A Digital "New World"

The Big Fusion between Ubiquitous Localization (GNSS), Sensing (IOT) and Communications (5G)

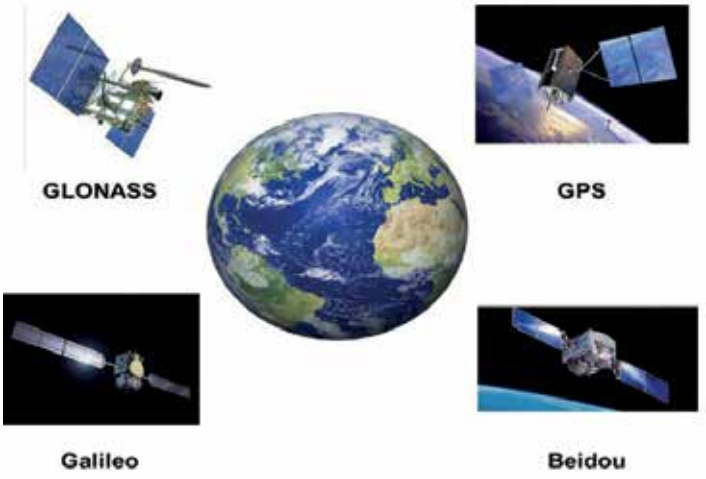

Fig. 1 - GNSS Multi-Constellation Scenario.

by Marco Lisi

La grande fusione fra servizi di localizzazione (GNSS), monitoraggio remoto (IoT) e comunicazione (5G).

We are at the dawn of the discovery of a "New World": not a virtual one, but the digital representation, in all its minute details, of our physical world, of planet Earth.
This epochal transition in the history of mankind is being triggered by three main technological trends:

- Ubiquitous Localization and Timing: Global Navigation Satellite Systems and other similar Positioning, Navigation and Timing (PNT) infrastructures make possible a very accurate localization in space and time of both people and things;
- Ubiquitous Sensing: from 1 to 10 trillion sensors will be connected to Internet in the next decade (a minimum of 140 sensors for every human being on the planet);
- Ubiquitous Connectivity: 2.3 billion mobile broadband devices and 7 billion mobile cellular device in 2014. In the next years 5G will dramatically increase both connectivity and data rates.

Enormous amounts of data are being collected daily and at an exponentially increasing rate. 99% of them is digitized and 50% has an associated IP address.

We are practically going for a detailed digital mapping of the world around us. It is an entirely New World we are facing, but we have not learnt yet how to navigate and explore it.

Ubiquitous Localization and Timing

Global Navigation Satellite Systems, such as GPS, GLONASS, Galileo and Beidou, constitute together a potentially

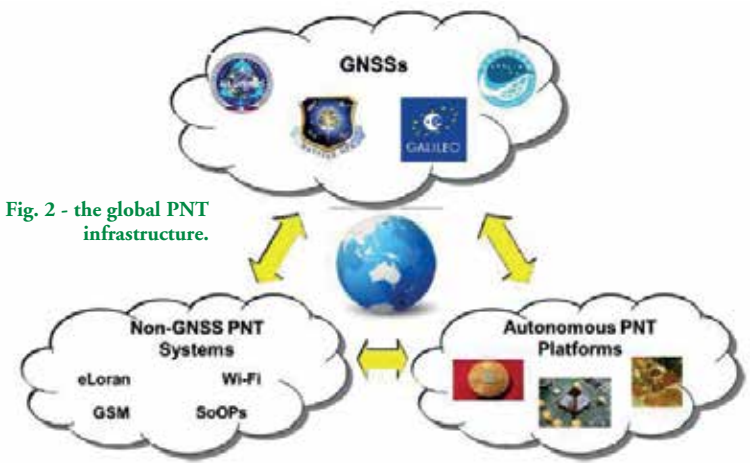

Fig. 2 - the global PNT infrastructure.

Fig. 3 - IoT impacts on business and society.

interoperable and coordinated infrastructure, supporting in a vital way most industrial and economic aspects of our society (fig. 1).

GPS in particular is nowadays considered a worldwide utility, tightly interconnected with all other critical infrastructures, from electric power distribution systems to air traffic management systems, from railways to water and oil piping networks.
In the mind of the average user (but also in that of many engineers) the main contribution of GNSS's, their true "raison d'être", is in providing one's accurate position and in allowing a reliable navigation, be it by car, by airplane, by train or by boat.
Precise timing is understood, at least by engineers, as an enabling feature of GNSS's and a very useful by-product, after positioning and navigation.
The reality, as shown by studies performed e.g. by the US Department of Homeland Security (DHS), is that in fact timing is the most strategic and essential of the services offered by GNSS's, and the one most affecting all critical infrastructures of our society.
Non-GNSS PNT systems and technologies are also being developed worldwide.
In the not so far future, a PNT system of systems, including GNSS and non-GNSS infrastructures, is likely to take place, while, at user receiver level, a fusion of data from GNSS and other sensors (such as inertial platforms, Wi-Fi, GSM, signals of opportunity, etc.) will become normal practice (fig. 2).

