A basic guide to Fixed Wireless Access limitations in rural/low-density areas

An analysis of traffic and subscriber density issues

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Author: R Steele

Telzed Limited UK. Consulting, Advisory and Interim Management Services

All correspondence: Lilac Cottage, Westerfield Road, Westerfield, Ipswich, IP6 9AJ, UK. Tel: +44 (0) 777 178 7607

Registered Office: Orchard House Park Lane, Reigate, RH3 8JX, UK

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1 Fixed Wireless Access has a role, but it is limited

1.1 Background

Fixed line broadband carries the vast majority of broadband traffic in most developed internet economies. The speeds (Mbit/s) and amounts of traffic (Gbyte/month) have been growing rapidly. Technological developments made this possible. Mobile broadband (data services) also plays a huge role but it can only carry a minority of traffic: ~4% in the UK and ~30% in a few EU countries. Around 10% is more typical. Generally mobile can carry a higher percentage if the total traffic per capita is less[1]. This follows logically as higher traffic volumes require more masts. This costs more, yet the monthly consumer spends on broadband (fixed or mobile) is often nearly static. In contrast, more traffic on fixed lines, costs little more. The cost base is set by the copper/cable/fibre technology. This is moving towards cGbit/s rates and more fibre based. More traffic on a fibre does not increase the fibre cost.

Recently there has been an increased interest in using mobile type technology or simply using mobile services (4G or 5G) to deliver a fixed broadband service to premises. This is possible as speeds of 30-100+Mbit/s are now typical. **The key question is: can this technology deliver an equivalent to a fixed service? This is Fixed Wireless Access (FWA) to replace the copper, fibre or coaxial cable links to the premise.**

Mobile and FWA have fundamental limitations. Large traffic volumes per month cannot be delivered to many customers without many masts to carry the traffic and/or high-capacity masts – and these are bound by spectrum limits and signal coverage. But dense mast deployment is expensive and so often uneconomic, though it has a role in some localities. With the emergence of 5G, offering faster speeds and more capacity per mast, to supplement 4G mobile, claims have been made that 5G or variations of 4G technology can give a FWA service and replace fixed line service. **This cannot be done except at a limited scale due to the costs of the many masts needed to deliver the traffic.** Mobile/FWA can still be the primary solution in some rural areas. FWA is particularly useful in emerging economies as fixed lines are non-existent or expensive.

This report examines the key technical factors that limit the potential for FWA *in developed countries* where the #Gbyte per month per premise is high. The focus is on rural, low density areas.

FWA in smaller higher density locations is not examined, but much of the logic and calculations in this and other Telzed work can be adapted to such locations. These *could* be viable but are not very common – in itself, this illustrates that there are problems.

Cleary FWA can be ideal where costs to access a premise are high. Fibre to the home costs rise with distance and if many premises are far apart (low customer density) then the cable

[1] "Fixed-line broadband substitution by mobile." See Figure 1

costs are not shared by many customers. This causes the well-known high rural costs for broadband. In turn this has led to rural economies being cut off from adequate broadband to give a two-tier broadband economy with some being held back by a lack of adequate broadband - a "digital divide." In part this is alleviated by government and industry subsidies to help rural broadband. This can deliver a universal broadband service (often done as part of a Universal Service Obligation – USO). Funding, regulation, franchises, competition *et al* issues in the rural areas are not discussed. "Only" the basic traffic and technical factors are analysed here.

This report may be read alongside other Telzed papers[2] that discuss how the traffic per month is the primary cost driver in mobile (and FWA) services or satellites. This is true for services that shares a finite resource, such as a mast or satellite. This and the other papers show why there are few, if any, developed internet countries that have mobile/FWA technologies carrying the majority of traffic, unless the traffic per capita is low.

1.2 Messages from this report

This report provides analysis to enable rural FWA limitations to be understood.

