JRC Whitepaper:	Operational Control of Mission Critical Networks and the Service Limitations of Public Mobile Networks

Executive Summary

This paper explores the approach adopted by Mobile Network Operators (MNOs) in providing a service to UK customers and in this context acknowledges the limitations that exist for these services to be used for the Operational Control of Mission Critical Networks, e.g. Energy Networks. Whilst the regulatory framework has encouraged market competition for service provision it has not encouraged the types of investment necessary to facilitate the needs of Critical Network Infrastructure Operators, e.g. the Energy Network Operators. The issues of note being;

- Regulatory framework is targeted at market mechanisms[1] to stimulate low-cost services to the consumer with limited obligations to be delivered in terms of coverage, performance, etc.;
- Service provision is targeted at population centres and communication corridors to maximise economic return resulting in 'not spots' of service coverage in locations that are uneconomic;
- Technical characteristics of cellular network design can result in a loss of service at the cell edge which is a particular issue in sparsely populated areas where cell density tends to be low;
- The speed of data transfer across the network has increased over time through technology enhancements but is still inadequate to address the critical application requirements of the Energy Network Operators;
- Mobile Networks have not been designed and deployed to have the necessary resilience to mains power outage to support the operational requirements of Critical National Infrastructure Operators.
- Technology refresh cycle and rate of refresh is tailored to the market demands of the General Public and has the potential to result in stranded assets for Enterprise Customers with the subsequent disruption and cost associated with replacement at relatively short notice;
- The characteristics of Network Design and the Operational model of MNOs does not lend itself to Quality of Service (QoS) guarantees; and
- Cybersecurity and the increasing risk associated with system attack poses particular challenges when considering the use of Public Networks to facilitate the Operational Control requirements of Critical National Infrastructure.

Notwithstanding the limitations noted it is important to acknowledge that the MNOs have invested heavily over many years to support the Mobile Communication needs of UK citizens with the competitive market facilitating the low-cost provision of Mobile Broadband services. Furthermore, In some instances, Energy Network Operators have deployed multiple service platforms in parallel including services provided by Mobile Networks to minimise the risk of disruption associated with limited individual system resilience.

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[1] As has been noted in Ofcom consultation, 'Discussion paper: Ofcom's future approach to mobile markets,' 9 February 2022, Discussion paper: Ofcom's future approach to mobile markets

Background

Telecommunications Regulatory Framework

The Office of the Communications Regulator (Ofcom) was established to administer the Telecommunications market in the UK from the perspective of market competition and as such has adopted a light touch regulatory model in comparison to that which is administered by Ofgem in the context of Energy Network Operators. This light touch regulatory model has translated into relatively little in the way of license obligations to be complied with. As a result, UK consumers have benefited from low-cost services and enhanced choice. However, the emphasis placed on competition by Ofcom has been to the detriment of the scale and reach of the networks deployed by the Public Mobile Network Operators. Whilst Ofcom imposed coverage obligations for the first time on the 3G licences awarded in 2000 this was set at 80% population coverage to be achieved by the end of 2007, this could be achieved relatively easily by deploying urban conurbations and communications corridors. In 2005 / 2006 Ofcom consulted on the approach to measure / test the Network Coverage achieved by the Mobile Network Operators (MNOs) ahead of the licence coverage obligation at the end of 2007. In response to this consultation process some of the 3G licensed operators[2] (O₂ and T-Mobile) argued that the coverage obligations should be removed. Since 2008 there have been increases to the 80% coverage target with enhanced coverage obligations imposed on the licensed operators, but these have been subject to concessions relating to the facilitation of 4G based services aligned to subsequent spectrum awards.

Auction Design and the Impact on Network Roll-out

Ofcom have adopted an approach which encourages upfront competition for spectrum access resulting in high spectrum access costs the consequence of such a framework has been that Network Operators have been less able to invest in and expand their network infrastructure due to economic constraints. Ofcom have considered this in the analysis that they have undertaken since 2015[3] to better characterise the variations in mobile coverage across the UK. In this analysis they note;

> *'This decision to upgrade a fixed and/or mobile network is essentially a commercial judgement for the network operator. They will likely assess the profitability of upgrading a network in an area by considering the potential demand for services as well as the costs of providing those services.'*

It is worth noting that other National Regulatory Authorities (NRAs), e.g. PTS in Sweden[4], have taken into consideration the impact of auction design on Network roll-out and have specifically prioritised roll-out obligations to guarantee full geographic coverage with the consequent impact on the spectrum value generated by the award.

