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WHITE PAPER

SATELLITE COMMUNICATION SERVICES:
An integral part of the 5G Ecosystem

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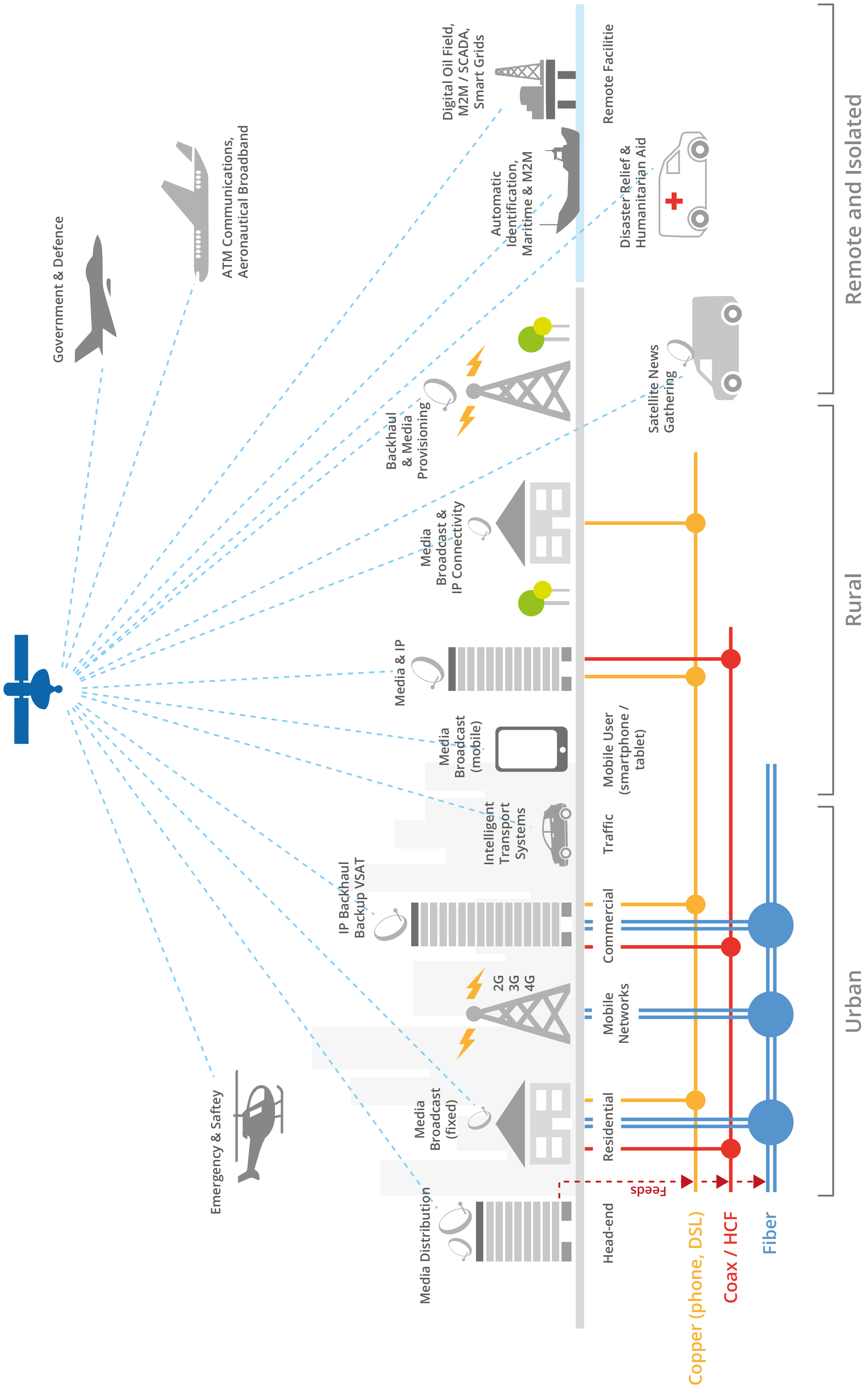
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Rural
Remote and Isolated

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Executive summary

Satellites will play a vital role in future 5G networks, and the benefits to users, including consumers, governments and industry, will come not from individual technologies, but from the quantum difference these services will make to mankind. ESOA's[1] members will make a valuable contribution to these cutting edge developments.

5G will be a network of networks - an ecosystem - with multiple technologies supporting a global infrastructure: satellite, Wi-Fi, small cells, and traditional mobile wireless networks, among others. Satellites have a particularly important role to play bringing services to users quickly, no matter where they are located and no matter the availability of terrestrial infrastructure. Satellites have three key characteristics that are critical for the success of 5G: wide area coverage, cost-effectiveness, and reliability (resilience).