The following messages are provided:

- The same rules apply to FWA as they do to mobile mast numbers, their capacities and dependence on traffic:
    - It is the amount of traffic downloaded (#Gbyte per month and hence the related busy-hour Mbit/s) that requires network capacity to increase and hence drives the cost
    - The speed of the download is not a very significant factor so long as the speed is adequate for the user (say 30Mbit/s or more)
    - The key cost driver is the number of customers x the amount downloaded per month per customer
    - Higher capacity masts carry more traffic, but spectrum and signal strength limits ensure the upper capacity limit is finite (the number of Gbit/s per mast is bounded)
    - Traffic rises ~30-50% per year, meaning about *ten times* more capacity is needed every ~8 years.
- Rural FWA has an additional cost driver over normal mobile - the area to cover. Low density rural areas need large-area cells. This may need large (high) masts
- Large capacity masts generally need higher frequency spectrum. But these spectrum bands often do not easily cover large areas

[2] See Telzed discussion papers. These cover guides to how the monthly download (#Gbyte) from N customers defines and average traffic (Mbit/s) that must pass through a mast or satellite. See Telzed rule of thumb

- High-capacity masts for small areas are technically relatively easy, but if they each only have a few customers then they may be uneconomic.

The key trade-offs are mast capacity, area, traffic and customer density. Given the finite revenue per customer, small area masts or very low density areas are not economic.

The data in this report shows that FWA:

- Likely has only a limited role to play in a national market, if the traffic is large – i.e. commensurate with a developed-country fixed line premise
- Can seem viable with current traffic but as this is likely to be ~10x more in about 8 years, the future economic viability may be limited/questionable
- Has to be niche service. It cannot replace fixed broadband except in areas where fixed is too expensive[3] and the FWA limitations can be dealt with
- Can be ideal where the traffic, area and density factors are favourable and alternative fixed broadband is too expensive (i.e. *some* rural areas)
- FWA ideally needs large mast areas, with large capacities per mast for rural areas (~Gbit/s or more). These tend to be hard to achieve simultaneously
- FWA networks risk being overloaded if the business plan only considers current or near future traffic demands
- Is not the only option. Satellites can service the same market, but the viability of them is yet to fully proven. They have some similar limitations – so they are logically focussed at under-served or poorly served areas[4]. Telzed analysis confirms that they should be viable for rural areas, based on traffic demands and a low subscriber base.

Some deeper messages are implied. Business cases for FWA need to be looked at carefully. Predictions that FWA has a major role need to be questioned. **Any paper or analysis that does not consider the traffic but discusses only the service speed may be "economical with the truth."** Investors/planners must be careful – FWA was perceived to be a major future direction for telecoms ~20+ years ago. Almost all failed. Some of the same reasons still apply. History should not be repeated.

FWA hype must be avoided. If it were really simple and cheap, plus able to carry huge amounts of traffic without ridiculous numbers of masts, then claims that 5G will replace 80% of UK fixed lines would also be true. This is surely nonsense (it cannot realistically happen), yet it has been claimed. This shows how false and dubious claims need to be separated from rational analysis and factual deductions. This work of this report keeps to basic traffic facts and theory. These apply universally.

Rural FWA certainly has *a* role. However it is limited.

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[3] This has already been discussed in other Telzed papers, e.g. Footnote 1 or "Mobile cell site numbers with growing demand and higher capacity per site." This new report provides a more comprehensive analysis of traffic and coverage issues

[4] See Telzed analysis that agrees with Elon Musk claims. This is counter to some claims that satellites can significantly replace fixed or mobile in developed internet countries. They cannot, due to similar traffic rules that limit FWA and mobile broadband

2 FWA is constrained by basic rules and therefore its use is limited

2.1 The key drivers in a FWA business case

The following defines a basic analysis of the traffic produced by customers in low density areas. The Telzed rule of thumb is used as a reasonable approximation:

User traffic (Mbit/s) = 0.01 x #Gbyte/month

The Telzed Factor (0.01) depends on time of day traffic factors and allowances for freak-day traffic peaks or growth over time. Larger values may be realistic. Note that 350Gbyte/month requires on average about 3.5Mbit/s in the busy hour (networks must cope with this peak demand). This is made in short bursts at, say, 30-70Mbit/s. So the user does not see the slow *average usage* as the download speed. This download is typical of current fixed line downloads as of end of 2020 in developed internet economies. Certainly some countries have only ~100Gbyte/month fixed line usage, but as annual growth is likely to be 30%+, then similar traffic will be seen in a few years.

