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Edgecasting and the M.A.R.S. distribution strategy

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1. Foreword

Access to reliable information is essential for a functioning and prosperous society, especially in times of crises. There are many other essential services such as access to energy, transport, banking, water, healthcare, government services and financial markets.

Relying on a single infrastructure to deliver essential services can lead to critical situations during emergencies. Events such as earthquakes, floods, wildfires, and extreme heat waves are often exposing the vulnerability of power grids and telecom networks in maintaining service continuity under such conditions. When the power grid fails, it often disrupts the availability of telecom services, water supply, air conditioning, and all other electricity-dependent essentials. Cellular networks are often among the first to go offline once they are entirely compromised or their backup batteries are depleted, leaving the population reliant solely on terrestrial or satellite broadcasting for vital information.

Resilience is greatly improved by integrating multiple infrastructures—such as the power grid with local solar panels and batteries, or terrestrial networks with satellite communication systems. While no single network provides universal coverage, there is scarcely any location that would not be covered by at least one network. Combining complementary networks in a multilayered infrastructure is a robust and cost-effective way of reaching every citizen anywhere in the world, thus ensuring that the essential services remain available in all situations, including in emergencies.

This is the foundation of the M.A.R.S. strategy: **M**ultilayered, **A**nywhere, **R**esilient, and **S**ustainable.

2. The infrastructure challenge

Traditionally, dedicated networks have been built for specific services and universal service obligations were placed on service providers and network operators. Satellite and terrestrial broadcast networks provide near-universal coverage and serve large audiences. They enable unrestricted access to media content and are essential to inform the public in emergency situations. Over time they have been hardened and made resilient so that they can continue operating when natural catastrophes strike.

Telephone networks initially allowed only individual voice communications. Over time, the telecom infrastructure evolved to support a whole range of Internet services, including media. The audiences have embraced the Internet as a media platform and mobile phones as their primary communication devices. The choice of content and convenience of access has never been greater. Following their audiences, broadcasters have added the Internet distribution in their portfolio.

At the same time, service providers including broadcasters are faced with increasing competition and the pressure on their budgets. Parallel content distribution over multiple broadcast and on-line platforms is increasingly a financial challenge.

In response, some broadcasters have adopted Internet-first distribution strategies and are pondering a future without broadcasting.

Public authorities and policy makers face a similar dilemma. They need a reliable way of communications to the public in time of crisis. In most countries broadcast network infrastructure is used for this purpose owing to its resilience and near-universal availability. At the same time, the benefits of Internet access motivate strong political support to the rollout of fixed and mobile broadband networks. As smartphones are personal devices that most people keep by themselves at all times one of the goals is to make the Internet infrastructure suitable for emergencies.

However, as these networks are deployed by commercial operators, coverage is typically provided only in those areas where it is profitable to the operators or where the rollout is subsidized by public authorities. The resulting coverage is large but not universal and even in the developed countries it does not reach all citizens. Another concern is that Internet access is not free which further limits the access to part of the population not able to afford this additional cost.

Furthermore, these networks may be congested in times of high demand and are vulnerable to disruptions, whether due to adverse human actions or due to natural disasters. Coverage expansion and increasing the network resilience both require ever larger investments.

In this situation it is tempting to consider consolidation. Technically, general purpose infrastructure such as fixed and mobile broadband networks can support almost any service. Therefore, so the reasoning goes, if broadband networks were universally available, with sufficient capacity and resiliency, the purpose-built networks could be discontinued, and significant savings could be achieved.

Is this true and, if so, would such a consolidation be wise?

To answer this question, it is not enough to look at the technology but to determine the required network performance. In other words, it is important to start from the requirements that essential services place on the network infrastructure.

3. Requirements - Integrating broadcasting and Internet based infrastructures

Ideally, critical services shall always be available to the entire population, everywhere whether stationary or on the move on land, sea, or in the air, and on as many user devices as possible. They should be affordable, economically viable, and environmentally responsible. They should also be available during crises and emergency situations.

The resulting requirements on network infrastructure primarily include:

- 100 % coverage of the population and 100% coverage of the territory
- The ability to reach any commonly used user device
- The ability to deliver linear, on-demand, personalized and interactive services
- High resilience
- Economic and environmental sustainability

No single network infrastructure, alone, is capable of meeting these requirements. Fortunately, this can be achieved by combining multiple different infrastructures both satellite and terrestrial.

In emergency situations, a multilayer network infrastructure that combines the broad and reliable coverage of broadcast networks with the capability to gather data from millions of citizens using battery-powered devices (such as smartphones with satellite NTN capabilities, home and car gateways that integrate terrestrial and satellite access, portable terminals for first responders, etc.) is the optimal solution to meet these needs. The availability of various terminal types that merge terrestrial connectivity with interactive satellite broadcasting services offers a comprehensive solution.

Media companies have today the imperative of reducing costs, from production to distribution. The focus in this case will be on the distribution side of the whole chain without forgetting the end to end implications.

