Arthur D Little

Viewpoint

5G: Closer than you think

Wireless broadband access is becoming essential to the functioning of modern life and a dominant part of communication networks. It is also seen as a key enabler of and a source of significant opportunities for innovation in delivering better services in the transport, utility, health, commerce and education sectors. As part of a general trend in which the best-effort Internet needs to evolve towards a quality Internet (as detailed in our report "The future of Internet"), this introduces serious and ever-increasing pressure on wireless network capacity and performance. With 5G technology, these networks enter the age of "steering and control" communication with more intelligence, closer to users. Beyond efficiency gain at all levels, it also calls for a paradigm shift in business models, policies and economics, as well as increased partnerships. This needs to be prepared as of today.

5G is more than a new radio access technology

New generations and standards of mobile technologies have been defined by evolution in radio access technology. From 2G to 4G, cellular wireless technologies have been evolving towards offering more speed, and each standard has been tagged with a handful of major attributes.

5G will be no exception. However, the sheer scale of the challenges this time makes 5G different. 5G should embrace a significant leap forward in terms of performance targets, as it needs to offer new possibilities to connect not only people, but also objects such as cars, wearables and home appliances. In order to meet these targets, 5G technology will embrace end-to-end connections – not just the radio access part. More importantly, collective and harmonized global standardization activity throughout Europe, the US and Asia will be all the more important for the success of 5G technology to allow a seamless experience globally and achieve economies of scale.

The race is on, but no standard has been defined as of now

Hardly a week goes by without some new announcement on 5G. Public authorities engage budgets to raise the innovation capacities of their territories (particularly Europe, to regain its leading position in the development of mobile technologies), Asian manufacturers see an opportunity to further develop their market shares, universities push research programs, standardization bodies define future requirements, and equipment manufacturers and operators compete to be the first to offer and benefit from this technology.

A global standard is yet to be defined. The International Telecommunication Union (ITU) is planning for detailed specifications to be released in 2020, and South Korea has already announced a 5G trial network for the Winter Olympic Games in 2018. 5G standards are also expected to unify a number of technologies introduced into 4G to consistency.

So what is really new in 5G?

Many changes to 4G will be incremental

- Provide 1–10Gbit/s of theoretical bandwidth (versus 100–300Mbit/s for 4G)
- Be available anywhere, although this relates to coverage efforts engaged by operators
- Enable connection to a massive number of objects
- Secure critical communications
- Be fully compatible across countries
- Use any and many kinds of frequencies

- Work in a crowd by allowing the convergence of heterogeneous networks
- Significantly extend battery life
- Significantly improve end-user experience

Real breakthrough, however, will come from the following enhancement:

- Super-low, sub-1ms latency, required for a number of new mission-critical services and applications such as machine-type communications (MTC), real-time gaming, control and automation.
- Ultra-reliable communications – for projects with critical services that are available 100% of the time in fields such as automotive, remote control (drones and robots), process automation, and health and emergency services.
- Open platform to enable cross-development of services by external parties, which can then be hosted on networks.

Potential 5G applications

1. 5G will offer greater possibilities for current mobile applications
   - Individualization of HD video on demand
   - Generalization of telepresence to simplify the use of video conferencing
   - Everything will be connected and transmit information, status data, position, etc.
2. New usages will also arise, taking advantage of technology breakthroughs
   - **Example 1**: Autonomous vehicles – reduction of road-traffic congestion

     Autonomous cars are making headway, with automated controls already widespread, such as adaptive cruise control and lane keeping. At the next levels the car will take full control of safety-related functions, and eventually the steering of the vehicle from start to stop.

     By reducing end-to-end communication latency to below 1 millisecond, an application for vehicle safety could manage bidirectional exchange of data for negotiation of automatic cooperative-driving maneuvers. In stop-and-go traffic, a driver assistance system could take over the steering of the vehicle to adapt the speed of all drivers in a limited area (within a radius of 15 km) in order to absorb the congestion.
   - **Example 2:** Tactile Internet[1]

     The sensitivity of control circuits when controlling rapidly moving devices (such as industrial robots) requires end-to-end latency significantly below 1 millisecond per sensor.

