Field Connectivity in a 5G World

Enabling tomorrow's use cases with Dejero *Smart Blending Technology*

Dejero

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Table of Contents

Executive Summary

While coverage of 5G often examines use cases like virtual and augmented reality, remote surgery, and the Internet of Things, we believe initial 5G deployments will better enable existing use cases and familiar industries—such as Broadcast and Media, Public Safety, Transit, and Enterprise.

Because of the cost and effort required—not to mention the many technical and regulatory decisions yet to be made—the transition to 5G will take many years and will be uneven; consequently, reliable communications will depend upon a mix of 5G and LTE networks for some time to come. Plus, while 5G promises to deliver new capabilities, it does very little to address problems associated with unreliable mobile networks, poor connectivity in remote locations, variable latencies, and other communications environments and scenarios—challenges addressed by Dejero's *Smart Blending Technology*.

For Dejero, 5G is simply a new ingredient in our blending recipe, joining 4G, satellite, Wi-Fi, and broadband connections. With patented (and patent pending) *Smart Blending Technology*, we are embracing the transition as 5G, LTE, GEO satellites, and emerging connectivity options come online, and we're proud to have played an important role in proof-of-concept projects which illustrate the potential of 5G.

Dejero

Introduction

5G is the fifth generation of cellular network technology and it holds tremendous promise to transform the role played by telecommunications technology in society.

5G aims to provide 20 times the peak data rate, 10 times lower edge latency, and 3 times more spectral efficiency than 4G LTE.

5G aims to provide 20 times the peak data rate, 10 times lower edge latency, and 3 times more spectral efficiency than 4G LTE. While previous generations (see Figure 1) of mobile networks were purpose-built to deliver services such as voice and messaging (2G), video calls and faster data (3G), or mobile broadband (4G), at a high level 5G has three major use case classes:

- Enhanced Mobile Broadband (eMBB)
- Massive Internet of Things (mIoT)
- Ultra-Reliable Low Latency Connectivity (URLLC)

From enabling the Internet of Things and autonomous vehicles, to supporting smart cities and agriculture, to delivering fiber-overthe-air, 5G is being positioned to unlock a world of new possibilities; at the same time, 5G will preserve the future of today's most popular mobile applications—like streaming video—by ensuring that usage growth can be sustained.

Additionally, through the use of edge computing, network functions virtualization, and software-defined networking (SDN) technologies, 5G introduces new degrees of configurability and agility. These features and characteristics are expected to enable communications providers to deliver customizable services to meet the specific needs of different industries, enterprises, users, and connection types.

Ultimately, 5G is "expected to enable further economic growth and pervasive digitalization of a hyper-connected society, where not only are all people connected to the network whenever needed, but also many other devices/things."[1]

While some practical matters are steadily being addressed, widespread availability of 5G is a long way off.

Figure 1 — Each new generation of mobile technology brings new services and capabilities which unlock new possibilities

Mobile Generation	1G	2G
Commercial Launch	1980s	1990s
Services	Voice	Voice, SMS, MMS, and data
Data Speeds	---	100 Kb/s to 300 Kb/s

[1] From the GSMA's Road to 5G: Introduction and Migration

While some practical matters (including the availability of spectrum and the readiness of devices) are steadily being addressed, widespread availability of 5G—and, specifically, the more advanced capabilities which promise ultra-low latency, blistering speeds, and much greater capacity—is a long way off.

In reality, we can reasonably expect an initial performance boost similar to what we saw with the move from 4G to LTE-Advanced.

From requirements to standards: ITU and 3GPP

The requirements for 5G are specified in International Mobile Telecommunications-2020 (IMT-2020), issued by International Telecommunication Union Radiocommunication Sector (ITU-R).

Defining the industry standards which guide network and equipment designs is handled by the 3GPP (3rd Generation Partnership Project), who chose the 5G NR (New Radio) standard together with LTE as their proposal for submission to the IMT-2020 standard. In practice, "5G" now refers to this latter meaning.