The total traffic from N customers has to be less than the mast capacity. In reality a mast with 1Gbit/s cannot be run at 1Gbit/s on average and real fill levels of c80% or much less are often used. This report keeps the analysis simple, avoiding fill factors, and so this gives an *optimistic number* of customers on a mast.

In addition to the customer traffic and mast capacity the other key factors for FWA in rural areas are:

- Mast area
- Customer numbers (area times customer density per hectare)
- The minimum acceptable customer numbers per mast. Below this, the service is not commercially viable.

The latter point relates to the cost of masts. These are not defined in this report. Costs vary hugely by country, as do the revenues. In general, the likely FWA revenue per premise will be close the typical national fixed broadband price, for perhaps 50-200Mbit/s over copper/fibre or FTTH[5]. The mast cost is defined by the size, technology and backhaul link to carry the customers' aggregate traffic to the core network. Smaller masts, in physical size and capacity, do cost less but more are needed. A few higher-capacity masts are virtually always cheaper than more smaller masts to carry same traffic and cover the same area (as shown by mobile operators' normal network strategies). This analysis is not done here, but it is

[5] Fibre to the home or fibre to the premise, FTTP. It is likely that many fixed line providers will tend to similar broadband prices that compete with the incumbent fixed operator. Say ~40€/month per premise [may include a PSTN service]. This defines a likely revenue, when predicted customer numbers per mast are used

assumed that anyone developing a business plan will know the minimum number of customers per mast to be profitable.

Clearly any mast that can carry more customers should be more profitable so long as the costs are not much higher. To address more customers requires an upgraded mast capacity *to carry the customers' traffic*. The customer number has almost no effect unless they download traffic. An optimistically low prediction of future traffic demand would help, but this is likely to be wishful thinking - traffic has always risen, often more than predicted. Furthermore, rural customers' usage is likely to be similar to the national average.

2.2 The influence of traffic is profound

Base Case

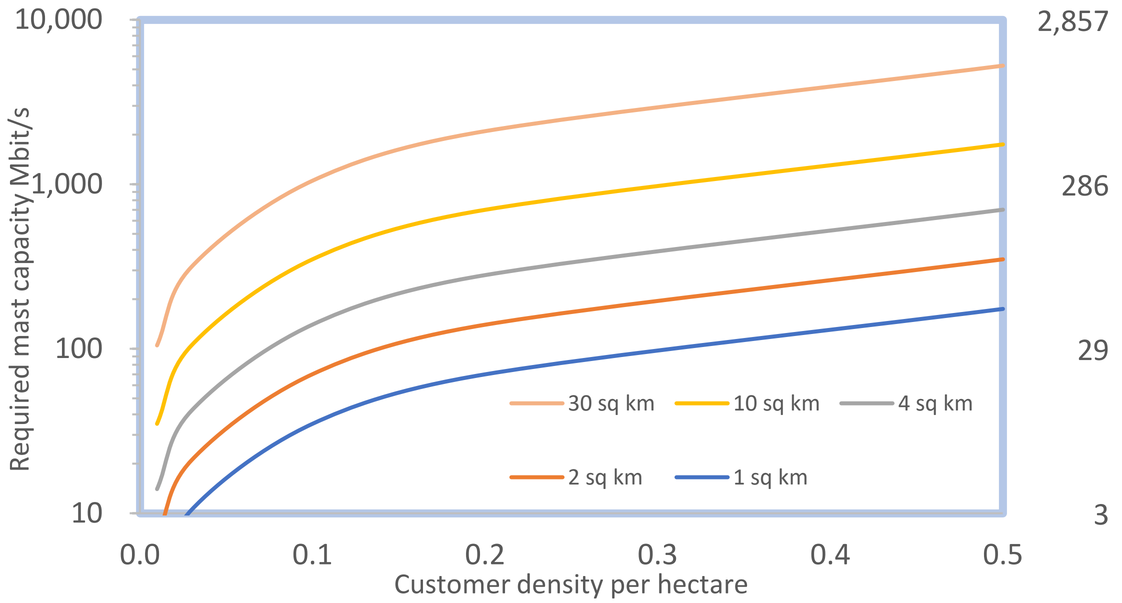
The following analysis assumes a base case usage of 350Gbyte per month. This rises 35% per year. A business plan is normally assumed to be viable long term, but a view just 8 years into the future is used here.