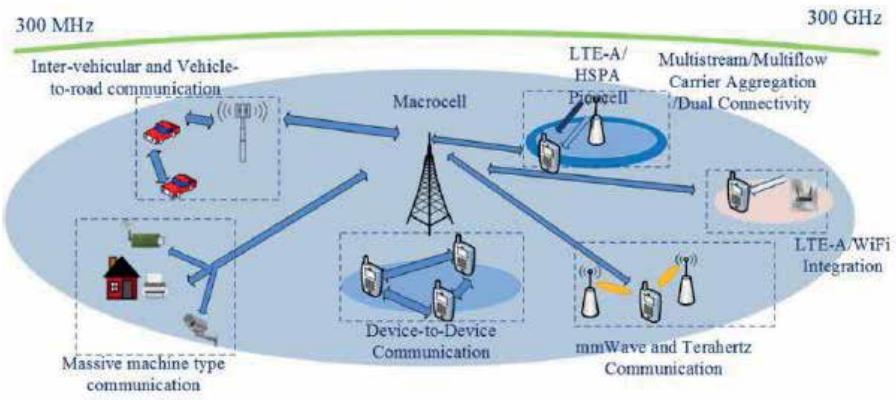

Fig. 4 - 5G infrastructure architecture.

Data deriving from different systems and platforms will be seamlessly "fused" at user receiver level, guaranteeing a high degree of availability and continuity.

Ubiquitous Sensing (Internet of Things)

The Internet of Things (IoT) envisions many billions of Internet-connected objects (ICOs) or "things" that can sense, communicate, compute, and potentially actuate, as well as have intelligence, multimodal interfaces, physical/virtual identities, and attributes.
The IoT is likely to revolutionize all aspects of our society and daily life (fig. 3).
Its exponential growth will actually imply the practical feasibility of an Ubiquitous Sensing: from 1 to 10 trillion sensors will be connected to Internet in the next decade (a minimum of 140 sensors for every human being on the planet).
Ubiquitous sensing, or ubiquitous "geo"-sensing to emphasize the spatial dimension, as deriving from IoT and from mobile broadband communications, will mean that we will be able to probe, even in real time, the phenomena around us, the surrounding reality, with capabilities far beyond those made so far available by our senses.
Enormous amounts of data will be available for our analyses, all of them referenced in space and time.

Ubiquitous Connectivity (5G)

5G, the forth coming wave in mobile communications, will realize a quantum leap towards the goal of ubiquitous connectivity (fig. 4).
As a matter of fact, 5G will not simply extend in a linear way the capabilities of the previous

Fig. 5 - 5G and the Internet of Things.

Fig. 6 - 16th century plan of the City of London

four generations of mobile networks. Its dramatically enhanced performance in terms of flexibility and throughput will make fully feasible those "smart" applications and infrastructures that require networking, high data rates, real time processing.
It is evident how 5G will become the natural complement of the IoT, its technological enabler (fig. 5).

A new perception of the world

An example will make clear the potentialities deriving from the fusion of ubiquitous localization and timing, sensing and connectivity.

Figure 6 shows a plan of the City of London in the time of Queen Elizabeth (16th century). Public (e.g. the London Tower) and private buildings are clearly identifiable, as well as London Bridge and the banks of the Thames river. Fairly detailed and useful for its time.
Figure 7 offers a far more detailed view of approximately the same area, as made available by Google Earth. The picture is fairly detailed and can enriched with street names, labels, photos, etc. Let us now imagine to be able to link and merge almost in real time all the information coming from thousands (if not millions) of sensors spread over the area (fig. 8).

Fig. 7 - City of London aerial view.

What we will get is a sort of "Augmented Reality" representation of the same geographical site, through which we might be able this time to exercise most of our senses: smell the clean waters of the river Thames, feel the slightly chilly wind along the banks, hear the sounds and calls of the six (or nine?) legendary ravens living at the Tower of London.

The role of satellites in the "Digital New World"

Satellites are going to play an important (in some cases primary) role in this new scenario. In terms of localization and timing, GNSSs presently (and most likely also in the years to come) are the backbone of a worldwide PNT infrastructure, also including alternative ground-based systems (such as eLoran) as well as stand-alone technologies (miniaturized inertial platforms and atomic clocks). As far as sensing is concerned, despite the enormous amount of sensors being integrated in smartphones and other portable devices, Earth observation will keep depending heavily on satellites of various complexity (down to nano and pico satellites) and with a variety of embarked sensors (multi spectral optical, radiometers, altimeters, SARs).