     In typical scenarios of industrial control with closed-loop systems, a master station will contact all sensors and actuators and present the acquired data to the control application at intervals of roughly one millisecond. In view of the typically large number of sensors (e.g. up to 100 for a printing machine), every individual sensor must be accessed within an end-to-end latency period.
   - **Example 3:** Real-time remote controls

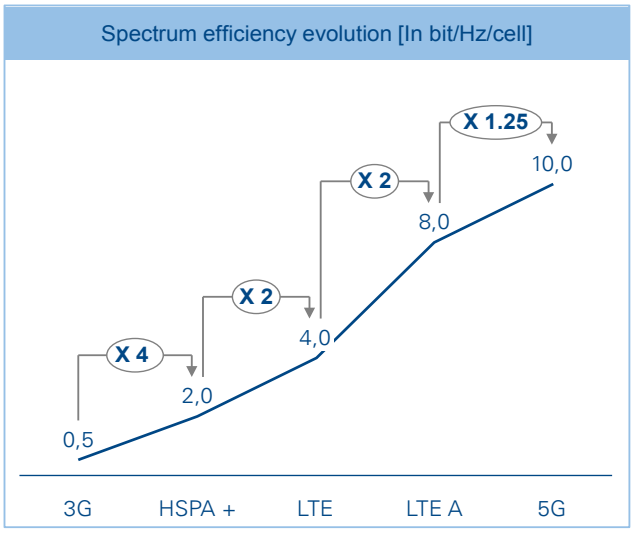
     Controlling robots in inaccessible or dangerous areas will be feasible with near-instantaneous and remote control (for disaster relief or building work on rooftops, for example). An operator wearing an exoskeleton will be able to receive real-time feedback (360-degree visual as well as tactile) of the behavior of the robot. This communication will also come from multiple sensors, even in distant locations (up to 15km).

Implications for networks are immediate

1. Spectral efficiency limited

Divining more data through a scarce and finite radio spectrum becomes a real challenge and makes the radio spectral efficiency one of the most important challenges. However, spectrum efficiency is approaching a plateau and will not deliver the expected increase in bandwidth improvement by itself.

Spectrum efficiency evolution [In bit/Hz/cell]



Source: Arthur D. Little

Therefore, to increase bandwidth, two elements are needed:

a. More spectrum

5G is likely to utilize frequencies below 6GHz (3GHz to 6GHz) as core spectrum and mmWave

1 Introduced in « The Tactile Internet », ITU – Technology Watch report – August 2014

(10–100 GHz) for ultra-dense access & backhaul. This, however, does not rule out the usefulness of sub-1GHz for more cost-effective coverage where possible. Nevertheless, considering the current spectrum allocation, finding a free chunk of spectrum in this range is likely to be a very long-term possibility. The much bigger challenge is to secure enough spectrum to cater for ever-increasing capacity demand and larger bandwidth, i.e. 100+ MHz for 5G technology in order to ensure much higher capacity. Wider use of carrier aggregation is likely to ease some of this burden.

b. **Denser network architecture, including small cells**

Additional/new antennas on rooftops will be needed, in order to increase the capacity of the network to the desired level. This will drive colocation on existing sites, as well as the need to establish new sites, especially in a dense environment. Radio sites will also increasingly be installed at street level and/or in buildings to accommodate specific hotspots.

Small cells will also be needed, with strong integration with the rest of the network to provide a seamless experience for users.

2. **Decentralization of network intelligence will require a new core network**

Achieving very low latency requires bringing network intelligence closer to users, which means local/very local data centers will be needed.

To achieve a round-trip latency of below 1ms, the communication delay due to the speed of light needs to be considered as well. Within 1ms, light travels 300 km – i.e., the maximum distance for a steering and control server to be placed from the point of tactile user interaction is 150km. However, this assumes no processing delays in communication. Taking the additional signal processing, protocol handling, and switching delays into account, this requires the mobile user to be within 15km of the application server – which means at the base of every cell. This could represent a significant increase in CAPEX requirements.

