services area reasonable or likely to become reasonable; and
    - (iii) the effects, or likely effects, that supplying, and charging for, the services would have on the operation or performance of telecommunications networks;
  - (b) the legitimate commercial interests of the supplier or supplier of the services, including the ability of the supplier or suppliers of services to exploit economics of scale and scope;
  - (c) the incentives for investment in:
    - (i) the infrastructure by which the services are supplied; and
    - (ii) any other infrastructure by which the services are, or are likely to be become, capable of being supplied.
- 1.7 In determining incentives for investment, regard must be had to the risks of making the investment<sup>3</sup>.
- 1.8 We have been instructed to engage you, on behalf of Telstra, to prepare a report based on your expert opinion, for use by Telstra in relation to the ACCC Inquiry. Telstra may seek to rely upon your report in any subsequent review of the ACCC's final decision. If that occurs, we will contact you.
- 1.9 By this letter, we set out our written instructions to you.

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<sup>1</sup> See section 152AB (4) of the CCA, noting that this subsection does not limit the matters to which regard may be had (see section 152AB(5) of the CCA).

<sup>2</sup> See section 152AB(6) of the CCA, noting that this subsection does not limit the matters to which regard may be had (see section 152AB(7) of the CCA)

<sup>3</sup> See section 152AB(7A), noting that this subsection does not limit the matters to which regard may be had (see section 152AB(7B) of the CCA)

## 2 Scope of work

2.1 You are retained to provide an expert report which addresses the following question:

*What are the technical issues, if any, that would arise if wholesale domestic roaming was declared without any geographic limitations? Please consider how and to what extent your opinion would differ if the declaration was subject to geographic limitations.*

2.2 Please explain the basis for your opinion.

## 3 Guidelines for preparing your report

3.1 While you have not been engaged in respect of any legal proceedings, Telstra is seeking a robust and rigorous independent expert report. We request that you prepare your report in accordance with Federal Court of Australia *Harmonised Expert Witness Code of Conduct*. A copy of the Code of Conduct is enclosed at **Attachment A**.

3.2 In particular, in preparing your report, we ask that you please:

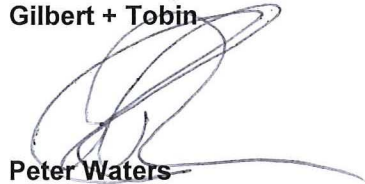
- (a) identify your relevant area of expertise and provide a curriculum vitae setting out the details of that expertise;
- (b) only address matters that are within your expertise;
- (c) where you have used factual or data inputs please identify those inputs and the sources;
- (d) if you make assumptions, please identify them as such and confirm that they are in your opinion reasonable assumptions to make;
- (e) if you undertake empirical work, please identify and explain the methods used by you in a manner that is accessible to a person not expert in your field;
- (f) confirm that you have made all the inquiries that you believe are desirable and appropriate and that no matters of significance that you regard as relevant have, to your knowledge, been withheld from your report; and
- (g) do not provide legal advocacy or argument and please do not use an argumentative tone.

#### **4 Confidentiality and legal professional privilege**

- 4.1 Presently, your report and all correspondence between us (excluding this letter) is subject to legal professional privilege. In addition, the information we have provided to you is commercially sensitive and confidential. For these reasons, we request you do not disclose or discuss your report, our correspondence or any information we provide to you with any third parties.

Yours faithfully

**Gilbert + Tobin**



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## Attachment A

### ***Harmonised Expert Witness Code of Conduct (Annexure A to Federal Court of Australia Practice Note GPN-EXPT)***

#### APPLICATION OF CODE

1. This Code of Conduct applies to any expert witness engaged or appointed:
  - (a) to provide an expert's report for use as evidence in proceedings or proposed proceedings; or
  - (b) to give opinion evidence in proceedings or proposed proceedings.

#### GENERAL DUTIES TO THE COURT

2. An expert witness is not an advocate for a party and has a paramount duty, overriding any duty to the party to the proceedings or other person retaining the expert witness, to assist the Court impartially on matters relevant to the area of expertise of the witness.

#### CONTENT OF REPORT

3. Every report prepared by an expert witness for use in Court shall clearly state the opinion or opinions of the expert and shall state, specify or provide:
  - (a) the name and address of the expert;
  - (b) an acknowledgment that the expert has read this code and agrees to be bound by it;
  - (c) the qualifications of the expert to prepare the report;
  - (d) the assumptions and material facts on which each opinion expressed in the report is based [a letter of instructions may be annexed];
  - (e) the reasons for and any literature or other materials utilised in support of such opinion;
  - (f) (if applicable) that a particular question, issue or matter falls outside the expert's field of expertise;
  - (g) any examinations, tests or other investigations on which the expert has relied, identifying the person who carried them out and that person's qualifications;
  - (h) the extent to which any opinion which the expert has expressed involves the acceptance of another person's opinion, the identification of that other person and the opinion expressed by that other person;
  - (i) a declaration that the expert has made all the inquiries which the expert believes are desirable and appropriate (save for any matters identified explicitly in the report), and that no matters of significance which the expert regards as relevant have, to the knowledge of the expert, been withheld from the Court;
  - (j) any qualifications on an opinion expressed in the report without which the report is or may be incomplete or inaccurate;
  - (k) whether any opinion expressed in the report is not a concluded opinion because of

insufficient research or insufficient data or for any other reason; and

- (l) where the report is lengthy or complex, a brief summary of the report at the beginning of the report.

