Obstacles to deploying a denser mobile network

January 2019

1 Executive Summary

Mobile networks do not provide perfect service in cities – there are not-spots and areas of insufficient capacity. Despite best efforts, this is not improving, indeed potentially it is getting worse as demands on networks grow but handset performance degrades due to supporting ever-more frequency bands. The solution will involve more cells and more capacity on existing cells; although it is not clear what the balance between these will be and it may vary across operators and cities. Indeed, there are many other open issues such as the balance between macrocells and small cells; between indoors and outdoors cells; between Wi-Fi and cellular; and between conventional deployment and shared-access deployment.

However, despite this clear need, new cell deployment has slowed in cities in Europe and Latin America, even while it increases in China and other countries, and cell upgrades are proving difficult in many cases. There are various reasons for this including:

- Costs of deployment are much too high due to difficulties in finding new sites, slow site approval processes, site rental costs, and costs of provisioning backhaul and power.
- Site upgrades are problematic because there often is insufficient space or mounting points for the large MIMO antennas needed for 5G.
- For indoor small cells self-deployment would help, but the right models for this commercially and contractually are still unclear.
- Mobile operators' finances are generally somewhat weak with relatively poor return on capital employed, making it harder for them to access financing and make the business case for deployment of additional infrastructure.

One, much discussed, approach to reduce costs is to share sites. However, given the lack of space on many city sites this may require a neutral host model where a third party develops the site on behalf of all interested operators. Enabling this needs the removal of regulatory barriers such as restrictions on sharing sites, electronics and spectrum; the defragmentation of spectrum holdings to enable shared antennas; enabling taller masts and higher transmit powers; and in some cases removal of various obligations that might have unintended consequences.

While Europe has struggled with new cell deployments, other countries have achieved more. For example:

- In China there is a much larger number of cells per subscriber, including small cells, driven primarily by very low costs for sites and backhaul.
- The US is not currently a leader in new cell deployment but is now enacting regulation to reduce rental costs and speed up permit approvals.
- Singapore has a high level of in-building cells helped in part by regulation that required building owners to provide space for equipment.
- Korea has led in fibre and mobile deployment partly due to industrial policy, partly due to a strong local manufacturing base and partly due to dense cities. The widespread presence of fibre has helped facilitate dense mobile networks.

Conversely, outside of these regions there is little that is innovative or encouraging to report. For example:

- The UK is struggling with a highly competitive market and low prices. Various efforts to ease planning and barriers have been welcomed but may have unintended consequences or might just be too little too late.
- France is being innovative in rural coverage and showing a willingness to consider new approaches which might eventually benefits in urban areas, but there is little direct focus on the urban issues.
- Efforts in Latin America to impose best practice and centralised regulation on the many local authorities have generally not been successful, resulting in a fragmented and bureaucratic site approval process.

Addressing these failures, and thus enabling Europe to keep up with the rest of the world in mobile broadband provision, requires Governmental and regulatory action across the areas of access to sites, better backhaul and the enablement of shared deployment models.

In terms of site access, approaches that might make a difference include:

- A unified window, across the different layers of government to obtain the necessary approvals relying on 'positive silence' approach with maximum waiting days to progress.
- A simple, nationally harmonised process to sell access to street furniture such as lampposts.
- De minimis planning rules for small cells where the visual footprint is small.
- Easy access to Government buildings and land with low prices set for rental.
- Similar rights of access and costs of land as other utilities such as water and gas enjoy.

Backhaul can be facilitated by encouraging fibre build with initiatives such as duct-and-pole access under commercial conditions and appropriate regulatory regimes. Ensuring backhaul to street furniture such as lampposts would be helpful for facilitating small cell deployment.

Above all, it is unclear what the communications architectures of the future will look like. A regime that allows for flexibility and innovation both in technology and business model, is needed to allow experimentation.

2 The current situation

2.1 Mobile service is imperfect

The ideal mobile phone service would provide perfect connectivity everywhere. To be perfect, the connectivity would not be a limiting factor on the speed of the application or service - for example for video the data rate available would be higher than the rate needed to provide the video feed desired. To be ubiquitous coverage would be needed outdoors, indoors, on trains, planes, and in tunnels without not-spots both in urban and populated rural areas. While this may be a utopian vision, there are many excellent reasons for aiming to achieve it, not just to deliver a high level of consumer satisfaction but also as a platform to enable potential new services such as those envisioned for 5G. Regulators and Governments are increasingly recognising this, with coverage obligations and similar approaches being used to effectively subsidise better coverage, for example the UK recently consulted[1] on a coverage obligation that had specific targets for geographical coverage, additional masts and household coverage. Similar approaches have been adopted in France, Germany, Brazil and many other countries.

The mobile service offered often falls short of this ideal, even in cities. Here, there can be not-spots where there is insufficient coverage, especially indoors. Capacity can also be a problem, with congestion occurring in busy areas such as major train stations, making connectivity difficult and compromised.

The situation may be getting worse rather than better in some places. Data demands are growing, rapidly in some countries[2], increasing network congestion. Phones that have support for additional frequency bands often have compromised component design in any given band resulting in worse performance.

2.2 Resolving this issue requires more capacity on existing cells and more cells

The two, interlinked, parts of the problem are insufficient coverage and insufficient capacity.

Coverage will predominantly be addressed with more cells, although enabling taller masts in rural areas, higher transmit powers, and the use of the 600 and 700MHz band will provide some gains. More cells can provide greater signal levels into areas of poor coverage - hence the reason UK, German and French award processes specifically require hundreds or thousands of new cells to be deployed.

Capacity can be addressed both with more cells, since each new cell adds additional capacity, and with more frequencies deployed on existing cells.

[1] https://www.ofcom.org.uk/consultations-and-statements/category-1/award-700mhz-3.6-3.8ghz-spectrum

[2] Different studies point to yearly growth rates between 31% and 46% for mobile data consumption, mainly led by video, always-on behaviour and more capable smartphones. See https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.pdf and https://www.ericsson.com/assets/local/mobility-report/documents/2018/ericsson-mobility-report-november-2018.pdf

However, understanding the balance between existing and new cells, and the preferred location of new cells is more complex and depends on a range of factors such as the amount and frequency of spectrum available to an operator. Questions include:

- The optimal balance between expanding existing cells versus deploying new cells.
- Whether new cells should be macrocells (mounted on rooftops or masts) or small cells (mounted below rooftop level). If small cells, whether they should use the same frequencies as the macrocells or new frequencies such as those at mmWave.
- Whether cells should be indoors or outdoors.
- What technology should be used - for outdoor cells 4G and 5G are obvious candidates, but for indoor cells Wi-Fi may be a useful compliment.
- Whether each operator should deploy their own cells or whether there should be sharing or even a neutral host in some geographical areas.

In answering these questions, operators will generally be driven by economics and will pursue the lowest-cost way of achieving the capacity and coverage that they deem necessary. However, the economics are influenced by a wide range of factors, some regulatory and including the costs of spectrum which will be weighed up against the cost of deploying additional cells, and there are many unknowns causing uncertainty in business case outcomes. This paper considers what these issues are and discusses whether there should be changes in various regulations and policies in order to facilitate the deployment of better networks.

There have been previous papers and discussions[3] about the barriers to the deployment of fixed networks, mobile networks and future 5G networks, which have been mainly classified into four areas (a) deployment procedures and rules, b) technology, c) the environment, and d) health concerns[4]. These have generally raised many valid issues, the most important of which are also reflected in this paper. They often include problems such as the difficulty in dealing with multiple local authorities who may have differing rules, the uncertainty of planning approval, the problems in getting power supplied to base stations, the high cost of sites when market forces are unrestrained, the restrictions on higher masts in rural areas, and issues with national or supra-national electronics communications codes.

The difference of this paper is in placing the issues in a wider context of strategies to achieve higher capacity and better coverage from mobile networks. This paper gives more discussion to concepts such as neutral host networks, heterogeneous networks and shared spectrum, and considers barriers to deployment in this broader context. It also gives more consideration to different frameworks for the operation of mobile networks and looks more broadly than the status quo to find solutions to problems that have often proven intractable when given a more conventional analysis.

[3] For example see BSG at http://www.broadbanduk.org/wp-content/uploads/2018/07/BSG-Report-Lowering-barriers-to-5G-deployment.pdf and Small Cell Forum reports SCF 050 and SCF 195 at https://scf.io/en/documents/new_documents.php

[4] See CAF/Analysys Masons 2017 report "Mobile Broadband Expansion. Eliminating Barriers for infrastructure Deployment in Latin America" available at: http://scioteca.caf.com/handle/123456789/1084

2.3 In most countries new cell deployment has not been a priority in the last few years

Data on the number of cells can be difficult to find - operators tend not to publish this information unless they are obliged to. In the US, the FCC publishes cell tower numbers, the most recent, from 2017 is provided below.

Cell Sites	2013	2014	2015	2016
AT&T	61,800	71,768	66,500	67,000
Sprint	55,000	55,000	55,000	50,000
T-Mobile	63,879	61,079	57,971	59,417
Verizon Wireless	46,655	50,065	54,000	58,300
U.S. Cellular	6,975	6,220	6,297	6,415*
Total by Top Wireless Service Providers	**244,753**	**245,585**	**240,735**	**241,091**
CTIA Reported Total Industry-wide Cell Sites	**304,360**	**298,055**	**307,626**	**308,334**

Table 2-1 - Source: FCC, Twentieth Mobile Wireless Competition Report, 2017, Section II.F, p72

It can be seen that the total industry-wide cell site numbers have remained relatively static over the period 2013-2016. There does not appear to have been material change in this since 2016 although the FCC has recently taken material steps to accelerate wireless broadband deployment by removing barriers to infrastructure investment[5].

An alternative way to look at the data is the volume of RAN sales. It is not possible to break this down into new base stations and upgrades to existing base stations so this can only give a broad indication.

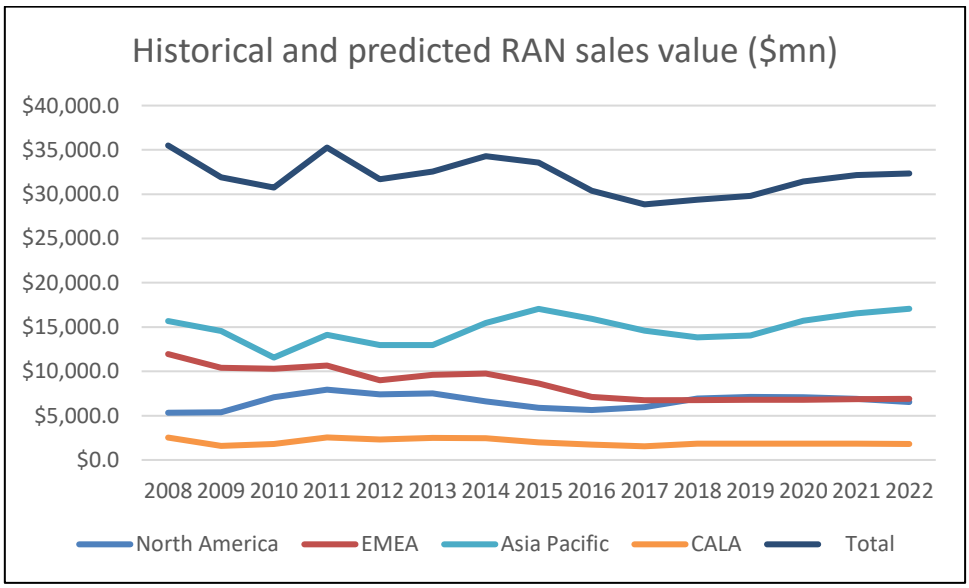

Figure 2-1 - RAN sales values. Source Dell'Oro Jan 2019

The figure shows that, with the exception of Asia-Pacific, sales of RAN equipment have fallen since 2008, although they are predicted to grow in coming years mostly due to 5G upgrade spending. This suggests that in most of the world new cell deployment has been weak.

