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uk spectrum policy forum

The Potential Impact of Switching Off 2G in the UK

A Report for the UK Spectrum Policy Forum by Real Wireless

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Real Wireless is the world's leading independent wireless advisory firm. Its network of experts includes engineers, physicists, economists, security advisors, business strategists and deployment specialists. Real Wireless clients benefit from a comprehensive portfolio of specialists and custom tools that analyse radio network performance, techno-economic impact and the business model implications of wireless systems. With this unmatched resource Real Wireless is able to advise the industry and all user groups, spanning businesses to governments, mobile operators, regulators and technology companies on every aspect of wireless technology.

Real Wireless has applied this unique range of technical and strategic expertise to some of the UK's biggest wireless infrastructure projects – from major stadium connectivity to shopping malls to transport systems — and has worked with operators, vendors and regulators on all forms of wireless connectivity. It has also advised governments and the European Union on the technical, social and economic implications of communications policy.

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About the UK Spectrum Policy Forum

Set up at the request of Government the purpose of the Spectrum Policy Forum is to be a pro-active industry-led 'sounding board' to UK Government and Ofcom on future policy and approaches on spectrum and a cross-industry 'agent' for promoting the role of spectrum in society and the maximisation of its economic and social value to the UK. We do this by exchanging news and views on developments in using spectrum, drawing on our industry expertise from around the world.

The Forum is open to the full range of UK spectrum users. Our members currently include over 240 companies and organisations with an interest in using spectrum for a diverse range of applications. In this context the term 'spectrum users' is to be interpreted in the widest sense - including all industry sectors which use (or will use) wireless techniques and organisations involved in the entire value chain in these activities.

The Steering Board ensure that the work of the Forum is properly framed, work items expedited in the correct manner and suitably resourced, and monitor progress on the delivery of the agreed work packages.

The current members of the Steering Board are:

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Executive summary

The UK's three 2G networks, which have been operating since the 1990s, still provide voice and machine-to-machine (M2M) services to important segments of these markets. While voice user numbers are falling rapidly, M2M quantities are growing and include the national smart meter network, which is still being deployed. 2G voice and text services are typically used by the elderly, who want simple, non-touchscreen phones – so called 'senior phones' - and by tourists coming to the UK. Key M2M use cases are vehicle telematics, asset tracking and the smart meter programme. In addition, the EC mandated in-vehicle eCall service, a system that automatically contacts the emergency services in the event of an accident, using both voice and data capabilities, is currently based on 2G/3G technologies.

Any plans to switch off (sunset) these networks need to be carefully thought through, planned and communicated to the end users and supporting ecosystems. Transitioning the declining number of voice users – who need to buy a new 4G-capable phone - should be relatively straightforward, at least for UK residents, if supported by appropriate information and marketing campaigns. Transitioning the M2M services – including smart metering - is a far more complex task, requiring the mobile network operators (MNOs) to work closely with all elements of the value chain to ensure that the introduction of new M2M connectivity technology/technologies is fully supported by an ecosystem able to support at-scale deployments. Such a transition could take 2-3 years – possibly longer - to plan and execute across the entire ecosystem. Similarly transitioning the eCall service needs careful consideration given that vehicles typically have a life of 10-15 years.

We support the view that 3G sunset for all UK operators is likely to occur ahead of the 2G sunset, although the transition of voice services away from 2G/3G to 4G Voice over LTE (VoLTE) may delay the 3G switch-off date, depending on the rate of user transition to VoLTE-capable phones. Until VoLTE is universal, there will be a need for 4G circuit-switched fallback (CSFB) to 2G or 3G networks. At present there is still a significant volume of non-VoLTE-enabled 4G devices relying on 2G/3G for voice.

The mobile industry expects that 3G sunset could take place in the next 2-3 years. 2G sunsets are probably unlikely to occur before the mid-2020s and possibly the early 2030s. There are two key determinants for these dates. One, how the two specific and prescriptive requirements evolve – these being the smart meter network and the eCall service – which share similar asset lives. And two, the development and national deployment (by the MNOs and others) of replacement M2M radio access technologies - in effect, what will be able to replace today's 2G M2M services at equivalent levels of coverage, cost and ecosystem support. Consumers should probably have 1-2 years' notice to replace their mobile devices, supported by information campaign, and possibly offers from the MNOs to encourage changeover to a newer device. The M2M market will be best served with 3-5 years' notice and the MNOs will need to dedicate resources to help guide these ecosystems into being able to support the replacement technologies.

MNOs have already refarmed 2G spectrum to meet demand for newer technologies such as 4G, and this will continue as demand from other access technologies grows. It is also possible that a single shared national 2G network could provide a long term solution if all of the technical, commercial and regulatory hurdles could be overcome.

Lessons learnt from overseas sunsets suggest the need for careful planning, clear communication, and ensuring that the affected users are a low percentage of the total base. These case studies also show the value of setting a clear date up to two years before sunset, during which no further new 2G devices can be activated. The UK should be able to benefit from the experiences of operators in Europe and North America, some of whom will switch off 2G at an earlier stage.

If planned and executed correctly, the implications of 2G services being withdrawn for all three UK 2G networks should have minimal implications at the time of actual switch-off for each network. Despite potential media interest relating to the more vulnerable 2G users, MNOs and the ecosystems should be able to work together to ensure a smooth transition, at whatever stage each MNO decides to switch off its 2G network, or to transition to a shared network, should that approach be taken.

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1 Introduction: The context for sunsetting

A sunset takes place when a mobile network operator (MNO) switches off a particular generation of cellular technology, at which point all devices and services on that technology cease to be served. Many, but not all, consumer devices, such as phones, support multiple generations of mobile technology as standard, minimising the impact of a sunset. However, industrial use cases for cellular technology, such as machine-to-machine (M2M) communications, are typically based on a single cellular technology. Hence the impact of a technology sunset varies by use case and device.

There are many drivers for an MNO to sunset one or more of its networks, though the most important one has often been the need to free up spectrum to be used on modern radio access technologies (RATs) with greater spectral efficiency, improved energy efficiency and enhanced functionality.

Based on interviews and surveys of MNOs internationally, the following drivers were identified as the most important ones behind a network sunset:

- Free up spectrum for other technologies that offer better cost efficiency and greater revenue-generating functionality.
- Avoid the cost of refreshing and maintaining end-of-life equipment. Newer RATs tend to be more cost-efficient to maintain, and the return on investment (ROI) in modernising 2G or 3G equipment will be lower than on expanding 4G or implementing 5G.
- Rationalise technologies to lower the operating complexity of running three or four different networks.
- Phase out inefficient or power-hungry base stations and devices.
- Reduce the variety of devices that need to be tested, provisioned and supported.
- Optimise the overall customer experience by migrating the entire user base to a more functional technology.
- Maximise the revenue opportunity by exposing all users to full mobile broadband applications, and shift the service and marketing focus towards higher value users and services.

The result of a sunset, if it is well timed and managed, should be higher capacity for the operator's most modern, efficient networks, greater overall cost and power efficiency, and an improved addressable market.

However, there are risks associated with sunsetting. These include:

- Possible reduced coverage, which may impede the MNO's ability to comply with regulatory coverage targets.
- Reduced coverage may also make it impossible for the operator to serve certain users or applications, and a decision must be made about the impact on the business of this loss.
- Even within the coverage area of the newer networks, the MNO may lose some subscribers who do not migrate. Again, an MNO must set a clear policy on which users it can afford to lose.
- A service may be migrated to the newer network, but may prove more expensive to run, because the new functionality is 'overkill'; or users may refuse to pay more for additional performance they do not require.

- On a newer network, MNOs may incur higher costs to finance or support more complex devices, even though the users may be using them only for basic functions, so those costs are not matched by increased service revenue.
- There may be negative impact on public image and reputation if the MNO is perceived to have 'left behind' vulnerable users, such as the elderly, or jeopardised important services, such as smart metering.

Most of these risks can be mitigated by getting the timing right for full switch-off. As an example, KT in Korea faced regulatory problems and subscriber lawsuits when it initiated 2G sunset in 2011 because it still had a large and active 2G community (5% of its base). By contrast, NTT Docomo in Japan successfully reduced the number of 2G users ahead of sunset in the same year, to just 0.3% of its base.

The market has already seen many wireless network sunsets, mainly of analogue 1G networks such as AMPS in the USA, TACS in Europe and J-TACS in Japan. The US operators have also switched off their TDMA voice networks.

Now, the focus is on the 2G and 3G networks, as operators start to plan to refarm the spectrum used for those technologies, to support 4G expansion or 5G deployment. Some 2G and a few 3G networks have already been switched off, especially in North America and south east Asia (see Section 6). In Europe, the process is in its very early stages and most MNOs have not set a firm date to switch off 2G or 3G. In some cases, 3G may be switched off before 2G, because the coverage footprint of the latter is harder to replicate cost-effectively with 4G.

Emerging approaches, such as fully dynamic allocation of spectrum to different services, will give MNOs greater flexibility to align their network migration with their service base, and some may support new strategies such as shared networks to keep 2G services running indefinitely (see Section 3).

This report will examine the 2G sunsetting options available to UK mobile operators, the likely timing and implications of 2G sunset, and provide some comparisons with international trends.

2 Services currently operating in the UK using 2G

2.1 2G usage trends in the UK and Europe

In the UK, as in the rest of Europe, 2G usage is in sharp decline as more users require faster data rates than GPRS supports. In Europe, the GSMA[1] forecasts that 2G will fall from 22% of connections in 2017 to just 1% in 2025 (excluding M2M) as shown in Figure 1.

[1] GSMA, 'The Mobile Economy 2018', https://www.gsma.com/mobileeconomy/wp-content/uploads/2018/05/The-Mobile-Economy-2018.pdf

Figure 1 European mobile subscriber base (excluding M2M) by connection technology. Source: GSMA

The requirement for mobile data to support a rising variety of applications has driven the adoption of 4G since it was launched in the UK in 2012. The appetite for faster, higher quality connections to support use cases such as high definition video streaming is expected to drive uptake of 5G services, which have started to be deployed in the UK in 2019.

According to Ofcom[2], 4G networks carried 85% of the UK's data traffic as of the end of 2018, up from 74% a year earlier, an increase which has been enabled by increased 4G coverage and more affordable devices and services.

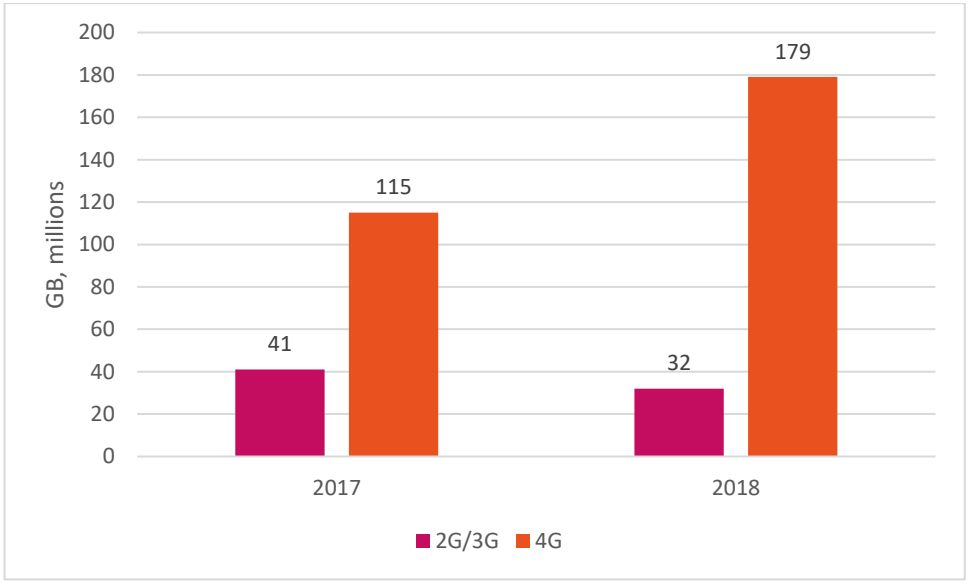

Figure 2 Mobile data traffic carried by 4G networks, compared to 2G/3G, in the UK in 2017 and 2018. Source: Ofcom

2.2 Reasons for services to remain 2G-based

There are several reasons why a case can be made to keep a service on a 2G network:

1. **It is voice-based.** Most 4G networks were initially deployed without native support for voice. This was because LTE does not support circuit-switched voice technology, as 2G and 3G do, but relies instead on an IP-based technology, VoLTE (voice over LTE). This is complex to deploy and optimise,

[2] Ofcom, 'Connected Nations 2018', https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf

and in the early years of 4G, the availability of devices supporting VoLTE was limited. For instance, in 2014-2015, only 11% of LTE smartphones launched with VoLTE support, according to the GSA[3]. That figure had risen to 67% in 2018. However, voice usage on 4G remains limited. According to Ofcom[4], in 2018 4G carried only 7% of the UK's voice traffic, with 3G and 2G carrying 81% and 12% respectively. Individual MNOs are reporting significant progress as of mid-2019 however, with the percentage of voice traffic supported by VoLTE typically around 60% and 2G only around 10%. The MNOs believe voice traffic on 2G, whether native or via Circuit-Switched Fallback (CSFB), will have all but disappeared by 2025, based on current trends. CSFB occurs where 4G coverage is poor/non-existent and the device switches to 2G or 3G and uses circuit-switched voice to make/receive calls.

