Emerging Technologies: the digital revolution around and above us

by Marco Lisi

Fig. 1 - GNSS Multi-Constellation Scenario

The article describes the main trends which are at the basis of the digital revolution affecting our society.

Internet of Things (IoT), broadband and ubiquitous wireless communications (5G), ubiquitous Positioning, Navigation and Timing (PNT): they are different facets of the "New Digital World" ahead of us, characterized on one side by the integration and fusion of different technologies, aiming at a new, enhanced representation of our physical world; on the other side by a progressive dematerialization of products and by their transformation in services.
This epochal process will also require a change in the way we approach engineering: a more systemic, concurrent and through-life perspective.
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. But also the world of manufacturing is going to be radically transformed, both in terms of organizational paradigms (Industry 4.0) and in terms of radically new technologies (Additive Manufacturing).
This epochal transition is being triggered by four main technological trends:

1. 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;
2. 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;
3. 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;
4. Progressive and ever detailed 3D modeling of our surroundings.

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 representation 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 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

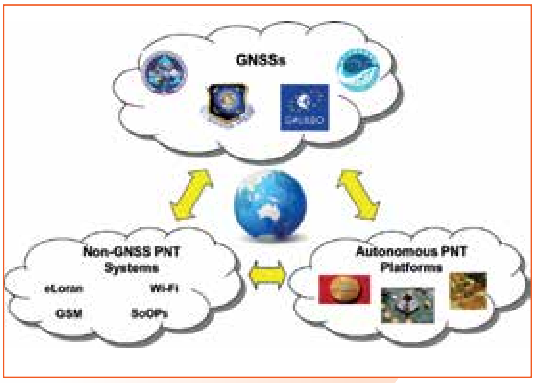

Fig. 2 - the global PNT infrastructure.

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

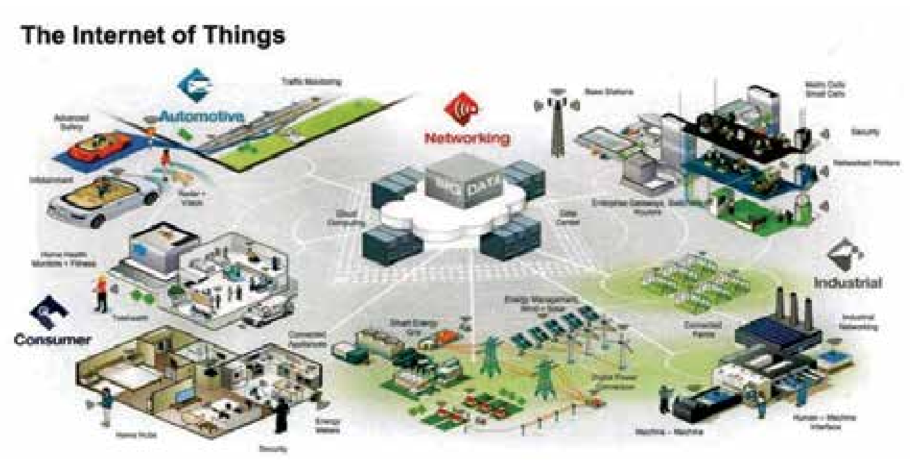

Fig. 3 - IoT impacts on business and society

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 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).

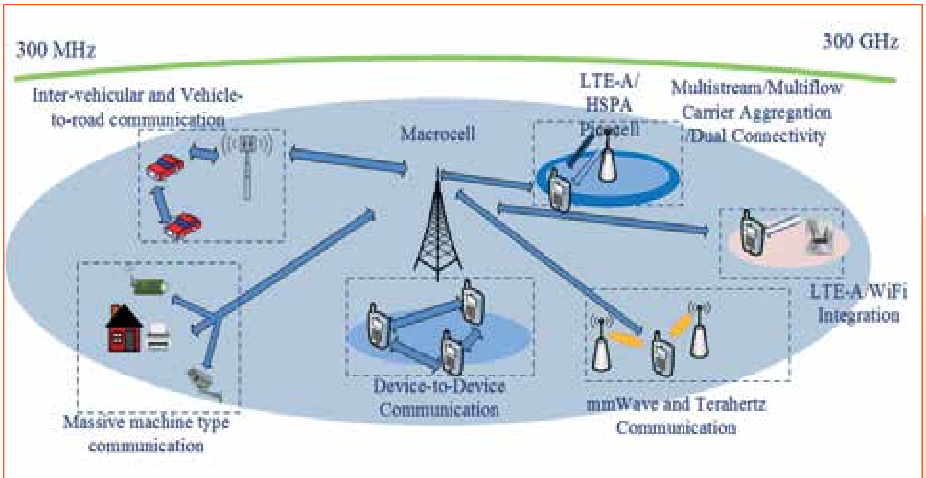

Fig. 4 - 5G infrastructure architecture.