While network trials and proofs of concept have been underway for a few years (see "A 5G First: Dejero, Musion 3D, and Vodafone Romania Deliver First Live Rock Concert Using 5G and Holographic Technology"), the final standards aren't expected to be established until 2020, when a draft new ITU-R Recommendation with detailed specifications for the new radio interfaces will be submitted for approval within ITU-R.[2]

Until such time that radio and modem standards are finalized, 5G equipment is more proof of concept than commercially viable—and claims of "5G-ready" should really be interpreted to mean "5G-getting ready."

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3G	4G	5G
2000s	2010s	2020s
Voice, video calls, MMS, and faster data	Faster data and more multimedia services	Faster data and low-latency services
2 Mb/s to 21 Mb/s	100 Mb/s to 1 Gb/s	10+ Gb/s

[2] See the ITU's page ITU towards "IMT for 2020 and beyond"

A 5G First: Dejero, Musion 3D, and Vodafone Romania Deliver First Live Rock Concert Using 5G and Holographic Technology

In 2019, as part of Dejero's preparations for 5G, we helped enable a world first: Dejero transmitters and receivers, Vodafone Romania's 5G network, and Musion 3D's holographic technology delivered a live, life-sized, 3D holographic video stream which allowed a remotely located performer to play on stage alongside a rock band.

This successful field demonstration would not have been possible without the capacity offered by a 5G wireless network, and hints at the possibilities offered should 5G coverage become ubiquitous.

> This world-first achievement was recognized with an IABM BaM award in the project collaboration category.
> For more information about this project, please visit www.dejero.com/resources

