A simple guide to satellite broadband limitations

A high level analysis of fundamental traffic issues

October 2020

File reference: Simple_guide_to_satellite_traffic_060102020.docx

Details: A discusson paper

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Table of contents

Document history
Ver 06102020 Initial version

1 Broadband satellite services are good, but still limited

1.1 Background

Fixed line and mobile (F&M) broadband have grown enormously in recent years. But both services have not fully succeeded globally. Many people and areas in the world are un-served or have a poor service that is slow and unreliable or has traffic that is limited to a few Gbyte per month. The welfare gains from using broadband are immense, so there is a major focus on improving F&M broadband services. Where these are limited, alternatives have been used, such as Fixed Wireless Access (FWA) using similar technology to mobile networks, but to supply services to fixed locations. Satellites have long been another way to deliver broadband or voice to remote areas.

Mobile and FWA have fundamental limitations, as large traffic volumes per month cannot be delivered to many customers without many masts to carry the traffic and/or very high capacity masts – and these are bound by spectrum limits and signal coverage. Such dense mast deployment is expensive and so uneconomic in many countries, though it has a role in some localities in most. With the emergence of 5G, offering faster speeds and more capacity to supplement 4G mobile, many 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 to a small scale due to the costs of many masts to deliver the traffic. Mobile/FWA can be the primary solution in remote areas and especially in emerging economies as fixed lines are non-existent or expensive. The same traffic limitations[1] also apply to satellites, as shown in this paper.

Satellite broadband has become increasingly capable as the satellite networks get cheaper due to technical satellite advances and lower launch costs. This transformation has started speculation about where satellites can be used, how the markets will be affected and if F or M broadband can be replaced or supplemented by satellite.

Satellite services were generally (and correctly) seen as addressing particular but significant, market niches, and are not capable of replacing a significant portion of F&M services or services' traffic. This seemingly obvious fact was confirmed by Elon Musk earlier in 2020: "*Elon Musk's Starlink is not a threat to telecom Industry"* and "*Starlink will likely serve the "3 or 4 percent hardest-to-reach customers for telcos*[2]".

Recently there have been renewed claims that satellites may have major impacts on the existing F&M players. This is NOT true – it is very unlikely that established F&M players will be adversely affected, except in limited situations/locations.

[1] See Telzed papers such as "Fixed line substitution by mobile". Several others discuss the issues of speed, traffic and how costs vary in F&M networks

[2] https://networking.report/news/musks-starlink-is-not-some-huge-threat-to-telcos/6906. This report's author comment at this time that it was strange that anyone could have thought otherwise

This report shows how the same traffic rules of course apply to satellites as they do to mobile masts. Therefore satellites cannot carry a significant portion of the F&M traffic.

1.2 Messages from this report

This report provides analysis to enable satellite limitations to be simply understood.

The following messages are provided:

- The same rules of traffic apply to satellites as they do to mobile mast numbers and their capacities
    - It is the amount of traffic downloaded that requires network capacity to increase and hence drives the cost
    - The speed of the download is not very significant so long as the speed is adequate for the user
    - The cost driver is the number of customers x amount downloaded per month
    - Higher capacity satellites or masts carry more traffic, but spectrum and signal strength limits ensure the upper capacity limit is finite (the number of Gbit/s per mast or satellite is bounded)
    - Traffic rises ~30-50% per year meaning ~ten times more capacity is needed every ~8 years.

- Even with 10,000 satellites each with 10Gbit/s capacity, **they cannot carry more than a fraction of developed countries' broadband traffic**

- Everyone should have good knowledge of the fundamental market figures and trends, both in their relevant countries and how this varies globally. Outcomes vary hugely so what is sensible in one market might be virtually impossible elsewhere
- Everyone should understand the basics of traffic and how networks are affected – this is fundamentally different in fixed network compared to mobile or satellites. Fixed is cost-driven by the customer numbers, technology and speed (fibre and/or copper to the premise) but masts and satellites are driven by the traffic - many customers have negligible impact unless they consume traffic
- Senior managers and analysists need technical/demand/market understandings
- Industry strategists *et al* need to be aware of false claims and those based on poor understandings. There are sources that may make false claims that are not credible – similar to: "5G will replace most fixed lines in countries like the UK." Such claims may be possible in theory, but they are fanciful in realty. This is an increasing concern as such views are now easy to propagate, no matter their solidity ("5G causing Covid" is a classic case where even fruitcake ideas now get reported). Therefore, elementary technical modelling plus comprehension is vital to avoid repeating erroneous claims

- Do not accept every analysis, as some may be wrong, even if they are from seemingly reputable sources.

