The Most Important Future Wireless Technologies and 6G Networks

ABSTRACT

Wireless technology is evolving in all areas of mobile and wireless communications, and it is one of the fastest growing sectors. The world has witnessed new mobile generations every decade, meaning a set of technologies in the form of a new architecture and structure. As researchers in the broadcasting industry, we must consider this new field of research and take advantage of its potential opportunities in broadcasting applications. In this paper, the aim is to draw a picture of future generation wireless technologies (6G) in terms of capabilities. 6G is envisioned to operate at Terahertz radio frequencies and to increase spectrum gain by Ultra Massive MIMO antennas and Full-Duplex communication. Comprehensive AI systems will be used. These technologies will enable data throughput in Terabits/s, which will easily cope with the future increase of video traffic and heterogeneous data for the next generation of digital TV, beyond 2030.

KEYWORDS

Wireless technology, 6G, Terahertz, Massive MIMO, ML, AI, full-duplex

INTRODUCTION

Wireless technology has evolved over the years, but the need for higher efficiency and reliability is never-ending. Wireless technology is continually evolving, and it has already changed significantly. Each generation of wireless technology has been designed to meet the needs of end users and network operators. Many possible multimedia services will require having high bitrate and ultra-low latency such as Holographic Type Communications (HTC), 8K TV streaming, and 3D video streaming [1]. Nowadays societies are becoming more and more data-centric, data dependent and automated. The rapid development these processes, which require data rates in the order of Terabits per second, a latency of hundreds of microseconds, and 10^7 connections per km^2, may exceed even the capabilities of the emerging 5G systems.

This discussion has recently motivated researchers to investigate a new generation of wireless networks, i.e., sixth generation (6G) systems, to meet the demands for a fully connected, intelligent digital world. According to global research, it has been found that 6G will be in use by the end of 2030, and the pace of development is such that in 2035, 5G technology will be obsolete and will no longer be used. Therefore, 6G review is a necessity.

TV broadcast has traditionally been dependent on unidirectional, one-to-many delivery networks to fixed TV sets (broadcasting). Nowadays, an increasing number of consumers watch linear or nonlinear content on their traditional home screens as well as on their smartphones and tablets. These new forms of media consumption dramatically increase the load on mobile networks.

This situation may require new solutions and approach [2]. So mobile generations become important in creating the new concept of TV everywhere. We need to consider new wireless technologies and take advantage of their potential opportunities in broadcast applications. Improvements have been made in the 5G architecture for video streaming and broadcasting, but there are challenges that 6G will have to deal with in the future.

The rest of this paper is organised as follows. Section II presents the spectrum and Terahertz technologies in 6G. Section III describes the novel antenna technologies and Ultra Massive MIMO, Section IV describes the Artificial Intelligence. Full-duplex communication is also discussed in Section V and Section VI concludes the paper.

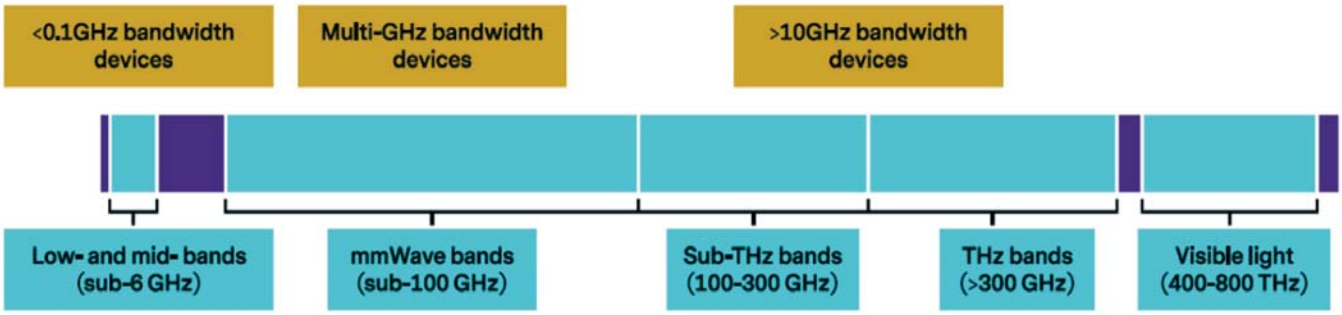


Figure 1. Potential spectrum regions for next generation of wireless networks.