[5] https://docs.fcc.gov/public/attachments/FCC-18-133A1.pdf

In Europe, the reasons for the stagnation in new tower build are varied but are essentially driven by the high cost of new sites, making expansion of existing sites more attractive. For many operators it has been possible to enhance capacity by deploying additional 4G spectrum on existing sites, and by re-farming 2G and 3G spectrum to 4G. Conversely, the costs of finding new sites have been high. This is because most of the easy-to-find sites have already been deployed. This has been exacerbated by the poor return on capital that many European operators have experienced[6], making it hard to raise funding and make the business case for the deployment of new infrastructure.

In many countries, and particularly in Europe, these problems of finding new cells were not particularly pressing while it was possible to expand capacity on existing cells. However, this route to growing capacity is becoming more problematic. While recent and forthcoming 5G auctions have provided more spectrum, often in the 3.5GHz frequency band, the practicalities of using this spectrum, discussed below, have led to related issues.

To enable the 3.5GHz frequencies to reach towards the cell edge operators plan to use beam-forming antennas, sometimes known as massive MIMO, which direct the radio signal, and by concentrating the energy allow it to travel further. However, these antennas work by having many antenna elements, spaced sufficiently far apart to enable focused beams. This makes them large and heavy - data on antenna size and photographs of typical antennas are provided below.

Figure 2-2 - Ericsson Massive MIMO Base Station for mid-bands

[6] This appears to be driven by policies that encourage competition such as enabling new entrants and preventing merger of existing players.

Mounting large antennas on existing sites is often challenging. The sites may not have the space for additional antennas, or the mounting options may not be able to take their weight. There may not be space for the additional feeder cabling required. Landlords may see the site upgrade as an opportunity to increase rental costs or decide to otherwise withhold permissions needed. It will be highly site dependent, but there is a risk that not all of existing sites can be seamlessly upgraded to 5G.

Even where beam-forming antennas can be mounted, there may be issues related to compliance with human exposure limits. Radio waves can cause harm to human health if sufficiently intense. There are advisory limits as to maximum exposure levels, published internationally by ICNIRP[7] and the IEEE[8] (which uses the similar levels as ICNIRP in many frequency ranges). The limits relate to total exposure to the fields radiated by a transmitter, such as a base station. As more carriers are deployed (and hence the bandwidth increases), the total site transmitted power grows. For a site with multiple carriers, especially if used by multiple operators, there is a real risk that additional frequencies will exceed the recommended exposure limit requiring mitigating measures. Such measures could be to increase the exclusion zone around the site (since power decreases with distance) or reduce the transmit power used by one or more of the existing carriers or change the position/orientation of the antennas. Changes to transmit power or antenna position may have impacts on coverage and capacity.

Whether these exposure-related limits will be an issue is deeply unclear. It is site-specific and depends on the amount of energy already radiated and the effective protection zone distance around the site. It is also very unclear how power levels radiated by 5G technology, such as adaptive beam-forming antennas, will be assessed. Papers from Nokia[9] and Ericsson[10] detail the complexity and propose approaches that are under consideration by international technical standards bodies such as the IEC and the ITU. Simplistically, beam forming antennas can lead to higher power levels when within the beam but very low power levels when outside the beam, as beam steering and TDD modes reduce the time that the beam is pointing at a given location. Human exposure limits are averaged over six (or 30) minutes so there is a strong argument that the realistic average power across the cell should be used and not the highest power when within a beam. This can reduce the exclusion area needed around a site from around 20m to around 10m - a massive change in site viability. Ericsson even offer a capability within the base station to ensure that stationary beams that would lead to the exposure limits being exceeded are avoided. It would seem highly appropriate for regulators to recognise realistic average rather than peak power levels.

The problem is exacerbated in some countries which have chosen to adopt lower human exposure limits than those recommended by international bodies. In Europe, these include Poland, Italy and Switzerland. These limits could require exclusion zones greater than 100m around cell sites, making 5G deployment virtually impossible in the dense city areas where it is most needed.

[7] https://www.icnirp.org/en/applications/base-stations/index.html
[8] http://standards.ieee.org/about/get/index.html
[9] https://www.itu.int/en/ITU-T/Workshops-and-Seminars/20171205/Documents/S3_Kamil_Bechta.pdf
[10] https://www.itu.int/en/ITU-T/Workshops-and-Seminars/20171205/Documents/S3_Christer_Tornevik.pdf

The EC appears to believe that human exposure limit concerns and legislation is potentially blocking deployment and makes it a key element of its guidance in the COCOM note[11] on best-practice national broadband strategies. Anecdotal input suggests that where broadband 5G carriers are to be employed it could impact as much as 50% of cells.

The problems with larger antennas and restrictive exposure compliance requirements suggest that while it will be the predominate form of investment from mobile operators over the next few years, in the longer-term continuing to expand capacity on existing sites will become progressively more difficult and expensive. This suggests a particular focus on the barriers to macrocell expansion in the short term. A summary of these issues is shown below.

Category	Information needed on current deployments	Advice / action
Civil works	• Power – energy dimensioning • Fiber availability • Impacts on other operators due to co-siting • Poles stability: reinforcement/replacement • Site rebuilding	• New antennas will require an more power • New battery and air-con check • Verify transmission capabilities and backhauling status • Analyse the “Static Load” of poles due to 5G equipment (RBS & Antennas) • Site re-engineering & design
Permissions	• Exposure Permit: several sites are already at legal limit. • New Urban Permit: to install new extra radio on top • Adequate property contracts (e.g. co-siting)	• Harmonise legal limit with international guidance, update compliance procedures • Switch off of radios with different technologies • Repositioning of antennas (height) • Permission to install large antennas on top of the current setup • New radio equipment require renegotiation with site property

Table 2-2 – Summary of issues with deploying and upgrading cells [Source – Ericsson]

As existing cells become more expensive to upgrade, this makes the option of new cells more attractive.

2.4 Problems with new outdoor macrocells

The problem with finding new macrocell sites in cities is that the low-hanging fruit has already been picked. Operators have been deploying macrocells for three decades or more during which time they have identified and deployed most viable sites. Remaining potential sites are often blocked by landlords. Some landlords simply do not want antennas on their roofs, perhaps for cosmetic reasons, perhaps because they do not believe the rental revenue offsets the inconvenience. This is especially true for older buildings, which often predominate in European city centres. Planning permission can

[11] https://circabc.europa.eu/d/d/workspace/SpacesStore/17577264-2b13-49a0-8b83-823f6694e386/COCOM18-06REV-2%205G%20WG%20Report%20Best%20Practices%205G%20National%20Roadmaps.pdf

also be problematic[12], especially for historical buildings, and this is exacerbated by larger beam-forming antennas. Government landlords are often unwilling to do deals, partly because the incentive of rental income is weak in not-for-profit entities. In major cities, Government buildings can form a large percentage of the total building stock.

Newer buildings may be less likely to have the sort of flat rooftop space typically needed for antenna mounting. Or that space may be utilised for the residents, making antennas an unwanted intrusion as well as potential complication with managing access for activities such as maintenance.

In Latin America, national governments have often seen their hands tied by local Government constitutional autonomy. There has been a common trend to establish overly strict set of rules at the local/municipal level that has been not proportional to the objectives they are trying to achieve, as well as complex and lengthy permit approval process, which limit the ability and increase the costs to deploy new sites. For example, the average permit approval process exceeds six months, and can reach to more than two years for certain counties or municipalities. Outdated regulations, discretionary processes, arbitrary requests and sometimes corruption are the most common problems characterising the municipal red tape in infrastructure deployment. For instance, according to the trade association Telebrasil, the city of Sao Paulo, has most recently had around 1,200 of new antennas' requests unresolved and takes usually more than a year to sort out authorizations, sometimes two years.[13]

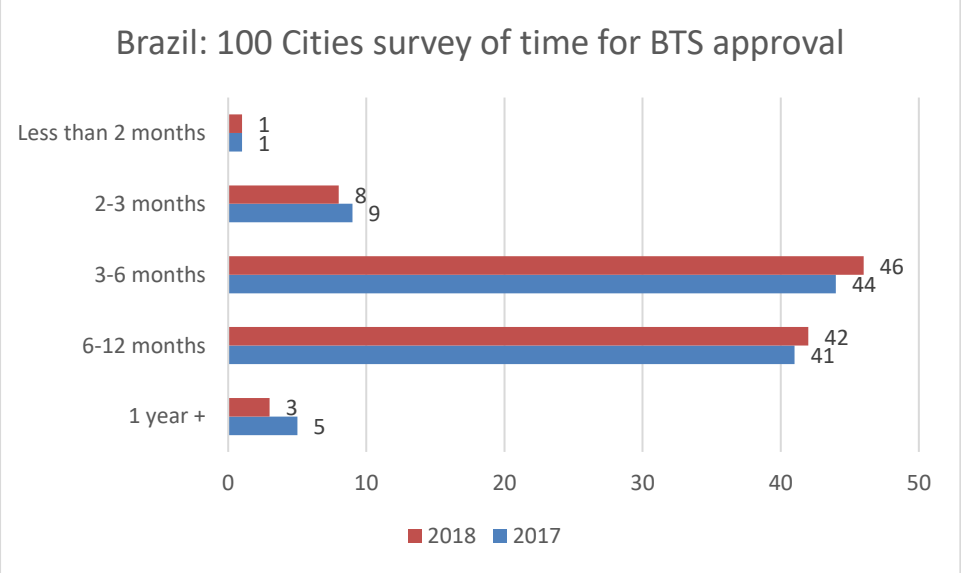

Figure 2-3 - Teleco "City Ranking of Friendly Cities" May 2018

Where there has been success, such as in Peru, this has been done through the passing of a bill that introduced a legal regime aimed at fostering private infrastructure investment, introducing an automatic approval at the municipal level if all legal requirements were met - a measure called "positive administrative silence".

[12] For example, the GSMA state that there is "a trend towards increasing delays in granting permissions. In ten EU Member States it still takes on average one year or more to receive all permits necessary to deploy a network antenna site." - https://www.gsma.com/publicpolicy/base-station-planning-permission-in-europe

[13] See http://www.telesintese.com.br/entidades-pressionam-por-volta-de-licenciamento-de-antenas-em-sp/

2.5 Problems with new outdoor small cells

Small cells are materially different from macrocells. By definition, they are not rooftop mounted. Instead, they tend to be deployed on the side of buildings or on street infrastructure such as lampposts and signage. Being deployed below the rooftops results in their coverage being restricted to the street that they are in (or multiple streets if deployed at a junction). This means many small cells are needed to provide the same coverage as a macrocell - 10x or more depending on the size of cell and need for complete coverage. However, typically, small cells are used only in specific areas where there is a high density of subscribers such as train stations, shopping malls, stadium and major tourist attractions.

Small cells need to be small physically. There is generally not space where they are mounted for a rack of equipment. Instead the preference is often for self-contained units that can be mounted, for example, on a lamppost with no additional racking needed at the base of the lamppost. This means they are often relatively low-capacity, being restricted to one or two frequency bands and a smaller number of carriers than macrocells.

The combination of localised coverage area and small capacity, means each small cell has relatively little value. Hence, for them to be economically viable they need to be very low cost both to buy and to install and operate. Anecdotally, the total through life cost of a small cell can be as much as 70-80% deployment and rental and only 20-30% equipment.