The last point was a feature of recent Telzed reports[3]. These noted how standards in the consulting and related industries may have degraded.

This report does not suggest that satellites cannot be successful. The potential is huge and the investment, led by experts, is surely based on sound business analysis and on pioneering advanced technology. The services can have a huge impact in some areas and on some market segments. **However, *they are not going to replace established existing F&M networks* – they cannot. So the existing traditional broadband operators will not be adversely affected.**

Satellites provide coverage and service in areas and in ways that F&M struggle to achieve**. It is a complement, not a substitution**. This should benefit almost all countries – those with developed broadband and also emerging economies. In terms of traffic-scale, it is a niche, but that is still a large market globally.

This report does not define the full list of satellite services and benefits. "Only" broadband data is discussed, as that is the primary source of traffic for most customers. There are significant additional services and customer types that can make use of satellite – discuss with Telzed if insights to this are needed.

[3] See Management consulting and business ethics and Fact based analysis and opinions – problems in the telecom and professional service industries

2 Satellite market capabilities

The satellite services are bound by the number of satellites and the capacity of each (defined in #Gbit/s). Each increases the available traffic that can be sent up and down to customers, in any one area. Note how it is the capacity, not speed that matters. Downloads from a 5Gbit/s satellite can be at 30Mbit/s or 1000Mbit/s. The end user will not be affected significantly. The data is downloaded in bursts and then there is no data transferred. Customers only use a satellite for a small fraction of the time. So it is the *average traffic in the hour* that matters.

The average traffic is defined by the total downloads per month (number of Gbyte). In turn this defines the average in the network busy hour (this is when services can be degraded, as outside this period there is little risk of overload). The number of Gbyte in the busy hour defines the average Mbit/s. Readers may confirm the Telzed Rule of Thumb (RoT) defines this traffic as:

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

This is accurate for many understandings. The Telzed Factor 0.01 depends on time of day factors and allowances for freak-day traffic peaks or growth over time. Larger values may be realistic. Note that 100Gbyte/month requires on average about 1Mbit/s. This is made at (say) 30Mit/s bursts over the hour. So the user does not see very slow average usage as a download speed.

This traffic calculation is central to both mobile mast usage and satellite usage.

The total user traffic in Mbit/s from N customers must be less than the satellite (or mast) capacity (say 5Gbit/s or 100Mbit/s respectively).

A satellite constellation has to be spread almost evenly over the globe to avoid gaps[4]. Some of the earth is not covered (northern and southern latitudes) – leaving only A% of the globe covered – Gkm^2.

The number of satellites S over any one country or region is set by the area Bkm^2. This in turn defines the capacity for all traffic in that region: S x capacity of each satellite in Mbit/s. Reality has to factor in engineering limits of a satellite that allow for growth and inter-satellite communications. So only C% of the ideal capacity may be usable.

A critical input is the average traffic per customer. This is highly variable by the market. In this analysis we consider two options:

- Advanced market *mobile-type* users. These consume ~10Gbyte/month. In emerging markets ~1Gbyte/month may be more real
- Advanced market *fixed-line type* users. These consume ~500Gbyte/month

[4] It is not possible to have say 50 satellites just over New York as this means a huge total number of satellites are needed as that density (many satellites per 100km^2) has to be similar across the globe

Note that both customer types' usage are higher than some countries today, but as traffic rises 30-50% per annum, such traffic values will be normal in many areas in a year or so. This usage is used with the Rule of Thumb to get the effective Mbit/s from the customers.

Global services are limited by the fact that most of the world is water or desert. Only E% of a constellation is actually used at any one time. We ignore ocean-specific services and airplane access etc though these can make use of satellites in "empty" areas.

These factors: RoT, E, growth rate, C, S, A ,G can be simply combined to defined the customer numbers N is a region.