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[2] https://www.ofcom.org.uk/__data/assets/pdf_file/0022/54445/3g_consultation.pdf
[3] https://www.ofcom.org.uk/research-and-data/multi-sector-research/availability-of-communication-services
[4] Sweden raises $323m in spectrum auction - Telecoms.com

![jrc - joint radio company logo]

Mobile Network Coverage / Service Limitations

As has been noted the regulatory framework has emphasised price competition which has benefitted the consumer in terms of service offering and choice but has directly impacted the extent to which Networks have been rolled-out / extended to serve the whole of the UK. The figure below has been extracted from Ofcom's Connected Nations: UK Report demonstrates the variability of coverage by MNO by UK Nations[5]
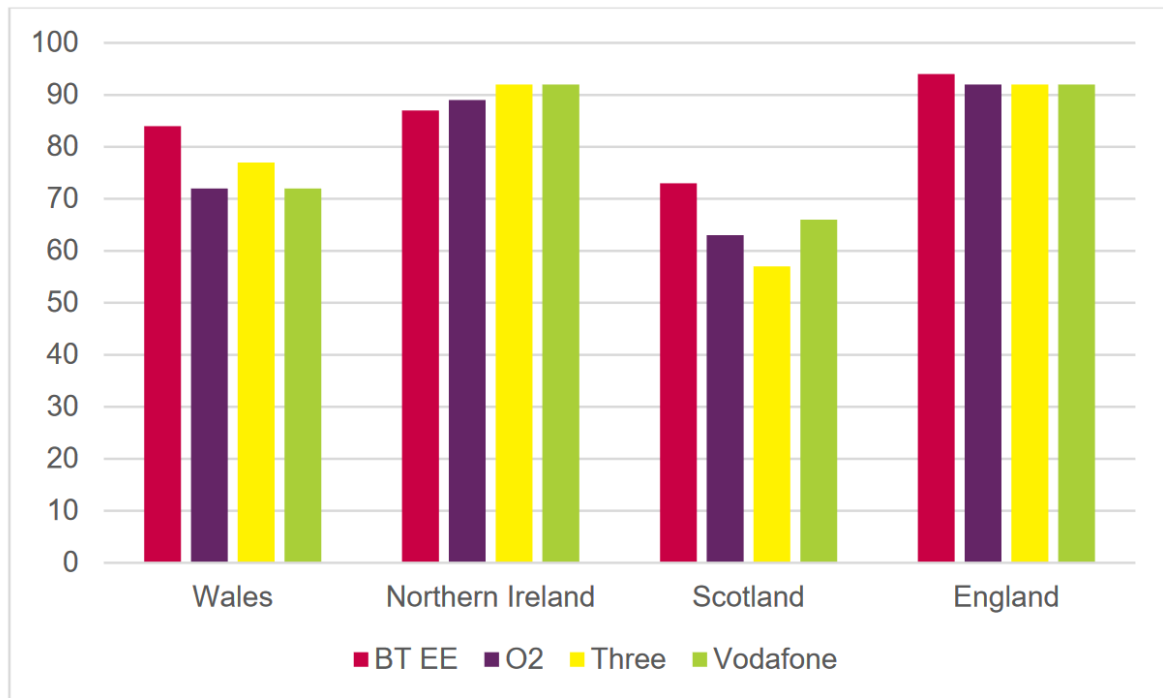
Source: Ofcom analysis of MNO predictions, September 2021.

Government interventions to Address 'not spots'

Coverage limitations / unserved areas have been characterised as 'not spots' and these are a consequence of two factors, planning constraints blocking infrastructure deployment, e.g. Areas of Outstanding Natural Beauty (AONB) and / or low population density making the investment in cell sites uneconomic. This is inherently a consequence of the regulatory framework and as such Government have acknowledged this regulatory failure through interventions to directly fund deployment to the 'not spot' locations. To date there have been two failed attempts to facilitate coverage to 'not spots' the latest incarnation is the recent commitment by the UK Government and the Licensed Operators to deliver the shared rural network[6,7] a product of a £1bn investment (£500m from Government to match £500m from the licensed operators). The focus for this initiative is the roll-out of 4G services to previously unserved communities in Scotland, Wales and North East of England by the end of 2025.

