Your 5G questions

Our interactive guide

A straightforward explanation of how 5G works for business and what it can offer.

The future is exciting.

Ready?

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What is 5G

5G is set to become an integral part of the world we live in and the way our world works.

Are you wondering what 5G is? 5G could be considered just a shift forward from previous generations of mobile connectivity. However, its potential is greater than any previous generation's. Vodafone believes 5G will enable changes in the way we live and the way business operates.

With 5G

- Peak speeds will reach and exceed 1Gbps.
- Mobile networks will manage traffic more efficiently than with 4G. This means network capacity will increase, so that users will enjoy higher and more consistent average speeds-even in crowded scenarios or in areas with less-than-ideal coverage.
- Latency will decrease and it will continue to do so overtime as 5G devices evolve. As the time between performing an action (such as moving a character in an online game) and getting a response will be reduced, user experience will be greatly improved.
- More devices will be able to connect to a 5G cell site, supporting the expected explosion in the number of devices as part of the Internet of Things (IoT).

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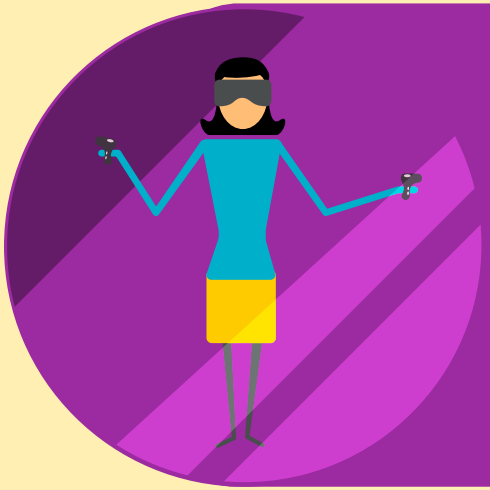
Enhanced Mobile Broadband

100 Mbps whenever needed.

>1Gbps peak data rate.

Read more.



Mission Critical Services

More than 60% latency reduction.

Read more.

What will 5G bring?

5G will create new opportunities. We can foresee some of them, but there will be others we cannot even imagine today.

Massive IoT communication

1M Devices per km².

Read more.

Did you know?

Latency is the round trip time it takes for a packet to go to and from the application server, measured in milliseconds.

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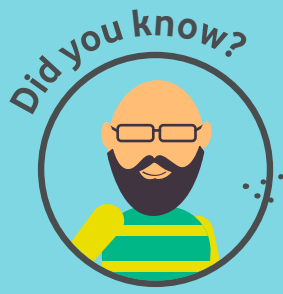
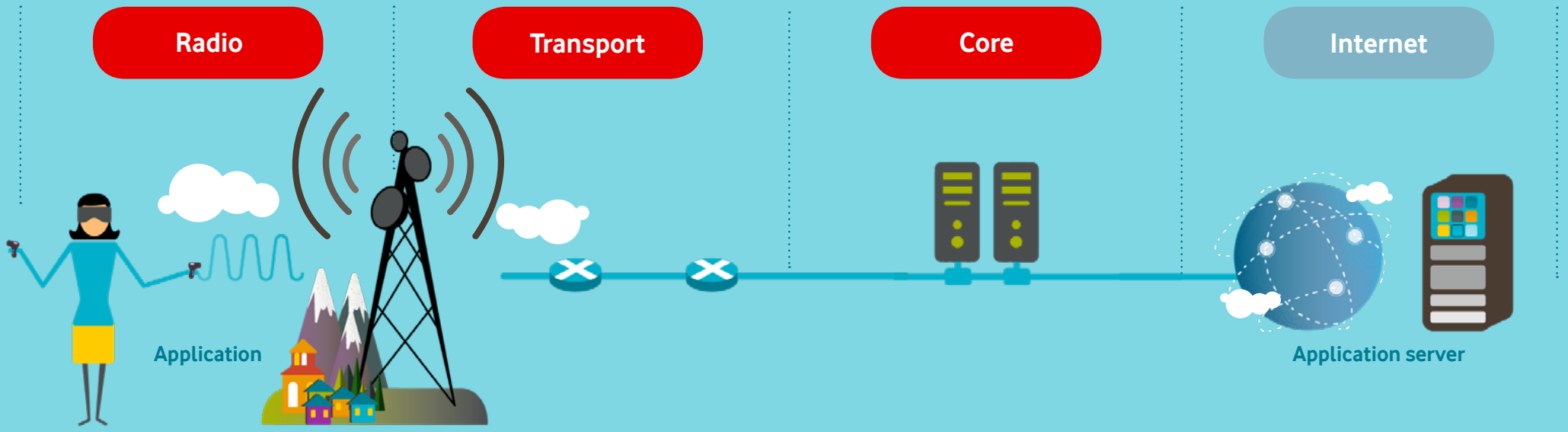
Let's start with **the basics**

Here we explain the fundamentals of our mobile networks: Radio, Transport and Core.