2. **It requires ubiquitous coverage.** 2G still has better coverage in rural and remote areas, and better indoor penetration, than 3G or 4G. This is particularly true of deployments in the 900 MHz band, with its superior propagation qualities, by Vodafone and Telefonica O2. Some M2M services require higher coverage than human services and this may be more cost-effective to achieve using 2G if data rates are very low. Agricultural monitoring is an example.

3. **It is the only connectivity available.** For human services, there are still some locations where 2G is the only available connection. According to Ofcom[5], in January 2019, 4G landmass coverage (by all operators) was 67% vs 78% for calls (2G/3G/4G). Complete not-spots (no operators) were 8% for 4G and 5% for calls. Premises data for indoor coverage is 78% vs 92% respectively again for all operators.

   This should improve significantly – for instance, EE's target for 4G landmass coverage by the end of 2020 is 95%[6]. Of the remaining 9% in 2018, most of the locations lacking 4G coverage from any MNO are rural, remote, or along roads and railways. There are no updated figures for what proportion of these locations are 'not-spots', with no cellular coverage at all, but if 2G were withdrawn today, there would still be rural users and devices which would lose all mobile connectivity.

   The government is seeking to improve mobile broadband coverage by setting coverage targets in new spectrum auctions. Furthermore the business case for extending 4G coverage and indoor penetration is improving as equipment costs come down, and as the introduction of 4G-based Narrowband-IoT (NB-IoT) provides improved cell range for M2M applications (see Section 3.2.1). When LTE is deployed in a sub-GHz spectrum band, such as 800 MHz, it achieves similar or better propagation qualities to those of GSM900 (or UMTS900, as deployed in the UK by Telefonica and Vodafone). 5G, too, will have sub-GHz deployment options in 700 MHz (new spectrum for cellular, to be auctioned in 2020), and refarmed 900 MHz.

4. **It does not require 4G capabilities.** Even where there is a good 4G signal, a user or service may regard mobile broadband functionality as overkill, and have no incentive to migrate to it or, most importantly, pay extra for it. A simple, low power and low cost device is all that is required for some humans (e.g. elderly people), and for some M2M applications with low data rates, such as

[3] GSA, 'LTE Ecosystem report July 2015', www.gsacom.com

[4] Ofcom, 'Connected Nations Update Spring 2019, https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2019-Update

[5] Ibid

[6] EE, https://ee.co.uk/why-ee/4g-coverage

equipment monitoring, smart metering or asset tracking. Provisioning such users with more expensive 4G devices - with functionality that will not be used and so will not generate revenue – reduces the operator margins in these markets. Conversely, retaining some spectrum to support these very low levels of data – which account for well under 1% of an MNO's total data traffic in the UK – may be a cost-effective option even into the 2030s.

2.3 Primary 2G-based use cases in the UK 2019

Table 1 below sets out the main 2G use cases, all of which fall into one or more of the three categories above and so remain well-served, in 2019, by a 2G network and the supporting ecosystems.

Table 1 Use cases supported by 2G in the UK

Use Case	2G Supply Structure	Comments
Voice and SMS – UK resident	MNOs, Mobile virtual network operators (MVNOs), retailers e.g. Amazon, Argos	Includes rural users where 2G could be the only network they are able to access
Voice and SMS – inbound roaming by tourist	Roaming agreements with overseas operators or device/SIM purchased just to use for holiday in UK	
Circuit-switched fall back	MNOs, MVNOs	Supports voice for 4G devices when out of a VoLTE coverage area.
M2M static end point excluding smart metering e.g. vending machine	MNOs, enterprise service providers bundling connectivity with maintenance, refilling etc	Classic IoT use case – long operational life expected
M2M – smart metering	2G/3G-based communications hubs still being deployed. Telefonica and Vodafone supply connectivity to these hubs	Need to keep these services operational until a replacement for the current smart meters/Communications Hubs is procured – possibly in early to mid-2030s
M2M slow moving and limited distance end point e.g. farm animal	MNO, vertical specific service provider, farmer self-install	Similar to the vending machine but this could be a local-only requirement in terms of coverage (e.g. over the area of a farm)
M2M moving end point e.g. connected car	MNOs, telematics service providers with MVNO deal, fleet management or auto after-market providers	This includes early connected cars with built in 2G/3G modem and telematics fleet tracking units typically added as an after-market fit

eCall	Embedded in vehicles	Mandated in new type approved vehicles from April 2018

2.4 UK operators' position on 2G services

The research for this report included interviews with senior executives within the three 2G operators in the UK, plus a selection of MVNOs and IoT service providers. For reasons of commercial confidentiality and sensitivity, the status and plans of individual MNOs cannot be revealed, but general points can be made which apply to all the operators to one degree or another.

Of the use case categories listed above, the most important ones in terms of current 2G usage are:

- Voice and SMS – UK resident
- Voice and SMS - Inbound roaming by tourists
- M2M services supporting circuit-switched data in vehicles and other end points
- GPRS low speed data service, mainly for messaging and M2M

(Smart metering is a special case which is considered separately – see Section 2.5)

eCall requires an embedded 2G/3G based system to be fitted to all new type approved vehicles from April 2018 and the provision of national infrastructure services to provide voice and data connectivity to the emergency services in the event of an accident. The eCall system reports the vehicle's location and other vehicle data and provides a two-way speech capability between the emergency services and the occupants in the vehicle. Currently eCall is specified for circuit switched voice technology i.e. 2G/3G, but standards work is underway to add IP based connectivity, thereby supporting 4G – however there is no agreed timescale for such an update to be released. With vehicle development cycles up to 5 years, the lifetime of vehicles being typically 10-15 years and circa 3 million annual new vehicle registrations[7] the quantity of 2G/3G eCall equipped cars in the UK before a 4G version completely replaces the 2G/3G version for new vehicles could be significant. However, once a 4G eCall specification has been finalised, the MNOs will need to continue to provide the connectivity service to 2G/3G eCall equipped vehicles until these vehicles reach end of life. Currently we believe the quantity of eCall equipped vehicles on UK roads is relatively small given it is only mandated for new type approved vehicles from April 2018 – but eventually this quantity will be growing at the rate of new vehicle sales – e.g. circa 3 million per annum

These use cases are supported by a combination of direct MNO services and by MVNOs. MVNOs use the infrastructure of an MNO and market mobile services to its chosen target customers. MVNOs come in all sizes and can simply be marketing and customer acquisition organisations through to large sophisticated operation closely linked to the MNO whose infrastructure it uses. The 3 largest MVNOs – Tesco Mobile, Virgin Mobile and giffgaff together reportedly have over 70% of the MVNO market. The UK has in excess of 50 MVNOs. Although some MVNOs focus on markets such as seniors or tourists we do not believe that MVNOs will significantly impact the MNOs strategy for 2G (and 3G) sunset.

[7] Department for Transport Vehicle Licensing Statistics 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/800502/vehicle-licensing-statistics-2018.pdf

2G-only devices typically make up 8% to 10% of the total base and this figure is in decline, although a majority of 4G devices still connect to 2G when that is the only available signal. However, up to 75% of an MNO's M2M connections are still on 2G in the UK.

Given the example of KT in Korea (see Section 1 Introduction), the size of the current UK 2G base would be seen as too large to make sunset desirable in the short term (that case study suggests successful sunsets happen when the user base is under 1%[8]). However, the more 2G usage declines, and the more alternative solutions come to market, the wider range of options MNOs will have for managing eventual sunset. These will be outlined in Section 3.4.

Indeed, none of the UK's three 2G MNOs has set a date for 2G sunset, though Vodafone has said it expects to shut down 3G first, probably in 2021 or 2022, according to comments made by UK head of networks, Andrea Donà[9]. This has already been stretched from a date of 2020, hinted at in 2016 by group CTO Johan Wibergh[10]. This demonstrates how sunset dates, for 2G or 3G, remain flexible, so that operators are able to choose the best timing for the business, and possibly to synchronise the switch-off with other network modernisation activities, to increase the efficiency and impact of the process.

The MNOs, although not committing to a date for 2G sunset, are generally talking in terms of a date between 2025 and 2030, whilst assessing the various ways switch-off could be best achieved (see Section 4). For instance, if a single, shared 2G network was agreed between two or even three MNOs, the lifetime for 2G could be extended.

2.5 Smart metering

The UK's smart metering programme, now coming under the remit of the Department for Business, Energy & Industrial Strategy (BEIS), is a large and complex programme to install smart meters in all homes and many small businesses (there are several criteria governing the latter, including number of full time employees and energy consumption ceilings)

Overall, the programme aims to install about 50 million smart gas and electricity meters to some 30 million sites by the end of 2020. The programme was split into three geographic regions – North, Centre and South.

Connectivity between the electricity and gas meters and the in-home display is made via a Communications Hub using Zigbee. The Communications Hub also connects to the central systems via a wide area network (WAN) - which in the Centre and South regions, going forward, will primarily use 2G/3G cellular connectivity provided by Telefonica. A mesh node system can also be deployed in the Centre and South regions to connect groups of properties in areas of poor cellular coverage. Figure 3 below shows the system overview with the Data and Communications Company (DCC) gathering all of the data from the meters. The contract to run this company was awarded to Capita in 2013, alongside the connectivity contracts to Telefonica (Centre and South regions) and Arqiva (North region).

[8] International Telecommunications Policy Review 2014, 'Terminating 2G Service in Korea: Policy Issues and Suggestions', www.itpr.or.kr

[9] Mobile News CWP, https://www.mobilenewscwp.co.uk/2019/06/10/vodafone-to-switch-off-3g-network-in-two-to-three-years/

[10] Mobile Europe, https://www.mobileeurope.co.uk/press-wire/vodafone-sets-end-date-for-3g-as-project-spring-ends

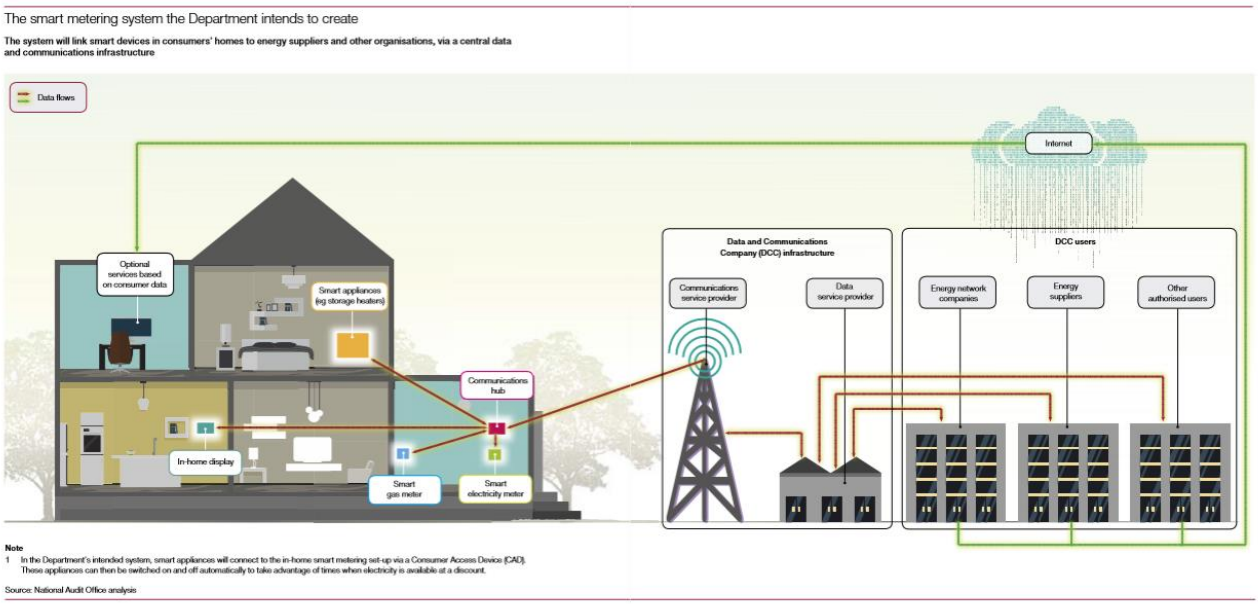

Figure 3 Smart metering system Source: National Audit Office

Two generations of smart meters have been released – SMETS 1 and SMETS 2. Initially, WAN connectivity contracts for SMETS 1 meters were individually negotiated by the energy providers with both Vodafone and Telefonica. Now connections for SMETS 2 meters are focused through the DCC and the WAN contract with Telefonica for the Centre and South regions – however those connections operating through the individually negotiated contracts with Vodafone and Telefonica are still in in service.

Currently all of the SMETS 1 generation meters operate outside of the DCC system (including the WAN contract) but plans are being pursued to bring most or all of this installed base under the aegis of the DCC.

The regular quarterly report from BEIS on the progress of the smart metering roll-out shows that, at the end of March 2019[11], there were 7.3 million electricity smart meters and 5.5 million gas smart meters installed in domestic premises and 1.2 million meters installed in small non-domestic sites – suggesting over 8 million 2G/3G Communications Hubs have been installed. Anecdotal evidence suggests that the vast majority of these installations are in the Centre and South regions. Most of these meters will be operating via the directly negotiated contracts between the energy providers and Vodafone or Telefonica, and not currently included in the DCC WAN contract with Telefonica for the Centre and South regions.