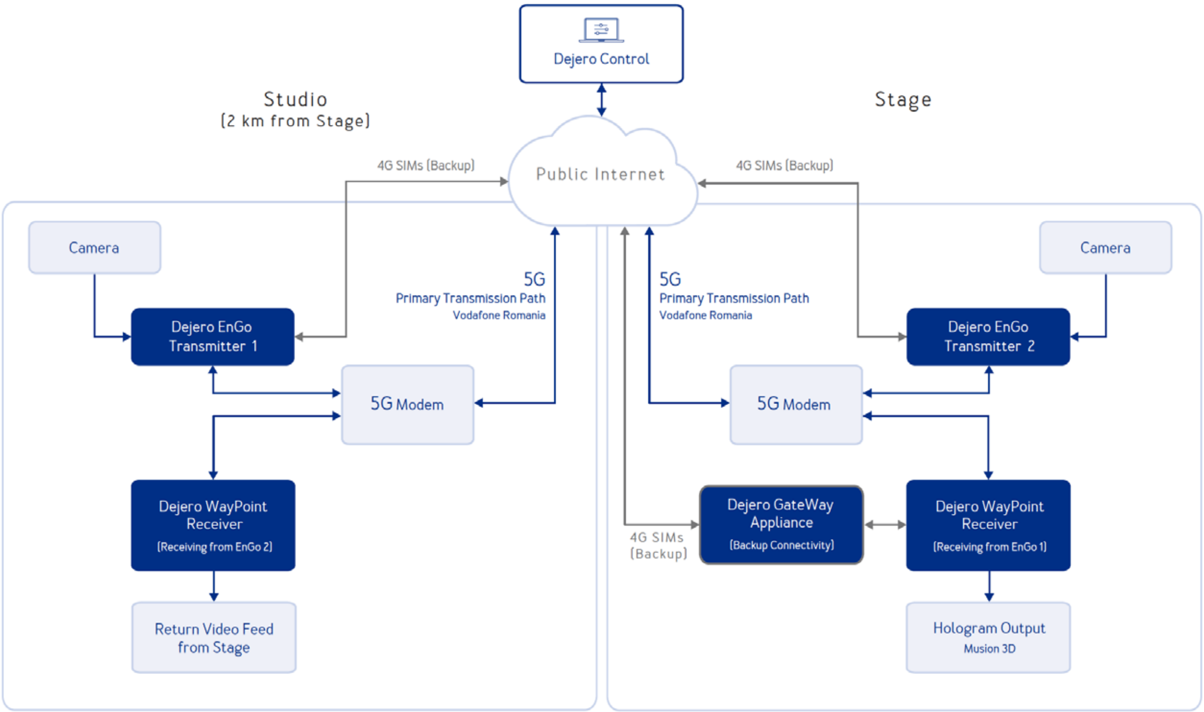


Figure 2 — The project relied on a Dejero EnGo mobile transmitter for the reliable transmission of the performer's hologram over the Vodafone 5G network; the signals were synced to both the venue and a return video and audio feed to the remote perfomer

Overview of 5G Technology

Broadly, a 5G network has three main components:

- **Radio Access Network (RAN)**: the part of a telecommunications system which connects individual devices to other parts of a network through radio connections
- **Mobile Backhaul:** The transport network which connects the core network and the mobile network RAN
- **Core Network:** The central part of the network, which provides the link between the mobile access and other networks (the wider Internet)

Of the three, the RAN will be the first to receive 5G upgrades, due to a combination of equipment readiness, relative ease of upgrade, and expected business case. While 3GPP is defining both a new 5G core network (5GC) and 5G New Radio, it is possible to integrate elements of different mobile network generations in different configurations:

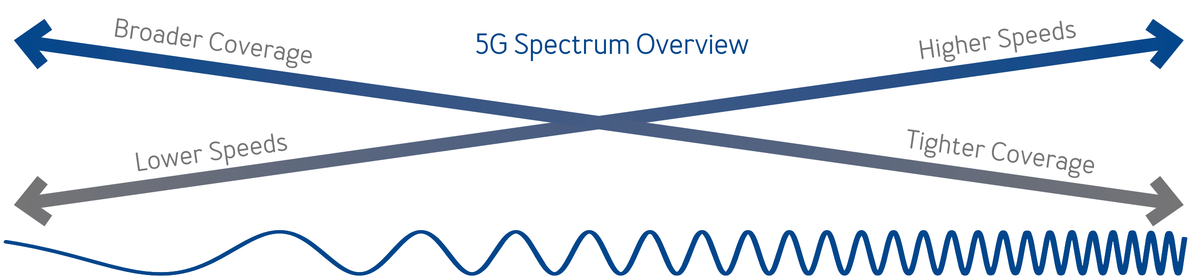
- **5G Standalone (SA)** uses only one radio access technology (5G NR or the evolved LTE radio cells), with the core networks operated alone
- **5G Non-Standalone (NSA)** combines NR radio cells and LTE radio cells using dual-connectivity to provide radio access; the core network may be either Evolved Packet Core (EPC) or 5GC

What's new in 5G?

5G brings a number of new developments and concepts, of which five are worth quick examination: expanded spectrum, small cells, massive MIMO (and beamforming), edge computing, and network slicing.

Expanded spectrum

5G networks need spectrum within three key frequency ranges to deliver widespread coverage and to support all use cases; Figure 3 provides an overview of the role of each range in enabling 5G services.[3]



Low band
Low Frequency (<1 GHz)

- **Supports widespread coverage of urban, suburban, and rural areas**
- Helps enable IoT services
- Extends coverage deep into buildings
- Europe has prioritized the 700 MHz band for wide area 5G deployments; the United States and Canada have already licensed the 600 MHz band

Mid-band
Medium Frequency (1-6 GHz)

- **Offers a mix of coverage and capacity —often called the "sweet spot"**
- Includes the 3.3 to 3.8 GHz range expected to be the basis of many initial 5G services—the "global backbone"
- Also includes other ranges which may be assigned to (or re-farmed by) 5G operators including 1800 MHz, 2.3 GHz and 2.6 GHz, C band, etc.