Key factors that are brought in to define the total traffic are the customer density (#per km^2 [sq km] or per hectare) and the mast area. This is the mast coverage, defined in sq km. The other factor is the mast capacity[6]. This may be a few 100Mbit/s or with the latest spectrum and technology (say 5G) it could be 1Gbit/s (1000Mbit/s) or even more. Most recent high speed (and capacity) reports are for 4G/5G deployments in cities for small areas of high-density demand. Rural services need large areas and ideally large capacities: possibly hard to obtain simultaneously.

The base case factors are combined in the following figure. This is worth further study as it combines the key factors into one ready-reckoner graphic to show how any one factor relates to the others. So more mast area requires more mast capacity for a given customer density.

[6] Not speed, though they are related. A 1Gbit/s masts could physically deliver services at 50Mbit/s or at 1000Mbit/s. This has negligible impact. The relevant limit is the total traffic that can be carried. The mast capacity must of course be ≥ the physical speed

Figure 1 Required mast capacity and customer numbers (right axis) versus customer density for different mast areas. Base case traffic = 350Gbyte/month or 3.5Mbit/s per customer



Source Telzed

This base case assumes 350Gbyte per month per customer (equivalent to 3.5Mbit/s). If there is a mast with 1Gbit/s capacity then ~286 customers are possible (143 for a 500Mbit/s mast, 29 for a 100Mbit/s mast). 400Mbit/s+ masts are likely to give a viable business case. It can deal with a low density of 0.1/hectare by using large areas masts (30 sq km). If small (1 sq km) Gbit/s masts are economic than nearly 2.9 customers per hectare are possible (off to the right, but this may be too dense to be truly rural).

As a few masts are normally cheaper than many small ones to carry the same traffic, a rural FWA business prefers to be close to the upper lines. But, these need larger capacity masts.

Large area masts might not be able to provide 1000Mbit/s+. So lower customer density has to be accepted (lower and to the left) if only 400Mbit/s is possible. This forces less customers (and less revenues). Half the mast capacity halves the maximum customers.

Note the fundamental “FWA niche dilemma”:

- There will be a maximum number of customers per mast (see right hand side axis) = mast capacity/3.5Mbit/s. This must be greater than the minimum customers for the mast to be viable. This in turn sets a lower bound to the business case, as there cannot be a viable business with very low customer numbers per mast. So, the lower part of graph is excluded
- Rural low density (left side) is viable, but mainly just with large area masts. Certainly cheaper lower-capacity masts may be used. But this reduces the customer numbers per mast, and requires more masts. The customer numbers per mast cannot go too low - the economic customer number viability limit. Nor can masts exceed a certain area - can 30 sq km be achieved? So, the very far left of the graph is excluded. This is expected as mountains and deserts are normally below an acceptable lower-density limit

- Larger area masts probably cannot deliver very high capacity and speed – the upper part of the graph is excluded due to radio spectrum, power and propagation limits
- The right of the graph seems better for a given mast capacity. This also gives more customers per mast (more revenue/profit). But, the mast areas are forced to be smaller (lower lines in graph) so more masts are needed. This is more costly to cover a given area & rural population.

If the minimum acceptable #customers per mast is low, then the viable domain is reasonable.

Example analysis: if the minimum viable customer/mast number is 50, then small area masts are not viable except at high density (right of graph). But large area masts are viable.