Wide area coverage and reduced vulnerability of physical attacks and natural disasters allow space-based satellite networks to:

- Foster the roll out of 5G service in areas that cannot be covered by terrestrial networks (e.g. isolated/remote areas, on board aircrafts or vessels);
- Upgrade the performance of limited terrestrial networks in a cost effective manner in underserved areas (e.g. sub-urban/rural areas);
- Reinforce 5G service availability by providing service continuity for M2M/IoT devices or connectivity and autonomy of intelligent cars with software updates on board moving platforms (e.g. passenger vehicles, aircraft, ships, high speed trains, bus, etc.);
- Ensure service anywhere, especially for critical communications, future railway train communications, and maritime communications;
- Enable 5G network scalability by providing efficient global multicast/broadcast coverage resources for data delivery;
- Create a reliable and ubiquitous communication system that is both highly secure and economically viable.

1 ESOA is the "EMEA Satellite Operators Association," a non-profit organisation serving and promoting the common interests of satellite operators from Europe, the Middle East, Africa and the Commonwealth of Independent States (CIS). The Association today represents the interests of 21 satellite operators who deliver information communication services around the globe.

Introduction

5G is the next generation of wireless access technology that much of the world is moving towards. By supporting a world in which "anyone and anything will be connected at anytime and anywhere"[2] , 5G is expected to enable new applications in various domains, including entertainment, health, automotive, transport and industry. The advanced communications of 5G are expected to bring enhanced mobile broadband, ultra-reliable communications, and massive machine-type communications.[3]

This next generation network has been described as having significantly more capacity and higher user data rates than today's capabilities, so as to meet the growing demands of users. In addition, an important goal of 5G is to provide increased resilience, continuity, and much higher resource efficiency including a significant decrease in energy consumption. Finally, security and privacy will need to be ensured to protect users and the important amounts of data that will be carried across the network.

The following requirements are often referenced for 5G:

- 1-10Gbit/s connections to end points in the field (i.e. not a theoretical maximum);
- 1 millisecond end-to-end round trip delay (latency in the access network, implying that content must be located close to the edge);
- 100x bandwidth per unit area;
- 10-100x number of connected devices;
- (perception of) 99.999% availability;
- (perception of) 100% coverage;
- 90% reduction in network energy usage;
- Up to ten-year battery life for low power, machine-type devices.

No single technology will meet all of these needs, and not all of these characteristics will be required for every 5G application. On the contrary, as the European Commission and other governments around the world have correctly recognized, to be successful and meet user demands, the 5G infrastructure will be an ecosystem of networked networks, utilizing multiple different and complementary technologies.

2 See, for example: http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/573892/EPRS_BRI(2016)573892_EN.pdf

3 GSMA, "5G Spectrum: Public Policy Position" (Nov. 2016).

The Technologies of the 5G Ecosystem

▶ A Technology Neutral Ecosystem

5G is intended to significantly improve the lives of citizens who, in a globalized world, are increasingly used to having always-on connectivity on multiple devices for a range of different purposes no matter where they are.

It is well recognised that Internet access, whether fixed or mobile, fosters inclusion and brings social and economic advantages to people no matter where they live. 5G should not be reserved for the urban elite even though the reality of telecoms operators' business models will likely result in the most densely populated areas being served as a priority.

At the same time, many countries still suffer from a Digital Divide. If this DIgital Divide is not to become a Digital Chasm, then policy making, to achieve widespread 5G deployment needs to be ambitious. This ambition must not only ensure that 5G networks are rolled out in urban areas but also help combat poverty and provide opportunities in communities in rural areas in developed as well as emerging economies. In the European Union around 27% of all citizens live in rural areas.[4] Further, in the United States, 39% of rural residents do not have access to terrestrial broadband.[5] 5G policymaking therefore needs to be balanced, holistic and technology neutral, striving to bring the best connectivity to all areas, many of which today have little or no connectivity at all without use of satellite communications.

Accordingly, a technology neutral approach to 5G that enables an entire ecosystem with competition between platforms is critical. Without such an approach, the benefits of 5G will remain untapped for most people, leaving them excluded and left behind in a world that is racing ahead in its technological developments. Only layers of complementary networks that play to the strengths of different technologies will complete the 5G vision that policymakers have for tomorrow's connected communities.

The integration of several (at times currently separated) heterogeneous networks to reach extremely ambitious goals in terms of range of services, performance, availability and programmability will also serve to make the business plans of different vertical industries viable by allowing their services to be provided ubiquitously and with stability in the network.

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4 http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban_Europe_%E2%80%94_statistics_on_cities,_towns_and_suburbs_%E2%80%94_patterns_of_urban_and_city_developments (In 2014, 72.5 % of EU-28 inhabitants lived in cities, towns and suburbs)

5 https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2016-broadband-progress-report.

