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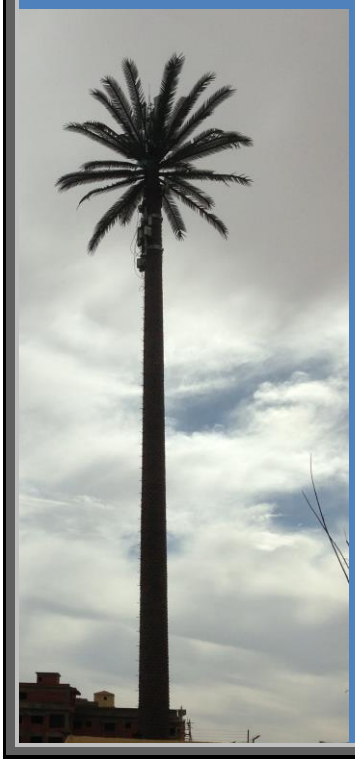
Fixed-line broadband substitution by mobile

A discussion paper

Roger Steele



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An analysis of the potential for mobile to replace fixed broadband lines

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This paper analyses the ability of mobile networks, especially 5G to replace a fixed broadband line. It uses analysis techniques developed in other Telzed papers, combined with a new way to examine existing markets.

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1 Summary: substitution by mobile or FWA[1] is limited but will happen in *some* situations

1.1 Divergent views of the future cannot all be right

This paper addresses a major area of concern for almost everyone in the telecoms industry - policy makers, strategists, investors, managers, employees, regulators and consumers - namely: how might the telecom industry develop with the arrival of 5G? Will 5G enable mobile to substitute for fixed lines?

Some experts are confident of the outcome and predictions have been made. They may be unconcerned with the fact that other experts predict quite different outcomes. Making the wrong predictions/investments/policies has risks: there could be major failures, with implications for everyone – in particular for the employees and investors. Customers are also affected, but they can often be moved to other suppliers, perhaps seamlessly.

The potential for mistakes is highly relevant as there have been many failures in the telecoms industry, so there are ample track records of false predictions and erroneous management/investment decisions. Apparent confidence by one party does not mean that "their" outcomes are more certain than they were say ~15 years ago when many telcos failed.

If there were no divergent views, then confidence in the outcomes should be almost universal and there would be no need for this paper. This paper highlights that some anticipated outcomes are highly unlikely, and it assists the identification of when the different outcomes can each occur. This matters, as decisions being made today again risk being proved wrong later.

1.2 Can mobile broadband substitute for fixed lines?

Key divergent views relate to whether mobile (and 5G in particular) will, or will not, replace *significant* numbers of fixed line services. Certainly, even 4G *can* replace a fixed line – there are now many mobile-only customers in most countries. 4G can provide quite adequate speeds for most users (~30-100Mbit/s) and 5G should enable up to ~1Gbit/s speeds. *Some* users[2] can already download 100s of Gbyte per month. But *major* replacement, or substitution, of a fixed line is less clear. This is not the same as major growth – huge growth in mobile traffic has been clear for a long time and will continue. But huge growth in fixed line traffic is also seen. Some decline in fixed line numbers is certainly seen in some countries, but mass replacement has *not* been seen. Could 5G be the game changer that sees the demise of the fixed line?

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[1] Fixed Wireless Access – use of a mobile network or similar technology to provide a fixed line type service

[2] Note that only a small percentage of customers on any mobile network make this "fixed-line level" of downloads. The average mobile downloads are typically only a few Gbytes, per month per customer, with some countries now in the range of a few 10s of Gbyte. See e.g. tefficient data. Fixed line downloads are often 100-300+Gbyte per month in advanced Internet economies

This paper examines the basic numbers that form a foundation for understanding the network changes that would be needed. The key factors that impact the outcomes are defined. The likely outcomes are unsurprisingly not absolute – they will not be the same in every country.

The short answers to the central questions are provided below. There is a greater need to understand: the reasons behind the answers; how the markets and technologies evolve; plus how the national and local situations all vary. Deeper understanding is better than "just" an appreciation of the answers below.

1.3 Summary of main conclusions

The key messages from this paper are:

- **Mobile is very unlikely to significantly replace fixed line broadband in most *developed* Internet broadband economies** (here defined as already having a developed Internet with significant broadband usage per person). Such markets have existing broadband over copper, cable and/or fibre to most premises. Mobile device penetration is typically ~100% of population. *Some* substitution will happen, but fibre-based broadband will still be required and will still carry the majority of traffic. **Large scale substitution of fixed lines will not occur.**
- Mobile can make more significant substitution of fixed lines in *some* developed broadband economies, especially smaller countries that tend towards a city state and/or if it is currently a leader in mobile usage. This is helped if the country has lower levels of traffic *in total* – as this means the mobile solution does not have to carry the huge fixed line traffic levels seen in the more developed countries with the greatest fixed line traffic. But this lower traffic per capita moves the country further from the fully developed broadband position. Such markets have greater mobile-substitution prospects because:
    - In **city-states**, more masts are often easier/cheaper to build and there are less costs for coverage-of-area and coverage-of-population than in larger countries. Most masts are then likely to be traffic-driven, and so are highly used (and profitable, compared to lower-used masts for low density and low traffic areas). Mast and lamp-post access rules are more likely to be simpler and standardised nationally
    - Current **mobile leading countries** will already have high mast densities and mast numbers (low subscriber numbers per mast), to enable the existing high mobile traffic. This increases the ability to provide a mobile-only solution using the existing masts. This follows from the simple fact that adding more antennae and capacity, including adding 5G to existing 3G/4G masts, is much cheaper than building new masts. Much of the civil costs, power, cabinets and backhaul can be re-used with low additional investment. But the substitution of fixed ability is still limited, if a fully developed broadband economy exists, because the limit is set by basic traffic demands and the cost-driver effect of traffic (data volume per month)
    - Therefore, developed Internet economies that are also small city-states are best placed to move to mobile, especially if total traffic per person is *not* very high and mobile usage is already high.