#### SUPPLEMENTARY REPORT FOLLOWING CHANGE OF OPINION

- 4. Where an expert witness has provided to a party (or that party's legal representative) a report for use in Court, and the expert thereafter changes his or her opinion on a material matter, the expert shall forthwith provide to the party (or that party's legal representative) a supplementary report which shall state, specify or provide the information referred to in paragraphs (a), (d), (e), (g), (h), (i), (j), (k) and (l) of clause 3 of this code and, if applicable, paragraph (f) of that clause.
- 5. In any subsequent report (whether prepared in accordance with clause 4 or not) the expert may refer to material contained in the earlier report without repeating it.

#### DUTY TO COMPLY WITH THE COURT'S DIRECTIONS

- 6. If directed to do so by the Court, an expert witness shall:
  - (a) confer with any other expert witness;
  - (b) provide the Court with a joint-report specifying (as the case requires) matters agreed and matters not agreed and the reasons for the experts not agreeing; and
  - (c) abide in a timely way by any direction of the Court.

#### CONFERENCE OF EXPERTS

- 7. Each expert witness shall:
  - (a) exercise his or her independent judgment in relation to every conference in which the expert participates pursuant to a direction of the Court and in relation to each report thereafter provided, and shall not act on any instruction or request to withhold or avoid agreement; and
  - (b) endeavour to reach agreement with the other expert witness (or witnesses) on any issue in dispute between them, or failing agreement, endeavour to identify and clarify the basis of disagreement on the issues which are in dispute.

## Annex B CVs

### Graham Louth – Aetha Partner

Graham has over 25 years' experience in the telecommunications industry, originally as a leading advisor to operators and regulators on regulatory issues such as universal service, interconnect pricing, retail price control, margin squeeze analysis and market reviews; then as Director of Spectrum Policy at Ofcom, the UK's electronic communications regulator, in which role he was responsible for many of the most significant developments in spectrum policy at the time, including the introduction of spectrum trading and liberalisation, refinement of spectrum pricing, auctioning of key spectrum bands, including the UK's 4G auction of the 800 MHz and 2.6 GHz bands, and regulatory reviews of various mobile network sharing and merger agreements. Graham also played a wider role within Ofcom as a member of the senior management group, reviewing and guiding regulatory policy across the whole of Ofcom, and playing an active role in the management of the organisation.

Graham joined Aetha Consulting as a Partner in September 2014.

Graham has worked for/with a wide variety of organisations including:

#### Regulators / Governments

Ofcom/Oftel (UK)  
Cabinet Office (UK)  
Dept for Culture, Media and Sport (UK)  
Dept for Business, Innovation and Skills (UK)  
European Commission  
ARCEP/ART (France)  
ANFR (France)  
BNetzA/RegTP (Germany)  
CMA/OPTA (Netherlands)  
ComReg (Ireland)  
FICORA (Finland)  
MCA (Malta)  
PTS (Sweden)  
ACMA (Australia)  
iDA (Singapore)  
Industry Canada  
Government of Pakistan  
TRAI (India)

#### Operators

BT (UK)  
Belgacom (Belgium)  
Centrica (UK)  
Eircel (Ireland)  
Energis (UK)  
France Telecom  
KabelNRW (Germany)  
Mobile Operators Assoc (UK)  
ONO (Spain)  
Portugal Telecom  
Proximus (Belgium)  
Retevision (Spain)  
Telecom Italia  
TPSA (Poland)  
Westel (Hungary)  
AOL (Europe)  
ECTA (Europe)  
Worldcom (Europe)  
Clear (NZ)  
Hutchison (HK)  
Telstra (Australia)  
Telecom New Zealand

#### Others

Motorola  
Ericsson  
Alcatel Lucent

## Education

- B.A. Honours Degree in Mathematics, Downing College, University of Cambridge (1980-1983)
- Certificate of Advanced Study in Mathematics (with Distinction), Statistical Laboratory, University of Cambridge (1984-1985)
- Ph.D. on Stochastic Networks: Complexity, Dependence and Routing, Statistical Laboratory, University of Cambridge (1985-1990)

## Employment history

Sept 2014-	Partner, Aetha Consulting Ltd
Oct 2009-Aug 2014	Director of Spectrum Policy, Mobile and Auctions, Ofcom
Mar 2009-Sept 2009	Acting Head of Spectrum Policy Group, Ofcom
Dec 2003-Feb 2009	Director of Spectrum Markets, Ofcom
1990-2003	Consultant / Senior Consultant / Principal Consultant / Head of Pricing, Costing and Regulation, Analysys Consulting Ltd

Examples of specific projects undertaken by Graham are presented below. These have been categorised in the following areas:

