CODEX OF THE FUTURE SERIES

THE FUTURE OF THE CONNECTED WORLD

UNLIMITED THINKING . EXPONENTIAL POTENTIAL

BY MATTHEW GRIFFIN

311 Institute Global Advisory : Forecasting : Innovation : Strategy

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ABOUT THE AUTHOR

Matthew Griffin, an award winning futurist and author of the Codex of the Future series, is described as "The Adviser behind the Advisers" and a "Young Kurzweil." Matthew is the Founder of the 311 Institute, a global Futures and Deep Futures advisory, as well as the World Futures Forum and XPotential University, two philanthropic organisations whose mission it is to solve global inequality and the world's greatest challenges.

Regularly featured in the global media, including AP, BBC, CNBC, Discovery, Forbes, Netflix, RT, ViacomCBS, and WIRED, Matthew's ability to identify, track, and explain the impacts of hundreds of exponential emerging technologies and trends on global business, culture, and society, is unparalleled.

Recognised for the past six years as one of the world's foremost futurists, innovation, and strategy experts Matthew is an international advisor and speaker who helps many of the world's most respected brands, governments, investors, and institutions, explore, envision, build, and shape the future of global business, culture, and society.

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A LETTER FROM OUR FOUNDER

MATTHEW GRIFFIN

WE LIVE in extraordinary times, in a world where individuals, organisations, and technology can impact the lives of billions of people and change the world at a speed and scale that would have been unimaginable just twenty years ago.

We also live in a world full of challenges, and a world where all too often negative news gets amplified at the expense of good news, and where tales of hope, inspiration, and positivity get drowned out and lost in the noise. It's no wonder therefore that today more people are more anxious about the future than ever before. And, arguably, a society which believes it's marching towards the darkness, rather than the light, has a poorer future than one that doesn't. Hope, however, is all around us and it's our purpose to light the way so all of us, people and planet, can prosper.

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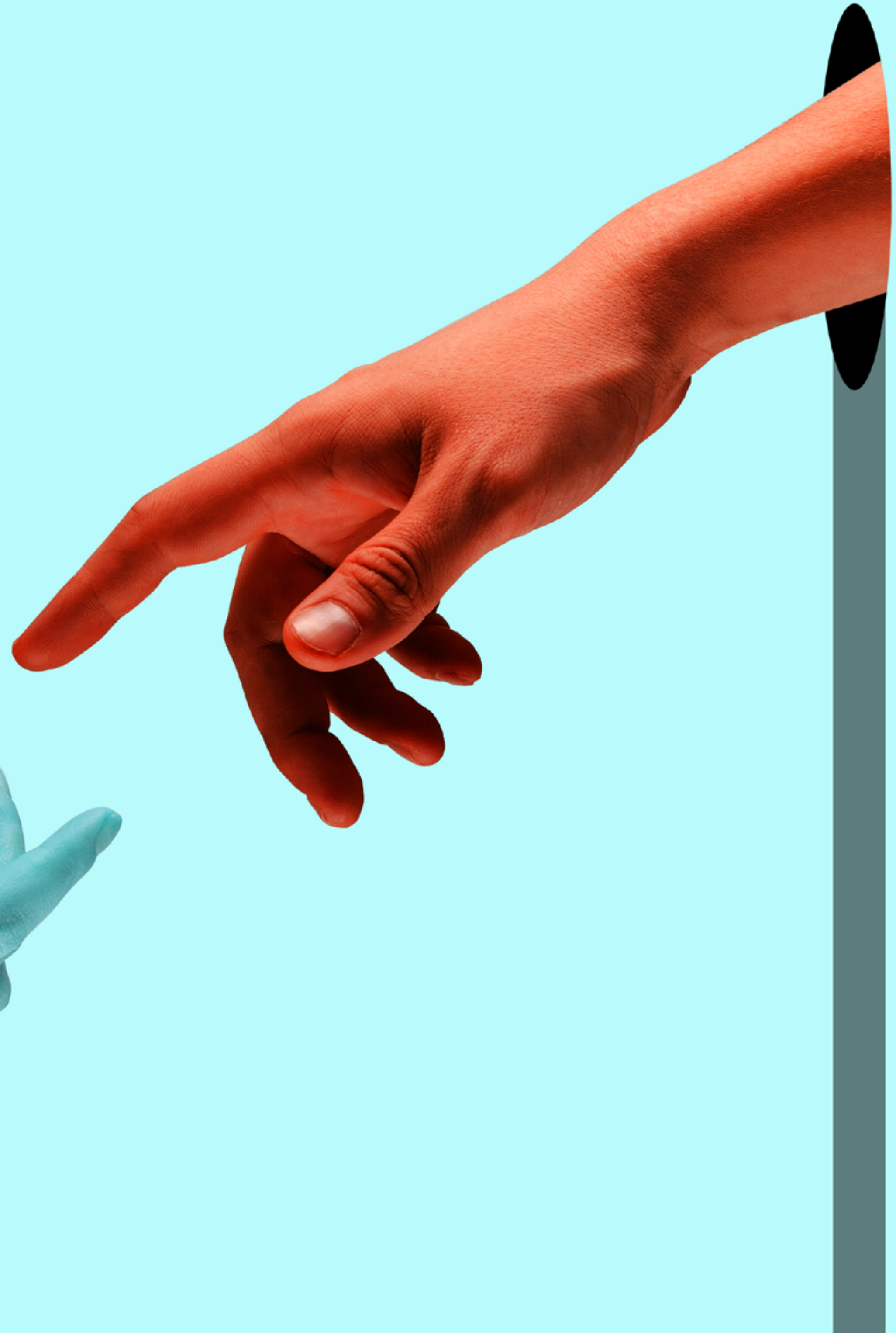
Leonardo DaVinci . 1491



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INTRODUCTION

AS HUMANS there's never been a time when we haven't lived in a connected world - whether it's the trees that connect with the Earth and the sky or ourselves who connect with one another and the bounty of things around us. Today though technology has evolved our concept of connectedness.

Not only has it changed how we connect with one another and what we can connect with, but it has also changed how we experience the world and our own potential. And by doing so it has ultimately changed every conceivable aspect of the Human Experience.

In this Codex I discuss the future of communications and the connected society, and explore their impact on global culture, industry, and society.

Explore More,

Matthew GRIFFIN
Founder

THE COGNITIVE 6G ERA

EVEN THOUGH 5G is still in the early stages of commercialisation governments and organisations everywhere are already looking to the future and what's next. And unsurprisingly that's 6G which will provide yet another revolutionary leap in mobile and wireless communications performance, and which could become the world's first truly "Cognitive" wireless technology.

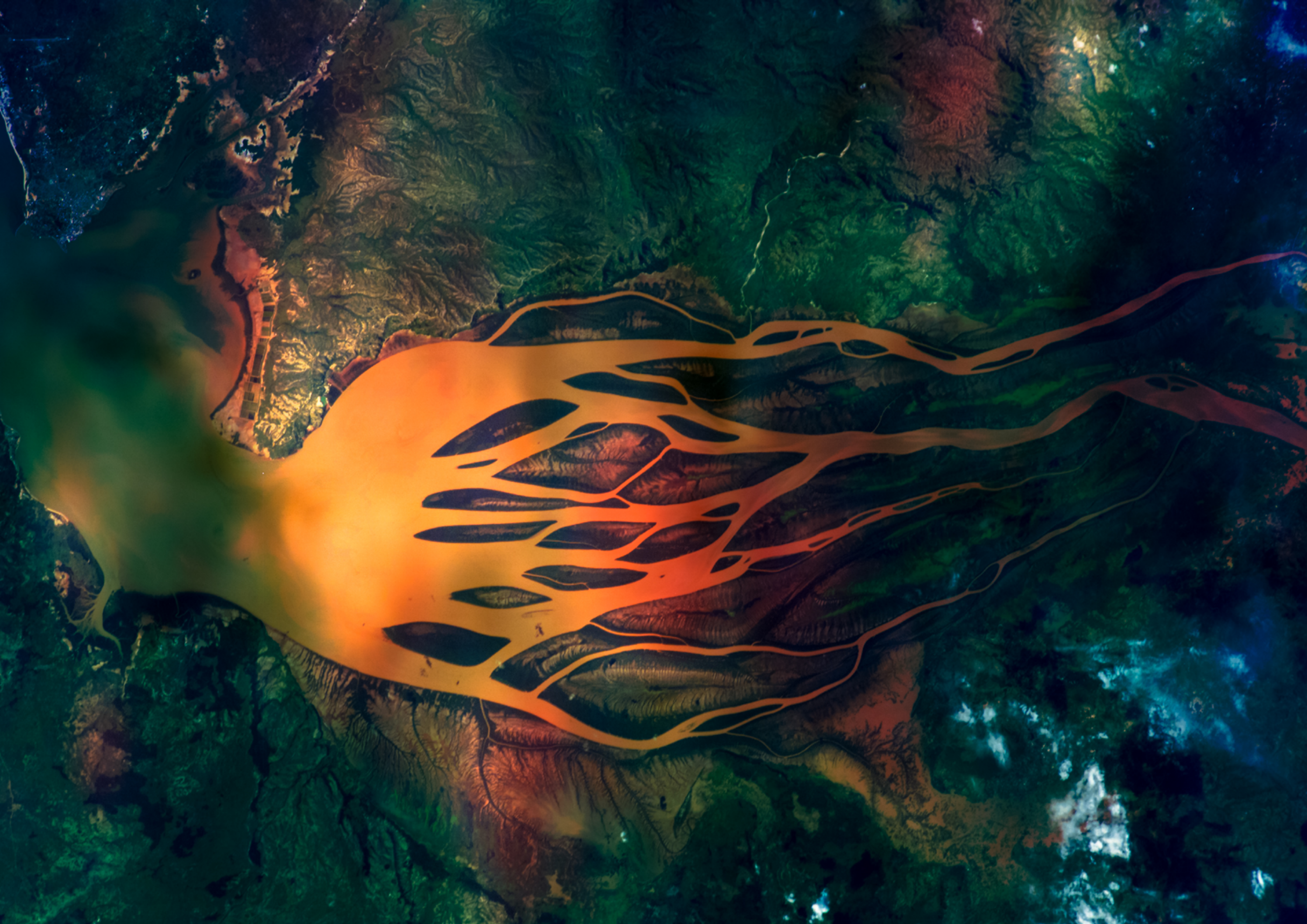
As is often the case with new wireless communications technologies most organisations believe that the global 6G deployment is already a given and are trying to carefully balance R&D programs, that build on their 4G, 5G, and eventually B5G experience, with the reality that we now live in a world increasingly dominated by new, exponential technologies. Any one of which could significantly impact 6G's future development and deployment.

Additionally, these exponential technologies could be the West's ultimate undoing when it comes to realising their ambition of global 6G dominance because whereas China's ruling party recently committed over $1.2tn to accelerate the development of many of these technologies, from Artificial Intelligence and quantum technologies, to materials and semiconductor technologies, the West mustered less than half that figure. Ironically, therefore, while the West could dominate in 6G thinking and thought leadership it's their lack of ambition elsewhere that could ultimately be their Achilles Heel.