- Mobile is likely to remain the dominant platform for the majority of citizens in **emerging economies**[3]. Though only a minority of citizens will usually be on fixed services they will surely tend towards having traffic levels similar those in the developed economies. Numerically few, these (probably) more affluent customers will account for relatively significant levels of traffic. As the national economy grows (GDP), then these fixed line service volumes should rise and the fixed traffic may well rise as a percentage the total: but fixed lines can be expected remain a minority broadband solution in the lower GDP/capita countries:
    - Mobile will dominate, as today, due to the low income, lack of existing fixed infrastructure and lower initial investment costs to provide a mobile-data service albeit with only a few Gbyte per month per user
    - **Mobile/FWA will continue to be the lead technology in emerging markets.** The fixed lines mostly do not exist. The key problem is to provide the traffic levels at low costs – this requires large capacity masts that also cover significant areas. The increase in required-capacity is significant to enable the Internet economy. In *selected areas* FWA may provide the capacity needed fixed line type usage. This needs high mast-densities, but this is likely to be more economical than fibre to the premises as fixed infrastructure might well not exist
    - To deliver the highest levels of traffic per premise the same limitations of mobile/FWA apply as in other countries. This implies that some such areas will need to move to fibre to the premises (more affluent and business areas). Emerging economies therefore will use a mix of mostly mobile (with low traffic per user) plus FWA[4] in many areas with fibre in some special areas
    - The lower traffic and revenues per user, and lack of existing fixed networks, will mean mobile traffic will surely remain the main medium for most users. This creates a developing country dilemma: low traffic and revenues are a result of low GDP, but higher GDP needs more traffic – this leads to low cost (price) and lower quality mobile data services[5]. The dilemma also leads to a lack of mast investment, but economic growth needs more/better masts.
- Although using mobile (typically using 5G or 4G technologies), possibly as a **fixed wireless access solution (FWA – also termed Fixed Wireless Broadband - FWB),**

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[3] Note that emerging economic markets here means the *telecoms markets* (fixed and mobile) provide only low traffic per person. Some such countries might still have reasonable high GDP levels and have developed industries, in particular within some regions. So the definition may include both low and high GDP countries. Of course, the correlation of mobile and broadband traffic with GDP levels is well known. They are also causally linked: more traffic increases GDP and higher GDP enables more masts and fixed broadband - past studies have shown this

[4] As an aside: mobile, as a new FWA service in selected localities, is debatably best considered as a "mobile service" (it will be mostly 4G or 5G technology based) but FWA built in the past using 3G/4G/proprietary might be considered a "fixed service." This is because new FWA is more likely to be a mobile-style business based on extending the same solution using "mast densification" and may well have services to the premise and peripatetic uses on the same mast Such definitions show how simple market definitions need careful thought

[5] This can manifest itself in busy-hour over-loaded masts, voice compression, large/cheap masts that would not meet (say) EU build rules, low signal levels to maximise coverage – poor indoor signal, microwave rather than fibre backhaul, limited network resilience etc. Microwave *can* be totally acceptable, but has some limits and can be subject to weather *et al* degradation – it has lower capex, especially when fixed network cables are few in number

to deliver broadband (and voice) to premises is very unlikely to account for significant percentages of premises in most developed economies. It may still be a success in some localities. FWA 5G or 4G can be successful as a low-level penetration service (few premises per km^2) – allowing a low-level competition and low-level substitution to fixed lines. This requires high capacity cells that also cover large areas to enable coverage of the customers without investment in many masts. This links to spectrum availability issues. FWA can also work in some small-mast/cell areas where few customers per masts are economic. But even in developed economies these will be mostly niche solutions or else huge numbers of new masts would be needed with unclear revenue sources to pay for them.

- The strategies for moving forward need to be developed everywhere. This requires detailed understanding of: the current market and how it developed; the overall numbers; and the potentials for both mobile and fibre.

There will be exceptions and some countries will have regions that will have areas that each need alternative solutions.

The success of 5G as a replacement for 3G and 4G or as a fill-in supplement in certain high demand regions to give additional speed and capacity, is not in doubt. The demand growth for more data and faster services is unlikely to diminish and 5G will succeed, as seen with the earlier GSM generations. The potential for new 5G services or new ways of using mobile is also not doubted in this paper. Such services are not examined. How significant these services will be in economic terms is uncertain, however the probability is that: **basic data (broadband Internet access) will be the dominant traffic type, and hence the dominant cost driver.**

1.4 Why are these outcomes not universally accepted?

These conclusions may seem contradictory to some claims made by some industry experts or some press reports. However the conclusions are based on solid numbers that in turn are based on basic physics and engineering. For mobile/FWA to take major market share from fibre/fixed broadband, a lot of factors would need to align including: the costs of delivering many small cell sites (each with significant capacity) would need to fall so that the marginal cost of many more sites is sufficiently low. Significant revenue growth would surely be needed to cover the cost. This growth seems elusive and **the transfer of significant existing fixed revenues to mobile from substitution, is unlikely.** Mobile revenues have long been close to static in most developed mobile markets. Vast numbers of new masts to deliver the capacity, that are funded by transferral of fixed revenues to help pay for them, is an unlikely outcome.

The confusion over the outcomes are probably caused by:

- Some erroneous conclusions being made by some parties.
- Bias in statements or in reporting of statements. Many operators and vendors have vested interests. Even with no expectations of replacing the fixed line network these players will certainly want: cheap spectrum; spectrum in good bands to cover area and to provide in-building coverage; a lot of spectrum to give the high capacity and minimise mast numbers; and cheap masts and low barriers to build. In short – some players “would say that, wouldn’t they?” It is in their financial interests to push the case for more mobile and 5G, but they may not *really* expect to replace many fixed

broadband lines. The traffic increase, even without fixed substitution, will still require large investments.

- Lack of understanding. Although this seems unlikely, the telecoms industry is littered with mistakes and failures. History can repeat itself. All industry leaders should be aware of past failures and the way major mistakes happen. They must take a sanguine look at the business plans. At the simplest: a ten-fold increase in traffic must never be assumed to cause ten times more revenue. The revenue might be the same or even less.

