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Satellites Intersects Enterprise Private Wireless Network

Cost Analysis and Evolution Prospects

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Introduction

The satellite and cellular industries have long progressed along parallel tracks intersecting where their complementary nature made it economically feasible. This did not happen often because the price of data backhaul made satellite communications a technology of last resort. However, both satellite and cellular technologies are evolving to improve performance and reduce cost. This promises to enable new deployment possibilities, chiefly among them are enterprise private networks in remote areas.

To understand the new possibilities, we developed a financial model to assess the costs of enterprise private wireless networks and to evaluate different design options for cost optimization. In this paper, we present the results of our analysis for a private wireless network deployment in a remote open area similar to an open-pit mine or a campus. This scenario provides a cost ceiling as other types of deployments, such as those indoors, have a lower cost. We preface the analysis with an overview of key trends in the satellite and cellular industries, and discuss integrating satellite and cellular communication networks – an area under development at the intersection of 5G and emerging low-earth orbit satellite constellations for broadband and IoT services.

This paper was born out of our activities in both the cellular and satellite sectors where we noticed a large divide between the two industries. We address the paper to three types of audiences: a. The satellite service providers who are looking to leverage developments in cellular; b. The wireless service providers, including those targeting vertical markets and neutral hosts focusing on enterprise applications; and c. Enterprises who look to implement connectivity solutions to service applications in the energy, mining, transportation and rural connectivity sectors.

Evolution of Satellite Services

The satellite industry generates most of its revenue from TV and radio broadcast services which in 2018 accounted for 79% of $126.5 B in total service revenue [Bryce Space & Technology]. However, broadcast revenue is eroding in favor of bi-directional Internet services that are increasingly in demand to serve different use cases such as aviation, maritime and remote communities.

To meet the changing demand requirements, the satellite industry introduced high-throughput satellites that operate in high frequencies such as the Ka-band (27 - 40 GHz). These satellites use multi-beam antennas to increase frequency reuse and provide capacity on the order of tens of giga-bits per second. Medium-earth orbit satellites (MEO) reduce the service latency of geo-stationary (GEO) satellites from about 500 msec round-trip delay to about 150 msec. As the economics of launching satellites continue to improve, low-earth orbit (LEO) satellites promise to further reduce latency to between 70-100 msec while providing capacity reaching into the terabits per second. Consequently, the price of satellite backhaul services has been declining. This, coupled with new pricing schemes by satellite service providers is making the business case for satellite services more affordable than ever before.

Evolution of Cellular Technologies

The mobile wireless industry has reached saturation in coverage and number of subscribers. Yet, despite its success, revenue growth is relatively stagnant: according to the GSMA revenue is expected to grow at 1.4% from $1.03 T in 2018 to $1.13 T in 2025 based on IoT and 5G services [GSMA, The Mobile Economy Report, 2019]. To improve their financial standing, mobile network operators (MNOs) are increasingly looking to monetize new services including enterprise services. MNOs are already in the process of implementing technologies that allow them reduce operating costs and introduce new services to market.

To meet the business challenges, cellular networks are transforming through network function virtualization (NFV) and software defined networking (SDN). The economics of these technologies allow for greater distribution of network functions to enable new deployment models. It is now possible to cost-effectively scale down in size networks based on 4G (LTE) and 5G technologies to meet the requirements of enterprises who typically have a few hundred users in one location.

In parallel to technology evolution, regulators are enacting new spectrum rules that allow enterprises operate their own networks independent of the telecom service providers. The two primary examples today are the Citizen Broadband Radio Service (CBRS) band in the United States (3.55 - 3.7 MHz) and the 3.7 - 3.8 GHz industrial band in Germany. In the US, 80 MHz of the 150 MHz band is allocated to general use on an unlicensed basis, whereas the remaining 70 MHz will be auctioned in June 2020 over relatively small county-sized areas. In Germany, a few large enterprises, such as Bosch and Siemens, have already submitted applications to purchase parts of the 100 MHz band for use in industrial automation at their facilities.

Virtualization is also enabling new deployment scenarios and business models for private wireless network. One model is cloud-based core infrastructure that leverages cloud-native technologies based on microservices. Coupled with an opex-based business model that reduces initial costs, enterprises have lower barriers to deployments.

Deployment Scenario

Market, technological and regulatory developments are converging to enable the deployment of enterprise private wireless networks. Yet, the commercial success for these networks will depend on the value proposition they offer the enterprise, specifically improving productivity and lowering cost of goods sold. As the value proposition is highly contextual, our quantitative cost analysis is only one part of the economic thesis. The benefit part of the thesis would have to be addressed in an enterprise-specific context.