Click on each of the red buttons for more information.



3GPP (The 3rd Generation Partnership Project) is a standards organisation that develops the interoperable standards for Radio and Core Networks, Services and Terminals. Our 2G, 3G and 4G networks are based the 3GPP standard and our 5G one will be too.



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What's 5G?

4G Evolution (4G Evo) is going to act as the bridge to 5G, making this the first time in history that one mobile network has needed the previous one to be born.

5G encompasses 4G Evo, a new radio standard - 5G New Radio (NR) and a new 5G Core (5GCN), supported by a transport and core architectural evolution to deliver great network benefits. For the first time two generations of technologies are going to be closely integrated together. Both 4G Evo and 5G will offer the possibility of higher speed and capacity, lower latency and importantly new possibilities in IoT.

4G

Evo

5G

New Radio (NR)

4G

Core Architecture evolution

5G

New Core

Did you know?

4G Evo is the evolution of the 4G network, with data rate and latency improvements. It includes IoT and other capabilities brought forward from 5G, such as Massive MIMO.

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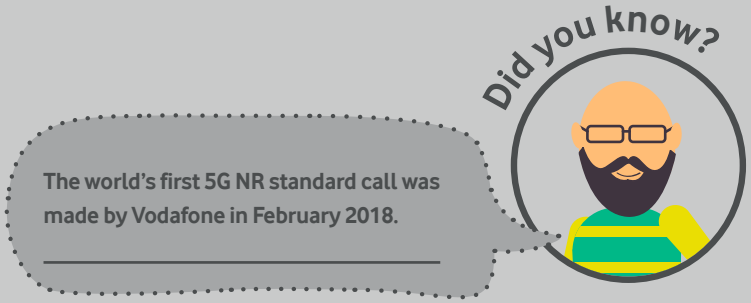
Radio

Current 2G, 3G and 4G networks use different radio interfaces. 5G NR is a new radio standard interface offering data rates higher than 1Gbps. It's more efficient, meaning it can transmit more data in the same amount of spectrum, as well as utilise more spectrum at once – so it has a double impact. It was defined in the 3GPP standard in December 2017. **Read more.**



Core

There are two phases for the Core Network to support the 5G New Radio.

- **Non Stand Alone (5G NSA)**. In the first phase the existing 4G core network (EPC) will be used to support the 5G launch, with only minor changes expected for the current core. The first 3GPP standard was closed in December 2017.

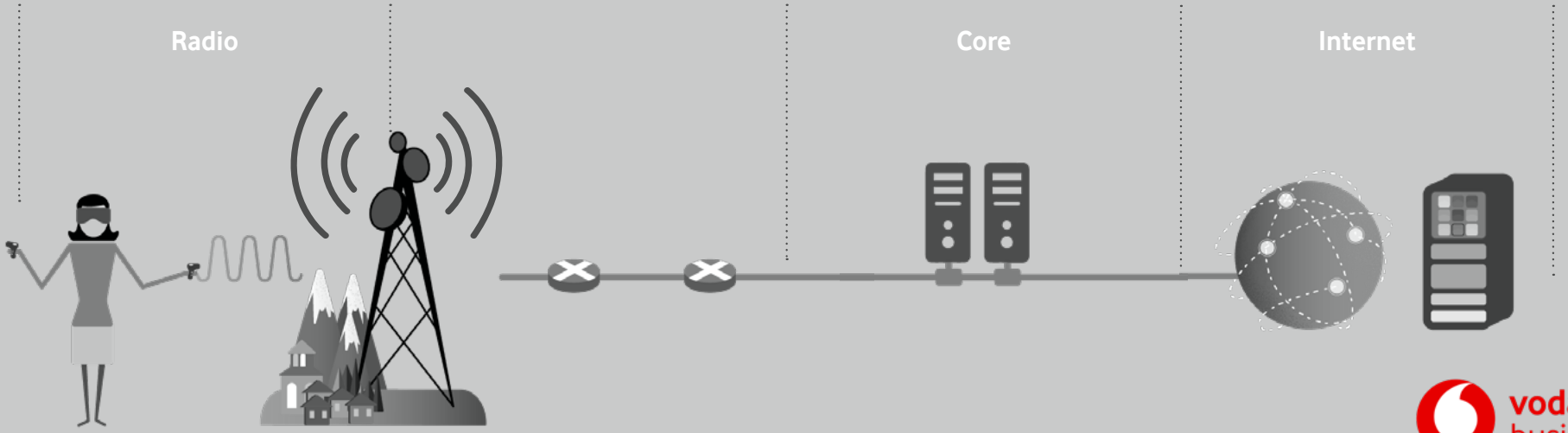
Click here to view 5G NSA diagram

- **Stand Alone (5G SA).** In the second phase of the new 5G Core (5GCN) will be introduced. the first 3gPP standard was closed in June 2018 and it introduces more flexibility and functionality. The standard was agreed by 3GPP in June 2018.