Historically the time that it takes to develop and commercialise a new wireless communications technology has always taken around ten years which means that we should expect the completion of the 6G standard in 2028 with mass commercialisation emerging around 2030, and mass deployment, which in 6G's case could significantly benefit from new materials technologies, taking place in the five years after that.

Furthermore, where previous iterations of the wireless standards, such as 1G, 2G, 3G, and 4G, have mostly been used to relay what I'd refer to as traditional business and human generated traffic, 5G and then especially 6G will see Machine to Machine and machine generated traffic, as well as a number of entirely new applications, occupy a greater percentage of the overall service makeup.

More on these later ...



GREAT OPPORTUNITIES . GREATER CHALLENGES

TURNING 6G into a reality and meeting everyone's monumental expectations is, needless to say, going to be a monumental challenge. So, before I dive into other areas of the technology let's have a quick look at some of these challenges that have to be overcome before the technology can get off the ground:

Massive Connectivity

One of 6G's greatest benefits will be the number of devices it can connect and the speed at which it can do it, but developing a network system that is both massively scalable as well as massively performant is going to be a challenge. As a consequence researchers will need to take all the following, and more, into consideration:

High Throughput:

The mission critical systems, and their complimentary upstream and downstream ecosystems, that use 6G will not only rely on being able to concurrently connect potentially billions of devices, some of which will be moving throughout massive 3D space, but the network infrastructure, such as base stations, will also need to be able to handle the enormous volumes of traffic in real time and with minimal delay.

Real Time Communication:

Real time communication with effectively no, or minimal latency, is a crucial requirement for future 6G networks and, arguably, this is also its most attractive benefit especially when it comes to helping organisations bring to market applications including autonomous vehicles, and a variety of other futuristic applications.

Scalability:

Industrial IoT enthusiasts predict that billions, if not trillions, of devices will be connected and operated in "future industrial ecosystems" with the emergence of concepts such as massive Machine Type Communication (mMTC), so, needless to say it's going to be challenging to tailor the design of 6G systems for such an unprecedented traffic demands.

Synchronisation:

While managing to cope with all the above 6G networks will also need to be able to handle synchronisation at massive scale, and they will also need to be able to cope when, for whatever reason, synchronisation fails.

Security

Given all the geopolitical furore issues with the security of 5G networks we can expect that security will feature heavily in all 6G developments and conversations. Therefore, here are a few of the top of mind topics that researchers will have to solve before 6G earns the opportunity to be deployed:

Access and Authentication:

The data generated by all the communicating nodes within 6G networks, as well as the data that's in

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transit, will all need to rely on strong access control mechanisms to ensure the right users, both humans and machine systems, have the right access. Therefore, as a consequence of the massive data loads, it's expected that traditional centralised authentication systems, for example those that use base stations, could create significant bottlenecks, the upshot being that new access control methodologies will need to be developed.

Auditing:

While auditing will likely never be at the top of anyone's list of 6G topics to pay attention to the fact remains that organisations, for whatever reasons, will need to evaluate the compliance and the behaviours of the network so that they can flag problems and erroneous behaviours. But, needless to say, auditing such a massive number of components and tenants will be a significant challenge, especially when it comes to enforcing the security of the system.

Availability:

Always on service availability will be a major requirement in many future 6G applications, but the large volume of interconnected and inter-dependent devices and systems will expand the risk of both conventional and non-conventional DDOS attacks by orders of magnitude.

Confidentiality:

The threat surface of future computing infrastructure, devices, and sensing systems, including IoT, will be orders of magnitude larger than today's threat surfaces. As a consequence 6G networks and their compute resources will need to be able to accommodate and support a variety of both traditional and non-traditional encryption methodologies, including lightweight encryption and even Post-Quantum encryption, in order to ensure the highest levels of confidentiality and privacy.

Integrity:

Alot of the data generated and ingested by 6G networks and their ecosystems, which will be massive, will need to be accessed and modified by authorised users and systems when in flight. Therefore, being able to protect it, against eavesdropping and modification, for example, will become an even more complex task than is today.

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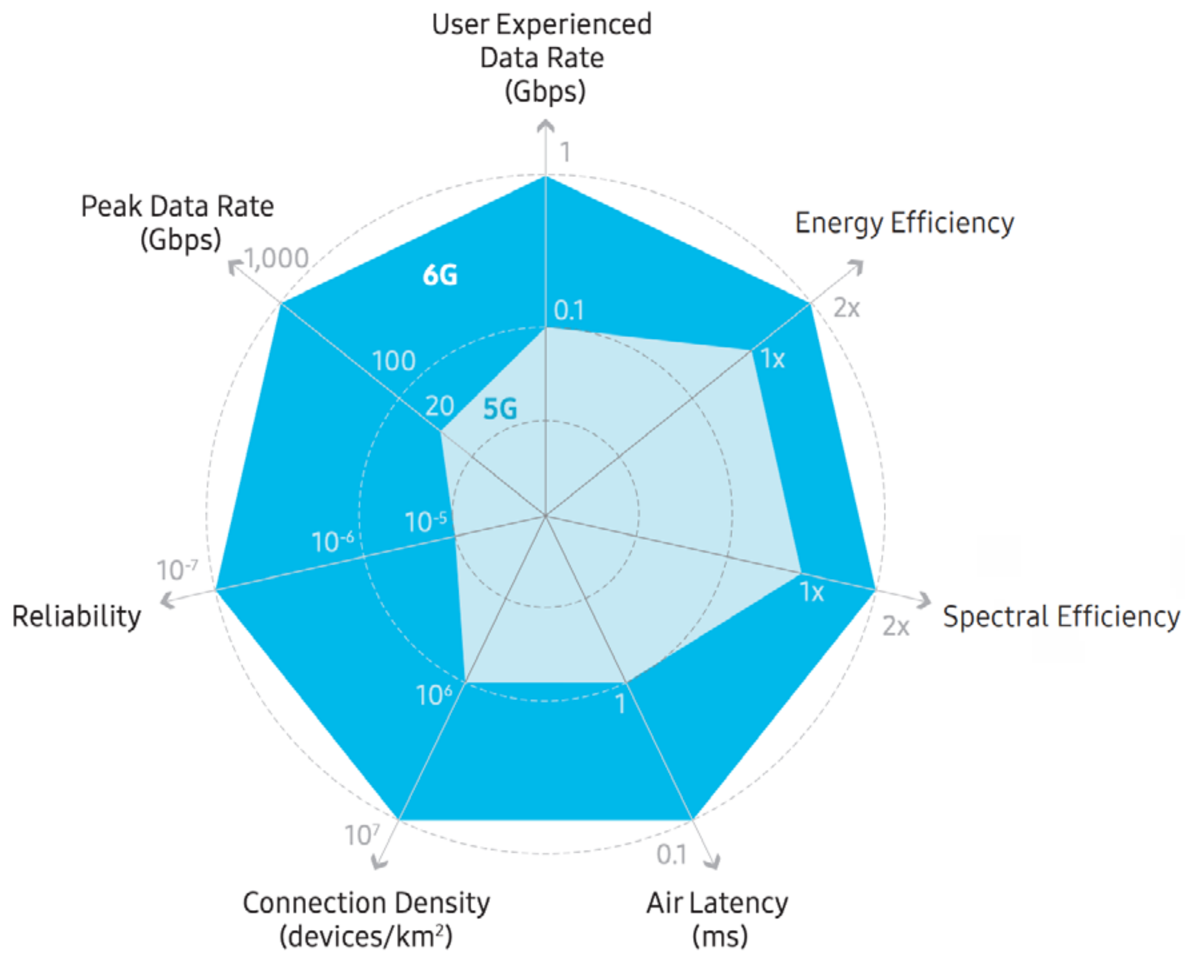


6G VERSUS 5G

Ever since the advent of 1G the subsequent generations of wireless communications technologies have made giant leaps in performance and scalability. And it's the same with 6G.

WITH GREAT SPEED COMES GREAT PAIN

Within the international community there are high expectations for 6G technology and this is born out by all of the preliminary roadmaps which, as you can see, show performance numbers that are not only orders of magnitude better than anything 5G has to offer, but orders of magnitude better than almost every other type of communications technology with the notable exception being fixed line communications, which we'll discuss later in this chapter, that are still orders of magnitude faster than 6G.

Inevitably as with all new wireless communications technologies people are going to focus on three key data points - speed, or the data rate, latency, and distance. And while two of these are impressive, one is most certainly not, and I'll bet you can already guess which ones I'm talking about.

SUPER FAST

From a speed and latency perspective 6G is going to score in the 1 to 2 Terabits per second range, with an average 1 Gbps data rate per user, and an impressive 0.1ms latency which, let's be frank, is so small it's literally real time. In fact both of these are so impressive that they open the door to some truly sci-fi like applications.

DEPLOYMENT HEADACHES

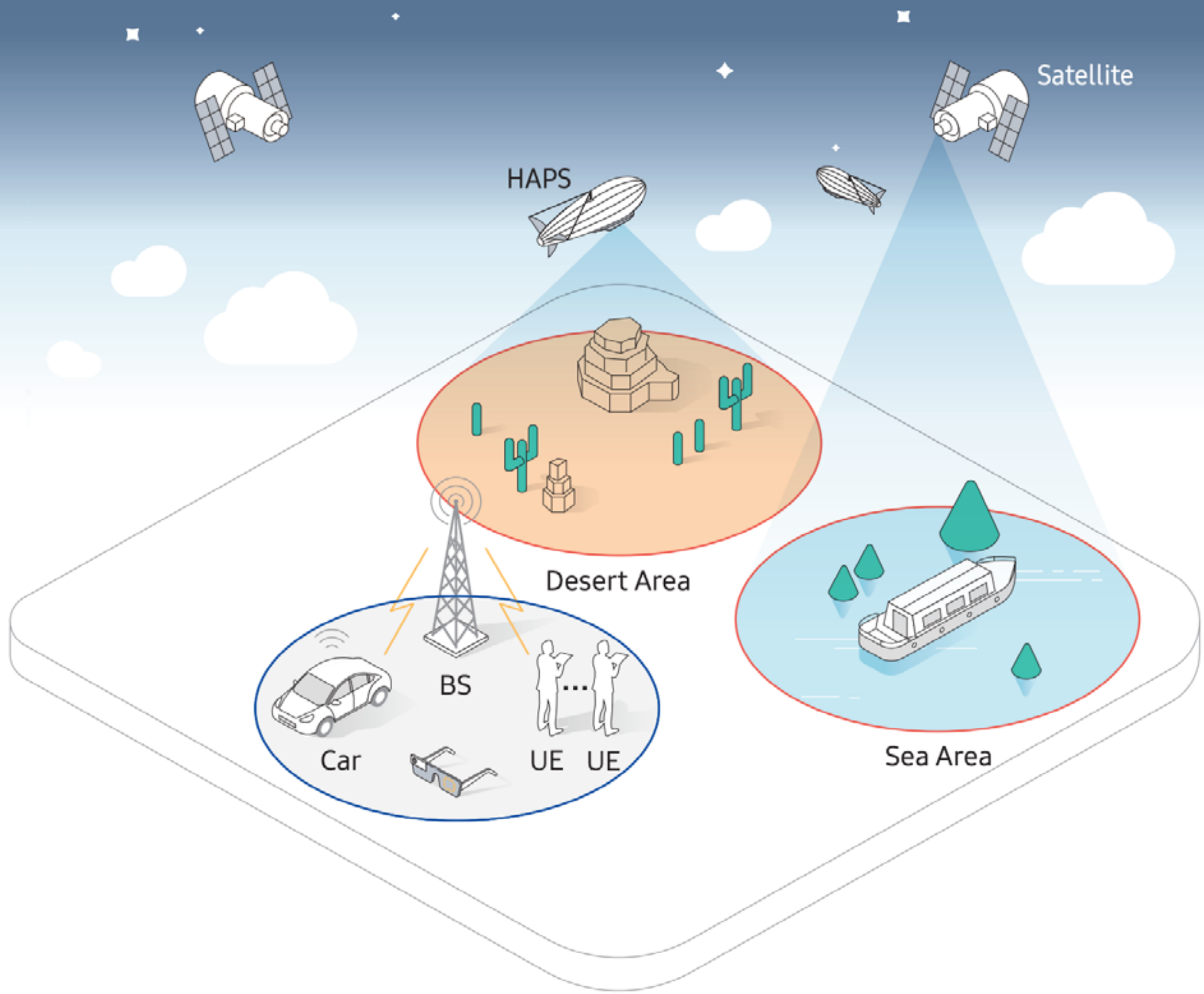
As for distance though, well, unlike 5G technology whose impressive stats are the result of millimetre wave technologies with 6G we're talking sub millimetre wave, and while a 5G signal can be blocked by a door, a wall, or even your hand, in 6G's case it's going to be worse - it'll get blocked by cardboard. And water vapour. And it goes without saying that that's a big issue.