Figure 1 Numbers of subscribers based on a constellation of 10,000 satellites

	10G mobile-type users		500G fixed-type users	
	2021	2029	2021	2029
#subs in USA	14,781,000	1,002,000	296,000	20,000
#subs in UK	362,000	25,000	7,000	500
Global #subs	175,000,000	11,858,000	3,500,000	237,000

Source: Telzed.10G or 500G refers to number Gbyte per month in 2021. This is higher per customer in 2029

Global constellation coverage is 65% of the globe, 65% of the world is assumed to be empty, satellites with 10Gbit/s capacity are 50% used ["fill factor"] - (both may be optimistic), 40% pa growth defines the future traffic in 2029. Geography means about 300 satellites over the US and less than 8 over the UK. This slightly worst-cases the number, as some satellites can send signals at an angle from over the sea, but the impact is small in percentage terms for large countries. Further, it is hard to get a line of site signal access to satellites that are near the horizon.

The following points are clear:

- Low traffic usage (mobile like) provides reasonable subscriber numbers. The values fit very well with addressing poorly served areas and for in-filling rural areas. It can help with the Universal Service Obligation – delivering a basic service to remote areas
- Only a tiny fraction of fixed line type subscribers can be served. Also, if they were served, then they would consume most of the capacity leaving little for mobile-type users
- Satellites cannot deliver fixed-line type volumes to more than a very few customers
- The subscriber numbers fall dramatically with time: this is due to typical traffic growth rates. Although offset by likely satellite number increases, 10,000 satellites provides a plausible base case (readers may alter the calculation for more or less satellites or for larger/smaller capacities)
- The number of mobile traffic type subscribers is significant, especially globally, even after 8 years of compound growth. Note this is mobile like usage. They may not be truly mobile smartphone type users
- Subscribers in any one country has no impact on usage or subscriber numbers in another. Unless next door and small countries
- The subscriber numbers are significantly more if traffic were lower on average. So a large number of very-low volumes users (1-2Gbyte/month) are possible. This fits with

some emerging market needs and with a small in-fill usage for customers in developed countries when not in range of normal 3/4/5G cells or near fixed networks (WiFi & broadband). Therefore it can help with the notorious coverage issues.

The last point is profound in UK and many countries. Normal mobile has failed to provide decent signals in low density areas, roads etc. This has not been fully addressed by the UK regulator and the operators, though of course service coverage has improved. As the total traffic required is low and supplements normal usage, satellites could be a very useful addition. This will help many countries.

Fixed broadband coverage is also poor in remote areas in UK and many countries. Satellites cannot cover more than a small number of such premises, with fixed-line type usage.

The major take-away is that the subscriber numbers are a small fraction of actual fixed or mobile numbers in UK or USA type countries. This confirms that satellites are no threat to the existing F&M players. There is not the capacity to carry more than a tiny percentage of the traffic.

Some 360,000 UK users making 10G/month mobile-like downloads is negligible compared to the total mobile subscriber numbers. So less than 0.5% of customers could be substituted for. This emphasises the fact that satellites CANNOT realistically substitute even a significant percentage of mobile traffic, and even less of the fixed-line traffic. The service is an additional one for the remote/unserved areas.

Small volume users, ~1Gbyte/month, can be addressed. This is clearly significant for remote areas. Remote monitoring and occasional-use, is a significant market.

Small volume usage is typical in emerging markets. So adding this service there, can be a huge benefit for the many unserved people and areas: the potential number of such subscribers is significant – 10x the numbers shown above for 10G type users.

The same results can be verified “in reverse” using Ofcom 2019 mobile data[5] that showed 3291Petabytes in 2019. This requires about 380Gbit/s per satellite, which is totally unrealistic, even with this 2019 mobile-user traffic of less than 3.5Gbyte/month. Only a small percentage of the future mobile market is possible via satellite.

[5]Ofcom Telecommunications Market Data Update Q4 2019. Note the mobile-user traffic was less than 3.5Gbyte but we consider in this report’s analysis near future mobile-type user traffic to be 10Gbyte/month to reflect growth and eliminate the many very-low volume SIMs (many not used for any significant broadband). This 10G value is in line with leading countries in tefficient data

3 Deeper implications of the analysis

The potential for satellites is clear in the above analysis. This is large globally with low usage and should provide a business case for the satellite operators. This is especially true if a price premium can be used – because there is often no economic way to get mobile masts or fixed line services into many regions.