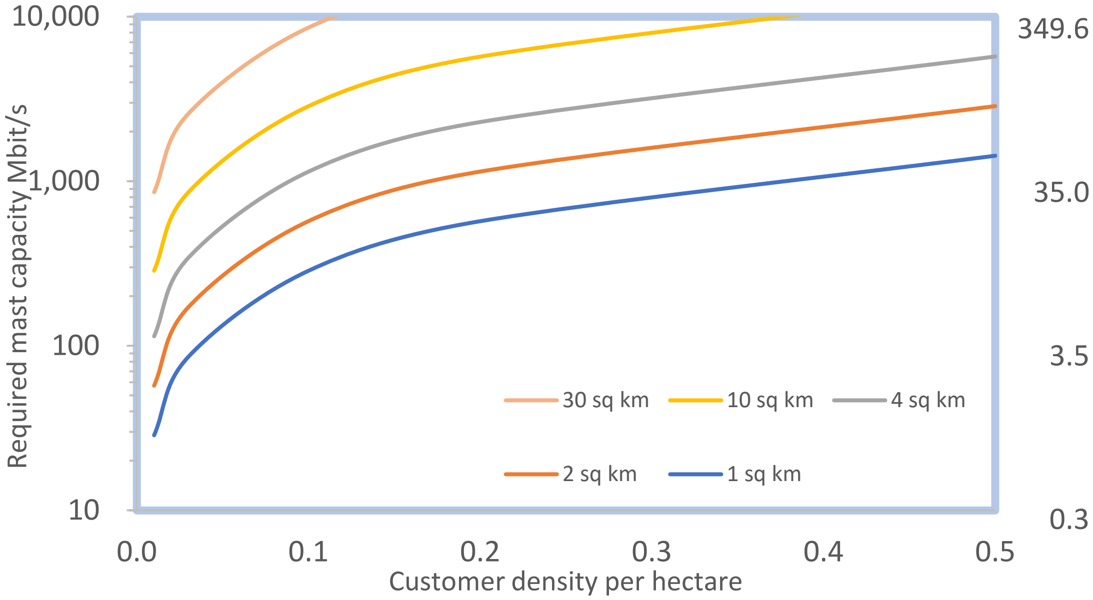
Note that the premises' density may be higher than the customer density. But it is not likely that there will be many FWA providers in the same area. It is a low-profit area anyway else FWA would not be considered in the first place. If only FWA is possible in an area (the fixed line copper or fibre is not viable) then the customer density will be closer to the premise density as most houses do need broadband.

A natural business focus is the top right of Figure 1. Masts with multi Gbit/s and able to cover 10 or 30 sq km. They can deal with higher customer density and maybe drift into some suburban coverage. This may be a fantasy. Multi Gbit/s masts are more likely only in city areas with distances measured in 100s of metres (areas less than 1 sq km), so are not suitable for rural coverage. This distance is likely when 5G Gbit/s-type services are reported.

Future demand

It is sensible to consider a future business with 8 years of 35% growth pa.

Figure 2 Required mast capacity (and maximum customer numbers on right axis) versus customer density for different mast areas. Year 8



Source Telzed

Figure 2 demonstrates the fundamental limits.

Even a 1Gbit/s mast can only deal with 35 customers. This is because eight years into the future, a customer generates ~28.6Mbit/s[7].

Large area masts need huge capacities. These are likely to be not technically viable (cannot carry the required #Mbit/s and cover the area).

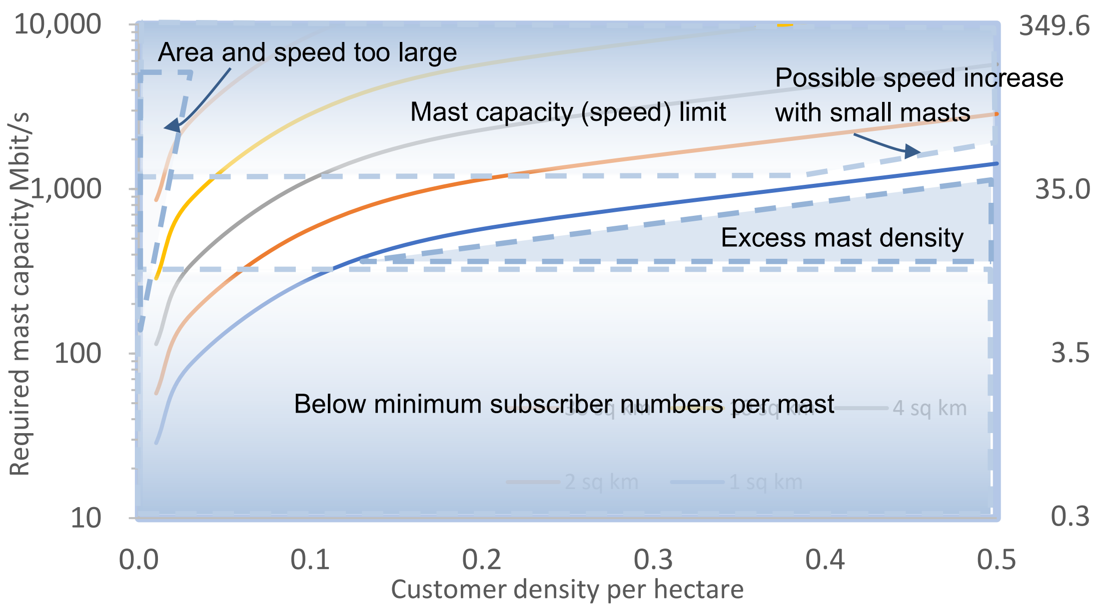
The minimum viable customer numbers per mast forces larger capacity masts. So if more than 20 customers per mast are required then all masts need at least 570Mbit/s capacity.