In fact this latter point is such a problem that companies are going to have to devote a significant amount of time trying to resolve the question of how they deploy 6G, and while deploying it with urban environments will be an up hill struggle deploying it in rural areas cost effectively is almost going to be a non starter.

Fortunately though most 5G deployments were built with the future in mind so existing 5G infrastructure should be easily upgradable, via a software update, to 6G. But that won't solve the distance issue, and just to put the issue into perspective back in 2020 in order just to blanket one single stadium, the Miami Superbowl LIV Stadium, with native 5G coverage Verizon had to spend over $25 million. And no matter who you are that's no chump change, especially when you scale it up ...

The upshot of all this is, of course, that in order to overcome this challenge researchers are going to need to develop novel types of antenna systems, likely based on liquids, liquid crystals, or metamaterials, or nano-technologies that are capable of both sending and receiving which would allow them to operate as a MESH network.

However, irrespective of the type of technologies that underpin these systems there is almost no doubt that they will need to be able to be easily integrated with other terrestrial and non-terrestrial communications technologies such



CONNECTING THE WORLD

6G is literally the first wireless communications technology that is truly designed to connect the whole world, and every domain - Land, Sea, and Space. As a consequence 6G's standards are being designed so that all of the individual multi-domain components can be seamlessly integrated with one another for optimal performance and coverage.

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as GEO, LEO, and Quantum satellite constellations, airborne drone, HAPS, and UAV networks, as well as more traditional RF and optical networks.

In short 6G is going to be a game changer. But it's going to be expensive and painful to deploy - hence the train of thought that 6G will operate using a cell-less architecture. And all that's before conspiracy theorists start burning down the infrastructure and causing interruptions in service ... which then brings us neatly onto the next part of our story.

AND THEN THE REST

While the giant mobile networks will undoubtedly spend billions of dollars promoting the speed of their 6G networks elsewhere people are going to be digging into the other details. Details such as connection density, power consumption, reliability, security, and spectrum allocation and use.

Connection Density

6G will see a significant step up in the overall connection density and this will be no bad thing as we see an increasingly large number of smart devices being both developed and deployed during this time frame which will include, as we'll see later in this chapter, all manner of extraordinary applications. While 5G supports 10^6 devices per square kilometer, or a million, 6G will support more than 10^7, or ten million.

Localisation and Mobility Rates

Two of the statistics that don't often make it into the charts is a wireless communications standards Localisation and Mobility Rate, in other words the speed at which things can travel before the network can no longer effectively maintain the connection, and the precision with which they can be tracked.

And, as 6G becomes increasingly important in helping keep our world moving, literally, 6G will significantly improve on 5G's stats, increasing the precision accuracy from 10cm on a 2D plane to 1cm on a 3D plane that could extend up to 10km altitude, and pushing the speeds from 500km/h to an incredible 1,000km/h - both of which will have significant roles to play when we consider 6G's applications.

Power Consumption

Power consumption is likely to be a big talking point given the state of today's

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climate, and while 6G will likely be significantly more power efficient than 5G, which in turn was up to 90% more power efficient than 4G, the devil is going to be in the details. And based on the data available we can expect 6G's power consumption to be approximately 0.1kW for an active antenna unit, and 0.2kW for an average broadband unit.

However, when organisations cite power consumption values for wireless communications systems they often talk about the power consumption per traffic unit, or data bits per kilowatt, and while the eventual stats for 6G will look impressive the fact of the matter is that as more people transmit more data across these networks overall power consumption will only go one way - up. And no matter how the figures are spun there will always be people who are unhappy with that situation.

Power Distribution

While many people will be focusing on the overall power consumption of 6G networks it's unlikely that many of them will pay much attention to another, but very important 6G feature which looks like it will make its way into the final 6G standards - namely the ability to use 6G signals as a means to provide wireless power to a myriad of devices that include everything from IOT sensors to larger 6G components including antennae, base stations, and even to the smart devices and gadgets themselves.

While no standards have been confirmed yet given the expectations and applications of 6G this is definitely a space to pay close attention to.

Reliability

Given the increasingly connected nature of our world, and as the speed and latency of wireless communications systems improves, which in turn enables them to be used for more critical applications and workloads, reliability is going to play an increasingly crucial and important role.

However, while many people will undoubtedly focus on 6G applications such as autonomous transportation, or V2X, we also need to bear in mind that during the 6G time frame smart systems and devices will become both increasingly automated and autonomous, and while it will be important that they are connected there will be a number of occasions where they do not have to be connected every millisecond, second, minute, or even hour, and, in essence, are able to drop off the network without any negative consequences.

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This said though there will be a large number of occasions where guaranteed seamless service and continuity, or "never drop" continuity, is required, which will include less exotic applications as E-Sports and gaming, immersive experiences, live events, and more exotic applications such as telepathy, tele-operations, and tele-prescence - for starters.

Like the standards that came before it 6G will undoubtedly be designed to be as much of a general purpose technology as possible which will mean it will have to carry all manner of workloads. It will also be the first wireless communications technology to near the same levels of reliability as fixed line networks, improving upon 5G's 99.999% reliability and bringing about 99.99999% reliability.

Satellite Integration

When the 5G standard was being developed very few people were looking up to the stars, or even considering the possibility that future communications would be augmented or supplied via GEO and LEO satellite constellations like the ones we see from SpaceX or OneWeb. And yet, fast forwards ten years and here we are, not just looking up but using some of these services, the result of which means that, unlike 5G 6G will have full satellite integration, and that in itself will be an interesting challenge to solve.

Security

Just as we saw with 4G, but then much more so with 5G, security is going to be one of the 6G criteria which is at the top of the priority list as more countries realise the benefits and pitfalls associated with their increasingly digital economies, and the issues associated with multi-tenant platforms.

As a result it is almost inevitable that 6G standards will focus on both network layer and physical layer security, and that Artificial Intelligence, Blockchain, Encryption, and new secure hardware designs, will play an increasingly oversized roll in standards development.

It is also highly likely that quantum security technologies, such as QKD, and Quantum Secure Direct Communications, or QSDC, which can detect eavesdropping and enable direct communications, will also be incorporated into the standards, albeit that quantum technologies will still be relatively nascent.

6G USE CASES AND BUSINESS MODELS

NOW IT'S time to explore future 6G use cases - some of which will likely be familiar to you and others that won't be because they'll be pushing the boundaries of what's possible even with 2030's technology.

As the whole world races to deploy 5G it's fair to say that not only will 6G supercharge the common 5G services we'll all experience, but that it will also enable and make common place the services that push 5G's boundaries.

WE NEED NEW ACRONYMS

Today we are used to the phrases Quality of Experience (QOE) and Quality of Service (QOS), but as we finally realise 6G's ability to merge all three types of worlds - the Digital, Physical, and Virtual worlds - we could argue the need for a new KPI-based acronym: Quality of Physical Experience (QOPE).

6G will be the enabler of the so called Sensory Network, but as we see the continued adoption and development of Brain Machine Interfaces (BMI), haptics, smart clothing, and other wearable technologies, 6G will be the central technology that allows people to participate in fully immersive Cyber-Physical sensory experiences - as well as even Cyber-Neuro ones.

As a result, not only will developers need to develop stringent new safeguards, for example, that prevent hackers from weaponsing technologies that could literally be used to electrocute the people using them, but they will also need to consider the users overall QOPE.

Diving deeper into the wormhole I could also argue the need for two more acronyms: Quality of Neuro-Experience (QONE) and Quality of Sensory Experience (QOSE). But that's another story.