- Aetha project
- Ofcom projects
- Prior regulatory projects
- Other projects

## Aetha projects

- **National roaming** – Support to the UK’s mobile network operators in arguing against a proposal by the UK government to require them to deploy national roaming to address coverage concerns (‘partial not-spots’); supported mobile operators to develop and present an alternative proposal that was then agreed with the government
- **RFI for wholesale mobile network and MVNE services** – Ran an RFI and benchmarking exercise for a major retail MVNO in a European market that wanted to explore options for the future supply of wholesale mobile network and MVNE services to support its existing customers and planned expansion
- **Spectrum auction** – Provided support and advice to a South American mobile network operator preparing to bid in an auction for AWS spectrum, including review of the auction rules and requests for clarification from the regulator, the running of a number of mock auctions for senior management and the bidding team, and the development of a bidding support tool
- **Merger review** – Expert witness for a South African mobile network operator explaining why acquisition of additional spectrum by the leading mobile network operator would be likely to lead to a significant lessening of competition in downstream mobile markets and putting forward a number of options to remedy the harm
- **Spectrum auction** – Supported a European mobile network operator to prepare for an important auction of mobile spectrum: reviewed regulator’s proposals, identified key issues and helped client successfully lobby for changes; reviewed market situation and advised client on appropriate

bidding strategy; provided them with a bidding support tool and ran a number of mock auctions; advised them on auction logistics and supported them during the bidding

- **Spectrum pricing and auction design** – Wrote two reports for a Latin American mobile network operator arguing for changes in regulation: the first compared the level and structure of annual fees for mobile spectrum across the OECD with those in force in the country at the time, successfully arguing for a significant reduction in annual fees for higher frequency bands; the second looked at a number of aspects of the design of a proposed auction for AWS spectrum, successfully arguing for a range of measures to promote competition and efficient spectrum use
- **International mobile roaming** – Critical review of evidence and analysis put forward by a regulator to justify proposal to significantly cut regulated international roaming rates and drafting of operator’s consultation response

## Ofcom projects

- **Spectrum trading** – Design and implementation of the UK’s spectrum trading regime
- **Spectrum liberalisation** – Formulation and implementation of the UK’s policy on technology and use neutrality
- **Review of spectrum prices** – Review and revision of administered incentive prices (AIP) for a wide range of spectrum licence products
- **Investigation of Competition Act complaint against various mobile operators** – Formal investigation of certain complaints of anti-competitive behaviour against two UK mobile operators; decision defended in front of Competition Appeal Tribunal (CAT); certain aspects of CAT decision successfully appealed to Court of Appeal
- **Digital Dividend Review** – A major programme of work to determine the future of the digital dividend spectrum – the spectrum freed up by the switchover from analogue to digital television
- **Award of DECT guardband spectrum** – Design and successful delivery of novel auction for award of DECT guardband spectrum (first-price sealed bid auction for concurrent licences)
- **Award of spectrum in 400MHz band** – Design and successful delivery of efficient auction for award of small amount of spectrum in 400MHz band (combinatorial first-price sealed bid auction)
- **Award of spectrum in 10, 28, 32 and 40GHz bands** – Design and successful delivery of the world’s first Combinatorial Clock Auction (CCA) for spectrum
- **Award of L-band spectrum** – Design and successful delivery of CCA auction for award of spectrum between 1452 and 1492MHz, including flexibility as to usage conditions (high vs low power)
- **Application of spectrum trading and liberalisation to the mobile sector** – A major programme of work over a number of years to assess and address the potential impacts on competition of allowing the incumbent mobile operators to deploy new mobile technologies (3G and 4G) within their existing spectrum holdings (900MHz and 1800MHz)
- **Design of auction for award of spectrum in 2.6GHz band** – Refinement of CCA format to requirements of 2.6GHz award, including flexibility as to split between FDD and TDD use; auction was postponed pending outcome of legal action by mobile operators, and then combined with award of 800MHz spectrum as a result of outcome of Government’s Digital Britain process
- **Defence of decision to go ahead with award of 2.6GHz band** – Preparation of defence of decision to proceed with the 2.6GHz award as soon as practicable
- **Review of the European Telecoms Framework** – Detailed review of proposed revisions to the European Telecoms Framework and recommendations for improvement

- **Digital Britain** – Government project to develop a strategic vision for the UK’s digital economy, and a programme of action to achieve it; a key component of the work concerned the future terms on which mobile operators would have access to spectrum, to promote investment and competition
- **European Commission review of proposed merger between Orange and T-Mobile in the UK** – Worked with the Commission to obtain undertakings from the parties to divest 2x15MHz of 1800MHz spectrum, to address concerns that their combined spectrum holdings might adversely affect competition; subsequently worked with Commission’s Monitoring Trustee to ensure the undertakings were complied with
- **Ofcom review of proposed network sharing agreement between Vodafone and Telefonica** – Reviewed details of proposed network sharing agreement to identify matters of potential concern
- **Government initiative to improve mobile coverage** – Support to the Government to develop and deliver a programme of investment (the Mobile Infrastructure Programme) to address not-spots in mobile coverage
- **Award of spectrum in 800MHz and 2.6GHz bands (4G auction)** – Major project over a number of years to design and deliver an auction for the award of these key mobile spectrum bands. A key part of the work was an assessment of the potential impact on competition of the award of the spectrum, and the design of competition controls within the auction to mitigate the most serious risks. The extent of coverage obligations to be included in the licences was also hotly debated. The auction was successfully held between January and March 2013, with all of the available spectrum being awarded to five winning bidders – the four incumbent mobile operators plus BT. The auction was subsequently audited by the National Audit Office (NAO) who concluded that Ofcom had achieved its objective of maintaining a competitive market, and noted that subsequent to the auction all four of the existing mobile operators had started to roll out 4G services. The NAO also noted that the proceeds achieved were within the range achieved in other European auctions.
- **UHF Strategy Implementation** – A major programme of work to assess the relative costs and benefits of migrating digital TV services out of the 700MHz band to allow its use for future mobile services
- **European Commission’s Connected Continent proposals** – Review of Commission’s proposed changes to European spectrum law and recommendations for improvement
- **2GHz MSS** – Assessment of compliance of 2GHz MSS operators with common conditions for the provision of MSS services in Europe
- **Mobile data strategy** – An assessment of the potential for various bands, currently used for other purposes, to become available on a European or globally harmonised basis to meet the growing demand for mobile data, and statement on next steps
- **Review of spectrum prices paid by the public sector** – Review, on behalf of the UK Government, of the prices being paid for spectrum by the public sector; project led to a far larger group of public sector users paying spectrum fees
- **Award of spectrum in 2.3 and 3.4GHz bands** – Initial work on the award of these former military bands
- **European Commission review of proposed mergers in Ireland and Germany** – Highlighted areas of potential concern to the Commission for their consideration
- **Chair of Spectrum Executive committee** – Chair of the executive committee responsible for overseeing spectrum policy work within Ofcom.