Sensible decisions need to understand the cost drivers, the trends and the market – is the market a developed EU type country, a city state, or an emerging-market? Is it already a mobile leader? Can it be an exceptional country (or region) where mobile traffic levels can **both** exceed fixed line traffic *and* enable many 100s of Gbyte per month per premise? This exceptional outcome does not seem to exist today, but there *might* be a few existing examples. Some regulators, industry leaders, operators *et al* seem to concur that this will **not** happen.

2 The global fixed and mobile markets

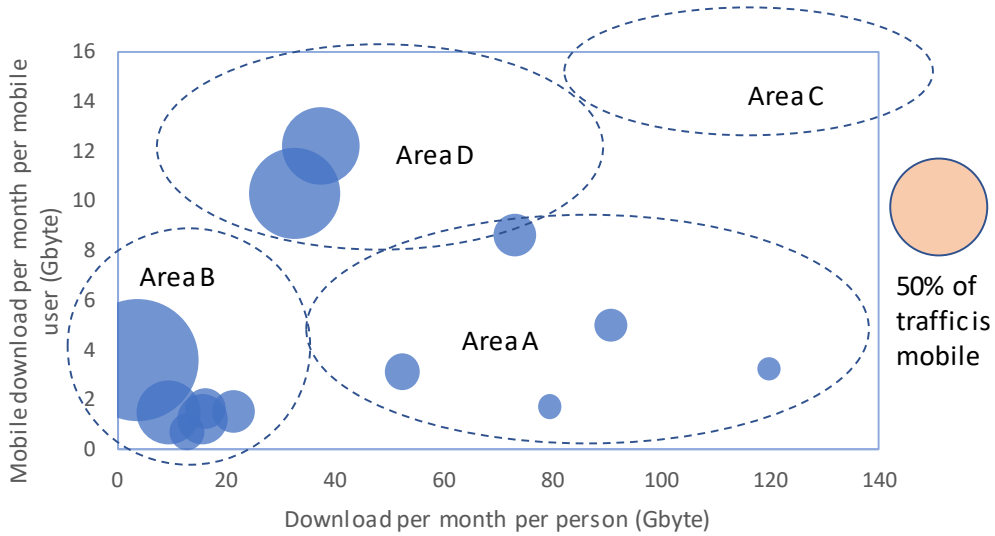
Before future predictions are made, it is useful to understand where the markets are today and what are the current trends. These are not the same in every country. The following discussions consider broadband data only, as this is the key driver for capex and revenue. Voice is ignored in this paper – but it adds some interesting additional aspects to the substitution discussion.

The following factors are useful to understand the current situation:

- The total traffic per person. This indicates the level of national development in the broadband and ICT economy. Developed countries have 50-100+Gbyte per person per month
- The percentage of national traffic that is carried over mobile networks. This shows the relative position of mobile compared to fixed line. This varies from ~3% to over 80%. The high figures are mainly seen in markets with few fixed lines (but there are exceptions)
- The mobile traffic per customer. This shows if users are making fixed-line type downloads per month (~50-300Gbyte per month per fixed line). This is not seen. Mobile traffic is usually only 1-20Gbyte per month per user
- Known trends. Both fixed *and* mobile networks see traffic growth of ~25-50% per year, implying: **10x more traffic every ~6-7 years**. The business plans of mobile have to cope with this "just to survive." Taking traffic from fixed is additional, and *yet more* incremental investment is then needed.

The first three factors are shown in the figure below for a selection of countries.

Figure 1. Mobile traffic per user is shown against total traffic per person. Bubble area indicates percentage of traffic that is mobile



Source: Telzed analysis using Cisco forecast tool and 2017 data, RTR Austria market reports 2016 & 2017, TRA Bahrain Q3 market report 2018. Countries shown: Global average, USA, Saudi Arabia, South Africa, Korea, Australia, UK, Sweden, Italy, Brazil, Nigeria, Austria, Bahrain

The current situation is more complex than might be expected. This shows:

- Developed countries (>~50Gbyte per month per person) have mobile traffic taking only ~10% or less of the total traffic (Area A, with small bubbles). The traffic per fixed line (per premise served) is usually >>50Gbyte per month: >200Gbyte per month is now commonly seen

- Developed countries mostly have 2-10Gbyte per month per mobile user (far below the 100s of Gbyte per fixed line). This gives a slightly distorted view of the mobile markets because many mobile devices use almost no data. Also, many mobile users and devices exist in any one premise so traffic per device or per customer inevitably seems low compared to the traffic per fixed line[6]

- Countries with mobile traffic that is a high percentage of the fixed line traffic, or even higher than fixed, tend to also have low levels of traffic in total (Area B). So a country that is mobile centred is not usually a leading Internet economy, as the total traffic is likely to be low

- There are seemingly no countries where mobile traffic > fixed *and* the traffic per person is ~50Gbyte or more. Developed countries that have significantly substituted the fixed lines and traffic, for a mobile service, are conspicuously absent (Area C)[7]

- Some emerging economies have mobile traffic > fixed (e.g. Kenya or Nigeria[8]). Such countries have >80% of traffic on mobile. But the very small percentage of users on fixed lines means they must each make relatively more downloads per month and this implies that their economic impact is disproportionately high - the Internet economy may be led by a relatively few fixed line users

- There are some "interesting countries" in Area D that have high mobile traffic levels (>10Gbyte per customer per month), >~30% of traffic on mobile and also high levels of total traffic e.g. Bahrain and Austria. Singapore and Finland are other likely candidates and might even be in Area C, but are not shown here as full traffic data was not available. Could such mobile-leading countries be the strongest candidates to move to Area C?