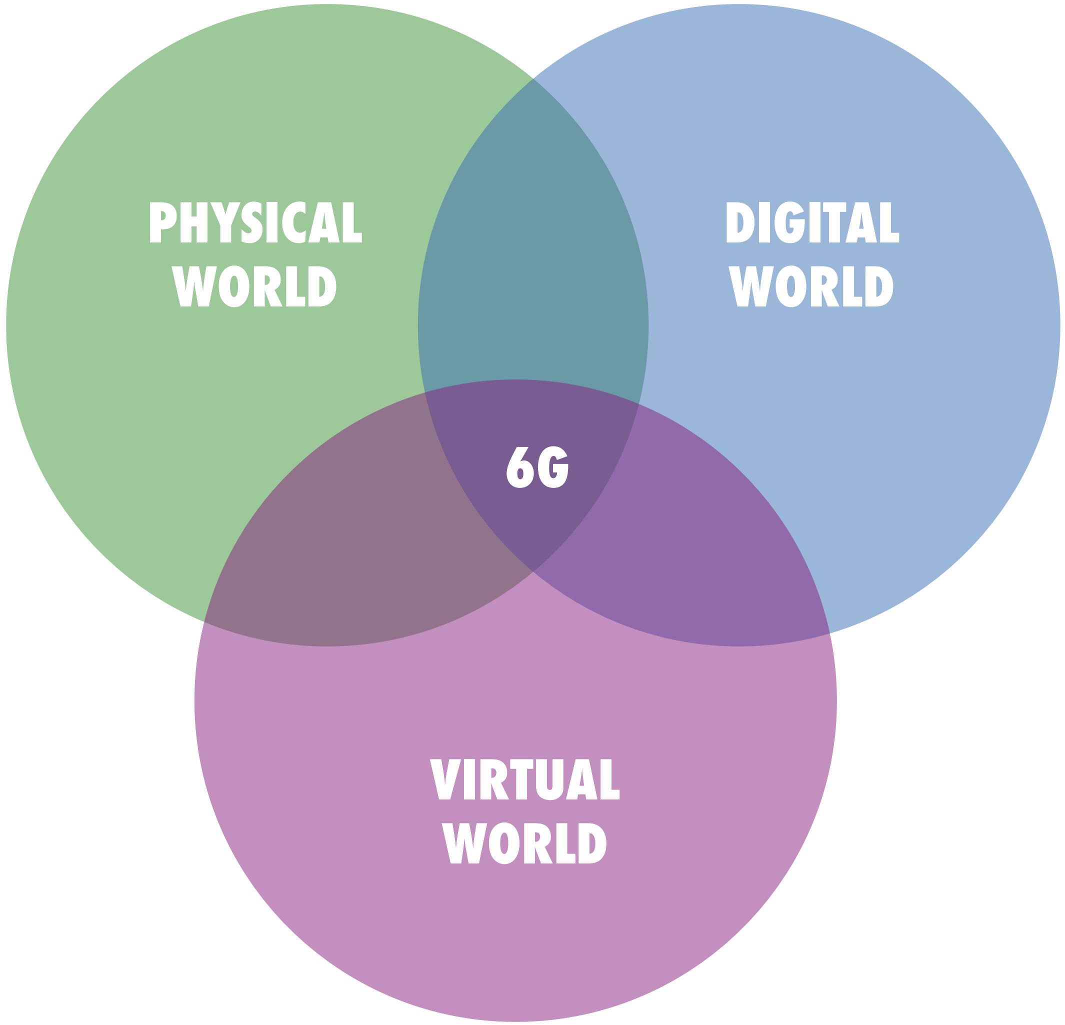
THE ODDITY OF INVERSE DATA GROWTH

When it comes to forecasting future 6G use cases the vast majority of people are going to look at 6G's density, latency, and peak performance specifications and work backwards. In other words they'll believe that the services with the greatest bandwidth demands that benefit from low latencies will be the primary beneficiaries of the technology.

However, while this is a good general rule to abide by it doesn't take into account the impact that Artificial Intelligence (AI), codecs, or new edge compute and system architectures, and rendering technologies will have on future bandwidth requirements.

Traditionally we are led to believe that higher resolution next generation imagery, for example, consumes more bandwidth than the previous generation - that 8K video, for example, should consume more bandwidth per stream than 4K. And so on. But since the launch of 4G, and even 5G, we have developed new and increasingly powerful technologies that to some degree flip that paradigm on its head.

As we continue to see giant leaps in the development of Adaptive Codecs and other technologies including Deep Learning generated compression



UNIFYING WORLDS

By the 6G timeframe there will have been significant technological developments across a multitude of areas, from Artificial Intelligence and Sensors, to displays and materials, and beyond. As a result we will see capabilities that target each of the three worlds mature and 6G and its ecosystem of products and services will be the technology that finally manages to merge them all into a single seamless experience.

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algorithms, as well as Foveated Rendering, and as we increasingly see AI embedded in "cognitive" devices that use Generative Adversarial Network (GAN) technologies to reconstruct images natively on the devices, we're increasingly seeing that we can push higher resolution content to the edge using up to 80 percent less data. And needless to say if those data streams are smaller then their bandwidth requirements are smaller too.

All these developments, therefore, have a significant impact when it comes to trying to predict which future use cases 6G will be uniquely positioned to support and the their timing.

To illustrate this point let's look at streaming video - a popular bandwidth hog. If, for example, we can reduce the amount of bandwidth it takes to deliver UHD, 4K, or even 8K content to a Virtual Reality device by up to 80 percent - whether it's a headset or a pair of glasses - then all of a sudden that use case could be viable in the 5G or B5G time frame rather than it having to wait until 6G arrives. In short, new technologies like those mentioned above could bring the timeline of this particular use case forwards by between 5 to 8 years - which is a significant change.

So, while data growth rates will inevitably continue their exponential spiral upwards as you can see when it comes to the amount of data being streamed we'll be living in the odd world of inverse data growth.

THE INTERNET OF EVERYTHING

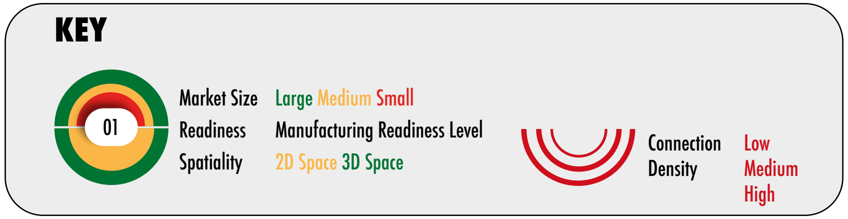
While many organisations still refer to the Internet of Things (IOT) I feel that from a futurists perspective the Internet of Everything (IOE) is a much better catch all.

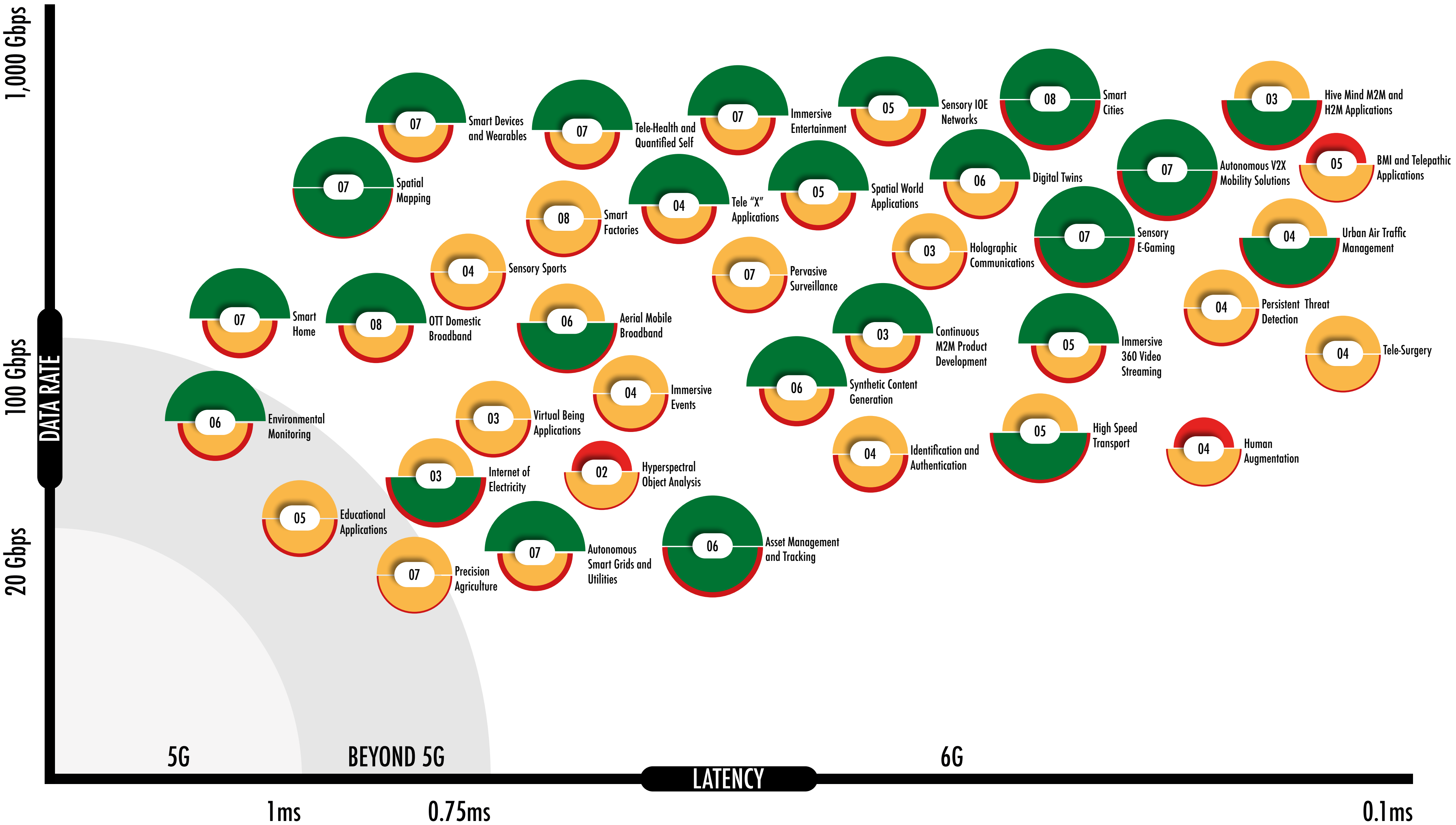
In the 5G era we very much lived in era of IOT and the era of the Internet of Slightly Smart Things. And no, I won't bother putting that into an acronym. By the time 6G arrives though those slightly smart things will be cognitively smart, and Sensor Fusion technologies, that aggregate and intelligently analyse sensor information at the edge of the network, will be a much more established.

In time though all technologies improve in both Cost-Performance and miniaturise, and during the early 6G timeframe many of today's bleeding edge technology innovations, which are displayed in the Emerging Technology Starburst at the start of this Codex, will start commercialising - technologies including BMI, quantum technologies, and nano-

6G USE CASES

As a General Purpose Technology 6G will be a significant technology multiplier in a world full of powerful complimentary exponential technologies. When combined these technologies will enable sci-fi like use cases that revolutionise every corner of our society.





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scale compute, energy, electronics, and sensor systems, as well as more obscure technologies such as Synthetic Biology.

When these, and other technologies, do start commercialising not only will 6G be the connective tissue that binds together traditional IOE systems, but it will also be the technology that binds together the Internet of Nano-Things (IONT) as well as the Internet of Neuro-Things (IONeT). And that's just for starters ...

BUSINESS MODEL INNOVATION

The emergence of 6G will also have a disruptive impact on current industry business models, most of which are not only unfit for the 6G era, but more importantly just won't work.

The current notion of a "network" has evolved from a very precise sense of ownership. The "operator" has traditionally owned the physical communication links, the service infrastructure, and the customer relationships. In the last twenty years though this model has been increasingly challenged and transformed by the emergence of Virtual Network Operators (VNOs), infrastructure sharing partnerships, and the trend of divesting network assets to specialised infrastructure operators, such as data center and tower operators – all of which are examples of how this "one owner rules all" model has been changing.

Nevertheless, the prevalent Operations, Administration and Maintenance (OAM) model still retains the "ownership," and most of the above concepts are seen as Service-Equipment contracts that just clarify the degree of ownership of an asset.

This is not a trend that can be expanded towards beyond 5G networks though, let alone 6G because most of the end-to-end connections will go through a multitude of players who won't be bound by static service level contracts, but will need to cross a rich ecosystem of dynamic technical, and economical, relationships.

While we often think in terms of plain connectivity, or mostly in terms of the data plane, the real challenges will come to the control and management aspects of a communication service. This significant disruption in the communication industry's business models and the relationships between the different stakeholders will be principally introduced via network virtualisation, which also includes network slicing.

