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Mobile cell site numbers with growing demand and higher capacity per site

A discussion paper

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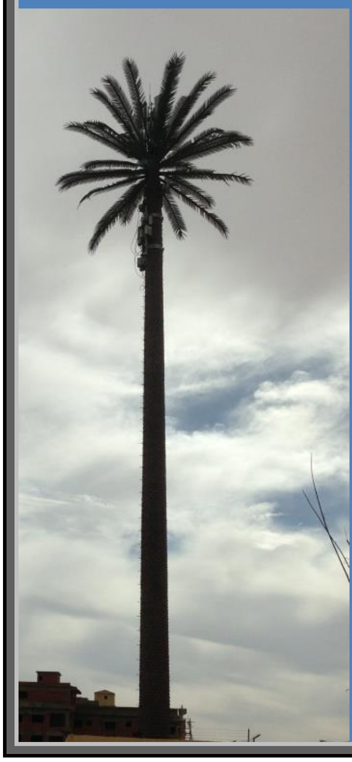

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This analysis relates to a 2018 McKinsey paper and to past Telzed work

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Demand density and cell numbers

A February 2018 McKinsey report has some useful messages: "*The road to 5G: The inevitable growth of infrastructure cost*" by Ferry Grijpink *et al*[1]. This Telzed paper adds to that report and links to past work by Telzed[2]. The strategic messages of this paper support the McKinsey report.

The McKinsey report shows:

- A 2017 demand of ~0.1-1 petabyte per km^2 per year in leading global urban centres [1 petabyte = 1 million gigabye (Gbyte)]
- The demand rises to ~1-3 petabyte per km^2 per year in 2025, with a few cities venturing over 5 petabyte
- Inner London demand in 2017 is ~0.3 petabyte per km^2 per year.

There are of course some expected outliers such as parts of Tokyo and New York. Helsinki is also a mobile data leader. The wide range of demand values is worth noting.

It is important to understand how this relates to mobile costs. The costs are primarily related to the numbers of masts (cell sites). This is partly offset by lower costs of smaller masts and cells. Operators still prefer fewer sites if these can cover the customers and traffic.

The current demand of the McKinsey report fits closely with UK mobile broadband usage (Ofcom) and Telzed's analysis of broadband usage. The analysis in this paper uses UK data but the values and messages are relevant to many countries. Understanding the mobile businesses' costs centres around the fact that a mobile cell (mast) has a finite capacity in Mbit/s. In the peak or busy period of the day, this cannot be exceeded – traffic slows down when too many try to use the same mast at the same time.

The McKinsey report covers Inner London, this has a population density[3] of ~10,000 per km^2, but this rises in many areas in the day due to commuting workers. In this analysis a subscriber value of 26,000/km^2 is used. The annual downloads (0.3 petabyte/km^2/year) means about ~1-1.5Gbyte per month per subscriber (in agreement with Ofcom and tefficient data on UK data usage levels).

0.3 petabyte generates about 830Mbit/s in the busy period. This can be easily derived; see Telzed paper. The actual values depend on the traffic profile across the day, profile of consumers in the region (heavy or low users), expenditure per month, price plans etc. The mast density in London for this traffic is *roughly* 40 masts[4] per km^2. This means each mast

[1] https://www.mckinsey.com/industries/telecommunications/our-insights/the-road-to-5g-the-inevitable-growth-of-infrastructure-cost?cid=soc-web

[2] A guide to broadband usage and Broadband strategic issues The former shows how downloads impact network costs – they basis for this paper and the McKinsey work

[3] https://data.london.gov.uk/apps_and_analysis/daytime-population-of-london-2014/ and https://en.wikipedia.org/wiki/Inner_London . The latter shows 10,000 per km^2, but the day time levels are higher

[4] See https://www.mastdata.com/37/37_Homepage.aspx This is used here to give the approximate mast numbers. Illustrative values are adequate for this paper's messages

has about 20Mbit/s capacity and 5-600 subscribers. This capacity (which is NOT the customer's average download speed which must be, and is, lower) may seem lower than some might expect, but many masts in 2017 will be 2G or 3G based and not all have 4G. The 20Mbit/s figure is a "working average" but traffic has considerable statistical variance, plus most sites should be built to cope with capacity growth of 30%+ per year. So, a recent mast is likely to have 40Mbit/s or much more, as the *physical limit*. ~100Mbit/s is possible with 4G, but on average it will be run at less than this, or else customers see service degradation. Some residential parts of Inner London have lower mast densities. This is possible with a higher limit for the #Mbit/s per mast or lower subscriber density or lower usage.