Read more.

3GPP **Read more.**

Click here to view 5G SA diagram



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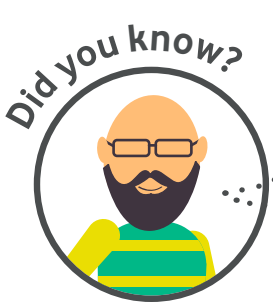
An **architectural evolution** is happening



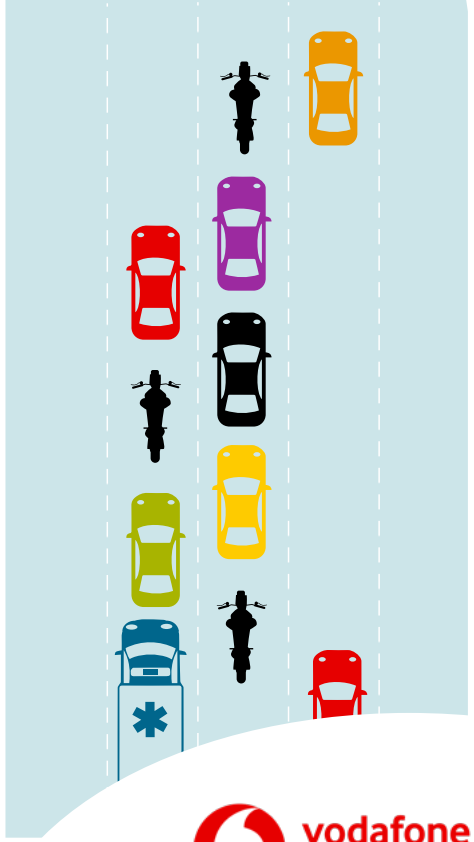
Virtualisation is nothing new. Virtualisation of servers has been used for a long time by the big social media and on-line retail organisations.

Click on each of the coloured buttons for more information.

Virtualisation | **Network Slicing** | **SDN**

There are several important ongoing changes to Vodafone's networks that will favour the introduction of 5G.

The first deployments of 5G networks will be capable of delivering improvements in both data rate and latency. In terms of end-user services, higher data rates will be delivered with 5g. The benefit of lower latency, important for applications such as mixed reality, will require network changes including Virtualisation, Network Slicing and Software Defined Networking (SDN).



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Voice

5G uses VoLTE capability to deliver voice services.

With VoLTE:

- Users are able to make and receive calls and use data without interrupting 4G download speeds.
- Increased voice call quality and performance – clearer calls and less background noise.
- High quality video calling with less buffering or pixelation.
- Faster call setup time – connecting users to their family and friends in an instant.

Did you know?

VoLTE:
Voice over 4G is also known as "VoLTE"- that's Voice over Long-Term Evolution. It allows voice calls to be carried across a 4G data network instead of using 2G or 3G.

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Data, speed & capacity

5G marks the move from Mbps to Gbps and Vodafone will increase network capacity to support this.

5G will enable an increase in data rate and capacity – although in the early days it will probably not cause significant changes in customer behaviour, as 4G did with video streaming and content sharing, for example. We are already seeing peak data rates of around 1Gbps in 4G networks, albeit in limited circumstances. By the time 5G comes, it will probably be experienced as a continuation of the current increase in mobile data speeds, rather than a revolutionary improvement.

Improvements in speed and capacity are mainly due to:

- Massive MIMO, already available in 4G Evo, which improves capacity, coverage and user throughput. **Read more.**

Click here for a diagram showing Massive MIMO.

- New Spectrum: In 5G there will be a greater spectrum available. 3.5 GHz has the broadest support for 5G globally and also has been identified in Europe (by Radio Spectrum Policy Group) as the primary 5G band to bring necessary capacity for 5G services. mmWave spectrum (in frequencies >24 GHz) is also identified for 5G for ultra-high capacity & innovative new services. 26 GHz band is a pioneer band identified by China & Europe for 5G in mmWave. The US, Korea and Japan have identified 28 GHz as their primary 5G mmWave band. 5G can also be launched on many existing bands including bands below 1 GHz (e.g. 700 MHz). **Read more**.

Click here for a diagram showing New Spectrum.