The network virtualisation model, enabled by ETSI, the European standards body, Network Functions

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Virtualisation (NFV), and Management and Orchestration (MANO), defines no business actors. Using this approach, it is, however, easy to identify the role of the Infrastructure Operators (IO), for example, the owner, and the Network Operator (NO) who operate the network in order to manage the lifecycle of runtime operations of MANO Network Service Instances (NSIs), for example, the network slices. MANO NSIs are based on templates that can be provided by a Network Service Template Provider (NSTP), typically a software company. The templates are built using virtual network functions (VNFs) that can be provided by VNF providers.

In light of this, 6G will facilitate a new breed of micro-operators. Private wireless communications and networking will accelerate with 6G. A hierarchical shift is occurring in the industry in which traditional carriers and MVNOs are no longer the sole providers of wireless services. This trend will accelerate with 6G as business customers such as enterprises, industry, and government, will increasingly become service providers for themselves and will extend communications services to others within their supply chains.

Localised 6G networks will be mesh based with peer to peer signalling within each trusted network. Neutral host provider solutions will extend beyond the radio network to include the core and transport. Neutral hosts will tie together networks of networks within supply chains. Traditional carriers will tie together neutral hosts as well as the global WAN as a whole. As neutral hosts expand solutions to include core networking, the service based architecture approach will extend to micro-operators, allowing them to take advantage of key capabilities that started with 5G and will become even more important in 6G networks such as network slicing.

Hyper-localised micro-services will demand user specific, use case specific, and QOE and QOS specific network slices on a per application and service delivery instance basis. Business models involving micro-operators and micro-services will rely upon a fully cloud native network, including virtualised infrastructure and programmable service realisation and delivery frameworks. There will be a need to identify business interfaces for provisioning, administration, and other OSS functions.

These interfaces will include both traditional APIs for Man-to-Machine programmability as well as Machine-to-Machine interfaces for support of AI based autonomous network management. The autonomous

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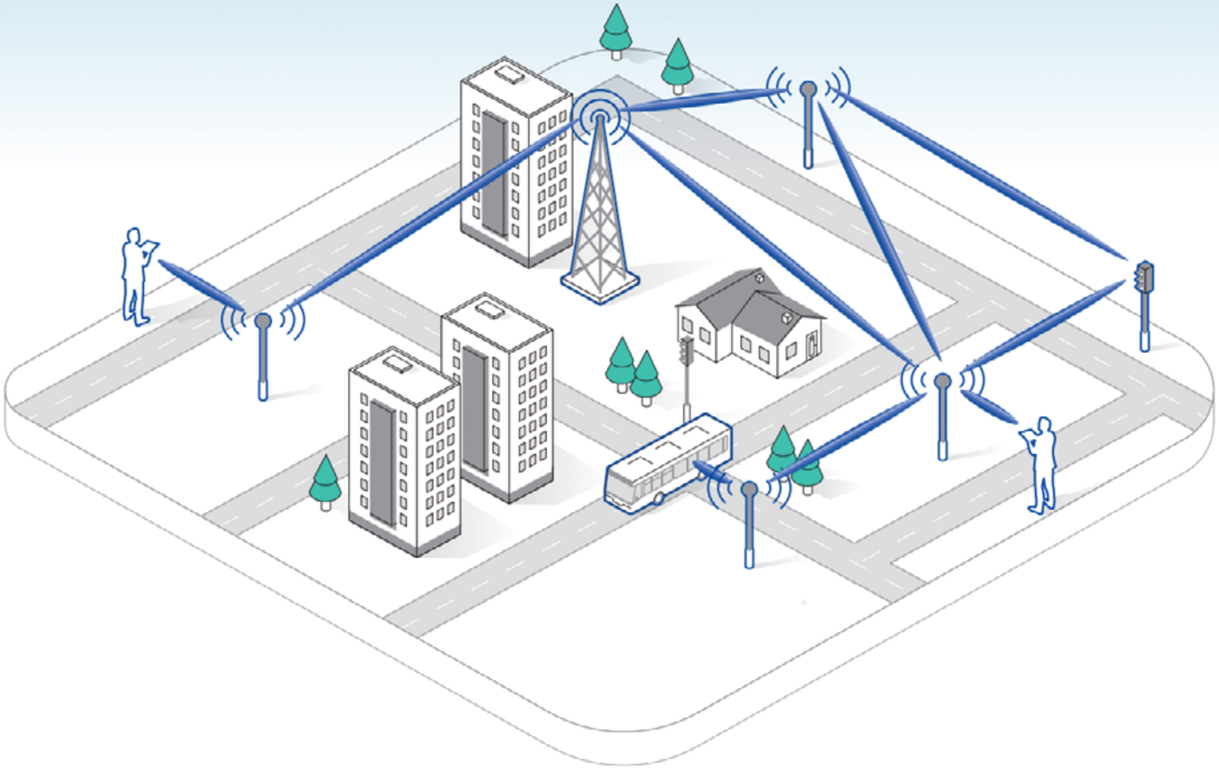
management is a key feature for micro-networks as they are not managed by MNOs. In some cases, their management can be delegated to MNOs or third parties that offer network management as a service.



SOLVING THE COVERAGE ISSUE

The nature of 6G's THz band spectrum will mean that 6G will be able to offer incredibly fast speeds. But that comes at the cost of transmission distance. To solve this coverage issue organisations will need to re-consider not just the design of base station components but also how all these components they can wirelessly integrate with one another to extend coverage.

ENABLING TECHNOLOGIES

WHEN DIVING deeper into the factors that will fuel the future development, deployment, and use of 6G we need to examine not one but two areas. Firstly, we need to examine the available technologies and their usefulness, and secondly we need to map those technologies against the standards development timeline.

After all, bearing in mind we expect the first commercial 6G deployments to emerge in 2030 we have to expect that the first generation of standards, which will need to be solidified by 2028 at the very latest, will be based on commercially available technologies from the 2025's.

This fact alone, for example, means that for the first generation of 6G we can rule in the appearance of Narrow AI in the standards, but rule out the use of Quantum AI until later on.

Then, moving on to the technologies themselves we can split them into two categories - General Purpose Technologies, which can drive innovation across multiple applications, sectors, and technologies, and other technologies which will only drive innovation in specific or niche areas.

ANTENNA TECHNOLOGIES

Developing new transceiver and antenna designs for 5G was challenging because of the need to design and manufacture millimetre wave components. And developing new transceivers and antenna for 6G, bearing in mind that 6G will also be expected to be able to incorporate cell-free MIMO services and be able to operate a cell-less architecture, is going to be orders of magnitude harder again.

Not only is this because of 6G's high frequency THz and holographic beam forming requirements, but it's also in part because of the increased challenges associated with signal distance, and higher Signal to Interference and Noise Ratios (SINR).

Then, to complicate matters further, there's the issue of trying to develop transceiver and antenna systems that meet all of the required cost, power, size, and weight requirements - for all parts of the network ecosystem.

As a consequence many ideas are being floated at the moment, including the development of fluidic, liquid crystal, metamaterial, and nanoscale, components, as well as smart, connected materials that can be spray painted onto surfaces. However, while there have been a number of interesting developments in the field, as we saw with 5G it is likely that this will be one of the last to be solved.

In addition to developing new systems though researchers are also going to have to fundamentally rethink how these systems are deployed, how they integrate and connect with the rest of the network, and how they're powered. And that is will be highly reliant on mew materials breakthroughs, which I'll discuss in the following segments.

From a deployment perspective traditionally cellular base stations have always been deployed in fixed locations and connected to fixed wireline backhaul and fronthaul networks. But,

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adopting this static network methodology and topology strategy in the 6G era will make it incredibly difficult and costly to deploy base stations that can accommodate the expected increase in data traffic, or fill the inevitable holes in coverage.
Also, while it's easy just to focus on base stations we also need be remember that in the 6G era the so called "Sensorisation" of the planet will force us to embed transceiver and antenna into sensors at the edges of the networks as well.

Suffice to say not only are these sensors going to be very small, with very small power requirements, likely in the sub 10nW range, but it's also going to be impractical to power them either with batteries or any other form of traditional direct power source. As a consequence the simplest way to power them will be to enable them to harvest energy from the environment around them, whether that's by incorporating backscatter-like energy systems and energy harvesting materials, such as nanophotonic materials, that generate energy from everything from 5G signals and light, to radiation and traditional RF, or other similar sources.

Therefore, while we do need new "novel" antenna technologies we also need to re-consider how we build the network. So, as we look ahead to 6G it will be increasingly important that base stations and other fixed assets can connect wirelessly to other network components, such as existing 4G systems, as well as 5G Integrated Access and Backhaul (IAB) systems. Furthermore, many researchers have shown support for the concept of Group Mobility, also known as a Mobile Relay or Mobile Base Stations, that can support mobile devices that are moving as a group – such as on an aircraft, bus, or train. The hope then is that by using a combination of new technologies and new deployment methodologies 6G won't run into some of the problems faced by 5G.

ARTIFICIAL INTELLIGENCE

There is no doubt that Artificial Intelligence (AI) will play not just a central role in 6G, but an enabling one, with this latter point being the most crucial, because, as powerful and as capable as all the other enabling technologies are they're all going to be playing second fiddle to AI.

Furthermore, as we see the emergence of new types of AI as well as new AI training techniques emerge during this time frame, for example Evolutionary or Open Ended AI that solves new problems in new ways, and Zero Shot Learning that allows AI's to "learn without data"

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to "make their own knowledge," there are inevitably going to be some surprises down the road that 6G researchers are going to have to content with.

And all that's before we discuss the emergence of Quantum Artificial Intelligence (QAI), including new QAI Machine Learning and Deep Learning models, and their potential impact.

Unlike some of the other technologies I'll discuss in this section AI will be embedded into the entire 6G stack, and this will include: the Intelligent Sensing Layer, the Big Data and Analytics Layer, the Intelligent Control Layer, and finally the Smart Application Layer.

It is also important, however, to bear in mind that the AI technologies, techniques, and tools, which will enable future 6G networks will likely be based on AI technologies that are commercially available or maturing in the 2025 timeframe.

Given AI's rapid rate of development, from Zero-Shot learning AI's which are able to learn and make their own decisions without having to be trained on data first, as well as edge, evolving, general, open ended, and shallow AI's, which all have their own pros and cons, this is going to be a very interesting space to watch.

Intelligent Sensing Layer

Generally, sensing and detection will be some of the most technologically primitive tasks in 6G networks which will be able to use Artificial Intelligence to dynamically and intelligently analyse and collect data from physical environments via an increasingly enormous number of systems, including cameras, drones, sensors, smartphones, wearables, and vehicles.

In this scenario AI will allow 6G networks to make decisions based on enormous quantities of dynamic and diverse data that they gather via direct interfaces with the physical environment which, in turn, will benefit a number of different key areas including environment monitoring, interference and intrusion detection, radio frequency identification and usage, spectrum optimisation and sensing, and so on.