Despite predictions of dramatic growth in outdoor small cells dating back decades, actual growth has been much lower. For example, the Small Cell Forum, in their document 050.10.03 - Small Cell Status Report[14] - provide the following charts showing annual and total deployments, respectively:

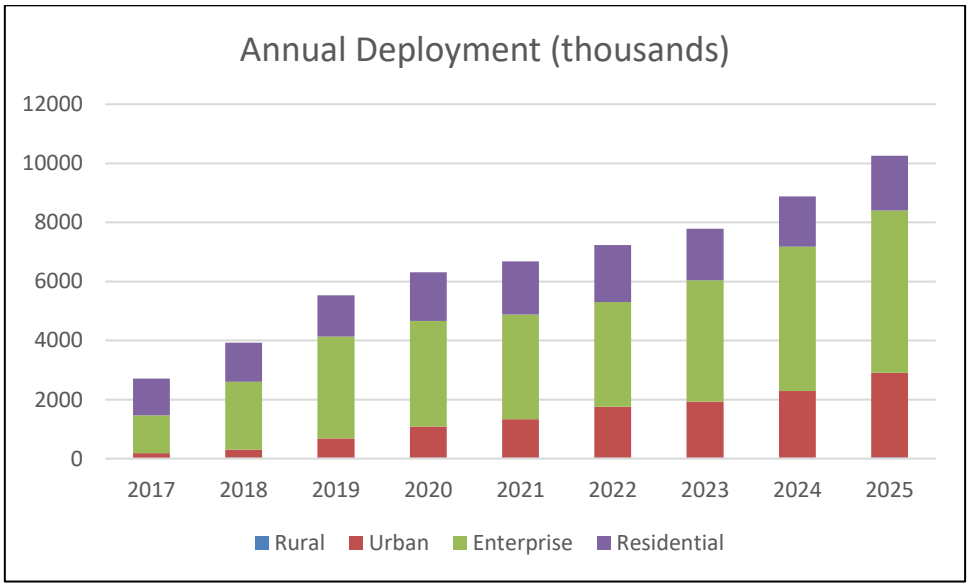

Figure 2-4 - Predicted annual deployments of small cells
Source : Small Cell Forum

[14] https://scf.io/en/documents/050_-_Small_cells_market_status_report_December_2018.php

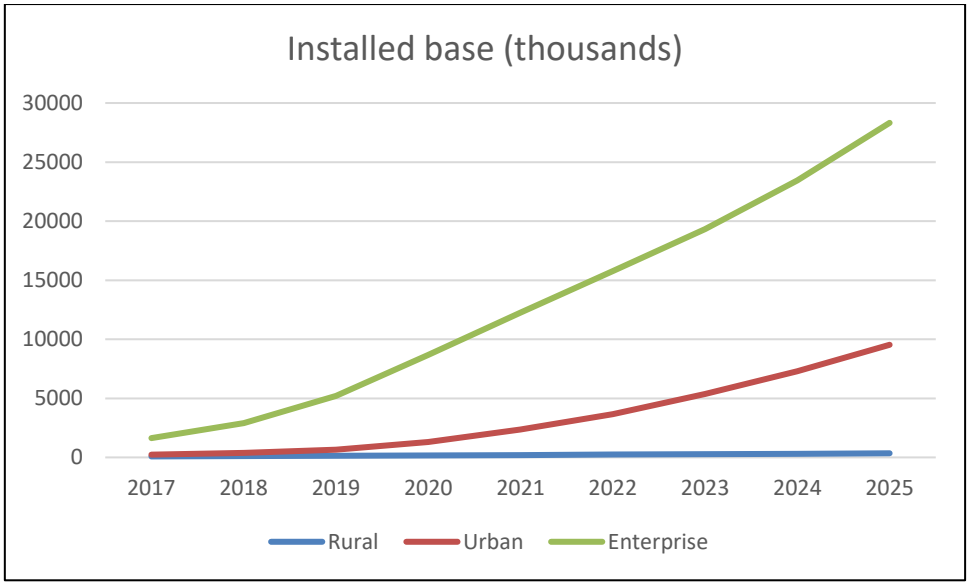

Figure 2-5 - Predicted total deployments of small cells
Source : Small Cell Forum

Here, it can be seen that the number of urban public small cells deployed recently is minimal.

The reasons for low deployment numbers are partly because operators have, up to now, been able to rely on macrocells as discussed above. Further, just like macrocells, site locations can be hard to find. Because of the low relative value, site rentals need to be very low, often below levels that landlords consider compensate them for any inconvenience. Access to street furniture is often difficult because it may be owned by local authorities and subject to various restrictions.

The SCF[15] have noted that:

> The most pressing challenges relate to the time and cost to deploy a small cell. For every cell, an MNO needs to gain site and equipment approvals; negotiate fees with the city or other landlord; deploy, provision and maintain the base station; ensure it has appropriate backhaul and power; and conform to the city's aesthetic and environmental regulations. All this can take up to two years per cell. Sprint has said it takes a day to deploy a small cell, but a year or more to get the permit, at a high cost for every individual site. That situation is clearly untenable in the era of large-scale densification.

The report states that the primary barriers to dense city networks are:

- Regulatory frameworks at national and local level are fragmented, preventing a scalable, cookie-cutter deployment process. This means that it can take many months, and even up to two years, to obtain approval to use a site.
- Local authorities can delay or forbid deployments for aesthetic, environmental or (often unsubstantiated) public health concerns but these rules are not consistent from city to city.

[15] See SCF 195 at https://scf.io/en/documents/195_-_Small_cell_siting_challenges_and_recommendations.php

- Fees for use of public infrastructure are inconsistent and sometimes so high that they break the business case for small cells in a particular city.

Small cell deployments, for the first time, mean that some of the key issues occur with local authorities rather than at a national level. This suggests that different approaches and incentives may be appropriate, which is discussed further in Section 4. Operators may also need to use a different approach, sharing poles, working sympathetically with the local authorities and minimising street cabinets[16].

Where used purely for capacity purposes, there is a limit to the number of outdoor small cells that is economically viable. This was explored in a paper by the author[17] which showed that because most of the mobile traffic was indoors, and that outdoor small cells tended to have poor in-building reach, any future enhanced mobile network must also have a strong indoor small cell deployment element or other way of delivering in-building capacity such as using self-deployed Wi-Fi. However, where small cells are deployed for other reasons, such as low-latency or to fill not-spots, higher numbers of small cells may be justified.

2.6 Problems with new indoor cells

From a technical point of view, deploying cells indoors is compelling. Estimates are that perhaps 80% of mobile traffic is generated indoors. Getting radio signal into a building from outside is difficult, with strength lost through the building fabric (often known as the building penetration loss). Conversely, indoor cells can provide excellent signal quality within the building and the building fabric partly insulates them from interference from outside, or from other indoor cells. Given the constraints on macrocells identified above, and the difficulty faced by small cells to provide good in-building signal, indoor cells will be increasingly critical. The SCF provide the following forecast showing how indoor small cells will dominate total deployments.

[16] See https://wade4wireless.com/2019/01/13/smart-cities-need-smart-permitting-processes-for-poles/ for a good discussion of the issues and some possible solutions.

[17] William Webb, (2018) "Modelling small cell deployments within a macrocell", Digital Policy, Regulation and Governance, Vol.20 Issue: 1, pp.14-22, https://doi.org/10.1108/DPRG-07-2017-0038

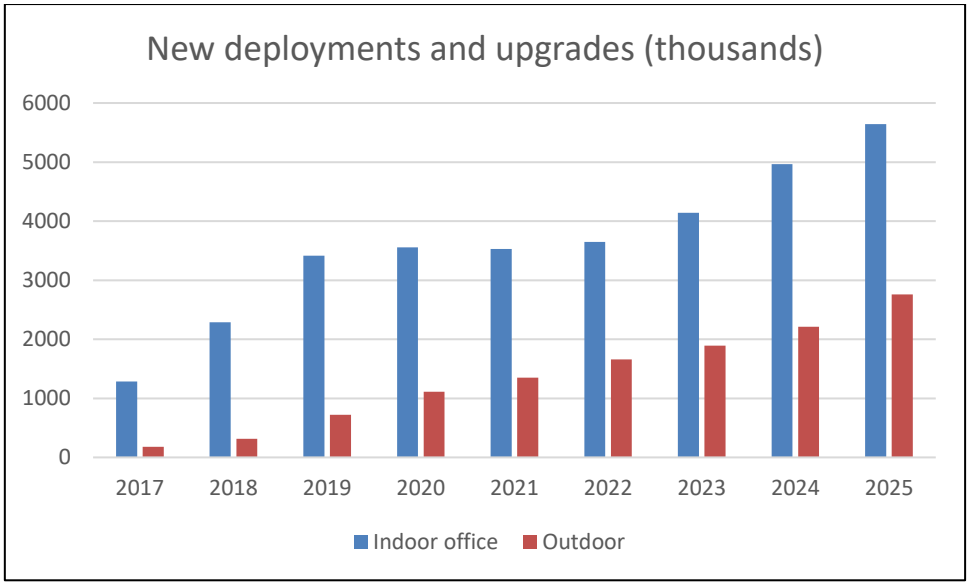

Figure 2-6 - Predicted total deployments of small cells
Source : Small Cell Forum SCF050-10-03

The problem for operators in delivering meaningful number of indoor small cells is logistical. In a country like the UK an operator might have 20,000 cell sites but there are more than 20 million buildings. While not all require an in-building solution, some require many cells. Deploying a 1,000-fold increase in cells is not logistically or commercially viable.

Indoor cellular solutions have also struggled due to the need for each operator to deploy their own base station. This both increases costs and is somewhat impractical in many buildings. Shared base stations tend to be problematic unless spectrum can be shared, or there is a common spectrum band for in-building use. These spectrum solutions have not generally existed to date, although concepts such as CBRS in the US might provide a way ahead from 2019. Space for equipment is generally problematic in buildings – Singapore have led the way here with legal requirements for building to provide equipment space for communications solutions.

2.7 Problems for shared deployment

Both outdoor and indoor small cells could become more viable with a shared deployment model. Such a model might be for operators to share sites more extensively than is common or might extend to a "neutral host" who builds a cell and then delivers capability to the mobile operator. Such sharing can be advantageous both financially and logistically. The SCF[18] predict that by 2025 around 50% of enterprise deployment of small cells and 20% of urban outdoor small cells will be neutral host.

Financially, shared networks obviously divide the cost of deployment and operations among the number of operators sharing the cells. This incentive has led to extensive network sharing across macrocells, but less so across small cells. This is not the place for a detailed discussion of sharing, but simplistically, macrocell sharing still allows operators to deploy their own electronics. This is difficult in small cells where there is often not the room for multiple electronic units, necessitating more

[18] SCF 050.10.03.

tightly coupled sharing (or alternative approaches such as cloud-RAN). This may not be allowed by regulatory rules, or may be difficult for operators that have different technical approaches to their networks.

Logistically, small cells may need to be shared. For example, lampposts provide an attractive platform for outdoor small cells given their height, regular spacing and typical single-entity ownership. It would be unsightly to have three or four operators all deploy antennas and equipment on each lamppost and it may not be structurally possible. A single, shared unit may be the only practical approach.

Such deep sharing would be an extension of current practice and may need new regulatory approaches to enable potentially including sharing of spectrum.

2.8 Summary

In this section we have discussed how mobile service is imperfect and that this can only be improved either with more capacity built into existing cells or through the deployment of new cells. However, both are problematic. Existing cells are reaching limits of practical antenna deployment and of maximum permitted exposure levels. New macrocells are hard to find now that the easy-to-deploy sites have all been taken. Small cells have challenges in their cost, the need for shared access, and the difficulty in finding sites. New shared access models would help in general, but are often prevented, or made problematic, by regulation.

