SCIENCES

Networks and Communications, Field Director – Guy Pujolle

Internet, Subject Head – Stefano Secci

The Tactile Internet

Coordinated by
Tara Ali-Yahiya
Wrya Monnet

Color Section

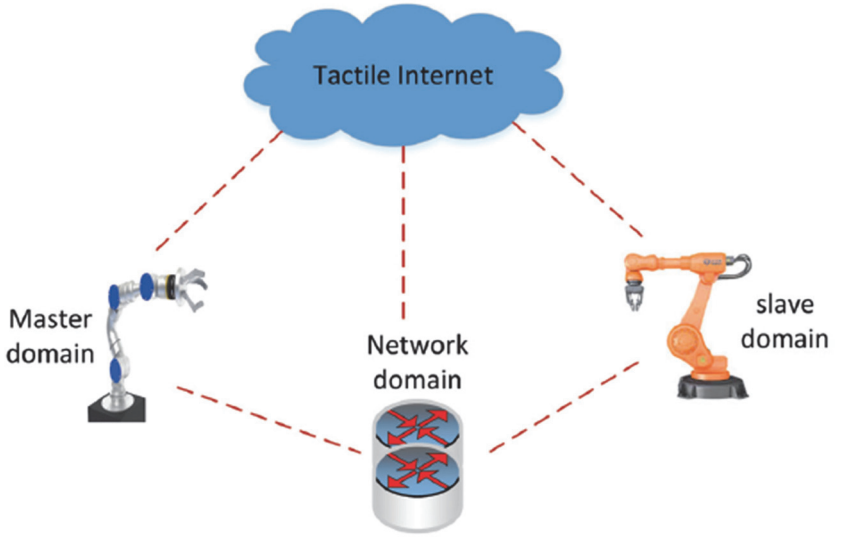

Figure 1.2. *Tactile Internet architecture*

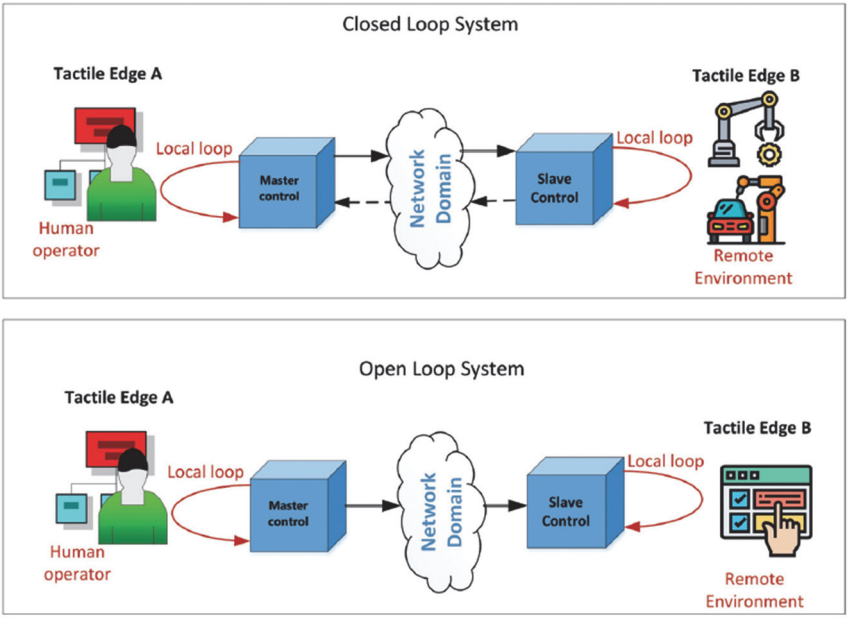

Figure 1.3. *Open-loop versus closed-loop systems*

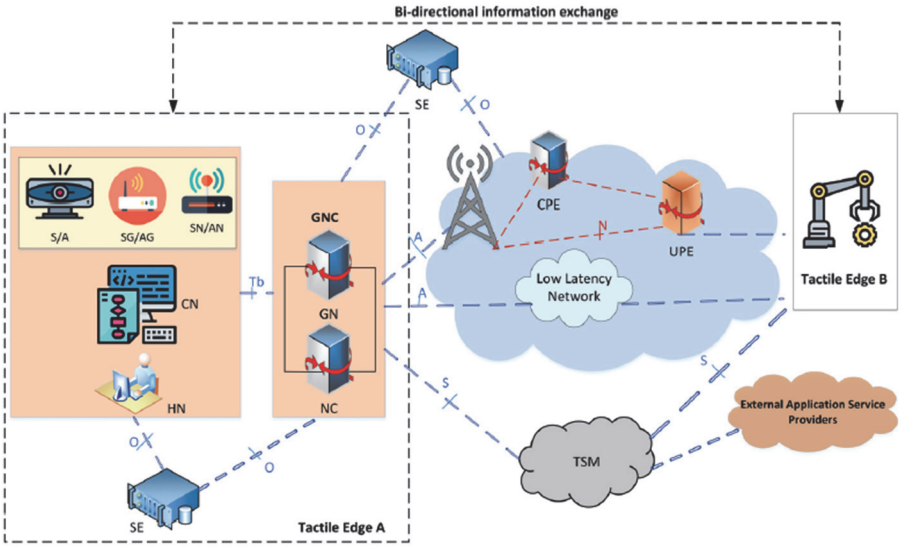

Figure 2.1. *TI reference architecture of IEEE 1918.1*

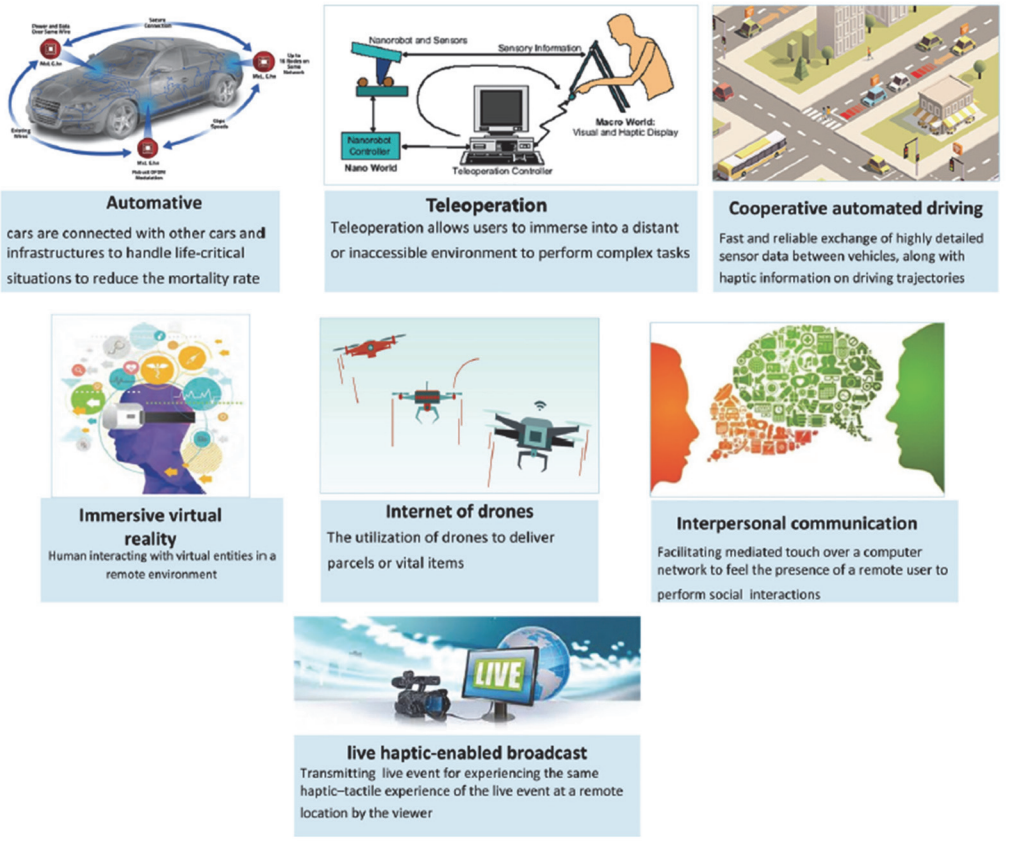

Figure 2.2. *Tactile Internet use cases*

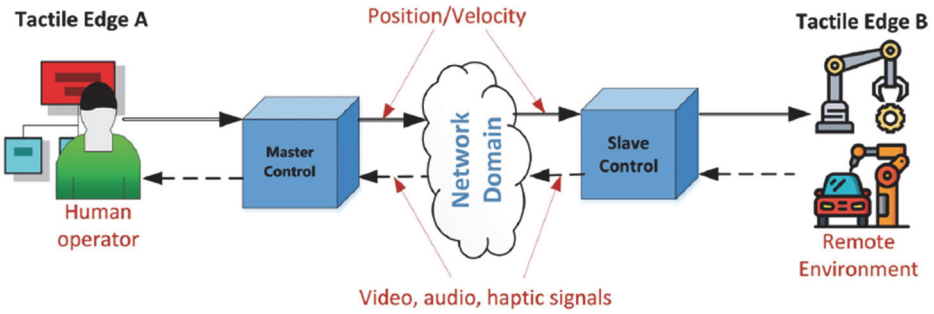

Figure 2.3. *Teleoperation use cases*

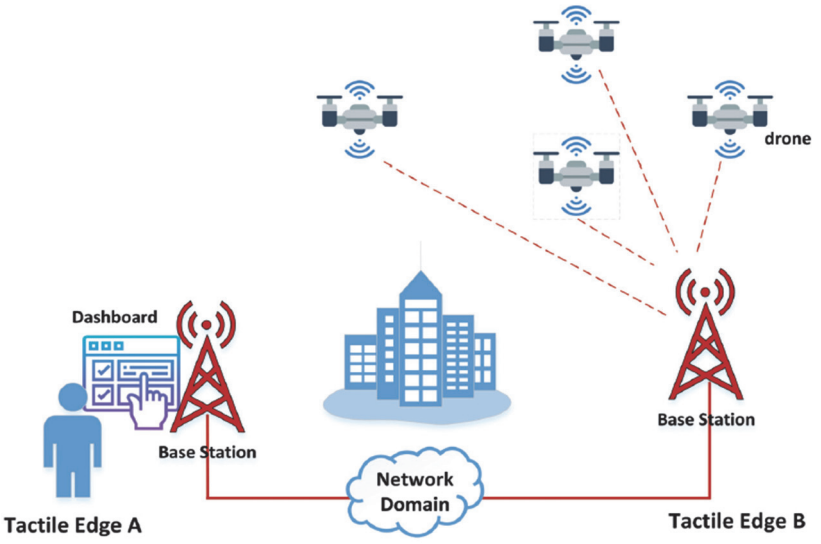