When considering cost reduction this cannot be a pure financial exercise but an opportunity to innovate relaunching reach and prominence redeploying resources to increase direct reach of citizens not only in their homes but also on their mobiles, cars, public spaces, collective transportation etc. with content appealing providing information, education and entertainment.

A pure exercise of cost reduction would only accelerate loss of audience share while we need to continue reaching and serving citizens reliably

In reducing costs, we also need to retain multiple ways of reaching audience preventing the risk of having a single provider of distribution infrastructure that can then decide to freely increase the distribution cost per user. For example, having an internet centric distribution strategy would put CDN providers and/or telcos in the position of freely increasing their costs per user.

For these reasons we are proposing the M.A.R.S. strategy combining **M**ultilayer distribution (online, satellite and 5G broadcast) to serve present and future audiences **A**nywhere, guaranteeing **R**esilience and providing a **S**ustainable combination of technology compatible with a medium to long term strategy.

4. The M.A.R.S. distribution strategy

The basic M.A.R.S. philosophy is synthetized for the sake of media centric distribution strategy in the following slide

M.A.R.S.

Multilayer combines different native IP infrastructures, ideally at least one terrestrial and one satellite network. Terrestrial networks include fixed broadband (e.g. fibre, cable), cellular (4G and 5G) networks, DTT and digital radio, and 5G Broadcast. Satellite networks could be GSO or non-GSO constellations. Different combinations are possible and each country can choose the one that best suits their needs.

Anywhere - thanks to the satellite component, the coverage is provided over 100% of the territory. Combination of different networks also enables access to an expanded population of user devices compared to individual networks.

Resilient - the integration of different infrastructures ensures that there are no single points of failure. The inherent resilience of the broadcast infrastructure is preserved and utilised. The use of battery-powered endpoints ensures the continued service availability in case of power failure.

Sustainable - in terms of both cost and carbon emissions. Investments can be directed where it is optimal in the economic sense. The value of the existing networks / past investments is enhanced. Traffic routing can be optimised for different criteria, including costs, quality, or energy use.

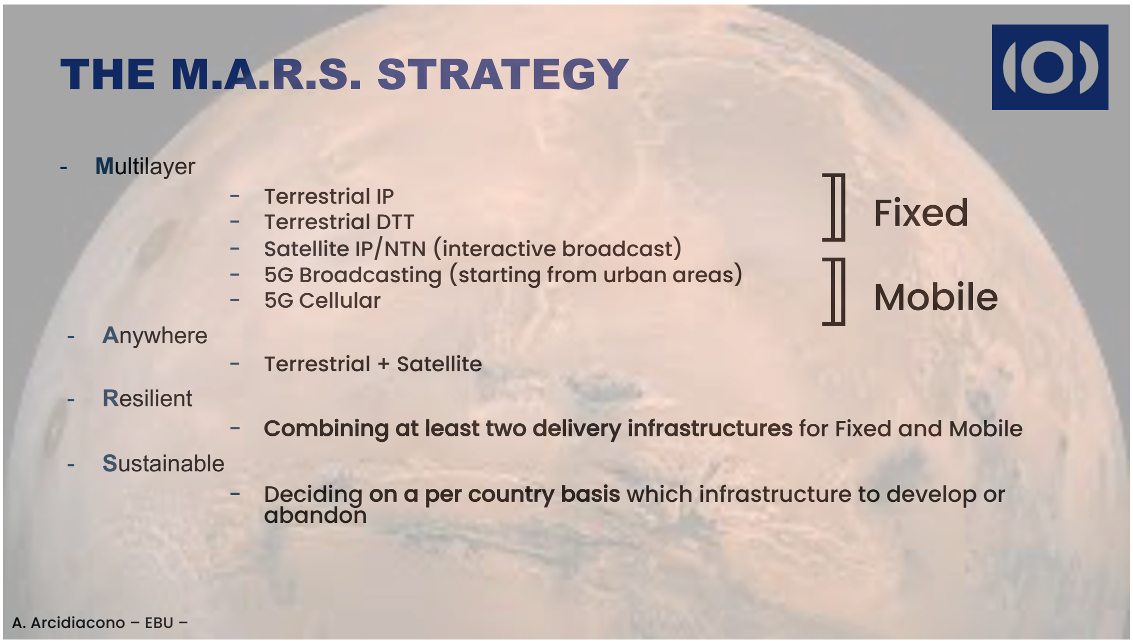
From the beginning modern media distribution has been the collection of **a series of verticals** each one serving a specific niche (small or big) linked to specific fruitions. As none of them is capable of providing all services to the entire audience, broadcasters are forced to distribute their content over multiple infrastructures in parallel, resulting in increasing cost and complexity.

The progressive development of open distribution formats (e.g. IP formats over multiple physical layers) has created the premises of a holistic way of delivering live or on demand contents to a variety of end devices.