As a result of the Shared Rural Network, it is predicted that 4G coverage in all four home nations of the UK will increase as follows[8]:

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[5] https://www.ofcom.org.uk/__data/assets/pdf_file/0035/229688/connected-nations-2021-uk.pdf
[6] https://www.gov.uk/government/news/shared-rural-network
[7] https://www.gov.uk/government/news/mobile-connectivity-revolution-to-boost-the-union
[8] https://srn.org.uk/forecast-coverage-improvements/

	4G Coverage from all MNOs		4G Coverage from at least one MNO	
	Pre-SRN	Forecast post-SRN	Pre-SRN	Forecast post-SRN
Overall	69%	84%	91%	95%
England	84%	90%	97%	98%
Scotland	44%	74%	81%	91%
Wales	60%	80%	90%	95%
Northern Ireland	79%	85%	97%	98%

% figures rounded to whole figures. Pre SRN figures taken from Ofcom 2020 Connected Nations Report published 12 May 2021, showing coverage data as of Jan 2021.

Scotland is predicted to benefit the most of the four home nations with coverage from all four MNOs to be delivered to three quarters (74 per cent) of Scotland's landmass by the end of the programme. This is an increase of two thirds and up from 44 per cent currently. Wales is predicted to see the next highest increase - with coverage from all four operators across its geographic area increasing by more than one third, from 60 per cent to 80 per cent. Northern Ireland is predicted to see 4G from all four MNOs rise to 85 per cent of its landmass, up from 79 per cent in 2020. The North East of England will see total 4G coverage jump from 68 per cent to 86 per cent.

Independent of the above intervention the Mobile Networks have prioritised network roll-out on the commercial benefit to be realised based on economically rational coverage. Hence resulting in the state mobilised SRN investment noted above to facilitate network roll-out to unserved communities which is not targeted at the needs of the Energy Networks and hence may or may not enable a service to historically unserved energy network assets.

Network / Service Design Aspects to Consider

Coverage as a Differentiator

The provision of Mobile services by the licensed operators was initially dependent on the coverage of their individual networks and as such Network Coverage in the initial stage of service launch and expansion was a key competitive advantage with those operators offering the most relevant coverage generating the highest number of subscribers and service income. This resulted in a race by Network Operators to increase their specific network coverage with the original four networks being joined by the 3G network of Three post 2000. However, as network coverage across operators stabilised in the period of 2000 to 2010 it was no longer a point of competitive differentiation and as such the Industry shifted the focus of its investment priorities to technology upgrades.

Consolidation of Network Infrastructure to reduce costs

With network coverage no longer being a differentiator the focus over the last decade has been on network investments in 4G technology and the emphasis placed on the roll-out of Mobile Broadband. To facilitate technology upgrade the industry has sought to minimise its Operating costs by infrastructure consolidation through the establishment of MBNL[9] (Mobile Broadband Networks Limited – Everything Everywhere & Three) and CTIL[10] (Cornerstone Telecommunications Infrastructure Limited – O_2 & Vodafone). In so doing the five original discrete mobile networks have been consolidated onto two infrastructure footprints and whilst there has been some increase in the active points of presence per MNO the actual number of discrete network sites has reduced with the inherent reduction of the diversity of network coverage available.

Cell breathing / Impact of frequency used

Public Mobile Services were initially designed to deliver mobile voice services and utilised spectrum in the 1 GHz frequency range which facilitated good coverage and in-building penetration. The shift towards Mobile Broadband services for consumers has prioritised wider spectrum blocks at higher frequencies 2GHz and above to facilitate higher download speeds to support streaming video on the go. As the industry has rolled out Mobile Broadband services at higher frequencies the number of active radio sites has increased to optimise the capacity needed per a cell to support traffic demand. As traffic demand has become more dynamic within a cell and the amount of spectrum resource available is finite the resulting phenomenon of 'cell breathing' occurs whereby the cell radius contracts as traffic demand increases and where possible traffic at the edge is offloaded to the adjacent cell. This works well in dense urban areas where site density is adequate to accommodate such cell breathing and offloading but in areas where site density is inadequate to accommodate this effect service provision at the cell edge will be unstable and can be lost.