## Prior regulatory projects

- **iDA (Singapore)** – Provided support in the development of policy recommendations for the most effective charging method for mobile services given current and future market conditions. The IDA was considering a move to a ‘calling party pays’ (CPP) tariff regime in place of the existing ‘mobile party pays’ (MPP) approach in Singapore, and we assessed the suitability and the implementation of such a move
- **Telekomunikacja Polska** - Presentations on European and UK telecommunications regulation at a series of top management ‘away days’
- **Optimus (Portugal)** - Bottom-up mobile costing model to determine the long-run costs of 3G voice and data services
- **OSIPTEL (Peru)** – Development of an accounting separation system
- **Ofcom (then Oftel)** – Model to estimate the long-run incremental costs (LRIC) of mobile networks in the UK, presented to the UK Monopolies and Mergers Commission as part of its investigation into wholesale call pricing
- **Ofcom (then Oftel)** – Update of long-run incremental cost model of mobile networks in the UK in connection with subsequent market review by Oftel of the mobile call termination market
- **Private client (Asia)** – Calculation of the long run incremental costs (LRIC) of mobile termination using bottom-up and top-down models, for a major mobile operator in Asia
- **Telecom New Zealand** – Support during the industry consultation process for determining a methodology to estimate the net costs of providing universal service and establishing a mechanism to fund its provision
- **Private client (Western Europe)** – Regulatory support on the treatment of fully-depreciated assets in the calculation of interconnection costs for a fixed incumbent operator in a Western European country
- **Orange Spain (then AUNA)** – Evaluation of a range of innovative, interconnection schemes and charging options. The project developed a LRAIC cost model for capacity-based interconnection, a charging scheme subsequently adopted by the regulator
- **Mobile network operator (Europe)** – Creation of an incremental cost model of interconnection and national roaming services; the model was also used to examine margins and pricing of end user services
- **Major ISP and network provider (UK)** – Created and obtained regulatory backing for the first unmetered wholesale Internet access service in the UK: Flat Rate Internet Access Call Origination (FRIACO)
- **Mobile operator (Europe)** – Quantitative and strategic benchmarking of mobile call termination provided by 20 operators, in support of a response to the regulators’ consultation.
- **Challenger operator (Europe)** – Development of a cost model for wholesale pricing strategy, followed by definition of pricing levels and a tariff structure.
- **Ofcom (then Oftel)** – Development of business models, forecasting the costs and revenues of local access providers using a range of current and future technologies, including: copper, fibre and radio

## Other projects

- **Challenger operator (Western Europe)** – Assistance to the Product Manager of the residential segment regarding competitor analysis of offers and prices, pricing analysis, and margin analysis

- **Global carrier** – Advice to board of directors on pricing and costing issues as it restructured its client base, with key market and client risks highlighted and evaluated
- **Government of Pakistan Privatisation Commission** – Privatisation of a fixed and mobile operator in Pakistan. Advisers to the government on the privatisation of its incumbent operator, PTCL (fixed and mobile businesses). Acted in consortium with investment banks and legal advisers to draw up the legal framework, estimate key operational variables (especially traffic), carry out the valuation of the operator and contribute to key sections of the Information Memorandum

### Conference presentations

Graham is a regular presenter at telecoms and spectrum conferences around the world

### Languages

English (mother tongue)

## Steve Lewis – Aetha Associate

Steve is an experienced consultant, telecoms solutions architect, commercial manager and professional engineer. He has a particular interest in change and transformation, and specialises in advising service providers on how to maximise the potential of their businesses, enter new markets and build new service offerings. As a commercial manager he has been responsible for wholesale deals worth over GBP 100m, and as a strategist and architect has brought numerous high value businesses to market.