High band
High Frequency (>6 GHz)

- **Needed to meet the ultra-high speeds envisioned for 5G**
- Travels shorter distances and is easily blocked (by leaves, buildings, rain, etc.)
- May be limited to high-density urban cores where small cells are cost-effective
- 26 GHz and/or 28 GHz bands (mmWave) have the most international support

Figure 3 — Overview of 5G frequency ranges and their respective roles in delivering 5G services

[3] The explanations in Figure 3 are largely adapted from the GSMA's 5G Spectrum – GSMA Policy Position

Small cells

Because the high-frequency band is very directional, requires more energy to travel further, and is easily blocked, providing coverage in this band requires a collection of many small cells.[4] The early locations for small cell sites are likely to be stadiums and other dense venues, because network operators are focusing investments on locations where they can gain the most benefit.

It's important to recognize that because these cell sites will be very small, and regions with small cells will be few in number, speeds will be highly variable and coverage will likely be limited to open, high-traffic areas (Figure 4).

> "The high frequency band needed for blazing fast 5G speeds is very directional, travels shorter distances, and is easily blocked"

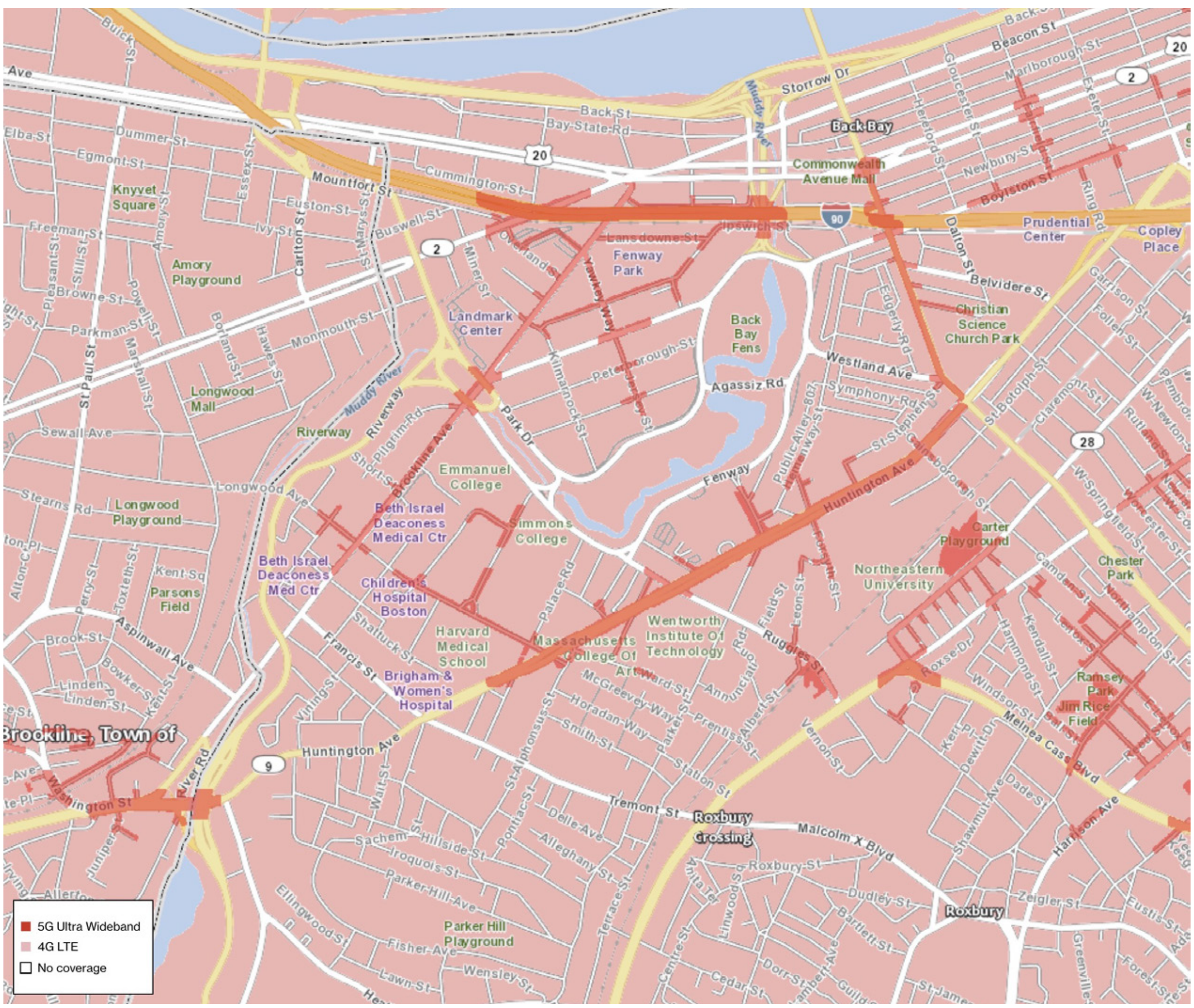


Figure 4 — This map showing Verizon's 5G Ultra Wideband coverage in Boston's Fenway/Kenmore area (as of November 2019) highlights the challenges of using higher frequency bands—coverage is extremely focused

[4] For the sake of completeness, the GSMA notes that "Recently, the introduction of small cells has given rise to the concept of fronthaul, which is a transport network that connects the macrocell to the small cells. Whilst mobile backhaul and fronthaul are different concepts, the term mobile backhaul is generally used to encompass both concepts"

Massive MIMO and beamforming

Massive multiple-input, multiple-output (massive MIMO) is an extension of MIMO, which groups together antennas at the transmitter and receiver to provide better throughput and improved spectral efficiency. Standard MIMO networks tend to use two or four antennas, while massive MIMO can use tens or even hundreds of antennas.

Beamforming uses signal processing to adapt the radiation pattern of the large antenna array to a particular scenario, with the goal of improving the speed of the mobile network.

Within 5G, massive MIMO and beamforming will work in tandem to deliver the high frequency coverage needed to enable the highest network speeds.