Figure 2.4. *Internet of drones use case*

Figure 2.5. *Interpersonal communication use cases*

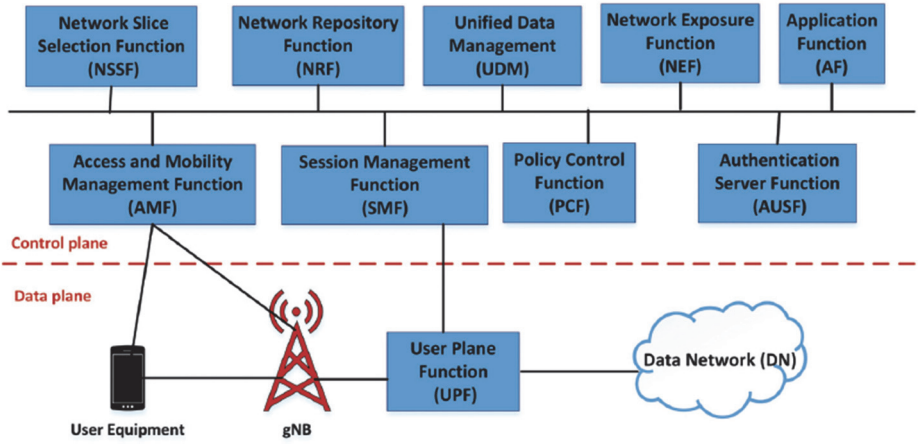

Figure 3.1. *5G architecture (ETSI 2018b)*

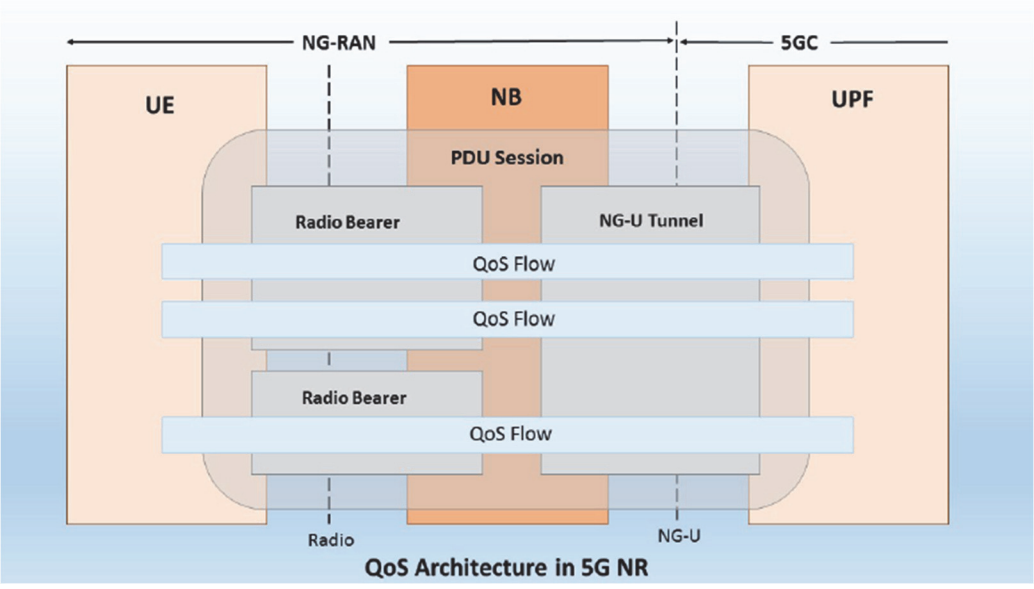

Figure 3.2. *5G QoS architecture*

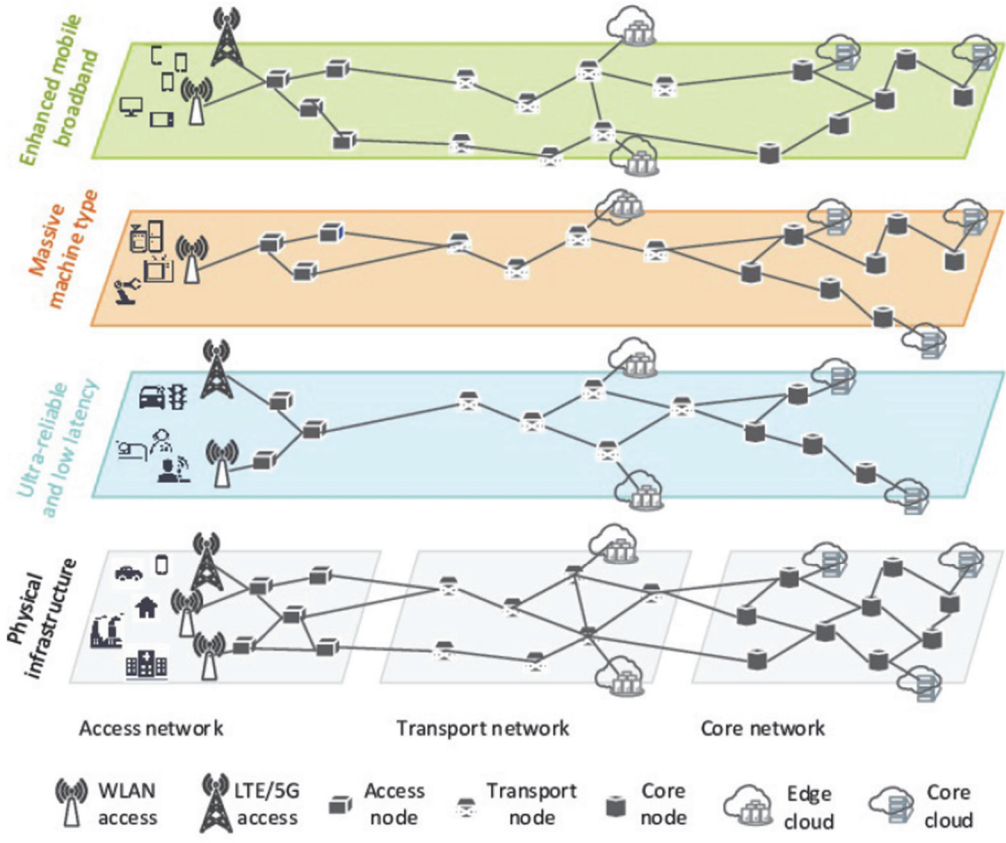

Figure 3.3. *Network slicing (Rost et al. 2017)*

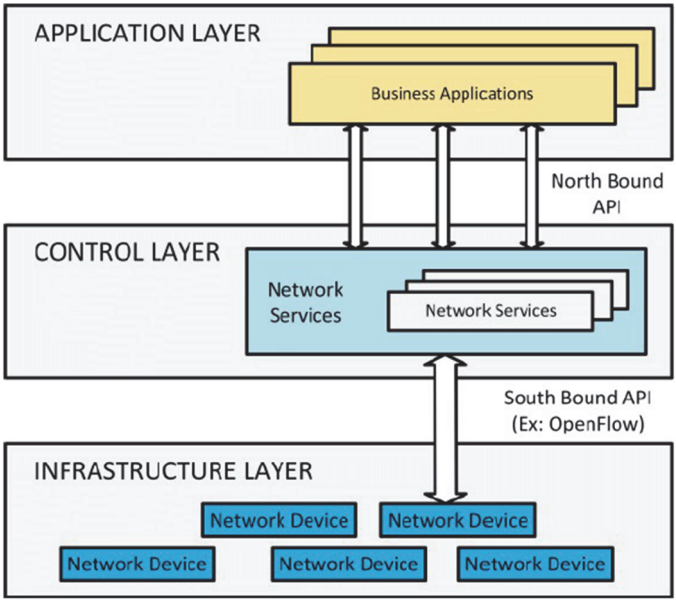

Figure 3.5. *Software-defined networking (SDN)*

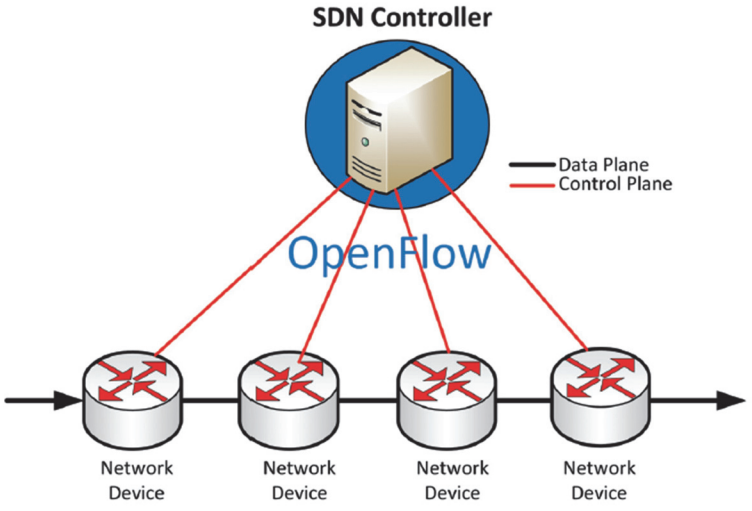

Figure 3.6. *SDN with openflow*

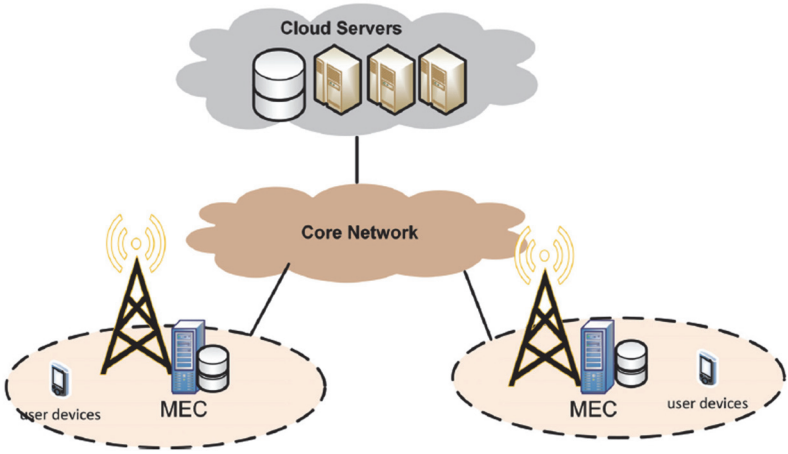

Figure 3.7. *MEC integrated with 5G*

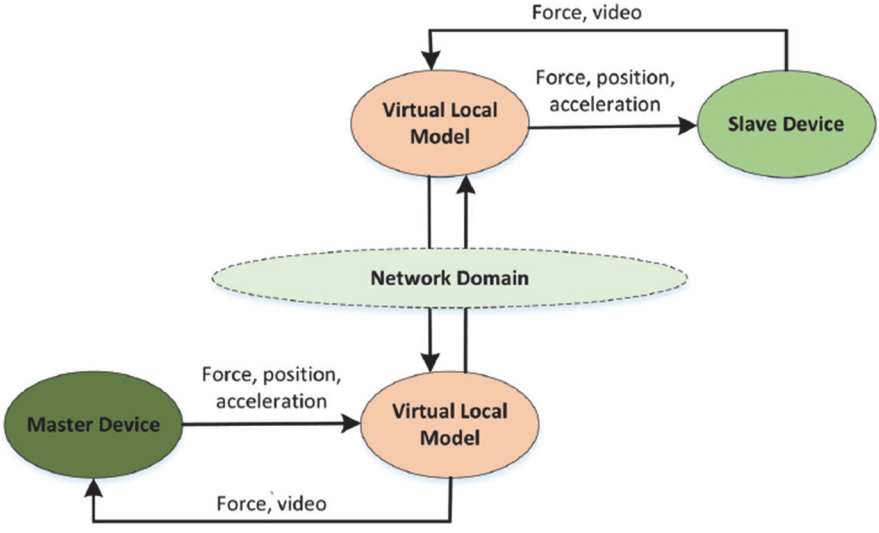