The Role of Satellite in the 5G Ecosystem

Many organizations, including the European Commission,[6] recognize that satellite networks will be a component of 5G infrastructure.

Not only can satellites provide ubiquitous, anytime coverage, but they can provide cost-effective coverage to many areas of the globe, which might otherwise go unserved.

Satellites are the only means to provide truly ubiquitous geographic coverage and mobility.

This feature is critical to the successful deployment and operation of 5G:

- Complementing connectivity for mobile nodes (ships, airplanes, vehicles and trains);
- Offloading a temporarily congested network;
- Providing backhauling services to fixed or moving base stations; and
- Providing emergency response/disaster recovery communications.

Satellites are inherently well suited to broadcast or multicast one-to-many transmission links, usually over long distances and large areas to multiple distribution hubs such as radio access points. Satellites can deliver very high data rate services in broadcast / multicast mode (e.g. data broadband connectivity and IP enabled video distribution via satellite) as well as in unicast mode.

Satellites today can deliver very high data (> 100 Mbps – 1 Gbps) in broadcast mode to outdoor radio access points for:

- High capacity two-way broadband services for complementary coverage to fixed or terrestrial wireless networks outside major urban / suburban areas;
- Direct delivery of linear / non-linear video transmissions TV / IPTV services to in-building fixed customers;
- Interconnection via 3G/ 4G / 4G+ / RLAN wireless access networks (for in-home / in-building distribution) for service delivery to in-building 'mobile' users.

The diversity of designs amongst satellite systems also contributes to their utility in support of the 5G ecosystem. **Increasingly, satellite systems deliver greater capabilities at lower costs by leveraging the particular characteristics of each system's global reach:**

- A single geostationary satellite can provide communications downlinks over wide areas, such as entire countries or continents, including to rural areas with no terrestrial connections. Further, a single satellite in geostationary orbit can deliver high-bandwidth, high-reliability services to a large number of connected devices, whether fixed or in-motion, simultaneously across a wide geographic region.
- Constellations of non-geostationary satellites can deliver high-capacity services to localized areas with the low latency that some applications require. Such satellites are operating already, with more constellations being planned for the 2020 timeframe, in time to participate fully in the 5G ecosystem.

Leveraging these varied strengths expands the range, capacity, and capabilities of 5G systems.

6 http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=17131

Satellite Use Case

Satellite-based solutions will be fluidly integrated in into Next Generation Access Technologies, enabling a broad range of use cases where the benefits of satellite can be leveraged.

Four broad classes of use cases that are immediately identified are trunking, back-haul, communications on the move and hybrid multiplay, each of which are explored in more detail below.

Trunking and Head-end Feed

This use case addresses high speed trunking of video, IoT and other data to a central site, with further terrestrial distribution to local cell sites, for instance neighbouring villages, as shown in figure 1.

