Hype & Realities of Cellular & Satellite convergence.

1. Purpose

The convergence of cellular and satellite technologies has recently generated significant buzz and promises of revolutionary connectivity. While promising, this convergence is not without serious complexities. This paper aims to shed light on its potential but also on the underlying challenges.

The purpose of this paper is to provide satellite as well as terrestrial operators a more accurate view of what can be accomplished with current technologies, and a clearer sense of what to genuinely expect in the short and medium term.

2. Long awaited convergence

After many years where we have seen the cellular and satellite industries operating independently, with little cooperation, we are now looking for a true convergence between the two fields.

When Cell & Sat was founded in 2005, it was already apparent that terrestrial and satellite technologies could be combined to develop efficient telecommunication solutions, in particular to reach the unconnected. Important joint developments focused on satellite backhaul for remote cellular base station. And today, while cellular operators are still extending their coverage deeply in rural areas and aim for a truly universal service, cellular backhaul represents one of the fastest growing market for satellite services providers, generating revenues close to $ 10 Bio in 2022 (wholesale capacity and service management included).

3. Innovative technologies

In recent years we saw many innovations both in the terrestrial and satellite networks, with a significant impact on the cost of data transmission, associated with a steady growth of the worldwide traffic.

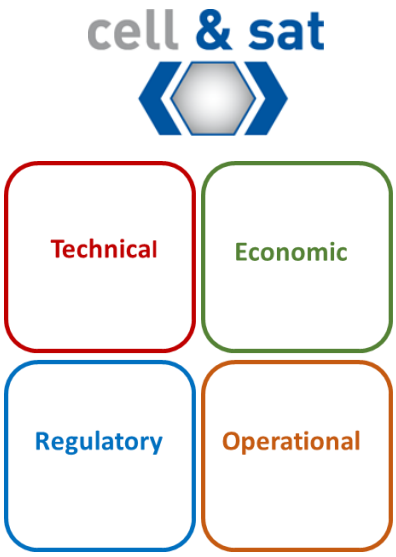
In the cellular world, 5G is now being deployed rapidly in most countries with subscriptions forecasted to reach 1.5 Billion in 2023. The new standard permits a large variety of services, from broadband fixed and mobile access, Internet of Things (IoT) and mission critical applications. It is also compatible with new high band spectrum, up to 26 GHz and more, to cope with the increasing capacity requirements. And its latest version, the Release 17 published in 2022, is the first to introduce “Non Terrestrial Network” (NTN) features allowing direct connectivity between terminals on ground and satellites.

In the satellite world, important technological developments of the last decade concerned cost-effective launchers, a wide range of satellite platforms ranging from high power very high-capacity “VHTS” down to small / nano satellites, regenerative and flexible satellite payloads using high performance active array antennas. And we saw many satellite networks deployed at different orbits: GEO, MEO and LEO. On the terminal side, new electronic beam-steering antennas have been introduced for efficient connectivity with MEO/LEO constellations as well multi-orbit satellite systems.

4. Lot of promises … but many challenges

There is today a lot of attraction for new applications combining both cellular and satellite technologies. This includes “Direct-to Device” (D2D) possibilities illustrated by the iPhone 14 able to reach Globalstar satellites for emergency messaging, as well as recent similar announcements for a variety of terminals (cellular IoT, smartphones, fixed broadband terminals) and different active or future satellite systems.

But it is also clear that many difficulties remain on the road to this desirable convergence. We anticipate that only a few players will succeed, it will be the organizations capable to address in parallel a variety of difficult challenges: technical, economic, regulatory as well as operational.



The challenges of Cellular & Satellite convergence

4.1. Technical challenges

The most obvious challenges relate to the difficulty to connect cellular terminals with satellites, at best at 600 km altitude (low LEO) or, at worst, at 36,000 km (GEO). The radio link budget requirements depend on the distance, the required bit rate and the frequency band used. It has an impact on gateway, satellite and terminal key parameters such as transmission power, antenna gains and receiver sensitivities. Today only VSAT type terminals equipped with high gain antenna(s) are capable of providing true broadband direct-access services, while smartphones remain limited to low bit rate messaging with, possibly, telephony and low bit rate data services as well in the near future. Furthermore, implementing direct satellite access to smartphones requires lower frequency spectrum, below 2GHz: this can be found in the highly sought-after UHF, L and S bands.

Other technical difficulties relate to time advance adaptation for long delay, as well Doppler shift compensation: the required evolutions have been introduced in Release 17 of the 3GPP standard.