Specific issues identified in this section are:

1. The key immediate need is the ability to modify current sites, particularly to add larger MIMO antennas.
2. Facilitating new macrocell sites through streamlining planning permission to remove bureaucracy and speed the process, access to Government buildings and greater rights over landlords.
3. Enabling outdoor small cells through better access to street infrastructure and reduced bureaucratic burdens.
4. Regulation facilitating deeper network sharing, where required.
5. Underlying these issues is the poor investment climate for operators with intense competition leading to below-average return on capital employed.

In the next section we discuss various national approaches around the world to resolving each of the issues identified in this section and we highlight best practice.

3 National approaches to enabling better mobile networks

3.1 Overview

This section considers approaches taken by a number of countries around the world and the lessons that can be learnt. It covers a range of countries across multiple continents looking at both successes and failures. That there are major differences can be seen from the chart below.

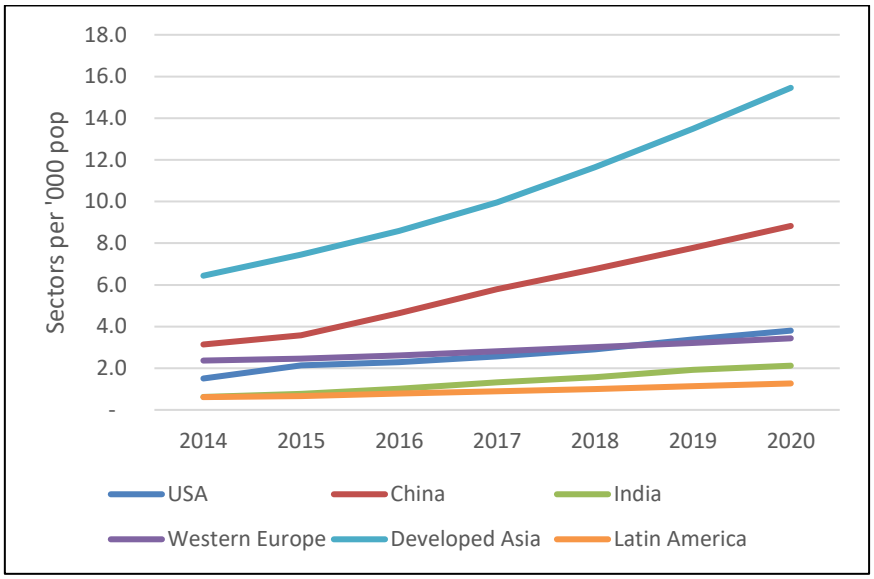

Figure 3-1 - Source : New Street Research, "Global Wireless Supply and Demand", 15 June 2017

This shows Latin America lagging, Western Europe and the US to have similar levels of deployed infrastructure per subscriber, but China to have approximately twice as much and Developed Asia (Japan, South Korea, Singapore and Hong Kong) almost twice as much again.

Figures from Deloitte are more striking. Their report[19] presents the data below.

[19] https://www2.deloitte.com/content/dam/Deloitte/us/Documents/technology-media-telecommunications/us-tmt-5g-deployment-imperative.pdf

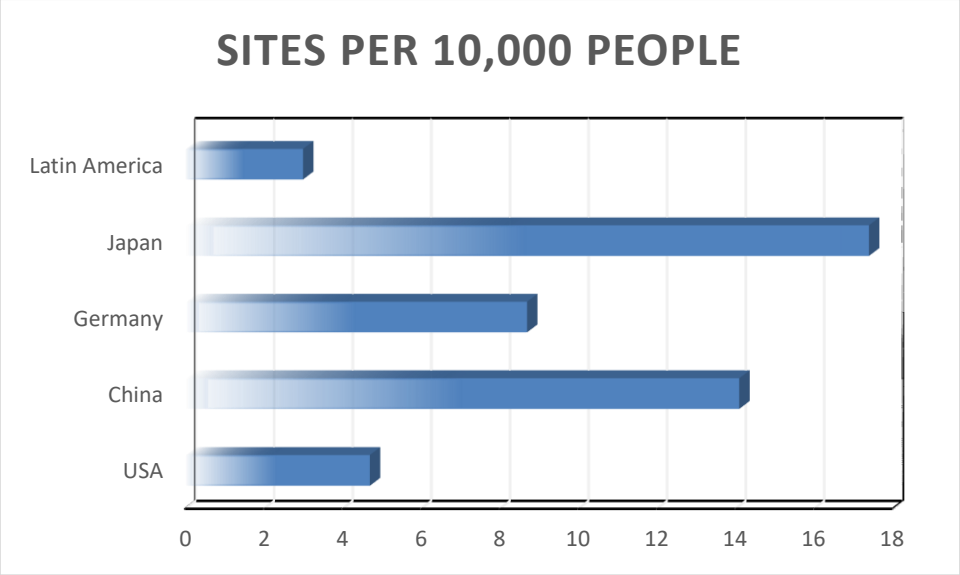

Figure 3-2 - Sites per 10,000 people in selected counties
Source: Deloitte, Ericsson

This suggests China has three times the level of deployed cells than the US on a per population basis. (On a square mile basis, the difference is even more striking with China having 10x the density of the US, but this may not be the best form of comparison as it depends on relative population density.)

This is predicted to continue, for example, the Small Cell Forum published the following forecast, based on research by Rethink Wireless.

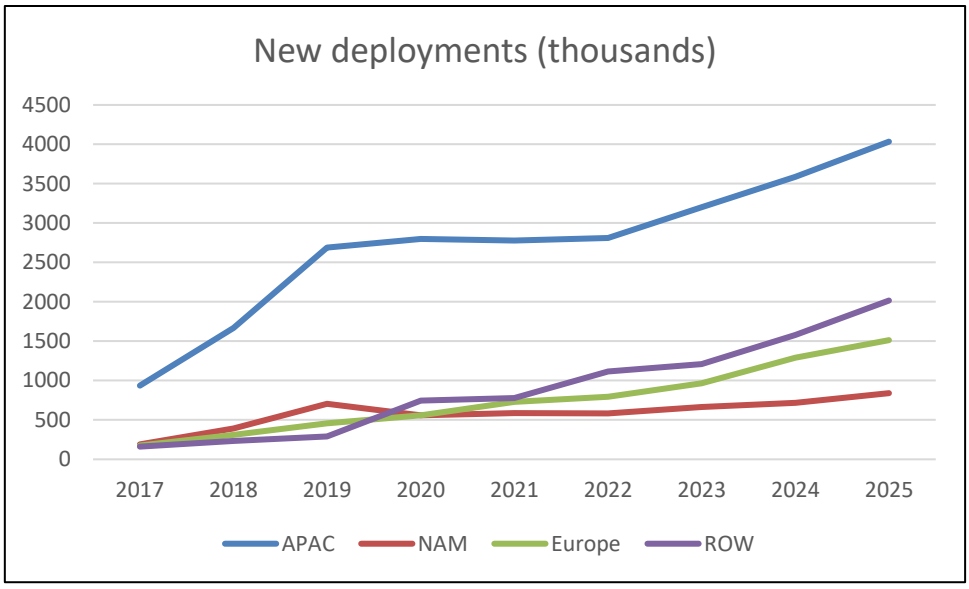

Figure 3-3 - New small cell deployments by region
Source : Small Cell Forum 216:10:01 - "SCF China Workshop" May 2018

This predicts that the majority of small cells in the next five years will be deployed in the Asia-Pacific region. If Europe could achieve the same sector density as China, or even better, Developed Asia, this would provide a huge improvement in capacity and coverage. Equally, if the status quo

continues then Europe will fall further behind major Asia-Pacific counties in terms of the reach and capacity of its mobile broadband network.

3.2 China

China has a significantly higher level of towers per subscriber than anywhere else in the world as shown below.

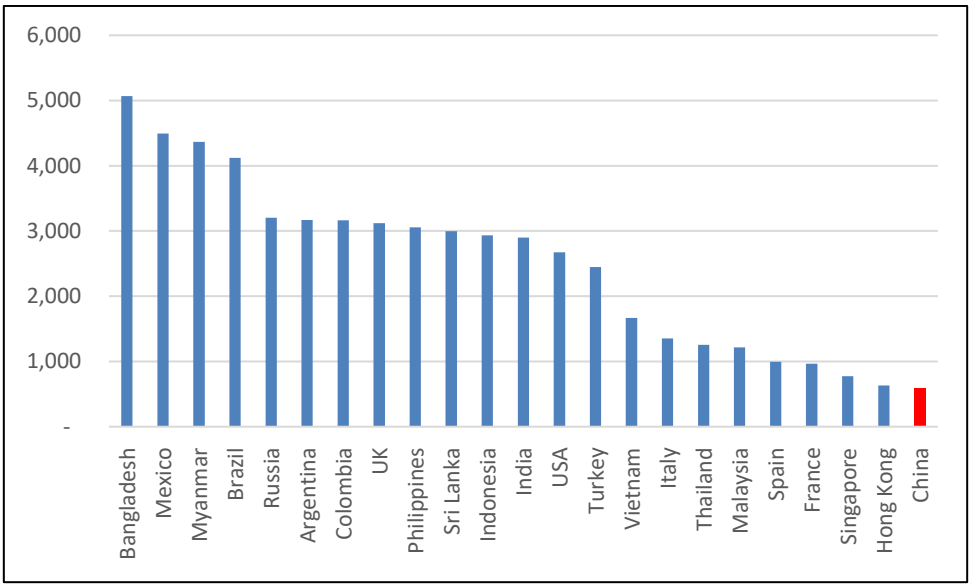

Figure 3-4 - Pops per tower (excluding small cells)
Source : New Street Research - "China Mobile" 21 May 2018

The reasons for such a high level of infrastructure deployment are not always clear but appear to be caused by (1) intense industrial policy pressure to deploy infrastructure and (2) extremely low unit costs for small cell deployment.

In terms of costs, New Street Research[20] suggest that the rental cost per lamppost or similar in China can be less than $10 per month, whereas it is typically $100 or more in the US (although see below for actions being taken to change this). Data is not available for Europe but the analysts suggest costs are likely to closer to the US. Backhaul costs per small cell are around $20-$30 per month for China but around $300 for the US and Europe. This is illustrated below.

[20] New Street Research, "5G Global Roadmaps", 21 November 2016

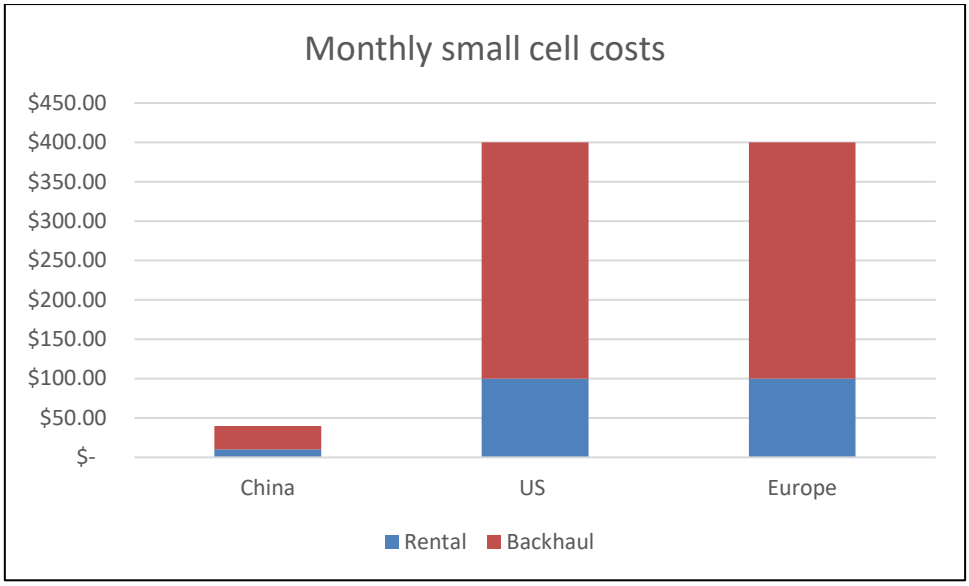

Figure 3-5 - Monthly small cell costs

Partly this is because Chinese operators have extensively built their own backhaul - an option that appears relatively low-cost in China perhaps due to low labour costs and lighter regulation around digging. Finally, the volumes of base stations purchased by Chinese may enable lower prices per base station.

