Routes to Market Report

28 - Satellite Technologies for Seamless Personal Communications

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CATAPULT Satellite Applications

Contents

1. Introduction and Scope

- This market briefing examines the role of satellite communications in the evolution of mobile communications towards 5G, considering the widely varying opinion on the goals for 5G – another quantum leap in data speeds, or a seamless and ubiquitous service offering *consistent connectivity*.
- The briefing will explore the effect of *Mobile Edge Computing* as a disruptive technology capable of enabling adoption and growth of satellite communications in the hitherto lightly penetrated the mobile backhaul market.
- The briefing's recommendations are applicable to all geographies, with an emphasis on use cases that address rural coverage, both in mature and developing markets.
- Consumer, Enterprise and Public Safety markets are examined. The Defence sector is out of scope.
- The briefing covers the period 2016 to 2020 (near term) and then provides an outlook to 2030 (longer term)

2. Market Overview and Opportunities

2.1. Market Dynamics in Mobile Communications – another quantum leap to 5G?

The mobile industry does not evolve incrementally. It tends to leap forward roughly once per decade with a new "generation" (G, for short) of technology. Analogue systems in the 1980's were followed by digital in the 90's (2G), internet protocol in the 2000's (3G) and mobile broadband in the 2010's (4G). Since data took over from voice (late 90s i.e. mid/late 2G era) as the main driver for network evolution, each of these generations has been increasingly optimised for data communications, bringing us ever faster download speeds.

Each decade has brought us a new G. What then should we expect from the 2020's if not another G of course – 5G! But what does 5G consist of – what is it trying to achieve? There is no shortage of suggested use cases for 5G. Billions of devices in the Internet of Things, augmented reality, driverless cars, 4K video, robotic control for Industry 4.0, remote surgery. But there has also been much heated debate recently about the business case for 5G. Respected contrarians such as William Webb, writing in his "The 5G Myth"[1] have led a backlash, challenging the commercial viability of another complete overlay of infrastructure, criticising the definition of 5G as yet another leap forward in headline data speeds and claiming instead that a goal of "consistent connectivity" is both more pragmatic and ultimately more likely to satisfy the needs of a greater portion of the customers – both consumers and enterprises.

2.2. Consistent Connectivity - the real goal for 5G?

Instead of a new 5G air interface standard designed to meet a tiny subset of the population consuming vast quantities of broadband content or engaging in new super-low-latency applications (AR, VR, V2X, 2actile Internet) in dense urban areas, "consistent connectivity" instead envisages ubiquitous, seamless connectivity achieved through a hybrid approach involving fixed broadband, licensed cellular and unlicensed WiFi. Such an approach – it is argued - could ostensibly provide a ubiquitous connectivity layer that extends broadband communications and rich applications and services to rural areas and covers all transport arteries including road, rail and sea.

There is nothing new about the idea of combining multiple access technologies in this way to form heterogeneous networks (het-nets). However, the challenge lies in making the experience seamless in multiple dimensions: a seamless experience requires more than slick inter-technology handovers to merely stay connected. It also demands that the characteristics of the user experience remain seamless during and after handover events - so that applications can survive being moved between mobile, fixed and WiFi access networks, without interruption of service or fall-back to a lower grade of service.

This definition of "service seamlessness" should not only be applicable to traditional voice, messaging and browsing services, but also to an increasingly wide range of popular services which are heavy in their bandwidth consumption (e.g. HD video) or stringent in their latency requirements (e.g. augmented reality).

2.3. Current perception of Satellite Communications

Currently, satellite is not generally part of the vision for seamless personal communications today because of a perception that its limited & expensive bandwidth together with its large latency budget would preclude "service seamlessness" (i.e. a uniform quality of experience no matter where the user is located) for a growing list of services that are becoming increasingly important – especially to enterprise customers.

The performance of mobile networks is constrained by the end-to-end latency and the bandwidth of the end-to-end connection. "End-to-end" refers to the chain of connectivity - from the air interface which connects a mobile phone or tablet to the nearest serving radio base station or tower, through the "backhaul network" - the plumbing which connects thousands of radio base station sites to the mobile core network, on to the interconnect with other fixed and mobile networks, the internet and the cloud.