SPECTRUM AND TERAHERTZ TECHNOLOGIES

Terahertz (THz) refers to frequencies in the 300 GHz to 3 THz range. We expect to see enhancements over the current 5G spectrum, and expansion of the spectrum into potential new bands from low GHz bands to low THz and the visible light region. The potential spectrum regions are illustrated in *Figure 1*.

The operation in existing bands will be enhanced in 6G with respect to the KPIs (Key Performance Indicators), but not every target is expected to be reached in all frequency bands. For instance, low frequency bands are often preferable in terms of spectral efficiency, reliability, mobility support, and connectivity density. In contrast, high frequency bands are often preferable in terms of peak data rates and latency [5].

The main reason for moving to higher frequency bands is to greatly expand the available spectrum compared to mmWave systems. But they also come with some major challenges due to the nature of propagation at these frequencies (including very short communication distances, blockage, and frequency dependent molecular absorption), hardware and system design.

In the THz region, hardware constraints and computational complexity will challenge the efficient use of wide bandwidths. Moreover, investigations into new waveforms, mitigation of hardware impairments and implementation of devices operating in that spectrum, are required. New transceiver architectures are needed along with new THz propagation models [6]. High power, high sensitivity, and low noise figures are key transceiver features needed to overcome the very high path-loss at THz frequencies.

Barriers to this technology advancement are the effects of high frequency on human health, ability to manufacture of equipment by vendors and business and commercialisation models.

These challenges make the THz region a new area where many open research problems exist from the hardware to the physical layer protocols.

ULTRA MASSIVE MIMO

The Massive MIMO (Multiple-Input Multiple-Output) concept was introduced in 2010 [13] and is a technology where the access points are equipped with a large number of antennas, which are utilised for spatial multiplexing of many data streams to one or, preferably, multiple users. In 5G evolution and 6G, further advancement is expected, such as Massive MIMO with more antenna elements, more layers for spatial multiplexing, and distributed antenna arrangement combined with new network topology. This technological evolution is called Ultra Massive MIMO. The Massive MIMO technology can bring at least ten-fold improvements in area throughput by increasing the spectral efficiency (bit/s/Hz/cell) [11].

The capacity of Massive MIMO grows with the number of antennas [12] so it would be desirable to have nearly infinitely many antennas, but how can that be deployed in a practically viable way? One option: physically very large arrays[1] of classic antennas that are small and well separated to enable essentially invisible deployment as shown in *Figure 2*. An ELAA consists of hundreds of distributed antennas that are jointly and coherently serving many distributed users.

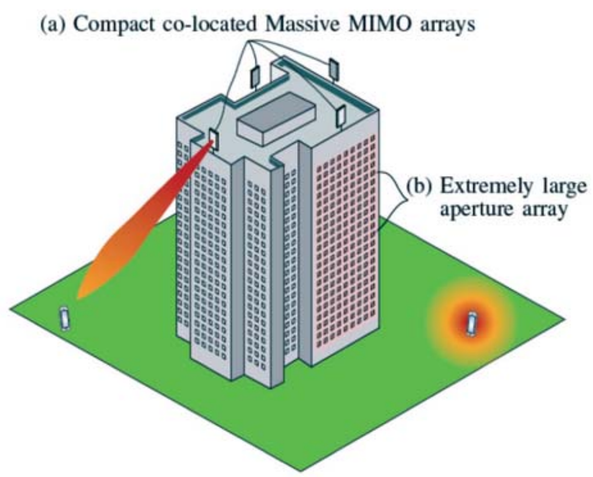


Figure 2. The first deployments of Massive MIMO use compact arrays (a). ELAAs where the antennas are distributed over a large area (b) [9]

[1] Extremely Large Aperture Array (ELAA)

Another option is to integrate an infinite number of antennas into a limited surface area, in the form of a spatially continuous transmitting/receiving aperture. This requires a new way of designing and analysing antenna arrays. Research in this direction is taking place under the names of Holographic Massive MIMO, and Large Intelligent Surface.

The concept of a large intelligent surface (LIS) has recently emerged as a promising wireless communication paradigm that can exploit the entire surface of man-made structures for transmitting and receiving information. An LIS is expected to go beyond Massive MIMO systems. Future structures, such as walls, are expected to be electromagnetically active. The LIS concept can be essentially viewed as a scaled-up version of conventional Massive MIMO systems. *Figure 3* shows an example of LIS system.