The dynamic effects of growth are not shown in the figure. Cisco sources show both fixed and mobile growing rapidly. Mobile traffic growth per year (as a percentage) is generally faster than in fixed lines (USA and Bahrain are exceptions). This surely reflects increasing use of mobile, some increase in consumer numbers (particularly in emerging markets) but not necessarily a reflection of major substitution of fixed line traffic. This is a key issue – fixed line traffic may grow by a slightly smaller percentage per year than mobile, but the total fixed traffic is usually very much greater. The "loss" of some traffic to mobile is not a concern as fixed traffic grows anyway by a significant amount. **Small *traffic* movements to mobile are not a sign of *service substitution*.** This is the real fixed to mobile substitution that matters – when the fixed service is terminated. Only then could any significant fixed revenues contribute to the mobile networks' additional network investment. Mobile traffic increases

[6] Logically mobile traffic per "mobile broadband user" seems a more logical measure but this is almost impossible to define in many countries as most SIMs have a data service even if rarely used. The only solid measure is the SIM (mobile user) numbers

[7] This is not an exhaustive analysis so some countries in Area C are quite possible

[8] Kenyan Wall Street and Statista: https://kenyanwallstreet.com/kenya-ranks-top-globally-in-web-traffic-generated-by-mobile-devices/mobile-internet-traffic/

that are greater on a percentile basis than fixed line growth is not a sign of service substitution or even of major changes in behaviour – both networks see huge growth and the need to download more mobile data has been clear for a long time. Almost everyone is using mobile more and finding new ways of using mobile, but they are not reducing the use of fixed. Mobile leaders such as Bahrain or Austria do not show significant reductions of fixed line numbers and Bahrain has also had a recent focus on FTTP (fibre to the premise).

The interesting mobile leaders in area D are worth further examination. These show that mobile can deliver significant percentages of the total market and imply that some such countries could move into the C region. This seems unlikely for countries in region B.

Strong mobile usage and mobile-only customers can disguise the fact that many "mobile only" users really use fixed for some or even most of their downloads – they may have no fixed line service but have not truly substituted. They use: someone else's fixed line, WiFi offloads, coffee shops and office/work networks etc.

Many countries now have significant fixed line fibre levels, and these are often are rising. It stretches credulity to imagine many already-fibre-served customers substituting to mobile. As so many countries have major fibre investment programmes in place, by the time 5G is fully available, the fibre will exist. In many countries it exists now (see FTTH Council[9]). Countries with high mobile traffic levels per person (e.g. most Scandinavian countries, Austria, Singapore, Bahrain) tend also to have high fibre penetration levels and/or high fixed network traffic carried over cable TV or copper or copper-fibre. There is a synergy in the use of fixed and mobile – this is to be expected. Examination of national reports on broadband and fibre, shows there is no significant sign that the market direction has been to mobile *or* to fixed - the direction has usually been to both. Exceptions may exist[10], but are surely not common.

Countries in Area D also seem to have slightly lower total traffic levels than in A. The reasons for this should be examined. Lower traffic implies a slightly less developed Internet economy. This shows that mobile tends to be a more significant medium for broadband when the total traffic is less.

Examination of the current situations and trends provide an important foundation for understanding. This leads to supplementary questions that have to be understood. Why has this outcome occurred? How do the outcomes fit with government aims and strategies? How do business strategies fit with the situation? What is the role of cable TV or existing FWA (both can be significant but only in some countries)? What are the cultural influences – TV viewing, use of satellite TV, content blocking etc.?

Major substitution of the fixed services by mobile is therefore unlikely in many countries where this has not already occurred. This conclusion is supported by the analysis of basic numbers in the following.

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[9] FTTH Council March 2019 FTTH/B Global Ranking

[10] Singapore has mobile traffic > fixed but is also a leader in FTTx (https://www.ftthcouncil.eu/documents/FTTH%20GR%2020180212_FINAL.2.pdf). Finland is a global leader in mobile consumption per user, but fixed line number have barely fallen. Many other Baltic and Nordic countries have *rising* fixed line broadband service numbers and these countries probably all are relatively strong mobile users. See "Telecommunication Markets in the Nordic and Baltic Countries 2017" 20 June 2018

3 Understanding the key numbers

3.1 Developed markets

These markets (Area A) have ~50Gbyte per month or more per person. The above data shows that most of these countries' mobile networks have much less traffic than fixed networks – less in total and also less per customer. If only 10% of fixed traffic were to be substituted for by mobile, then the mobile traffic would roughly double or triple. This 10% may be a relatively small loss for the fixed operators (though fixed operators are likely to react to such a loss before it fully happens, especially if the traffic loss started to also lead to loss of access line services[11]), yet the impact on the mobiles is enormous. This is a multiplicative increase. As mobiles will need 10x the capacity anyway (normal growth every ~7 years), one might argue that an additional factor of 2 is not significant. This is not the case. Mast numbers and investment are **directly driven** by the traffic and a factor of 2 change *is* hugely significant. Of course, if the mobile network had significant spare capacity (unlikely) then more traffic can be accommodated at minimal marginal cost, but surely no mobile network has 50% or 90% that is "spare"?

The lost fixed line traffic volumes to mobile will not result in a doubling of mobile revenues because most customers will retain the fixed line – it would initially be mostly be a substitution of fixed *traffic* and not of the fixed *service*. Mobile revenues would therefore remain roughly constant. **Even if the fixed line service were terminated, the users in the premise will almost certainly be pre-existing mobile customers and the fixed-revenues will not become new mobile revenues – they simply become pre-existing mobile consumers of *more* mobile traffic**.

Any mobile tariff plan with unlimited traffic limits or large volume discounts have clear risks. More traffic frequently does not give significant revenue increases – mobile ARPU is roughly constant both with time despite huge volume changes. Developing countries can still see major growth of consumer numbers, though the additional ARPU may be low.

Mobiles have been able to cope with the traffic growth without major revenue growth for reasons that include: equipment has become cheaper; 4G provides more capacity; and more spectrum has been issued. Together these have enabled more data to be carried without huge increases in mast numbers and/or costs. Surely 5G capacity increases will deliver similar results. The mobiles need the 5G capacity simply to deliver the known mobile traffic increases. Technical advances and equipment cost trends (4G over 3G etc.) have enabled rising volumes without major additional revenues. 5G will presumably continue this trend.

More systems on existing sites is far cheaper than adding new masts. Certainly, additional mast sites will tend to be smaller and therefore cheaper per mast, but the incremental costs are clear, and most mobile business plans would prefer to deliver the same capacity by upgrading existing sites. Developed markets typically have a large mast base to build upon.