### Key skills

Telecommunications, Business and Technology Strategy; Programme Management; Procurement; Business and Technology Transformation; National roaming and MVNO new businesses; Technical and Commercial due diligence; Operations Improvement; OSS/BSS Architecture; Data Analysis; Process design and optimisation; IPTV; VoIP

### Education

- M.Eng. Microelectronics and Software, Newcastle University (1991-1995)
- MBA, Durham University (2001-2005)
- MA (Phil). Philosophy, Open University (2007-2009)

### Employment history

- 2013 – Present SL Consulting Ltd (South Africa)
- 2011 – 2013 PrimeTel (Cyprus)
- 2010 – 2011 Lycamobile (UK)
- 2007 – 2010 Analysys Mason (UK)
- 2003 – 2007 BT Syntegra / BT Consulting Services (UK)
- 1997 – 2003 Tertio Telecoms Ltd (UK)
- 1995 – 1997 Vodafone Ltd (UK)

Examples of specific projects and roles undertaken by Steve are presented below. These have been categorised in the following areas:

- Corporate Management
- Fixed and mobile service providers
- MVNOs
- GSM-R
- ISPs
- ICT
- Regulatory
- Due Diligence

### Corporate Management

- CTO at PrimeTel PLC for two years leading a substantial business transformation programme. PrimeTel is a quad-play service provider and the largest independent telecoms company in Cyprus. Established a PMO for the transformation and redesigned most customer management and billing

processes, and alignment with eTOM. Strategy, design, procurement and implementation of a highly successful new national roaming MVNO business, replacement of a legacy Cisco voice network with a Sonus SIP VoIP solution, redesign of the IPTV business and introduction of the first Hybrid IPTV solution in Cyprus, introduction of the first FTTH network to Cyprus, deployment of sub-marine optical cables to Israel, Egypt and France. Design and deployment of a Cloud Computing environment. Complete OSS/BSS transformation to real-time on-line charging and customer management. Responsible for all technology operations, budgeting, supplier relationships, and line management to approximately 150 staff.

### Fixed and mobile communications service providers

- Developed a national roaming strategy and network architecture for a new entrant LTE operator in Bulgaria.
- Billing system replacement strategy and procurement for a leading cable operator in East Africa.
- Led the process analysis work stream using eTOM as a frame work for the separation of Botswana Telecom into a service provider and an infrastructure company prior to privatisation, advising the Botswana government. Drafted interim framework agreements for sharing of infrastructure, such as sits, ducts and poles.
- Defined a programme to replace several complex legacy, business critical, retail and wholesale systems for Vodafone UK. Advised on Next Generation OSS/BSS strategy, provided requirements analysis, and delivered an NPV analysis and five-year business case, which was used by the board for approval of a GBP10 million budget. Went on to successfully deliver the first phase as Lead Architect, working with three different suppliers, including offshore organisations
- Ran workshops in Tehran to advise Iran’s national PSTN operator on how to approach wholesale billing for market liberalisation
- Delivered pre-sales consultancy and solutions design to Vodafone Japan and Accenture, which led to a GBP3 million OSS delivery project, working with staff at all levels up to CTO
- Redesigned sales, support and billing processes for the BT Global Services on a programme to replace all country specific OSS/BSS systems with a Single Operating Environment (SOE), taking responsibility for the interfaces to third party distributors and suppliers
- Carried out process redesign and optimisation for MNP at Vodafone. Designed a provisioning solution for MNP
- Designed and implemented call modelling software at Vodafone to show how egress call hand-off routing could be optimised to BT, so as to gain the lowest network costs
- Participated in GSM standardisation activities on behalf of Vodafone UK, attending ETSI working groups and drafting standardisation documents.

### MVNOs

- Negotiated an AU\$200m wholesale airtime agreement for an MVNO in Australia and managed the contract drafting process through to signature. Commercial and project management of implementation through to successful business launch.
- Responded to the MVNO regulatory consultation in Cyprus and negotiated favourable terms on behalf of a new entrant. Went on to project manage the market strategy, proposition design and IT and organisational transformation programme definition
- Developed an MVNO / Sub-brand strategy for an established tier 1 mobile operator in UAE. Acted as lead architect in the design and procurement of new OSS and BSS systems
- Developed the launch roadmap for an MVNO new entrant in South Africa

- Strategy, architecture and procurement for an MVNE and MVNO B-Brand for a Tier-1 operator in Saudi Arabia
- Commercial negotiations for MVNO deployments in France, Poland and Ireland. Regulatory compliance for launches.
- MVNE technical strategy and procurement for an MVNE in Saudi Arabia
- Advisor to an MVNE provider in the UK.

### GSM-R

- Provided technical design support to DeutscheBahn and Nortel DASA and acted as architecture lead in a ‘first-in-the-world’ real-time network management solution for GSM-R

### ISPs

- Lead Solutions Architect working with a customer trying to understand an opportunity to develop a broadband business in the UK that identified and used Local Loop Unbundling (LLU) opportunity. Leading a team of architects from various parts of BT which led to a contract to supply infrastructure and services worth approximately GBP2 billion over five years

### ICT

- Designed and developed an SS7 based mobile network solutions for MNP, and pre-pay SMS for T-Mobile UK
- Drafted the initial version of the SIM Application Toolkit ETSI standard (TS11.14), which is now implemented in most mobile devices world-wide
- Advised a fixed line operator in the Middle East on the technical and regulatory aspects of launching an international VoIP carrier business
- Specified a mobile network order management product for a OSS/BSS software vendor as part of their product development process
- Solutions architect for provisioning and mediation systems at Hutchison 3G, Vodafone Japan, Vodafone Hungary, Vodafone Egypt, Vodafone Greece and FTML Lebanon