The number of mast/cell site is assumed here to be 40 per km^2, but of course this varies a lot across Inner London. The City of London is small, but has a population of more than 150,000/km^2 during the day. This generates ~2petabyte/km^2/year needing 5400Mbit/s at the busy period. The mast density there is about 290 per km^2. This means the average capacity per mast is similar (~20Mbt/s and ~500 persons per mast) – which is expected because the network technology will not vary much by district.

As expected, the McKinsey report fits with other analysis and data on the number of masts and the amounts downloaded. Using the numbers of petabytes per km^2 per year is a good way to understand demand. Converting this to the Mbit/s generated in the busy period is another way to understand the demand. Note how the measured download *speed* to a single device is not one of the parameters that has a significant impact. It is the *average download speed over the busy hour* that matters. This relates to the petabytes per km^2 – hence McKinsey used this. In turn this drives the investment costs (mast numbers) that McKinsey highlights.

To help with further analysis and understanding:

- 1 petabyte per year requires about 2700Mbit/s total capacity at the busy period
- The number of petabyte per km^2 per year = Subscriber density [*#/km*^{2}] x Monthly download [*Gbyte*] x 12/1,000,000
- 1 Gbyte download per month requires *about* 0.035Mbit/s in the network busy period
- The number of subscribers per mast = (mast capacity in Mbit/s)/ (0.035 x #Gbyte per month per subscriber)
- The number of mast sites per km^2 = N = [0.035 x (subscriber density per km) x (Gbyte per month average download per sub)] / (total capacity of a mast site in Mbit/s).

The number of mast sites per operator is: N x market share %. This formula can also be adjusted to find N for low market penetration to target houses for a FWA scenario. This a potential 5G business approach. So, a 5% market share and 1Gbit/s cell could need only one sub-urban mast for every ~5km^2 to deliver "next year's" fixed broadband download of 200Gbyte/month. If the spectrum can cover this area. A number of other "ifs" apply.

The exact values above depend on time of day traffic profiles and customer behaviour. Some countries have a national average of about 1000 customers per mast site, but this is less in city areas (500 or less) as data usage is higher in the day and while working, but at home the same mobile device probably uses WiFi and fixed broadband. So mast densities can be much lower in residential areas.

A mast capacity of ~20Mbit/s or less, is still seen today, especially using 2G or 3G. Some operators with limited spectrum may have even less capacity. 4G can deliver about 100Mbit/s per mast. 1Gbit/s is currently a potential outcome from 5G. This is the mast site capacity, not the download speed seen by the mobile device.

The tables below show the mast site numbers per km^2 for various average downloads per month (Gbyte). 1Gbyte is typical of many countries today. 10Gbyte is already consumed in leading markets and many countries will soon have this level of usage. 100Gbyte per month is verging on today's fixed-line broadband usage levels - this is not consumed by more than a few mobile customers as many price plans have limits much less than this figure due to the obvious outcomes if that became the normal consumption made by all customers.

Table showing mast numbers depending on downloads, customer density and mast working capacity in the busy period

		Monthly download		
	Sub-urban density 5,000/km^2	1Gbyte	10Gbyte	100Gbyte
Mast capacity	20Mbit/s	8.8	88	880
	100Mbit/s	1.8	18	180
	1Gbit/s	0.2	1.8	18
	Petabyte/km^2/year	0.06	0.6	6

		Monthly download		
	Urban density 25,000/km^2	1Gbyte	10Gbyte	100Gbyte
Mast capacity	20Mbit/s	44	440	4400
	100Mbit/s	8.8	88	880
	1Gbit/s	0.9	8.8	88
	Petabyte/km^2/year	0.3	3	30

		Monthly download		
	High urban density 150,000/km^2	1Gbyte	10Gbyte	100Gbyte
Mast capacity	20Mbit/s	220	2200	22,000
	100Mbit/s	44	440	4400
	1Gbit/s	4.4	44	440
	Petabyte/km^2/year	1.8	18	180

Source: Telzed

Note how the observed urban mast site numbers (30-300/km^2) fits with current 1-10Gbyte downloads per month and with site speed limits of 10-100Mbit/s.

The McKinsey report does *not* show any of the leading cities to have more than 10petabyte/km^2/year even in 2025 – this means that mobile is not expected to significantly substitute for fixed line usage. This is logical/sensible and is in line with, for example, the UK ministry (DCMS) & Ofcom views. Of course, there will be part substitution and we will all need more capacity from both fixed and mobile. Interesting areas for further study are the countries where significant substitution *will* happen and those countries where mobile already dominates over the fixed network. Please contact Telzed to discuss this further.