Figure 3.9. *Model-mediated architecture*

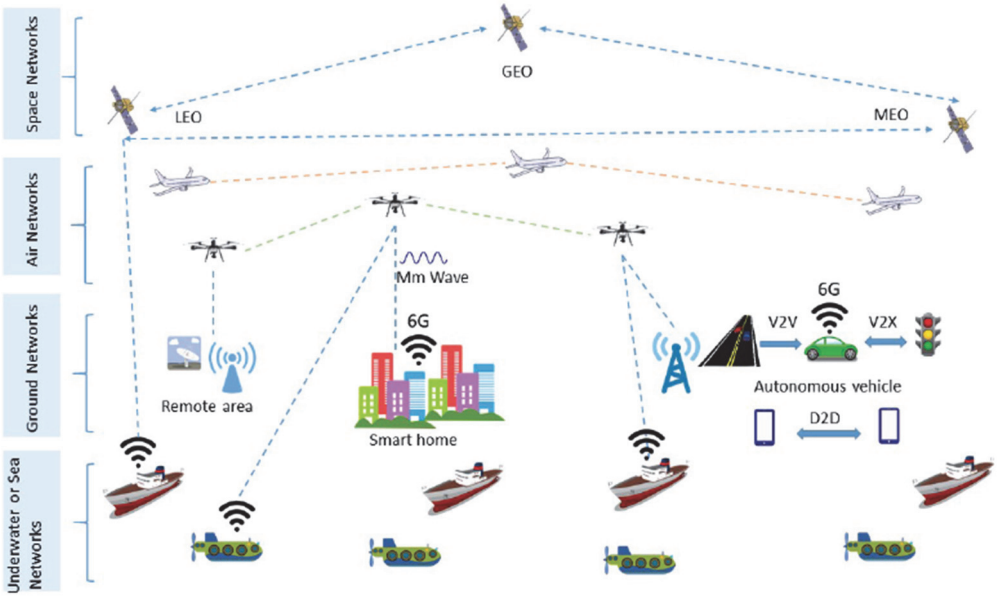

Figure 4.2. *Architecture of 6G*

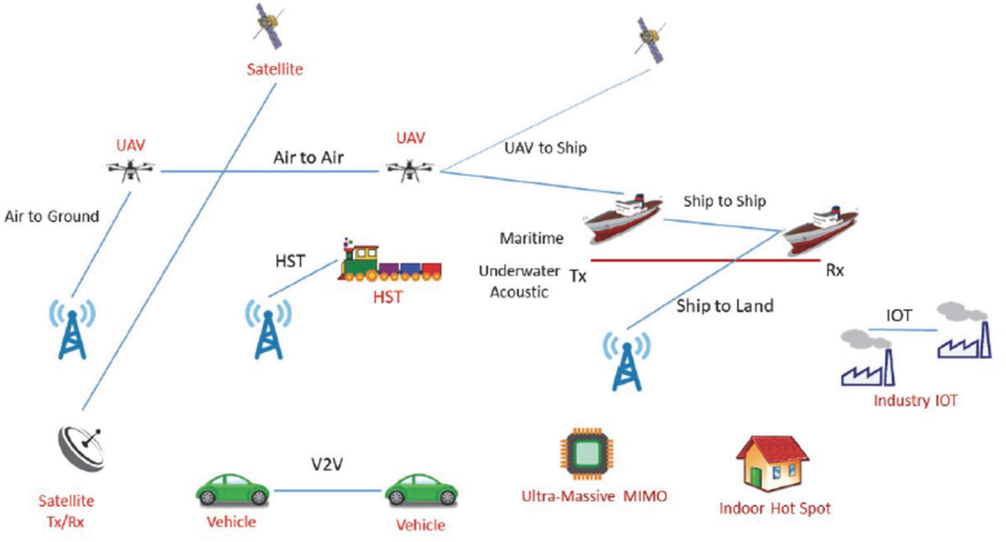

Figure 4.3. *6G wireless channels. Rx: receiver; Tx: transmitter*

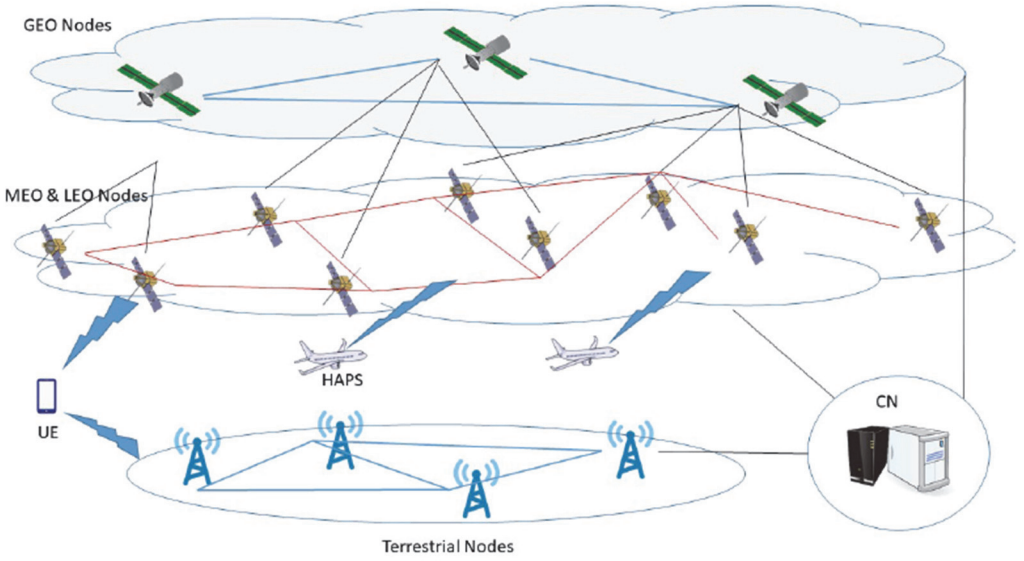

Figure 4.5. *System architecture of the 6G system*

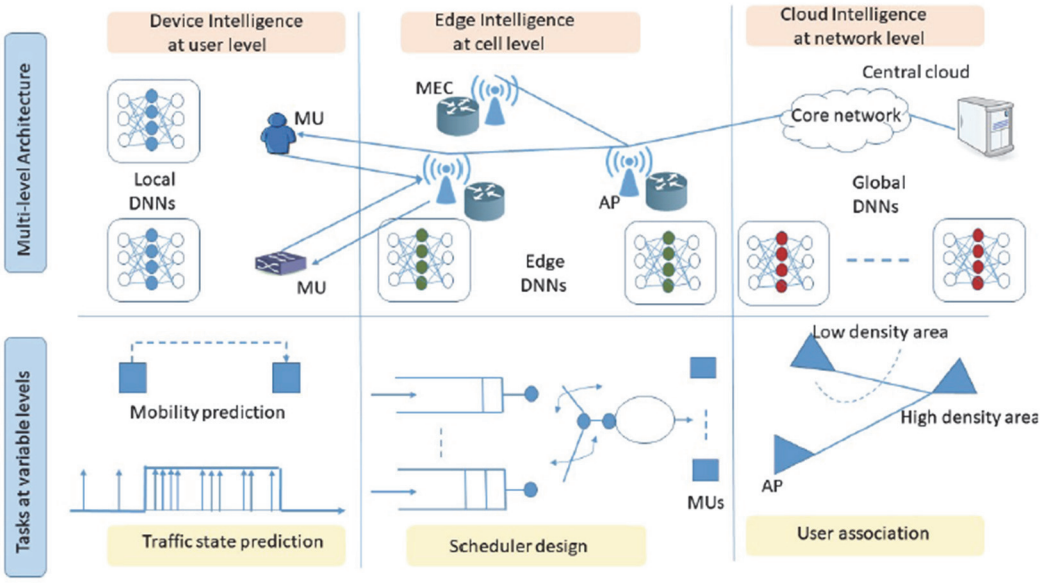

Figure 4.6. *Multi-level architecture in 6G*

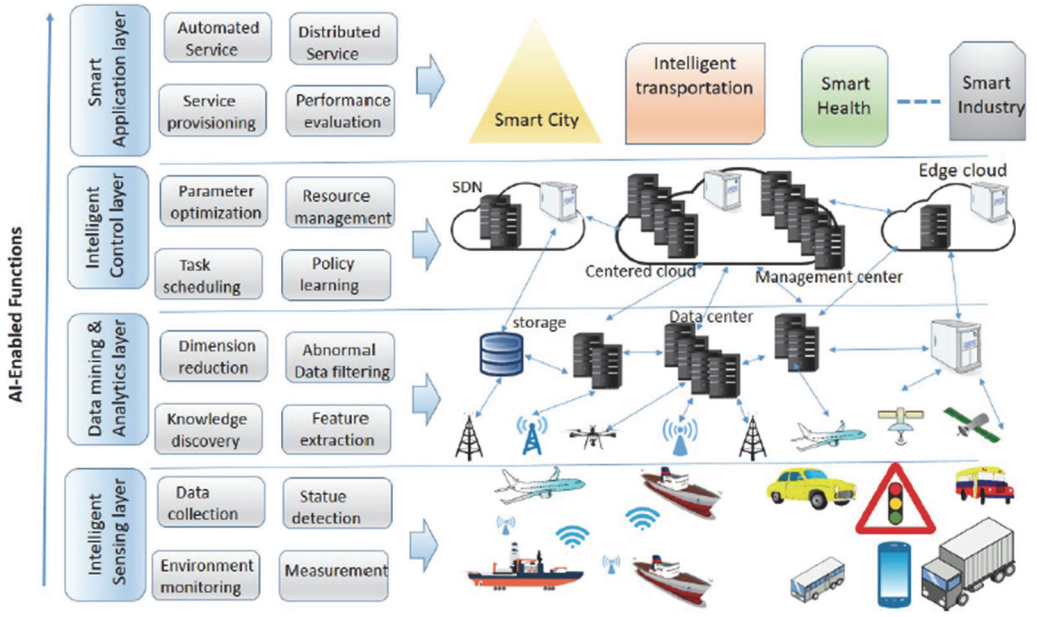

Figure 4.7. *AI-enabled intelligent 6G networks*

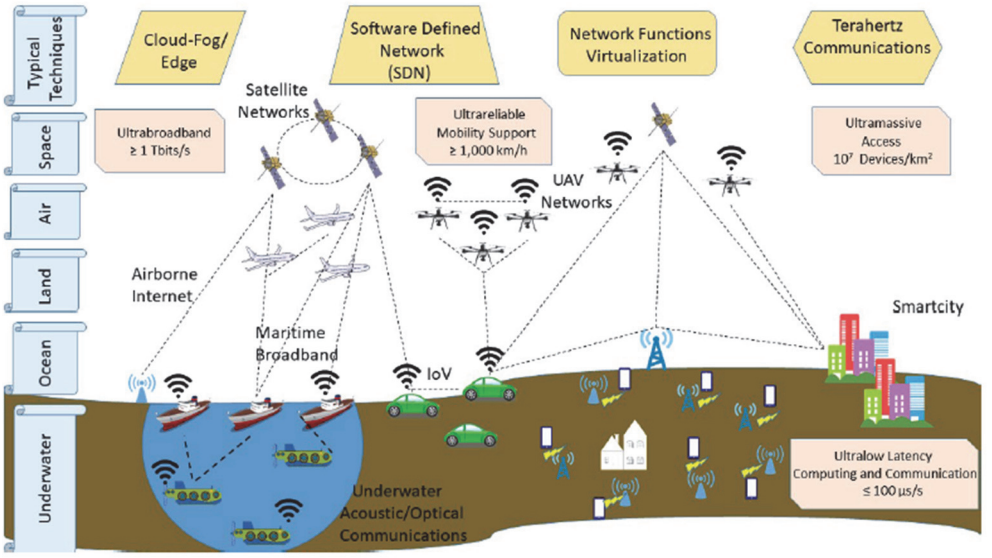

Figure 4.8. *AI/ML applications in 6G to support ultra-broadband, ultra-massive access and ultra-reliability/low latency*