### Regulatory

- Technical advisor for a South African government initiative to understand the delays in deploying telecoms infrastructure and the development of a Rapid Deployment Policy. Recommendations included better sharing of existing infrastructure, such as ducts and poles and simplification of municipal processes for issuing wayleaves and permits.
- Delivered a detailed study into OSS/BSS service competition for Ofcom. This work considered the competition implications that arise from ownership of OSS/BSS systems, and the likely future direction of the industry. The outcome was used to guide upcoming UK regulation

### Due diligence

- Conducted a detailed operational review of Telecom New Zealand’s XT network, including a complex managed outsource relationship with Alcatel-Lucent, making recommendations for business improvement and reliability. As a result of this work, ALU agreed to pay TNZ NZ\$100m in compensation for the under-performance of the network.

- Carried out technical due diligence for a private finance organisation on a national fixed-line network in a Baltic country, providing a detailed analysis of their technical and commercial strategies for Next Generation services and network build
- For a broadband voice (VoIP) new entrant, carried out a technical, operational and regulatory due-diligence study in the months leading up to launch. Ensured that IT systems and processes were sufficiently well designed to support the rapid acquisition of new customers
- Carried out technical due diligence on a national operator in Mauritius in support of a financial transaction
- Market and technical due diligence for a software vendor considering an acquisition of an SDP company
- Contract due-diligence for a smart meter provider in South Africa. Review of the contracts with their prime contractor for the installation and operation of smart meters across their province

### Languages

- English (mother tongue)

## Prof. William Webb – Aetha Associate

William is a Director at Webb Search Consulting, a company specialising in providing the highest level of advice in matters associated with wireless technology and regulatory matters. He is also CEO of the Weightless SIG, the standards body developing a new global M2M technology. He was President of the IET – Europe’s largest Professional Engineering body during 14/15.

He was one of the founding directors of Neul, a company developing machine-to-machine technologies and networks, which was formed at the start of 2011 and subsequently sold to Huawei in 2014 for \$25m. Prior to this William was a Director at Ofcom where he managed a team providing technical advice and performing research across all areas of Ofcom’s regulatory remit. He also led some of the major reviews conducted by Ofcom including the Spectrum Framework Review, the development of Spectrum Usage Rights and most recently cognitive or white space policy. Previously, William worked for a range of communications consultancies in the UK in the fields of hardware design, computer simulation, propagation modelling, spectrum management and strategy development. William also spent three years providing strategic management across Motorola’s entire communications portfolio, based in Chicago.

William has published 14 books, over 100 papers, and 18 patents. He is a Visiting Professor at Surrey and Southampton Universities, an Adjunct Professor at Trinity College Dublin, a Board member of Cambridge Wireless, a member of the Science Advisory Council at DCMS, other oversight Boards and a Fellow of the Royal Academy of Engineering, the IEEE and the IET. In 2015 he was awarded the Honorary Degree of Doctor of Science by Southampton University in recognition of his work on wireless technologies and Honorary Doctor of Technology by Anglia Ruskin University in honour of his contribution to the engineering profession. His biography is included in multiple “Who’s Who” publications around the world. William has a first class honours degree in electronics, a PhD and an MBA.

## Annex C A layperson's guide to how roaming works

- C.1. The ability for users to make use of their mobile phone or other mobile device whilst visiting a geographic area outside the coverage of their home network has been a feature of mobile technology standards since the advent of GSM in the early 1990s. The original driver for the inclusion of 'roaming' within the GSM standards was the political desire within Europe for mobile phone users to be able to continue using their mobile phones whilst visiting other countries in Europe, and to begin with both the standards and the practical implementation of roaming were focussed on this case. The service offered was however somewhat crude. Subsequent developments of the standards have aimed at improving the user experience of roaming, and to a limited extent broadened its application to support roaming between networks within a single country (aka 'national' or 'domestic' roaming). Subsequent generations of mobile standards (e.g. 3G UMTS, and 4G LTE) have continued to support roaming and made further improvements in the user experience possible. Nevertheless, roaming is still a less than seamless experience for the end user.
- C.2. Roaming, whether international or domestic, operates roughly as follows:
- C.3. In order for a mobile device to make use of a mobile network it needs to register with that network. The mobile device does this by sending a message to the mobile network requesting access. Included in the message is a code that uniquely identifies the subscriber – the International Mobile Subscriber Identity or IMSI. (The IMSI is usually stored in the SIM that the user has installed in the mobile device).
- C.4. When the network receives a request for access it checks to see if the subscriber is one of its own customers (if the IMSI is one that it has issued). If not, it next checks to see if the IMSI has been issued by a mobile network operator with which it has a roaming agreement. If it has, it next checks to see if the subscribers of that network are permitted to roam onto the requested network within the geographic area that the mobile device is located within<sup>18</sup>. If they are, the network sends a message to the home network of the subscriber to ask if the subscriber is a valid user and is allowed (by the home network) to roam, and if so what roaming services the subscriber is permitted to use.
- C.5. If the home network is happy for the subscriber to roam onto the visited network, it will send back a message to the visited network with details of the subscriber and the roaming services that they are permitted to use. The home network will also update its record for the subscriber in its Home Location Register (HLR) with the location of the visited network, so that if it receives any incoming calls or messages for the subscriber it knows where to send them.
- C.6. The visited network will then temporarily add the subscriber to its Visitor Location Register (VLR), recording the subscriber's details, including the services it is allowed to access and the identity of the home network. Finally the visited network sends a confirmation message back to the mobile device to say that it is registered on the network, and at this point the mobile device will usually display the name of the network on which it is registered on its display.
- C.7. Thereafter the visited network handles the mobile device in much the same way as it would any of its own subscribers' devices, in particular keeping track of the area within which it is located so that

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<sup>18</sup> We discuss the specification of these areas in more detail below.

it can find the device it needs to communicate with it (for example to deliver an incoming call or message).