We designed the financial model around the case of an outdoor LTE private wireless network covering an area of 25 sq. km (Figure 1). This size is representative of an open-pit mine, but could also be for a campus deployment in a remote area. In our scenario, coverage is the limiting factor: the demand on capacity is less than the total that the network provides. We designed the wireless network to mount compact base stations (i.e. small cells) on 25 m towers which provide a coverage radius of 658 m in the 3500 MHz frequency band. The peak and average capacity per base station is 93.8 Mbps and 28.2 Mbps, respectively.

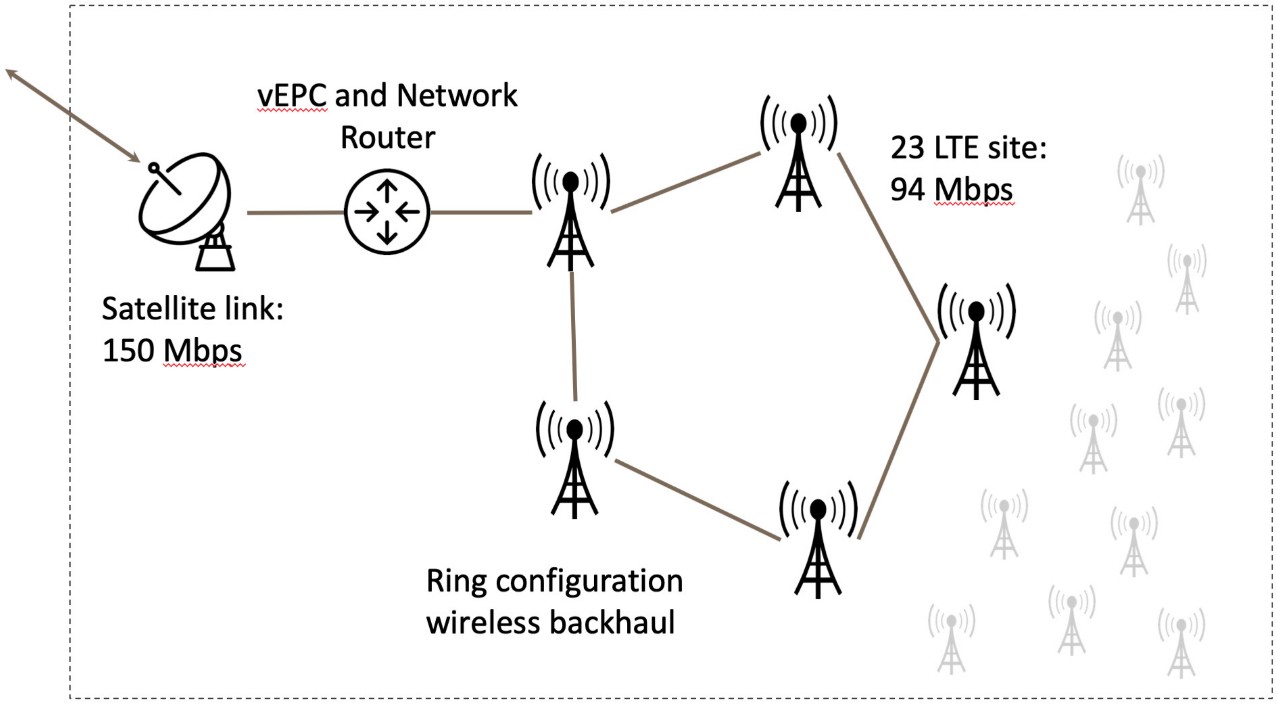

Figure 1: Network deployment configuration.

The LTE cells interconnect through terrestrial wireless backhaul in a ring configuration. Connectivity to the Internet is via a satellite link operating in the Ka band which uses a 1.2 m diameter antenna. A virtual evolved packet core (vEPC) which controls the LTE network includes the necessary enterprise service features such as voice calling and local traffic breakout so that only communication with the outside of the network is carried over the satellite link. We opted for this architecture as opposed to the one where the vEPC is integrated into the base station because of feature and cost purposes. We factored for 78% of the total traffic to remain local, so only 22%, not exceeding 150 Mbps, passes over the satellite link. Table 1 summarizes the deployment parameters for the network.

Table 1: Summary of key network deployment parameters.

Coverage area, sq. km	25
Number of cells	23
Frequency carrier, MHz	3500
Channel bandwidth, MHz	20
RF output power, per antenna, W	5
Antennas, MIMO order	2x2
Access mode	TDD
Cell height above ground, m	25
Cell radius, m	658
Peak throughput per cell, Mbps	93.8
Average throughput per cell, Mbps	28.2
Maximum traffic transported over satellite, Mbps	150

Cost Assumptions and Financial Summary

Capital expenses account for the cost of equipment, installation, testing and commissioning services for all the network elements and ancillaries required for operation. Table 2 summarizes the LTE network capex, and Table 3 summarizes the satellite backhaul capex.