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Reducing Latency

Multi-access Edge Computing (MEC) brings low latency applications closer to customers, considerably reducing end-to-end latency.

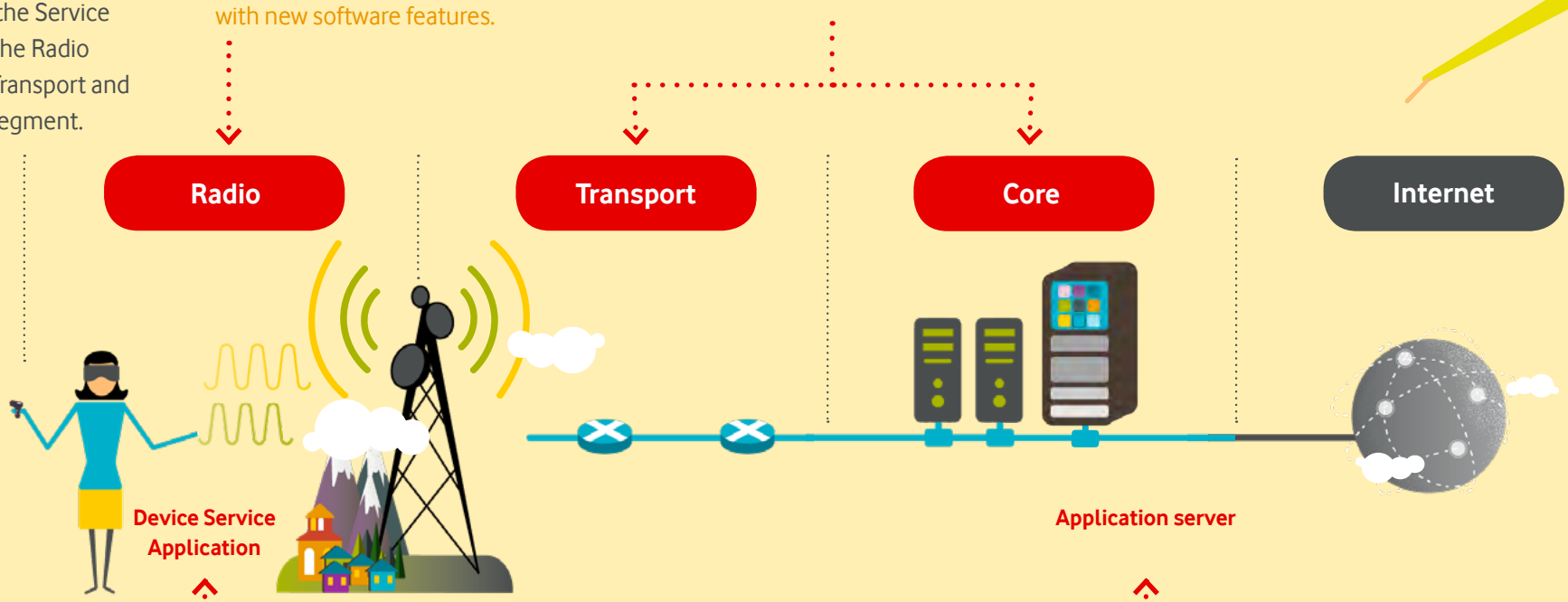
There are four main contributors to the end-to-end latency: the Service Application Processing, the Radio Interface, the Network (Transport and Core), and the Internet Segment.

Radio latency can be reduced with new software features.

Transport and Core Network latency will be reduced via MEC, which basically means deploying the Service Application in the network closer to the user, and implicitly also cancels the **Internet** Segment latency. **Read more**.

Did you know?

4G Evo/5G + MEC will deliver lower latency than either 4G Evo or 5G alone.



Processing of Service Application running in the user device and in the application server represents improvements in latency and requires co-operation between the service provider and application provider.