- C.8. If the user of the mobile device then wants to make a call or send a text, they do so in the usual way – e.g. dial the relevant number. The way in which the visited network handles such calls or texts is then determined by the information that the home network sent to the visited network when it authorised the visited network to allow the subscriber to roam.
- C.9. At its simplest, the visited network can handle the call or text in the same way as it would handle a call or text from one of its own subscribers. The only change is that the bill for the call or text is sent to the home network rather than subscriber. This was the way in which international roaming was originally implemented, but it has a number of issues:
- a) The home network has no control over the cost of calls and text messages that the roaming subscriber is incurring – information about the charges incurred are not sent in real time. As a result (home) mobile operators are generally unwilling to allow pre-pay customers access to such roaming services – because they may incur charges in excess of the amount they have pre-paid and the mobile operator has no way of recovering such excess charges.
  - b) (Post-pay) customers can suffer bill shock as they can run up a large bill for roaming without realising.
  - c) Customers will not be able to make use of certain special short-code numbers that their home network operator has defined – for example to access their voicemail service or customer support centre – since these will not be recognised by the visited network (or will be routed to the visited network operator’s service instead of the home network operator’s service).
- C.10. To address these problems, standards have been developed to allow the home network a greater degree of control over calls and texts originated by roaming subscribers on a visited network – Customised Applications for Mobile network Enhanced Logic (CAMEL). If both home and visited networks implement CAMEL, a home network can instruct the visited network to apply CAMEL control to any call and/or text originated by a roaming subscriber, when it authorises the visited network to allow the subscriber to roam.
- C.11. When a user makes an outgoing call or text under CAMEL control, the call is controlled by the home network rather than the visited network. This has a number of advantages:
- a) The home network can apply charges to the customer’s account in real time during the call, and, for example, terminate a call if the customer runs out of credit during the call
  - b) The home network can provide the customer with real-time information about the roaming charges that they have incurred, and, for example, send them a message when they reach a certain threshold or limit
  - c) The home network can instruct the visited network to route a call to a different number to the one actually dialled by the customer (number translation) – for example to route a call to the customer’s home voicemail service or customer service centre when they dial the relevant short-code.
- C.12. The user experience when making a call or text under CAMEL control can therefore be very similar to the experience that the user would have on their home network. CAMEL control does however

require additional functionality and capacity in the visited and home networks, and also additional connectivity between them. For this reason CAMEL control is not usually applied to all international roaming calls and texts, only to a subset of them (in particular calls and texts made by pre-pay customers). However, if a domestic roaming service is to be as transparent as possible to end users it is likely to be necessary for all calls and texts to be CAMEL controlled – so that the home network can manage and control those services in the same way as it would if the subscriber were on their home network<sup>19</sup>. This will require the visited and home networks to install sufficient capacity in their core networks to support CAMEL control of all calls and texts made by roaming customers.

- C.13. So far as incoming calls and texts are concerned, these are received initially by the home network of the subscriber. The home network uses its home location register (HLR) to identify the location of the subscriber and sees that the subscriber is roaming on another network. The home network sends the call or text to the visited network for delivery. The visited network routes the call or text to the subscriber's mobile device in the same way as it would an incoming call or text to one of its own subscribers.
- C.14. Mobile data traffic may also be controlled using CAMEL, but in practice is much less likely to be so because a simpler mechanism exists for home network charging and control as follows: When a roaming subscriber wants to use mobile data services when on a visited network, they are connected to a data switch in the visited network (a Serving GPRS Support Node or SGSN). Usually that data switch then initiates a connection with a data switch in the subscriber's home network (a Gateway GPRS Support Node or GGSN), which connects the data session to other services, such as the Internet. All mobile data traffic whilst roaming is therefore routed through a data switch in the subscriber's home network (the GGSN), which can carry out the required charging and control.
- C.15. Implementation of roaming therefore requires:
- a) A commercial agreement between the home and visited networks (including arrangements for wholesale billing and payment)
  - b) Interconnection between the home and visited networks to allow signalling messages to be exchanged for the purposes of authorising roaming subscribers
  - c) Interconnection between the home and visited networks to allow the delivery of calls and texts to roaming subscribers<sup>20</sup>
  - d) If CAMEL is implemented, additional functionality, capacity, and interconnection between the networks to allow calls and texts to be CAMEL controlled
  - e) Interconnection between the home and visited networks to carry roaming data traffic.

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<sup>19</sup> An alternative partial solution that has been used in the past is for the visited network to implement the dialling plan of the home network directly in its switches, but this requires additional work by the visited network, which has to be repeated for each operator whose customers might roam onto the visited network, and needs to be updated each time the home network makes changes to its dialling plan. As such it is less flexible, more prone to configuration errors, and requires more coordination between network operators than does the approach of controlling all calls and texts with CAMEL.