To some degree, this appears to be a case of higher volumes (of sites, equipment, backhaul) leading to lower prices, in turn leading to higher volumes. It may be that China got to this position because it took a wrong turn in 3G, deploying TD-SCDMA in an effort to stimulate local vendors and avoid royalty payments to US suppliers. This proved to be a poor technology, requiring operators to deploy a large-scale Wi-Fi footprint to cope with traffic growth over several years. These Wi-Fi access points then provided a relatively easy upgrade path to TD-LTE, paving the way for large-scale small cell utilisation.

There are still difficulties. At a Small Cell Forum workshop, the following barriers were identified in China.

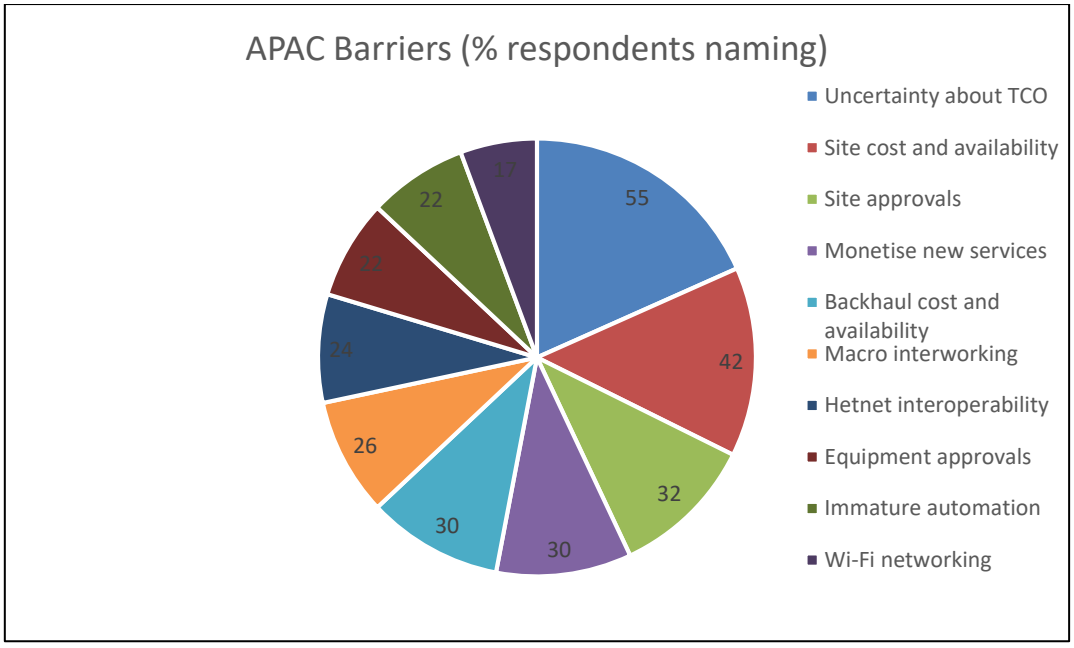

Figure 3-6 - Source : Small Cell Forum 216:10:01 - "SCF China Workshop" May 2018

Costs, including site costs and site approvals, are seen as major issues, suggesting the easier site options may be mostly used.

The lessons here are unclear. Certainly, if costs can be reduced then larger volumes of small cells will be deployed. Reducing site rental and backhaul costs clearly helps. But whether the low costs in China are due to policy choices, or to different market conditions, is hard to determine. Further, China is materially different from much of the rest of the world in terms of its industrial policy and the age of its cities. Nevertheless, it is clearly a country to watch. Considering the issues summarised in Section 2.8.

1. *Ability to modify current sites, particularly to add larger MIMO antennas*. It is unclear whether this is an issue in China.
2. *Facilitating new macrocell sites through access to Government buildings and greater rights over landlords*. There is no specific information on this, but the speed of build suggests that finding sites is not overly problematic at present.
3. *Enabling outdoor small cells through better access to street infrastructure and reduced bureaucratic burdens*. Access to infrastructure appears to be favourable and issues such as planning regulations do not seem to be constraining.
4. *Regulation facilitating neutral hosts and other new approaches to network deployment*. There does not appear to be a need for this at present in China given the density of cells already deployed.

3.3 US

The US is not a leader in small cells. As shown earlier, cell numbers in the US have been relatively stable over the last 4-5 years, and the US is only mid-ranking in terms of cells per subscriber. There is no clear consensus about why this is but it appears to be a mix of:

- A relatively plentiful supply of spectrum, provided in rapid and innovative ways by the FCC, enabling macrocells to keep up with demand.
- A relatively low data usage per subscriber resulting in networks being less stressed than other countries.
- Potentially, higher off-load to Wi-Fi than in other countries, perhaps due to a greater willingness to embrace Wi-Fi, although there is no evidence to substantiate this.

More cells, and especially small cells, are seen by some as important in the deployment of 5G, and this has resulted in the US looking for ways to encourage small cell deployment. Recently, the FCC has used two sections of the Communication Act that give it preemption authority[21] to remove what it perceives to be deployment barriers by speeding up access to utility poles - establishing a 60-day shot clock for small cell approval coupled with a cost recovery approach to fees.

The new FCC rules restrict local governments from taking more than 60 to 90 days to review applications and put more restrictions on the fees they can charge, including a cap equal to a "reasonable approximation" of the costs involved in the process. Cities are required to charge carriers no more than $270 per year per cell-site in access fees. Before the new policy, carriers could expect to pay $500 per pole annually, on average, according to an agency study[22]. Further developments such as the output from the FCC Broadband Deployment Advisory Committee (BDAC), Model Code for Municipalities Working Group[23] are discussed in more detail in Chapter 5 of the SCF Report 195. This suggests a varied picture across the US with some States actively working to reduce deployment barriers but others resisting change.

This is all helpful, but the impact is unclear given the varied nature of implementation and the focus on Governmental assets. The SCF believe it to be material and as a result forecast higher small cell growth in North America than most other regions.

A different policy pursued in the US is the Citizens Broadband Radio Service (CBRS) concept allowing shared access to spectrum in the 5G band at 3.5GHz. CBRS is a relatively complex scheme that provides, in principle, a way for building owners and occupants to self-deploy routers that are compatible with 5G handsets. It also allows operators to share, lease and explore flexible approaches to spectrum. The first CBRS deployments are expected in 2019. With its innovative culture the US might explore a range of approaches that CBRS enables including:

1. Self-deployment of 5G alongside Wi-Fi routers, leading to in-building service provided privately.
2. Neutral-host deployment by third party operators, providing a roaming-like service to mobile operators inside larger buildings.
3. More outdoor small cells from mobile operators due to the cheaper equipment (enabled by much greater economies of scale) and access to spectrum that does not compromise their macrocell usage.

[21] : Section 253 - "Removal of barriers to entry", and Section 332 (7) - "Preservation of local zoning authority"
[22] https://www.fcc.gov/sites/default/files/ad-hoc-commitee-survey-04242018.pdf
[23] https://www.fcc.gov/broadband-deployment-advisory-committee

Which of these approaches might transpire is unclear and indeed, all might find a place in various different situations.

It is too early to know whether the US can provide important lessons for others. However, the US has demonstrated that regulatory action can be used to try to facilitate cellular network deployment. Considering the issues summarised in Section 2.8.

1. *Ability to modify current sites, particularly to add larger MIMO antennas*. While there is no specific information on this, it is likely that this is problematic in the US.
2. *Facilitating new macrocell sites through access to Government buildings and greater rights over landlords*. There are some initiatives[24], but it is unclear whether they are effective.
3. *Enabling outdoor small cells through better access to street infrastructure and reduced bureaucratic burdens*. Recent US initiatives address this space well.
4. *Regulation facilitating neutral hosts and other new approaches to network deployment*. CBRS will be helpful and historically the US has been open to new business models.

3.4 Latin America

In Latin America, the federal structure of larger countries like Brazil, Mexico or Argentina has created a substantial obstacle: the high level of autonomy of local and regional authorities has resulted in a plethora of divergent regulations regarding infrastructure deployment and the use of land within the different jurisdictions. This creates barriers to entry for those who need to undertake construction, require use of land or rights of way permits for network deployment.

[24] See https://www.whitehouse.gov/presidential-actions/presidential-memorandum-secretary-interior/ and https://www.whitehouse.gov/presidential-actions/presidential-executive-order-streamlining-expediting-requests-locate-broadband-facilities-rural-america/

Existing Barriers for Infrastructure Deployment in Latin America

Administrative	Environment	Health	Technology
• Excessive information requests from multiple bodies • Lack of uniformity of regulations • Lack of any regulation or knowledge of any good practices. • Lack of defined process, times, extension of timelines. • Numerous public consultations • Informality and lack of continuity of local decision, corruption • Disproportionate fees • Lack of certainty and predictability, and due judicial processes.	• Minimum distance between antennas • Minimum exclusion zones • Land use restrictions • Establishment of special zones • Excessive camouflage measures • Air authority's approval • Prohibition over use conservation and cultural places • Prohibition to use rural areas aimed at preserving nature	• Lack of any regulation on non-ionizing radiation exposure. • Lack of any communication policy of existing regulations and international recommendations • Definition of limits deviating from national standards • Definition of different standards by zone • Multiple requests of impact studies for different local bodies • High frequency of reporting • Multiple instances for approval – federal, local regulations, often conflicting	• Prohibition of shared use • Mandated shared use. • Lack of differentiation between macro and small cells. • Definition of different fees and taxes by technology. • Double charging of licensing fees for shared sites • Spectrum tied to a specific technology, rather than mobile service

Figure 3-7 – Source: Analysis Masons/CAF

There have been numerous efforts in the region to tackle infrastructure deployment barriers, but with often insufficient results as discussed below.

- **Mexico:** Between 2012 and 2018, Mexican Federal Government made available access to 15,000 federal and state buildings and other passive infrastructure (ducts, towers, poles, and rights of way) through an electronic process and lowered its costs. It also gave access to 11 million electricity posts and masts, and co-ordinated the de-regulation of 84 municipal processes in the Hidalgo State that are now able to provide authorisations within 7 working days as well as eased the aeronautical authorization for approving the height of masts. However, the use of Federal buildings has not been easy and suffers significant delays.
- **Colombia:** Many of the 1,122 municipalities of Colombia have set their own regulations. In some cases, the regulations for deploying infrastructure have been so stringent that MNOs have been unable to deploy more sites which has created uneven coverage and service quality across different municipalities. As a consequence, the national government took several steps to standardise regulations for obtaining permits:
    - In 2009, the government created a law that obliges regional and local governments to take all necessary measures to facilitate the deployment of infrastructure.
    - In 2012, the Communications Regulations Commission (CRC) and the National Spectrum Agency (ANE) issued a set of guidelines that described best practices in visual integration, health and safety, and listed the requirements and processes for issuing new permits.
    - The National Development Plan 2014–2018 obliges municipalities to identify the barriers to deploy infrastructure and adopt measures to remove them.