It is also worth noting that highly accurate sensing, real-time sensing, and robust sensing capabilities will also be of great benefit in these networks - especially since they'll undoubtedly need to support ultra-high reliability and ultra-low latency applications of all kinds.

Furthermore, the dynamic and highly mobile 3D, or "Multi-Domain and Multi-Space" nature of many of these

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applications will also lead to what's known as Spectrum Characteristic Uncertainty (SCU), where the network has to adapt and react to whatever gets thrown at it, and this too will benefit from the above.

Big Data and Analytics Layer

It's the role of this layer to process and analyse the enormous amounts of raw data that's being detected and sensed by 6G networks and generate insights which, in turn, can be used by the different components of the network to generate corresponding actions.

The massive amounts of data that's collected, which could end up being exascale in the long run rather than just petascale, will be heterogeneous, non-linear, and highly dimensional, so Artificial Intelligence (AI), analytics, and data mining will all play a crucial role.

However, the huge volumes of data present will be costly to transmit and store in dense networks so it's absolutely necessary that future AI models are able to reduce the data dimension, filter it, and where feasible process it at the edge of the network or in the most resource efficient way. AI based data mining, such as PCA and ISOMAP, will likely be two common AI algorithms that can help 6G networks transform higher-dimensional data into a lower-dimensional data which, again, in turn, will dramatically decrease the computing time, storage space and overall model complexity. AI gives us an excellent opportunity to understand the essential characteristics of 6G wireless networks like never before and gain an in-depth knowledge of their behaviour which, bearing in mind these networks will not just be both automated and autonomous, will be crucial especially with regards to architecture slicing, cloud computing resources, protocol adaptation, resource management, signal processing, and so on.

For example, based on the "discovered knowledge" ISAGUN will be able to efficiently understand the mobility patterns of UAVs in the sky, establish the channel path loss model of satellite ground links, and then predict the device behaviour in ground networks - and that's just one data stream among billions or even trillions.

Intelligent Control Layer

Briefly, the Intelligent Control Layer mainly consists of AI based, rather than computation based, automated and autonomous decision making, learning, and optimisation, and it will use

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information from the lower layers of the 6G architectural stack to enable agents, such as devices and base stations, to independently and intelligently decide, learn, and optimise their own actions, actions that can include everything from network association, power control, and routing, through to spectrum access and supporting diverse range of different services.

In order to realise best these benefits though every agent in the stack would need to have its own AI brain and be capable of both independent learning and decision making - something that would then let them all improve and optimise their behaviours and thereby adapt and improve the services they offer across the entire stack - from the edge computing services, right through to independent heterogeneous network configuration and design, network slicing, spectrum allocation, Integrated Space-Air-Ground-Underwater Network (ISAGUN) routing, and overall resource management.

Intelligence will be the byword of 6G networks and it will allow them to be self-configuring, self-optimising, self-organising, and self-healing - all of which will dramatically improve the networks overall coverage, connectivity, Quality of Experience (QOE), and Quality of Service (QOS).

It will also significantly improve their ability to cram more data into the same amount of spectrum in an energy efficient way, especially when it comes to beam forming and eliminating RF anomalies, and finally, but certainly not least, it will significantly improve the performance of Massive Multiple-Input Multiple-Output, or MMIMO, applications that rely on both mmWave and THz transmissions.

Smart Application Layer

The main responsibility of this layer will be delivering application specific services to the devices, people, and the machines who need it – whatever they are, wherever they are, and whatever the services are – and then analysing the quality of those services and making the necessary real-time adjustments to ensure high levels of QOE and QOS.

This breaks down thus: Firstly, the activities of smart devices, infrastructure, and terminals in 6G networks will be managed by the smart application layer via AI techniques that help the network self-organise. And, secondly, the layer will be responsible for evaluating service performance including factors such as data quality, QOE, and QOS, and will also be responsible for intelligently managing the networks Cost-Performance, in terms of resource

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efficiency, including computational efficiency, energy efficiency, spectrum utilisation efficiency, and storage efficiency.
Additionally, and needless to say, AI based programming and management will also be required to support the various high-level smart applications, such as automated services, smart city, smart grid, smart health, smart industry, smart transportation, and all manner of other "smart" services found in this layer.

BLOCKCHAIN

6G networks performance characteristics will all be multiples better than previous generations – all of which will be necessary to meet the requirements of both existing 5G services, which in time will scale up massively, and new services that are made possible by 6G's latency, speed, and reliability, and its ubiquitous connection for the Internet of Everything (IoE). Add into this the huge and varied data volumes, auditing, security, as well as the demands of access fairness, collaboration and co-operation, geo-location, resource scarcity and management, time sensitivity, and transparency, and all of a sudden you have a significant challenge – one that blockchain is arguably perfectly positioned to solve in a low cost, secure, and smart way.

Furthermore, by integrating blockchain with AI and Deep Reinforcement Learning techniques it's possible to improve 6G's QOS, and hence QOE, and allow the smart sharing of resources, improve caching regimes, and ultimately make the network inherently more flexible, performant, and stable.

OPTICAL TECHNOLOGIES

In recent years Optical Wireless Communication (OWC) technologies have attracted extensive research interest because of some of their outstanding features which naturally lend themselves to a multitude of 6G scenarios. Therefore, it's only natural that as a result they've become viewed as an increasingly favourable complementary technology to Radio Frequency (RF) based wireless technologies to help enable and support 6G. It's thought that OWC features such as high data rates, high security, low cost, low energy consumption, low latency, and wide spectrum, will all help address some of 6G's future demands.

Plus, asides from these the Internet of Everything (IoE) and the Tactile Internet, for which 6G will be a key enabler, will undoubtedly usher in the development of a multitude of futuristic real time cultural, industrial, and societal applications. And, in this world of massive device

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connectivity, OWC technologies can play an integral role in everything from network monitoring and resource sharing to sensing, while at the same time meeting 6G's high security, low latency, and low power consumption requirements.

The four main OWC technologies under consideration include Free Space Optics (FSO), Light Fidelity (LiFi), Optical Camera Communication (OCC), and Visible Light Communication (VLC), and in terms of infrastructure, all of these have differences in the type of transmitter, receiver, and communication media.

VLC, for example, uses Light-Emitting Diodes (LEDs) or Laser Diodes (LDs) as transmitters and Photodetectors (PDs) as receivers, and only uses visible light as the communication medium.
LiFi is similar to WiFi technology, providing high speed wireless connectivity along with illumination, and uses LEDs or defuse LDs as transmitters and PDs as receivers. It also uses VL for the forward path and Infrared (IR) as the communication medium for the return path. However, it can also use VL as the communication medium for the return path, but the receiver devices in most user equipment, such as smartphones, aren't equipped with high power LEDs which, consequently, means that the uplink communication in the VLC and the LiFi don't perform well. Moreover, they also cannot perform well in return path if the uplink is a diffused light and faces serious interference affected by the downlink lights.

OCC, meanwhile, uses LED arrays or light as a transmitter and a camera or image sensor as a receiver. The built in complementary Metal-Oxide Semiconductor cameras facilitate the ability to capture photos and videos. The camera can be either global shutter or rolling shutter type, and OCC normally uses VL or IR as the communication medium. However, ultraviolet (UV) spectrum can also be used as the communication medium.

FSO technology, lastly, usually uses LD and PD as the transmitter and the receiver, respectively. However, Heterodyne Optical Detection Receivers are also used in FSO communication, which can normally be operated using the IR as the communication medium but can also be operated using VL and UV. While all these various OWC technologies have their pros and cons their future use in 6G networks will rely on their ability to overcome a number of different challenges that include challenges associated with atmospheric loss, flickering, frequent handovers, FSO backhaul bottlenecks, inter-cell

> **"Smart connected spray on materials that can be easily applied to any surface will accelerate 6G deployments."**

interference, limited uplink speeds, and low data rates in some instances.

All this said though there is hope within the OWC community that Artificial Intelligence (AI) will be able to overcome or mitigate some of these limitations, especially when it comes to OWC applications such as Connected Home, indoor robotics applications, Smart Healthcare, and OWC data mining – the latter of which could significantly improve the performance of ultra-dense 6G OWC networks in the areas of correlation, data rates, flow prediction, network traffic management, ranking, spatial and temporal analysis, and more.

QUANTUM TECHNOLOGIES

While there is no denying that quantum technologies of all kinds, whether it's Quantum Artificial Intelligence (QAI), that I discussed briefly above, communications, computing, encryption, sensors, and all manner of other associated quantum technologies, represent a step change in technology capability, it might very well be the case that when it comes to 6G the majority of them simply aren't commercially viable or mature enough to be included in the first iterations of the 6G standards.

Hence, while some quantum technologies, such as Quantum Key Distribution (QKD), and Quantum Secure Direct Communications (QSDC) may, and in fact are highly likely to, make an appearance in 6G networks at some point in time, it's much more likely that overall quantum technologies will play a greater role in future wireless network standards such as 7G.

MATERIALS

It could very easily be argued that many of the world's aspirations for 6G networks will lie on our ability to design and manufacture cost effective new materials, that range from the outright exotic to the novel, as well as everything in between, that can be easily manufactured at deployed at scale.

So, to overcome some of 6G's inherent challenges today researchers around the world are busy designing, prototyping, and testing all manner of new, smart and energy sustainable materials in the pursuit of developing new classes of Reconfigurable Intelligent Surfaces (RIS), that include everything from diode based antennas to graphene and metamaterials, which could be used to coat or even spray paint objects in the environment, from ceilings to mirrors to walls, and which would allow those surfaces to operate as reconfigurable

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reflectors or transceivers for massive 6G access when equipped with embedded active Radio Frequency (RF) elements.

By using this approach, which has the advantage of turning any dumb or legacy asset or surface, from highway bridges to office buildings and beyond, into a smart component of the 6G network, these re-configurable surfaces would also be able to provide more capacity to a user than they need, with the added benefits of also being able to control energy consumption and circumscribed EMF in order to avoid interference from unconnected devices, and to minimise their impact on the people around them.

While developing new materials for the 6G era is needless to say hard it appears that researchers have learned some valuable lessons from their issues with 5G mmWave deployments and are keen to avoid those issues with the next generation network.

Energetic Materials

Energetic materials is a bit of a misnomer here because overall the materials I'll discuss in this segment come from a variety of classes which aren't categorised. However, what they all have in common is the fact that when manufactured in particular ways they can all be used to harvest energy from their environment and that they can then use that energy to power objects. Objects that range from tiny IOT sensors and devices, where batteries or connecting them to traditional DC power would be both impossible and impractical, all the way through to objects that include everything from 6G antenna and components all the way through to larger objects including wearables, satellites, and even your common-a-garden smartphones.

Made possible by advances in manufacturing technology, which include nanomanufacturing, we're seeing a wide range of new types of materials coming through that can harvest energy from a wide variety of different sources – whether it's light, magnetism, sound, thermal, or vibration, radiation or RF in the air, or even from the 5G and 6G signals themselves. And, as research continues we're seeing the energy efficiency of these materials, which include backscatter, bacterial and biological, and piezoelectric materials as well as other more exotic materials such as electromagnetic, magnetostrictive, or thermoelectric generator materials, make dramatic leaps in efficiency and performance.