<sup>20</sup> For voice calls this is simply standard voice network interconnection.

- C.16. All of the above requirements can be met using existing standard technologies which are already deployed worldwide for the purposes of international roaming. Domestic roaming does not materially differ in terms of its technical requirements (although see below re limiting the geographic availability of roaming), although the level of demand and hence capacity required may be materially greater than that required for international roaming.
- C.17. For the purposes of our report it is also helpful to understand how, and when, a mobile device selects the network it wishes to make use of. This operates roughly as follows<sup>21</sup>:
- a) When a mobile device is switched on (or Airplane mode is disengaged) it will first try to reconnect to the network with which it was last registered.<sup>22</sup>
  - b) If that fails, the device will next do a scan for all available networks.
  - c) Assuming that it finds at least one network, it will then identify the highest priority network that is available, based on a number of lists that are stored in the device or SIM – these lists give priority to the subscriber’s home network and any ‘equivalent’ networks, any networks that the user has identified as being priority networks, and any networks that the subscriber’s home network has identified as priority networks. This latter functionality in particular is important, as it allows home network operators to ‘steer’ customers towards particular networks when they are roaming – for example networks operated by members of the same corporate group.
  - d) The mobile device and SIM also store other lists, of ‘forbidden’ networks, and the mobile device (but not the SIM) stores a list of forbidden ‘location areas’ within each network, where it is not allowed to roam – it will not attempt to register with these networks or in these areas.
  - e) The mobile device will then attempt to register with the highest priority network that is available (and not forbidden).
  - f) If for any reason it is unsuccessful, it will attempt to register with the next highest priority network that is available (and not forbidden), and so on until it is successful<sup>23</sup>.
  - g) Once the device has successfully registered with a network it will remain on that network until one of two things happens: either it loses signal from that network (moves out of coverage), or a pre-specified period expires (the ‘higher priority network search period’ – this is pre-specified on the SIM of the subscriber and is a period between 6 minutes and 8 hours, in units of 6 minutes).
  - h) If the mobile device loses signal from the network it is registered on it will look for another network using the same process as when it was first switched on – whilst this is going on it is not connected to any network.

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<sup>21</sup> For the purposes of this simple description we assume that the device is using automatic network selection.

<sup>22</sup> Some devices may try first to connect to their home network.

<sup>23</sup> If it cannot register with any of the networks listed in its preferred network lists, it will randomly select from amongst the other networks that are available that have ‘good’ signal quality. If it cannot register with any of those, it will try to register with the remaining available networks in order of decreasing signal quality.

- i) If the higher priority network search period expires, the device remains registered with its current visited network but looks to see if a higher priority network is now available (for example its home network). If one is, it will attempt to register with that higher priority network, and if it succeeds it will be de-registered from the network it was previously registered with.
- C.18. Note that the roaming device is not continuously looking for its home network or the network with the best quality signal – it only looks for a different network if it loses coverage from the network it is currently registered with, or at some pre-defined interval (minimum 6 mins and potentially longer). Furthermore, even then the device may not select the network with the best quality signal – it will select a ‘preferred’ network if one is available, even if the signal quality is not as good as from an un-preferred network.
- C.19. For international roaming it is standard practice for visited networks to allow roaming customers to make use of their network in all areas where the visited network has coverage. By contrast, in the case of national (aka domestic) roaming the geographic area within which roaming customers are allowed roaming access will often be limited. Current standards support such geographic barring by allowing the visited network to identify Location Areas (LAs)<sup>24</sup> in which roaming is allowed and those in which it is not allowed, potentially differently for each roaming operator.
- C.20. A location area is a group of cells in a network that are (usually) geographically adjacent to each other. Each cell belongs to exactly one location area (i.e. location areas do not overlap except to the extent that the coverage of the cells at the edge of one location area may overlap with the coverage of the cells at the edge of another location area), but each location area usually contains a number of cells. The original reason for defining location areas in networks was to reduce the geographical area that is paged when the network needs to establish communications with the mobile. Larger location areas reduce the frequency with which mobile devices need to update the network as to their location – a mobile device only needs to send a location update to the network when it moves from one location area to another, not from one cell to another within a location area. Their use to define the geographic limits of roaming was a later addition.
- C.21. When a visited network receives either a registration request or a location update from a roaming device, it will check to see if the subscriber concerned is allowed to roam in the location area that the device is now located within. If the subscriber is not allowed to roam in the current location area then the network will reject the registration request or location update using the message ‘roaming not allowed in this location area’. This tells the device that it might be allowed to roam onto this network elsewhere, but it isn’t allowed to do so in the current location area. The device stores this information so that it doesn’t keep trying to register with the visited network in this location area (although this information is lost when the device is switched off). The device then looks for another network in the same area onto which it can roam (if any is available).
- C.22. It is also possible for a visited network to restrict the network layers that a roaming device can access, for example to allow it to access the visited network’s 3G capacity, but not its 4G capacity.

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<sup>24</sup> Location areas can be sub-divided into Routing Areas (RAs) in 3G networks and Tracking Areas (TAs) in 4G networks, but the current standards do not support rejecting roaming access requests (or location updates) at the level of these smaller areas.