If a 2sq km mast can only carry 500Mbit/s then this means only 17 customers – a maximum density of ~0.09 per hectare.

These numbers are clear in the figure and easy to define with pocket calculator complexity. Is any mast viable with just 20 customers? As this mast has to cover several sq km, then it has to be physically large. It cannot be a cheap mini mast on a lamp post, as might be possible in a city.

The fundamental issues are clear from some ratiocination and from this figure. Large area mast cells mean fewer masts but that is often incompatible with high capacity, due to basic radio and spectrum limits. Smaller masts are less likely to be overloaded and can have more capacity, but more are needed (resulting in more costs).

Figure 3 As above, with limits shown. Year 8. The viable business domain is much smaller than Figure 1



Source Telzed

Only 8 years into the future the possible target business case is limited – a niche service.

[7] This is totally feasible if current trends are followed. HD TV and on-line viewing are still embryonic services. Multiple screens in one premise become more common. Interactive gaming demands will grow. Telecoms history has shown the traffic growth has often exceeded many predictions of the hopeful and naïve

The low mast density (large masts) that makes FWA attractive, is probably not possible.

Note that the growth in traffic has a huge impact compared to Figure 1. This emphasises the fact that traffic drives the costs in FWA and mobile networks. This is important, yet it is sometimes ignored.

2.3 Mast speed (or capacity) values are almost irrelevant without traffic measures – the danger of "false facts"

This may be a trivial point, yet it seems to be ignored in some analyses.

A single mast with 1Gbit/s speed (and capacity) on a high building in a town centre could give the entire town a Gbit/s service. 30,000 customers can get it, *so long as they do not use it much*. They could only download about 3Gbye per month. This is mobile handset type usage and far below fixed line usage. See: Telzed rule of thumb.

The fact that the mast gives a Gbit/s service to 30,000 customers is correct. Logically it is then simple/cheap to give the entire country access to a Gbit/s service. But this type of analysis and statement is hugely misleading: true but also false. It is a Gbit/s service, so long as you do not use it (much).

A similar true/false analysis is possible with satellites. A 20Gbit/s satellite can provide 200 services at 100Mbit/s. Even with an "over-sell" of three, only 600 customers are possible. Again, this is correct. It is also totally misleading:

- Oversell factors or contention ratios are often not robust engineering approaches
- A real satellite customer might download 200Gbyte/month (2Mbit/s equivalent). So 10,0000 customers per satellite are possible. A claim-error from reality by a factor of about 16x or *far more* if satellite customer usage per month is less
- It implies that the Starlink business case and claims are unlikely to be viable. Is it really likely that Starlink/E Musk does not know some traffic theory?

These two analyses are part of the wider problem of false or dubious claims. The difference is that these analyses are correct, but also wrong. A deeper message is that business plan assessments need proper understanding of networks and traffic. Do not believe headline claims and numbers unless you can check the workings. NB many telecom experts would dismiss both examples, from experience and general telecoms knowledge and not need to do the calculation. But it is possible for anyone to be mis-led.