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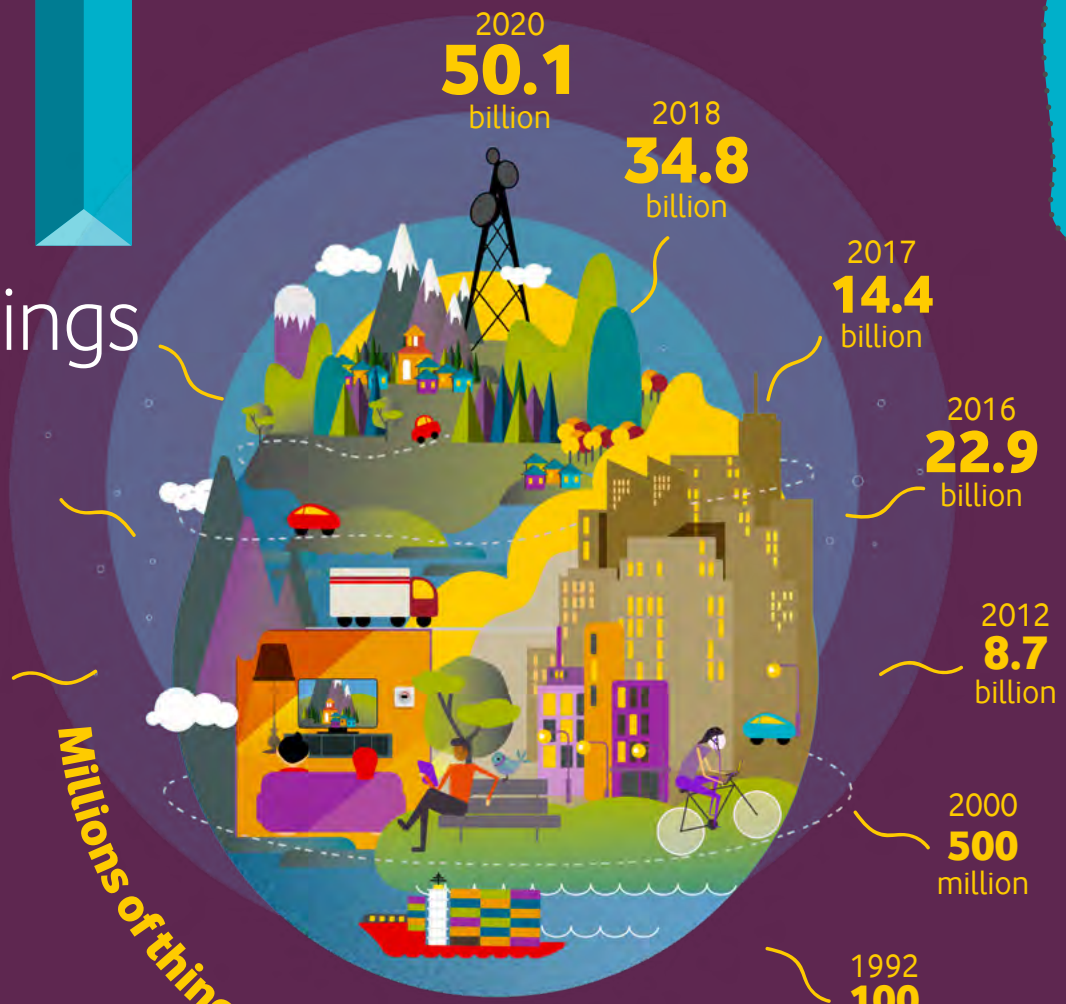
IoT

Internet of Things

A revolution in our lives is coming with an internet connected world.

There are two IoT technologies that have just started to change the way we currently understand the world: Narrow Band Internet-of-Things (NB-IoT) and CAT-M.

NB-IoT is designed to support services requiring low throughput, extended coverage and long battery life.
It's designed to enable very low cost devices supporting new use cases such as car park management, water meters or waste bin management, among other uses.



Did you know?

We target to reuse the concept in smartphones to provide text-only messages in conditions of low coverage or low battery. In 5G, it could be extended to media.

CAT-M, which is a simplified LTE design, complements NB-IoT supporting real time voice, mobility, lower latency and higher throughput in a smaller coverage area compared to NB-IoT. It's the best solution for applications such as wearables, electricity meters or elevator emergency services.

Other LTE categories could be the more appropriate solution for high rate demands with very low latency, such as telemetry for cars.

The process of making Vodafone's networks more suitable for IoT devices is already well under way. **Read more.**

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The 5G countdown has started!

Enjoy the journey!

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The future is exciting.

Ready?

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eMBB

One example of the use case where Enhanced Mobile Broadband (eMBB) matters is multi-media:

- Media will truly become on-demand from any location even in crowded areas. Users will expect to be able to enjoy 4K movies downloaded in a few seconds without a Wi-Fi connection and send videos with a great experience.
- Live Interactive broadcasting: Making live and interactive TV broadcasts and sporting events an immersive viewing experience, just as if you were at the live event.
- Augmented Reality (AR) on the go: AR cloud-based mobile services based on geolocation data and local visual navigation will give:

  » Better tourist information on the go.