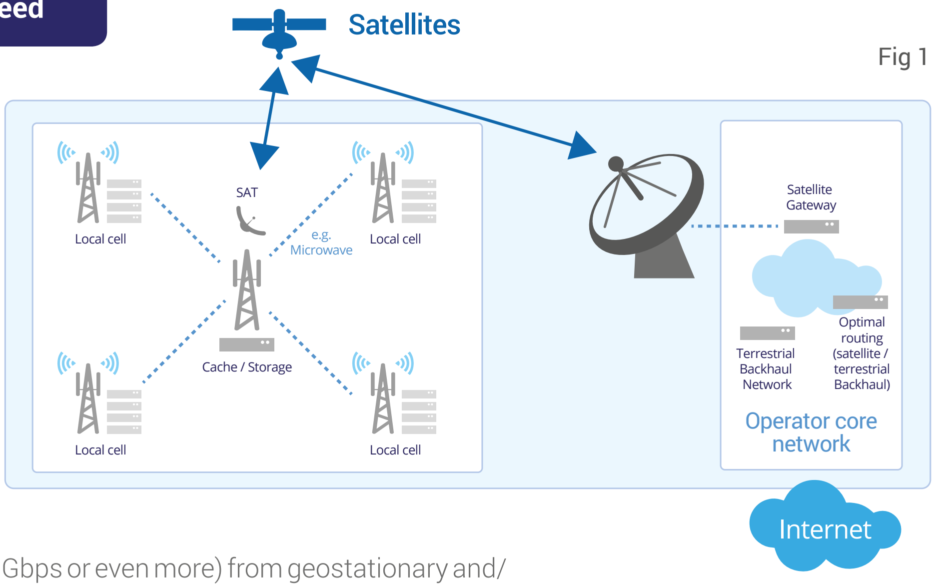


Fig 1

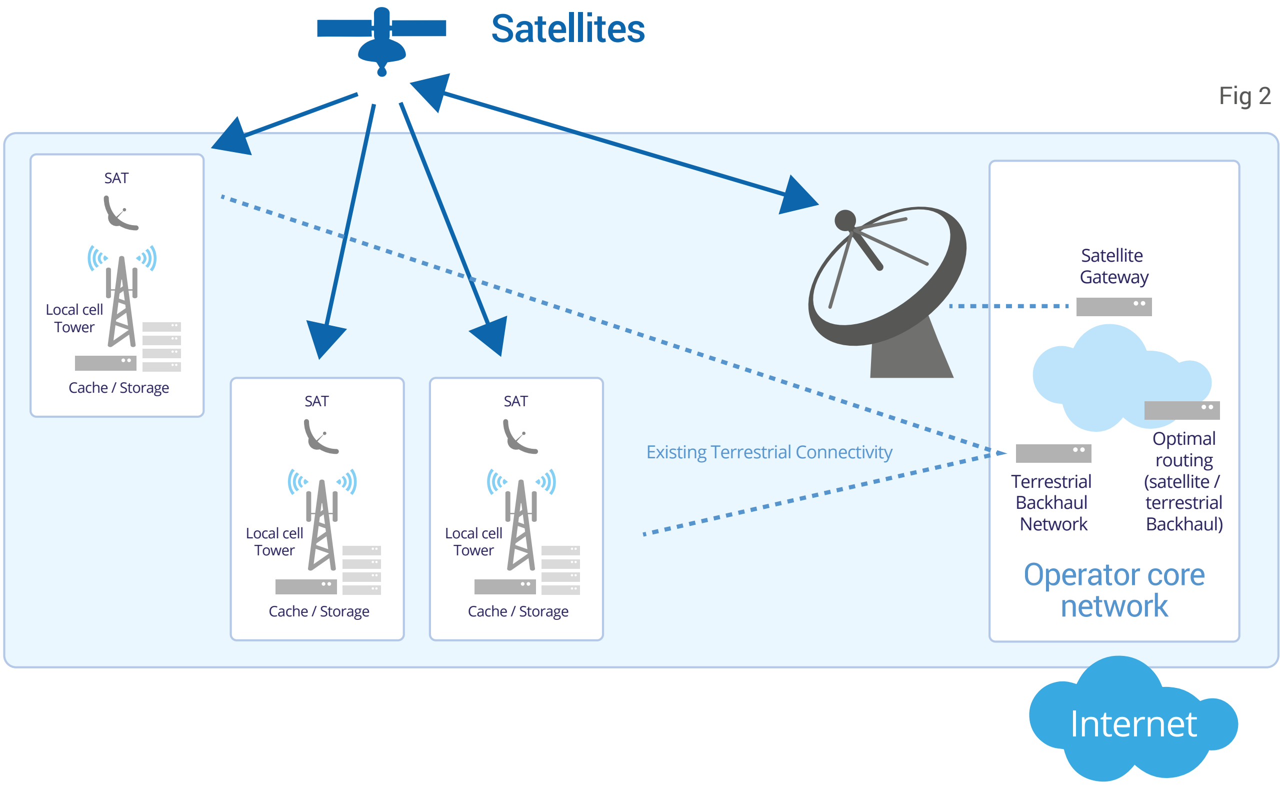
A very high speed satellite link (up to 1 Gbps or even more) from geostationary and/or non-geostationary satellites will complement existing terrestrial connectivity.

Examples of this Use Case include:

- Broadband connectivity to areas where it is difficult or not possible to deploy terrestrial towers, for example, maritime services, coverage on lakes, islands, mountains or other areas that are best or only covered by the satellites; across a wide geographic region.
- Disaster relief: During natural disasters or other unforeseen events that entirely disable the terrestrial network, satellites are often the only option;
- Emergency response: besides wide-scale natural disasters, there are specific emergency situations in areas where there is no terrestrial coverage. An example of this situation is public safety response following an accident in a power plant
- Broadband connectivity to tactical cells for mission critical communications;
- Broadband connectivity for network head-end;
- Secondary/backup connection (limited in capability) in the event of the primary connection failure or for connected cars. Enabling Over-the-Air Firmware and Software (FOTA/SOTA) services to get information updates, such as information regarding Points of Interest (POIs), real-time traffic, and parking availability ("infotainment").

Backhauling and Tower Feed

This use case is about high speed backhaul connectivity to individual cells, with the ability to multicast the same content (e.g. video, HD / UHD TV, as well as other non-video data) across a large coverage (e.g. for local storage and consumption), as shown in the graph below. The same capability also allows for the efficient backhauling of aggregated IoT traffic from multiple sites.