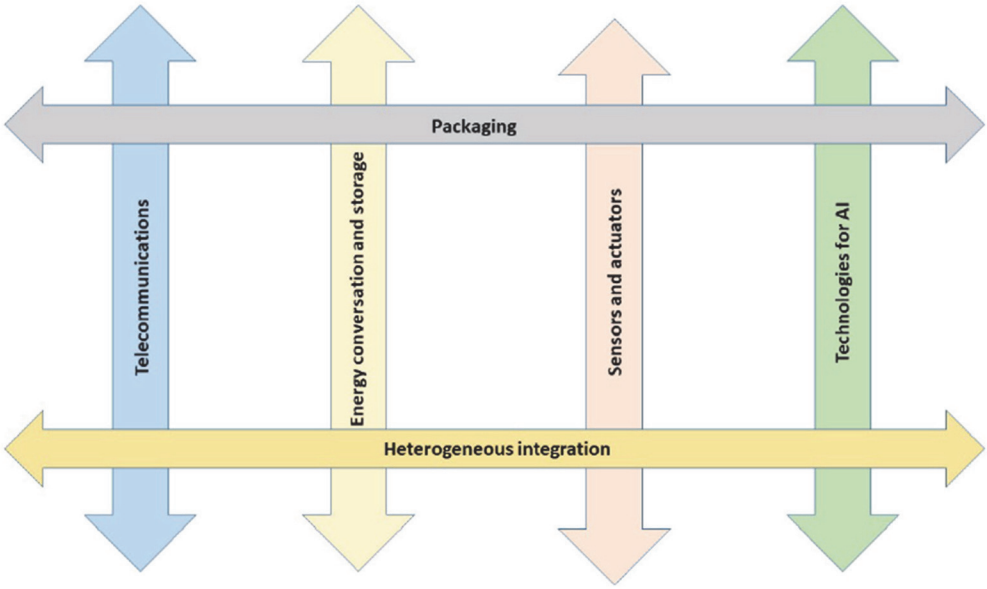

Figure 4.9. *Schema of vertical and horizontal MEMS-based application domains relevant to the 6G and TI future development and deployment*

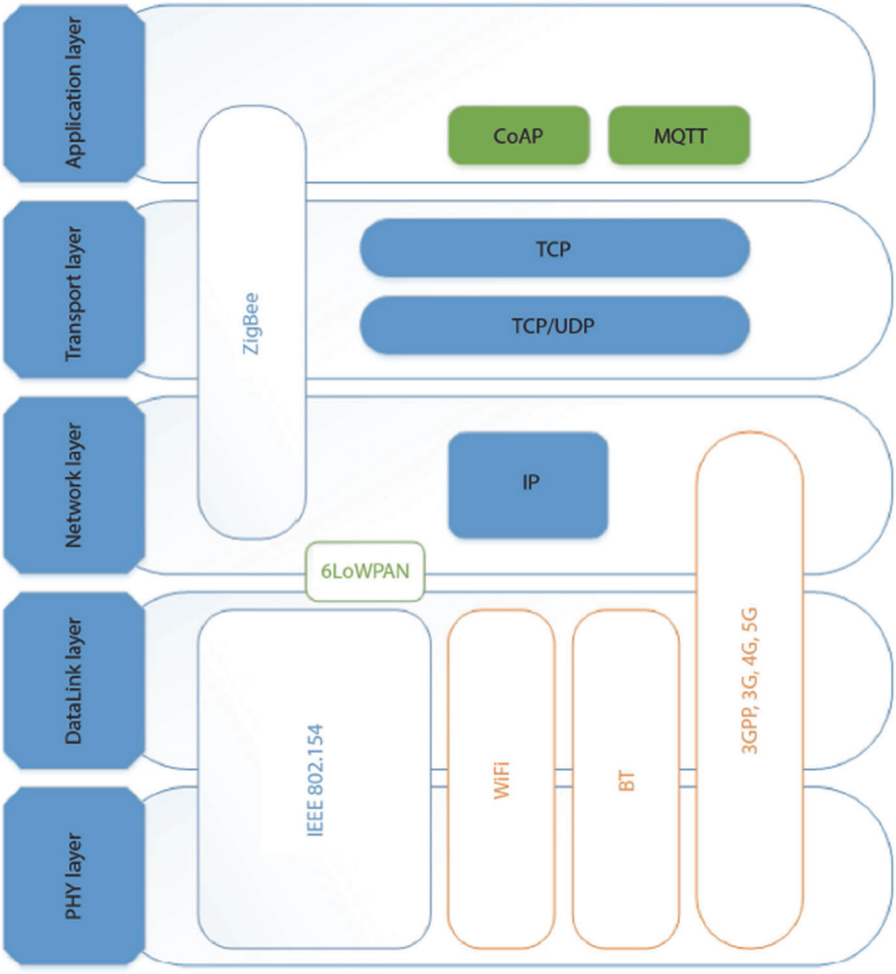

Figure 5.2. *Five-layer IoT and its equivalent OSI layers*

Figure 5.5. *MQTT standard packer structure*

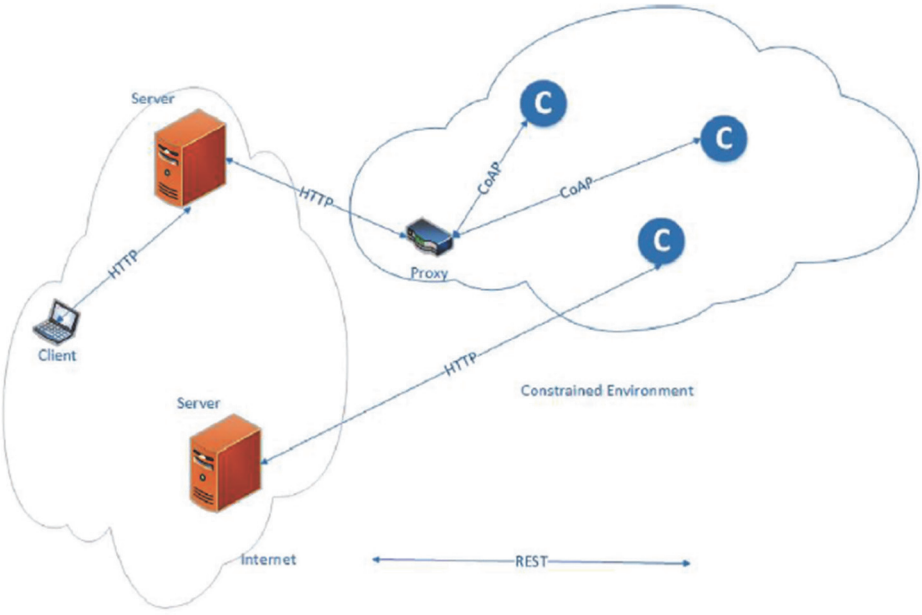

Figure 5.8. *CoAP architecture*

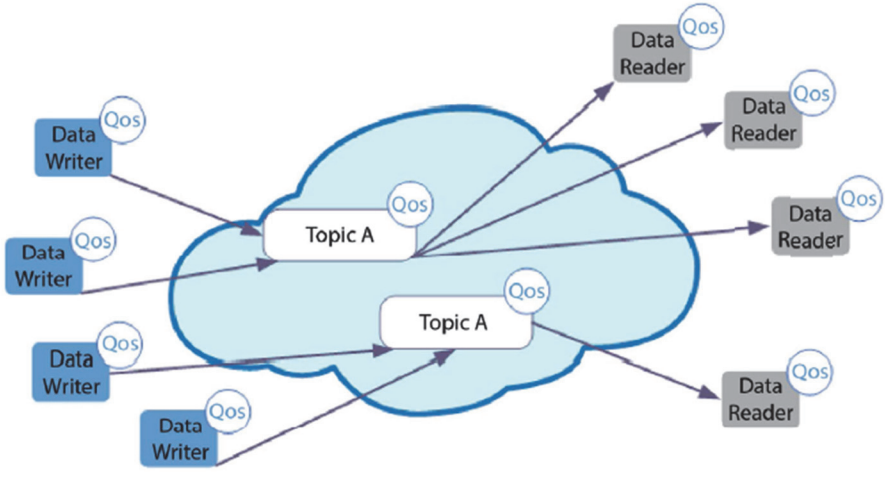

Figure 5.10. *Architecture of a DDS protocol to connect applications systems*

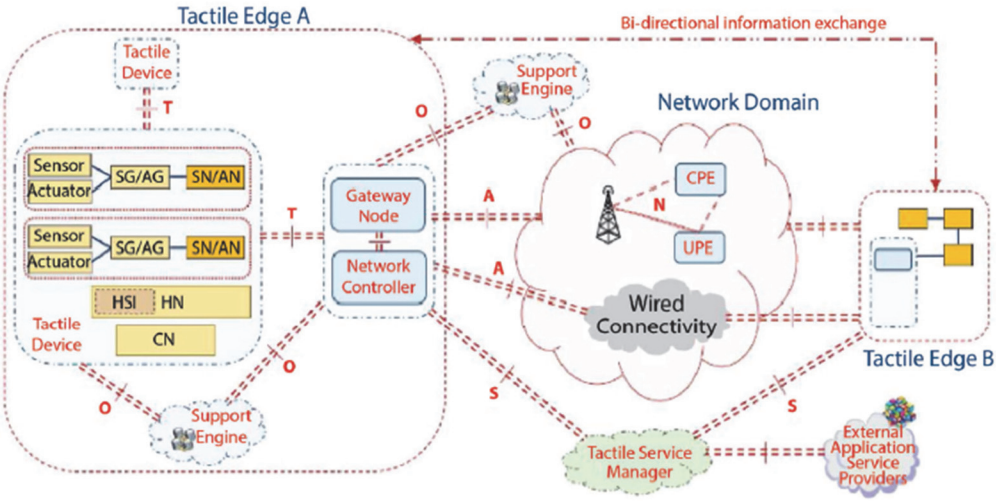

Figure 5.13. *IEEE P1918 Tactile Internet reference architecture (Holland et al. 2019)*