From early 2019 an increasing percentage of new Communications Hub WAN connections have been made via the Telefonica contract for the Centre and South regions – we understand that the percentage of new connections via the Telefonica contract is, as of July 2019, close to 100%. At the end of March 2019, out of 12.8 million domestic smart meters installed, 630,000 supported the SMETS 2 specification and used the Telefonica-contracted WAN connection via the DCC.

We understand that the Communications Hub, when first installed, searches for a 3G connection and if it is unable to make one, it searches for a 2G connection. We were unable to determine, out of the current

[11] BEIS Smart Meter Statistics – Quarterly Report to end March 2019
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/804767/2019_Q1_Smart_Meters_Report.pdf

installed base, how many use a 2G or a 3G connection. Since the general gathered wisdom in the industry suggests that 3G services will be switched off before 2G, it is unlikely that 3G services will be able to support the smart meter system post-2G switch-off.

Consideration might also need to be given to the overall end-to-end smart metering system behaviour if high volumes of 3G connections in the Centre and South regions are turned off simultaneously on either Vodafone's or Telefonica's 3G network. Will the system behave in a predictable, stable and deterministic manner?

The Telefonica contract, to deliver connectivity services runs for 15 years and was placed in Sept 2013[12]. The contract can be extended by up to five years at BEIS/DCC's behest.

A 4G version of the Communications Hub has been discussed and it could possibly be available next year subject to rigorous system testing. BEIS assumes that the smart meters will not need to be replaced for at least 15 years.[13]

This suggests that, unless there is another major field upgrade to the Communications Hub before the end of the expected 15-year life of the system – which seems completely implausible - then Telefonica will need to keep its 2G network running to support its smart metering contract in the Centre and South regions until at least 2028 – and possibly up to 2033. In addition, given that some of the SMETS 1 meters are connected via Vodafone's 2G/3G network, then the same requirement will likely apply to Vodafone. Real Wireless is obviously not party to the contractual details regarding the option to turn off 2G and/or 3G services within the contracted period – our understanding is that the contracts are for services and not any specific technology.

Concern was also expressed by Energy UK – the trade industry for the energy sector – as to the impact of prepaid smart meters losing connectivity. Currently, around 12% of homes use prepay, whose system connects via the DCC platform to load the prepaid energy amount into the meters. If there is a loss of connectivity this could mean users are unable to access gas and/or electricity. Energy UK was concerned that potentially vulnerable users could find themselves unable to access gas and/or electricity if the WAN connection to the Communications Hub were lost. The media response to such a scenario could be damaging to those involved.

On September 16th 2019, as this report was being finalised, BEIS published a consultation which included a proposal to introduce a new post 2020 licence framework which would allow energy providers to continue to install smart meters until the end of 2024 – effectively extending the installation programme by 4 years. The consultation also notes the expectation of a 15 year asset life. The implications of this consultation will not be known for some time and therefore this report cannot come to any real conclusions on the impact of this new development, however the possible outcomes of what is proposed could be:

i. Giving greater impetus to deploy a 4G Communications Hub – since on the assumption that this can be done relatively quickly – then fewer 2G/3G Communications Hubs will be deployed

[12]O2, https://news.o2.co.uk/press-release/telefonica-uk-signs-1-5bn-smart-meter-deal/

[13] NAO Report Rolling Out Smart Meters – National Audit Office November 2018 Clause 22 'The Department has tried to 'future proof' the smart metering system for the next 15 years, but it is difficult to predict what will happen over that period'. https://www.nao.org.uk/wp-content/uploads/2018/11/Rolling-out-smart-meters.pdf

ii. Further delaying the 2G switch off date for Telefonica and Vodafone on the basis of a 15 year life for any smart meters deployed up to the end 2024 and only equipped with a 2G/3G Communication Hub

In summary:

1. The UK smart meter programme uses 2G/3G wide area connectivity in the Centre and South regions to connect the smart electricity and gas meters into the DCC systems.
2. To date, some 8m 2G/3G Communications Hubs have been installed, mostly having WAN connectivity under individually negotiated contracts with Vodafone and Telefonica.
3. Going forward, new installations will come under a single WAN contract with Telefonica but will still use 2G/3G for wide area connectivity.
4. BEIS expects smart meters to stay in service for at least 15 years – which could require the 2G/3G Communications Hubs to remain in operation until late 2020s to early 2030s.
5. Alternatively, the Communications Hubs could be updated to, say, 4G connectivity but this would be a very expensive exercise and it is not clear who would fund such an upgrade before the re-procurement of smart meters – which could possibly commence in the mid to late 2020s. Also, there would need to be a high degree of certainty that the 4G landmass coverage at that time would match the 2G landmass coverage.
6. The smart metering system will therefore need to be a key consideration when Vodafone and Telefonica make plans for 2G switch-off. It is possible that the smart metering system will become the key determinant of the date when Vodafone and Telefonica turn off their 2G networks – because of the cost of upgrading the 2G/3G Communications Hubs.
7. The use of prepaid smart meters, potentially by the more vulnerable members of society, requires wide area connectivity in order for the prepay system to operate correctly. Any loss of connectivity could leave these users without gas or electricity. Media response could be damaging to those involved.
8. It is too early to understand the potential impact of the BEIS consultation announced on September 16th 2019

In addition to the smart meter programme there are circa one million advanced electricity meters in use today across large and small businesses relying on 2G connections to provide remote reading capabilities and representing in excess of 40% of the UK's electricity consumption. Advanced metering has also been deployed to a similar scale in the gas sector. Any potential switch off of 2G will therefore need to consider the operational life, the development timescales for replacement products and services and the implementation logistics and timeframes around the advanced meter eco system.

3 The viability of alternative connectivity solutions and migration paths

3.1 Description of the most viable alternatives to 2G for the UK market

The following section provides a summary of most of the potential alternative connectivity solutions for voice and M2M services if 2G (and 3G) networks are switched off. As shown in Table 2 these are:

- 4G cellular options – VoLTE for voice services and NB-IoT and LTE-M (recently rebranded Cat-IoT and Cat-M) for M2M services
- Future 5G options (not yet standardised) for both voice and M2M services
- Non-3GPP options, notably LoRaWAN, Sigfox, 802.11ah/HaLow for M2M services

- For selected use cases, satellite systems for M2M services

Table 2 Alternative connectivity solutions

Technology	Capability / Comment	Coverage/ Range	Battery Life	Device Cost
3GPP Cellular Mobile Solutions				
3G	Unlikely to provide a solution to 2G Sunset as 3G networks in the UK are likely to be switched off in a similar timeframe or earlier	National coverage, but less depth than 2G	Worse than 2G	More expensive than 2G
4G/LTE				
Standard 4G	Designed for high speed data, not for low speed IoT (or voice). Supports voice via VoLTE	National coverage 67% 4G landmass coverage and 78% landmass coverage for calls (2G/3G/4G) [14]	Significantly worse than 2G	Significantly more expensive than 2G or 3G
LTE-M IoT	Machine-to-machine variant of 4G operating in a narrower bandwidth. Still significant capability vs 2G	National coverage could be achieved and better range than 4G, but still less than 2G	Better than standard 4G. Unclear how it compares with 2G	Designed to be cheaper than 4G modems. Expected to reach 2G cost levels in time given sufficient volume
NB-IoT	Alternative 4G IoT solution to LTE-M. Designed to match/better 2G range, battery life and cost. Vodafone strong supporters, but unclear if other operators will deploy this or LTE-M or both. Understood to be some network hardware/cost implications with some vendors	Should be similar to 2G (if not better) – but limited deployment to date to verify	Designed to have long battery life (better than 2G)	Designed to be cheaper than 4G modems. With sufficient volume expected to reach 2G levels in time

[14] Ofcom Connected Nations Update Spring 2019 https://www.ofcom.org.uk/__data/assets/pdf_file/0021/146613/connected-nations-update-spring-2019.pdf

Technology	Capability / Comment	Coverage/ Range	Battery Life	Device Cost
5G	Even higher speed, low latency solution. Voice service supported Also designed for massive IoT, although initial versions will rely on LTE-M and NB-IoT to support IoT services	As per LTE-M and NB-IoT, at least initially	As per LTE-M and NB-IoT, at least initially	As per LTE-M and NB-IoT, at least initially
Non 3GPP Developments				
Wi-Fi	Could provide a localised wireless link back to a nearby access point connected to a fixed/mobile network	Very limited – up to 100m or so	Good – similar to 2G	Cheap – significantly cheaper than 2G
WiMAX	Dying technology. No UK national networks			
IoT Wireless Developments				
Sigfox	A proprietary non-cellular wide area low power IoT solution. 1000 sites currently installed (75% UK pop) with plans to reach 2000 sites (95% UK pop). Currently an uplink only service. Potential future satellite component to boost coverage	Good range (up to 50km), so better than 2G, but overall national coverage still less	Good battery life, better than 2G	Low cost devices, but proprietary so scale may not match cellular
LoRaWAN	Competitor to Sigfox – with around 400 base sites deployed in the UK. Typically more location specific rather than full national coverage	Good range (up to 15km) but lacks full national coverage	Good battery life	Low cost devices, but proprietary so scale may not match cellular
LP Wi-Fi (HaLow)	Future development to give a low power long range version of Wi-fi. Operates in frequency bands below 1GHz and provides a minimum data rate of at least 100 Kb/s. Longer range IoT solution compared to ZigBee or Bluetooth	Range up to 1km	Unknown – expected to be better than standard Wi-Fi	Lower cost than 2G. Scale dependent
Zigbee	Low complexity short range solution for wireless networking for applications that require low-rate wireless data transfer	Short range, similar to Bluetooth	Good battery life	Low cost – less than 2G
Satellite Technologies				
GEO	GEO satellite systems can provide good outdoor coverage over wide areas and good throughputs. Whilst they could be an alternative to 2G for some applications in rural areas, they are unlikely to offer a cost-effective mass market alternative, e.g. for low cost IoT	Good coverage, but weak in-building coverage	Poor, in comparison to 2G and cellular in general	High cost
LEO	Emerging LEO systems seek to use mass production of low-cost, low altitude satellites to reduce per-	Good coverage from	Not known, expected to be better	Likely to be high cost

Technology	Capability / Comment	Coverage/ Range	Battery Life	Device Cost
	satellite and in-orbit delivery cost – but need a high number of satellites. Use of high frequency, low orbit satellites reduce latency and improve link performance. Could be a niche coverage solution, but not a mainstream alternative	satellite, although indoor penetration will be limited	than GEO but still poor compared to 2G	

3.1.1 Cellular options

4G

The 3GPP has standardised several technologies to support 4G alternatives to 2G in its core use cases – voice/messaging and M2M applications. For voice, the alternative is VoLTE, which will increasingly become a default feature of LTE handsets as operators extend their 4G voice coverage (see Section 4.1 for further discussion).

VoLTE will become the dominant technology for voice services post 2G/3G sunset although depending on timescales voice on 5G will have been standardised and voice services could evolve from VoLTE to 5G-based services where 5G infrastructure has been deployed.

The 3rd Generation Partnership Project (3GPP) standards body has also standardised three technologies to support M2M applications over cellular networks, though these can also support voice and messaging. These technologies are:

- Enhanced-GPRS, which has been trialled in a few countries such as France, but appears to have attracted no interest amongst UK MNOs.
- Two LTE-based technologies NB-IoT and LTE-M. These narrowband LTE technologies were tailored for low-complexity M2M connectivity – an aspect previously missing in LTE (or 3G) and an area where arguably GSM still provided the best solution. LTE-M supports downlink peak rate of ~1 Mbps over a 1.4 MHz channel, while NB-IoT allows a downlink peak rate of ~100 kbps over a 200 kHz channel.

The lower data rate of NB-IoT allows better coverage, longer battery life, and a better fit with stationary, sensor-driven IoT use cases. On the other hand, LTE-M is suitable for a broader, but more demanding set of applications with vehicular speed mobility and VoLTE support (NB-IoT does not support either feature).

They are complementary although it remains to be seen whether UK operators will use them both or just choose one. Typically operators in Europe have tended to favour NB-IoT, with Vodafone being a strong public advocate, whereas LTE-M was initially deployed more actively in the USA, though T-Mobile USA now has a nationwide NB-IoT network also.

NB-IoT is designed to have a better link budget than standard LTE to ensure coverage is improved in hard to reach areas where IoT devices (such as sensors or meters) might be deployed. We expect some of these developments will also carry across to existing services. For example LTE-M supports voice capability and therefore offers the potential to improve voice coverage using its 1.4 MHz narrower channel bandwidth.

An advantage of the LTE IoT networks is that they are typically enhancements to existing LTE networks (not the deployment of a full new network), but also have better propagation and range than standard LTE from the same sites so deploying them can immediately improve the coverage of an LTE network. In some scenarios that would extend LTE to be closer to the coverage of 2G without deploying additional sites.

5G

Within the period to 2025 we would expect to see 5G launched and substantially rolled out across the UK. If 2G networks are unlikely to be switched off before 2030, it may be that some 2G services are migrated to 5G rather than 4G, though that will depend on operators' strategies and priorities for roll-out, which are not yet fully clear. For instance, matching the coverage of the 2G network would require the MNOs to have deployed a 5G coverage layer in sub-GHz spectrum, but some operators do not expect to do that until the late 2020s, and not to achieve ubiquitous, 2G-like coverage until the early 2030s. The UK MNOs have not made final decisions about their priorities in this respect but it may be that, even into the 2030s, 4G will have broader coverage than 5G.