2.4. Why is Latency so critical?

Mike Belshe of Microsoft published a report in 2010[2] which showed the direct correlation between network latency and web page download times. Interactive applications are similarly affected by latency, becoming unusable.

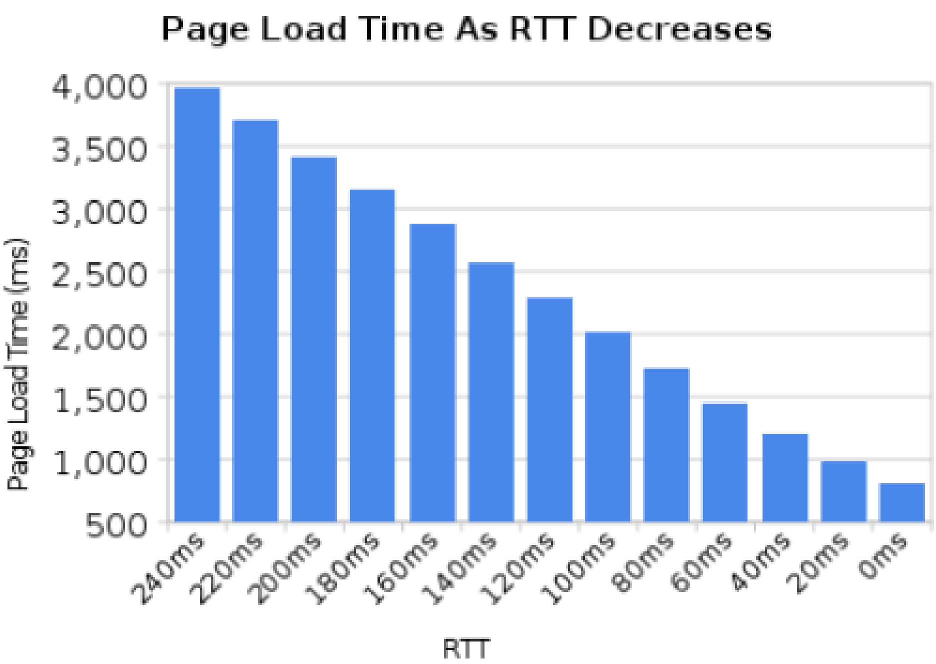

Fig. 1 The effect of network latency on web page download times[2]

Why does this matter? Users are impatient – and they are trained to expect good performance when connected via fixed, wifi networks and terrestrially backhauled mobile networks. Google has cited Kissmetrics' surveys that demonstrate that "*A one-second delay in page response can result in a 7%*

reduction in [advertising click] conversions." along with *"47% of consumers expect a web page to load in two seconds or less."* [3,4]

2.5. Mobile Backhaul using Satellite Communications – fit for purpose?

Often, the weakest link in the chain from a bandwidth perspective is the backhaul domain. This is already true of terrestrial backhaul, especially when microwave radio links are chained into long chains or rings. When the backhaul domain includes a satellite segment, the bandwidth bottleneck is dramatically constrained and the latency budget is affected drastically. The latency at the mobile air interface has been reduced in each generation of mobile infrastructure so that a typical round trip response time (mobile to cloud to mobile) for a terrestrially backhauled 4G LTE mobile network might be expected to be between 60-100ms. Low earth orbit (LEO) satellite systems, while exhibiting lower latencies, have also tended to support very low bandwidths and thus have not targeted the mobile backhaul market, instead historically focusing on the satellite phone market. High Throughput GEO satellite space segments operating in the Ka band offer greater bandwidths (however still far short of typical terrestrial backhaul) but their biggest problem is that they add an additional RTT delay of at least 500ms. Even in the case of medium earth orbiting (MEO) solutions, a space segment RTT of 150ms is to be expected. The effect of these delay budgets on Quality of Experience - particularly for interactive data applications, coupled with the unit cost of bandwidth have been the major barriers to widespread adoption of satellite mobile backhaul.

And yet the promise of ubiquitous coverage, and therefore the ability to create a blanket connectivity overlay across large geographical areas remains attractive to mobile network operators - if only the unit cost and latency of satellite backhaul could somehow be transformed.