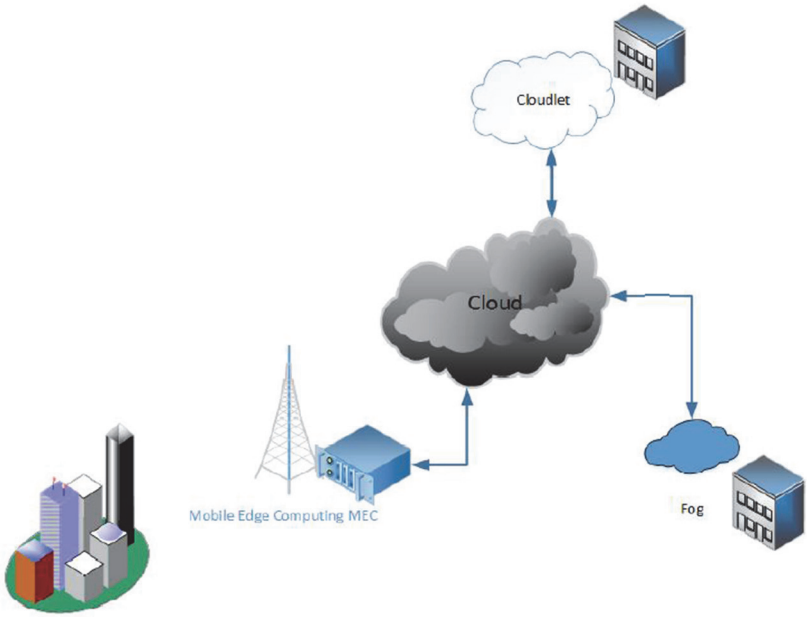

Figure 5.14. *Edge computing in IoT systems*

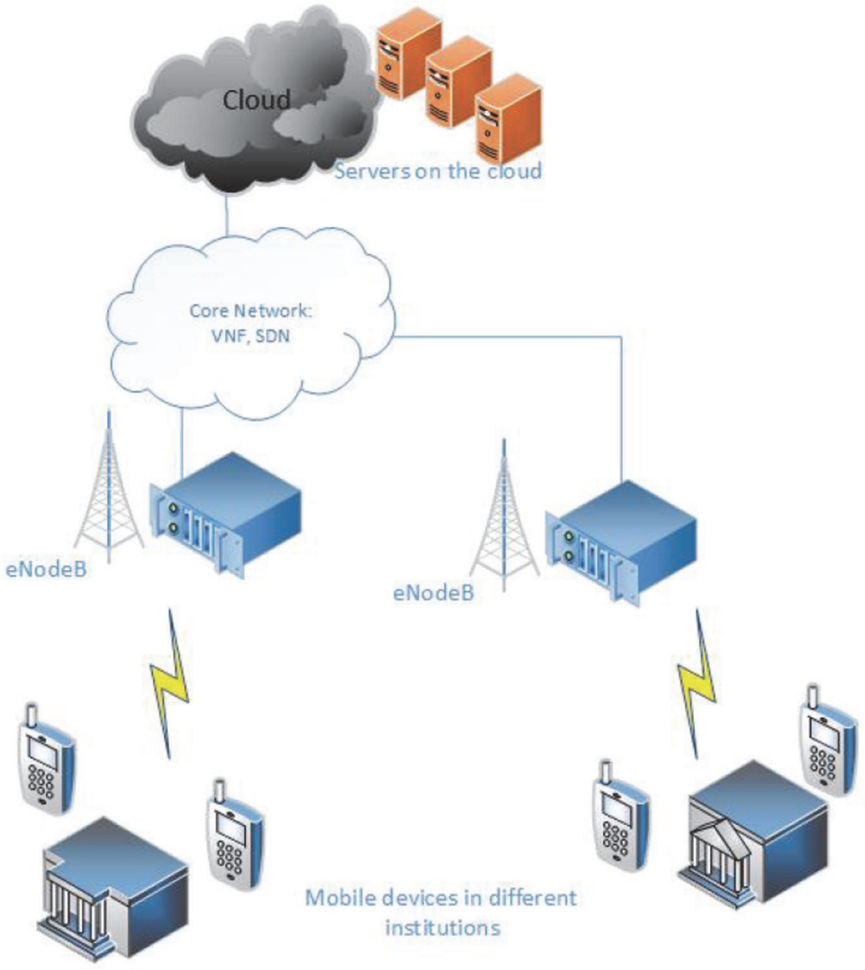

Figure 5.15. *SDN and VNF in the core network and the MEC access to them*

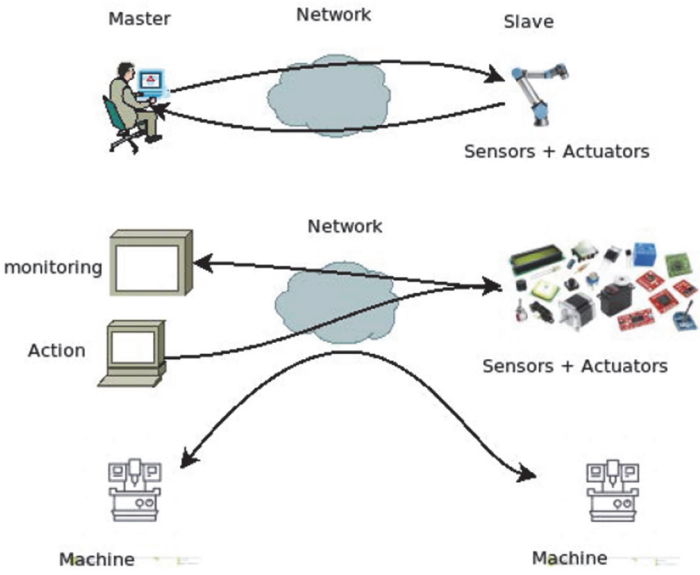

Figure 5.17. *Communality and difference between the IoT (bottom) and the TI (top)*

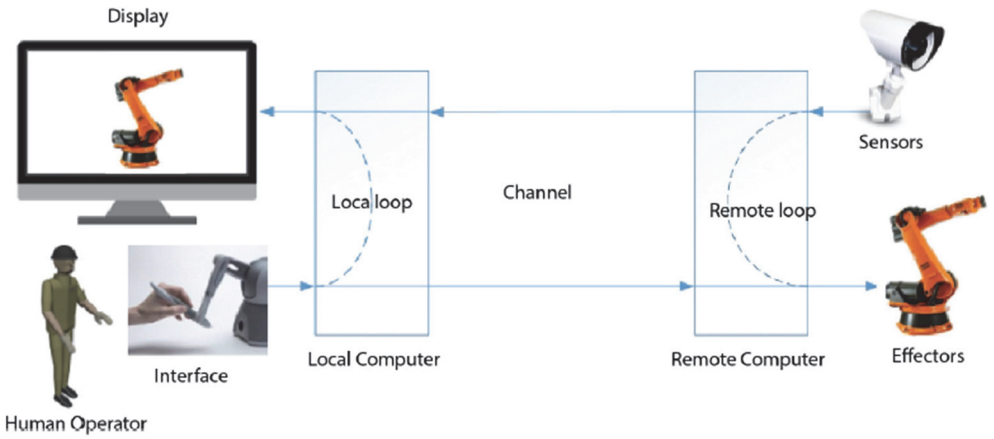

Figure 6.1. *Telerobotics as first devised by Sheridan (Ferrell and Sheridan 1967)*

Figure 6.2. *Different telepresence applications*

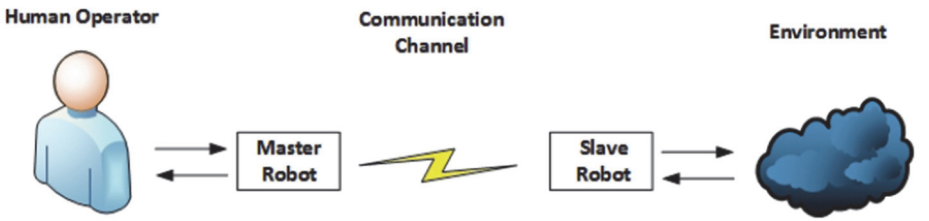

Figure 6.3. *Components of a telerobotic*

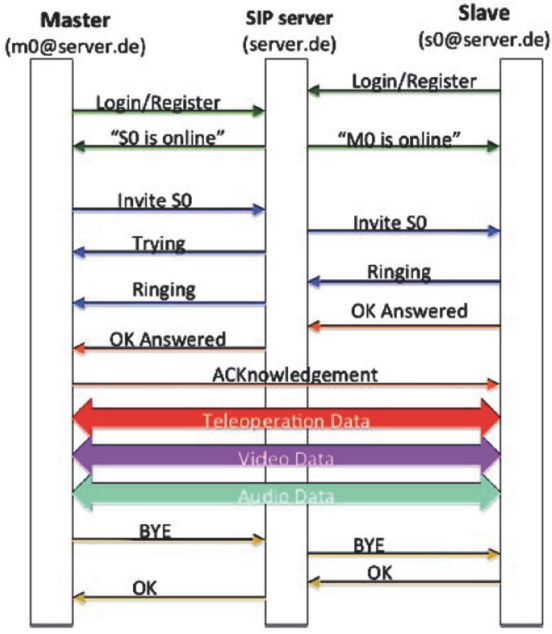

Figure 6.18. *SIP master to slave call with both users addressed on the same server (source: King et al. 2010)*

Figure 6.19. *Twenty actuated DOF and a further four under-actuated movements for a total of 24 joints in a dexterous hand from The Shadow Robot Company (source: https://www.shadowrobot.com/dexterous-hand-series/)*

Figure 6.20. *Hapex glove contains haptic feedback. Connecting to the shadow robotic hand, it can mimic the glove movements (source: https://haptx.com/robotics/)*

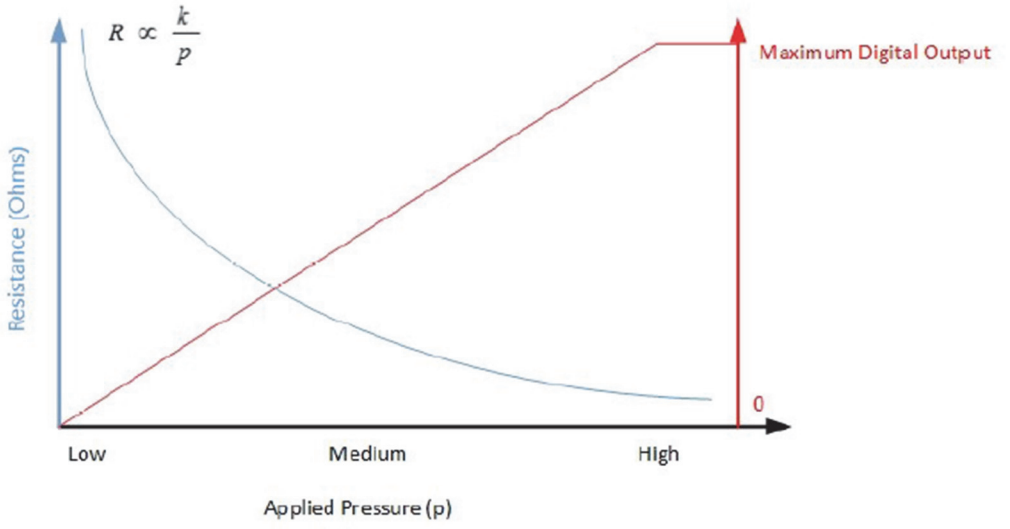

Figure 7.1. *Piezoelectric resistance characteristic with applied pressure*

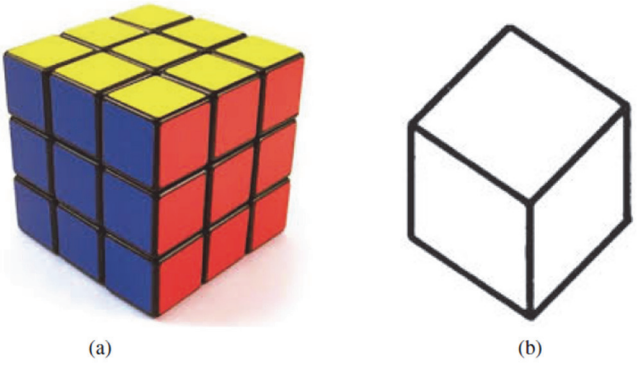

Figure 7.2. *Two cubes: (a) is different in its local shapes from (b) which is smooth. Both are globally a cube*

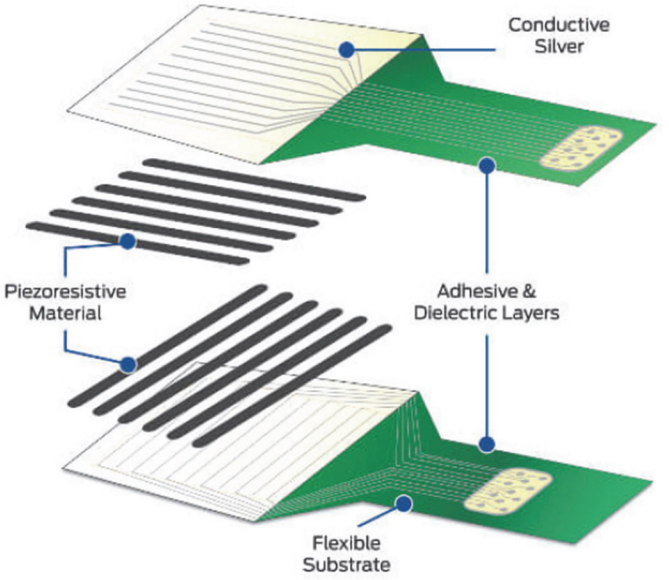

Figure 7.3. *Thin tactile sensor technology from (https://www.tekscan.com/)*

(a) Phantom Omni

(b) Novint Technologies Falcon

(c) Force Dimension Sigma 7

(d) Dexmo

Figure 7.4. *Some commercially available haptic interface devices*

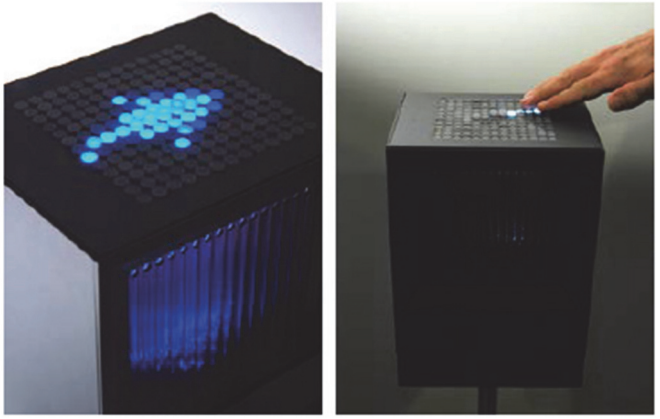

Figure 7.5. *A tactile interface device: Lumen (Parkes et al. 2008)*

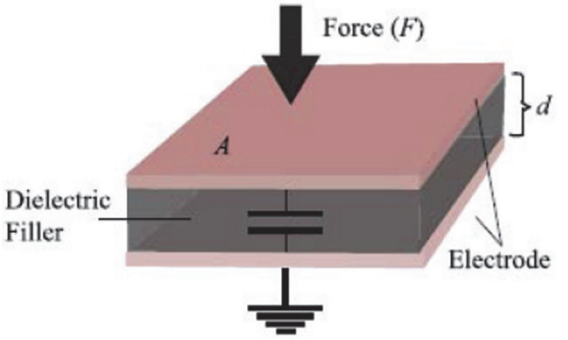

Figure 7.7. *Parallel plate capacitor consisting of two parallel plates of area A separated by distance d (Dahiya and Valle 2013)*