Such true-but-false claims can also undermine the reputation of the source on other matters.

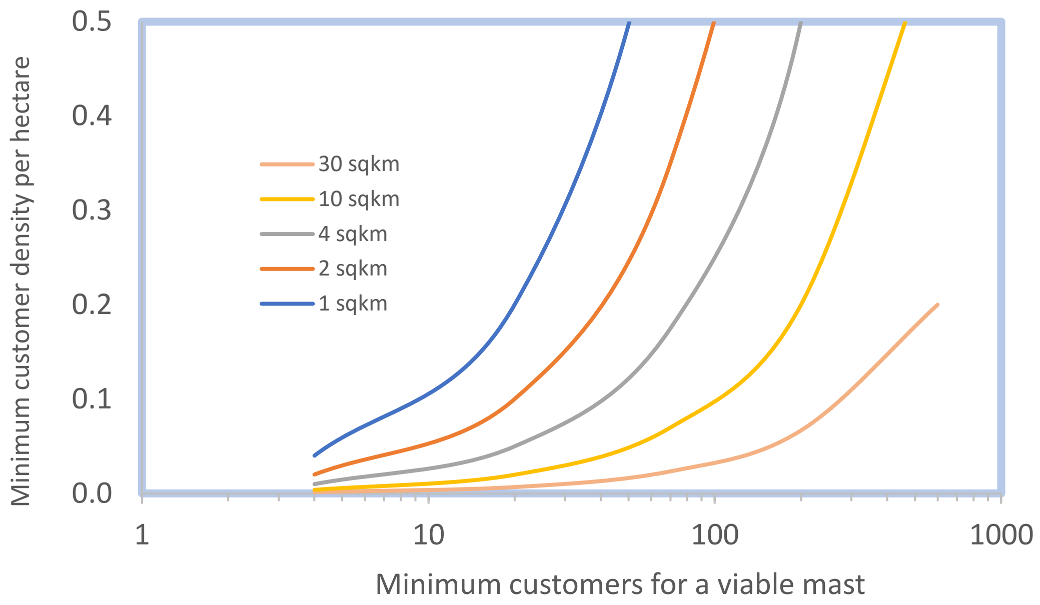
This report provides the details needed to form more robust FWA assessments.

2.4 What are the minimum customer numbers per mast?

The following examines the required customer numbers. It is reasonable that any FWA plan will be able to define a minimum number of customers per mast to be viable. This is not directly related to the traffic or speed, only to the revenue and mast costs. In turn this required-revenue, and resulting customer numbers, defines the customer density needed. A large area mast can deal with low density. A small mast area needs higher customer density to get the required customer density/numbers to pay for the mast.

This figure shows how density and minimum customer numbers are related.

Figure 4 Customer density needed to provide a viable mast, for different mast areas



Source Telzed

This is where the key economic calculations are required. A mast with 250 customers is likely to be viable (significant of fixed-line-type broadband revenue, plus some telephony). But what if there are only 50 customers? This sub 100 customer per mast is the likely business focus where a rural FWA business gets close to its limit.

If a 2sq km mast needs 50 customers, then it must have a density of about 0.25 per hectare. This density can then be applied in Figure 2. This shows a mast with nearly 2Gbit/s is needed. This might be difficult. Is a 2Gbit/s mast cheap enough for just 50 customers? Could it cover 2 sq km?

So low customer numbers per viable mast works, if the mast is cheap enough – the left side of Figure 4. This can deal with low density, if a large area mast can give the coverage. Yet this may still need large mast capacities (see same mast and density in Figure 2).

The other extreme of needing many customers per mast has similar problems as too much traffic. 200 customers per masts assists with addressing higher density areas but this requires huge mast capacities when translating that density and traffic into Figure 2.

This is the fundamental niche market problem that FWA is forced into:

- High customer numbers and high density leads to huge mast capacity and/or many masts. This is likely to be not viable – mast investment is too large. This is why fixed broadband is used: over 60 FTTH builders are active in the UK
- Dealing with low customers per mast, if this is viable, is an ideal target as low densities are likely to be fiscally difficult to serve with FTTH. Low costs per mast are required. But even this is likely to run into mast capacity problems with time
- Can the mast cost be low enough *and* can it cover the area needed? Large area coverage needs tall and expensive masts but needs more customers per mast to pay

for it. But many small masts are likely to cost even more than a single mast, for the same demand.