- In 2015, the ICT ministry and attorney general's office issued a joint memorandum to remind municipalities of their legal duties to comply with the law on the National Development Plan 2014–2018.

Despite these efforts of the Colombian government progress has been slower than expected, with a limited number of municipalities adopting the recommendations. This lack of compliance suggests that the problem is not solely a lack of technical capacity at the local level, but that municipalities prefer autonomy.

- **Brazil**: In 2015, the Brazilian Government enacted a Federal law to update the rules on licensing of new sites, called the 'General Antenna Law', which can be classified as a progressive piece of legislation that, if enforced, would expedite investments in expanding mobile networks. At that point, more than 600 municipalities, typically the larger cities, out of a total of 5,570 in the country, had municipal laws with conflicting rules.

  Hundreds of cities across the country still have rules on minimum inter-site distances, restrictions on installing equipment and antenna close to hospitals, nursing homes and retiring homes, unduly onerous requirements in terms of studies and documents that need to be submitted and many other factors that impose dramatic barriers for network expansion and densification. A common problem is the time it takes for them to approved new installations - often years.

  Two of the most iconic cases are São Paulo, one of the largest cities in the world, and Brasilia, the capital of the country. These two cities have not had a single new site installed in more than two years and are still struggling to approve new municipal laws, compliant with the federal regulation, that dictates that only the national regulator ANATEL can regulate in matters of telecommunications, EMF and other technical aspects.

Some other approaches undertaken, both from public and private sector, are:

a. Providing public information of how cities are doing in terms of quality of service and friendliness to infrastructure deployment like "Friendly Antennas Campaign" of the Argentine regulator, ENACOM[25], or the "Ranking de Calidad Distrital" of OSIPTEL the regulator of Perú,[26] or the "Ranking of Friendly Cities" of Teleco a consulting firm of Brazil[27].
b. Enacting a National Development Plan that included backbone fibre rollouts, use of public and state-owned enterprises buildings (Colombia, Argentina, Brazil)
c. Issuing an infrastructure law (Perú, Brazil) trying to promote the 'positive silence principle' which promotes automatic authorizations after a certain period of time.
d. Mandating the use of public lands and Government buildings for deploying infrastructure (Mexico, Chile, Argentina, Brazil).

[25] https://www.enacom.gob.ar/antenasamigables
[26] https://sociedadtelecom.pe/ranking-calidad/
[27] http://www.teleco.com.br/cidades_amigas_BL.asp

The key lesson appears to be that achieving homogeneous regulatory practices across municipalities will require the central agencies to create incentives that generate high levels of voluntary compliance.

Considering the issues summarised in Section 2.8.

1. *Ability to modify current sites, particularly to add larger MIMO antennas*. This is not a big problem in Latam.
2. *Facilitating new macrocell sites through access to Government buildings and greater rights over landlords*. There are several initiatives as mentioned above, but it is unclear whether they have been effective as this process means dealing with another institution.
3. *Enabling outdoor small cells through better access to street infrastructure and reduced bureaucratic burdens*. No information, no special distinction to small cells
4. *Regulation facilitating neutral hosts and other new approaches to network deployment*. No particular initiatives.

3.5 Singapore

Singapore has a relatively high level of cellular infrastructure. This is likely due to the density of the population on the island and the prevalence of multi-dwelling and office buildings that merit in-building cellular solutions. The Government has also deployed an island-wide Wi-Fi solution for public access. In-building deployments have been assisted by innovative and very valuable regulations that require building owners to provide space and easy access for telecoms equipment.

However, operators have struggled to deploy more cells outdoors, especially small cells, often citing restrictive planning rules. The regulator, IMDA, recently published a consultation considering a review of the Code of Practice for Info-Communications Facilities in Buildings (COPIF)[28]. COPIF already provides rules and regulations that ease access for mobile operators, but the revisions propose extending these. In their responses to the consultation, the operators noted how the existing code of practice is not always adhered to and that building owners can often find other ways of blocking mobile access.

Singapore, at present, appears to be lacking a clear path to a denser deployment of small cells. Equally, it has concluded that 5G might not be deployed until 2020, and has not yet allocated key 5G frequencies. Mobile data growth rates in Singapore are relatively low – in the region 10%-20% a year – which may result in less pressure on operators to find more cell sites at present. Some national players are investigating the deployment of a single wholesale network for outdoor small-cell coverage.

It would appear that Singapore's high density of cells is likely predominantly due to the nature of the island, encouraging widespread in-building solutions. These tend to lead to a large number of cells per person, although each cell may have relatively less capacity. Favourable regulation promoting communications solutions has very likely helped operators with in-building and rooftop access.

[28] https://www.imda.gov.sg/regulations-licensing-and-consultations/consultations/consultation-papers/2017/public-consultation-on-the-review-of-the-copif

It is possible that a focus on in-building deployments including facilitating access to buildings, might help in other major cities, although, as discussed above, new approaches based on shared spectrum and self-deployment or neutral hosts, may make these codes of practice less important in the future. One point to note is the ability of building owners and others to often find ways around regulation that improve the situation for the mobile operator but almost invariable make it worse for the building owner as a result. As we will see in other countries, such regulation can have unintended consequences and while it appears a relatively simple thing for Governments to do, might not be a panacea. Considering the issues summarised in Section 2.8.

1. *Ability to modify current sites, particularly to add larger MIMO antennas*. Recent changes to code powers might help in this respect.
2. *Facilitating new macrocell sites through access to Government buildings and greater rights over landlords*. As above, it is not clear whether there is access to Government buildings but these may be less prevalent in Singapore.
3. *Enabling outdoor small cells through better access to street infrastructure and reduced bureaucratic burdens*. No clear initiatives.
4. *Regulation facilitating neutral hosts and other new approaches to network deployment*. The regulations that require buildings to provide space for telecommunications equipment are very helpful and might be considered elsewhere.

3.6 UK

Like much of Europe, the UK does not have a dense infrastructure. Cell site numbers appear relatively static. While operators have announced small cell deployments, these are typically only a few hundred cells, not materially changing overall deployment numbers. UK Governments have shown greatest concern with rural coverage, resulting in coverage obligations on one of the 4G licenses auctioned in 2012 and proposals for further obligations on 700MHz 5G licenses to be auctioned in coming years.

Efforts to improve access to city centre sites led to the Digital Economy Act 2017 which introduces, amongst other changes, a new Electronic Communications Code (the 'New Code'). This makes a number of legal changes in areas such as the security of tenure of leases, the right of operators who are on a site to share it with others without changing leasing fees, the right to upgrade equipment on site free of charge, the guarantee of lease terms being passed onto new owners and the value of the site to be based on its general usage, rather than specific telecoms usage.

While these changes have been welcomed by operators, the changes are more concerned with better access to existing sites rather than facilitating access to new sites. Because they tend to reduce the rental received by the owner, or otherwise make leasing less attractive, there is some evidence that sites are being withdrawn from the market and site negotiations have “ground to a halt” as a result[29]. Hence, the potentially unintended consequences of the code might be making site access worse in the longer term.

[29] https://www.mobileeurope.co.uk/press-wire/uk-s-electronic-communications-code-signals-failure-all-round

As part of a wider review of telecommunications, first by the National Infrastructure Committee[30] and then DCMS[31], the Government decided to establish a "barrier busting taskforce" to help remove barriers to the deployment of fixed and mobile telecoms infrastructure. This is a department within Government established to undertake initiatives such as:

- The Street Works Toolkit - a best practice guidance for local authorities and others around issues related to digging streets and similar - predominantly related to fibre deployment.
- A set of Local Connectivity Groups, bringing together local councils, Ofcom, landowners and industry stakeholders to encourage local authorities to develop holistic pictures and plans.
- Guidance for those building new homes and offices on connectivity.
- Helping with access to duct and poles, especially where owners are blocking access.

The majority of these initiatives relate to fibre build, although this may help provide better backhaul for mobile cells. While set up with good intentions, the group appears relatively small and has limited effect to date. The idea of the local connectivity groups appears to have changed to publishing a best-practice guide and the group's activities are focused on "best practice" publication and identification of problematic legislation. While best-practice guidance is well-intentioned, it is unlikely to overcome barriers.

The lack of tangible success may, partly, be because Civil Servants often do not make good barrier busters, and that they are not strongly incentivised on a results basis. There have also been some initiatives at a company level, for example BT have proposed[32] that access to critical street infrastructure should not be franchised to one entity but should remain open for all, and have even offered to open access to franchises they hold.

Hence, although the UK appears to have been active in promoting 5G and the deployment of more cells, in practice, the effects of the activity are likely to be minimal and may even be counter-productive in some situations. Considering the issues summarised in Section 2.8.

1. *Ability to modify current sites, particularly to add larger MIMO antennas*. The new code is helpful in this respect.
2. *Facilitating new macrocell sites through access to Government buildings and greater rights over landlords*. While the UK recognised the problem, there does not appear to be any material improvement in the situation.
3. *Enabling outdoor small cells through better access to street infrastructure and reduced bureaucratic burdens*. No specific regulation, although various "barrier busting" activities aim to provide guidance.
4. *Regulation facilitating neutral hosts and other new approaches to network deployment*. Nothing specific although some publications and research activities are looking into this.

3.7 France

France has had a long tradition of concentrating on improving rural coverage. Previous regulation requiring national roaming (between national operators) in rural towns and villages. More recently,

[30] https://www.nic.org.uk/wp-content/uploads/Connected-Future-Report.pdf
[31] https://www.gov.uk/government/publications/future-telecoms-infrastructure-review
[32] http://telecoms.com/496456/bt-pleads-for-open-access-to-street-furniture/

the regulator, ARCEP, decided that rather than re-auctioning mobile spectrum where the licence was due to expire, it would, instead, allow operators to retain the spectrum in return for new rollout obligations for operators that were unprecedented in their ambition. Each operator will deploy at least 5,000 new cell sites across the country, some of which will be shared. Government authorities will work closely with local authorities to identify the areas that need to be covered.

There is also an agreement to accelerate the coverage of transportation routes, so that all of the major roads and even regional railways have 4G coverage. Ubiquitous indoor telephone coverage is also targeted, notably by using voice over Wi-Fi.

France has also mandated national roaming in some cases such as in villages where coverage has been delivered as part of a licence obligation. This could potentially be expanded, for example to small cell networks, and might be an important precursor to various forms of neutral host network.

Essentially, France has decided to subsidise rural coverage, albeit indirectly by forgoing auction revenue rather than direct payments. However, the ability to share sites, to use Wi-Fi for voice and to work more closely with Government might also bring benefits to cities.

Perhaps most importantly, it is the willingness of the regulator to consider different approaches that suggests that France might provide leadership within Europe. Considering the issues summarised in Section 2.8.

1. *Ability to modify current sites, particularly to add larger MIMO antennas*. No specific information available.
2. *Facilitating new macrocell sites through access to Government buildings and greater rights over landlords*. No specific information available.
3. *Enabling outdoor small cells through better access to street infrastructure and reduced bureaucratic burdens*. No specific information available.
4. *Regulation facilitating neutral hosts and other new approaches to network deployment*. No specific information available.

3.8 Korea

Korea is well known for being one of the best-connected countries in the world. Most obvious has been in its rapid deployment of fibre connectivity, but its mobile networks are also some of the most advanced.

Some of the reasons for this are similar to Singapore – a developed nation with a dense population, a high percentage of high-rise and multi-dwelling units and a strong industrial policy element driving infrastructure deployment. For example, the 1987 “Framework Act on Informatization Promotion” established a high priority national broadband deployment plan. The goal of the Act was to “improve the quality of life for the nation and to contribute to the development of the national economy, thereby promoting the informatization and laying the foundation for the information and communications industry and achieving the advanced information and communications industry infrastructure.” That same year, the Korean government started digitising national data in important areas, such as resident registration, real-estate registration, and finance, as part of its efforts to lay the groundwork for a digital economy at the national level.