[11] Any substitution analysis of fixed line services must consider fixed line operators reacting by price reductions should the changes become significant. Many incumbent fixed operators are fixed-mobile players – would they cannibalise their own fixed business

Fixed line operators have their own problems – how to cope with the 10x traffic growth every ~7 years plus the need to move towards speeds of >>50Mbit/s. The speeds can (and are) met by delivery of fibre to premises or close to the premise (hybrid fibre/copper or fibre/cable TV). The technological step means that 50Mbit/s or 1Gbit/s is possible. The marginal cost of the faster speed is then low. Hence some fibre-only operators can offer 100s of Mbyte/s (far above most current consumers' needs) as they have little to benefit from offering incremental speed-based prices, even though this may erode the value-proposition of speed seen by customers. In contrast: incumbents with major xDSL service bases will want to charge both a fibre and speed premium. They have to face the investment step-up to fibre that is needed to deliver the speed needed.

The *volume* of traffic has little impact on a fixed line business's cost. This is because the concentration point for traffic is in the core network where economies of scale are huge. Of course, any FTTx solution that has traffic concentration systems close to customers may prove to be costly in the long term if this will soon need to be upgraded as the traffic per customer rises. So, key factors are:

- The marginal cost of increased service speed is low, once the move to fibre is made, and the fibre goes close to the premise
- More traffic has low incremental cost in fixed networks.

The contrast with mobiles is significant:

- The marginal cost of increased service speed is set by the move to 4G or to 5G. The service speed is set by the technology and spectrum available per mast. Arguably this both is a known factor and effectively a fixed cost
- More traffic causes a *direct increase* in the required mast numbers (and hence in costs) unless compensated for by cost reductions, which only happens over time. The marginal cost of more traffic, in the short term, *is* significant.

If service speeds are >50Mbits (or maybe a few 100Mbit/s) then most customers do not care. In theory mobile can also deliver this sort of speed. "1Gbit/s" is widely touted as being possible with 5G. FTTx clearly can deliver this. So the critical driver for mobile costs is the traffic volume. **The impact of more traffic on mobile is vastly greater than on fixed networks.** This is critical to understanding the implications of moving to different Areas in the above figure.

The basic numbers are simple to analyse. We assume the business needs includes the requirement to build a network that is able to meet predictable traffic demands ~6+ years into the future. Using this we can see:

- Developed markets will generate traffic of ~500-1000Gbyte per *person per month* (up from 50-120 today). ~300Gbyte per month is already seen as an average per fixed line.
- With several persons per household, traffic levels of several terabytes per month per fixed line will be needed. Such Terabyte per premise demands are already seen in leading households and SOHOs.

- Using the **Telzed Rule of Thumb**[12], this traffic requires about 10-35Mbit/s in the busy hour per premise. Several HD TV or UHD users could push this number up. Also the physical speed must be more than the average speed to avoid periodic overloads. Even so, a service speed of few 100Mbit/s is adequate. 35Mbit/s or even a few 100Mbit/s is easy enough to meet with either 5G and FTTx. Even 4G is surely able to provide enough *speed* for many premises.
- A mast capacity has to be shared. So a 100Mbit/s 4G mast is only adequate for a few premises. A 1Gbit/s 5G mast is only able to service about 50 premises (assuming 20Mbit/s busy hour usage or ~1000Gbyte per month). In fact this is an over estimate as some engineering overhead is needed in networks for traffic variance and to cope with growth – few masts are built to run at the capacity limit. They run at perhaps 60-80% of maximum and when new will probably be run at a much lower fill factor.
- With only a few customers per mast the required new investment in masts and in backhaul links is enormous, **unless the mast is designed to cover large areas and the planned-for market penetration of substitutional services is very low**.

The above figures contrast to the roughly 500-1000 subscribers per mobile mast seen today with 3/4G in the UK, from using ~3Gbyte per month.

Mobile can certainly take on a small percentage of fixed lines' total traffic but larger substitution requires a very radical change to the cost structures of the mobiles. This approach might seem plausible, but a mast will also have "normal mobile" users who will use about perhaps 50Gbyte/month, so some trade off is required. The limit is set by the simple formula, based on the Telzed Rule of Thumb:

N x Mobile download * 0.02 + M x Fixed download x 0.035 < mast capacity [in Mbit/s]

Where there are N normal mobile customers having a monthly download of perhaps up to 50Gbyte/month and M fixed lines (with perhaps up to several 1000GByte/month "Fixed" downloads). The Telzed factor is set here to 0.02 for mobile users who may consume traffic more evenly spread over the day than fixed lines which will concentrate downloads in streaming services in the evening, hence a Telzed factor of 0.035 is used[13].

There can be no "normal mobile users" if the mast capacity is only 1000Mbit/s and there are 30 or more fixed subscribers – the fixed lines consume all of the capacity. The number of normal/existing mobile customers per mast has to be well less than 1000, unless the mobile usage is low and/or there are very few fixed line subscribers.

An assumption of 1000Gbyte/month per fixed FWA line is arguably too optimistic. This is only ~3x the current fixed line traffic of leading countries. **If the business must cope with 10x the current fixed line traffic then a 1Gbit/s mast can deal with only <~20 customers.**

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[12] Busy hour traffic (Mit/s) = TF x download per month, where Telzed Factor = 0.01-0.035 depending on time of day factors and the download is in GByte. A corollary is: numbers of subscribers per mast < (mast capacity [Mbit/s])/ (TF x download per month). See Telzed papers including "The need for speed" and "Mobile cell site numbers with growing demand and higher capacity per site"

[13] Some analyses might reasonably use a more optimistic (lower) Telzed Factor for fixed or mobile but the general strategic messages from this formula do not alter.

This “mast to just up the street” is almost converged with FTTH or “sharing” the fixed line broadband WiFi with some neighbours.

The mobile business case is clearly viable if the level of fixed premises that substitute to mobile is low. This does not require many new masts to be built. Therefore a purely mobile play that does not substitute for fixed is (as should be expected) quite viable. Adding 5G to an existing mast is potentially cheap, depending on the mast design (something that varies significantly by country/region/operator). So countries with already significant mobile mast densities have a head start over others that need incremental mast builds. Some countries in Area C above may have this useful start of high mast densities (Finland is understood to be in this situation).