  » Advertising of special offers as people shop

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Mission Critical Services

5G will help enable applications such as:

- Industrial Remote Inspection: Power lines, radio masts, oil and gas pipelines, railways, methane detection – all of these and so many other types of time critical industrial inspection will be made easier, safer, and more efficient.
- Safer working: Control of heavy machinery from a distance will make hazardous situations safer for humans.
- Remote Surgery: Remote control of devices for improved medical services and procedures that would otherwise be unavailable to rural communities.
- Power plan/grid: To fully use green energy, the peak times of energy consumption need to be smoothed out so that energy supply and demand is more balanced. Thanks to reliable, low-latency data communications, the utility companies can maintain balanced supply in the grid.
- Smart vehicle and transport: Vehicle-to-everything (V2X) to make roads safer and more environmentally friendly, while allowing buses and public transportation to run more efficiently. Ultimately 5G has the potential to be the communications infrastructure that will support autonomous driving.

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Massive IoT

A revolution in our lives is coming with an internet connected world. Sensor networks will monitor, track and automate capabilities to improve efficiency in:

- Agriculture & environment.
- Smart buildings & cities.
- Consumers & utilities.

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Radio

Radio technology is used to connect a mobile phone to the radio mast. Each mast serves an area referred to as a cell. Cells are arranged like the cells in a honeycomb hence the term “cellular networks”.

Cells work with each other to minimise radio interference through the careful allocation of radio channels. In rural areas, the cells can cover several kilometres, but in busy traffic areas, cells are subdivided into smaller cells to provide more capacity.

2G,3G and 4G operate in different frequencies which helps to optimise coverage and capacity. The same is true of 5G where optimisation will be guided by 5G trials.

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Core Network

There are two types of Core Networks:

- Circuit Switched Core (CS), mainly used for voice in 2G and 3G.
- Packet Switched Core (PS) in mainly used in 2G,3G (data only), 4G (data/voice) and 5G (data/voice).

In the CS, there are dedicated connections mainly to carry voice between users, and in the PS the communication is done through IP packets that are more efficient and help the more from Circuit Switched technology towards the move ubiqitous technology of IP.

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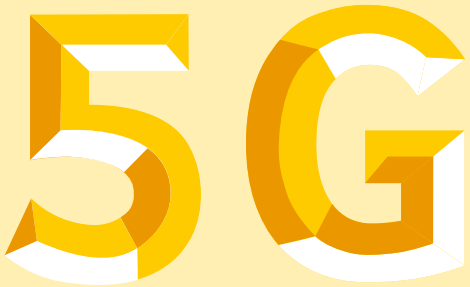

5G New Radio

The “New Radio” cellular technology that is being developed as part of the 5G network is based on a similar design to the existing LTE (4G Evo) technology. This means an evolutionary development from 4G LTE but with improvements in the following areas.

It works more efficiently in larger spectrum allocations than 4G Evo such as:

- Those available in new frequency bands beyond 3GHz.
- It’s able to operate in high frequencies in the 24GHz to 28GHz range (sometimes referred to as ‘millimetre wave’ range) as well as in existing cellular frequencies (including those used by LTE).
- Leaner design allows any future vertical or service-specific enhancements to be added more easily, and can help with energy efficiency.
- It’s able to easily integrate with the existing LTE network for efficient use of radio mast sites.

It should also be noted that many of the service capabilities of 5G can be supported to a large extent by LTE, meaning that some of the benefits 5G will bring, for example low latency, can be enjoyed in advance of NR.

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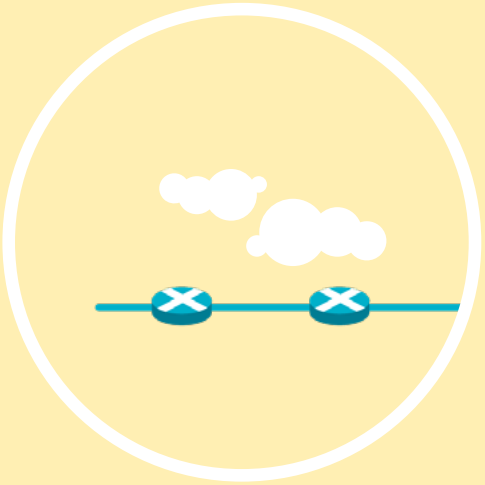

Transport

Transport is the term used to describe the network infrastructure between the radio mast and the core network. These networks are also often referred to as access and backhaul networks. Connections are typically fibre but microwave is used where a wireless connection is more appropriate.

Microwave connections have been key technologies for the final connection to the radio mast for the previous generations of 2G-4G. With the introduction of 5G, new IP Microwave advances including millimetre wave (mmWave) technology provide the opportunity to support higher bandwidth and lower latency.

The use of IP Microwave is likely to be balanced with more use of fibre in the transport network and combined optical multiplexing technologies which have the potential to cope with the new bandwidth and delay requirements of 5G.

5G is likely to stimulate the adoption of further new technologies that are being developed for access and backhaul networks to guarantee ultra-low latency and resilience to support the new services made possible by 5G.