Today it is possible to combine multiple delivery systems to optimize distribution using the M.A.R.S.” approach which not only optimizes the current distribution but also enables the development of new services which is a key prerequisite for retaining the audiences, in particular during the transition.

This allows media companies to make their distribution portfolio future proof by achieving two key objectives:

- Financially sustainable distribution of media services in the future
- Modernized distribution infrastructure that supports advanced services



The basic rule to guarantee resilience while staying economically sustainable is that of combining/integrating at least two independent distribution infrastructures for each fruition. The synergies inherent in the M.A.R.S. approach exploit the laws of physics to lower the total cost of operations of the integrated solution.

Media service providers no longer need multiple separate distribution arrangements with different vertical operators. Instead, a M.A.R.S. service provider can optimize their distribution across different infrastructures. Contracts with individual vertical providers are not excluded but the presence of M.A.R.S. operators in a country increases the choice and lowers the distribution costs. Cost reduction is a result of increased competition, the efficiency optimization in M.A.R.S. and the scale due to the potential to serve other sectors beyond media distribution.

5. From strategy to actual deployment

The European Broadcasting Union (EBU), with support from the European Space Agency and a consortium of over 34 companies, is working within the 5G-EMERGE project to develop technical specifications and implementation guidelines (www.5G-emerge.com). This effort is paving the way for the industrialization of a new generation of terminals, enabling the practical realization of the M.A.R.S strategy.

The 5G-EMERGE project is postulated on the following hypothesis:

The distribution infrastructure must enable efficient distribution of present and future services to 100% of the population and over 100% of the territory. It must be able to reach the most popular user devices and must allow continuous gathering of usage data. It should be financially viable and environmentally sustainable.

Today, media distribution is characterized by the dichotomy between broadcast and OTT/online distribution.

- Broadcast networks (terrestrial, satellite, cable) are only used for linear radio and TV. They are efficient for serving large audiences but cannot provide on-demand and personalized services because they are one-way only.

- On-demand services are distributed only online over unicast. Technically, this provides flexibility but is not very efficient and does not scale well for large audiences.

But,

- No single distribution option can serve all users and all use cases
- Modern broadcasters use all available distribution options to maximize the reach. This incurs high costs.
- Linear TV is declining, especially with younger audiences
- Increasing demand for personalization
- The online environment is dominated by the global Big Tech companies.
- Smartphones and smart TVs can only be reached via telecom operators and it is not free to air.
- Most of the media use happens at home while the use on the move is growing.

Most important types of user device:

Type of device	**Where is it used**	**What kind of service**	**How is it served**
TV set	Home	Linear TV, on-demand	DTT, satellite, cable, streaming
Radio receiver	Home, car	Linear radio	FM, DAB+, (streaming)
Smartphone	Anywhere	On-demand, linear	Streaming

These user devices are also important for emergency information.

The current trends suggest that in the future:
- The same types of user devices will remain important
- Personalized services will be default
- Unification of linear and on-demand portfolios. Linear services will be only an option that the user can choose.
- Linear services as 'a single product for a mass audience' will lose importance
- Only IP enabled and bi-directional distribution infrastructure will be relevant
- Traditional cable TV networks will be replaced by IP networks (DOCSIS, fiber)
- Satellite networks will evolve into collaborative multilayer solutions with terrestrial.
- Edge computing will enable better ways of distribution, i.e. by combining satellite and terrestrial distribution with local storage and processing; dynamic switching between broadcast, multicast, and unicast, etc. This will also enable optimization and gathering of user data.
- The complementary nature of different distribution networks will be utilized to increase efficiency, respecting the laws of physics and economy.

To benefit from the ongoing trends and technological developments the media companies will need to transition from today's segmented market to a future ecosystem based on interconnected IP infrastructure, i.e. the M.A.R.S. strategy.

5.1 Example of a transition plan

The idea is to implement the M.A.R.S. strategy with a progressive deployment introducing new distribution solutions.

Integrating the terrestrial and satellite IP infrastructures we can develop new opportunities to serve the market at a sustainable cost, sensibly lower than the present total cost of distribution.

Concerning services to mobiles and vehicles the proposal is to combine cellular networks with 5G broadcast networks to directly and freely reach new audiences including young ones. Here the proposal is to start serving urban and highly populated areas, leaving to a longer-term double coverage of rural areas with a complementary offer based upon satellite interactive broadcasting provided via GEO and NTN networks.

Introducing edgecasting, combining the edge with satellite broadcast, terrestrial IP networks and 5G Broadcast. The edge device connects to any available distribution infrastructure, and allows storage, local processing, and playout of content tailored to individual users.

It is future proof as it benefits from the developments in the wider industry, retaining the capabilities for emergency communications, e.g. via 5G Broadcast and/or satellite.