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

Additive Manufacturing (3D Printing)

Additive Manufacturing (AM, also known as “3D Print) enables the fabrication of objects through the deposition of material in order to obtain fit-for-purpose hardware, as opposed to traditional subtractive processes, where material is removed from larger, semi-finished products (fig. 6).
Like many new manufacturing processes, 3D printing arose from the merging of previously existing technologies: the coming together of Computer Aided Design (CAD), inkjet nozzles and automated machine systems.
AM includes a large family of processes and technologies and can be applied to a wide range of materials ranging from metals, polymers and ceramics but also food, living cells and organs.
Today, AM is a standard manufacturing process in a significant number of industrial applications and high potential is anticipated (and in many cases already demonstrated) in high end technology sectors, including aerospace, turbine industries and medical applications.
The increasing availability, at affordable prices, of 3D printers for personal use, is likely to revolutionize the world of manufacturing as well as that of retail commerce of goods: in a not so far future (applications are already available on the Web) people, by clicking on a specific product in a specialized catalog online, will purchase and download digital files allowing the manufacturing of chosen products at their own premises, with their personal 3D printers.
In this way, the progressive dematerialization of products, that has already conquered the music and books markets, will further extend to many other consumer goods, such as, e.g., housewares, toys and tools.

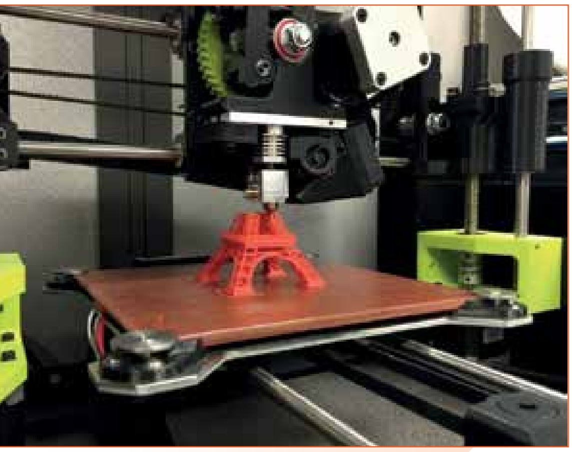

Fig. 6 - 3D printer at work

As a matter of fact, in the future we will be exchanging and trading not physical goods, but rather their Intellectual Property Rights (IPR’s).

Autonomous Driving

Significant advancements in satellite-based positioning are contributing to the development of better transport services and new applications for safe transport and smart mobility.
With its flexibility, fast growing capability, low infrastructure costs and long-term sustainable use, GNSS is an important asset in the design of new Intelligent Transport System (ITS) infrastructures.
Smart mobility applications improve the efficiency, effectiveness and comfort of road transport through:

- Navigation, the most widespread application, provides turn-by-turn information to drivers via portable navigation devices (PNDs) and in-vehicle systems (IVS).
- Fleet management on-board units (OBUs) transmit GNSS positioning information through telematics to support transport operators in monitoring the performance of logistic activities.
- Road traffic monitoring services collect floating car location data from vehicles through PNDs, IVS and mobile devices to be processed and distributed to users and other interested parties.

Safety-critical applications leverage precise, reliable and secure positioning in situations posing potential harm to humans or damage to a system/environment:

- Advanced Driver Assistance Systems (ADAS) support the

Fig. 7 - Autonomous Driving.

Fig. 8 - Technology adoption curves.

driver during the driving process and act as a first stepping stone towards Autonomous Vehicles.

- In cooperative ITS and connected vehicles, GNSS positioning is a key element for providing situational awareness through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, enhancing the safety and comfort of the driver.
- Dangerous goods can be tracked by transmitting GNSS-based positioning data on the vehicles carrying them, along with other information about the status of the cargo.

Liability- and payment-critical applications can have significant legal or economic consequences depending on positioning data:

- In Road User Charging (RUC), GNSS-based solutions are designed to charge motorists for the actual distance travelled, without barriers or gantries, and provide interoperability between national cross-border schemes.
- In Pay-As-You-Drive (PAYD), insurance telematics rely on GNSS data to increase the fairness of motor insurance for both insurers and subscribers.

Regulated applications apply the transport policies introduced by national and international legislation:

- GNSS-enabled IVS are used in the pan-European eCall, which accelerates emergency assistance to drivers and passengers by sending an emergency call to 112 and also providing positioning information in the unlucky event of accident.
- Smart tachographs leverage GNSS positioning to support road enforcers, recording the position of a given vehicle at different points during the working day.

The emerging technology that is going to act more disruptively in our everyday lives, showing in a most evident way how the fusion of other technologies can make new services available, is Autonomous Driving (fig. 7). Autonomous vehicles can take over activities traditionally performed by the driver, thanks to their ability to sense the environment, navigate and com-

Fig. 9 - The Moon Village

municate with other vehicles and road infrastructure when combined with connected vehicle solutions. Widespread adoption of autonomous driving can reduce traffic accidents, reduce fuel consumption and improve traffic flow, as well as improve driver comfort.
Autonomous vehicles are enabled by the combination of different technologies and sensors, allowing the IVS to identify the optimal path of action.
The adoption of Autonomous Driving is going to happen much faster than everyone thinks, following adoption curves closer to those typical for digital technologies, rather than to those typical for transportation systems (fig. 8).
In other words, while cars took decades to be widely adopted, Autonomous Driving will have a worldwide spread in just a few years.
Many believe that Autonomous Driving will probably be the single largest societal change after the Internet. One thing is for sure: Autonomous Driving will destroy the traditional concept of the car as a personal good to be owned, moving to the paradigm of transportation as a service and hence confirming the transition from products to services mentioned in the introduction.