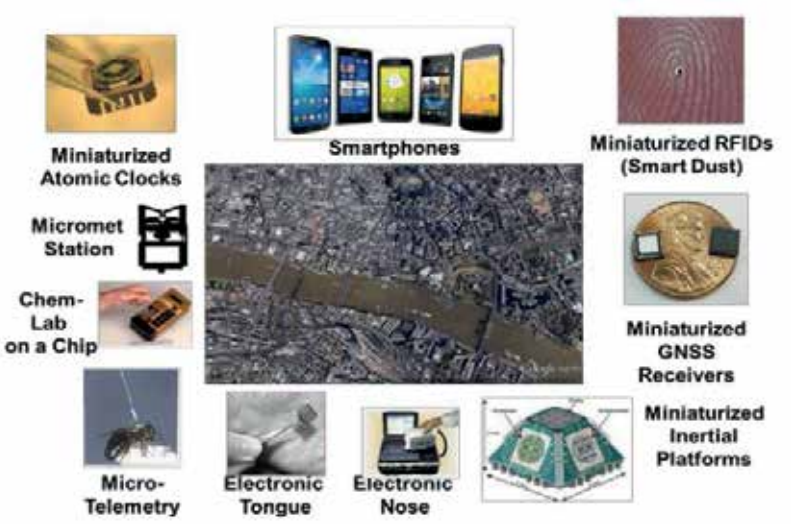

Fig. 8 - An "Augmented Reality" evolution through data fusion

In the area of telecommunications, notwithstanding the exponential development of mobile cellular networks, both in terms of data rates and coverage, satellites remain the primary solution to guarantee services over the oceans and to provide an affordable last-mile connections to users in scarcely populated areas.
Moreover, satellite networks, both for trunk and mobile communications, are the natural back-up for terrestrial networks, improving the overall resilience, security and availability of the world telecommunications infrastructure.
Satellite and terrestrial system integration, already being experimented with 4G mobile cellular communications systems, is high priority in the agenda of the coming 5G network, with the clear purpose of achieving a truly ubiquitous coverage.
This integration will require the development of interoperability standards to make the two sectors interconnect efficiently and reliably, both at network and at IP levels.
In conclusion, we are rapidly moving towards an integration of PNT, Remote Sensing and Telecommunications systems leading to a worldwide, system of systems infrastructure (fig. 9).

Conclusion

Ubiquitous Localization and Timing, Ubiquitous Sensing, Ubiquitous Connectivity: these three main technological trends are triggering an epochal transition in the history of mankind.
We are practically going for a detailed digital mapping of the world around us, for an evolution of reality as we can sense it today towards an enriched, augmented reality.
It is an entirely New World we are facing, but we have not learnt yet how to navigate and explore it.
The future asks for an ever closer integration and fusion of Telecommunications, Sensing and Positioning, Navigation and Timing applications.

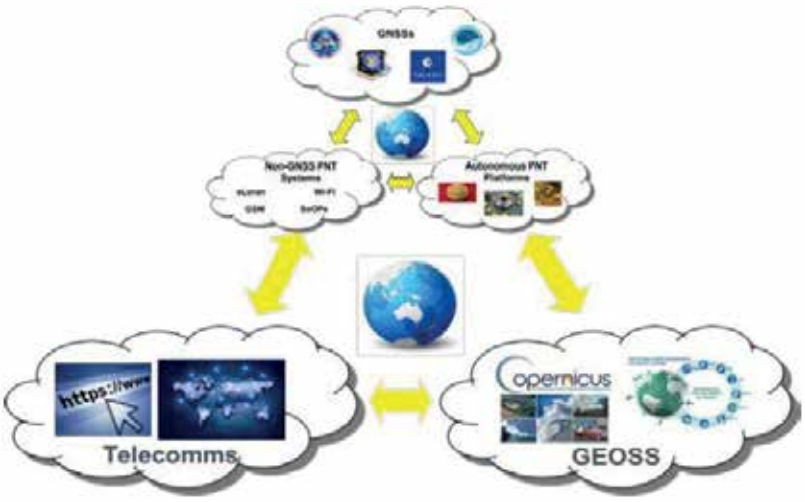

Fig. 9 - Worldwide systems of systems infrastructure.

KEYWORDS
GNSS; PNT; IoT; COMMUNICATION; INFRASTRUCTURE; NETWORKS; PRECISE TIMING

ABSTRACT
La grande fusione fra servizi di localizzazione (GNSS), monitoraggio remoto (IoT) e comunicazione (5G). Un "Nuovo Mondo" digitale si profila all'orizzonte: le tecnologie sono sempre più onnipresenti nella nostra vita quotidiana e termini come geolocalizzazione, Internet of Things (IoT), connettività, sensori, GPS, GNSS o rappresentazione digitale sono ormai conosciuti anche ai non addetti ai lavori. Il mondo dell'industria è sempre più basato è devoto ai sistemi di posizionamento satellitare e sulla misura del tempo. I principali trend tecnologici del momento come il GNSS e altre infrastrutture PNT, l'Internet delle Cose e la connettività (5G) cambieranno drasticamente la nostra vita quotidiana; l'integrazione fra queste infrastrutture (GNSS, IoT e connettività) giocherà un ruolo fondamentale per la realizzazione del "Nuovo Mondo" digitale.

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