6. New solutions to increase reach and open new markets

6.1 Smart edgecast combining Terrestrial IP, 5G Broadcast and Satellite

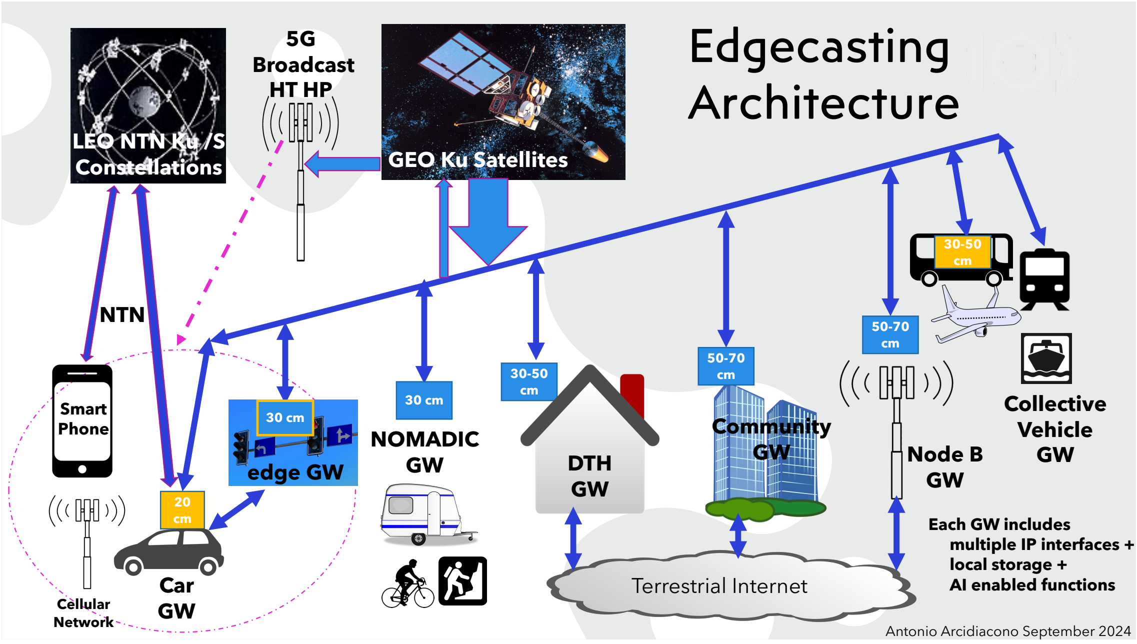
IP edgecasting with local storage and intelligence enables smart "personalization". Live contents as well as content aimed at consumption by a large population of users will be delivered in multicast using satellite or 5G broadcast aiming at reducing CDN costs. Initially it will mainly serve customers not covered by terrestrial IP. Progressively citizens should be encouraged to install a common IP gateway managing satellite and terrestrial to further reduce CDN costs while introducing new services.

The introduction of a new generation of direct satellite broadcasting services will also open to the development of new formats (e.g. volumetric) attracting new audiences

A combination of 5G broadcasting in urban areas with satellite edgecasting will support a new offer to car manufacturers able to directly manage a permanent service offer to their clients.

Areas covered by 5G broadcasting will open the direct to Smartphone market for free to air video and audio services.

In the figure here below the architecture of the various opportunities opened by the **edgecasting** approach is illustrated.



6.2 New services facilitated by technology innovation

The rapid evolution of technology has ushered in a new era of media consumption, where personalization is no longer a luxury but a necessity. The transformative impact of technological innovation on the media landscape is today evident with new services that are redefining the way we interact with content.

We are now considering how advancements in artificial intelligence, machine learning, and data science are enabling hyper-personalized experiences facilitated by an edgecasting approach, tailoring content to individual preferences and needs. From multilingual content delivery and accessibility features to dynamic program guides and AI-powered product placement, these innovations are reshaping the traditional broadcasting model.

Furthermore, local AI functionalities could democratize content creation, where individuals can become content producers, curators, and commentators. This shift in power dynamics could empower audiences to actively participate in the media ecosystem, creating new opportunities for engagement and monetization.

By combining the power of broadcast and unicast, we can deliver targeted content to specific audiences, while simultaneously leveraging the scale and reach of broadcasting. This hybrid approach opens new avenues for advertising, sponsorship, and subscription models, hopefully driving revenue growth and innovation.

These technological advancements are not only enhancing the viewer experience but also reshaping the media industry. By embracing personalization, diversity, and user-generated content, we can create a more engaging, inclusive, and profitable media future.