Latency

Latency is a measure of delay. In a network, latency measures the time it takes for some data to get to its destination across the network. It is usually measured as a round trip delay - the time taken for information to get to its destination and back again. The investments made in the roll-out of Mobile Broadband has reduced the latency in the networks, see below, but in spite of this improvement this still precludes mobile networks from servicing the critical control requirements of Energy Networks, e.g. Teleprotection, etc.;

- 120ms for 3G cellular data

- 60ms for 4G cellular data

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[9] MBNL - Mobile Broadband Network Limited
[10] Cornerstone Telecommunications Infrastructure Limited - UK leading mobile infrastructure services

Furthermore, as cells adjust to accommodate traffic demand and all traffic is treated equally (no prioritisation of traffic exists) the requirements of Machine-2-Machine applications designed to monitor and control Energy Network Assets can be impacted by discrete loading of the cell by e.g. a bus full of school children streaming video.

Power Autonomy

Public Mobile Networks have been designed to deliver a 'reasonable endeavours' service to address the needs of their customers, i.e. the General Public, to enable mobile broadband for applications e.g. video streaming, e-mail, social media, on-line gaming, internet traffic, voice, etc.. To this end, the market has only demanded a service level that can be expected rather than depended upon and independent of a regulatory requirement for networks to be resilient they have not been configured that way. A recent economic study[11] has estimated that a significant capital investment of £414m would be required to make a Public Mobile Operator's Network suitably resilient to mains power outage. MNOs have chosen to avoid such an investment as it is unnecessary to address the needs of the consumer. To this end, evidence gathered by Ofcom[12] demonstrates that 'Power cut' events are the second most common reason for Mobile Network operational failure. Independent of an economic case for the MNOs to invest in their network infrastructure to ensure it is resilient to mains power outage there is a practical limitation to the deployment of back-up power to radio sites which is the lack of physical capacity to accommodate an Uninterruptible Power Supply (UPS) and/or generator to individual sites, notably roof tops and roadside monopoles see typical examples below;

Roof tops will be unable to accommodate UPS / back-up generator due to lack of space and / or insufficient structural capacity, whilst roadside structures such as the monopole depicted will not have a suitably secure area to locate the UPS / Generator and this infrastructure would be a target of thieves.

Economic Drivers of Technology re-fresh

As has already been noted the emphasis placed on infrastructure investment over the last decade has been to facilitate enhanced capacity and speeds of Mobile Broadband with the roll-out of 4G (LTE) technology. This has been dependent on the deployment of 4G capable equipment both in the Core

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[11] https://www.jrc.co.uk/Plugin/Publications/assets/pdf/ICT-Economic-rationale-for-enabling-Smart.pdf
[12] https://www.ofcom.org.uk/__data/assets/pdf_file/0024/209373/connected-nations-2020.pdf, pg. 56, Figure 27.

and Radio Network in addition to a profound expansion in the back-haul capacity in the network. This technology roll-out has been motivated by three factors;

(i) Consumer demand for enhanced service provision compared to 3G[13];

(ii) Cost efficiency gains to be realised through migration to 4G, lower cost of bits / Hz; and

(iii) The benefit to be realised from the migration of spectrum from the old standard to the new standard resulting in lower cost of traffic in terms of bits / Hz.

