FEATURE

5G: ENABLING TECHNOLOGIES & APPLICATIONS

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As a result of digitisation of organisational/personal information and the ever increasing popularity of smart devices and applications, the demand for high-speed data connectivity is putting great pressure on existing mobile networks.

According to white papers published by Cisco Visual Networking Index Forcast [1], the global mobile data traffic will increase manifold in the next few years, reaching 77.5 exabytes per month by year 2022, and there will be 12.3 billion mobile-connected devices (including machine-to-machine modules).

It is estimated that the average smartphone will be generating 11GB of traffic per month (as compared to 2GB per month in 2017), while nearly 80% of the world's mobile data traffic will be videos by 2022. Countries like the United States, China, South Korea and Japan are in the race to develop, test and deploy 5G communication networks, not just because 5G technology will enable new types of services (such as autonomous vehicle system) and so gain great economical advantage, but it is also commonly agreed that 5G technology is a strategic resource for staying ahead, military-wise.

It is also generally believed that the 5G wireless system will eventually govern almost everything in a city or even a country, e.g. in critical areas such as traffic flow, utilities, lighting, healthcare, smart city applications and more.

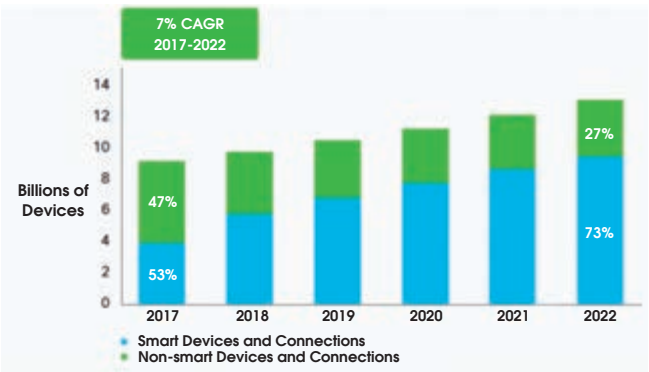

Figure 1: Global growth of smart mobile devices and connection [1]

FIVE TECHNOLOGIES TO PROPEL 5G & THE CHALLENGES

To achieve the KPIs of 5G (high download speed, low latency, ultra-reliable and provide massive connection capabilities), various technologies have been identified as the potential key to enable components to the 5G networks [2]:

1. Milimeter Wave: Higher data transmission rates require wider spectrum width allocations. In order to transmit at a data rate of several Gbps, a new, unused, high frequency band has to be exploited. The conventional mobile signal resides in the UHF range between 850MHz and 2.5GHz.

   For the 5G network, the proposed allocated spectrum is the mm-wave band, which spans from 30GHz to 300GHz. By migrating mobile signal frequency band from MHz range to GHz, the available spectrum has to be increased by 3 order. However, unlike existing mobile signal frequencies which can travel reliably over several kilometres, mm-wave frequencies signals are easily blocked by buildings, rain or trees. So, mm-wave networks can only be deployed for short-range, densely populated areas such as urban cities. Alternatively, there are proposals to utilise the sub-6 GHz frequency band to trade for longer transmission length with decent transmission speed improvement.
2. Small cells: If the mm-wave spectrum is adopted for 5G network, an antenna with a much smaller dimension has to be used in the network infrastructure. Small cells are low-power, miniature base stations and are typically placed every 200-250m within an area, in contrast to traditional cell networks where the base stations can be kilometres apart. So the service provider of mm-wave networks will face greater infrastructure challenges as hundreds of thousands of small cells have to be placed in a given area to ensure service quality.
3. Massive MIMO: MIMO stands for Multiple-Input Multiple-Output. A MIMO system utilises a large number of antenna elements at the base stations. By doing so, these antenna arrays provide extra degree of freedom, in spatial aspects. Thus spatial multiplexing techniques

can be adopted to substantially increase spectral efficiency per cell. However, signal interference is severe when many antenna arrays aggregate together.

4. Beam Forming: Beam forming is possible when the antenna arrays in a MIMO system are capable of auto-aligning themselves in a particular pattern so that the signal beam emitted is efficiently transmitted to a nearby user. In other words, the antenna array is "smart" and able to focus a signal beam in a designated direction. This also reduces wastage of transmission power in other undesired directions and, at the same time, elongate the signal propagation length in the desired direction. The main challenge here is the highly complex algorithm computation to estimate the antenna pattern and it eventually leads to high power consumption for implementing the complex computation.
5. Full Duplex: Full duplex capability of the 5G antenna is crucial to ensure low latency of data transmission. In a full duplex system, the transceiver will be able to transmit and receive data at the same time, on the same frequency channel over the same antenna. Major advantages of the full duplex system are a shorter system response time as well as saving of physical resources. However, simultaneous uplink and downlink on the same resource block can cause self-interference.

EMERGING APPLICATIONS

5G is perceived as the fundamental platform for many new and high economic value applications. The following are some potential applications that can be made possible with 5G network [3]:

Automotive: With ultra-high reliability, ultra-high availability and ultra-low latency features offered by 5G connection, it will be possible for vehicles to connect with the surroundings at various travelling speeds, e.g. vehicles can be connected to other vehicles, pedestrians, roadside infrastructure etc. With this, several interesting applications will be feasible, such as vehicle platooning, where a group of self-driving cars can travel very closely together at high speed yet safely, to provide a smoother traffic flow.

Smart Cities: Urban populations have been increasing exponentially every year and this has been driving strong needs for better city resource conservation, efficient energy management and rapid emergency response etc. to attract investment and visitors.

5G networks offer massive connectivity feature and ultra-fast data transfer technology that a city will need, both for governance and use by residents. For example, smart grid and advanced electricity metering infrastructure, digitalised municipal services and city safety monitoring system are a few aspects that a smart city will want to adopt.

Health care: The health care sector will also benefit from 5G high bandwidth, low latency and high reliability, high availability and massive connectivity features. Wearables (e.g. portable artificial heart) which provide mobility convenience to the user will require a reliable network connection for data collection. Another benefit is remote surgery as the physical location of the surgical team and the patient will not be a limitation since the virtual surgical equipment and the physical one are connected to the network.

CONCLUSION

5G mobile technology is viewed as the fundamental platform for futuristic, militarily strategic and high-economic value applications/systems that will greatly improve the way we live. The major key features that 5G can offer, besides high data transmission rate, are ultra-low latency (<1ms), ultra-high reliability and massive connectivity. The deployment work of the 5G network is expected to kick off in 2020, and the competition to get ahead of this 5G race is stiff. There are 5 key technologies that have been identified to the essentials components of 5G network: The mm-Wave Technology, Small Cells, MIMO system, Beam Forming and Full Duplex system. Finally, we also see several interesting applications that can be the result of a 5G network. ■

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CONGRATULATIONS

Congratulations to **Y.Bhg. Tan Sri Dato' Ir. Emeritus Prof. Dr Chuah Hean Teik** who received the World Federation of Engineering Organisations (WFEO) Medal of Excellence in Engineering Education 2019 award at the World Engineers Convention & WFEO General Assembly in Melbourne on 23 November 2019.