2.6. Mobile Edge Computing as an enabler for Satellite Backhaul transformation

In recent years, a re-examination of mobile network architecture has resulted in the development of a Mobile Edge Computing (MEC) framework, currently undergoing standardisation by the European Telecommunications Standards Institute. The Industry Standardisation Group (ISG) for MEC is now in its third year of work to define MEC standards and drive interoperability.

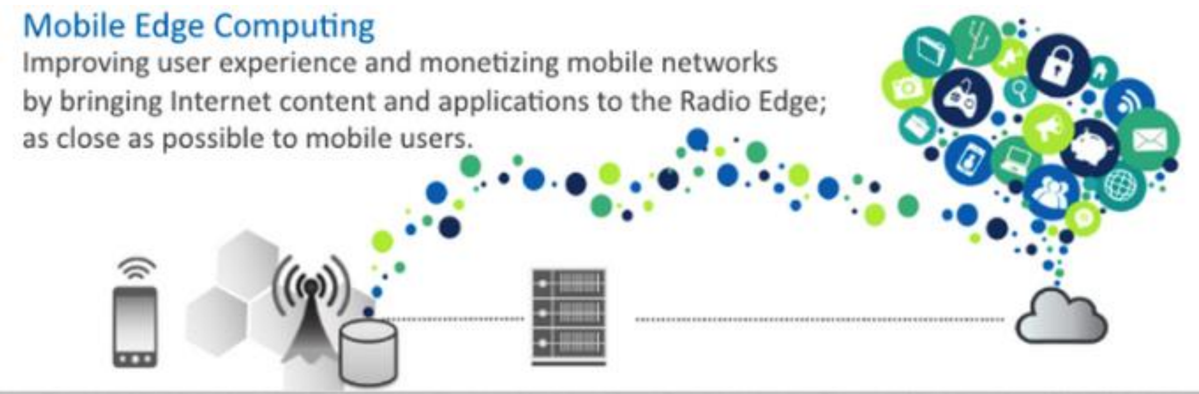

Fig. 2 The goal of Mobile Edge Computing[5]

The purpose of MEC is to host popular content and latency-sensitive applications at the edge of mobile networks, near the served users, and on the users' side of the major bottlenecks and sources of latency in the backhaul, core and internet segments of the end-to-end path. MEC consists of hardware and software that is either deployed as an overlay or is tightly integrated with an existing element such as a backhaul aggregation hub switch or router. MEC is a virtualisation environment capable of hosting many third party applications.

Use cases for MEC include edge caching of video content, edge hosting of IoT analytics processing, edge hosting of latency-sensitive augmented reality applications, edge hosting of emergent cloud computing microservices and serverless computing functions e.g. Amazon Web Services' "lambda compute" framework. In fact, MEC is tailor-made for any mobile application that - while needing to be internet-connected - could also benefit from ultra-low latency or avoidance of backhaul costs associated with heavy downloading of content.

As a UK-based example of MEC-enabled Satcoms early adoption, EE - in cooperation with Facebook's Telecom Infrastructure Project - has piloted a solution using a combination of Satellite Backhaul and Mobile Edge Computing to provide mobile broadband coverage and user experience to remote communities in the Scottish Highlands[6].