The high penetration of fibre and the appetite for broadband connectivity that this brought helped with the deployment of mobile communications.

The influence of the chaebols, massive investments in R&D and the collaboration of the public and private sectors also created a favourable climate for the rapid development of mobile telephony in Korea. Koreans are early adopters and tech-savvy consumers, particularly receptive to new technologies. The widespread availability of Wi-Fi also ensured a ready availability of sites and backhaul for dense cell deployment.

It has not all been success – Korea deployed its own technology, a version of WiMax called WiBro (Wireless Broadband) which did not succeed and was replaced by 4G networks. Since then, it has adopted and influenced global standards. It remains keen to be at the forefront of technology as evidenced by its desire to implement the first 5G network at its 2018 Winter Olympics, although this was not particularly successful, being seen as too early for any real subscriber engagement.

Broadly, Korea appears to have succeeded due to a mix of demographics, culture, national champions and a dense fibre network forming a firm basis for a dense wireless network deployment. Considering the issues summarised in Section 2.8.

1. *Ability to modify current sites, particularly to add larger MIMO antennas*. No specific information but macrocell sites may be less important given density of infrastructure.
2. *Facilitating new macrocell sites through access to Government buildings and greater rights over landlords*. As above.
3. *Enabling outdoor small cells through better access to street infrastructure and reduced bureaucratic burdens*. No specific information but barriers appear low given the density of deployment.
4. *Regulation facilitating neutral hosts and other new approaches to network deployment*. No specific information available.

3.9 Austria

Austria has set out its desire to be a 5G leader and has listed six principles to achieve this:

- Investment-friendly climate for new technologies
- Nationwide availability of fibre infrastructure
- Significant amount of new spectrum
- Accelerated demand for digital technologies and applications
- New digital value chains and business models
- 5G-compatible network elements and user devices

Most of these are somewhat vague at present, but the Government has set out a desire to make cell deployment simpler. This allows:

1. Free access to public assets such as streets in order to lay cable and install small antennas. Larger antennas and masts require a contract.
2. Similar levels of access to assets owned by local authorities or any associated entities.
3. Access to private land to lay cable, but compensation must be paid and access is time-limited.

These ideas should help especially with the deployment of small cells in cities, and somewhat with the deployment of larger cells.

3.10 Summary

In summary:

- In China the large number of cells is partly an accident of history - but suggests that there may be a need to lower costs in order to trigger larger volumes which then leads to even lower costs.
- The US is not a leader in cell deployment, but it is innovative, and new ideas may emerge. It is trying to push down some of the costs and delays of deployment, especially for small cells leading to over $2bn in savings[33].
- Latin America has been struggling to sort out inherent difficulties for basic deployment with municipal autonomy and is searching at a central level for a way to discipline local governments and create incentives so as not to become blocks to national digitization plans.
- Singapore was a leader and a favourable planning regime may have helped, but it is unclear where it goes from here - perhaps it needs to be more innovative now?
- The UK is struggling with a highly competitive market and low prices. Various efforts to ease planning and barriers have been welcomed but may have unintended consequences or might just be too little too late.
- France is being innovative in rural coverage and showing a willingness to consider new approaches which might also bring benefits in urban areas.
- Korea has led in fibre and mobile partly due to industrial policy, partly due to a strong local manufacturing base and partly due to dense cities. The presence of dense fibre has helped facilitate dense mobile networks.

There is no clear panacea which results in better mobile deployment – if it were that simple then other countries would have realised and implemented the solution already. Also, every country is different, with different demographics, different culture, different politics and government, and different ages of cities and buildings.

Those countries with relatively new cities, built in recent decades (China, Korea, Singapore) often benefit from good fibre availability. They may also have more uniform and readily accessed street furniture. Finally, planning restrictions may be less, because buildings are not considered historic. Europe is generally the opposite, with historic cities where fibre availability is inconsistent and cannot be guaranteed.

There may be a chicken-and-egg effect where numerous small cells are needed to drive access and drive down prices, but until this can happen prices are too high and logistics too burdensome to allow numerous cells to be deployed. China appeared to get around this by accident through the need to deploy a large number of Wi-Fi nodes during the 3G era. Singapore and Korea also have a large Wi-Fi deployment which likely helped.

[33] https://www.fcc.gov/document/economists-carrs-5g-order-saves-2b-stimulates-24b-investment

Conversely, most European and Latin American initiatives to date have had limited effect. Many countries have concentrated more on rural access, with limited impact on urban areas. Barrier busting groups have yet to deliver significant improvements and may be insufficiently resourced. Changes to site access and rental regulations have been welcomed but may actually reduce the number of sites available if landlords feel that the regulations result in increased burdens upon them or reduce the rental potential.

Clearly Europe and Latin American cannot simply take the "Chinese approach" – it would not work in the different environment. However, the case studies suggest that realistic policies that Europe and Latin American might helpfully adopt include:

1. Facilitate quicker and lower-cost macro cell roll out by removing barriers such as planning approval, giving operators more rights over landlords and addressing other concerns.
2. Ensure very low prices for access to cell sites, especially small cells. The US has recently moved in this direction. It is practical where the sites are Government-owned, but may be harder where they are commercial.
3. Enable widespread fibre deployment. Initiatives to help can include duct-and-pole access, street works guidance and regulatory policy.
4. Facilitate lower-cost small cell equipment perhaps through harmonising form-factor requirements which all countries can agree that meet planning requirements.
5. Provide a framework that encourages innovation including from new entrants and new technologies. Even where new ideas fail, their legacy can be helpful.
6. Follow international standards on EMF regulation and exclusion zones.

These ideas are developed further in the next section, along with other approaches that might benefit Europe, leading to recommendations for regulators and others.

4 Recommendations for regulators, governments and others

4.1 Introduction

The previous sections have laid out the issues with extending the reach and capacity of mobile networks, the need for more capacity on existing cells and for more cells, and the difficulties in realising this. They have looked at initiatives taken by various countries in order to understand national best practice. This section makes recommendations based on this analysis that could deliver better mobile networks. Note that these recommendations would facilitate the deployment of additional mobile sites but should not be taken as a way to increase obligations on mobile operators to deploy more coverage or capacity.

4.2 The need for flexibility and innovation

As mentioned in Section 2.2, the optimal solution to deliver perfect mobile connectivity is not clear, is likely to vary from situation to situation, and will change over time. It might include various mixes of enhanced macrocells, outdoor small cells, indoor small cells, Wi-Fi, self-provision, neutral host networks, increased sharing and changed regulation. In the short-term enhancing existing sites is the most important issue, but this will tend towards new sites in the medium term. All of this suggests that prescriptive approaches to the best architecture and technology for future networks carry a high risk of failure. Equally, approaches that simply aim to allow the market to determine the best outcome risk failing because of regulatory barriers and externalities that have often prevented good market-based outcomes.

Waiting for the best approach to emerge in another country and then copying it, may not work. China has a strong leadership in cellular infrastructure but this appears to be for reasons that are country-specific and would be hard to copy elsewhere.

This suggests that regulation which sets out clear coverage and societal objectives then encourages innovation, allows many different approaches to be trialled and facilitates the growth of those that look most promising might be most likely to succeed, especially in a free-market European environment. It also suggests that regulators should take aim at the barriers that increase the cost and complexity of site upgrades and new site approvals.

4.3 Enhancing existing sites

Initial 5G deployments are likely to focus on adding 5G carriers and antennas to existing macrocell sites, particularly those in dense urban areas. These enhancements face two key problems:

1. Difficultly in mounting additional, relatively large, antennas, often exacerbated by regulation or landlord restrictions.
2. The potential for existing legislation on human exposure-limits to cause undue restrictions due to taking theoretical maximum, rather than realistic average, exposure levels.

These issues can be addressed by enhanced codes of access, such as those developed in the UK[34], and by updating human exposure guidance, perhaps at a multi-national level. In rural areas, enabling taller masts and higher transmit powers would help improve rural coverage.

4.4 New site access

Mobile networks need sites for base stations. All possible future network scenarios require more sites and yet sites are increasingly hard to find, procure and implement. Where regulators intervene, it is often to assist in site access. Intervening in commercial arrangements carries some risk as it may result in those owning the sites withdrawing from the marketplace. However, there are clear benefit in making access to public-sector assets easier. This includes:

- Simple access to street furniture such as lampposts and street signage. As well as cheap and easy ways to find and procure sites, matters might also be improved with a commercially-facing entity that can pre-approve site access and sell quick access to street furniture such as lampposts.
- Improved access to Government buildings and land, with departments established whose success measures are the number of sites they manage to provide access to.

More generally, all sites need backhaul and facilitating more widespread communications capability helps in this process. Initiatives that encourage more fibre deployment in cities are welcome, such as duct access, and approaches such as the UK's Street Works guidelines.

For smaller cells, planning rules might be relaxed, especially where the footprint is minimal.

Where problems do occur, "barrier busting" teams might be able to help, so long as they are appropriately resourced and incentivised.

4.5 New models of infrastructure build and ownership

It is possible that the best way to deploy small cells will be through a different build and ownership model where sites, equipment and even spectrum is shared. This seems highly likely to be the case for indoor small cells, quite likely for outdoor small cells, but unlikely for macrocells.

Such models raise questions about single wireless infrastructures and monopoly supply of network, albeit in specific, restricted areas, both geographically and functionally. Regulators should review all relevant aspects of regulation to understand whether there are any barriers, intended or unintended, that would prevent the emergence of neutral host networks or other similar models.

Small cell models might also be facilitated by the encouragement of Wi-Fi - for example, we saw how in China this might have helped move to a wider-scale small cell deployment model. Governments could make their own Wi-Fi resources such as Eduroam and GovRoam publicly available as a complement for mobile networks in selected hot-spots - indeed this is already happening in places like the Hague[35]. They might then go a step further with tenders to allow a single provider to co-locate cellular transmitters alongside (or within) the Wi-Fi routers.

[34] See https://www.ofcom.org.uk/phones-telecoms-and-internet/information-for-industry/policy/electronic-comm-code for an introduction to this regulation.
[35] https://wifinowevents.com/news-and-blog/city-of-the-hague-netherlands-launches-secure-publicroam-free-wi-fi-service/

Neutral hosts and Wi-Fi access might benefit from different commercial models, with perhaps various forms of MVNO emerging to offer a service consolidated across different networks (eg along the lines of Google-Fi, offered in the US). Regulators might consider ways to make MVNOs more attractive to operators, perhaps by allowing more collaboration between them if there is a vibrant MVNO retail marketplace.

There may also be a role for commercially agreed forms of national roaming, perhaps on a limited basis or in specific cases, to facilitate models of this sort. National roaming has typically proven unpalatable to operators in the past, but when applied to specific cases that facilitate operator objectives it might be seen as advantageous.

4.6 Affording operators the same rights as utilities

In many countries utilities have particular rights in areas such as part-closing roads, digging trenches, gaining access to private and Government land (eg to lay cable or install cabinets or equipment) and similar. For example, in the UK utilities have certain rights to close roads as follows[36]:

> When carrying out work in the public highway permission has to be given in the form of a road opening notice issued by the local authority. Each authority has its own application procedure and these usually require at least 10 days' notice, although large projects, or busy roads, can take several months. Utilities can obtain these direct from local authorities but others usually need to make a written application and pay fees in the region of £100 for domestic properties and £300 for commercial.

