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Question 3.2: Even with the adoption of 5G, it is expected that utilities will continue to adopt a mix of radio technologies for different purposes. Describe the differences, advantages, an disadvantages between 5G and other wireless radio technologies in the context of power utility use cases.

Requirements of communication-based power utility use cases have a huge variety, thus one wireless technology, e.g. 5G, cannot be optimal for all. In this contribution, the use cases are categorised into monitoring, control, and protection. We also consider the range, e.g. intra-substation, vicinity of the substation, or inter-substation data transfer. We focus on the following parameters: bandwidth, reliability, latency, device density, and service priority. Monitoring typically includes a large number of sensors expected to grow exponentially giving it the highest device density and bandwidth. On the other hand, as protection is crucial in maintaining power grids operational, it has the requirements for the highest reliability, service priority, and lowest latency. Control communication requirements are between monitoring and protection; depending on the application reliability is equally high to protection. 5G is one of the wireless technologies preceded by prior generations, e.g. 4G, and advanced by 6G. Currently, there are a variety of 5G NSA (non-standalone) solutions, which use 4G for support, available commercially, while 5G SA (standalone) is at various stages of implementation and roll-out globally. 5G promises several services and features compared to its predecessors including network slicing and edge computing and communication types: mMTC (massive Machine-Type Communication), URLLC (Ultra-Reliable Low Latency Communication), and eMBB (enhanced Mobile Broadband).

Overall, when compared to prior generations of wireless technologies an improvement can be seen for all parameters. However, even 4G is well suited and meets the requirements of monitoring and some control applications. The latency and reliability that 5G promises could be seen as meeting the requirements of protection communication, but the current measurements of the commercial 5G networks in Finland show that there is still a need for some advancements to reach the promised targets. Especially URLLC is relevant thanks to its requirements of low latency and high reliability needed for protection use cases and must be further developed with 6G to reach sub-millisecond latencies. Meanwhile, mMTC can be used to communicate with a large number of sensors and devices to transmit monitoring data, while eMBB could be used to control distributed energy resources due to its average latency and larger bandwidth.

As the section of the frequency spectrum for wireless technologies increases, 5G reaches the mmWave spectrum. Naturally, as the frequency increases the distance the signals carry drops and thus 5G does not have a similar range to for instance satellites. To combat the challenge of low range, 5G employs small cell base stations compared to the prior technologies and increases the cell density. The higher cell density enables edge computing, in which case applications could run at the edge rather than at the core including power grid applications. While the concept of edge computing is not new and already with 4G cloud computing is available the possibility to remain at the edge only with 5G truly enhances this feature.

Another consideration is licensed or unlicensed spectrum; with a licensed spectrum, the operator has the exclusive rights to the licensed frequency band, which could be relevant for time-critical use cases such as protection to ensure no other traffic blocking the transfer. Most IoT devices use the unlicensed spectrum, where anyone can operate possibly causing interference between various data transfers. In a confined area using IoT devices for monitoring even in the unlicensed spectrum has potential, but the interference of other traffic must be measured. A similar aspect is private and public networks, in a public network the data transmitted is visible to everyone while in a private network only those connected to the network can access it. Typically, substation networks have been private, but with the roll-out of 5G features such as network slicing or edge computing some parts of the communication infrastructure could be in a public network encountering cyber security challenges different to a limited private network.

Power grids provide an intriguing vertical for communication technologies due to the variety of requirements, thus the aim cannot be to implement all power grid communication via 5G or any other technology, but rather carefully select the best possible technology to meet the requirements provided by the utilities. Furthermore, it would be relevant to think about these solutions not only in terms of the best possible communication network conditions but also in the worst situations. Power grids combined with communication infrastructure needed for modern smart grids could be otherwise easily left vulnerable to wide-area disturbances. Thus, wireless technologies should be also studied in the worst possible network conditions, not the best promises given by communication theory and teleoperators.