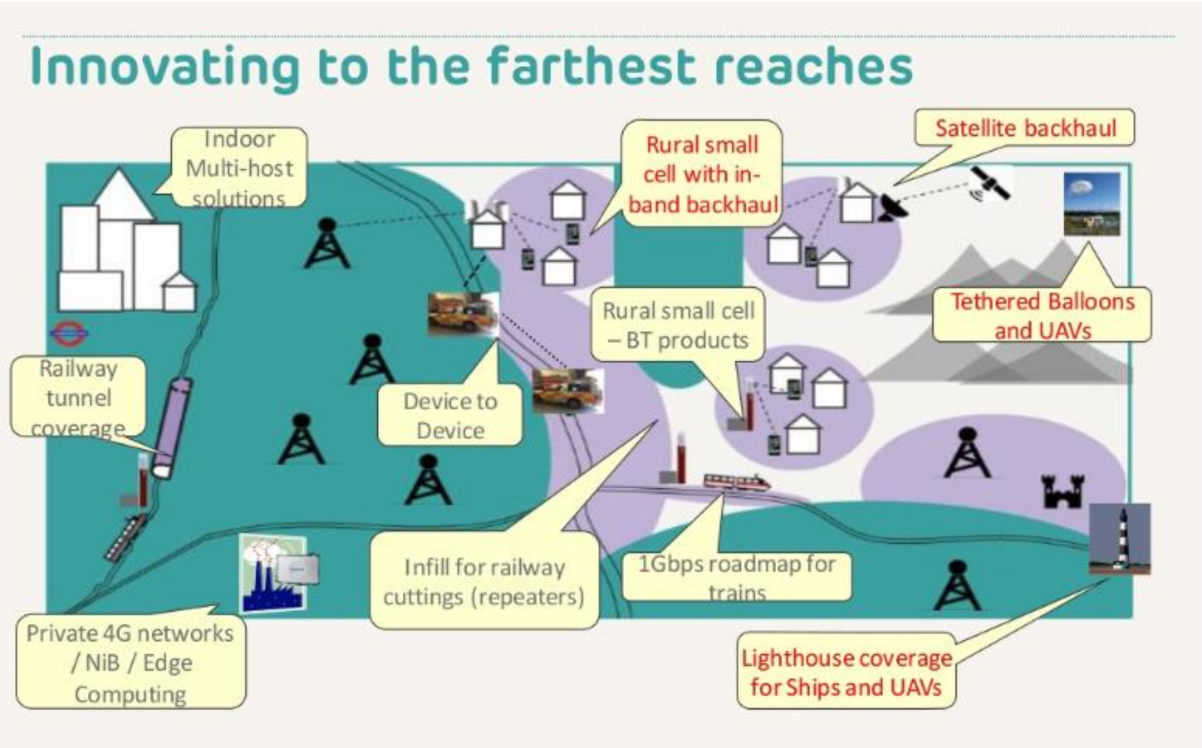

Fig. 3 Driving Connectivity in the Scottish Islands: Droneways and Airmasts, Mansoor Hanif, BT/EE, TIP Summit, Menlo Park, November 1st 2016

As a further example, Augmented Reality (AR) - much-hyped in consumer and gaming markets - is gaining significant traction in industrial applications. For example, PTC - who acquired Vuforia, the AR division of Qualcomm – has combined AR-based 3D mechanical inspection with its IoT edge analytics to enable field service personnel to view real-time assembly manuals as well as animated gauges displaying IoT sensor data, rendered on top of the real-world view of a piece of machinery undergoing maintenance or repair[7]. Instead of sending an expert from HQ – incurring time and expense - a local lower-skilled operative can now carry out complex maintence tasks in remote locations. Ultimately this type of combined AR/IoT solution has the capability to transform operational practices in fields as diverse as oil and gas exploration, roadside automotive repair and recovery, farming, logistics, public safety, ship-building and healthcare.

Fig. 4 AR/IoT/MEC for Industry 4.0 – combining visualisation of real-time IoT sensor measurements with 3D Augmented Reality procedures and instruction manual overlays

Imagine a field service engineer, sent to repair a combine harvester in a vast Kansas wheat field, where 4G cellular coverage is challenging. Satellite could be the backhaul connectivity of choice for providing coverage to such locations. However, to make use of the AR/IoT application there is a major challenge to overcome. If the realtime IoT data is being processed in the cloud, then - without an edge compute infrastructure such as MEC - the delay budget is too great, making it is impossible to synchronise visualisation of the data with the AR content, running locally on the engineer's mobile device. Furthermore as this type of industrial AR application evolves to use untethered lightweight AR headsets with limited battery, storage and processing power, a degree of computational offloading will become necessary in order to supplement the embedded compute and storage capacity of the headset. This offloading is a further driver for MEC, which helps drive the business case for adoption of AR/IoT for remote field service applications, which thereby become feasible for the first time over satellite-backhauled 4G/5G cellular networks.