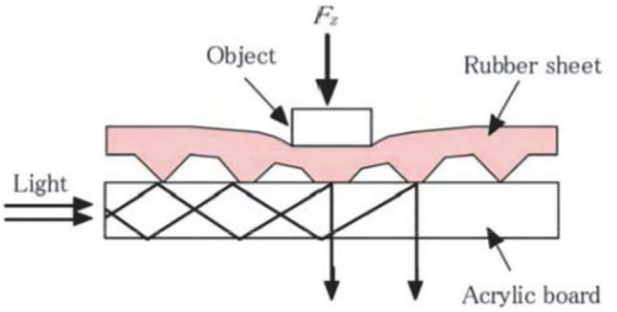

Figure 7.8. *Principle of optical tactile sensor (Ohka 2007)*

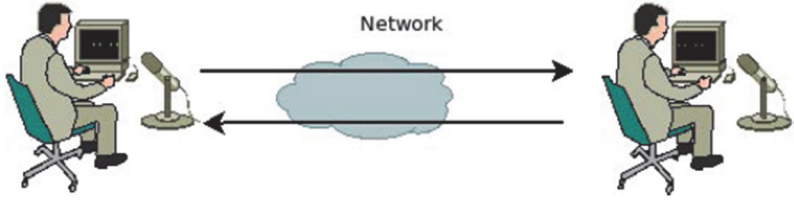

Figure 7.11. *Conversation in a video teleconferencing is two times unidirectional*

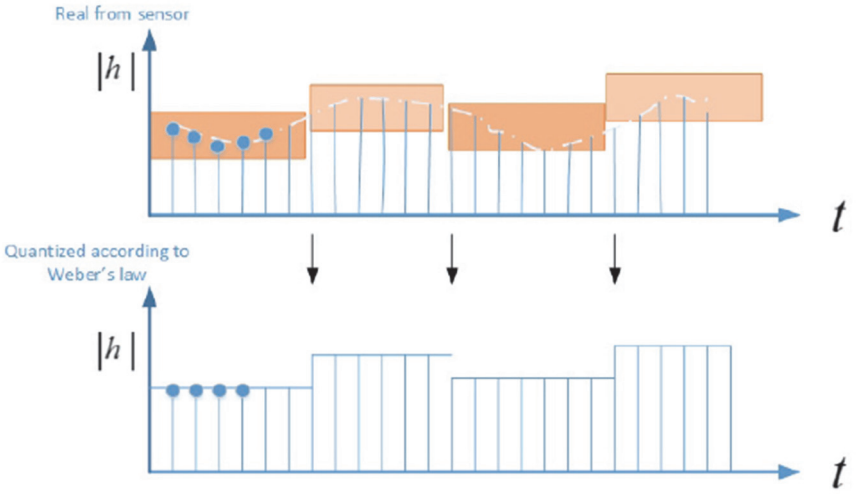

Figure 7.12. *Perceptual deadband compression*

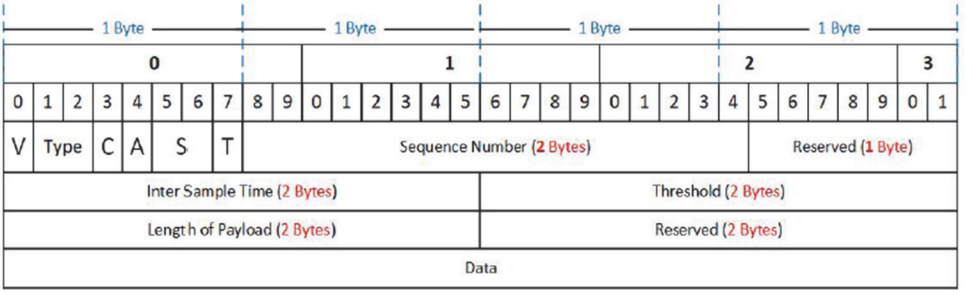

Figure 7.17. *The frame of HoIP protocol (Gokhale et al. 2013)*

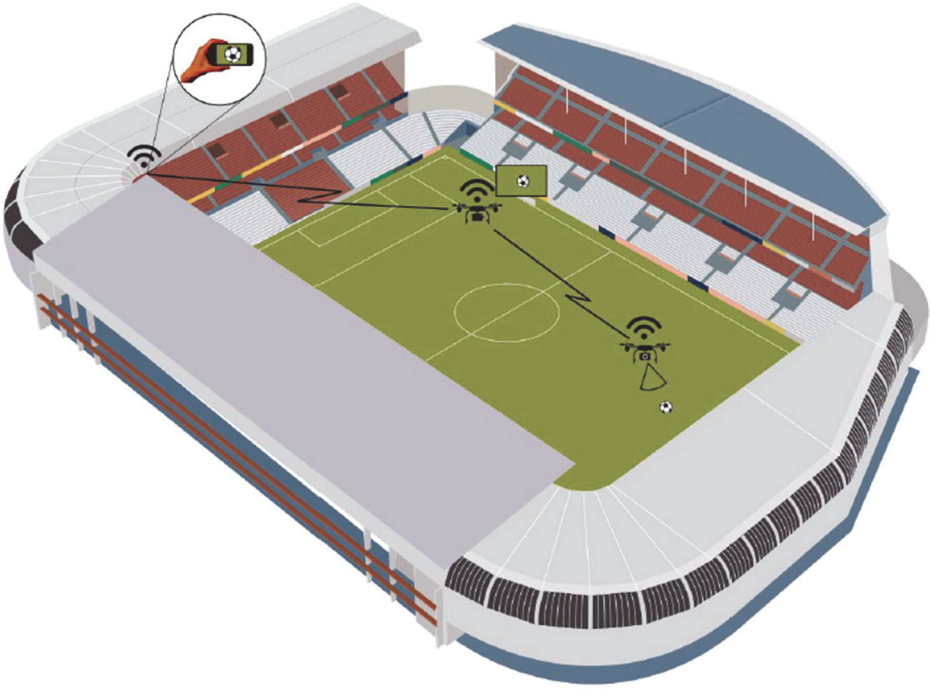

Figure 8.1. *A subset of two robots in a WNR that is used to relay the video of a sporting event to a spectator too far away to receive it in HD from the filmer UAV using a second one, a relayer. The filmer UAV is capable of tracking the sporting event and the relayer UAV is capable of placing itself in a position to relay the video, in HD, to all the spectators on its side*

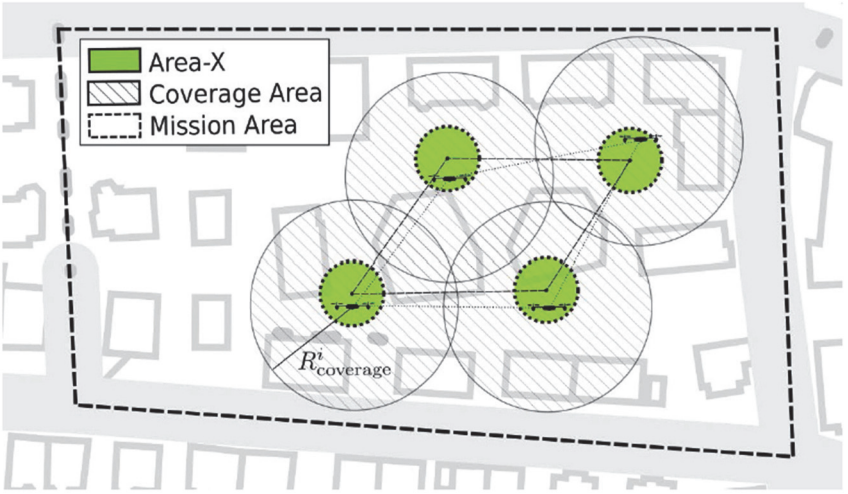

Figure 8.2. *Example of a WNR for Mobile Cellular Infrastructure inside its Mission Area. The single UAV with its R^icoverage tries to maximize the fleet Coverage Area by moving inside Area-X while still keeping the formation*