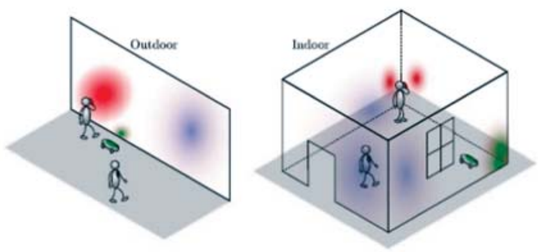


Figure 3. An example of three terminals communicating to a LIS in indoor and outdoor scenarios [10]

In fact, the 5G developments enhance the transmitter and receiver functionalities, but the wireless channel propagation remains an uncontrollable factor that can degrade system performance. Looking beyond 5G, the advent of electromagnetic components that can shape how they interact with wireless signals enables partial control of the propagation. A reconfigurable intelligent surface (RIS) is a two-dimensional surface whose properties are reconfigurable rather than static. The surface consists of many discrete elements with controllable properties. When an RIS with N elements is added to the system which are illustrated as coloured squares in *Figure 4*, N controllable paths are added to the end-to-end channel. The amplitude and phase of each element can be tuned to improve the signal quality at the receiver.

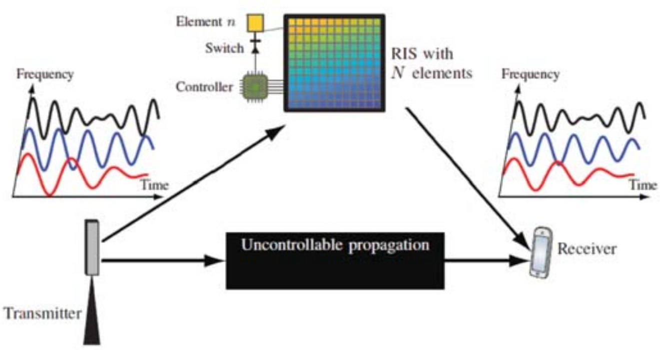


Figure 4. RIS-aided communication system with controllable propagation paths [3]

The limit of a large number of antennas has been studied in the multi antenna literature for decades and is a main motivation behind the Massive MIMO technology. The emerging technologies, such as Holographic Massive MIMO, ELAA, LIS, and RIS can be utilised to increase the capacity of communication systems beyond Massive MIMO [8].

ARTIFICIAL INTELLIGENCE

Machine learning (ML) along with Artificial Intelligence (AI), are revolutionising technologies that create new research opportunities in various areas, including 6G communications. Wireless technology becomes more complicated for every generation with many sophisticated problems to design for and optimize. AI allows all system components to obtain and evaluate a massive amount of real-time information. In this way, system can handle complex optimisation tasks and improve overall system performance.

Some potential research areas include channel modelling by ML techniques in situations where the traditional approach leads to highly complex algorithms or in complex propagation environments that have unknown channel properties. So, there is a potential advantage in optimising the physical layer using ML. Other research fields are channel estimation and detection based on ML, resource allocation, management and power control, beamforming in Massive MIMO, etc. *Figure 5* shows an example of multiple ML-based use cases.

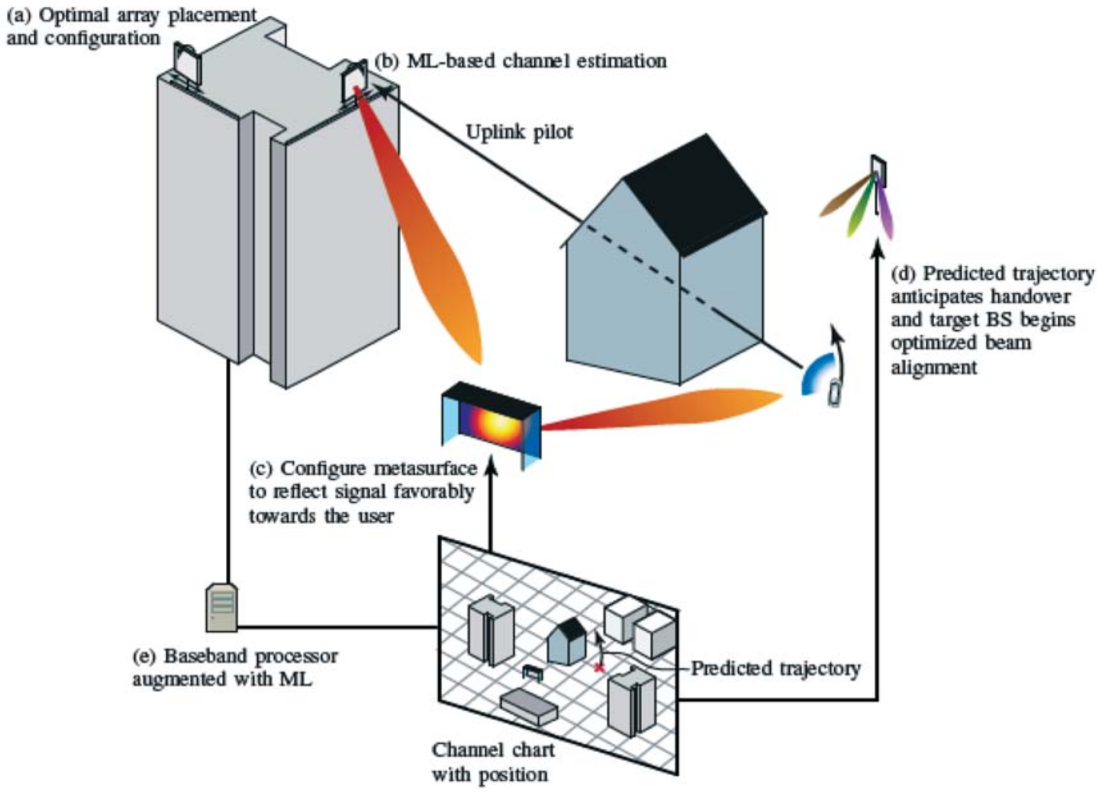
6G implementation will require fundamental support from Artificial Intelligence (AI) and Machine Learning on the network's edge and core [4].