As we get closer to seeing the first 6G

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deployments you can expect to see and hear a lot more about energy harvesting materials and innovations, and you can also expect to hear a lot more about wireless energy transmission innovations, which will include everything from laser to microwave energy transmission systems.

Graphene

Graphene, which also includes Carbon Nanotubes, and Graphene Nanoribbon materials, is a wonder material that has an incredibly broad range of applications – both within and outside of the 6G arena. But for all its promise being able to manufacture it at scale and at low cost still poses a significant problem to its ultimate adoption. Although, that said, solving these issues are simply a matter of when not if as researchers around the world close in on new ways to manufacture it that include everything from extracting it from Spinach leaves to extracting it from recycled household waste and other commercial by products.

When it comes to THz technologies though graphene is right up there with the best of them, and so far it's been used to design new THz antennae, camera systems, and computer chips. It's also shown very promising results when it comes to the detection, modulation, and generation of THz waves.

Add into all this the fact that graphene also solid state, operates at room temperatures, has outstanding electrical, mechanical, and optical properties, and that it's re-configurable, which would make it an ideal component in RIS systems, especially at much higher frequencies above 1 THz, and it's easy to see why more and more people around the globe are excited about its 6G potential.

Metamaterials

The interest in metamaterials has been growing rapidly over the past ten years, driven by new communications and technology requirements, and also by new aerospace and defense requirements.

As a consequence there has been an acceleration in the development of new digital and tunable metamaterials that can change their precise arrangement, geometry, orientation, shape, and size, which, in turn, gives them the all important "smart" ability to manipulate all manner of electromagnetic waves by absorbing, bending, blocking, or enhancing them in order to achieve capabilities that go far beyond what is possible with conventional materials.

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It's the combination of all these characteristics which make them ideal 6G candidates for everything from "novel" types of antenna, all the way through to new smart surfaces, that include all manner of different nomenclatures, from Reconfigurable Intelligent Surfaces (RIS) that I mentioned earlier in this section, through to new Hypersurfaces, Intelligent Reflective Surfaces (IRS), and even more adaptable Software-Programmable Metasurfaces (SPM) – most of which contain active THz components and metamaterials in arrays of separately programmable "tiles" that can amplify, collimate, polarise, redirect, and otherwise manipulate those all important 6G THz beams.

Tunable Dielectric Materials

Millions of cellphone users might not know it, but their phones rely on a small Barium-Strontium Titanate (BST) component to tune into signals for clear reception. That's all well and good, but researchers know that while today's cellphones, including the newest 5G phones, operate at frequencies below 6 GHz, the next wave of 5G phones and anticipated 6G cellular communications will operate at frequencies above 30 GHz where BST doesn't perform well.

So, as a result researchers in the US have developed a new tunable dielectric that has the same performance as BST but at 100 times higher frequencies. It also, crucially, works above 30 GHz and up to 125 GHz, which ultimately means BST could be replaced and the new material could bring much needed clarity and extra bandwidth to future 6G smartphones and other high-frequency electronic devices.

VIRTUALISATION

Today it's recognised that it's highly unlikely 5G will be able to meet all the requirements of future services, especially bearing in mind that with the proliferation of IoE there will be high demand for communications between "things," such as the connection of all the machines in a factory, and even potentially Smart Dust devices. Different things also have totally different requirements for communications. For example, smart meter reading requires less than 100 kbit data transmission per day, while Augmented and Virtual Reality terminals would transmit dozens of gigabits of data per second. In the time of the IoE, let alone some of the other future 6G applications that are already being discussed, such as BCI and sensory applications, among many others, needless to say many future services will

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require new network service features that 5G simply won't be able to satisfy.

One of the fundamental problems is that current mobile network architectures are mostly fixed, predefined, and optimised for certain existing and known services, which means that they are unlikely to play well with new services that have totally different features – something that's already being avidly discussed by researchers in the 6G field who commonly talk up 5G's ability to "open the door to new services" but not support them fully as they continue to evolve or mature over time.

As a result of all this future 6G mobile networks will need to have the built-in capability to support a myriad of unknown services and have network architectures and functionalities that can adapt to them, which, in turn means that open interfaces and the virtualisation of the network, and ergo the full abstraction of the software layer from the hardware layer, via Software Defined Network (SDN) and Network Function Virtualization techniques (NFV) and other complimentary agile technologies such as Microservice Chaining, will be crucial.

ENABLING TECHNOLOGIES . CONTENDERS

WHILE I have covered the major 6G enabling technologies in the previous pages given the rate of technological change I thought it might be prudent to include this "Part II" addendum where we take a quick look at some of the other technologies that could make an appearance and impact future 6G development and deployment.

In my opinion the following technologies, which could have some interesting ramifications either for specific parts of the 6G stack or all of it, are worth mentioning and putting on any watch lists.

PHOTONIC COMPUTING

Photonic computing, which can also include Nanophotonic Circuits, and even Photonic Neural Networks, have already been demonstrated in various labs around the world, and while they are in the early stages of development given their nature they could have a transformative impact on various parts of the 6G stack - from improving the decision making speed of AI, and the "cognitive" abilities of the network, to improving the speed and latency of the network and underlying components themselves.

PROTOCOLS

There is also alot of debate in the research community about the development and introduction of a new protocol for 6G and an upgrade of the existing ones so they can be compatible with the new technology and mitigate the high path loss that's associated with high frequency THz spectrum communications.

Additionally, there is also a need for new hardware that can improve the overall transmission range of THz communications and a need for a new "robust system" of algorithms that can manage the handover of Cubesat and UAV communications, ISAGUN, and other important 6G components.

QUANTUM AI

Artificial Intelligence will undoubtedly play one of, if not the, most important roles in the development of 6G standards. But as discussed most of the AI technologies embedded into the 6G stack will be based on narrow AI, so called Cognitive AI, and traditional Machine Learning and Deep Learning schemas.

As we reach this decade's mid point though we will see a dramatic uptick in the number of researchers focused on Quantum AI ML and DL development, and given some of the stunning early quantum technology results, for example with respects to Quantum Communications as well as Quantum Supremacy, adding QAI into the 6G stack could, with one stroke, revolutionise 6G development.


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6G STANDARDS . DIFFERENT BUT SIMILAR

UNLIKE 5G standards development, which saw hundreds of companies and consortiums come together to develop and agree the first 5G standard, 5G NR Release 15 in 2018, which then allowed companies like Qualcomm to design and manufacture the first 5G compliant hardware solutions in 2019, 6G is going to one of the first emerging technologies to be developed under the auspices of a new technology "Cold War" as countries increasingly see technology standards leadership and ownership as being key to their future security, sovereignty, and ultimately prosperity.

Exemplified in 2020 by the introduction of targeted US government Blacklist policies by President Trump, especially against Chinese companies like Huawei and ZTE, 5G quickly became a geopolitical battleground and football, the net result of which accelerated China's plans not only for self-reliance, but also dominance in everything from technology research and development to standards, beginning from 2025.

The net result of this means that it is highly likely therefore that 6G, as we are already seeing with the splintering of internet as well as 5G and Artificial Intelligence standards, will be the next victim. And this makes mapping out the standards difficult, but not impossible.

While there will no doubt be some bifurcation of 6G standards, the degree of which will be driven by China's confidence in its own abilities to set the global agenda and realise commercial success in the open marketplace, these are more likely to be subtle and on the margins with China likely to still adhere to many of the core standards - a tweaking rather than a tear down if you will.

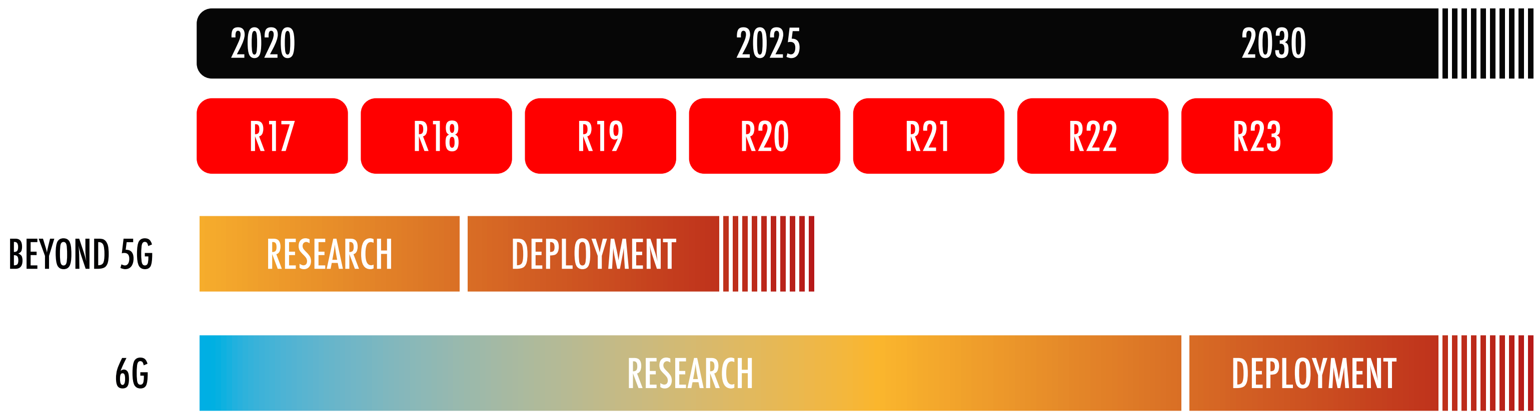
After all, not only would starting again and re-writing the standards from a blank slate be an expensive waste of time it would also likely have a significant impact on Chinese companies ability to commercialise and sell their technologies outside of China's own borders - as well as, potentially, only serve to accelerate President Xi's so called "Economic decoupling" of China from much of the rest of the world.

THE 6G STANDARD

Naturally, at the moment there is little hard information about what future 6G standards will look like but nevertheless it's estimated that the international standardisation bodies including 3GPP, ETSI, IEEE, the ITU, and other standards development organisations, will sort out the standards for 6G by the year 2028 to 2030.

While the rollout of 5G is still underway though researchers around the world have already started working on developing what comes next and have penned a tentative timeline for Beyond 5G and 6G which is shown on the next page.

Bearing in mind that the ITU Radio communication sector (ITU-R) issued its 5G International Mobile Telecommunications-2020 (IMT-2020) standard back in 2015, and that 3GPP issued their 5G Release 13 in the same year it's likely that the ITU will complete their 6G ITU-R IMT-2030 standard by the end of 2030, and that 3GPP will finalise their 6G Release 23 around the same



6G TIMELINE

It takes on average anywhere between 10 to 15 years to develop and agree a new wireless communications standard and as 6G research begins in earnest it will run in parallel for some time alongside Beyond 5G research and development.

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timeframe.