An unpublished report from Deloitte, commented on in the trade press[37], said that rents on mobile phone masts should drop dramatically, with a pricing model loosely based on that used for utilities, where a mobile network pays £7,500 yearly in rent for sites in rural areas, and £9,200 in urban areas, water and energy companies would pay £270 and £280 for the equivalent amount of land and time-scale. In the US it is suggested that the approach discussed earlier of removing deployment barriers by speeding up access to utility poles, establishing a 60-day shot clock for small cell approval and adopting a cost recovery approach to fees could save $2 billion and stimulate incremental investment of $2.4 billion.

Most regulators do not consider mobile operators to be utilities. The definition of a public utility is often taken to be something along the lines of[38]:

> Public utilities (just "utilities" in British English) are typically defined as companies that supply what are considered basic (essential) services to homes and businesses, such as electricity, gas, waste disposal, water and sewer connections, where competition is very limited.

Mobile operators typically do not deliver services to homes (although this could change with 5G and related technologies) and often operate in a market where competition is significant. Until now, they have not been considered as utilities. However, mobile broadband is becoming seen as an essential service, and competition is lessening as networks are shared. As discussed above, there are

[36] http://www.utilityserve.co.uk/road_opening_notices.php
[37] https://www.theregister.co.uk/2015/03/24/mobile_operators_treated_as_utilities_not_spots_uk_ofcom/
[38] https://en.wikipedia.org/wiki/Category:Public_utilities

arguments for single neutral hosted networks in cities, and possibly elsewhere, where there might no longer be competition. Hence, there is a growing argument that mobile should be treated in a similar manner to other utilities in their ability to perform street works, have access to land, pay reasonable rental fees and so on.

4.7 European or national level?

The recommendations set out above have all been aimed at a national level. In Europe, some regulation relevant to telecommunications is also set at a multi-national level by the European Commission (EC). It is unclear that there is any particular benefit in such multi-national regulation in this case. Much of the change needed is country-specific and dependent on many unique factors, such as access to street furniture.

The EC themselves set out some ideas in a publication by COCOM[39] entitled “Report on the exchange of Best Practices concerning national broadband strategies and 5G "path-to-deployment". It recommended that countries:

- Accelerate the work on small cells by relevant policy advisory and expert groups in order to address at least the main obstacles, including a more coherent approach to EMF limits.
- Establish an overview of national approaches for protection against non-ionising radiation – these include calculation methods and measurement tools, information for the general public and awareness campaigns.
- Identify best approaches to promote access to public property as a strategic policy initiative to facilitate the installation of small cells (e.g. on lamp posts).

As can be seen, these focus on the issues surrounding human exposure limits, which the report sees as problematic. The concepts are all laudable, but as noted elsewhere in this report, “best practice” documents and weakly worded recommendations rarely have much impact.

There is also an EC initiative associated with small cells[40]. Termed the “Light deployment regime for small-area wireless access points”, at the time of writing it was seeking input, and set out its purpose as:

> […] reducing the time and the administrative burden currently associated with the deployment of small cells. The Commission will propose, in this context, an implementing act which will specify the physical and technical characteristics, such as the maximum size, weight, and where appropriate emission power of the small cells that will benefit from the exemption. The Commission's proposal for an implementing act has to respect the policy objective of EECC Article 57 to prevent the undue restriction of small cells deployment, while taking due account of potential impacts of such a simplified deployment regime. These include environmental and health and safety issues, to the extent, if at all, that they cannot be

[39] https://circabc.europa.eu/d/d/workspace/SpacesStore/17577264-2b13-49a0-8b83-823f6694e386/COCOM18-06REV-2%205G%20WG%20Report%20Best%20Practices%205G%20National%20Roadmaps.pdf
[40] https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2018-5660684

adequately protected by rules of general application to which operators of small cells covered by the implementing measure would remain subject.

This appears a useful, specific, activity which might help deliver economies of scale in small cells as well as providing national administrations with detail they can use to reduce restrictions on deployment.

At the time of writing, bodies like the GSMA were collecting input from around Europe to help the EC develop this initiative. This was showing a very mixed picture in small cell deployment, with some countries such as Italy having a regime that allowed for rapid deployment without any permissions needed, while other countries had no regimes that facilitated small cell deployment. The length of time to get permission varies from one to six months where there are initiatives and likely longer in other cases. Publishing the regulatory activity in each country and highlighting best-practice could be an important spur for those countries that have yet to consider this space. However, such initiatives tend to take many years, and ways of delivering outcomes faster might be considered, perhaps in the form of initial findings which would allow countries to start developing their own legislation while final conclusions become firmer.

The EC could play a useful role in publishing information as to the relative "mobile friendliness" of different countries or cities. This is already done for Nordic countries[41] where useful insights as to how cities can perform better are drawn out, and the best and worst performing cities identified. Extending this across Europe would provide valuable data to allow cities and countries to learn from others and would bring an element of naming-and-shaming which could be powerful.

4.8 Local level incentives

Particularly for small outdoor cells, key barriers and enablers occur at a local level – often a city, town or local authority region. For example, cities often control access to street infrastructure, provide permissions for street works and grant planning permission. To date, the responses of cities has been varied, with some being keen to promote themselves as testbeds for the latest technology (often 5G) while others have aimed for revenue maximisation, or for associated policy objectives such as coverage or disadvantaged areas alongside city centres. Operators have noted that they are unable to roll out small cells everywhere simultaneously and so will prioritise their deployments[42], deploying first in those cities with favourable environments.

This suggests that public information on local authority policy as it relates to mobile deployment might be appropriate. This would allow residents in a city or region to understand when policies were hindering deployment, and if they felt this was undesirable, to pressure the politicians or civil servants involved. For example, the operators in a country might collectively publish a list of those areas where they would normally deploy rapidly, but because of local issues the deployment had been delayed. This clearly cannot be led by Government, but central Government might support and publicise any initiative. Collective publication from the operators might prevent "gaming" by one

41 http://groenitblog.itb.dk/sites/default/files/20161031%20NBCI%20Report%202016%20v1.0%20%28002%29.pdf

42 See, for example, https://www.verizon.com/about/our-company/fourth-industrial-revolution/forthcoming-competition-between-cities-over-wireless-technology

operator or any disclosure of commercially sensitive deployment plans. The national operators could take the lead, or an industry body such as the GSMA might develop a framework that could be used in each country.

4.9 GSMA recommendations

In a report on rural deployments[43], the GSMA helpfully set out their recommendations related to ways to facilitate rural connectivity as follows:

Central authorities

- Provide standardised national procedures for antenna permits.
- Define a simplified process for modifications to existing sites, site sharing and co-location, and small cells.
- Define national notification and consultation requirements.
- Define national requirements to assure compliance with relevant health and safety regulations andseparate health and safety compliance from town planning.
- Provide an independent appeal process.
- Provide national guidance on visual integration for infrastructure.
- Provide consistent content for public information materials on health and safety considerations of mobile network antennas.
- Prohibit the unfounded imposition of zones that exclude mobile network antenna sites.
- Facilitate access to land and infrastructure (public buildings, electricity, backhaul, and backbone) for MNOs.
- Pursue mapping initiatives of relevant infrastructure and make this data available through a single information point.
- Imposing a general obligation to make advance notifications of planned civil works.

Local authorities

- Implement efficient processes for handling construction permits for mobile network antenna sites, consistent with the national framework.
- Defer to national agencies on expertise, policies, and technical requirements.
- Follow national health and safety policies for approving permits.
- Where community members express concern, support local engagement between stakeholders.

They also provided a case study for Colombia where they noted that the many thousands of local municipalities had varying rules and regulations. Attempts to provide national guidance and best practice had not been successful though:

> Despite the goodwill of central agencies, progress has been slower than expected, with a limited number of municipalities that have adopted the recommendations and complied with these laws. This lack of compliance suggests that the problem is not solely a lack of technical capacity at the local level, but that municipalities lack incentives to comply with the regulations.

[43] https://www.gsma.com/mobilefordevelopment/resources/enabling-rural-coverage-report/

5 Recommendations by entity

5.1 Introduction

This section takes the discussion of the previous section and develops specific recommendations by particular entity, such as regulators and Governments.

5.2 EC

- Publish guidelines on small cell form factor and planning regulations.
- Publish guidance on interpretation of human exposure-related issues.
- On an annual basis consult with the mobile industry as to whether there are other areas that could benefit from EC involvement.

5.3 Government

- Encouragement of innovation in both technology and business model.
    - Publish a "Digital Strategy" setting out the aspirations of the country for digital services and the ways these might be delivered.
    - Publish discussion document on future mobile networks, detailing Government thinking on overall market structure and covering concepts such as neutral hosts, shared spectrum, single wireless networks in selected areas, self-deployed mobile solutions, etc.
    - Set aside funds for research into innovative new ideas.
- Regulation to improve access to sites, giving operators more control over landlords and reducing bureaucracy and cost.
    - Where appropriate provide national regulation to apply at regional and local levels, with legal and political incentives to encourage implementation including standardised fees for access to public facilities, one-stop shop provision of all necessary regulatory processes and maximum time limits for permits to be granted.
    - Consider publishing regulation such as the UK's new code.
    - Establish a barrier busting team to act as a gateway for input, a resource to address issues and a permanent centre of expertise in best practice.
- Access to Government land and buildings for site deployment.
    - Provide a centre for data on Government buildings, pricing policy and enquiries about availability.
    - Regularly publish metrics such as requests received versus requests approved.
    - Conduct an annual review of the effectiveness of the approach.
- Access to Government networks such as Wi-Fi, including backhaul.
    - Enable public access to Eduroam and other similar networks.
    - Tender for in-building cellular coverage in key Government buildings.
- Encouragement for fibre deployment, with possible support for deployments that facilitate mobile networks.
    - Publish a policy on fibre deployment covering Governmental aspirations, preferred competitive framework, etc. Discuss how fibre to street furniture and other base station locations might best be provided.

5.4 Regulator

- Improve the range of existing sites by allowing higher masts in rural areas, higher transmit powers and making available 700MHz spectrum to enhance capacity at lower frequencies.
- Encouragement of innovation in both technology and business model.
    - Build on Government policy publications (see above) with more detailed discussion of policy and regulatory approach.
    - Have a named champion for innovation along with funding available for any studies necessary.
- Facilitate fibre availability, especially for backhaul, through appropriate regulatory policy.
    - Enable duct-and-pole access.
    - Provide a clear competition policy for regulating fibre networks.
- Flexible access to spectrum, including enabling spectrum sharing, leasing and allowing new business models. Reducing cost of spectrum access through maximising supply and making available shared spectrum in certain bands.
- Removing barriers to neutral host networks and other innovative deployment approaches.
    - Consult on neutral host, self-deployment and other new approaches to understand any barriers to deployment or facilitation needed.
    - Establish team to address issues arising.
- Also those factors listed under “EC” above, where the regulator is in a different region, or otherwise not party to EC regulation.

5.5 Local authority

- Implement efficient processes for handling construction permits for mobile network antenna sites, consistent with the national framework.
- Access to street furniture on a simple and low-cost basis.
    - Publish a list of all street furniture owned including location, facilities available, etc.
    - Publish an access policy which specifically lists costs and restrictions.
    - Provide a single point of contact for requests for access with obligations to respond within fixed timescales.
    - Where access is constrained and multiple MNOs cannot deploy, facilitate the establishment of a neutral host with rights to the assets.
- Improved access for street works.
    - Provide equal access to MNOs as to other utilities.
- Reduced bureaucracy in areas such as planning permission.
    - Publish planning permission guidelines.
    - Consider where a de minimis approaches can apply such as with small base stations.
- Single point of contact for mobile operators.
- Where community members express concern, support local engagement between stakeholders.

5.6 Operator

- Publish a list of target cities for small cell / 5G deployment along with assessment of local barriers.