It should be noted of course that the 700 MHz spectrum band that will be used for 5G services has not yet been auctioned by Ofcom and it is possible that not all of the mobile operators will acquire spectrum in this band at the auction.

As with previous technology generations 5G will continue to evolve over time adding additional features and capabilities. This will be the focus of significant ongoing standardisation and vendor community effort, including in areas relevant to 2G replacement, such as lower latency, accelerated cost reduction and support for massive IoT and mission critical services. It remains to be seen, however, whether many of the proposed new use cases are commercially viable – so the initial deployment driver in the UK will be enhanced mobile broadband, leaving the timescales or probability of a ubiquitous M2M-optimised 5G network in doubt.

3.1.2 Non-3GPP wireless technologies

Wi-Fi HaLow

The IEEE has an ongoing set of specification developments to enhance and deliver new capabilities within the 802.11 standards family, the basis of Wi-Fi. While Wi-Fi has been mainly focused on wireless broadband and wireless LAN, it is increasingly extending its scope to overlap with low power WAN and WPAN systems.

The most relevant development as a 2G alternative is 802.11ah (HaLow), which targets the LPWAN sector, and any future successor to be developed during the 2020s. The IEEE's 802.11ah process started – initiated by Qualcomm – in 2014 and the Wi-Fi Alliance announced the HaLow branding in 2016. A branding and certification announcement by the Wi-Fi Alliance is usually the trigger for product launches, even before the standards are finalised but to date, only one company, Korean start-up Newracom, has shipped a chip (in use in a Korea Telecom gateway), and other chips on the horizon are from start-ups rather than Wi-Fi heavyweights like Broadcom. It is unclear, at this stage, whether HaLow will develop an ecosystem or whether vendors have been put off by the existing number of LPWAN contenders, or by the nascent state of commercial LPWAN business cases.

Critics have said 802.11ah is a step too far in extending the reach of the Wi-Fi technology, and HaLow entails too many compromises compared to technologies which were designed from scratch for the low power IoT. HaLow, at least in its initial specification, will not be as low cost or low power as LoRa or Sigfox, though if the large Wi-Fi ecosystem does get behind it, costs could fall rapidly. Supporters say that

delivering up to a few Mbps over distances up to a kilometre, with support for thousands of nodes per access point, will be its sweet spot and that could make it a strong replacement for some GSM applications.

In general IEEE 802.11 standards have done a good job to ensure new developments are backwards compatible with existing solutions and devices, which means there is always a significant base of devices which can use new Wi-Fi extensions. We expect Wi-Fi to develop to support ever larger volumes of connected devices, in a similar manner to the way massive IoT is being developed for 5G.

3.1.3 Other LPWAN options:

There is a range of proprietary IoT wireless technologies in addition to the standardised 3GPP and IEEE developments already discussed above. The most equivalent to GSM are the unlicensed low power WAN (U-LPWAN) solutions, which support low power, long range connectivity with low to moderate data rates, in licence-exempt spectrum, typically 868 MHz in Europe. The technologies with the most significant market presence internationally, and most visibility in the UK, are LoRaWAN and Sigfox.

> **Sigfox** is a proprietary system based on an ultra-narrow band wireless modulation scheme. It offers a low throughput (~100 bps) and low power but extended range (up to 50km). It operates on a subscription-based model with up to 140 messages per day per device. Together with its UK partner WNDUK, Sigfox announced in November 2018 that it had reached a key coverage milestone, with 1,000 base stations installed, connecting over three quarters of the UK's population. The plan is to extend the deployment in the coming months, with 2,000 base stations reaching 95% of the nation's population[15].
>
> **LoRaWAN** works in typical channel bandwidths of 125 KHz with range of up to 15km, up to 20dB indoor penetration and throughput of about 50 kbps. In June 2018 two UK LoRa initiatives announced that they had joined forces to create what they claimed to be the country's largest LoRaWAN network. Things Connected and The Things Network (TTN) together boast 400 base stations across the country[16]. Semtech, one of LoRaWANs developers and a sponsor of the LoRa Alliance, suggests 200,000+ LoRa-based gateways will be deployed worldwide by 2019, supporting 80m LoRa-based end nodes on private and public networks with 95+ public network operators in 51 countries. According to IHS Markit 40% of all LPWANs are predicted to run on LoRa by 2019.

In terms of evolution out towards 2025, we envisage the major focus to be on extending coverage and footprint of the wide area solutions such as Sigfox and LoRa, and reducing cost. As the cellular 4G and 5G IoT solutions become established we expect there to be significant competition between these solutions, with major focus on reducing cost, improving battery life and ensuring support for ever larger volumes of connected 'things' (massive IoT).

Most current market analysis points to LoRaWAN and NB-IoT becoming the leading LPWAN technologies, supporting different operators and business models because of their different spectrum. For instance, a May 2019 forecast by IHS Markit[17] suggests that these two technologies will account for 86% of all LPWAN links in 2023, with LoRaWAN mainly occupying private networks (although it has also been deployed by some MNOs such as Orange France).

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[15] Sigfox WNDUK, Sigfox network operator for the UK announces 1,000 base station installs covering more than 50m people, 2 Nov 2018, https://www.sigfox.com/en/news/wnduk-sigfox-network-operator-uk-announces-1000-base-station-installs-covering-more-50-million

[16] Mobile Europe, https://www.mobileeurope.co.uk/press-wire/uk-lora-initiatives-join-forces

[17] IHS, https://technology.ihs.com/Services/484941/cellular-iot-intelligence-service

3.2 Satellite options

Satellite is the ultimate system for ubiquitous coverage though has traditionally been expensive and subject to high latency, and used only in very remote areas or for specialist services. However, very small satellites (nanosats), and new use cases in the IoT, are creating an expanded role for satellite players in the wireless market.

The satellite IoT market, according to a forecast by Rethink, will be worth $5.9 billion globally by 2025, including hardware and connectivity fees, with a base of 30.3 million devices. It will take off in earnest from 2021, but incumbent satellite providers will come under pressure from a wave of start-ups, leveraging recent advances in smaller satellite technologies. Operators include OneWeb, SpaceX, Telesat, Samsung, Leosat and Kuiper Systems.

4 Migration options

As outlined above, the UK's MNOs are unlikely to switch off their 2G networks within the next five years at least. Whilst 2G voice users may be a rapidly declining base, and a low value one in terms of ARPU (average revenue per user), there are still a few key M2M services that are important to the MNOs' business, notably smart metering (see Section 2.5) and vehicle telematics.

However, this does not mean that operators are not discussing and evaluating the options for migration and sunset. These fall into two categories. One is network migration by the MNO, which can vary from a gradual reallocation of spectrum over many years, to an abrupt switch-off. If the MNO is driving the pace of the sunset, it will need to consider how to smooth the transition for 2G users and services, and evaluate which ones it can afford to lose.

The other is migration by the user. In an ideal scenario for the MNO, all the 2G users would naturally move to other technologies on their network, freeing up the spectrum without the need for active intervention. As we have seen, many MNOs will not consider starting the process of sunsetting a network until its user base has naturally dwindled to just a few percent of total customer numbers.

In both categories, the options vary according to the use case, and will be analysed in this way. See Table 2, below, for a full use case breakdown.

4.1 MNO migration strategies by use case category

- **Voice and text service**

  These will need to be migrated to a 4G VoLTE solution. This solution is already available and in use with operators. However, today the end user requires a smartphone in order to obtain the VoLTE capability. Hence there is a need for a range of simpler and cheaper 4G VoLTE devices to address this market. Typical user bases include older people who want uncomplicated devices with basic connectivity – so called 'senior phones'; as well as tourists from countries where featurephones are still prevalent, or who want to use a low cost device and service whilst abroad to avoid roaming charges.

  This is not a difficult or complex development, is perfectly achievable and is likely to happen anyway. By the time a 2G switch-off is imminent, we can expect the numbers of users in this category to be much reduced compared with today. The cost of entry level VoLTE smartphones will

certainly have fallen significantly too. Already, VoLTE phones are coming to market, from Indian and Chinese manufacturers, priced below £50.

Operators which have already switched off 2G in other countries have been divided between using a 'carrot' approach – offering an incentive to migrate, such as a free or subsidised phone or a low cost tariff for the first three months – and a 'stick' – simply sending communications to warn them that their service will be switched off on a given date, and steps to migrate to LTE. The choice usually depends on how important it is to the MNO to retain its 2G customers, which in turn often relates to that MNO's own KPIs – for instance, whether market share by numbers of users is more or less important than ARPU or profitability. In the latter case, there would be less commercial pressure to retain as many 2G users as possible. The tactics may also be influenced by whether the MNOs are all switching off around the same time, or if one operator decides to move first, with the potential risks in terms of PR.

A timely education and information programme, similar to the one run for digital TV switchover, would be desirable to help occasional or elderly users to understand their options and provide simple steps to change technology.

We can also foresee media interest around 2G switch-off and we expect MNOs would want to avoid any poor publicity based on leaving the elderly and other vulnerable users either confused as to what they need to do, or left without connectivity in an emergency situation.

- **Rural coverage**

  This is reliant on improving 4G and 5G coverage to match or exceed that of 2G, so that rural users and businesses are not stranded. This will be driven to some extent by regulatory requirements, with EE, for instance, targeting 95% 4G landmass coverage by the end of 2020, and Ofcom currently reporting that 'not-spots' account for 8% of the UK landmass[18] (see Section 3.1 for details of current coverage status according to Ofcom). The economics of the solution depend on several factors, some of them in the MNO's control, others capable of being influenced by government policy. These include:

  - the successful purchase of sub-GHz bands by operators in the 5G spectrum auction
  - the emergence of low cost 4G and 5G equipment for the sub-GHz bands
  - access to affordable backhaul with the emergence of options such as lower cost satellite, self-backhauling rural 5G cells, or government-driven fibre expansion
  - the number of users generating revenue in the low coverage areas and the potential to increase revenues by adding new services, including fixed wireless, and by adding new M2M services in rural areas, such as smart agriculture
  - Potential changes to planning regulations to support extending mobile coverage particularly in rural areas such as the recent joint consultation by the Department for Digital, Culture, Media and Sport (DCMS) with the Ministry of Housing, Communities and Local Government[19]

  By the time 2G is withdrawn the coverage from 4G (at least for VoLTE and low speed data) ought to be at least as good as the current GSM service. Though the UK is not in this position today, 4G

[18] Ofcom Connected Nations update: Spring 2019 https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-update-spring-2019

[19] https://www.gov.uk/government/consultations/proposed-reforms-to-permitted-development-rights-to-support-the-deployment-of-5g-and-extend-mobile-coverage

coverage is continually improving and with the use of the lower frequency bands at 800 MHz, for 4G, and 700 MHz or refarmed 900 MHz, for 5G, it should be possible with the necessary investment to provide equivalent if not better coverage as the 4G site density increases. The UK MNOs claim they are already well on the way to matching 2G coverage with 4G, and a bigger issue is how to address complete not-spots (without even a reliable 2G signal) economically.

One option that has been discussed is for the MNOs to move towards a Shared Rural Network (see Section 4.5).

- **Machine-to-Machine (M2M)**

  As outlined above, there are two 4G-based IoT solutions, NB-IoT and LTE-M. The challenge at present is that these solutions are not yet fully deployed across the UK. It is also not clear whether operators will choose to deploy one or both of these solutions. For instance, Vodafone is a strong supporter of NB-IoT, but only controls the physical network for half of the UK because of its sharing arrangements with Telefonica O2, which has so far been less committed to NB-IoT roll-out. EE has trialled NB-IoT and seems likely to deploy it commercially. However, there is a risk of fragmentation with different operators choosing different solutions plus the potential for the deployment of proprietary systems such as Sigfox and LoRaWAN by MNOs or alternative providers.

- **eCall**

  Assuming that a 4G based eCall specification is released and implemented then there will be a slow evolution to a 4G based eCall as new vehicle models are type approved. During this transition, the length of which will be determined by OEM new model development cycles, and for the lifetime of 2G/3G eCall equipped vehicles, 2G services will need to be maintained – assuming that 3G services are sunset before 2G services.

4.2 M2M ecosystem migration issues

For M2M use cases, it is not just the MNO and its network migration, nor the end user, that will affect the nature and timing of sunset. There is a complex ecosystem of end point supplier, devices, SIM management platforms and managed services which underpins some M2M sectors including smart metering and telematics. Before a 2G network can be switched off with minimal disruption, there needs to be a clear path for M2M service providers and chip/device suppliers to move to a new network.

The length of time it takes to develop replacements for current devices and SIM cards will dictate when it is realistic to switch off a 2G network. In many cases, the devices were deployed with the assumption they could last for a decade or far longer. If the service will not benefit from higher data rates or other 4G capabilities, there will be no incentive for end users or service providers to migrate unless they are forced to by a sunset.

The MNO, then, has a responsibility to communicate with ecosystem players, particularly device makers, M2M platform operators and integrators, about likely timescales for sunset. This will not be practical until there is industry consensus around connectivity mechanisms, and sufficient scale in the ecosystem to drive prices right down. Whatever the migration path, there will be a shift from current SIM card devices and provisioning services to embedded, remotely updateable eSIM for cellular solutions, or a no SIM approach for the unlicensed options.