Whilst consumers are aware of the migration of mobile services from 1G through to 4G and current developments associated with 5G that occur over decades it is important to note that the standards on which the network functionality is based are constantly being updated by 3GPP[14], see release programme depicted in the image below;

Source: 3GPP TSG SA#87e, 17-20 March 2020, e-meeting document SP-200222   © 3GPP 2020
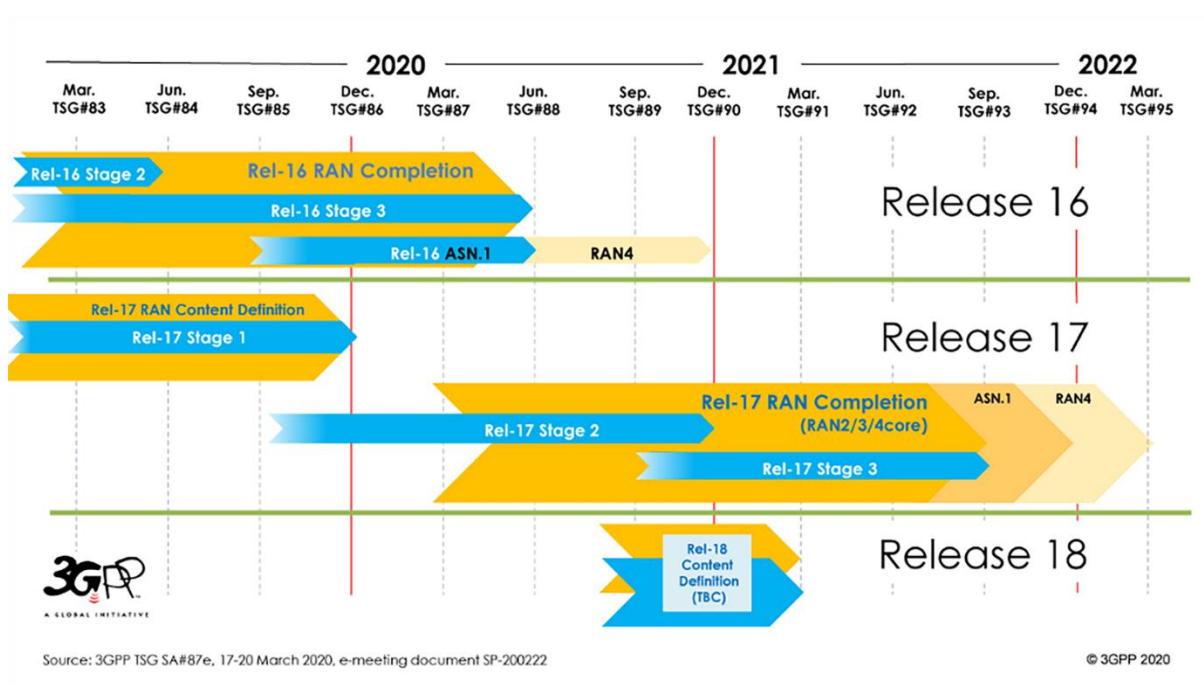
This programme of constant development is typically resulting in a wholesale upgrade of the network functionality every ten years[15] with a consequent need for end devices to be upgraded / replaced in a similar timeframe to realise the service benefits. Whilst this replacement cycle can easily be accommodated by consumers with handsets typically replaced every two / three years it is much more challenging both financially and operational for Enterprise users when embedded devices need to be replaced.

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[13] https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2015/4g-outperforms-3g
[14] https://www.3gpp.org/specifications/work-plan
[15] The shaping up of the European 6G vision… Towards "Internet for all"? Slide 10, SPF Plenary 2021.10.21 Simon Fletcher, CTO Real Wireless,

The manifestation of technology obsolescence is the programme underway by Openreach to withdraw the Public Switched Telephony Network whilst the MNOs have signalled their intent to Sunset 2G and 3G services, BT has already indicated that its 3G services will be withdrawn by 2023[16].

Commercial Framework

The service offering available from Mobile Operators is tailored to the needs of the consumer and as such does not contemplate priority status for critical system operators. Furthermore, MNOs are unable to offer a Quality of Service (QoS) guarantee because the network infrastructure has not been designed with the necessary levels of resilience, as noted in the Power Autonomy section, and the investment required would be disproportionate to the economic gain to be realised. Moreover, there is a clear lack of enthusiasm from the MNOs to address such a market demand. Whilst, Government has sponsored the development of a 'resilient' communications network based on an existing Mobile Networks Infrastructure, Emergency Services Network (ESN), it is understood that this network is only partially resilient to mains power outage even though it has received a total investment to date estimated at £9.5bn[17].

