INTERACT – D1: State-of-the-art and key challenges

Deliverable D1 is available in the member's area

In the first months of work, participants of INTERACT have defined the challenges and the first envisioned solution that will constitute the core of the coming work in the action. The deliverable is a working document available only for members. A short summary of the different addressed items is proposed below. The full document includes much more details about the identified challenges for future communication networks and about the first tracks followed.

General objectives: previous wireless networks (up to 4G) have focused on providing communication links, first between human users (telephony), then between human users and centrally-located content and service providers, such as video streaming and online shopping. Each new generation has had a new radio interface based on a disruptive approach. 5G is the first one to have a radio interface that is an evolution of the previous generation, still, it introduces *de facto* a feature, researched for quite a while but never actually implemented in a cellular system, i.e., active antennas with beamforming (4G has references to them, but does not really use the technology in a widespread mode). In other words, 5G is aiming at making full use of the spatial dimension. In parallel to the radio interface (which has already been standardised), 5G has also new approaches concerning the network architecture and features, e.g., virtualisation, slicing, cloud and edge, which extend from the radio component to the very core of the network (still under standardisation, but mostly already defined). In addition to the development of higher data rates, 5G extends the network beyond human users to embrace machines. Doing so brings two new constraints, namely Massive Machine-Type Communications (mMTC) and Ultra- Reliable Low Latency Communications (URLLC), which attracted a large number of works in recent years and opens many applications beyond the mere human usage, like those of Internet of Things (IoT). However, the 5G network still aims to provide communication links between these machines/devices and some centralised coordinating and data-gathering entity, often located remotely in the cloud rather than within the network, and its human users are typically not expected to interact directly with these devices. As research in 6G has already started, the many explored directions address a large set of key components. One of the main aspects is to increase the intelligence in the network at all levels, to manage the ever-increasing heterogeneity in communicating devices and key performance indicators.

The action includes 3 disciplinary groups:

WG1: Radio Channels: extensive efforts are being devoted to obtaining a comprehensive understanding of radio wave propagation in several frequency bands for the development of future wireless networks. The task of WG1 is to further this understanding by providing an open and collaborative forum for the exchange of ideas, definition of key challenges, and identification of directions for research on radio channels. Two specific sub-working groups have been created:

> **SubWG mmWave and THz sounding (THz)**: the goal is to concentrate the expertise on radio channel measurements and analysis;
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> **SubWG Reconfigurable Intelligent Surfaces (RIS)**: the goal is to focus on the modelling and analysis of future smart radio environments empowered by controllable and smart surfaces.

Initial works concern radio channel measurements (channel sounding, e.g., for MIMO or multi-link, for (sub)THz frequency bands…); channel modelling addressing a large range of different vertical applications, environments, and modelling methods; RIS modelling, performance analysis, and prototyping and real-life measurements.

WG2: Signal Processing and Localisation: the goal of WG2 is to design novel physical layer technologies by combining the data information from statistical learning with the theoretical knowledge of the transmitted signal structure. Encoders for short block lengths, channel estimation schemes, beamforming and (massive) MIMO processing in sub-6-GHz and mmWave bands will be considered. The WG aims also at designing new positioning and localization techniques. One specific sub-working group has been created on **Integrated Sensing And Communications** (SWG-ISAC).

Initial works addresses Signal Processing for Communications (self-supervised learning of precoders under nonlinear power amplifiers for energy efficient massive MIMO systems, phase noise correction techniques using Machine Learning, non-coherent approaches…), localisation (human shadowing impact, machine learning tools, use of drones…). ISAC is also very active, investigating the use of millimetre waves, co-design and co-existence of communication and sensing systems.

WG3: Network Architectures and Protocols: the goal of WG3 is to propose new networking paradigms to perform human-to-thing communication, suppressing the perception of any intermediary. This fluid communication will require a network database for different use cases, dynamic infrastructure management – possibly with the help of machine learning– and adequate distribution of the computing load between different network components.

Machine learning is impacting networking and is studied in many different contexts.

The action also includes 4 vertical teams oriented towards specific applications:

VT1: Health and Well-Being: VT1 covers societal challenges related to health and well-being. It aims to address scientific challenges dealing with health data communication around or inside the human body using wearables, implants or ingestible electronics, and supporting infrastructure to convey the health data to relevant care centres or medical facilities.

One specific sub-working group has been created on **Exposure to Electromagnetic Fields** (SWG-EMF). The objective is to contribute to the standardisation of evaluation methodologies and of measurement analysis for the assessment of human exposure to EMF. This is undertaken for mobile and wireless

communications systems in general and for novel systems in particular, associated with both base stations/access points and mobile terminals.

VT2: Transportation: VT2 strives to increase the knowledge about the vehicular communication channel at current and future carrier frequencies, and further the contributing technologies and their integrations to bring connected and cooperative driving closer to a reality. Both conventional sub-6GHz frequencies and millimetre wave and sub-terahertz bands are of interest. A focussed effort to collect data and make it widely available is planned.

VT3: Industrial Automation: VT3 covers topics related to the fourth revolution of Industry, Industry 4.0. This specific context leads to very strict requirements in terms of reliability and latency, calling for the design of novel transmission techniques, considering the use of mmWave and THz bands, and the need for channel state information in harsh environments.

VT4: Smart Buildings and Cities: VT4 concerns several societal challenges, including cities or buildings. It will emphasise both on very high-rate communications and/or ultra-dense networks. ln our daily life, popular hot spot areas attract dense crowd and introduce high traffic demands.