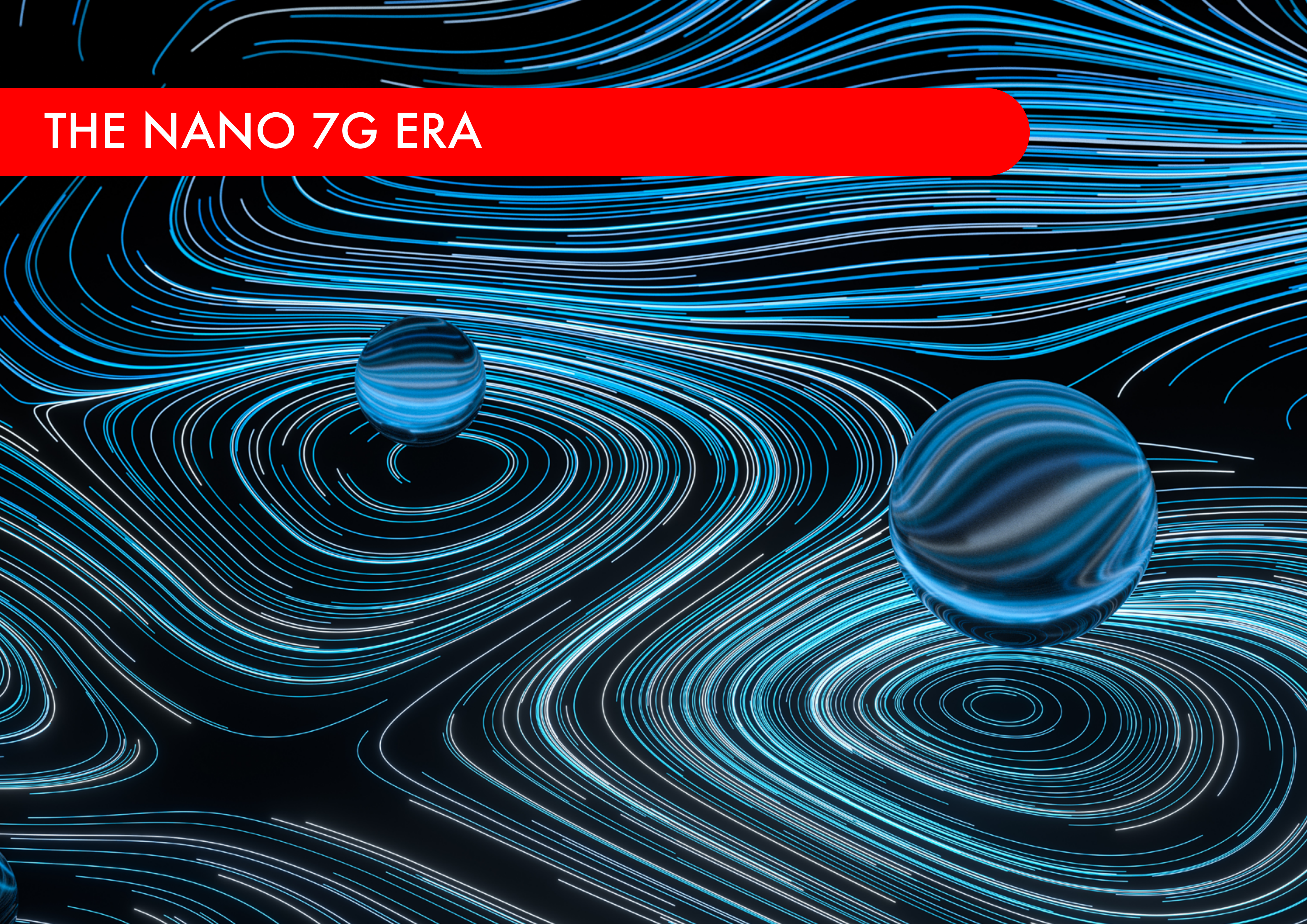
6G research started in earnest in 2018 when the ITU established the first working group to explore the technologies needed to support Beyond 5G and 6G. Then, in the same year the Academy of Finland founded 6Genesis, a flagship program focusing on 6G technologies, which was quickly followed by similar initiatives which sprung up in China, Japan, South Korea, Japan, Russia, and the USA.

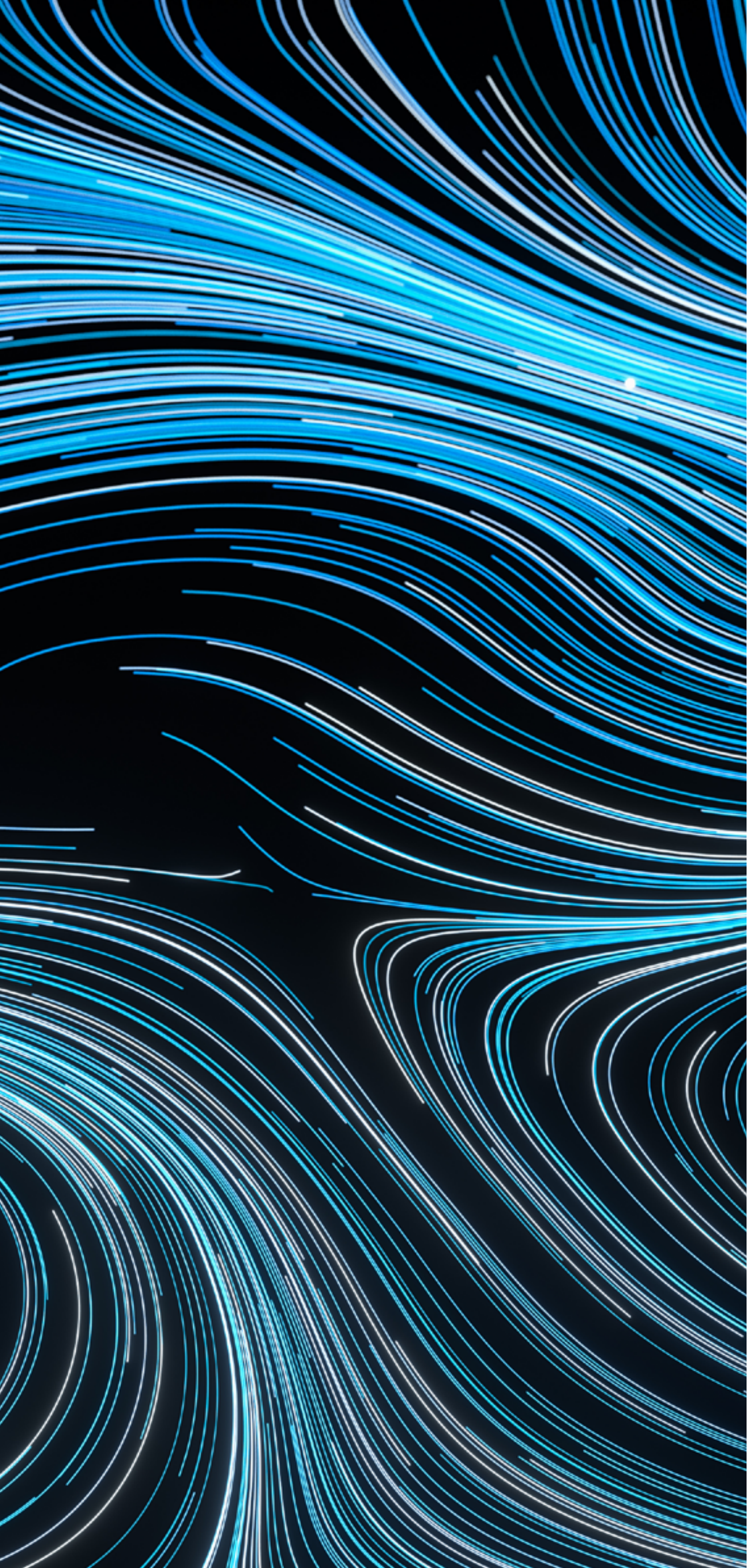
So far the work at some of the research centers has shown that 6G will be capable of transmitting a signal at "human computational capability and speeds" by the year 2035 which, in itself, would be a societal game changer.

When it comes to 6G standards development though while many of the existing 5G candidate technologies will still apply so the majority of researchers in the field are concentrating their efforts on finding novel ways to incorporate the key disruptive enabling technologies, that we discussed in the previous section, that will guarantee 6G's Quality of Experience and help it's overall deployment and adoption.

As we look forwards to what a final 6G standard could look like it's important to bear in mind some of the key criteria it'll need to meet including being able to enable: cell-free MIMO, energy harvesting and backscatter communications, intelligent wireless communication, massive scale network automation, pervasive "Cognitive" Artificial Intelligence, reconfigurable front ends, the Internet of Everything and ISAGUN things, and, last but certainly not least, operate at the THz band and wide spectrum.

THE NANO 7G ERA





5G IS being deployed globally, albeit at a slow starting pace. 6G standards and technologies started being discussed in 2018 and prototyped in 2021. And in the US the FCC has already auctioned off blocks of 6G and 7G spectrum which, bearing in mind that 6G is estimated to land in 2030 and 7G would then be estimated to make an appearance in or around 2040, is an impressive example of forward thinking.

It also shows the lengths governments are willing to go to support and develop the future wireless communications technologies on which all of their economies and prosperity increasingly rely.

When we look forwards to 7G, which will likely be a massive macro and nano scale sensory network, everything is of course highly speculative and subject to change, but despite that we know that historically future standards have always sought to fix the architecture and service flaws in previous generations of wireless technologies, and that researchers have always tried to find new ways to leverage emerging technologies to enhance the networks overall utility.

Therefore, with respect to 7G we can expect researchers in the field to focus on developing a truly intelligent adaptive self-managing cognitive network, eliminating dedicated connected power systems and receivers, enhancing wireless global roaming and group mobility capabilities, increasing network density and speed while decreasing latency, and reducing power consumption – most of which will be expected to be orders of magnitude better than those found in 6G.

We can also predict that future biological, molecular, neuromorphic, and quantum AI and computing technologies, as well as nano technology, synthetic biology, and “smart” things will all play increasingly dominant roles in enabling and underpinning future 7G standards - in everything from helping supercharge connectivity and speeds, to dropping latency and enabling the capabilities of the network.

Furthermore, we can also predict that 7G networks won’t just be highly automated but that they’ll be fully autonomous and programmable – complete with the inherent ability to intelligently evolve their own architecture and service designs based on sensory inputs.

7G will also need to support increasingly dense, extensive, and varied ISAGUN and 3D space requirements, which could include extending the benefits of 7G to the edges of space, as researchers

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around the world increasingly try to establish 7G as the world's first truly global wireless communications system.

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CONCLUSION

PEOPLE SAY change is a constant, but in today's technology fuelled world this simple phrase is a deceiving, and often comforting, misnomer because change isn't constant, it's exponential, and the only boundaries to what we can achieve as individuals and as a global society are the ones that we invent for ourselves.

As researchers and scientists increasingly prove that nothing is impossible, that yesterdays science fiction is simply the future generations status quo, and as we all continue to bear witness to an increasingly rapid rate of change that's affecting and transforming every corner of global culture, industry, and society the future belongs to all of us equally, and we should never loose sight of that.

As you race into your own future I wish you well, and never forget you have all the friends and support you need around you as we all voyage through time and space together on this fragile living spacecraft we call Earth.

Explore More

MATTHEW GRIFFIN
Founder

Notes:


THIS IS NOT THE END.
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