Table 2: Capital expenditures for the LTE private network.

LTE base stations and vEPC	$373,600
Terrestrial wireless backhaul	$138,000
Ancillaries and fixed assets (cables, connectors, poles, mounting hinges, grounding kits, shipping to site, etc.)	$126,500
Sub-total - physical assets; LTE & terrestrial backhaul	**$638,100**
Power to LTE base station locations	$46,000
Construction & buildout	$110,400
Test, configuration & commissioning	$127,900
Project management & network design services	$268,170
Sub-total - non-physical assets; LTE and terrestrial backhaul	**$552,470**
Capex: LTE & terrestrial backhaul	**$1,190,570**

Table 3: Capital expenditures for satellite backhaul.

Remote VSAT; up to 150 Mbps; 20W; includes antennas, ancillaries, and spare elements	$15,000
Site survey, preparation & construction	$11,100
Test, configuration, commissioning, and service activation fee	$14,550
Capex: Satellite backhaul	**$40,650**

The total capital expenditure for the entire network is $1,231,220.

We did not factor the cost of spectrum in this deployment scenario. Spectrum costs are typically capital expenses, but may also be a recurring expense depending on the market. As we stated earlier, it is possible to operate in 80 MHz of the CBRS band in the United States at no cost. In Germany, the cost of leasing 20 MHz of spectrum for 10 years over a similar area is €26,000, which is additive to the total network cost of ownership.

The operational costs summarized in Table 4 include the satellite backhaul capacity lease and recurring energy expenses, equipment warranties, software licenses, and support and maintenance expenses. They amount to about $224 k per year.

Table 4: Annual operating expenses for LTE private wireless network with satellite backhaul.

LTE & terrestrial backhaul opex	
Power - LTE & terrestrial backhaul equipment	$11,406
Vendor support & maintenance license fees	$67,908
LTE & terrestrial backhaul opex	**$79,314**
Satellite backhaul opex	
Capacity lease: $75/Mbps/month; 150 Mbps	$134,844
Vendor support & maintenance license fees	$13,125
Power - satellite equipment	$350
Satellite backhaul opex	**$148,319**
Total Operating Annual Expense	**$227,633**

The total cost of ownership over 5 years would be $2.37 m of which capex accounts for 52% ($1.23 m) and opex accounts for 48% ($1.14 m) as shown in Figure 2

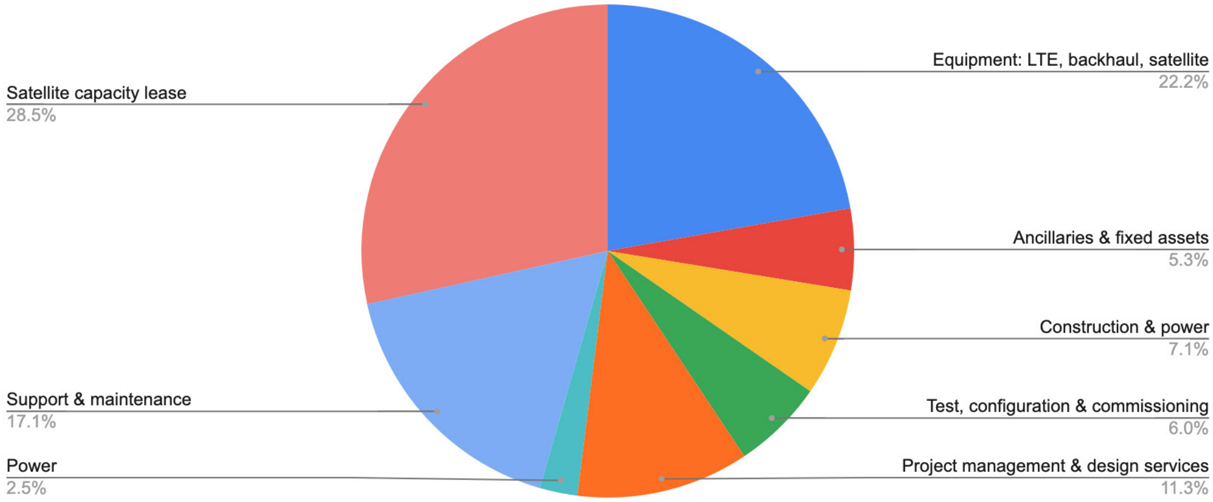

Figure 2: Total cost of ownership over 5 years for LTE private wireless network with satellite backhaul.

Observations and Takeaways

The LTE private wireless network dominates the capital expenses while satellite capacity lease dominates the operating expenses. This is primarily as we provisioned for 150 Mbps for the satellite link based on total average network capacity of 649 Mbps, of which 506 Mbps is local.