FULL-DUPLEX COMMUNICATION

Current wireless systems use time division duplex (TDD) or frequency division duplex (FDD) methods, which are called half-duplex, where transmission and reception are not performed at the same time or frequency. In full-duplex communications, the transceivers will be capable of receiving a signal while also transmitting concurrent in the same frequency band as shown in *Figure 6*.

This can potentially double the spectral efficiency and allow a more flexible use of the spectrum, therefore making it a promising technology for future wireless networks. The main challenge is self-interference (the interference generated by the transmit signal to the received signal) suppression in system design and planning. Full-duplex deployments require antenna and circuit redesign to reduce the interference between transmitter and receiver circuits in a wireless device. Future technology advancements will enable simultaneous

Figure 5. Five different parts of the network where ML can be applied. [9]



transmit and receive, to increase multiplexing gain and the system throughput without using additional bandwidth [7].

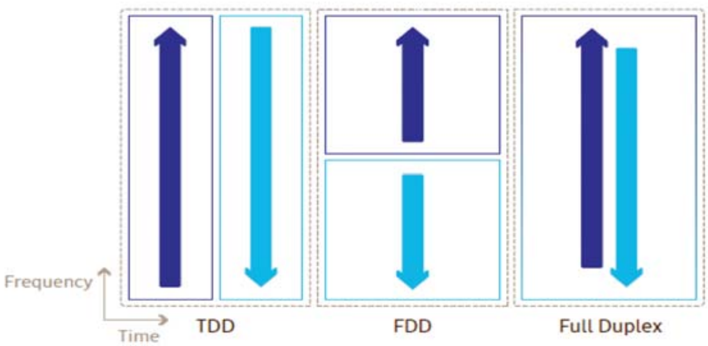


Figure 6. Operation of duplex modes.

Related research has been done on self-interference cancellation techniques, which typically require both analogue and digital domain. Some techniques used to cope with self-interference are isolation between transmit and receive antennas, analogue cancellation in the RF domain and digital cancellation in the baseband.

CONCLUSIONS

The design of future wireless communication will be the result of evolutionary changes of technologies already used, and of the emergence of new technologies. Several technologies will converge with next generation wireless networks (6G) to enhance the performance of existing applications while expanding capabilities to support new and innovative applications. It would be very much energy and bandwidth efficient. This paper discusses technologies that will evolve wireless networks towards 6G, and highlights some important lines of research from the recent literature include support of the terahertz band and higher frequencies leads to much faster connections and a better experience for people, novel antenna technologies and ultra-massive MIMO, evolution of duplex technology to support Terabit data throughputs, and comprehensive AI to realise more efficient, reliable, and low cost communication systems.

These technologies are still in the early stages, but both academia and industry are initiating research activities to shape the next-generation wireless communication system and taking the first steps. The development of Massive MIMO communication technology is now in the hands of the product departments of companies such as Ericsson, Huawei, Nokia, etc. A large number of communications, signal processing, and optimisation algorithms have been developed over the years and it remains to be seen which ones will work well in practice.

The goal is forecasting potential future requirements for critical multimedia services and the advanced video and image applications and defining the ideal conditions based on their KPIs.

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