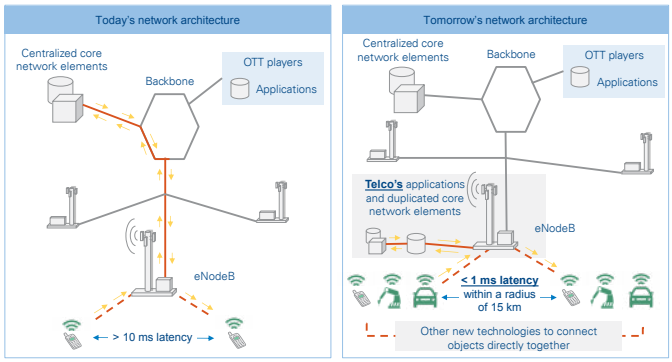
Complexity is added when taking into account inter-operator interconnection. These are currently done at a limited number of points of interconnection, which will need to be significantly increased in the future.

3. **The transmission network needs to be reshaped**

Transmission network capacity is not just a challenge for 5G. However, the nature of potential and foreseen new services and applications poses yet another, bigger challenge in terms of quality, resilience and reliability of transmission lines.

Achieving sub-1ms delay will require complete redesigning and reconstruction of transmission architecture, involving a majority of fiber links.

The evolution of network architecture



Source: Arthur D. Little

Business models impact

1. **A strong need for partnerships between existing and new players**

Partnerships are needed at many levels to make 5G a success:

- A global definition of the norm will need to be defined and accepted worldwide.
- With the deep interconnections between hardware, software and applications, 5G is a platform that requires a significant level of partnerships and cooperation from companies from a wide range of horizons. Telecom equipment vendors, IT providers, telcos, applications developers and content providers will need to work together. Companies such as car manufacturers, industrial players and utilities are already getting involved in the development of the technology.
- Different types of networks owned by different operators will also need to be interconnected and seamlessly integrated (local area networks, wi-fi-type networks, private networks, mutualized rural networks, etc.)

2. **Cheaper networks (per GB, but also per user and per square km)**

Lowering costs will be one of the key objectives of 5G systems. This will be realized through lowering the delivery cost (per bit/km^2) primarily. The cost could also be lowered through "greener" telecommunications, increasing the lifetime of products, delivering technology through software, and more pragmatic and efficient plug & play and self-managed networks.

In addition, one of the main network costs will increasingly come from real estate (the sites). Therefore, network and radio resource sharing will play a bigger role, beyond the

current simple site and box partial hardware sharing. 5G networks will also need to be well connected and integrated sets of many networks in order to cost-efficiently fulfill the coverage and capacity demand in future mobile broadband systems.

3. A potential regain of power for telecom operators

   As mentioned, real-time applications will need to be located close to the user. They will therefore be hosted on the network, close to the base stations. The network operator will then be the natural player to manage and control these applications and their ecosystem, which will potentially allow the telecom operators in the ecosystem to regain power. However, other players could play a key role like proximity data center or NFV/SDN asset light players, which could optimize part of the traffic. To achieve this, networks will need to have a certain level of openness and quickly engage in the right partnerships in order for third-party developers to develop the applications that will then be hosted on the networks. Defining a standardized interface for the applications developer to work with will be key.

4. Licensed and unlicensed spectrum

   More spectrum will be needed. Spectrum located in both licensed and unlicensed bands will be used, impacting the business case of the mobile operator differently. Carrier aggregation is a must, together with intelligent management of spectrum rights, taking into account dynamic temporal and local spectrum sharing.

   Regulatory bodies will need a much more consolidated and harmonized approach to ensure better use of these invaluable and scarce resources and avoid fragmentation. Changes in spectrum allocation regime, utilization and licensing will be essential, together with synchronization of releases of specifications that impact operation and business models.

Key implications

- **Current networks must be designed with 5G in mind.** Design must take into account future evolutions, especially on decentralised core architecture and transmission needs.
- **Spectrum needs are huge.** Using and sharing large amounts of both licensed and unlicensed spectrum calls for changes in operating and business models.
- **5G (and therefore operators) will handle billions of devices and humans at the same time,** with a wide range of requirements in terms of capacity, latency, security, reliability and business models.
- **Access to sites will become increasingly critical,** as much denser networks will be needed, with impact on the number of sites and amount of equipment on each of them. Small cells will also be a key part of 5G design.
- **Standardized interfaces will foster applications** imagined and developed by third parties.
- **Application hosting platforms in the networks will develop,** changing revenue models & shifting value. It will be important for telecom operators to keep control of these platforms in their networks, which will migrate closer to users.
- **Partnerships will grow in importance,** with an open innovation spirit in mind. 5G success depends not only on the underlying technologies, but also in rethinking business models and economics.

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