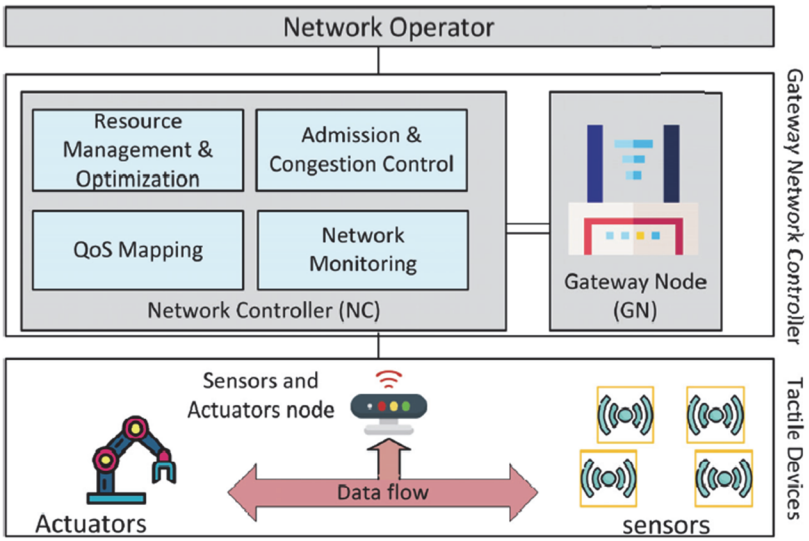

Figure 9.1. *GNC architecture*

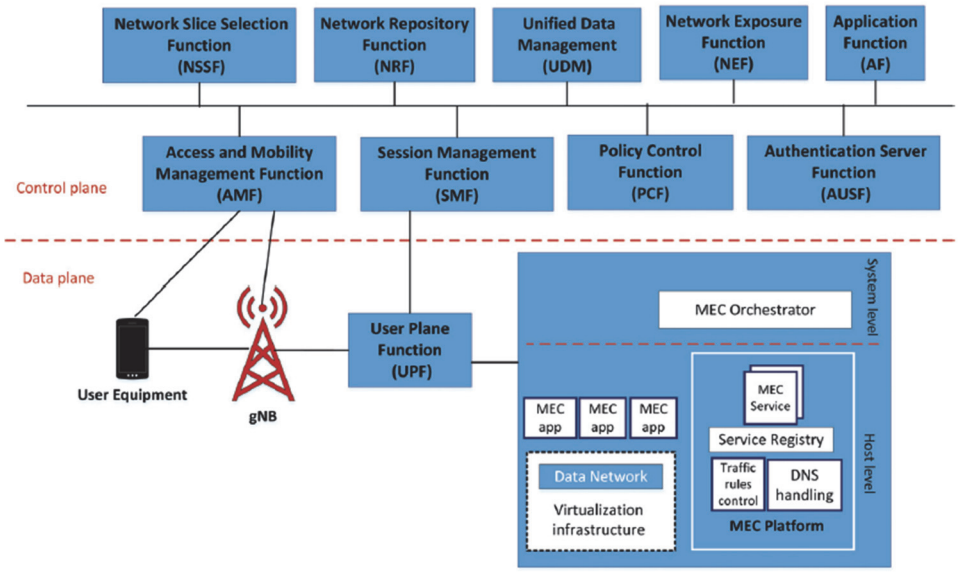

Figure 9.2. *MEC integrated with 5G*

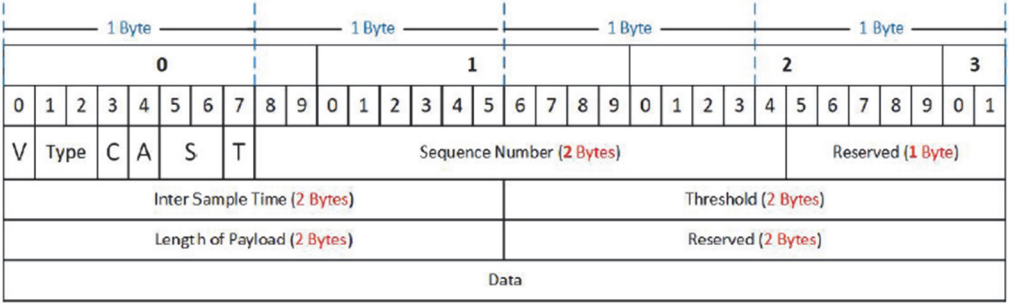

Figure 9.5. *HoIP in the protocol stack*

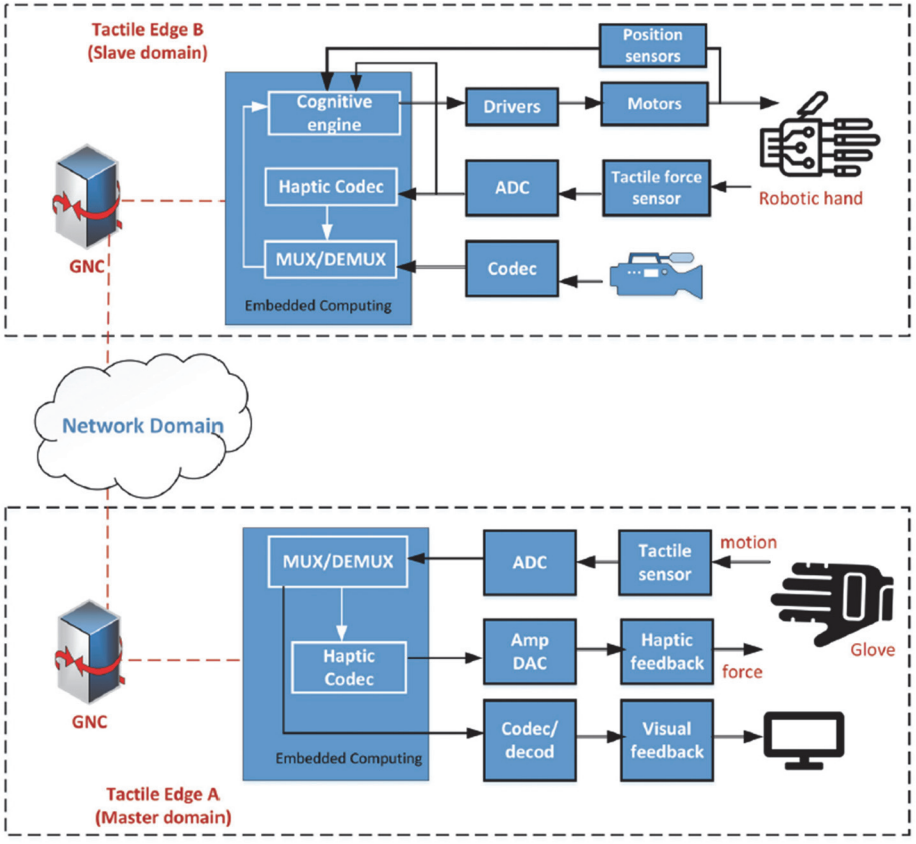

Figure 9.6. *Teleoperation system design*

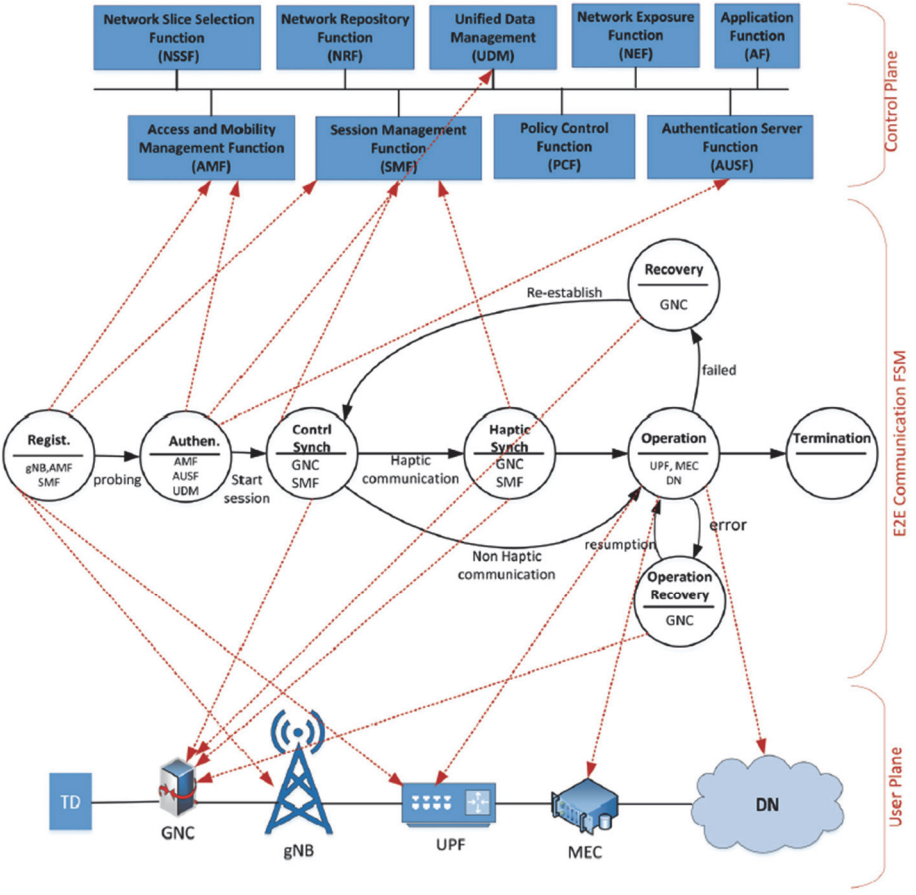

Figure 9.7. *Moore FSM for E2E communication in an integrated 5G and IEEE 1918.1 architecture*