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5G NSA & SA

In current 4G mobile networks the radio network works to the Evolved LTE standard and the core network is referred to as the 4G Evolved Packet Core (EPC). In pure 5G the equivalent standards will be 5G New Radio (NR) and a new 5G Core Network (5GCN). 5G Core Network (5GCN) is a new architecture that is being defined from scratch by 3GPP. As well as being able to serve 5G New Radio it introduces more flexibility, more open-ness and new protocols and will be able to operate as a software defined network. It will also make possible a unified authentication framework, unified subscription control, unified Quality of Service framework and charging and supports the creation of network slices.

However unlike previous generations that required that both access and core network to be of the same generation, with 5G it is possible to integrate elements of different generations in different configurations. This means that a 5GCN can support just a single radio network type - 5GNR or Evolved LTE and this is referred to as 'standalone'.

It is possible to combine multiple radio access technologies for example both 5GNR and Evolved LTE radio cells. This is referred to as 'non-standalone'. Clearly this could be an advantage where both 4G and 5G radio cells will be deployed.

There is a lot to consider within the detail of the new standards that will determine how networks are actually deployed.

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5G Standards

5G standards are being established by the 3rd Generation Partnership Project (3GPP) which unites seven telecommunications standard development organisations in order to produce the Reports and Specifications that define important standards for cellular communications. 5G for several years has been and remains at the heart of their work.

Vodafone works closely with the 3GPP and in 2016 played a role in bringing national operators together to avoid the establishment of different 5G "standards" resulting in an acceleration of the 3GPP 5G NR standardisation schedule.

The 3GPP finalised the first implementable specification of Non-Standalone (NSA) 5G New Radio (NR) operation in December 2017 in line with the accelerated plan thus giving the green light to mobile and network manufacturers to produce commercial equipment. Operators keen to deploy 5G will therefore be able to base their early deployments on the NSA specification

This standard completion is an essential milestone to enable cost-effective and full-scale development of 5G NR and will help the creation of vertical use cases. The 3GPP is not only working on 5G New Radio but also introducing improvements for 4G Evolution as part of the 5G framework.

Major 3GPP milestones

December 2017

- Non-Standalone New Radio (Release 15)

June 2018

- 5G: Standalone 5G New Radio and New Core (Release 15)
- 4G Evo: Further evolution (Release 15)

December 2018

- Further RAN – Core Network deployment options (Release 15).

December 2019

- Further evolution of 5G New Radio and 4G Evo (Release 16).

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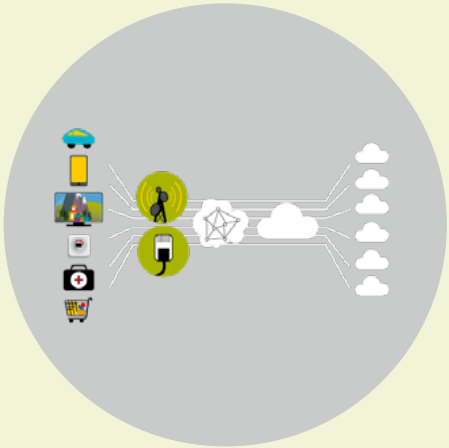

Network Slicing

5G makes it possible to offer specific services to different customers by providing virtual/logical “network slices” over the same physical network, giving them the performance characteristics they require such as guaranteed bandwidth or low latency in order to enable new services and new devices that are dependent on these characteristics.

For example, an autonomous car will rely on V2X (vehicle to anything) communication which requires low latency but not necessarily high throughput. A video streaming service watched while the car is in motion will require a high throughput and consistent latency in order to ensure an acceptable viewing experience. Both communications streams could be delivered over the same common physical network but on different virtual or logical network slices. This optimises the use of the physical network and provides the specific characteristics required by the application.

It is possible to deliver slicing capabilities that are enabled by the 4G Core Network (EPC). The 5G Core Network will be able to deliver a more scalable and flexible capability with enhancements to elasticity, automation, isolation and security. It will also be possible to dynamically create network slices to manage specific uses.

It is important to consider that the creation of an end to end network slice involves the radio, transport and core networks. To facilitate the creation and management of each network slice, new networking technologies are required including Software Defined Network (SDN), Network Function Virtualisation (NFV) and management via orchestration layers.

Network slicing is expected to play an important role in 5G networks because of the multitude of use cases and new services 5G will support. These new use cases and services will place different requirements on the network in terms of functionality, and their performance requirements will vary enormously.

