**6G Networks\***

**Background**

5G provides:

* New frequency bands such as millimeter wave spectrum.
* Advanced spectrum usage and management in licensed and unlicensed bands.
* Complete redesign of the core network.

However rapid development of data-centric and automated processes require a data rate of on the order of terabits per second, latency of hundred of microseconds (5G is 1 ms, LTE Advanced is 10 ms) and ten million connections per square km.

This may exceed capacity of 5G systems so researchers at looking at a new generation of wireless systems. Hence 6G.

Will need:

* Novel disruptive communication technologies: 6G could benefit from terahertz and optical frequencies for transmission.
* Innovative Network Architectures.
* Integrating Intelligence in the Network. Intelligence will be brought from centralized facilities to end terminals.

**6G Use Cases (applications)**

* Augmented reality and virtual reality: Proliferation of AR/VR applications will deplete the 5G spectrum and require 1 Tbps as opposed to 5G’s 20 Gbps. For latency reasons AR/VR traffic can not be compressed.
* Holographic Telepresence (Teleportation): One estimate says 3D holographic display will require over 4 Tbps. All five senses will be digitized, adding to capacity needed.
* EHealth: Remote surgery and healthcare workflow optimizations. Besides cost major current limitation is lack of tactile feedback. Needs strict QoS requirements (99.99999 percent reliability, sub-millisecond latency and mobility support). This possible with 6G spectrum availability and refined intelligence.
* Pervasive Connectivity: Mobile traffic growing three-fold from 2016 to 2021. Density going from 106 devices per sq km in 5G to 107 devices per sq km in 6G. More than 125 billion devices by 2030 including personal devices, sensors, vehicles etc… A need in 6G for 10 to 100 improvement in energy consumption versus 5G. Eighty percent of traffic is generated indoors which 5G can not penetrate.
* Industry 4.0 and Robotics.
* Unmanned Mobility: Connecting autonomous vehicles requires unprecedented levels of reliability (99.99999%) and latency (below 1 ms). There will be vehicle sensor data traffic and drone traffic.

**6G Enabling Technology**

1. Disruptive Communication Technology:

* Terahertz Communication between 100 GHz and 10 THz.
* Visual Light Communication (VLC) – mostly indoors.
* Full Duplex Communication Stack – transmit and receive simultaneously.
* Sensing and network-based localization – will allow shaping of beam forming patterns, predict handovers and other localization uses.

1. Innovative Network Architecture:

* Integration of multiple frequencies: Number of heterogeneous radios in device. Connect to multiple cells at a time. Seamlessly transition between different heterogenous links.
* 3D Network Architecture: Connectivity to drones, balloons and satellites.
* Disaggregation and Virtualization of Network Equipment: A process that has started.

1. Integrating Intelligence in Network:

* 6G complexity precludes manual operation. Machine learning for telecommunication networks in infancy but could be used.

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\*M. Giordani, M. Polese, M. Mezzavilla et. al, “Toward 6G Networks: Use Cases and Technologies,” *IEEE Communications Magazine,* March 2020, 55-61.