Perhaps many mobiles have no real plans to “take on” the fixed line broadband market. They will achieve almost the same revenues anyway unless large percentages of fixed customers terminate services and somehow make available the “fixed” revenues. The investments just to cope with 10x the existing mobile traffic are bad enough:

- Moving from 5-20Gbyte (current traffic levels in leading mobile user countries) to 50-200Gbyte per customer per month
- This means busy hour traffic will be about 1-7Mbit/s per mobile customer
- This implies about 140-1000 customers per 5G 1Gbit/s mast. This is close to current mast/customer ratios at the lower traffic predictions but at the higher traffic levels about *five times* more masts would be needed.

The new 5G investment is therefore very considerable at the higher traffic levels. If the mobile traffic ambitions are more modest (<50Gbyte per month per customer) then the prospects for 1Gbit/s masts to cover the needs are good, but this implies no *significant* substitution of fixed lines services or even of fixed traffic. **This is probably the outcome planned for by most developed-country mobile operators.**

The required mast number increases may partly explain some of the requests from operators for more/cheap spectrum, better/cheaper backhaul, low cost and quick mast approvals, harmonisation of planning rules across countries or regions, etc. These also assist the business case, even without any fixed substitution intentions for all market types.

The business case could be improved if there are additional 5G service revenues from IoT etc. These are not covered in this paper.

3.2 Emerging market analysis

These tend to download just a few Gbyte per mobile user. A high percentage of the traffic is often over mobile. As some consumers have no device at all, and the relatively small number of fixed lines can still provide significant traffic volumes, the net mobile traffic is low: ~1-5Gbyte per month per mobile user (see Figure above, Area B).

Such countries need major growth to develop the Internet economy. A 10x traffic growth in ~6 years may be insufficient as both the traffic and customer base may have to increase. The traffic needs per person are not fundamentally much lower in such countries but affordability issues and geographic coverage must also be addressed. So a 50x traffic growth to both expand the economy and deal with normal growth is hard to achieve.

There are usually few fixed lines existing to build upon, so building up the mobile network seems a logical approach – the cost can be kept down by using ~1Gbit/s 5G masts on existing masts to give ***more than*** 10x the capacity growth from such a move. This follows from the lower start point (less traffic and probably lower current mast capacities). This still means only ~50Gbyte per user in ~6 years. This is certainly good by today's measures and would relate to perhaps ~200Gbyte per premise. High end users may not find this sufficient and so more targeted use of mobile (and fibre) may be needed:

- Community and small area FWA developments to provide larger capacities to relatively few customers. This may be at a higher price than the basic price for 20-50Gbyte per month for truly-mobile users. FWA services are then not quite the same as mobile, even if the underlying technology may be the similar
- Selected areas will need fibre to the premise or close to. The same drivers of large capacity (1000Gbyte per month) per premise that force low customer numbers per mast may make the fibre solution viable, but only in selected areas.

Note how the same fibre to masts for FWA type services and for truly mobile customers' masts, have overlapping needs with to fibre to the premises. Convergent strategies will be sensible, just as the are in developed countries, though the accent will be much stronger on mobile-only solutions for the majority and FWA only for selected more-affluent areas with fibre for relatively few localities.

3.3 Advanced mobile economies

Some countries are already leading (area D above). The mobile traffic volume is relatively high compared to fixed and the total traffic is reasonably high, showing a developed Internet economy – so both fixed and mobile levels are high. How and why this outcome has arisen should be examined and understood. Both fixed and mobile traffic will rise, but there is a greater potential for mobile to substitute for fixed than in these countries. This follows from:

- User behaviour is already more aligned to using mobile services
- There are probably high numbers of masts and many masts per person
- High mobile traffic suggests that there is an existing willingness to readily issue large amounts of spectrum.

This suggests that greater substitution of fixed lines will be possible due to the existing mast count and consumer attitudes to mobile. This may be contrasted to (say) the UK where mobile signal coverage is still a major issue (23% of premises have poor signal from at least one 4G operator and main roads have only 64% 4G coverage by all operators). This is a serious matter as it is a poor outcome for truly mobile (peripatetic) users and this surely impacts confidence in mobile in general – further reducing of the consumer willingness to consider a mobile-only supply option. The great Unique Selling Point of *mobility* is not there. The familiar low indoor premise coverage further reduces the potential to substitute to mobile.

Having more existing masts provides a good base for 5G and the new Gbit/s masts to give a substitutional service. The difficulties of this should not be under-estimated:

- Is the start point low? If total downloads are "only" 30-50Gbyte per month per *person*, then the national traffic still has to catch up with leading countries. This means a larger number of additional masts to deliver the capacity needed (catch up traffic *plus* fixed substitutional traffic *plus* normal growth of 10x in ~6-7 years)

    - A high percentage of traffic on mobile seems to be a good start point for fixed substation, but less impressive when the total traffic per person is low.
- Can existing masts physically be upgraded to carry 5G and Gbit/s?
- The same limitations of number of customers/traffic per mast apply, as in all countries.
- Other factors must align such as:
    - the fixed/fibre broadband providers do not respond to a loss of customers in the unlikely event of material substitution
    - backhaul costs to the additional masts do not rise significantly. Surely the cost *woul*d rise as the same ducts and cables are no longer shared with fixed line services because of the (hoped for) large substitution by mobile[14].

There are of course other factors that limit FWA substitution potentials (contact Telzed to discuss). These include many of the same ones that caused FWA for voice and low speed data to fail in many countries ~15+ years ago.

