the most advanced enabling technologies which will permit the next leap forward are reviewed.

4.3.2 Enabling Technologies

4.3.2.1 5G systems and SatCom

Next generation wireless system, which is defined as fifth generation or 5G, will be the ubiquitous ultra-broadband network enabling the Future Internet (FI): as described in [4], it will enable "full immersive (3D) experience" enriched by "context information" and "anything or everything as a service (XaaS)" and will open the way to a world where the network has been reduced to a ubiquitous "pipe of bits". After the adoption of 5G systems, a revolution in the Information and Communications Technologies (ICT) field can be envisaged. It is worth underlining that, with respect to the current wireless communications, the future 5G communications shall guarantee the key performance indicator gains that are reported in Table 4.1 [4].

In this context, the issues of connection, security, mobility, and routing management will be effectively afforded. Full compatibility with current and future incremental 4G releases will be guaranteed by the possibility of instantiating any type of virtual architecture and installing any kind of network and service application efficiently.

In order to play an active role for the future 5G networks, the next generation of High-Throughput Satellite (HTS) systems for broadband distributed user access shall satisfy the user bit rate requirements reaching the "terabit connectivity" from the present tens of Gbps. Regenerative satellite with flexibility in the uplink and downlink connections, e.g. as described in [5], will provide the paradigm of 'Internet in the sky' necessary for the provision of the global IoE.

Table 4.1 5G key performance gains

Key Performance Indicator	Gain to Be Afforded
Throughput	1000× more in aggregate, 10× more at link level
Latency	1 ms for robot remote control or tactile Internet applications, below 5 ms for the download of 2–8K videos
Reliability	Ultra-high
Coverage	Suitable for a seamless experience
Battery lifetime	10× longer
Spectrum utilization	All spectra, from cellular bands to visible light

To manage efficiently the huge demand of user capacity and the propagation impairments, mitigation techniques required to realize an efficient EHF satellite transmission, a very attractive technique is the smart gateway and the adoption of the paradigm of SDN/NFV [6]. Smart GW for the feeder link is based on the use of a number of GWs connected by a terrestrial fiber network to route feeder link data by diversity availability to counteract occurrence of unavailable gateway(s). This operation requires the management of complex handover procedures and a precise localization of the mobile users.

4.3.2.2 Cooperative/assisted localization and UWB

Accurate localization of the user is nowadays very important, both for delivering new smart services (location-aware) as well as for outdoor and indoor navigation. An important support to enhanced-value location-based services can be identified in the integration of GNSS and other positioning techniques. In particular, GNSS involves several systems such as GPS, GLONASS, and the upcoming GALILEO, plus other regional navigation systems, so increasing the service availability in outdoor environment [7, 8].

Moreover, Peer-to-Peer Cooperative Positioning (P2P-CP) technique is able to improve the GNSS receiver performance in terms of availability, accuracy, and Time-To-First-Fix (TTFF) and can be an effective solution [9]: in P2P-CP context a terrestrial wireless communication link is required between cooperating users to allow the aiding information exchange; to this aim, short-range communication systems such as WiFi and Bluetooth can be used.

On the other hand, Dead Reckoning allows to estimate the user motion either in indoor or outdoor scenarios without any external infrastructure assistance, relaying only on a single terminal and its internal sensors [10]: nonetheless, this technique is often integrated with GNSS to improve the position accuracy when satellite signals are not available for a short time. In presence of hostile conditions, i.e., when the LOS to the satellites is partially or totally obstructed for a long time, the received signal strength might be too weak for an appropriate processing, leading the GNSS-based localization to degrade or even fail: in this context, stand-alone techniques may not afford the location services requirements.

Ultra-wide band (UWB) technology could be a good candidate for an accurate localization of smart devices. UWB can be also used successfully to enhance the accuracy of other positioning technologies. Diversity navigation employing multiple sensing technologies can overcome the limitation of individual technologies, in particular in harsh environments [11].

4.3.2.3 Wireless sensors networks

The realization of a monitoring system can be achieved through the implementation of a dedicated Wireless Sensor Network (WSN).

The WSN is composed of autonomous modules (with sensors for the detection of environmental parameters), which are characterized by low cost, small size, very low (down to no) maintenance effort, reduced environmental impact, and equipped with on-board intelligence.

This solution allows the monitoring system to acquire and process a signal and send the information to an operation and alert center via SMS: hence, it can be responsible for the safety and monitoring of areas subject to environmental risks.