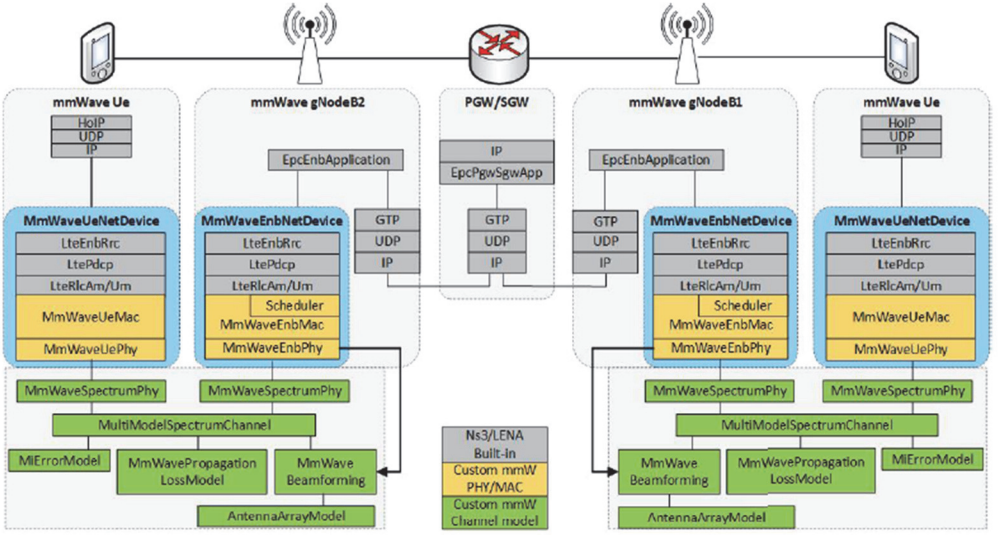

Figure 9.12. *End-to-end network architecture*

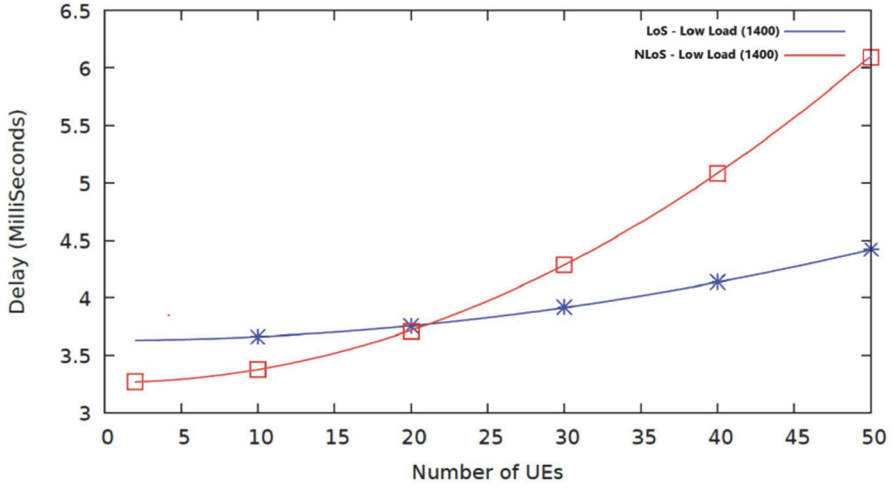

Figure 9.13. *Delay versus number of UEs for low load (LoS and NLoS)*

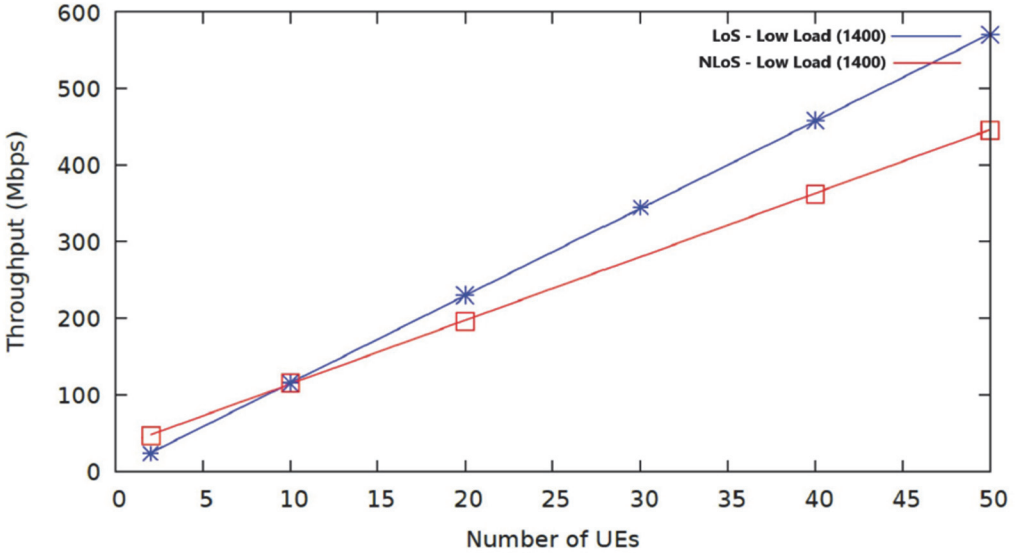

Figure 9.14. *End-to-end network architecture*

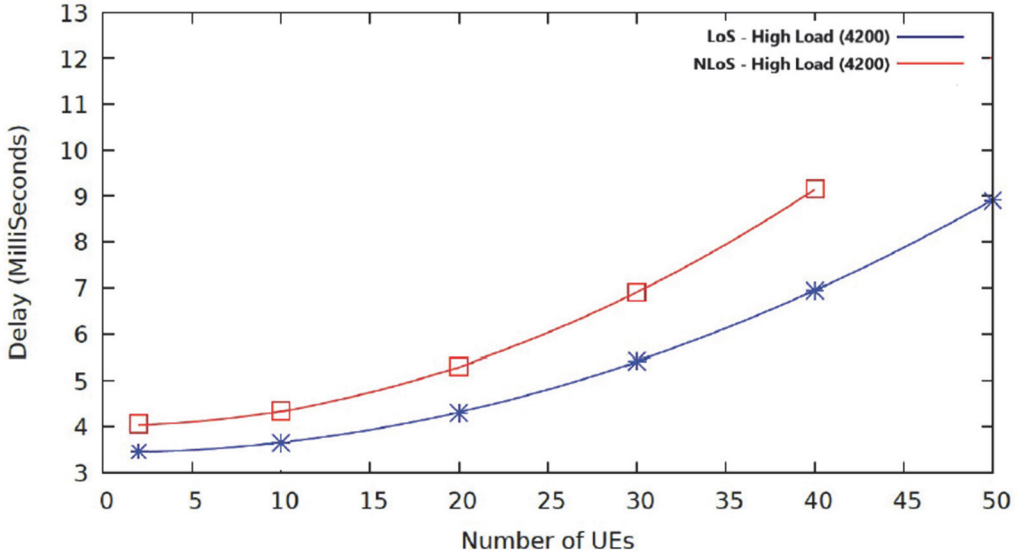

Figure 9.15. *Delay versus number of UEs for high load (LoS and NLoS)*

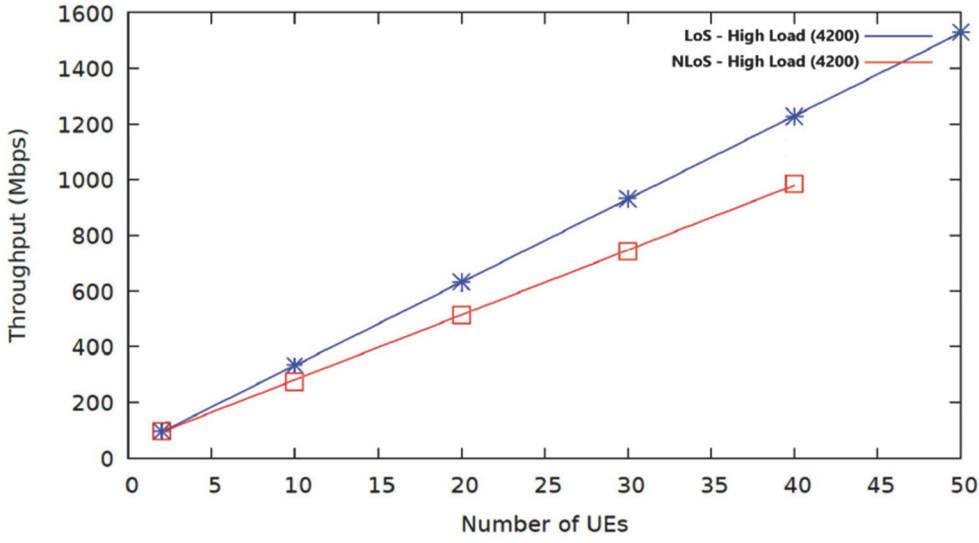

Figure 9.16. *Throughput versus number of UEs for high load (LoS and NLoS)*

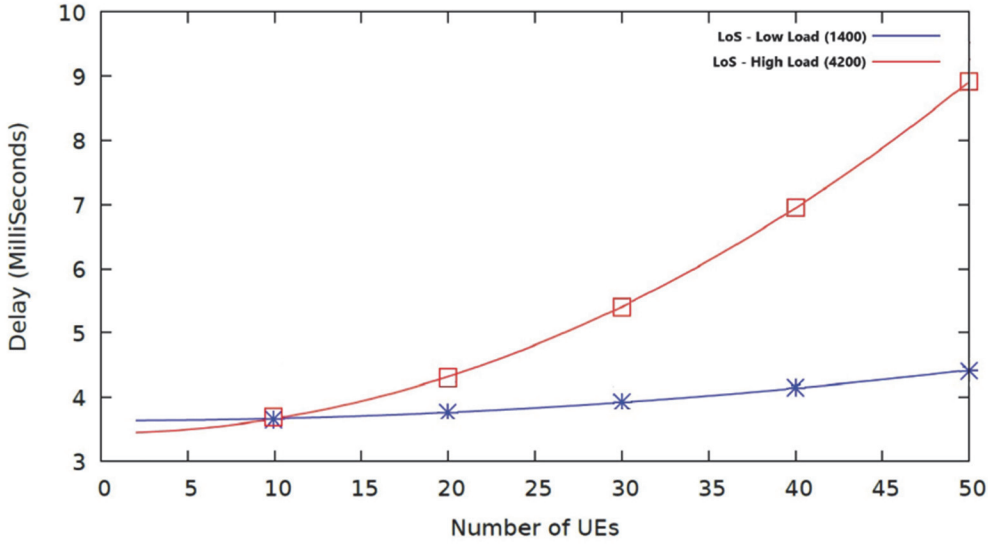

Figure 9.17. *Delay versus number of UEs for LoS (low load and high load)*

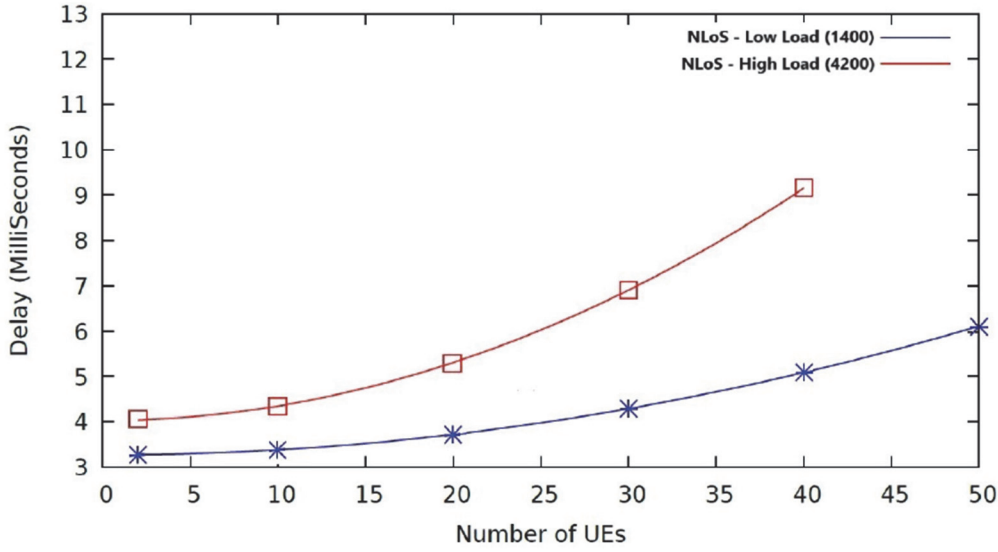

Figure 9.18. *Delay versus number of UEs for NLoS (low load and high load)*

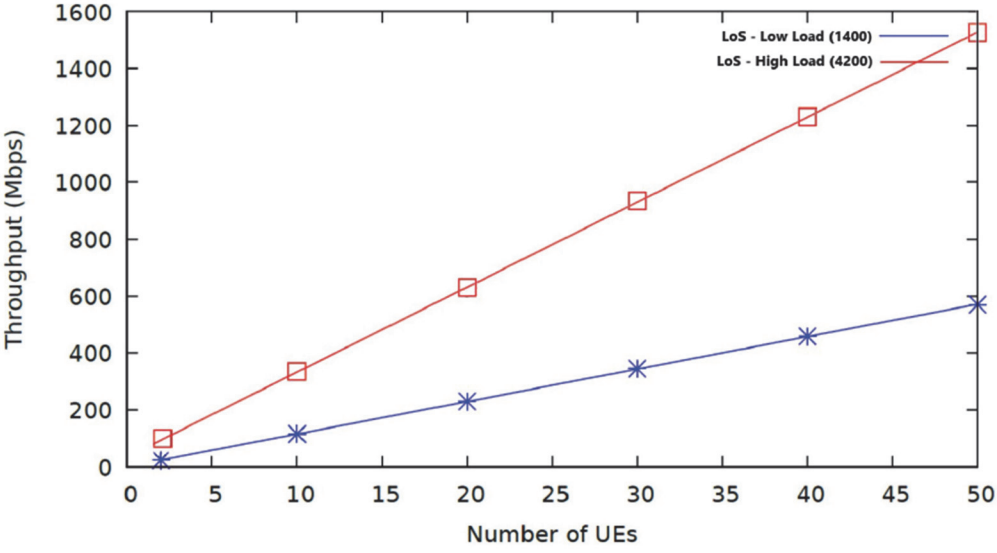

Figure 9.19. *Throughput versus number of UEs for LoS (low load and high load)*

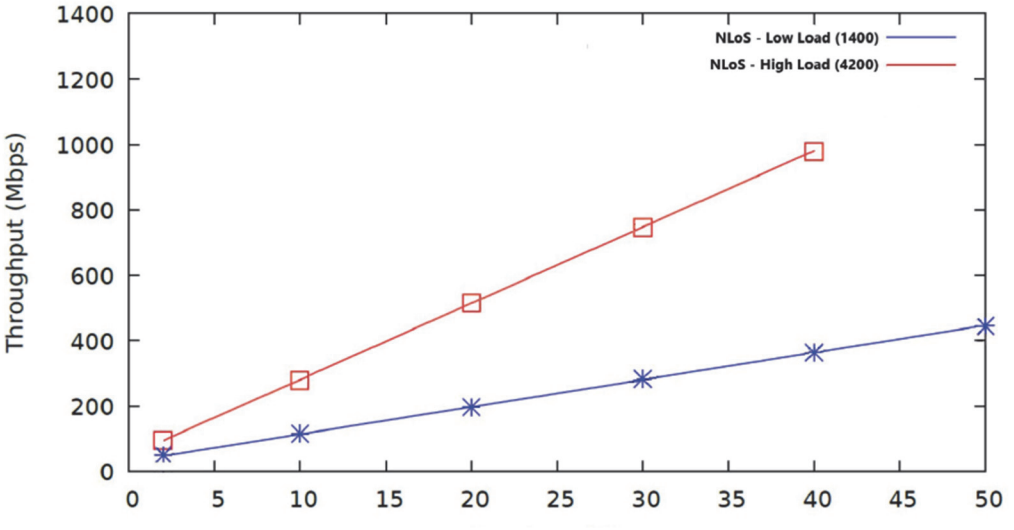

Figure 9.20. *Throughput versus number of UEs for NLoS (low load and high load)*