We have not examined addition services, say to islands or to aircraft or corporates. These are useful additional service increments to the main basic-broadband service analysed here.

The numbers and thinking presented here is not intended to be precise, but it enables strategic appreciation. Experienced telecom business leaders and consultants should know the market demands and so the conclusions should have already been known even if the exact numbers were not known. This report's author had the same conclusions before this analysis was formalised. Less experienced analysts should be all be able to make their own similar market/demand modelling to verify the satellite potentials and limitations.

Bigger concerns are why new claims for satellites are still being made, to the effect that F&M operators will be significantly impacted. This report shows that this cannot be the case in most developed Internet economies. Additional capacity in under-served areas is a good outcome and should be welcomed by the existing F&M players as they have less obligations to invest in these marginal areas. This outcome is good for consumers and regulators, and so benefits the national economy. More broadband is good for everyone. Certainly this *impacts* the F&M players, but not in a bad/serious way. So why the alarmist claims?

Analysts and junior consultants should:

- Never take headline reports on satellites or other telecoms subjects at face value. They may be wrong. It is easy to identify "fruitcake" claims, but erroneous claims and analyses now seem to be more common – these can be harder to identify
- Always have an understanding of the technical/market and demand numbers. Fundamental laws of physics and traffic cannot be broken and need to be applied to the situation
- Check claims and make your own analysis. Too many claims are repeated. This is difficult to identify as even some seemingly reputable sources may be wrong. Always have your own analysis and develop an appreciation of the source data and the fundamental principles
- Beware of some traffic calculation methods
    - Data traffic is best modelled by the average data rate. Circuit switched methods that consider services as numbers of "50Mbit/s services" do not reflect how many networks operate
    - Physical service speed is often not a good basis for analysis – the 50Mbit/service might only be used for a few minutes in the hour. Erlang theory does not apply to shared packet-based networks, in a simple way. [NB Telzed has used Erlang type methods to derive similar customer numbers as above, but it needs different definitions of traffic. This similar result is expected as, with many customers, different statistical traffic models

usually converge]. For similar reasons, contention ratios or over-sell factors are often *not* good traffic models in broadband/packet-based calculations

- Numbers of simultaneous users is also not useful in most cases (think: a 200Mbit/s mobile mast can only have c10 customers downloading at 20Mbit/s at the same time, but in reality, it copes with c1000 customers).

Senior management should:

- Be careful of how the work is carried out
- Double check claims and reports before they are released
- Be careful with the need to sell a report or make an impact that can lead to false statements or misleading ones. It may not be very exciting to report that only limited market penetration will happen but if that is the conclusion or is clear in source-data, then such facts should be reported, Do not over-hype the results to support a given agenda
- Already know the main results of this report, at least in general terms
- Be especially careful if the client demands a certain outcome.

Legal experts and **regulators** can take lessons from this analysis and the history of claims:

- Be careful that any expert and supporting resources fully verify the evidence used back to source. "Company X claimed Y" may not be a factual point that should be used. Y might not be realistic
- Ensure that the references to a report are indeed sound. Quoting evidence that itself is based on weak data can undermine the rest of a report
- Beware that some seemingly sensible sources might not be robust
- Look at other reports from a source: this could indicate that there is a poor approach within the business. One report that is based on dubious data could weaken the results in another relevant report. This is especially true if there is any possibility of the same team working on the relevant report. Even if not the case, errors elsewhere diminish the reputation. This can undermine a case.

It is re-iterated that satellites have a viable business. The potential is huge and the market is global. The technical aspects of the satellites and the rocket science that lowers costs, are pioneering. This will probably make the services viable this time[6]. This still cannot compensate for the fundamental limitations of satellite capacities and numbers. This ensures that **satellites cannot carry major portions of existing fixed line traffic. They even struggle to carry major portions of mobile traffic. The real services have to be focussed more on market areas not already fully addressed – rural, remote, underserved, and difficult/expensive to address areas.** These conclusions are based on physical network limitations that also are behind why Elon Musk confirms the same points.

[6] This remains to be proved. Satellites services have often failed in the past. The recent Oneweb history shows how difficult the business still is

A number of other market opportunities exist, but are not covered in this report. **Existing fixed and mobile operators need not be worried about significant loss of market share to satellites.**

Please contact Telzed for further advice and help if needed

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