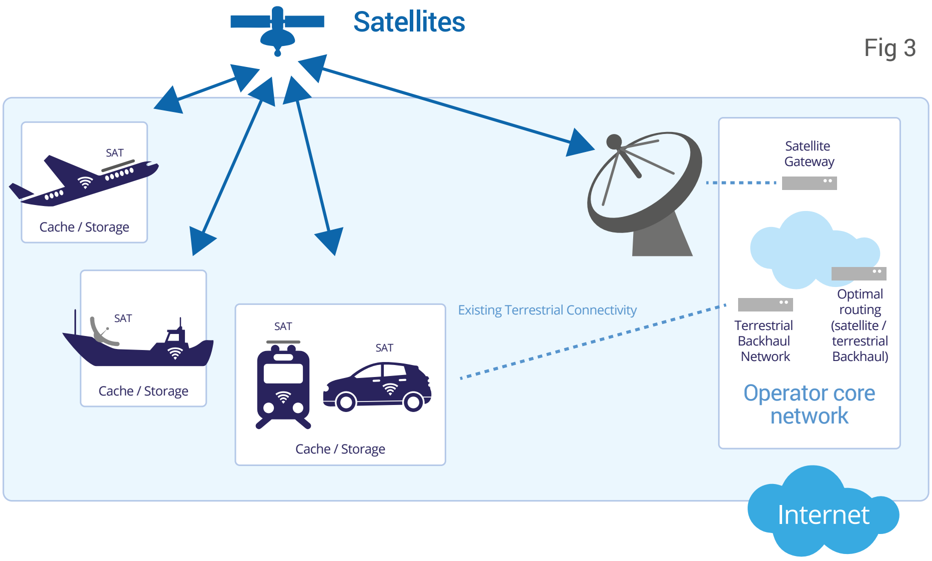
A very high speed, multicast-enabled, satellite link (up to 1 Gbps or even more), direct to the cell towers, from geostationary and/or non-geostationary satellites will complement existing terrestrial connectivity.

Examples of such Use Case include:

- **Broadcast service to end users, vehicles, etc. (e.g. video, software download), support of low bit-rate broadcast service e.g. for emergency messages and synchronisation of remote sensors and actuators;**
- **Providing efficient multicast/broadcast delivery to network edges for content such as live broadcasts, ad-hoc broadcast/multicast streams, group communications, MEC VNF update distribution.**

Communications on the Move

This use case is about high speed backhaul connectivity to individual in-motion terminals on planes, vehicles, trains and vessels (including cruise ships and other passenger vessels), with the ability to multicast the same content (e.g. video, HD / UHD TV, FOTA, as well as other non-video data) across a large coverage area (e.g. for local storage and consumption), as shown in the graph below. The same capability also allows for the efficient backhauling of aggregated IoT traffic from these moving platforms.



A very high speed, multicast-enabled, satellite link (up to 1 Gbps or even more), direct to the plane, vehicles, train or vessel, from geostationary and/or non-geostationary satellites will complement existing terrestrial connectivity where available.

Examples of this Use Case include:

- Connectivity complementing terrestrial networks, such as broadband and content multicast connectivity to phased-array platforms on the move, in conjunction with a terrestrial-based connectivity link to base stations or relay-on-board moving platforms such as high speed trains/buses and other road vehicles, to ensure service reliability for major events in ad-hoc built-up facilities;
- Connectivity for remotely deployed battery activated (M2M/IoT) sensors, or handset devices with messaging/voice capabilities via satellite (e.g. fleet management, asset tracking, livestock management, farms, substations, gas pipelines, digital signage, remote road alerts, emergency calls, mission critical/ public safety communications, etc.);
- Two-way telematics capability enabling automotive diagnostic reporting on connected cars, user base insurance information, safety reporting (e.g. air-bag deployment reporting, advertising based revenue, remote access functions (e.g. remote door unlocking);
- IoT devices on containers (e.g. for tracking and tracing) connected via a Relay UE on a transport vehicle such as a ship, train or truck;
- Broadband connectivity to UASs via satellite consistent with Resolution 155 (WRC-15).

Hybrid Multiplay

This use case is about high speed connectivity including backhaul to individual homes and offices, with the ability to multicast the same content (video, HD/UHD TV, as well as other non-video data) across a large coverage (e.g. for local storage and consumption). The same capability also allows for an efficient broadband connectivity for aggregated IoT data. In-home distribution via Wi-Fi or very small cell ("nano-cell"), is shown in the figure overleaf.