Emerging Technologies in Space

The Director General of ESA, prof. Woerner, set forth the idea of a "Moon Village", a village on the moon built by huge 3D printers and inhabited for months at a time by teams of astronauts. The plan outlined by the ESA is that, starting from the early 2020s, robots will be sent to the Moon to begin constructing various facilities, followed a few years later by the first inhabitants (fig. 9).
Back in 2013, ESA teamed up with building companies to start testing out various Moon base-building technologies, and determined that local materials would be the best for constructing buildings and other structures, which means no need for transporting resources from Earth at an astronomical cost. But the problems to be solved for the realization of such stable manned infrastructure on the Moon (a true follow-on of the International Space Station) involve much more than just building technologies. The Moon Village will be a large and complex system where requirements related to operations and safety of life will be of paramount importance.
Moreover, from an architectural viewpoint the "village" will have to be expandable and "open" to the integration with other systems, hence integrability and expandability will be two key issues. But first and above all, the Moon Village will have to be affordable and sustainable, i.e., its cost will need to be assessed over its life-cycle.
As a "Wild West" town in the old times, "Moon Village" will have to provide a number of essential infrastructures. In particular, the exploration of the Moon with human and robotic missions and its colonization, through the establishment of permanent bases, will require planetary communications and navigation infrastructures.
Even in space, emerging communications (5G) and PNT technologies will provide reliable and affordable solutions for a communications and navigation infrastructure (fig. 10).

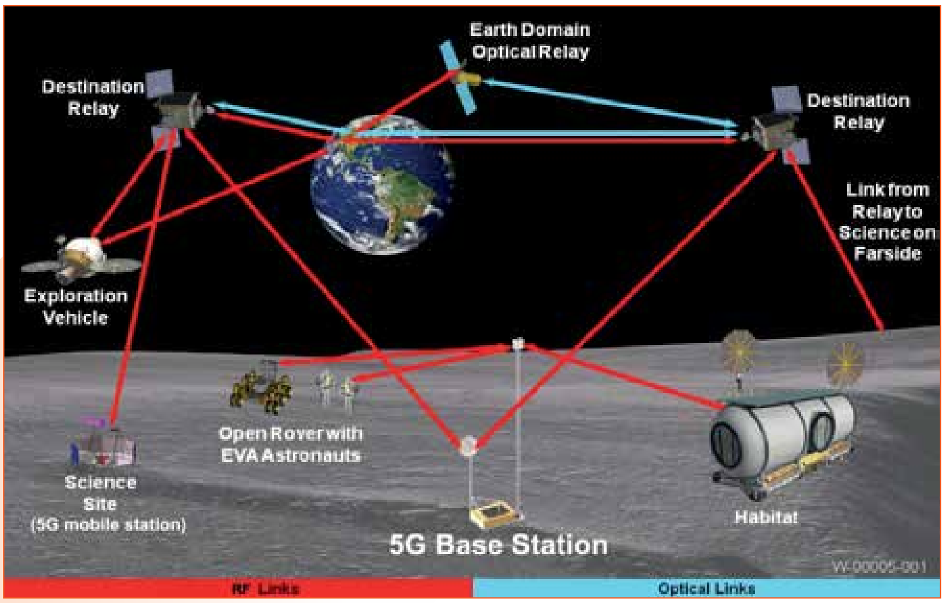

Fig. 10 - Moon Communications and PNT infrastructure.

Conclusion

Ubiquitous Localization and Timing, Ubiquitous Sensing, Ubiquitous Connectivity, 3D Digital Modeling: these four main technological trends are triggering an epochal transition in the history of mankind, characterized by an increasing predominance of services in our economy.
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 yet learnt how to navigate and explore it.

Moreover, the emerging technologies will cause radical transformations of our society, such as those related to Autonomous Driving.
Our space exploration activities are also going to be affected, a good example being ESA's vision of a Moon Village, a stable base on our natural satellite from which to start the commercialization of Space.

ABSTRACT
Ubiquitous Localization and Timing, Ubiquitous Sensing, Ubiquitous Connectivity, 3D Digital Modeling: these four main technological trends are triggering an epochal transition in the history of mankind, characterized by an increasing predominance of services in our economy.
These emerging technologies will cause radical transformations of our society: it is an entirely New World we are facing

KEYWORDS
Digital era; technological trend; GNSS; PNT; 5G; autonomous driving; 3D modeling; Galileo; Additive Manufacturing; IoT

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