The cost structure puts the focus on the wireless technology first as the enterprise seeks to evaluate the cost-benefit equation for the terrestrial component. On the other hand, the satellite component has to be justified in terms of continuing operations where no lower cost option is available.

Unsurprisingly, reducing the cost structure makes it imperative to minimize the amount of traffic over the satellite link. This is possible by using different technologies such as local cache and edge computing to minimize data transfer to the cloud. The use of edge computing to balance the distribution of workloads and data transfer between the edge cloud and the centralized cloud is among the key emerging technology areas as enterprise increasingly leverage cloud services.

In this scenario, we had to rely on MEO-type service because it aligns with the network capacity requirements. For higher throughput, we would need to wait for next-generation MEO satellites or for LEO constellations which are in the process of being launched. We expect that by 2022, the price of satellite backhaul capacity would be further below our assumption of $75/Mbps/month as new constellations enter service. This would not only impact the opex, but also the capex related to satellite equipment as we anticipate higher equipment volume will reduce their price.

Different types of cost optimization are possible depending on the pricing of satellite backhaul and layout of the network. In the case where the area is much larger and sparse than our scenario, it may be economical to implement direct satellite connectivity to the base station. In this case, the technical requirements to provision for a peak of 93 Mbps results in prohibitive cost. However, new pricing models from satellite service providers to pool connections would help to reduce the total cost to a manageable figure. Additionally, as the cost of satellite communications comes down, implementing a direct transport becomes more cost effective.

5G versus 4G

MNOs are in process of deploying 5G for broadband applications in a few markets such as Korea and the United States. Moreover, 5G enables enterprise use cases to help service providers augment their revenues. This raises the question on how 5G impacts the cost structure of enterprise private wireless networks and how performance will compare with LTE.

While these questions require more space than this white paper allows, we summarize a few of our insights:

- 5G could reduce latency practically to sub 5 msec, reaching 2 msec in certain cases where the network and application are highly optimized. In comparison, LTE could practically reach 20 msec. How the enterprise values latency is strictly a function of its applications.
- The 5G ecosystem for enterprises not yet developed as LTE which is mature and offers lower price points. It will be a few more years before the 5G cost structure reaches that of today's LTE prices.
- Connecting IoT devices and sensors is a key enterprise application as seen today in different verticals such as energy, mining, transportation and others. LTE support NB-IoT technology which allows connecting devices over a long range while consuming low power. IoT connectivity on 5G exceeding the capabilities of NB-IoT is scheduled for Release 17 with estimated deployment timeline of 2023 at the earliest.
- LTE and 5G offer a similar implementation paradigm for local private wireless networks that operate in isolation of the MNOs. 5G is better suited than LTE for MNOs seeking to penetrate the enterprise market, because 5G is more flexible than LTE in distributing network functions.

The last point has an impact on the cost of enterprise private networks as service providers look for recurring revenue in exchange for network services. This mandates less capex for the enterprise to justify an increase in operating expenses. To implement such model, the MNO has to justify the recurring cost by providing value-added services to the enterprise.

Future Developments: Satellite-Cellular Intersect

Efforts to integrate cellular and satellite technologies are accelerating with satellite companies taking an active role in 5G standardization activities at the 3GPP. The 3GPP identified 12 different use cases of how 5G and satellite can integrate to form a hierarchical network; but more exist. The current plan schedules satellite-related features for 3GPP Release 17.

While integration of satellite communications into 5G is an important area of activity, we cannot give it its full dues in this paper. However, we present the following elements as being critical to this activity:

a) Spectrum decisions relating to 5G should consider current and future satellites (high, and very high throughput satellites of different orbits).

b) Support multicasting in 5G specification to take advantage of satellite capabilities.

c) Incorporate intelligent routing, dynamic cache management, adaptive streaming and quality-of-service features across networks to optimize the use of different transmission technologies in the network for different types of content, for example, latency sensitive vs. latency insensitive and high bandwidth vs. low bandwidth.

d) Incorporate SDN and NFV technologies into satellite networks and harmonize them with those implemented in cellular technologies.

As a concluding remark on the future prospects of intersects between satellite and cellular communications we note a number of emerging applications in the shipping, maritime and aviation sectors that offer good immediate opportunities for the two industries: communications on the move for persons and devices is one of the sweet-spots for this intersect.

Conclusions

Technology and market evolution are reducing the cost of private wireless networks and satellite backhaul communications. Our analysis of the cost of private wireless networks in remote areas, identifies the terrestrial network capex and satellite backhaul opex as having the most impact. Future network evolution will reduce pricing as more satellite capacity is projected to become available within the next 2-3 years. Moreover, enterprises have different options of terrestrial network architectures and technologies to choose from to optimize the cost structure.

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