Content personalization

- multilanguage
- managing accessibility with personalized experience
- local recommendation AI enabled engine filtering content to be stored
- dynamic program guide
- personalized product placement with AI with
- local object-oriented insertion for each customer
- selecting viewing time, anytime, including live
- producing local audio and video with synthetic characters

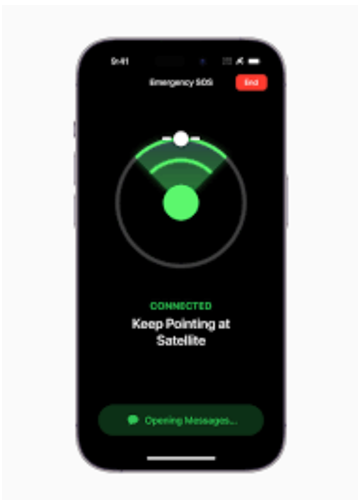
Combining broadcast with unicast

- brand power is moving from the enterprise to the individual
- new professional creators to be integrated in the media delivery to attract new audiences (e.g. young audience) and address new commercial sources of revenues
- we can combine and synchronize a broadcast content (e.g. sport or music) with commentary and second screen data provided by individuals that will monetize through collateral advertising.

6.3 Use cases and enabling technologies

In the last 30 years DVB* for direct to home (Ku-band) media delivery has been the only consumer grade satellite media technology reaching hundreds of millions customers.
More recently NTN like direct to device solutions (Apple/Globalstar, T-mobile/Starlink, 3GPP NTN, etc.) are also raising market attention
The search for a disruptive and consumer grade phased array technology is finally producing tangible results and represent an additional element of acceleration for what concerns satellite terminals enabling the deployment of new services. The deployment of Starlink connectivity services has been triggering a massive non-recurring investment and paving the way for the production of consumer grade compact and self-pointing satellite terminals opening new market opportunities for Ku and Ka band satellite systems. Starlink terminals are used for connectivity services using LEO satellites; flexible and low cost phased arrays will also facilitate the development of new broadcast and edgecast services.

Starlink
IP broadband terminal



Iphone/Globalstar
Emergency Messaging

Iridium
IOT Messaging

In the last 30 years satellite broadcasting success has been fundamentally linked to the zero marginal distribution cost per additional user typical of broadcasting with the largest share of the capex investment often covered by the end customers. The possibility of delivering at reasonable costs and without major regulatory hurdles tens of channels/products represented in the 90's and end-to-end value proposition innovative enough to attract concrete investments sustaining the industry to reach breakeven in a reasonable time span. Success was linked to a large consumer market sustaining competing offers. A few anchor players (Kirch, C+, Telepiù, etc.) made the substantial nonrecurring investments that facilitated the commercial launch.

Combining the advance in technology coming from phased arrays of new generation with the flexibility of software defined receiving devices and the intelligent functions that can be operated at network edges, several new markets can be addressed. Broadcasters can substantially reduce their distribution costs while improving/developing new formats and attract new audiences:

- Thanks to the user-friendliness of new satellite gateway devices the installation of user equipment will be highly simplified not requiring in most cases the intervention of a local installer.

- Car manufacturers will be able to install compact satellite terminals into their vehicles being able to directly manage a permanent service offer to their clients and beyond. Taking a multilayer approach the mobility market is a natural target market for a solution combining *Direct to edge* with local storage deployed from home to electric vehicles charging stations and direct to mobile very small terminals integrated in any vehicle. Using smart edgecasting gateways with self-pointing antennas to deliver and control large quantities combined with small mobile terminals on vehicles to ubiquitously deliver essential data while receiving key telemetry parameters
- In view of the low cost and flexibility of user terminals new non media applications can also be deployed starting for example from Power Grid Operations managing smart network edges.

6.3.1 NTN and Interactive edgecasting

Non-Terrestrial Networks (NTN) are part of the 5G-3GPP system architecture, applicable to GSO and non-GSOs, from L/S-band to Ku and Ka band and beyond

For edgecasting or reaching end-user terminals (direct to cellular or vehicle) EBU has launched the 5G-EMERGE partnership project (www.5G-EMERGE.com) financed by ESA now entered with its pre-industrialization phase, supported by 34 partners.

A Work Item launched in the 5G-Media Action Group (www.5G-MAG.com) addresses multicast-broadcast-edgecast service scenarios with or without native return link.

6.3.1.1 Satellite edgecasting and NTN in emergencies

Cellular networks are unable to reach 100% of the territories and maybe be subject to long interruptions due to power cuts. Therefore in particular during emergencies, a satellite-based NTN solution can reach populations delivering media services on a daily basis

User terminals need to be:
- consumer grade
- easily deployable (self-pointing antenna)
- battery powered
- providing a return channel to acknowledge reception and essential local information during emergencies.

Future NTN specifications will benefit from the one-to-many advantage of broadcasting and should integrate those user terminal requirements on personal devices, vehicles, terminals for first respondents, home gateways, etc.

AI technologies to extract information from a very large number of devices (millions) is essential for a cost-effective answer to emergencies. Retrieving information in real time from any terminal increases the ability to provide essential support to populations eg identifying areas in need of assistance or predicting disaster patterns.