Smart metering is the most prominent example of a use case which will only be successfully migrated if a whole value chain coalesces around a single new hub and device solution (see section 2.5). However, the same challenges can be seen in telematics, in which the asset lifecycle could relate to the life of the vehicle

rather than the connectivity, and in which that connectivity is part of an extended value chain that involves the MNO forming commercial relationships with module makers, auto makers, after-market players, telematics services providers, enterprises and others. For a large telematics contract, all of these relationships might have to be renegotiated to ensure a smooth transition.

In M2M, it is therefore more important than in consumer services that operators communicate their plans well in advance and provide the supply chain with as much time as possible to work out their best migration solution. It is important for operators not to make the legacy 2G problem worse by continuing to sign up new 2G connections. This is simple with consumers, and most MNOs which have switched off 2G have done so smoothly with only 6-9 months' notice to human customers. The story is different in the IoT, where contracts and device lifecycles are often 10-15 years. But until platform providers, SIM service providers and specialised MVNOs have a clear view of the operators' next generation IoT networks and associated strategies including its costs and device availability, they will continue to activate new 2G connections even if the MNO has ceased doing this directly. Further increasing the 2G sunset challenge.

4.3 End user migration options

From an end user's perspective, the 2G legacy migration options are broadly similar, although there are more options in the IoT space. Hence the likely approach is:

- **Voice and text services**

  These will need to be migrated to a 4G VoLTE solution. While the network solution is available today with most operators, the devices are still relatively expensive and complex. Over time a greater range of simpler, cheaper 4G VoLTE devices are expected to emerge to specifically address this market, typically for older people who want uncomplicated basic connectivity. Some of the handsets which are emerging from Indian and Chinese vendors are priced well under £50 with VoLTE support and can be offered by the MNO or unlocked.

- **Rural coverage**

  Extending/enhancing 4G coverage to replicate 2G is under the operator's control and there is not much the end user can do about it, other than selecting the operator that offers the best coverage in their area of interest. Other than satellite phones which are still expensive, there are not really other viable options from an end user perspective. As explained operators are continuing to deploy 4G (and subsequently 5G) and this issue is expected to be resolved naturally over time, although it may take many years. This rural coverage issue is likely to be a key determining factor as operators look t fix on a 2G sunset strategy and timeline.

- **Machine-to-Machine (M2M)**

  There are more options emerging as alternatives to 2G to address the needs of IoT services, as outlined above. However, as we stand today none of them are really mature and provide a fully viable alternative, although this is expected to change significantly over the next five years or so, and certainly within the timeframes before 2G sunset becomes likely. The choice will largely depend on the individual requirements for the end user service, such as the requirements for throughput, battery life, coverage and so on, and the state of deployment maturity at the particular time. These are covered in more detail in Table 2, below.

- **eCall**

The only migration option for vehicle users will be to buy a new 4G eCall equipped vehicle as and when these become available.

4.4 Table of operator and user migration options by use case

There are different tactics available to operators and users, to migrate away from 2G networks, depending on the use case. Table 2 summarises the main approaches for each of the 2G use case categories identified in Section 2.

Table 3 Migration paths and primary alternative technologies by use case

Use Case	Primary Alternative Technical Solution(s)	MNO Migration Path	Ease/Difficulty of Migration	User Migration Path
Voice and text – UK resident	4G VoLTE	Subsidise new handset, or offer other incentives to migrate	Simple, cost of incentives are low for a small user base of mainly elderly or low traffic users	Purchase 4G handset
Voice and text – incoming tourist	4G VoLTE	Promote 4G handsets to visitors	Harder to manage than for residents, and MNOs may choose not to support these users – roaming revenue loss would be trivial given their low usage levels	Purchase 4G handset or rent one at the airport. Some MVNOs, such as Lebara and LycaMobile, target incoming tourists
Circuit - Switched Fall Back	Full 4G VoLTE coverage and device support	Replace 2G/3G and non-VoLTE handsets with 4G VoLTE phones	Depends whether MNO can support VoLTE devices across all existing 2G/3G coverage areas	Purchase VoLTE handset, rely on over-the-top voice solutions alone
IoT static end point excluding smart metering	Cellular IoT – NB-IoT and LTE-M - or Unlicensed-LPWAN	Requires site visit to replace end point and possibly development of new platforms to	Time consuming and cost:benefit ratio may be poor. Costs will depend on ecosystem	If MNO does not provide attractive migration path, option to move to an alternative service

e.g. vending machine	solutions such as LoRaWAN and Sigfox	make data available to the users of such services	developing for end points	provider – private network operator, M2M-as-a-service. Limited motivation to move to higher performance networks
IoT static – smart metering	A 4G communications hub has been discussed but there are uncertain plans for development and deployment	Not clear – it would be too expensive to change all 2G/3G communication hubs	Expensive and time consuming	Not in users' control. Suggests that Telefonica and Vodafone will need to keep their connectivity operational until a replacement for the current smart meters/Communications Hubs is procured – possibly in early to mid-2030s
IoT slow moving and limited distance end point e.g. farm animal	Similar options as for IoT static end point	Replace end points and central unit if not using an MNO provided solution	Could be time consuming depending on number of end points and relatively expensive	Similar options as for IoT static end point but potentially more suited to a local LoRa WAN deployment in unlicensed spectrum
IoT moving end point e.g. Connected car	NB-IoT or LTE-M	Telematics use case will require change-out of the whole fleet and possibly the software used to provide data such as location, direction of travel and speed	Telematics is a time consuming and expensive change – operators expect to get typically 5 years operation from any telematics capital expenditure	Connected cars do not typically offer a modem upgrade path. User-driven migration likely to follow replacement cycle of car
eCall (2G/3G)	4G version of eCall	Need to support the 4G eCall specification to allow the emergency	Expected to be relatively easy - once the full system	Only by new vehicle purchase

		services to access data and speech services to/from vehicles that activate the eCall system	specifications have been agreed	

4.5 Other options for MNOs

Table 3 presents a view covering the current to medium term, however it seems likely that 2G services are likely to continue in operation for some considerable time (10 years or more) with at least some operators and clearly the above aspects are likely to evolve in that timeframe.

It is important to remember that there are alternatives to complete switch-off, which are becoming more sophisticated over time. These relate to flexible use of spectrum and site assets, or increased sharing, to support a long life for 2G services, while minimising the resources those need to consume.

- Flexible spectrum usage

Today's MNOs have greater flexibility than was available during past sunsets to keep legacy services alive while minimising the cost and resources they use. Operators have always been able to reallocate spectrum gradually from an old service to a new one (TACS to GSM, for instance), in order to keep the legacy service running for as long as that made commercial sense, but in the past it was a static process.

In the 2020s, more dynamic spectrum allocation systems are becoming available, often related to the migration of network optimisation and core network functions to the cloud. For instance, a larger amount of spectrum bandwidth can be used for 2G whenever there is more GSM traffic, but at other times, the majority can be used for another technology such as 4G, potentially just leaving the 2G control channels operational. That reduces the issue of spectrum being underused because it has been reserved for a very occasional or low-traffic application.

UK operators have already started to refarm some 2G spectrum – EE launched its initial 4G networks in some of its 1.8 GHz spectrum, which had originally been 2G-only; Vodafone and O2 refarmed some 900 MHz spectrum for 3G. There were no public reports of negative impact on 2G customers from these processes, and now the MNOs would have greater flexibility to allocate varying quantities of spectrum to different RATs according to fluctuating demand, enabled by technologies such as Huawei's CloudAIR.

- A Shared Rural Network

One option that has been discussed is for the MNOs to move towards a Shared Rural Network – a single 2G network into which each one would contribute some funding and spectrum (a small amount each), and which would support remaining 2G services on behalf of all the operators indefinitely. That would free up almost all of each MNO's 2G spectrum and would avoid any issues of migrating unwilling users or services. The network would operate until those 2G services died a natural death. In theory, a shared network would not have to be confined to rural areas but could support low-data M2M services across many environments. The network sharing arrangements in the UK, especially between Telefonica and Vodafone should make this relatively straightforward to implement.

- Private network operators or neutral host providers

Private LTE networks have emerged as an alternative for enterprise and industrial connectivity, driven by the ongoing digitisation of several verticals. Private networks are not new, but LTE is now able to offer this capability and provide enterprise and industrial connectivity, potentially hosted by an MNO or as an entirely independent network (perhaps using shared, licence-exempt or industrially allocated spectrum). One option to replace a particular 2G-based enterprise M2M service would be for the enterprise, or a specialised operator, to support a future version on a private or neutral host network, if the service was not commercially attractive for the MNO to migrate to its own 4G or 5G system.

5 Implications if 2G-based services are withdrawn

The implications for UK citizens and businesses, if 2G services are withdrawn, should not be significant, provided 2G sunset is timed and managed intelligently by MNOs. Based on our analysis of the 2G landscape, interviews with UK operators, and a survey of international MNOs (see Chapter 6), we believe the following factors would minimise any negative implications for the UK, ensure a smooth transition for users, and support the MNO's commercial objectives.

- Avoid hasty sunsets – rely on flexible spectrum management systems, or shared networks, to reduce the resources used by 2G gradually but keep services running until they are close to a natural death.
- Accelerate progress on planning and deploying the most promising replacement for 2G, in terms of coverage, cost, user capabilities and support for the MNO's business case. Rapid decisions will help drive a large-scale ecosystem, which in turn will drive down device costs and provide reassurance for the whole ecosystem. In the UK, NB-IoT, perhaps complemented by an unlicensed option like LoRaWAN, looks the most likely candidate but it is still inconsistently supported by MNOs and there is a risk of market fragmentation.
- Communicate any plans well in advance, with clear roadmaps for alternative network availability, so that users can plan their transition with full information. This is primarily important in the machine-to-machine environment, especially in use cases where there is a complex value chain and many organisations that need to support a migration.
- Consider the M2M ecosystem in all the key verticals where 2G services are active and ensure that changes to the M2M RAT are catered for throughout the ecosystem.
- Provide information and clear education to 2G users, especially those in vulnerable groups like the elderly, and use procurement systems to ensure there will be availability of affordable VoLTE smartphones, and phones which are usable by those who need a particularly simple user interface.

If these steps are followed to mitigate the risks of 2G sunset, the implications should be manageable and can be summarised by use case as follows:

- Voice and text, UK residents (e.g. elderly)

Likely to be very small numbers by the time of full switch-off. For instance, if the 2G human base were reduced to 0.5% of the total UK mobile base, that would equate to about 270,000 people in 2025. The implications for the MNOs are therefore minimal in terms of revenue or market share. Availability of low cost VoLTE handsets should ensure that nobody is 'left behind' unwillingly, though an education programme, and some device incentives, could improve perception of the change, whether initiated by the government or the MNOs.

- Voice and text, incoming tourists

Likely to involve larger numbers, when considering incoming visitors from emerging economies, in particular, where 4G coverage and availability may still be far lower in the mid-2020s than in the UK. The low amounts of roaming revenue 2G users would generate mean the commercial implications for MNOs are minimal. The government might be concerned about the impact on how the UK is perceived as a tourist destination, which could be addressed by motivating low cost pay-as-you-go MVNOs to promote and provide cheap LTE services at airports and ports.

- Circuit-Switched Fallback for non-VoLTE phone users

Voice services for non-VoLTE phones (or VoLTE-capable phones that have not been enabled for VoLTE services) will rely on CSFB onto a 2G or 3G network. MNOs will therefore need to monitor the actual penetration and trends of VoLTE-capable phones and ensuring that such devices are enabled on their networks when deciding the timescale for 2G sunset. Any marketing and information campaigns relating to the need to buy a new phone ahead of 2G sunset will also need to get this VoLTE message across as most users will not be aware of this technical detail.

- M2M static end points e.g. vending machine and IoT slow moving and limited range e.g. farm animals

The UK's MNOs do not provide user numbers for these M2M services, but all say they represent a small percentage of total connection numbers and an even smaller percentage of data traffic (less than 1% in most cases). If the alternative LPWAN strategy is mapped out clearly, it should be possible to transition most of these customers without significant disruption to their service or the MNO's revenues.

Some will respond to a carrot approach – an introductory period when 2G prices are frozen, for instance, whilst they get to try the additional capabilities supported by 4G, such as monitoring a larger number of data points in a smart agriculture scenario (for instance, cross-referencing of soil, water and animal movement readings, rather than conducting each separately). Others will not see any benefit from LTE, and can either be persuaded to move to a U-LPWAN provider, if available, or supported on the 4G IoT network at the same tariff as 2G. The latter would minimise disruption to the customer until their contract naturally expires, at small expense for the MNO.

- M2M fast moving and/or long range e.g. telematics and smart metering

As discussed in Section 4.2, these are the use case categories where there are the biggest potential implications if the migrations are not handled effectively. These would affect the MNOs, since these services tend to involve large quantities, long-term contracts with high value customers which should therefore not be left behind. They would also risk disruption to many players within complex value chains, with implications for important services affecting large numbers of end users – households with smart meters and large commercial fleets. In a worst case, disruption to such services could have broader socio-economic ripple effects such as a delay in achieving government smart energy targets. A well-thought-out strategy, formed in discussion with all ecosystem players and with a clear network migration in mind, is essential to avoid those negative implications and instead open up new opportunities for MNOs and their high value M2M customers – such as introducing telematics customers to enhanced services enabled by LTE, with higher revenue potential for the MNO and higher business impact for the fleet.