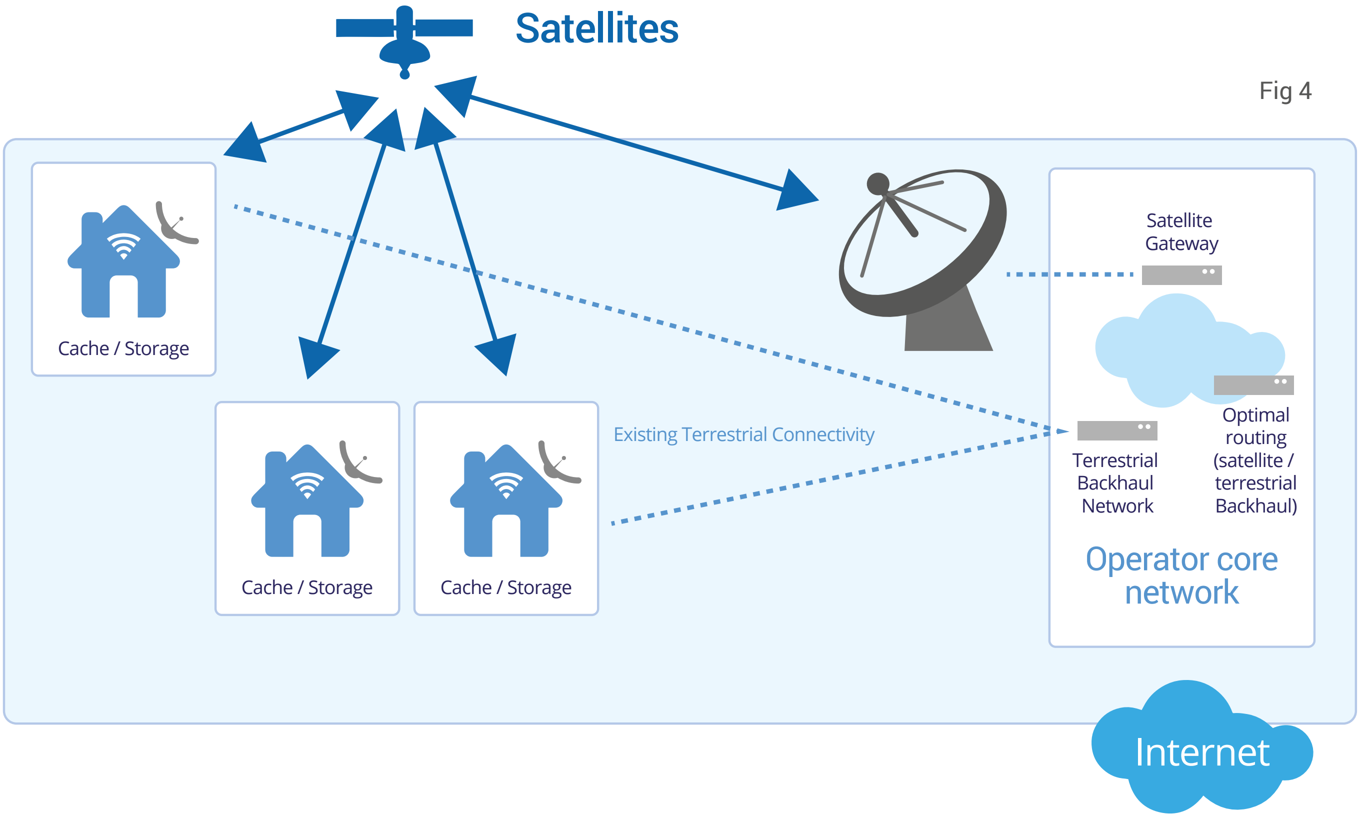


Fig 4

A very high speed, multicast-enabled, satellite link (up to 1 Gbps or even more), direct to the home or office, from geostationary and/or non-geostationary satellites will complement existing terrestrial connectivity. Direct-To-Home (DTH) satellite TV, integrated within the home or office IP network, will further complement this use case.

An example of such a Use Case includes connectivity complementing terrestrial networks, such as broadband connectivity to home/Small Office cell in underserved areas in combination with terrestrial wireless or wire line.

Advanced Satellite Solutions

▶ Today's Satellite Services

High throughput satellite (HTS) networks are operating on a global basis and can provide broadband service to end-users with speeds of 25/3 Mbps and higher.

These systems can support a wide variety of applications, including broadcast and multicast distribution of content, and are instrumental in bridging the digital divide by offering high speed, high capacity, anywhere, anytime services, particularly where terrestrial infrastructure is unavailable. As discussed, below, future systems will have significantly greater speeds and capacity.