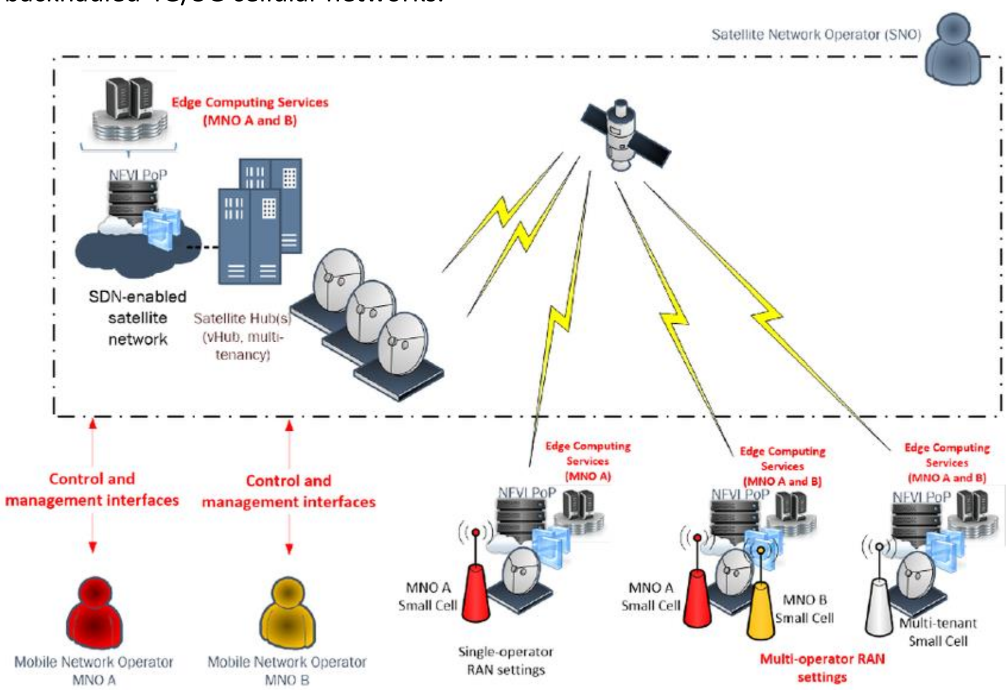

Fig. 3 Enhancing Satellite Mobile Backhaul using Mobile Edge Computing[8]

Current trials of MEC show the improvement in Quality of Experience (QoE) and the cost saving potential for MEC, even in conventional terrestrially-backhauled mobile networks[9]. The case for MEC in satellite backhaul is likely to prove all the more compelling, and apart from moving the needle on cost and QoE, it is even likely to make use cases viable over satellite backhaul that were previously unusable due to excessive latency (e.g. augmented reality) or prohibitive in terms of cost (e.g. HD video streaming).

3. Customer and Value Proposition to Customer and End User

The end customers fall into 3 broad segments, some of which will be further sub-divided:

1) The consumer
2) The enterprise
3) The public safety & emergency services

In the case of the consumer, there is almost no awareness of the technologies that are involved in providing mobile communications. The fact that satellite might play a role is very much hidden from the end customer.

Certain large enterprise customers in specific sectors are acutely exposed to the coverage and capacity "black spots" in today's mobile networks. Logistics, utility, oil and gas, maritime, automotive are all examples of industries that are intolerant of non-ubiquitous mobile coverage. The potential for blanket coverage enabled by satellite communications is more likely to resonate with this type of end customer – who in turn would lobby mobile network operators and governments to make more innovative use of space derived communications technologies to overcome the current cost and performance barriers to its widespread adoption as well as overcoming the need for specialist terminal equipment to directly access the satellite air interface.

The exposure to non-ubiquitous coverage and capacity, leading to an awareness of the potential role for satellite as a blanket connectivity overlay is even more acute for the public safety and emergency services sector. Personnel in rural locations may use satellite communications today but this is considered niche, expensive and far from seamless, in that specialist terminal equipment is required that is, at best, only partially integrated with the integrated services offered by the terrestrial public safety communications networks following the TETRA standard. Often satellite is considered a last resort, to be wheeled in for disaster scenarios when the mobile network itself has been damaged or overloaded. Rarely has there been an opportunity for satellite to form a significant part of the coverage solution under normal operating conditions.