- eCall

EC countries are mandated to provide a national eCall service. At this point therefore, a working assumption would be, that following the introduction of a 4G based eCall service in the UK, 2G services cannot be withdrawn until all 2G/3G eCall equipped vehicles have reached end of life and no new vehicles

are being sold that only have 2G/3G eCall capabilities. Although somewhat difficult to predict it could take 20 years before this situation comes about.

6 Learnings from other countries where 2G networks have been switched off

6.1 History of 2G and 3G sunsetting globally to date

As of July 2019, a total of 20 GSM networks run by national mobile operators have been switched off completely, as well as four networks using regional 2G-like technologies (NTT Docomo's PDC in Japan, and the Personal Handyphone System used for low cost services in China, Japan and Thailand). There have also been five total sunsets of 3G (W-CDMA) networks[20].

In addition, there have been seven complete sunsets of CDMA networks. These usually affect both 2G and 3G services (the dividing line between the CDMA generations, CDMA 1X and CDMA2000, are less distinct than in 3GPP technologies).

Firm dates before 2026 have been set for sunsets of a further 15 GSM and 13 W-CDMA networks (in five cases an operator has set a timeline for both switch-offs). There are also three further CDMA sunsets scheduled.

The regional patterns vary widely. Figure 4 summarises the 2G and CDMA switch-offs to date, and highlights how the Asia-Pacific region has led the way, accounting for 75% of the total, or 21 sunsets. There have also been seven 3G sunsets in the region. One operator, Spark New Zealand, turned off 2G and 3G simultaneously. The main rationale for these closures is to release 2G spectrum for more efficient later generation technologies.

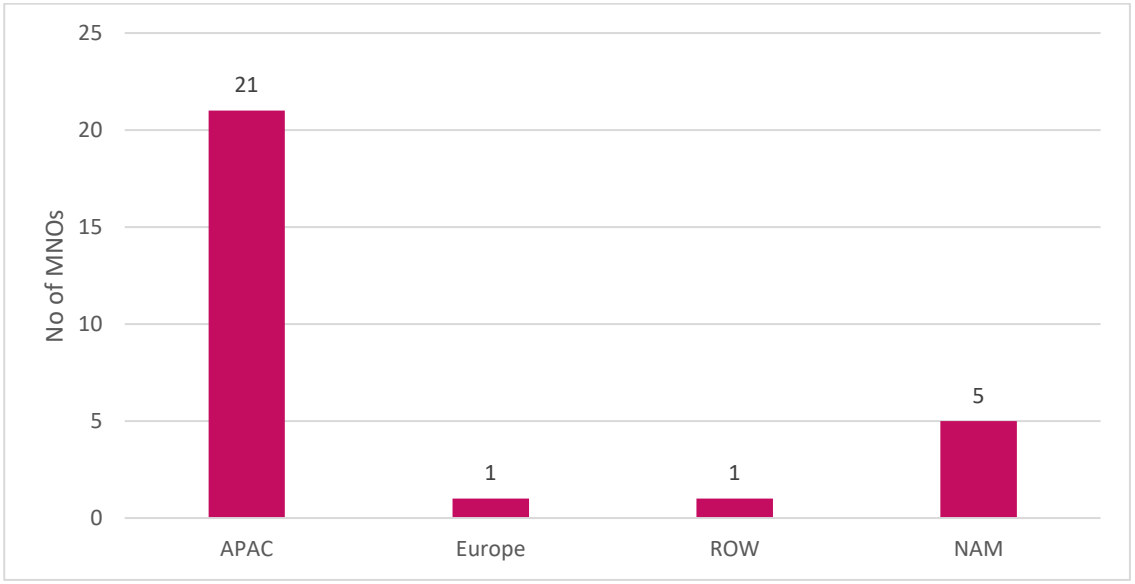

Figure 4 Number of MNOs which have already switched off 2G (GSM or CDMA) by region, July 2019

[20] Source: Operator statements, GSMA, Rethink survey

In Australia, all three MNOs have turned off GSM - Telstra at the end of 2016, with Optus following by August 2017 and Vodafone Australia in June 2018. In New Zealand Spark closed its CDMA network in 2012 and 2 Degrees closed its 2G network in March 2018.

The most active APAC countries in sunsetting 2G are countries with very dense populations with high levels of mobile data usage, a combination of factors which has put pressure on operators to free up spectrum for LTE. For instance, all three South Korean operators turned off 2G networks (GSM or CDMA) in 2011; all three Japanese MNOs turned off 2G between 2008 and 2011; the three Singaporean operators switched off GSM in 2018; and in Taiwan, the four MNOs turned off 2G in 2017 and followed with 3G (UMTS) in 2018.

In some markets, moves to sunset older networks are being led by non-GSM operators because technologies like CDMA and Sprint's iDEN ended up without a 4G migration roadmap of their own. That limits options for sharing spectrum flexibly between multiple generations of technology which is possible with the 3GPP standards. This has been seen in North America, especially Canada, where Bell, Telus and several regional players turned off CDMA systems in 2017 or 2018, in order to make more efficient use of their spectrum resources and avoid being left at a competitive disadvantage against their GSM-based rivals. In the USA, Sprint turned off iDEN in 2013; while Verizon Wireless plans to sunset 2G and 3G CDMA by the end of this year. Sprint has said it will do the same in 2021 or 2022, though this plan may be accelerated should its proposed merger with T-Mobile USA proceed. T-Mobile itself plans to sunset GSM in 2020.

The need to abandon a legacy technology is not the only factor behind an early sunset in North America however. AT&T switched off 2G in 2017 in order to free up spectrum for LTE and to reduce its operating costs by supporting fewer networks. At the end of 2020, there will be no GSM networks operating in North America.

By contrast, the Swiss operator Sunrise, has turned off one band (1800 MHz) it used for 2G. but still retains 2G services in 900 MHz. CNT in Ecuador has also completed both 2G and 3G sunset, switching off CDMA (2G and 3G) in 2014.

The full list of operators which have switched off a 2G or 3G network, or have scheduled a sunset, is included in Appendix A.

6.2 Plans for future 2G sunsets globally

Globally the majority of operators, whilst evaluating the future options for their 2G and 3G networks, have not yet set a firm date. As shown in Appendix A, dates have been set for only 31 further sunsets (and whether those dates remain unchanged will depend on market factors such as mergers).

In Europe, dates have been set by one or more operators in just five countries (including Swisscom's Lichtenstein subsidiary, which will turn off GSM in 2021, one year after its parent). In Switzerland, Sunrise will turn off GSM900 in 2021 and 3G in 2024. In The Netherlands, T-Mobile is the only operator to set a date so far, with plans to sunset 2G in 2020.

Some European and APAC operators will switch off 3G before 2G (and of those as-yet undecided on their schedules, this is an option which is often under consideration). For instance, Telenor Norway will turn off 3G in 2020, but 2G only in 2025; while in the same country, Telia has a date for 3G sunset (2021) but not for 2G. In Sweden, all three national MNOs have set a timeline for 3G sunset (Telenor in 2020, Tele2 and Telia, which share a network, in 2025). None have announced a 2G switch-off date.

No sunset plans have been confirmed in Latin America, Africa or the Middle East. In many markets in those regions, active usage of 2G services, in particular, is expected to continue well into the 2030s, especially

where rural coverage is required and where there are still large numbers of voice-centric consumers with very low cost devices.

Some emerging economies will plan for 2G sunset. Telenor has taken a group level decision to maximise spectral efficiency across its international subsidiaries and has scheduled 2G sunsets already in Myanmar (for 2022), as well as in several Nordic operations. It has also set a date for 3G switch-off in Myanmar in 2025-26 and in Pakistan in 2023, but in the latter market, intends to keep 2G running "indefinitely".

6.3 Expected trends in international 2G switch-off

The data above indicates that, in the majority of cases, operators have not made a firm plan for 2G sunset and are still evaluating their options. Many are refarming portions of their 2G – and in a few cases 3G – spectrum to augment 4G capacity, as 2G usage declines, rather than turning off 2G altogether. EE is a good example, refarming the 1800 MHz band spectrum from 2G to 4G.

As technologies for flexible usage of spectrum between multiple radios improve, these options are becoming easier to implement and more resource-efficient. That provides operators with the flexibility to keep increasingly small amounts of spectrum active for 2G in the years ahead, rather than engaging in a full shutdown. We expect large numbers of MNOs to keep their options open until at least 2030, especially in countries where new spectrum is becoming available for 5G at commercially viable prices, and so operators are not facing a capacity crunch in the short to medium term.

Real Wireless and Rethink Technology Research conducted a survey, in July 2019, of 56 national MNOs across the globe, which have not yet turned off 2G. The purpose was to understand the timeframes they consider most likely for their 2G sunset, even when they have not yet set a firm deadline; and the services that would be affected[21]. The results of the survey are summarised in Figure 5

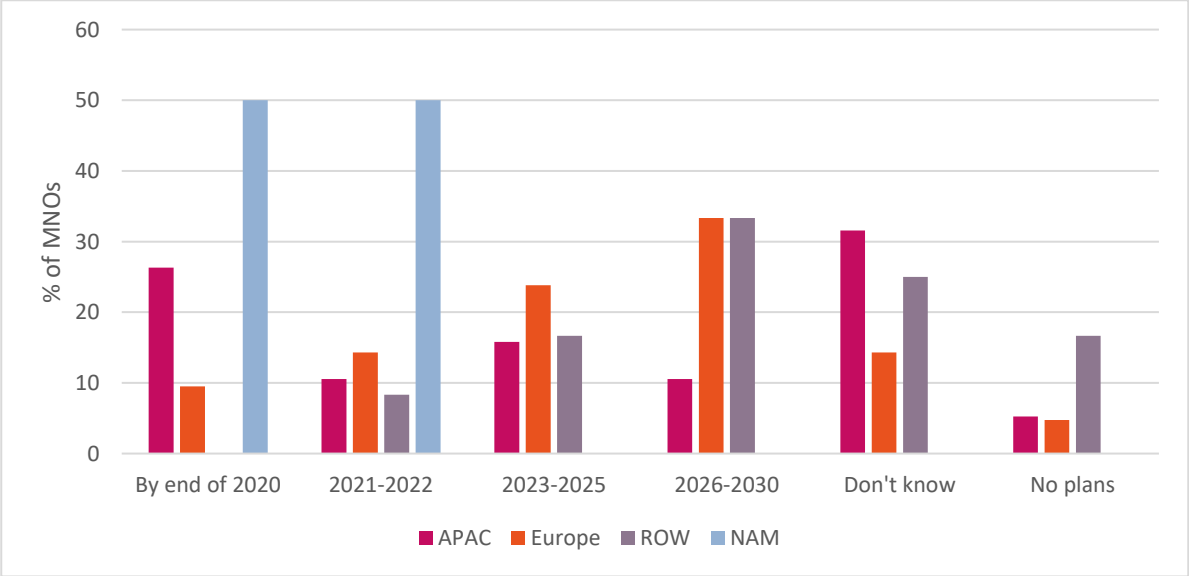

Figure 5 In what timeframe do you expect to switch off 2G? (% of MNOs by region)

[21] The survey respondents were split by region as follows - APAC 19; Europe 21; Rest of World 12; North America 4

As the previous section highlighted, the region with the most uniform approach to 2G sunset timescales is North America. Of those MNOs which have not already switched off 2G, all of them will do so by the end of 2022. In APAC, although this region has led the way so far, there is a variable approach to 2G sunset, reflecting the diversity of the markets in this area. Of the MNOs surveyed, 26% plan to turn off 2G by the end of 2020, and 11% in 2021-2022, most of these being in developed economies with a high level of 4G usage. But 36% either do not know in what timeframe they would be likely to switch off 2G, or have no current plans to do so at all. 16% expect sunset to happen in 2023-2025 and 11% in 2026-2030.

In Europe, the expectations are weighted far more heavily towards the second half of the decade, with one-third expecting to turn off 2G in 2026-2030, and 19% saying they do not know or have no plans. Only 10% are likely to turn off 2G by the end of 2020, with 14% in 2021-2022, and 24% in 2023-2025.

In Africa, LATAM and the Middle East, only 25% anticipate a 2G sunset before 2026, and 42% have no plans or no idea of a date as yet.

6.4 Migration periods and tactics

An important issue for MNOs considering a 2G sunset is how far ahead to prepare customers for this. Most operators say they expect to have a period of at least a year before switch-off, in which they will not activate new devices, but will engage in various activities to encourage the existing base of users to migrate. The length of time, and the money and effort invested, in this process, is likely to vary between human subscribers and business/M2M users; and according to the value of the 2G base to the operator's particular KPIs.

As the survey results reveal (see Figure 6 below), two years is the most common time period in which MNOs expect to continue to run 2G purely for legacy users (with no new activations even for established services). In Europe, 38% of the sample said they would allow a two-year period, compared to 10% planning just one year, and 38% which would support three or more. The anticipated migration periods are longer than in North America and APAC, where 25% and 21% respectively would allow just one year between ceasing activations and switch-off. The belief that longer periods may be necessary may reflect the European MNOs' lack of real world experience of sunsets, which makes them cautious; or in some cases, their relatively heavy usage of 2G as an M2M network.