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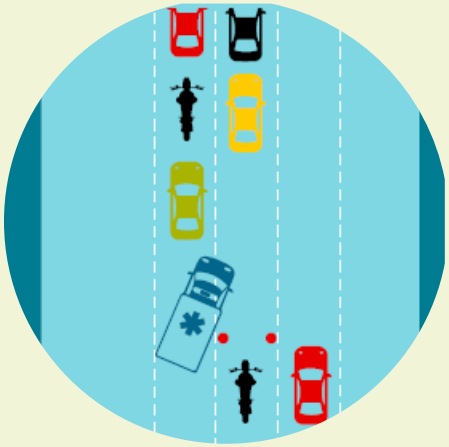

SDN

The introduction of Software Defined Networking (SDN) in the Transport Network will make it possible to move from a collection of multi-technology networks to a single transport network", where IP, Optical and IP Microwave networks will be all integrated and controlled by a new SDN controller.

This will allow the integration of different technologies from multiple vendors into a single end to end transport network. SDN in the transport network brings many benefits including intelligent and automatic transport connectivity provision, monitoring, performance, troubleshooting and network optimisation. It also automates many of the functions which are now done manually by operational staff. SDN will also facilitate the introduction of network slicing and new service categories required in roll out of transport network to support 5G.

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Massive MIMO

Multiple Input Multiple Output (MIMO) describes the function of an antenna that is capable of running multiple communications channels, massive MIMO as the name implies means that it it able to do this at scale. This technology is already available in 4G Evo and will evolve for use in 5G. In June 2017 we delivered the world's first Massive MIMO rollout in Madrid at the 2017 Pride event with 1 million+ people. Vodafone deployed 10 Massive MIMO base stations in central Madrid, which sustained coverage for the over 1 million attendees very successfully while at the same time gathering improvement opportunities which could then be applied to subsequent events. Vodafone also deployed Massive MIMO at the Sinan Erdem Dome in Istanbul for the Euroleague Basketball.

With Massive MIMO the way the signal is radiated is changed, providing multiple beams of signal, where each beam is assigned to a unique user or a group of users, allowing more effective communication, providing higher site capacity and less interference.

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Spectrum

More spectrum (frequency bands) and more bandwidth means more speed and more capacity!

In 5G, operators can get additional frequency bands on top of the ones currently available in 2G, 3G and 4G. The big difference on the frequency bands is the portion of bandwidth available in each frequency band.

The maximum carrier bandwidth in 5G is 100MHz while in 4G is 20MHz. Additionally carrier aggregation is possible and 5G and 4G spectrum can also be aggregated to get more speed and capacity.

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Radio Latency

Radio latency can be reduced from today ~12 ms to ~3ms in both 4G and 5G, thanks to the 4G short TTI or the equivalent non-slots 5G, that define the minimum time to transmit data in a system.

The lower the time, the lower the total latency. In 5G this lower latency could be available from the time services are launched and will improve with the deployment of additional 5G technologies in the network.

It is worth noting that low latency radio consumes more baseband on the network and in the user device which affects battery life – so low latency radio should be allocated to services that really need it.

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Network Latency

Latency will be reduced via Multi-Access Edge Computing (MEC) which basically means deploying the Service Application and the Core Network closer to the customer.

Low-latency support will be provided via a combination of virtualised Core Network locations Lean Technology Centres - (LTC) and specially built Edge Technology Centres (ETC) progressively deployed closer to customers over time to meet latency targets. It should be noted that this implicitly also eliminates the latency from travelling across the Internet.

For example, a user may be browsing through social media and come across some VR content that a friend has published. When the user puts on the VR headset to view the content, they will be anchored to a VR Service Application much closer to their location, e.g. in the same city, than the social media server over internet.

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IoT

Vodafone has already embarked on a worldwide rollout of NB-IoT.

NB-IoT and CAT-M were first introduced in 3GPP Release 13, and the same technologies were selected as the IoT solution for 5G, with improvements in data rates and low latency values in coming releases.

NB-IoT was created based on the cellular IoT concept in a development lead by Vodafone and is now the leading Low Power Wide Area (LPWA) technology globally. Vodafone worked with an ecosystem of technology providers to drive the standardisation of NB-IoT with 3GPP. The benefit of this approach is a single standard that the whole industry can work to, based on cellular technology rather than a fragmented and incompatible ecosystem of different technologies.

The ability of NB-IoT service on cellular to improve the penetration of coverage within deep indoor locations is important. One of the early spin-offs of the standardisation effort is the work that Vodafone is doing with chipset providers, to re-use the NB-IoT concept in a smartphone text-only messaging service, providing users with a fall back means of communicating in conditions of low battery or low coverage. With 5G, this service might be extended to include additional media. Vodafone is also engaged with some mobile equipment manufacturers in this area, using NB-IoT to help develop the connectivity specification for wearables, which has a very small battery and transmit power, generally only one antenna. It was added to the standard in 3GPP Release 14.

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