It should be noted that whilst the end customers for satellite-backhauled seamless personal communications based on Mobile Edge Computing are the consumers, enterprise workforce and public safety responders mentioned above, the value chain serving those end customers involves: some 600+ mobile network operators globally; wholesalers of mobile backhaul (e.g. Verizon Business, BT etc); combined backhaul equipment/managed services providers (e.g. Ericsson, Nokia, Huawei, Accenture, Wipro etc); Network sharing joint ventures (e.g. CTIL and MBNL in the UK market); wireless towers companies in USA, India etc; and not forgetting of course those providing the nascent satellite backhaul offerings already present in the market (e.g. Gilat, Avanti, O3B etc). Some or all of these players may become involved in the supply chain of mobile backhaul augmented by MEC-powered satellite connectivity.

The proposition of Seamless Personal Communications is 3-fold:

- Offering the end-user ubiquitous coverage i.e. available everywhere that the user might travel,
- Offering the end-user consistent quality of experience, underpinning seamless service levels i.e. offering a quality of experience that is not degraded depending on the location,
- transformational unit cost structures for the space segment to drive adoption of satellite backhaul, achieved through intelligent positioning of content and services at the "edge" of the network i.e. on the user's side of the space segment.

The question of the proposition to the customer begs the more fundamental question of who is the customer. The most obvious direct customer for a MEC-enabled satellite backhaul offering might be the mobile network operators, like for instance EE/BT who are already starting to deploy MEC-enabled satellite backhaul.

Web-scale companies (Google/Facebook/Amazon) and content providers (Netflix/Youtube) have a vested interest in seamless, consistent connectivity and have demonstrated through various initiatives discussed later, their intention to innovate independently of mobile operators to achieve this. The complexity of how these webscale companies benefit from connectivity, despite not directly investing in it – and hence not having direct control over it – is one of the biggest techno-commercial conundrums of our time. The advent of a WiFi-first het-net approach to 5G based on a combination of licensed and unlicensed spectrum together with a neutral-host model for sharing/wholesaling network access infrastructure would disrupt the current deadlock which is hampering investments in network infrastructure. If such a het-net approach plays out in full, the potential customers of MEC-enabled satellite backhaul might become the neutral host wholesalers or the webscale companies themselves.

4. Market Competition

- Positioning Satellite in the backhaul domain requires the development of a robust business case to compete with the current and evolving backhaul technologies e.g. fibre; p2p and p2mp microwave; millimetre-wave radio self-backhauling and Ethernet managed services, often based in turn on a combination of the previous technologies at the physical layer.
- Nevertheless, the very existence of radical projects to explore alternative wireless access and backhaul technologies to serve remote areas – from Google's Loon balloons, to EE's backhaul drones, to Facebook's project ARIES – proves the inadequacy of the current backhaul options and the importance that the web-scale internet players and the mobile operators share in solving the rural connectivity challenge.

5. Role of UK Companies

- EE (now part of BT) has been a strong advocate of MEC – both in terrestrially backhauled network scenarios and – more recently – in GEO satellite-based scenarios to enhance the reach and resilience of EE's 4G LTE network as part of EE's plan to cover 95% of the UK landmass, a target very much linked with the awarding of HMG's Emergency Services Network (ESN) project to EE/BT.
- Satellite communications players such as Avanti Communications PLC are already deploying commercial solutions that include some elements of MEC within a GEO-based solution. (citation: EE/Gilat/Avanti PR)
- To the knowledge of the author, there has been no publicly announced trial or live deployment of MEC as part of a MEO-based solution. This is somewhat surprising, given that the combination of the lower inherent latency, further improved by MEC offers a far more

compelling prospect of "seamless experience" than GEO-based solutions. There is a potential role here for a UK player to take the lead.

There are a number of UK companies already active within the MEC ecosystem. Examples being Qortus, a vendor of MEC software and Jonesthefone Consulting, a specialist provider of consulting and advisory services to multiple players within the MEC ecosystem.