A critical message from the McKinsey report is *the need to spend a lot more to build the many more masts that are going to be needed*. Even if they are cheaper, more masts mean significant investment. The critical follow-on issue is the possible lack of major revenue increases. Significant growth in traffic has happened since 4G introduction and many (possibly most) IoT and OTT services could work fine over this network. 4G did not produce huge new revenues but enabled far more capacity - the effective network cost per petabyte/km^2/year fell, so the customer's net price per month remained almost constant.

Strategic issues

The McKinsey point needs re-emphasising: "*To maximize their [mobile operators'] returns on 5G, they'll need to understand how network infrastructure and the associated cost base will evolve over the next few years.*" To this can be added: they must identify the elusive new revenue streams. What are they?

The above question needs a much longer analysis than can be provided here.

The McKinsey report shows 3 scenarios with total cost of ownership for the radio network ranging from 60% to 300% increase. The lower figure is from just a 25% annual growth in traffic. This is a conservative figure. The higher figure is from a plausible 50% growth rate.

Plans should consider some other issues and facts that include:

- The past failures and huge mistakes made by many operators despite the huge expertise and monies at stake. Think, for example: the many telco failures ~15 years ago or of the early 3G business plans where none of the many predicted services succeeded other than voice, messages and vanilla internet access
- Revenues frequently do not meet expectations. Ten times more traffic almost never causes 10 times more revenue. Zero increase might occur
- Critical services can have a price premium
- Mobile coverage has often been poor (especially so in the UK), so consumers travel or work often *without* relying totally on a mobile service being available. A mobile service is rarely *totally* critical to the customer
- Autonomous cars is one possible mobile application, but they have to still work without any signal. The availability of the mobile service cannot be vital. So, a price premium is hard to justify. The car has also to be network autonomous
- Recent ARPU and total revenue trends – note the lack of growth
- Fixed line broadband is *already in place.* 20Mbit/s or more is common in developed countries, that will be 50Mbit/s or much more in a few years. The download (#Gbyte/month) is almost unlimited and the marginal cost of more Gbyte is small. Fixed line investment is already partly a sunk investment. Contrast this with the "incremental site numbers" of mobile with more Gbyte/month in the tables above
- Fixed line downloads of 100-200Gbyte/month on average are already seen. This is 10-100 times mobile downloads
- Traffic has been growing 25-50% per year. There is no reason to expect this to stop
- Converged fixed and mobile strategies by players like Vodafone

- Past FWA plans have often failed. The reasons are manifold
- A FWA/mobile solution that is based on many small masts that are driven more by coverage and spectrum limitations, and might even replace most fixed lines, requires a slightly different analysis to the tables shown earlier. This delivers high speed and might have less than 100 subscribers (mobile or fixed) per mast. This scenario has been mooted. It is not considered in this paper – it *might* work (contact Telzed). Clearly the cost per mast, including backhaul, needs to be low. As pointed out before by Telzed, low backhaul fibre cost is likely only if it is shared with fixed lines – making mass-substitution of fixed broadband problematical
- Many 5G solutions are *applications*, and not telecoms services. The value of the telecom service is susceptible to competition and arbitrage over a basic broadband service
- Monetising speed, is difficult as it depends on signal strength, handset and other users' traffic – not in control of the operator
- Low latency or delay time in the network is a value proposition. But the best performance possible is typically from the "straight through" network. Additional systems investment is needed to slow some services to give differentiation. It only requires one player in a market to offer customers "best available latency for all customers" for the idea to be competed away
- The CEO of BT in November 2017: ""*I talk to other CEOs around the world... and we've all been struggling a little bit to make the business case work*.[5]"

A strategic plan might centre on the above tables. 5G is surely (?) able to provide 100Mbit/s-1Gbit/s per mast. As mobile monthly downloads rise to 10-50Gbyte per month, then this can be delivered *without many new cell sites*. Such demand may not be long in coming and is already possible in some price plans and is consumed by some "mobile warriors." This is effectively the 4G history being repeated. This does not mean there cannot be huge numbers of new applications with 5G, but the application/service market is not fully within the telecom market.

More sites may be needed because of spectrum issues – providing usable in-building signal levels or because it only works when customers are almost in line of site to the antennae. The business case for this is less certain and "new 5G services" may be required to supply the revenues. The telco needs to be able to get some of the revenue which must also be incremental.

Discussions are welcomed – please contact the author at Telzed.

[5] https://www.theregister.co.uk/2017/11/16/bt_boss_yeah_making_a_biz_case_for_5g_is_hard/


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