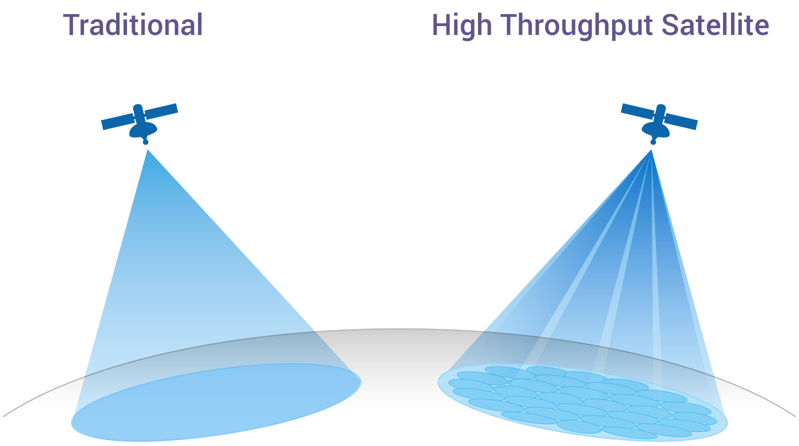


Fig 5 - From traditional wide-beam to HTS satellites

Some of the components of HTS satellites design are:

- Efficiency
- Throughput
- Coverage
- Architecture
- Spectrum

All of these components impact the business model for satellite design and are driven by go-to-market business criteria.

▶ Architecture Considerations

Satellite broadband performance continues to improve:

- **Satellite operators are deploying hybrid networks that support converged broadband and broadcast services;**
- **Ground infrastructure manufacturers continue to enhance the performance of gateways and personal equipment;**
- **Space infrastructure manufacturers maintain a continuous R&D effort to further increase the throughput delivered by the satellite (including by increasing frequency reuse in multiple spot beams, as shown and compared to traditional satellites in Figure 3) while reducing the overall cost of the mission (satellite and launcher) to keep the economic model viable.**

Moreover, the improvement of the economic performance of satellites will continue to be enhanced by the deployment of flexible payloads allowing the services to adapt to evolving service needs, after launch and throughout the satellite lifetime. Being able to optimise the capacity to the market requirements has a direct impact on the overall business model.

Thus, the combination of new satellite network architectures based on Low/Medium Earth Orbit (LEO/MEO) constellations and architectures based on Geostationary Earth Orbit (GEO) satellites means that satellites can play diverse roles to meet multiple service requirements while always leveraging the core strengths of reach and resilience as well as cost and spectrum efficiency.

▶ Advanced Satellite Technology

The dividing lines between satellite and terrestrial networks are softening. Developments in terrestrial wireless networks and services are influencing the prospects for satellite services. In the past, the establishment and configuration of services across satellite and terrestrial segments was mostly performed manually and in a static way. Today, the delivery of services and content over networks, operated by different entities, call for new types of partnership arrangements and for a unified end-to-end control and management. The transition to network function visualization (NFV) and software defined networks (SDN) not only facilitates the integration of network functions of different vendors, it also potentially facilitates the integration of different technologies onto the same platform to:

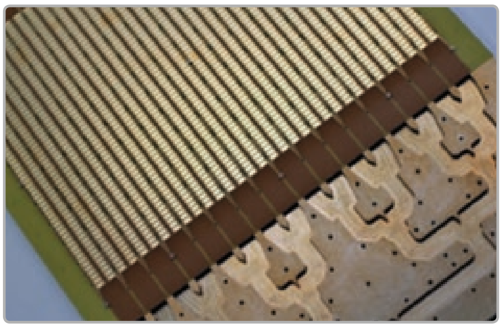
- **Enable the delivery of high quality end to end performance to the final users;**
- **Differentiate business models (e.g. by introducing inherent flexibility to enable the support of new and innovative services and applications that were not envisaged when the network infrastructure was planned and deployed);**
- **Improve business performance (including the reduction of operation costs and end user terminal pricing).**

This means that satellite technology will "blend in" to the overall 5G network architecture, aligning its NFVs into the edge and core cloud infrastructures. As a consequence:

- **The network management service will manage the traffic directed to the satellite according to bandwidth, latency and other application requirements.**

Satellite technology could have its functions integrated at NFV level, creating a denser and more operable and scalable platform for a telecom operator. In combination with 5G "network slicing", dedicated VNFs could address different connectivity concerns.

Satellite broadband promises fast, flexible internet access from anywhere in the world with major satellite operators already deploying next-generation satellites with high data throughputs. To enable the widespread adoption of satellite broadband, especially for mobile users, the satellite industry is developing next generation terminals using, among other things, a new reconfigurable antenna technology, known as Metamaterials Surface Antenna Technology (MSA-T), shown in Figure 6. This antenna offers the electronic beam-steering performance of a typical phased array antenna, with much lower power consumption offering a dramatic cost reduction compared to mechanical products and many of the size, weight and power challenges associated with the existing techniques are alleviated. No longer will accessing satellites require traditional equipment with high power requirements for the user; new technology is unlocking the full potential to track satellites while also being portable enough to attach to a vehicle or take into the field.