3.4 FWA or 5G will struggle to replace fixed broadband

The basic numbers and analysis above shows that there are some major difficulties for mobile/FWA/5G to replace fixed line broadband. **The issue is not speed.** The primary issue is the traffic – realistic traffic levels require many masts, even if each mast is able to deliver Gbit/s type capacities. If the mast capacity increases to more than 1 Gbit/s then of course the business case for mobile improves. A wide range of issues still arise, including:

- Very high speed services (multi Gbit/s masts) may require higher frequency spectrum. This tends to be more of a line of site service and may have poorer in-building penetration
- As mobile tends towards more line of site, known problems increasingly become apparent. Service offers are subject to: customer house location (Can you see the mast? Is there a school/building/hill/tree in the way?); whether other users on the same mast slow your service down; can the service deliver voice to enable the fixed line to be terminated (surely this is not a major barrier); customer reluctance to have new antennae on roofs
- Service speeds may slow down with smaller signals – the service depends on the location and it is not a guaranteed service. Users get what they can get at that location. So the service is only "*up to* X Mbit/s." This hugely reduces the value of speed as a service proposition – if cannot be relied upon to be available
- Speed is a statistical service – the user's speed depends on the traffic of other customers (a slow down during the busy hour is common). Again, this reduces speed

[14] This self-limit to substitution was identified in previous Telzed work such as "A guide to understanding broadband usage"

as a key factor in the proposition – a “use case” cannot place major reliance on a speed being available

- Mobile costs are traffic driven so it requires cheap masts and backhaul as mast numbers rise. This is plausible but requires cheap equipment, low site build and planning costs and ideally cheap existing fibres for backhaul (likely to be caused by existing FTTx)
- Planning permission for masts and backhaul. Regulators and national/local governments should be able to reduce this time and cost. The site rental costs must be low
- Spectrum and competition trade off. Spectrum is finite. More spectrum enables higher capacity per cell/mast. This implies fewer mast and less costs, but if the spectrum is more for “line of site only” then the mast numbers are driven by this and the masts are not fully utilised. This increases the cost to serve. More competitors leaves less spectrum per operator – this means less capacity and so fewer customers per operator and possibly fewer per mast, unless the mast can cover larger areas (which needs suitable spectrum)
- Unless masts can be shared by competitors then the total investment may rise. This is not a new phenomenon but may become more critical as spectrum is at higher frequencies and the coverage (distance to customer) issues become more dominant because it forces up the mast numbers
- Smaller masts might not be easy to share with other operators. Current mobile masts are often shared by different technologies (2/3/4G) or even between operators. This cost-reducing mast-share factor is likely to be country specific. Can lamp-post type masts be shared? If not, then duplication must result and the overall investment must rise, unless competitive-supply of infrastructure is reduced
- Mobile/FWA is often an anecdotal service. Local geography (obstructions etc.) often mean that a few premises in any cell cannot be served. This means some fixed line service must still remain in place. Therefore the major fixed network costs are not avoided – they only fully go away as the last customers are disconnected. There is then no incentive to even slightly reduce a fixed network’s coverage as *complete* replacement is surely almost impossible. This is in addition to the need for a fixed line network for the mobile/FWA backhaul and to provide other business services that are not possible over mobile. Consumers are surely not impressed by a mobile/FWA that is only: “Probably available, subject to local survey of your premise. Therefore you and a significant minority may still need to retain a fixed line.”

4 Summary of key messages

The following provides a summary of *some* key points, but this is *not* intended to be an exhaustive list. For a more detailed analysis that is focussed on a particular country or market or operator, please contact Telzed. Real plans need to consider: national strategies, business plans, markets, government plans, USO, rural coverage plans and subsidies, spectrum, plans for fibre to the home/mast, regulation etc. This paper still provides a useful basis for other work and enables some of the more fanciful ideas for mobile, 5G and FWA to be easily dismissed. More complex plans and analysis should still align with the basic network cost drivers and limitations identified in this and other Telzed papers.

The divergent views on the ability for mobile to substitute for fixed networks need to be fully understood, given the current/future demands and the known technical costs/capabilities: why are they made and which claims are credible? Claims that mobile can replace fixed broadband need to be looked at critically. Mobile can deliver the desired speed, but the required number of masts for *realistic* traffic demands, show that major substitution not likely in many situations. In short:

- Mobile/FWA can *technically* replace fixed lines, but this cannot realistically happen to a significant degree in developed countries with large traffic volumes. Basic traffic demands, mast capacity limitations and the economics of many masts set major limits. In addition, the ability of fixed/fibre lines to carry vastly more traffic at very low incremental cost when such lines already exist or will soon be in place, are other primary reasons
- Developed countries can have more substitution in some selected/special areas or as a low percentage of all customers, but not nationally
- Countries, already with high mobile traffic, and many existing masts that can be upgraded to carry 5G or higher capacity 4G, have more prospects for larger fixed substitution. This is helped if the total traffic is less per capita than in the more developed counties. Delivering 100s of Gbyte/month per person is simply not likely over mobile due to mast numbers and backhaul costs – and cheap mast backhaul is only possible if shared with fixed lines (so costs would rise and self limit major substitution)
- Developing economies that already have mobile as the primary solution for most citizens are likely to continue to have mobile and FWA as the main solution. This may hold back the national economy due to the fundamental limits of the traffic over mobile/FWA networks. The lack of existing fixed infrastructure means that the investment for national fixed broadband is likely to be prohibitive. So the broadband Internet economy has to be based on lower traffic levels which implies lower GDP growth.

It is the traffic (#Gbyte per user or per km^2) that primarily drives the mobile costs. This is a basic concept but seems to be ignored in some discussions that focus on the availability of high speed. Given good spectrum, a single tall 5G mast could deliver 1Gbit/s to 100,000 subscribers. This makes a good business case *so long as the customers make very few downloads* (<1Gbyte per month). This traffic is unrealistic in most countries. It *is* just about valid for the very near future, in only some countries (mostly emerging markets). This Gbit/s mast capacity provides a near term opportunity (before downloads rise to 10s of Gbyte/month) for 5G to extend the coverage of mobile significantly - to more customers or to give more downloads to a limited number of customers. Therefore, future predictions or

reports on mobile and 5G that do not discuss the traffic demands over time and focus simply on speed and short-term capabilities, should be looked at carefully, as the primary cost driver is *traffic*. Traffic depends on customer numbers times the downloads per month per customer. The traffic growth is significant, so longer term plans must cope with this.

Some 5G and mobile claims may be influenced by the desire to get as much good spectrum as cheap as possible, and lower the costs of masts and backhaul etc. and to attract additional investment. Much of this investment will be needed to simply to meet normal mobile growth and there may be no real expectation of any major substitution of fixed (though an operator or vendor might make the claim). The desires are legitimate, but the claims may not be. This paper should help to identify such claims from the more balanced views.