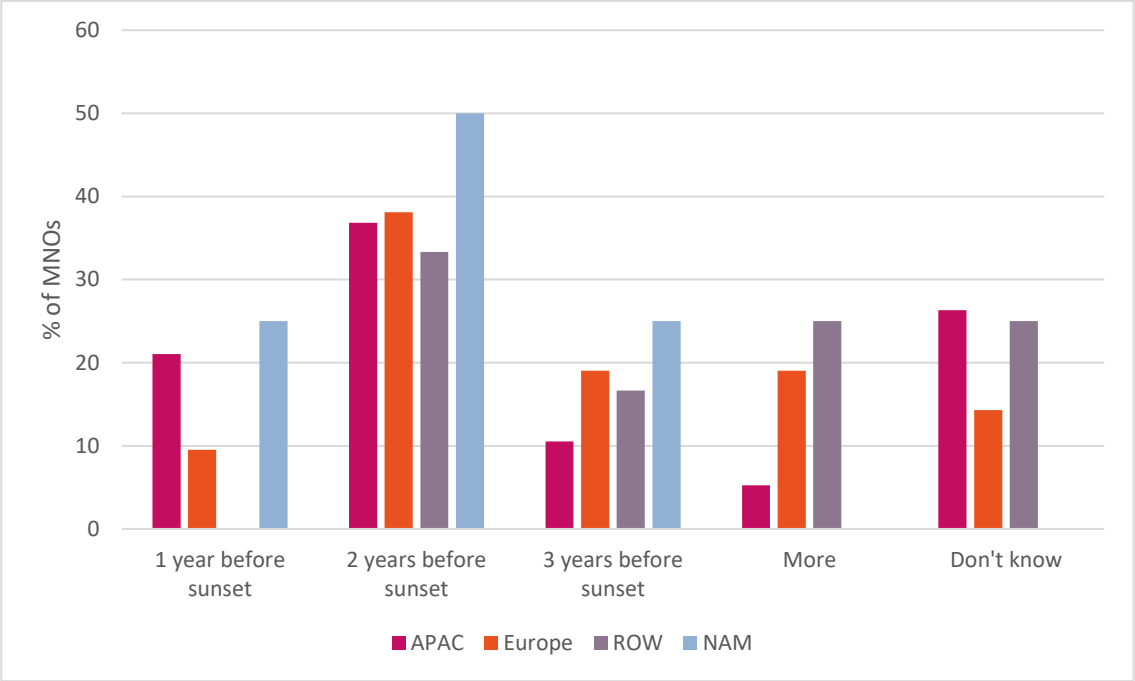

Figure 6 In what timeframe would you expect to stop activating new devices and users on 2G? (% of MNOs by region)

In most cases, operators with a long expected migration period are those which have significant customers using the kind of M2M services that do not readily lend themselves to 4G migration. Two Nordic operators said that the most challenging customers to convert would be those with M2M services that do not require higher data rates or lower latency than 2G supports, but have remote coverage requirements, or a very large installed base of devices to convert. In these cases, customers may be reluctant to transition to another network, because they have no incentive to do so, and when forced, may migrate to a non-cellular service.

These operators are therefore looking at working with M2M customers over a period of up to five years to migrate or replace devices, and continue to support the existing 2G services, sometimes in a very limited amount of 2G spectrum. This is especially likely to be the case where an MNO has a large-scale or government contract for an M2M service. In this situation, a government may allocate spectrum to support a long term 2G option, as Thailand is doing for utility M2M applications.

By contrast, for human users, there is generally a shorter period of 1-2 years between ceasing new activations and switching off completely. There are more tactics that can be employed to encourage consumers to move to new networks than there are for M2M applications running well on 2G.

And as the Nordic respondents said, for many MNOs, especially in developed economies, the loss of low-spending 2G consumers would not be a significant issue, and might be welcome as a way to boost ARPU. “By 2025 or later, losing a few 2G consumers will make no difference to any of our KPIs, and will improve some, such as ARPU,” said one of the interviewees. “In M2M, though, we have long-standing relationships with large organisations, which may also be users of other services such as 4G. We need to maintain their trust and support, and recognise that their replacement cycles are longer than those of handsets, and their reasons to move away from 2G may be limited.”

The M2M users might be the most valuable to many European MNOs, but not all of the operators support these services. When asked what services they currently support on 2G networks, the dominant ones in all

regions were, predictably, voice and messaging, and rural connectivity. All MNOs said there were currently rural connections that were supported only on 2G, which might be important for some agricultural or telematics services as well as humans. And only 5% of MNOs in Europe and Asia had succeeded in moving all their voice traffic off 2G – usually to 4G, which entailed a ubiquitous LTE network with VoLTE implemented throughout.

Some have specific services targeting the elderly, often including connectivity bundled with specially adapted handsets or with services such as home monitoring or personal alarms, and say that these are often 2G-based (29% in Europe have a defined 2G elderly user base). However, most do not distinguish these users from their general base, and many offer services targeted at older customers across all their networks. Figure 7 provides a summary of our findings.

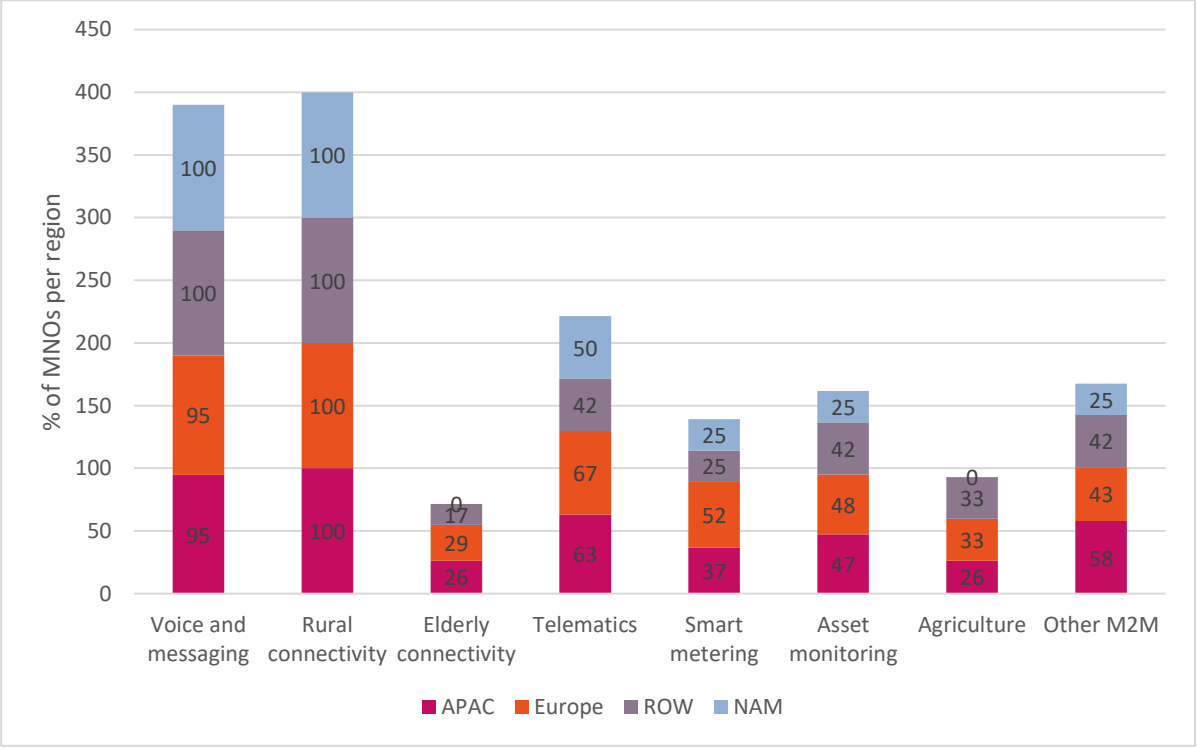

Figure 7 What are the services currently supported by 2G? (tick all that apply - % of MNOs by region)

Over the coming years, we expect that there will be more operators which make the transition to VoLTE and maintain their GSM networks entirely for M2M purposes.

The most common M2M applications running on 2G in Europe are (percentage of MNOs):

- Telematics – two-thirds of operators support services in this category on 2G
- Smart metering – 52%
- Asset monitoring – 48%
- Agricultural services – 33%

In addition, 43% had other M2M services which fall outside these categories.

Only a few MNOs in Europe (fewer than 10%) said they expected to launch brand new M2M applications on 2G, though most will continue to enhance their current services. Globally, operators which have launched

NB-IoT or LTE-M at scale say they will launch any new M2M services on those networks, with T-Mobile USA and China Telecom being examples. Only a few operators are interested in upgrading 2G services by implementing Enhanced-GPRS – France being the country where this has been most seriously trialled.

6.5 International case studies

A selection of operators which have switched off 2G, or have firm plans to do so, were interviewed about their experiences.

- **Thailand**

In some emerging economies, governments are encouraging legacy network sunsets as part of national programmes to boost spectrum resources for 4G or even 5G, and to drive uptake of more advanced services. In Thailand, for instance, the government has agreed a date of October 31 2019 for switch-off of all three MNOs' 2G networks (the operators are AIS, DTAC and True).

The operators had requested this support in order to refarm spectrum for 4G (or in True's case, 5G – this MNO will refarm 850/900 MHz 3G spectrum rather than participate in the upcoming 700 MHz 5G auction).

The government has established a programme, run through local authorities, to educate users and businesses about the changes and to explain options for migration – comparable to those programmes run by many governments around analogue TV switch-off.

The MNOs say they expect to offset the costs of migration in full with increased ARPUs. The simultaneous sunset across all three networks removes the risk of a first mover losing customers to a rival.

The MNOs are investing in marketing campaigns to encourage users to migrate and are subsidising 3G or 4G handsets for a period of six months commencing in October. They claim that an "insignificant number" of users remain outside 3G or 4G coverage and so consumers will not be left behind. However, the migration numbers are not small – AIS says that about 3.2m of its 40m SIM card base was on 2G services at the start of 2019. However, a large number of these SIM cards are dormant or belong to people with multiple connections. A market study by Fitch Solutions suggested that only 176,000 2G voice subscriptions were active at the start of 2019[22].

The regulator has taken steps to protect the base of 30,000 machine-to-machine connections running on 2G in Thailand. For users which do not choose to move to 4G, it has designated the 920-925 MHz band for unlicensed M2M use, which may stimulate uptake of a cellular alternative such as LoRaWAN. It has also allocated 400 MHz spectrum to the utilities, which are the main users of 2G M2M services.

- **T-Mobile USA**

T-Mobile USA has undergone a complex series of spectrum refarming initiatives to maximise its resource efficiency, and now plans to switch off GSM by the end of 2020. It has been using progressively less spectrum for 2G and says most of its remaining GSM connections are for M2M (about 96% in 2019). It has been investing heavily in NB-IoT and claims to have a "nationwide" network in 600 MHz, covering one million square miles in 44 states. It will work with major business M2M customers to migrate them to NB-IoT and says it will ensure that, where such customers need particular areas of coverage, NB-IoT expansion

[22] https://www.fitchsolutions.com/corporates/telecoms-media-technology/2g-shutdown-positive-cope-evolving-thai-mobile-market-dynamics-24-01-2019

there is prioritised. It will also offer a series of different promotions and introductory tariffs to encourage users of consumer M2M applications to transition ahead of shutdown, under its NB-IoT BeeAware brand.

The advantage that T-Mobile has over other US carriers is extensive sub-GHz spectrum, following its spending in the 600 MHz auction, for LTE and 5G. This makes it easier for the operator to achieve 2G levels of coverage at affordable capex cost and so ensure that very few 2G users are left behind.

It has been gradually reducing the amount of spectrum it uses for 2G since 2012, when it started to move its 3G HSPA network from the AWS band, which in the USA is more commonly used for LTE, to the 1.9 GHz PCS or 2G spectrum, alongside its 2G network. That freed up the AWS spectrum for LTE. To support this change, T-Mobile shut down 75% of its 2G capacity to clear PCS airwaves for 3G, and installed multi-RAT 2G/HSPA+ equipment on over 20,000 macro sites.

The remaining 2G network, which will be maintained until the end of 2020, is known as 2G-M2M and is a modified version of the company's 2G system that is specific to M2M services. This minimises the amount of spectrum that has to be retained for 2G.

T-Mobile said the biggest barrier to customer migration to 4G is the increased cost of the 4G devices. On the consumer front, financing deals and falling device prices have seen most customers migrate naturally to newer networks.

For M2M customers, T-Mobile is offering a financing programme to help business users, or those with home automation services on GSM, transition to LTE devices. It did not share many details but said the financing scheme would extend over periods of up to five years and in some cases would require no upfront payment.

- **Korea Telecom**

Operators which shut down 2G in the 2020s are likely to face far fewer challenges than those who moved very early. Not only are there emerging alternatives to 2G, such as NB-IoT, to support service migration, but MNOs can learn from the problems that early movers encountered.

In South Korea, for instance, KT faced delays enforced by the regulator, KCC, and a class action lawsuit from 900 subscribers, in the process of sunsetting its 2G network from 2011 to 2012.

The operator was initially denied permission by KCC to switch off 2G, because it still had 5% of its total base (about 810,000 users at the time) on 2G. By contrast, operators which had already turned off 2G in other countries, such as Softbank and NTT Docomo in Japan, had successfully reduced 2G numbers to a far lower level before the sunset – in Docomo's case, only 0.3% of its base, or 202,000 users, at the time of sunset in 2011. KT also gave only three months' notice to subscribers that it planned to switch off 2G, whereas Docomo had publicised its intention more than three years before the final termination date.