The management in quasi real time of millions of messages over satellite spots covering hundreds of Kms by Asynchronous Multiple access techniques is key to optimize support to end users

Flexible satellite performance (e.g. variable EIRP, spot size) would ideally complement the deployment of different categories of terminals on a daily basis and during emergencies

6.3.1.2 Satellite edgecasting and NTN on a daily basis

The development of satellite NTN (Non-Terrestrial Networks) and interactive broadcasting is poised to significantly evolve towards satellite edgecasting, leveraging local intelligence and storage at network edges. This convergence promises to provide new solutions for content delivery in particular into unconnected or low density populated areas, offering unprecedented benefits to users worldwide.

Satellite NTN will complement connectivity, particularly in remote and underserved areas. By integrating satellite networks with terrestrial networks, seamless coverage can be achieved, enabling ubiquitous access for essential communications.

Interactive broadcasting, powered by advanced technologies like 5G and satellite NTN, will allow deployment of traditional one-way broadcast communication into a two-way experience with users able to interact with content providers in real-time enhancing a sense of community and engagement. At the same time content and service providers will have the ability of collecting data from their users, helping defining a successful editorial line while increasing the value of their services.

Satellite edgecasting is a promising paradigm that leverages the power of edge computing and storage to optimize content delivery and reduce latency. By caching and processing content closer to the end-users, satellite edgecasting can significantly improve the quality of experience, using AI functionalities to personalize a rich user experience.

The integration of local intelligence at network edges will enable intelligent decision-making and adaptive content delivery. By analyzing user preferences, network conditions, and content characteristics, edge devices can optimize the delivery of personalized content, reducing network congestion, terrestrial CDN costs and improving overall user satisfaction.

Satellite-based CDNs will play a vital role in distributing content efficiently and reliably. By strategically placing content caches at various points in the network including next to end users, in their homes, vehicles or smartphones, satellite CDNs can minimize latency and improve content delivery performance.

Edge computing can help to optimize resource allocation and prioritize traffic, ensuring that critical applications receive the necessary bandwidth and processing power.

By processing sensitive data locally, edge computing can reduce the risk of data breaches and cyberattacks.

Edge devices can analyze user preferences and network conditions to deliver tailored content, improving user engagement and satisfaction.

The convergence of satellite NTN, interactive broadcasting, and satellite edgecasting holds the potential to reshape the future of connectivity and content delivery, unlocking the full potential of this transformative technology, ushering in a new era of innovation and user experience.

6.4 Examples of enabling technologies developed in the 5G-EMERGE project

6.4.1 Nomadic terminal – Minwave - Low cost Self-pointing interactive Edgecasting

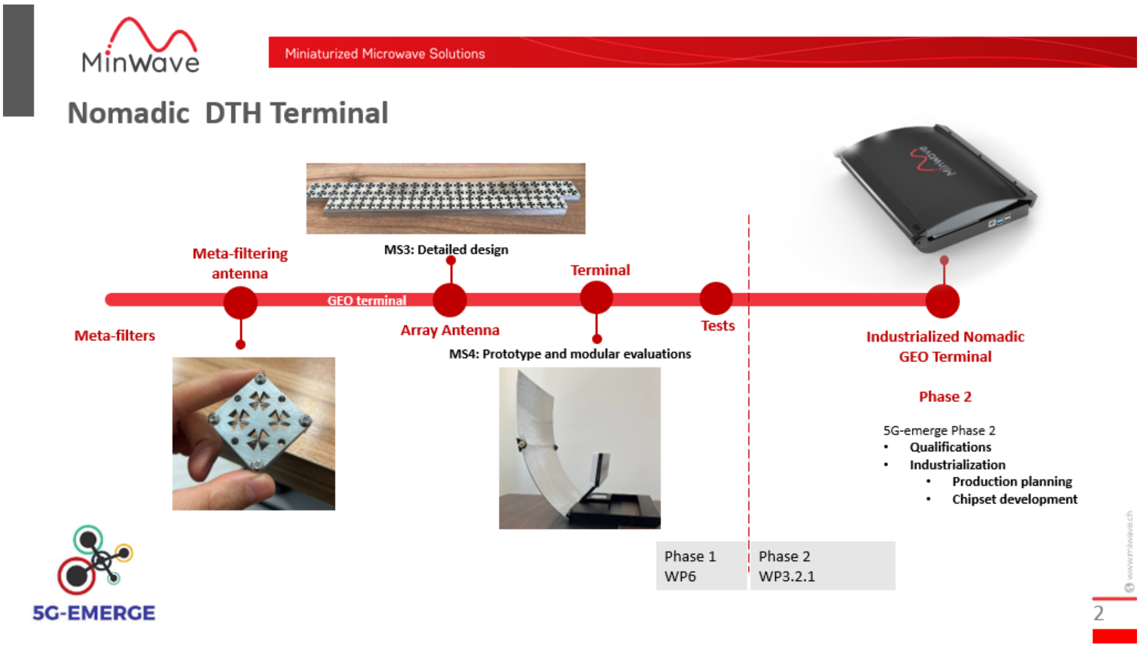
Leveraging upon new low cost phased array technologies and combining those with a traditional feed plus reflector approach it is possible to develop consumer grade user terminals for interactive broadcasting and edgecasting. To demonstrate this concept while fulfilling also the emergency service requirements in the phase one of the 5G-EMERGE project a prototype of a nomadic terminal has been designed and developed. Self-pointing, low-cost and low-power consumption are the key requirements for this user terminal that is compact and light enough for fixed and nomadic applications and can automatically locate the satellite position in the sky without requiring a user intervention other than broadly looking towards the satellite arc. This portable terminal has the form factor similar to a small laptop-sized reflector that can be broadly positioned towards the sky by a human but fine-tuned automatically using a phased array feed.