Traffic demands should be examined closely. How much traffic can be carried by mobile, how much mobile traffic can substitute for fixed and, more importantly, how many fixed line *services* can be substituted by mobile, all need close examination. The current start points must be examined closely. These vary hugely by country type (developed economy, city states, emerging markets, leading mobile states) and even by region and operator. The trends also vary by country, though everywhere must expect huge traffic growth of both fixed and mobile.

As large scale substitution of fixed line services by mobile/FWA is unlikely in most developed markets, FTTx is needed to deliver the traffic capacity needed. Speed is not the major issue (mobile 5G or even 4G can surely also deliver ~100Mbit+ speeds, which is probably good enough for most). FTTx is needed in almost all countries even if just for the high demand and more affluent areas due to the traffic demands.

Fixed lines have low cost sensitivity to the traffic downloads. This is in contrast to mobile/FWA networks where **the key cost driver *is* traffic**. There *is* a cost for faster speed over fixed lines, but it depends on the technological step chosen – once fibre is chosen then more speed has a relatively low marginal cost.

Developing economies can expect to remain mobile centred and can use Gbit/s services to each mast to deliver reasonable levels of traffic. High volume customers will need high mast densities (FWA type solutions) and are likely to also need some FTTP/x for high demand areas. The choice will be dense-mast FWA or FTTP in the higher volume and more affluent areas. Such solutions are doubtful for low income areas – forcing a low traffic per user mobile service on the customers.

Developed economies with major existing fixed broadband and FTTx investments underway will probably need FWA only for a few local developments or as a low penetration option for an operator that expects only a low market penetration. FWA/mobile for USO areas is certainly an option. This requires few masts but needs spectrum suitable to cover the area. Therefore 5G/FWA will probably not try to address more than a fraction of the fixed line broadband market: the main use would seem to be to be in high demand areas of cities and to supplement the existing 4G supply. 3G & 4G traffic will surely migrate to 5G.

Major population and geographical coverage issues (as seen for example in the UK where, even now, many premises have inadequate 4G coverage) exist. 5G will assist, but there is no logic that it will be a silver bullet as the spectrum, mast number and coverage issues are similar to 4G (possibly often worse in the higher frequencies), even if the 5G mast capacity is higher.

This paper has not addressed the many other 5G network services (“use cases”) that might deliver customer value and perhaps new revenue to the mobile operator. This would make

the business case for more masts more attractive. This can be addressed on request. Any suggestion that these will provide game changing revenues for the mobile, must be looked at *very critically* as the primary traffic driver and hence cost driver in any mobile is surely just more broadband Internet traffic.

Additional information: UK markets and references

Basic analysis using UK data shows the validity of the calculations

The above basic analysis and traffic calculations can be checked using UK data. There are ~50,000 masts. Mobile traffic was 211Million Gbyte per month (June 2018 from Ofcom Connected Nations report December 2018). This implies current mobile traffic generates ~40-140 Mbit/s per mast in the busy hour. This depends on the traffic time of day profile and therefore the Telzed rule of thumb factor (0.01-0.035, probably at the lower end in a mobile network but higher in fixed). This fits reasonably with typical mast technology and the fact that most data is now on 4G (that has more capacity than 3G). This may seem low, but some masts still only use 2G or 3G.

Note that a mast capacity might be 100Mbit/s but if there are three sectors (common) then the maximum speed one customer could get is about 30Mbit/s (in line with actual values being reported).

10x more mobile traffic (basic growth without any significant substitution of fixed line services) means existing masts must carry 2100million Gbyte per month or ~400-1400Mbit/s in busy hour. If upgraded masts are really able to carry 1Gbit/s then the mobile operators might be just about able to carry the likely traffic *without huge investments in new masts*.

It is very likely that some areas will have even greater demand and more masts will be needed. Obviously if masts were able to carry even more traffic, then the pressures on the network become less.

The UK data shows that the basic figures, which relate downloads to busy hour traffic show that mobile networks meet current demands using ~50,000 masts and could cope with 10x more traffic without enormous increases in the mast numbers *if* 5G is able to deliver Gbit/s type mast capacities that can also cover similar areas to the existing masts. This assumes existing masts can be upgraded. These assumptions may not be certain in UK or in many other countries as this depends on spectrum and the existing mast structures. The service also has to work indoors (few users do huge downloads unless sitting down and not physically moving). If these spectrum/mast/coverage factors are not met, then many more masts will be needed – is this likely?

The total UK fixed line traffic is ~20x the mobile traffic. This is likely to rise ~10x as well in ~7 years time. If just 10% of this traffic were to be substituted by mobile then the mobile networks would need to carry an additional ~4000 million Gbyte/month. Even if every mast could carry 1Gbit/s then mast numbers must rise from ~50,000 to ~150,000. This requires a huge additional investment. What are the revenue sources to pay for it?

Additional useful data sources

Papers on the Telzed web site cover related issues in more detail. These also reference other sources that give similar views that 5G and mobile will not make major substitution for fixed lines in developed countries (see e.g. Ofcom, DCMS, ITU).

The following papers should be valuable additions to this paper:

- **"A guide to understanding broadband usage,"** which discusses how traffic is the key cost driver in mobile networks. That 2017 paper overlaps with this "Fixed line broadband substitution by mobile" paper and provides useful foundations.
- **"Strategic issues for fixed and mobile broadband"** This paper provides insights to assist with strategies.
- **"Mobile cell site numbers with growing demand and higher capacity per site."** This paper shows how cell numbers are driven by traffic and how the calculations tie in with McKinsey analysis.
- **"The need for speed."** This paper looks more in depth at broadband speed and how consumers need faster services but perhaps not the full speeds that some are offering or planning to offer. Ofcom has issued a paper in May 2019 that now shows UK broadband speed is rising only 25% per year. This is well below the 50% value of Nielsen's Law and as was seen previously in the UK. Contact Telzed to discuss this potentially significant new trend to a slower rate of speed increase.
- **"Response to: Delivering the Broadband Universal Service."** This paper has a Telzed response to Ofcom's broadband USO definition. It is relevant as mobile or FWA is a realistic solution to a USO in any country.

Together with this paper, these enable a reader to obtain a good basis for further analysis and future plans.