In order to reverse the suspension of its sunset, the operator offered various incentives for users to move to 3G including exemption from 3G subscription fees for the first three months, followed by discounted rates for two years; free devices (with 34 available to choose from); and a payment of KRW33,000 for a returned 2G device. Other benefits included loyalty points and air miles.

The case study has been widely cited by other MNOs, as a valuable lesson in the need to drive the 2G base down to a small percentage of the base before setting a firm deadline for sunset.

- **Switzerland**

Switzerland is currently the most advanced European country in terms of plans for 2G sunset. Sunrise has implemented the continent's only sunset, closing down one of its two separate GSM networks (the one running in 2.1 GHz) in 2018. It will sunset its other 2G network, in 900 MHz, in 2021 and its 3G network in 2024. Meanwhile, incumbent Swisscom will sunset 2G in 2020.

Sunrise said the most important aspect of its 2G sunset planning was to offer attractive reasons for users to migrate ahead of time. These mainly consist of heavily subsidised high end smartphones, or more modest devices for free, plus discounted monthly tariffs for the first three months.

The operator worked with larger business customers individually to come up with customised migration options for M2M services.

The other important aspect of its migration strategy was to invest in expanding VoLTE over its entire 4G footprint so that it dramatically reduced the need for users to fall back to 2G (or 3G) when they were in gaps in VoLTE coverage. Sunrise differentiated itself from Swisscom when it deployed LTE initially in 800 MHz rather than 1800 MHz, which has enabled it to achieve 4G coverage and in-building penetration that is closer to that of 2G, for lower capex cost than attempting that in a higher spectrum band. Sunrise said the improved propagation made a 2G network in 2.1 GHz spectrum redundant, and that it will have matched its 2G coverage with VoLTE by the time it turns off its 900 MHz network.

One factor which simplifies Sunrise's strategy is a limited amount of M2M business. The company says it does not see 2G M2M as a revenue stream of any significance currently and will only make the decision about whether to invest in NB-IoT or LTE-M when it sees market demand. Most of its migration issues, then, relate to humans and to voice, hence its focus on VoLTE.

Swisscom is relying far less on incentives such as subsidised devices, and is instead running an information campaign to persuade its 2G customers of the benefits of moving to 4G such as the ability to watch video on the move. It is not currently offering financial support to migrate from 2G handsets or M2M devices, though it is possible those incentives might be introduced in the last six months or so before sunset, in order to move the last stragglers off 2G. Swisscom is not commenting on that, just saying that it is giving consumers and businesses plenty of notice and clear information about how to get a new device.

7 Summary and conclusions

Operator Perspectives

Since introduction in the 1990s, 2G technology has proved to be a resilient, reliable and value for money radio access technology and any plans to switch off 2G will need to take into account the remaining volume of connections, and the importance of the then remaining 2G use cases.

A full 2G sunset is likely to be a long term option in the UK, happening after 2025 and possibly around 2030. Operators will look for more efficient ways to keep 2G running so they can refarm an increasing amount of the valuable 2G spectrum for 4G, and reduce the amount of cost and effort they spend to support and maintain legacy users and networks.

Refarming of 2G spectrum to more modern/efficient technologies has already occurred and will continue – with a minimum volume of spectrum being left to support 2G traffic. For example, EE refarmed 2G 1800 MHz spectrum to launch its 4G network, and O2/Vodafone refarmed 2G 900 MHz spectrum to support 3G.

We support the view that 3G sunset for all operators is likely to occur ahead of the 2G sunset, although the transition of voice services away from 2G/3G to 4G VoLTE may delay the 3G switch-off date depending on the rate of user transition to VoLTE-capable phones. Until VoLTE is universal, there will be a need for 4G circuit-switched fallback (CSFB) to 2G or 3G networks.

2G has proved popular because of its coverage – achieved particularly through the use of 900 MHz spectrum. Any radio technology replacing 2G will need to at least match this coverage by the time of switch-off. The MNOs are confident that 4G will approach this coverage level within the next 2-3 years, and that the bigger challenge is to eliminate the mobile not-spots in remote areas.

Until ubiquitous coverage is commercially realistic, MNOs can consider steps which reduces usage of 2G whilst keeping some of the network alive to support legacy users indefinitely. Options include shared 2G networks and dynamic spectrum sharing between multiple radio access technologies.

Voice Services

Human-based 2G use cases such as voice services for seniors and tourists, are manageable assuming switch-off is not imminent. By 2025-2030 there should be a much reduced base of humans on 2G - upgraded devices that will automatically link to 4G with VoLTE in this timeframe.

We believe that public marketing campaigns will need to be run to ensure that people understand the need to buy a new phone and the timescales for doing this. Operators could also drive the transition by marketing and/or special prices to transition to a simple 4G handset.

M2M Services

However, whilst the numbers of consumers who regularly rely on 2G networks are falling rapidly according to the MNOs, there are still important and growing machine-to-machine applications running on 2G. Strategies to achieve 2G-equivalent coverage for these applications must be carefully thought out and communicated, if MNOs are to smooth the migration of the complex M2M ecosystems which underpin services like smart metering and vehicle telematics.

The market needs to provide clear, easy to buy and deploy M2M solutions that purchasers can reasonably expect to remain operational for up to 10-15 years. Currently the M2M connectivity supply side appears fragmented and complex to navigate. A strategy to stop adding new M2M users onto 2G networks also needs to be developed by all parts of the 2G M2M ecosystem – including MNOs, system integrators, SIM providers and platform operators. This requires a clear nationwide alternative (or alternatives) to 2G M2M services. Whilst NB-IoT and the unlicensed spectrum LoRaWAN could emerge as the most likely candidates in the UK, at present there is no alternative technology solution to 2G which provides a similar nationwide footprint, capability, ecosystem and cost.

For now, in the absence of this clear path to an alternative M2M network, new M2M users continue to be added onto 2G networks, further compounding the switch-off challenge.

M2M services, especially in telematics (fleet tracking) and basic connected car services, are hard to switch off quickly because of the large number of players in the value chains, the long technology and contract lifecycles, and the limited need for anything more than 2G capabilities. The situation is worsened by the difficulty and cost of replacing the in-vehicle modem.

Sufficient notice periods for 2G switch-off should allow the M2M supply side ecosystems to align to new radio access technologies. This could involve developing new modems/end points, new platforms and new processes. 2-3 years would seem to be a suitable period for such developments but a longer period will be required to transition existing M2M deployments where longer asset lives are typical - potentially 5-7 years.

Smart Meters

Smart meters represent the most significant use case in terms operational timelines and migration complexity, and these are a major barrier to full 2G switch-off by Vodafone and Telefonica O2, which provide the connectivity for the current Smart Meter Communication Hubs. There are likely to be some 30 million 2G/3G Communications Hubs installed in homes and small business, each connecting one or two meters into the smart meter network, once the deployment programme has completed. These hubs and meters were assumed to have 15-year asset lives when the programme was being developed. With the smart meter installation programme scheduled to complete in 2021 this perhaps indicates that 2G services will need to remain operational until early to mid-2030s. It is possible that before the end of the current smart meter installation programme a 4G-based Communications Hub could replace the 2G/3G version but that will still leave a large proportion of the total being 2G/3G-only.

eCall

eCall was mandated in the EC for new type approved vehicles from April 2018. The system specification is currently 2G/3G based but a 4G based version is being planned. Based on 3-5 year new vehicle development cycles and a 10-15 year vehicle lifetime, the length of time necessary to provide 2G services to support eCall could be in excess of 20 years.

Single Network

One option to support the key 2G-based services more efficiently, without taking on the challenges of turning them off entirely, could be operating a single network – possibly along the lines now being discussed for the 'Shared Rural Network'. There could be several regulatory, technical, commercial and migration hurdles to overcome to achieve such a network but we see this as potentially a sound strategy. This could support the current smart meter operations and other specific use cases but such a programme should also be tied into preventing more new 2G-based devices from being deployed.

Lessons from Abroad

UK and European MNOs can benefit from being late to sunset 2G networks, as they can learn from the experiences of operators which have already gone through this process in other parts of the world – the USA, for instance, will have no 2G network left by the end of 2020, while 2G sunsets took place in Japan and South Korea from 2010 (even earlier for a few CDMA operators). The most important lessons to take from those early movers are to avoid hasty switch-offs – smooth sunsets like those of NTT Docomo or AT&T have involved providing customers with plenty of notice, working with device makers to ensure a strong supply of affordable handsets and modules, and waiting until the 2G base has naturally dwindled to a low percentage (ideally less than 1%) of the total. Operators which have reported disruption to their own businesses, and to their customers, have often been those, like KT, which tried to turn off 2G while they still had a substantial GSM base of users, and without allowing sufficient time (only 2-3 months) to educate and inform those customers about transition options.

Appendix A – International 2G/3G Switch Off

Operators which have switched off 2G or 3G networks, or set a date to do so, by region[23]

Region	Country	Operator	2G/3G	Tech switched off	Switched off (date)	Plan to switch off (confirmed)
Europe	Lichtenstein	Swisscom	2G	GSM		2021
Europe	Netherlands	T-Mobile	2G	GSM		2020
Europe	Norway	Telenor	2G	GSM		2025
Europe	Norway	Telenor	3G	UMTS		2020
Europe	Norway	Telia	3G	UMTS		2021
Europe	Sweden	Telenor	3G	UMTS		2020
Europe	Sweden	Tele2	3G	UMTS		2025
Europe	Sweden	Telia	3G	UMTS		2025
Europe	Switzerland	Sunrise	2G	GSM900		2021
Europe	Switzerland	Sunrise	2G	GSM2100	2018	
Europe	Switzerland	Sunrise	3G	UMTS		2024
Europe	Switzerland	Swisscom	2G	GSM		2020
APAC	Japan	NTT Docomo	2G	PDC	2012	
APAC	Japan	NTT Docomo	2G	GSM	2011	
APAC	Japan	Softbank	2G	GSM	2010	
APAC	Japan	KDDI	2G	CDMA	2008	
APAC	Australia	Telstra	2G	GSM	2016	
APAC	Australia	Optus	2G	GSM	2017	
APAC	Australia	Vodafone	2G	GSM	2018	
APAC	New Zealand	Spark	2G and 3G	CDMA	2012	
APAC	New Zealand	2 Degrees	2G	GSM	2018	
APAC	Bangladesh	Grameenphone	2G	GSM		2025

[23] Source: Operator statements, GSMA, Rethink survey

APAC	India	Reliance Jio	2G	GSM	2017	
APAC	India	Bharti Airtel	2G	GSM		2019
APAC	Macau	Hutchison	2G	GSM	2015	
APAC	Macau	Smartone	2G	GSM		2019
APAC	Myanmar	Telenor	2G	GSM		2022
APAC	Myanmar	Telenor	3G	UMTS		2025-2026
APAC	Malaysia	Digi	2G and 3G	GSM and UMTS		After 2020
APAC	Pakistan	Telenor	3G	UMTS		2023
APAC	Singapore	M1	2G	GSM	2018	
APAC	Singapore	Singtel	2G	GSM	2018	
APAC	Singapore	Starhub	2G	GSM	2018	
APAC	South Korea	KT	2G	GSM	2011	
APAC	South Korea	SK Telecom	2G	GSM	2011	
APAC	South Korea	LG U+	2G	GSM	2011	
APAC	Thailand	DTAC	2G	GSM		2019
APAC	Thailand	AIS	2G	GSM		2019
APAC	Thailand	TrueMoveH	2G	GSM		2019
APAC	Thailand	DTAC	3G	UMTS		2021 (target)
APAC	Taiwan	Chunghwa	2G	GSM	2017	
APAC	Taiwan	FarEasTone	2G	GSM	2017	
APAC	Taiwan	Taiwan Mobile	2G	GSM	2017	
APAC	Taiwan	Taiwan Star	2G	GSM	2017	
APAC	Taiwan	Chunghwa	3G	UMTS	2018	
APAC	Taiwan	FarEasTone	3G	UMTS	2018	
APAC	Taiwan	Taiwan Mobile	3G	UMTS	2018	
APAC	Taiwan	Taiwan Star	3G	UMTS	2018	
APAC	Taiwan	Asia-Pacific Telecom	3G	UMTS	2018	

NAM	USA	AT&T	2G	GSM	2017	
NAM	USA	AT&T	3G	UMTS		2021
NAM	USA	Verizon	2G and 3G	CDMA		end 2019
NAM	USA	T-Mobile	2G	GSM		2020
NAM	USA	Sprint	2G and 3G	CDMA		2021 or 2022
NAM	Canada	Bell	2G and 3G	CDMA	2018	
NAM	Canada	Bell	3G	UMTS		2025
NAM	Canada	Telus	2G and 3G	CDMA	2017	
NAM	Canada	Telus	3G	UMTS		2025
NAM	Canada	Manitoba Telecom	2G and 3G	CDMA	2016	
NAM	Canada	SaskTel	2G and 3G	CDMA	2017	
NAM	Canada	Rogers	2G	GSM		2020
NAM	Canada	Rogers	3G	UMTS		2025
LATAM	Mexico	Telefonica Movistar				2020
LATAM	Ecuador	CNT	2G and 3G	CDMA	2014	

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