The development is based on patented miniaturized meta filters, meta-antennas, and meta-filtering antennas, which employ resonant metamaterials to manipulate waves at ultra-compact sub-λ scale and in a full-metal structure with very low loss comparable with waveguide and horn antennas. The monolithic integrations of metallic components and their integration into the planar platforms enable to fabricate small and energy-efficient RF front-end solutions with feasible bandwidth between 1% to 40% from C-band to V-band. These advantages add a minimal height (usually $< \lambda/2$) to the antenna, so a semi-planar structure is obtained. Other notable advantages of this antenna, designed and manufactured by MinWave, are the ability to provide switchable linear H/V and circular RH/LH polarizations and integrated miniaturized filters or multiplexers. Integrating MinWave's patented metamaterial diplexer to the wide-band antenna allows the separation of RX/TX in this architecture and the building of a full duplex terminal.

Folded reflector and the overall system package that is about 30x25x5 cm^3.

The developments have been structured as follows:

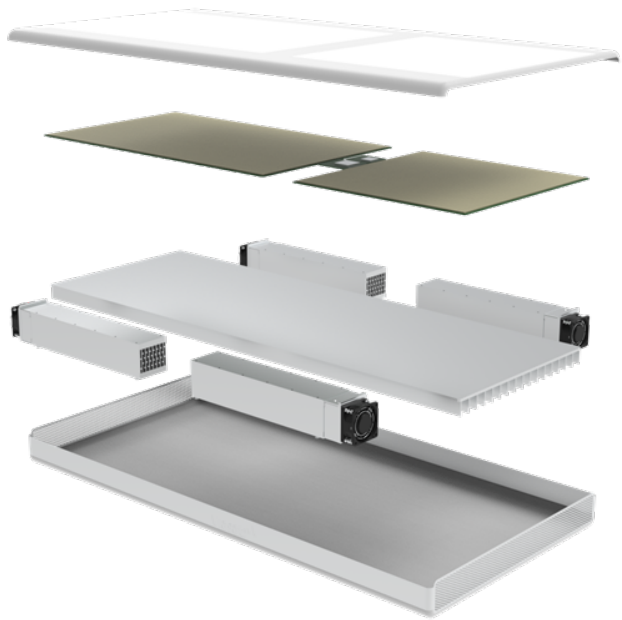
- Detailed design of a feed array capable of both transmitting and receiving signals within the frequency range of 10.7-14.5 GHz.
- Implementation of the feed array system and performance of the modular tests on the feed system.
- Assembling the terminal, carry out the assembly process and perform modular tests, ensuring seamless communication between the antenna system and the modem, and implementation of beam steering algorithm along with the tests in the Anechoic chamber.
- Test the system integrated with a two-way satellite modem (with an L-band interface) able to receive in DVB S2X and transmit using a Non Orthogonal Multiple Access (NOMA) solution implemented using an Enhanced Spread Spectrum Aloha scheme (ESSA) with successive interference cancellation (SIC) to manage interference on adjacent satellites while maximizing system capacity on the return link managing millions of terminals at a sustainable cost.



6.4.2 Antenna for vehicles - Viasat Self-pointing interactive edgecasting

The antenna aperture consists of an array of antenna element modules that will integrate the radiating element and the corresponding RF integrated circuit used to adjust the amplitude and phase of the RF signal and allow electronic steering of the antenna beam. This radiating module is integrated onto a motherboard printed circuit including a beam forming network, DC power distribution and monitoring and control electronics.

This approach differs from the current approach having all the radiating functions (and expensive part of the PCB) addressed in a limited sized antenna module. This approach leaves more space to accommodate everything else on a single PCB board, thus greatly reducing the cost by not having several complicated interconnections and boards. This new architecture will also require a complete redesign of the structural and thermal management of the terminal.



Pictorial view of the main building blocks of the new terminal.

Expected performances for the first prototype (the following numbers will be reviewed and updated during the phase 2 of the 5G-EMERGE project).