Whilst Mobile Network Services have historically had a relatively long shelf life it is clear from the communications about the Sunsetting of 3G and 2G services that the MNOs are contemplating a relatively short notice period in terms of service withdrawal, i.e. 18Mths for 3G[18]. It is anticipated that 2G based services will continue beyond 2023 with a recent announcement from DCMS[19] suggesting that it will be available until 2033 at the latest but it is expected that this is very much a long stop date and 2G services will be withdrawn before the end of this decade.

Security

With the increasing emphasis being placed on ensuring the appropriate cybersecurity arrangements for Critical National Infrastructure are in place to avoid significant events, e.g. Colonial Pipeline Attack[20] or Irish Health Board Attack[21]. There is an increasing awareness that Mobile Networks by their very nature are public networks and therefore open networks. Whilst communications across Public Networks can be encrypted and hence made secure the transfer of this information via public networks allows it to be more readily intercepted and also creates more opportunity for system attack where the Public network interfaces with the Private Network leading to greater importance on 'patch' Management by the MNO and hence a critical operational dependency being administered by a third party who may only subject to relatively minimal commercial constraint.

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[16] https://www.theregister.com/2021/07/15/bt_3g_shutdown/
[17] https://www.publictechnology.net/articles/news/%E2%80%98no-later-2025%E2%80%99-%E2%80%93-emergency-services-network-faces-further-delays-and-cost-rises
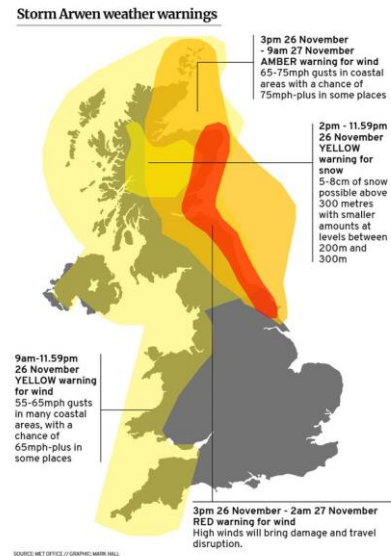[18] https://www.theregister.com/2021/07/15/bt_3g_shutdown/
[19] https://www.gov.uk/government/news/a-joint-statement-on-the-sunsetting-of-2g-and-3g-networks-and-public-ambition-for-open-ran-rollout-as-part-of-the-telecoms-supply-chain-diversificatio
[20] https://www.nytimes.com/2021/05/08/us/politics/cyberattack-colonial-pipeline.html
[21] https://www.bbc.co.uk/news/world-europe-58413448

Case Study – Storm Arwen the Communications Challenge

An article by the BBC[22] has highlighted the issues posed by Storm Arwen in particular the limitations associated with the migration from PSTN based services by Openreach whilst also acknowledging the issues resulting from the loss of mobile services due to mains power failure. The lack of robust and resilient public communications networks clearly poses a problem for consumers to be able to communicate with Friends, Family & Emergency Services, but also poses a significant challenge for the Energy Network Operators to be able to communicate with its customers in the event of an emergency of this type. Furthermore, from an operational perspective there is a clear need for the Energy Network Operators to be able to a suitably robust and resilient wide area voice communications capability to facilitate system restoration in such an event and this requirement can not be supported by Public Mobile Networks.

In addition to the above;

- An article has been published by a regional paper after Andrew Bowie MP (Con, West Aberdeenshire and Kincardine) publicly urged Energy Minister Greg Hands to call for an Ofcom review of mobile communications network resilience during adverse weather. Bowie observed that DNOs' efforts to reconnect customers experiencing power outages from Storm Arwen were hampered by reliance upon mobile communications systems which collapsed during the storm.

- Richard Holden MP's (Con, North West Durham) constituency was severely impacted by Storm Arwen, leaving many of his older constituents in rural areas without mobile signal due to their reliance on VOIP connections. Notably, there has been a petition in Holden's constituency calling on BT Openreach to discontinue the VOIP rollout which has already received 400 signatures. In Parliament, he has highlighted the need for energy companies to engage with local resilience forums but has not raised the vulnerability of mobile networks.

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[22] https://www.bbc.co.uk/news/uk-england-cumbria-59564480, Storm Arwen: Why power cuts left people unable to phone for help, December 12th 2021.