6. Revenue Projections

	2016 (Million USD)	2017 (Million USD)	2020 (Million USD)	2030 (Million USD)
Satellite Mobile Backhaul (enhanced by Mobile Edge Computing)	101	141	663	5,708

1) Satellite backhaul market size = % satellite backhaul market share x total mobile backhaul market size
2) Current % market share of satellite backhaul estimated at 0.5% of total backhaul market (estimate based on data sourced from an anonymous Tier 1 operator incorporating plans for a first phase of satellite backhaul to serve rural communities in a mature Western market - figures adjusted to take into account the greater penetration in emerging markets).
3) % market share of satellite backhaul assumed to grow from 0.5% in 2016 to 0.7% in 2017 to 2% in 2020 to 5% in 2030
4) Global mobile backhaul market sizes in 2016 & 2020 based on Markets & Markets' Mobile & Wireless Backhaul Market by Equipment, by Services – Worldwide Market Forecasts and Analysis, 2015-2020[10] (2017 and 2030 derived by interpolation and extrapolation, respectively – assuming CAGR 13.18% over the entire period)

7. SWOT Analysis

7.1. Seamless Personal Communications

Strengths	Ubiquitous (seamless) coverage of remote, unserved areas. Ability to cover highways and railway lines as effectively as rural communities
Weaknesses	Complexity, time to market and "ownership" of MEC node.
Opportunities	Leverage the synergies between a combination of drivers for seamless coverage and experience: IoT in specific verticals (energy, logistics etc) + seamless personal communications for enterprise & consumer + capture the refresh of public safety networks (e.g. HMG ESN project to replace aging TETRA network with 4G "virtual network" provided by EE – will it be the first of many?) responders
Threats	Price erosion of conventional backhaul, other "radical" approaches to serve rural areas (Google Loon, Facebook ARIES etc)

8. Opportunity/Blocker/Enabler

No fundamental technology changes are required to the space-side Technical development is needed to integrate MEC technologies into satellite terminal equipment.
The greater challenge lies in establishing a value chain that joins hitherto unconnected players whereby the satellite communications operator offers a MEC Platform as a Service (PaaS) model to allow the mobile network operator to self-provision content and applications onto each MEC node. This generates an opportunity for specialist consultancy and system integration.

The greatest value in revenue terms ought to stem from the new demand created by MEC-enabling satellite backhaul, thus meeting hitherto unattainable latency and unit cost targets that make the business case for viable market growth.

9. Market Dynamics

With a CAGR of 13.18% the mobile backhaul market is growing at a healthy rate. The voracious consumption of video content on 4G networks and the advent of 5G mean that this growth is unlikely to plateau in the foreseeable future. Satellite accounts for less than 0.5% of that market today. This report has highlighted the barriers that have impeded penetration of this market by satellite-based solutions and has posited the adoption of Mobile Edge Computing (MEC) as a way to address these inherent barriers.

10. Market Trends

The key stakeholders in the MEC market to date are Nokia, Intel, Huawei and Juniper on the equipment side and Vodafone, BT/EE and Docomo amongst mobile network operators.

- Alongside the major vendors and operators mentioned, there are are some notable startups in the MEC ecosystem: notably, Saguna, Vasona & Qortus.
- Webscale companies (Google, Facebook, Amazon) are watching MEC closely and some have engaged in join trials e.g. Vodafone/Google(Youtube)/Nokia throughput guidance trial (citation)
- The MEC supply chain is global, with innovation loci in Israel, China, US & Scandinavia
- Within the Space sector, there has been little awareness so far of the transformational potential of MEC, with the exception of the EE/Avanti/Gilat announcement (citation)

11. List of Abbreviations

5G	Fifth Generation Mobile Network
AR	Augmented Reality
CAGR	Compound Annual Growth Rate
ETSI	European Telecommunications Standards Institute
HD	High Definition
IoT	Internet of Things
ISG	Industry Standardisation Group
MEC	Mobile (aka Multi-access) Edge Computing
P2P	Point to Point
P2MP	Point to Multi-point
QoE	Quality of Experience
RTT	Round-trip time
TETRA	Terrestrial Trunked Radio
VR	Virtual Reality
V2X	Vehicle to Everything
WiFi	Wireless local area networking based on 802.11 standards

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