To be compatible with cellular terminals, new developments are also needed on satellite platforms and payload. We have seen big progress in GEO satellite design for high capacity: 1 Terabit/s payloads have been developed using very high gain multibeam antennas. In parallel, some LEO satellites are being tested with large active array antenna – up to 64 m^2 and more – to be capable to connect unmodified smartphones. It is also foreseen that some new satellites developed for 5G NTN applications will have regenerative payloads with cellular on-board processing. In the coming years, we expect further progress in the design of high-performance satellites, but the difficulties associated with these new developments remain high.

4.2. Economic challenges

Connecting cellular terminals from space requires efficient satellites as well as optimized ground equipment: gateways with improved sensitivity, electronic steering antennas for fixed wireless terminal, new generation of smartphones, advanced management tools. The deployment of LEO satellite constellations with several thousand of satellites will also be essential.

These new developments imply important engineering effort, and significant investment for the manufacturing, launch and operation of large satellite fleets. It is estimated that an efficient NTN LEO constellation requires an initial investment up to $ 10 Bio, not including the yearly recurring operational costs. It is no surprise that only major players could pretend to take a share of this market!

Another challenge is to be competitive with terrestrial solution. We all witnessed the optimization of terrestrial mobile and fixed communications systems, with the cost of data transmission continuously decreasing. In the meantime, recent broadband satellite systems can charge less than $1 per Gbyte … but this may not yet be low enough to address the low-income rural market of developing countries.

4.3. Regulatory challenges

Very important factors, both for cellular and satellite industries, are related to regulation. Among the most influential parameters for operators is the right to utilize “managed” radio frequencies, associated with the required technical parameters to avoid inter-operator interference.

By default, cellular and satellite operators use their own, distinct, frequency bands. But the introduction of satellite-based cellular applications raises a new question: should satellite operators be allowed to use cellular frequencies to access regular smartphones? Or should the new NTN mobile terminals have access to distinct terrestrial and satellite frequencies?

Both approaches are currently being discussed, with potential significant impacts on the size of the accessible market .. as well as on the long-term value of the spectrum owned by operators. The shared spectrum approach also raises additional technical challenges to ensure that the introduction of NTN coverage does not reduce the quality of existing terrestrial cellular services.

4.4. Operational challenges

Last but not least, with future NTN mobile networks using terrestrial coverage as well as possibly multiple satellite orbits, we anticipate significant operational challenges. These need to be addressed by the converged cellular satellite operators to provide acceptable service quality to their subscribers.

5G mobile operators have introduced advanced mechanisms to control the QoS offered to their end users, and they differentiate user categories by defining different Service Level Agreements (SLA). Similarly, satellite operators have developed their own tools to deliver reliable managed services to residential and professional customers: such operation platforms were developed initially for GEO satellite, to account for daily traffic variations as well as potential radio propagation impairments (e.g. rain fading). More recently, MEO & LEO constellations have introduced additional complexities to be able to offer reliable services with constantly moving satellites and regular constellation upgrades.

Addressing the operational requirements associated with dual terrestrial - satellite networks will be another big step, and it may imply interworking between multiple operators with different information systems. In the short term, satellite operators are already developing management platforms to operate multi-orbit (GEO + MEO/LEO) systems. Another level of difficulties will then be associated with the deployment of multi-layer NTN 5G cellular networks, including possibly terrestrial microcell and microcell components, and multi-orbit GEO/MEO/LEO satellites and the option to add coverage by a fleet of High-Altitude Platform Stations (HAPS).

5. Some initial conclusions

Cellular and satellite convergence is very promising, but several important points need to be considered. Satellites are not meant to replace terrestrial networks, and they should be seen as a complement rather than a replacement. Also, expectations are different for broadband access using fixed terminals, and direct satellite connectivity with smartphones which is more complex. Finally having access to the right spectrum is essential to provide an efficient satellite access to mobile devices.

Integrating terrestrial and satellite networks is a multifaceted endeavor with a variety of technical, economic, regulatory and operational challenges. While recent developments of the 5G standard serve as an important foundation, fully integrated networks will take time to materialize and may even be associated only with future “6G” evolutions of the 3GPP cellular standard. Major players in both the telecommunications and satellite industries need to collaborate closely to drive this convergence forward. This involves strong technical and operational expertise and long term investments in standardization, research and development. Due to the ubiquitous coverage of cellular and satellite systems, it will also require a strong support of national and regulatory authorities around the world.