As a matter of fact, a wireless sensor network for Environmental Monitoring Applications defines a prototype of Smart Grid: the goals of these networks can be extremely differentiated and, sometimes, contradictory, e.g., the responsiveness and the energy efficiency of the networks are opposite requirements. Moreover, this kind of communication system can be seen as a building block of the definition of the so-called IoT and an example of M2M.

4.3.2.4 Visible light communications

Exploiting the visible radiation for communications is one of the most promising technologies for short- to medium-range next-generation nomadic access [12]. A huge available bandwidth, ultra-dense indoor channel reuse, no interference to radio channels, and perceived biological compatibility are the most relevant features. Light propagation can be spatially confined to provide secure accesses only to desired users; moreover, different wavelengths can provide multi-carrier like digital transmission schemes. Challenges to be solved are related to coexistence with other light sources, including the solar radiation, the availability of low-cost detection devices, and emission compatibility for long-range links.

4.4 New Paradigms and Challenges

4.4.1 SDN/NFV Paradigm

Individual advances on each technology components are not enough unless an efficient and versatile integration framework is built. Fortunately, the path to a seamless integration of access components and services provision has been marked in the last years through the ever increasing presence of the "virtualisation" concept [11]. NFV and the abstraction of network entities (Software Defined Networking) provide a flexible and powerful framework for the provision of next-generation digital services in a future efficient hybrid system. The physical infrastructure is distributed among different operators and technologies: the satellite/terrestrial access, the mobile networks, cloud service operators, and an IT infrastructure carrying the physical components of the NFV. The radio access itself can be virtualized producing benefits in terms of flexibility and availability (e.g. during emergency contexts) [13].

4.4.2 Cognitive Paradigm

Focusing on wireless access technologies, higher computing resources are available for the communication layers in the terminals, so complex operations can be accomplished in order to seek for appropriate and efficient spectral resources. The "cognitive" paradigm has been largely explored from the research community in the past, but it is in the next-generation networks that it will play a significant role [14]. The cognition, as in humans, is applied to solve specific problems. One of the killer challenges in modern wireless terminals is the energy impact of radio access functions. Cognitive strategies along with the application of Game Theory can realize distributed optimization of radio resources in a quickly changing environment [15].

4.4.3 Social Paradigm

The trend toward a "global connectivity" and the large availability of smart devices equipped with different sensors lead to an increase in the adoption of the social networking concepts within the future architectures.

Users may be the source of important information to be shared with others (emergency situation, intervention scene, accident, etc.). The efficient and timely sharing of information among users enables the development of innovative services for enhancing quality of life, mobility, security, and emergency management. Moreover, the concept of social interactions may be extended to "smart objects", which will autonomously establish social relationships so as to build a social network in the IoT [16].

4.4.4 HBC Paradigm

A natural evolution of current communication systems is the "remote sensorial perception". The Human Bond Communication paradigm has been recently proposed with the aim to transmit the features of a subject in the way humans perceive it [17]. The translation and transmission of the overall perception of a physical subject into the information domain allow users to access a multi-dimensional communication space. The exploitation of all five senses and their complex interactions will open to new and unexplored opportunities in the future telecommunication ecosystem.

To enable such innovative technology, several technological challenges shall be solved, ranging from the security issues to the energy efficiency ones, including electromagnetic compatibility, reconfigurability and resiliency.

4.4.5 Specific Security and Privacy Mechanisms

Fast-changing topologies and propagation conditions also have impact on security aspects of the radio communication. Delegating the security aspects to traditional layers (i.e. transport and application layers) is a weak choice in a "hyper-connected" Internet-of-Everything world. This is why physical layer security has gained recently large interest and consensus. Securing the waveforms for cognitive wireless networks is however a challenging task, but not fully addressed here [18].

4.5 Conclusions

In the future, pervasive Internet *Ecosystem,* communication, localization, and sensing capabilities will be seamless integrated for the provision of innovative services. Heterogeneous systems, smart objects, and users will be part of an overall network, as foreseen in the vision of the challenging IoE.

New architectures are necessary and rely on enabling technologies and the most promising paradigms for implementing a high flexible and reconfigurable system able to support multi services platform. 5G systems, satellite communication, satellite/terrestrial localization systems, WSNs, and visible light communications will be the main components of the future architectures and their integration will be provided through the adoption of one or more novel network concepts such as SDN/NFV, cognition, social networking, HBC, and user-controlled security.

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