3 Summary of the FWA analysis

This report shows graphically the relationship of mast areas, mast capacity, customer numbers per mast, and the customer density. These vary depending on the traffic (#Gbyte per month downloaded).

The opportunity for FWA in rural areas seems reasonable if the traffic per customer is similar to or lower than current developed-market usage (~350Gbyte/month). The opportunities are still limited, depending on the costs to serve. These costs are not defined in this report, but they define the minimum customer numbers needed per mast. This can be used to define the other factors using the data and graphs provided.

Serious problems are clear due to the known rising traffic per broadband customer. This will probably restrict FWA to limited areas and where other solutions are not possible. Other solutions do exist. FTTH is being deployed, even in rural areas. Fixed copper/copper-fibre solutions improve over time. Satellites can deliver useful traffic volumes and are viable in low density and under-served areas. Very-low customer density *is not a major problem* for satellites as they each cover huge land areas. Arguably this is their primary target market.

Rural FWA has many other issues that are not addressed in this analysis. For example:

- Limited coverage due to hills or trees. A service that only covers 80% of customers in a target zone is questionable. What do the other 20% of customers do?
- As an anecdotal service (get it if you are lucky), FWA is hard to market and may cause customer complaints. See: UK copper-fibre broadband where the customer had little idea if the service will deliver 5Mbit/s or 70Mbit/s - it depends on the distance to the cabinet and copper quality. How can FWA be ordered if the service might not work in some rooms or depends on a home receiver's location and so operation cannot be reliably predicted?
- Low mast backhaul costs probably depend on cable cost sharing with FTTH. If a cable exists, then FTTH is a natural add on to those near the cable. Can that reasonable request be stopped? FWA therefore also enables competing FTTH to customers near the mast/cable
- Rural backhaul distances are probably long, with cost implications
- FWA upload speed is likely to be restricted but FTTH has few such limits. Many applications need near symmetric speeds
- Customer reluctance to put receivers on roof-tops
- Long term traffic growth has little impact on fixed/fibre. Mast-based services are always subject to capacity limits and so future traffic volumes are critical
- It is a statistical service. The performance will vary depending on the usage by others sharing the same mast. This is normal in mobile masts and in fixed PSTN where the

downloads can be slow or calls may be blocked. With ~1000 customers per mobile mast, a predictable performance degradation is both normal and easy to define. If there are only 30 customers on a FWA mast, a few heavy-using neighbours could slow the service of others. This is less predictable than in traditional networks (the traffic variance is relatively larger, with fewer users[8]).

Ideal solutions would have large masts to cover large areas (maybe on a hill or tall structure). Good spectrum choice (usually low frequencies) helps to give the coverage. However high frequencies are probably needed to give the capacity and these may be more line-of-site-only. Higher frequencies can be more sensitive to trees or weather. It is likely that good-for-coverage lower frequencies are in limited supply and so this restricts any large-area masts' capacity. Such good spectrum may also be expensive.

This report also notes how simplistic views of telecoms can use factual/correct calculations, yet these provide false insights. This is highly relevant today – "facts" can show false conclusions. Deeper analysis and understanding is often needed. The point is emphasised in this report as both rural and urban FWA may seem ideal, but this may not be realistic with a complete analysis.

This report does not provide complete answers. But the figures provide a solid basis for strategic insights and decisions. The clear message is that FWA has a role, but this may be limited. This report does not claim that FWA is not sensible. It exists and can be an ideal solution. The report "simply" provides basic numbers to help with further strategic assessments.

Please contact Telzed for further advice and help if needed

See Telzed web site for additional papers

[8] This is familiar to those sharing a slow home broadband network, as the behaviour by others in the same house can stop others doing TV streaming etc. It is also a fundamental aspect of traffic theory. This means that the average usage of a mast or a shared resource has to be lower (as a percentage of the maximum), with fewer customers. This further limits the business case niche from the optimistic values used in the report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