Size	<80cmx40cmx10cm (without modem)
Frequency covered	17.7-20.2GHz, 27.5-30 GHz
Scan angle	60 degrees scan (can be more with degraded perf)
G/T 0 and max scan angle	12.5 and 9 dB/K
EIRP 0 and max scan angle	56 and 54 dBW
DC power (100% duty cycle)	<650W without modem
Operating temperatures	-40 to 55C (TBC)

6.4.3 Far edge gateway - FTA-Inverto

The Far Edge is the core reception component in the 5G-EMERGE architecture. It deals with incoming multicast content and acts as the counterpart of the DVB-mABR and DVB-Native IP Server. Content received is extracted from the mABR protocol and stored in a local cache. The cache is fronted by a reverse proxy which makes the content available to Clients requesting it over DVB-I compatible interfaces. The cache is uniquely capable of answering unicast requests incoming via HTTP.

Edge caches can be scaled according to the local requirements. Edge caches in a Direct-To-Home scenario only need to be capable of answering requests from a very small number of clients, whereas edge-caches located on a communal network may have to deal with thousands of simultaneous requests.

6.4.4 Edge Applications

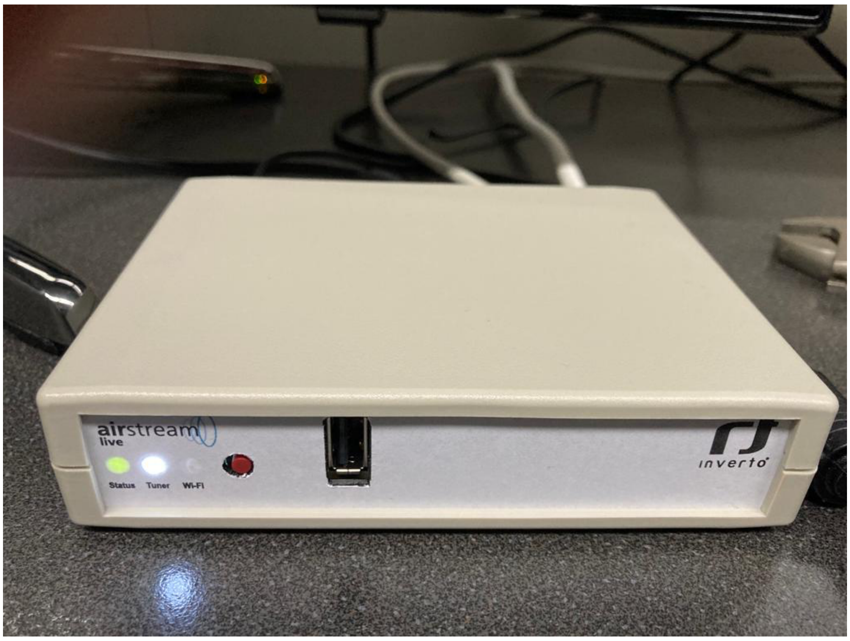
The actual functionality of Edge Caches is implemented as specific applications running in a virtualised software/container environment. The setup and maintenance of this virtualisation run-time is part of the 5G-EMERGE architecture and is compatible with the 3GPP SA2 architecture[3]. This environment allows the rapid and simplified deployment and maintenance of containers, each implementing specific functionality. Some of the applications running on the Edge are: the mABR Gateway, the Content Cache Management, the local Origin and Reverse Proxy, the device discovery mechanism, etc. Most of these applications relate to the Client applications that request data from the local edge cache. The whole edge-based ecosystem acts as a single cloud with distributed resources.

6.4.5 Far edge versions

The far-edges functions are specific to each 5G-EMERGE use-case; three different far-edges were developed:

- ‘Direct-to-Home’ micro edges optimised for stationary or nomadic reception and content consumption in apartment/building/complex/hotels.

- 'Direct-to-Edge Node' micro edges optimised for installation and operations in access network nodes like 5G gNodeB (base stations) or network gateways operated by Content Delivery Network (CDNs) Providers/Internet Service Providers (ISPs).
- 'Direct-to-Vehicle' micro-edges optimised for reception on the move, for example in cars, planes, trains, buses or vessels installations to receive content that will become available to passengers inside the vehicle.



These are the different components of the far-edge that have been developed so far:

- Far Edge satellite signal receiver and the stream decapsulation software (FTA).
- Varnish Enterprise cache to meet the project's needs.
- Micro-edge devices and VMs for hosting Far Edge apps.
- FLUTE gateway with Varnish Enterprise cache on micro-edge device.
- Micro-edge discoverability with the 5G-EMERGE Far Edge apps on the local network by UE (User Equipment).

7. Conclusion

As we look to the future, the convergence of innovative technologies, from consumer phased arrays to AI powered edges, presents exciting opportunities to transform our traditional satellite broadcasting services and continue leveraging the advantages of the law of physics.

By embracing Smart edgecasting, we can deliver a diverse range of services, from everyday use to critical emergency support. The success of this transition depends on driving down end user device costs while stimulating consumer adoption, ensuring the flexibility and quality of service essential for our ambitious goal of supporting a Multi-layered, Accessible, Resilient, and Sustainable distribution network for our own terrestrial mission to M.A.R.S.