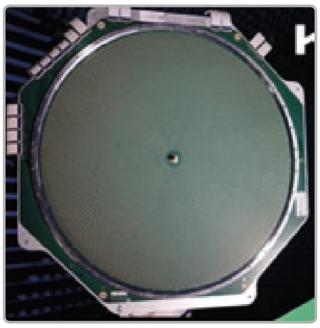


Fig 6 - Antenna array and feed network antenna technology

Ensuring Satellites Can Play a Role

▶ Policy Must Enable the Role of Satellite in 5G

Satellites are a critical component in 5G.

To ensure satellite's ability to meet the growing user demands for broadband, there are certain key principles that regulators and policy makers globally must adhere to:

Technology Neutrality

A stable, resilient, inclusive 5G ecosystem requires the adoption of policies that ensure competition among platforms. Policies that focus solely on the fibre core of 5G networks, or that equate 5G access solely with terrestrial wireless technologies, will fall short of making 5G successful across the globe. Accordingly, it is critical that policymakers take the time and effort to understand how different technologies can and should interwork – trying to integrate an essential component like satellite later, as an add-on, will be inefficient and burdensome and will impose unnecessary additional cost to providers and users alike.

To this end, policy makers must avoid making assumptions or interventions that lead to the creation of blanket 5G requirements for features such as high speed or low latency that will only result in an underperforming or over-engineered 5G network that serves few use cases and the resulting few people. Fostering and incentivising the emergence of common standards from the start to enable an integrated and interworking eco-system of network technologies so that interfaces can seamlessly communicate with different technology solutions (e.g. both GEO,LEO and MEO satellite systems), will further promote the 5G vision.

Cost-Efficiency

Users across the world are disappointed that they do not have the coverage they need where they need it.[7] Accordingly, policy makers should ensure that the most cost-effective platform be supported to meet user demands. Satellite, because of its anywhere, anytime availability will often be the most cost-effective technology, especially in rural and remote regions of the globe.

Access to Spectrum Resources

Spectrum is an issue for all wireless systems, whether terrestrial or in space. As terrestrial mobile systems move into the millimetre wave bands above 6 GHz, where satellite systems have been operating for many years, consideration needs to be given to the co-existence needs of both sectors. A rapid deployment of 5G is best served by focusing the spectrum needs of terrestrial 5G networks to bands other than those used by satellite already. This approach will also ensure that both technologies can work together, each enabling part of the value chain to ensure reliability, reach and quality of service.

Satellites make intensive use of several portions of the frequency spectrum both above and below 6GHz for their services (including for high-throughput satellites in Ku and Ka-band).[8] As a result, and given the long-term nature of these investments, it will be critical to maintain a viable and sustainable access to traditional satellite bands, such as the C, Ku and Ka-band, as well higher bands including the V and Q bands beyond to ensure the growth of the satellite community within these bands.

Standardisation

It is critical that 5G network (global) management / signalling, namely advanced traffic management, develop in a way that leverages the capability of satellite networks to support appropriate applications and services . Progress is being made to include satellite as part of the 3GPP 5G standards[9] and as part of IMT-2020 in the International Telecommunication Union. Such efforts are critical to ensuring that the benefits of 5G networks can be realised.[10]

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7 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/412618/Government_Response_FINAL__1_.pdf . Department of Culture Media and Sport, Tackling Partial Not Spots in Mobile Phone Coverage, 12 March 2015

8 Ku band is 12 – 18 GHz and Ka band 18 – 31 GHz

9 In line with the requirements that "the 5G system shall be able to provide services using satellite access" in 3GPP TS 22.262 "Service requirements for the 5G system; Stage 1 (Release 15)

10 The ITU-T Focus Group on IMT-2020 draft "Report on application of network softwarization to IMT-2020" (IMT-O-041) emphasizes in its recommendations to ITU-T Study Group 13 that "IMT-2020 network architecture is required to include multiple RAN technologies including satellite" and recommends studies "of the integration of satellite technologies into the IMT-2020 network architecture." This should be accomplished in the near term.

Conclusion

Satellites are a critical component of the 5G telecommunications landscape.

They will complement as well as compete with other technologies in meeting the needs of users worldwide. The satellite “sweet spots” of trunking, back-haul, mobility, and hybrid multiplay will be used to complement other high-bandwidth connectivity links, such as broadband fibre optic, xDSL, Wi-Fi, WiGi and even Li-Fi (optical wireless communications)).

Only by this ecosystem of technologies, including satellites in their multiple orbits and frequency ranges, can 5G achieve its vision of bringing next generation connectivity to all users across the globe. Investment and technology decisions are being made now for 5G technologies, and it is important that governments and institutions embrace and foster a “system-of-systems” approach based on common standards and technology neutrality, to minimize the risk of costly and complex changes in the future. By working together, policymakers and industry players will realise a dramatically improved connectivity experience for tomorrow’s generation that will deliver ubiquitous services and improve the lives of all citizens.

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