Edge computing

Unlike previous generations of mobile network technology—which required traffic to traverse the network to some destination and then return, incurring significant latency—5G aims to locate applications and the cloud compute, storage, and network functions needed to run them, close to the access edge.

By doing so, 5G promises to drop latency significantly (the aim is for <1ms), which is expected to enable and improve applications including Internet of Things use cases, autonomous systems, and augmented reality. Of course, applications which still need to traverse the Internet to reach an ingress or egress point will not see latencies this low.

> "Applications which still need to traverse the Internet to reach an ingress or egress point will not see the sub-millisecond latency envisioned for edge compute-enabled use cases"

Network slicing

Through network slicing, 5G gives network operators enormous flexibility and agility to meet the varied needs of their user base.

A network slice can be thought of as a software-defined wide area network (SD-WAN); through technologies including virtualization and SDN, network slicing enables multiple independent logical networks to operate on the same physical infrastructure, configured to deliver a particular set of requirements.

Network operators can combine different network characteristics into distinct slices, and then offer those slices for particular applications, industries, or even enterprises.

> "Network slicing is one of the more complicated parts of 5G, and it will be a while before such services are commercially refined. Plus, connectivity use cases which benefit from (or demand) operator diversity will gain little or nothing from network slicing."

Note that network slicing is one of the more complicated elements of 5G, and it will be some time before such services are introduced and commercially refined. Plus, since an operator is dedicating part of their network to the slice, the application needs to be one which will generate a good ROI—and even then, slices will be operator-specific, so connectivity use cases which demand or benefit from operator diversity will gain little or nothing from network slicing.

Industry Applications

When 5G networks and devices are more widely available, we expect to see significantly improved performance and productivity, especially where cellular networks become congested.

While coverage of 5G often examines use cases like virtual and augmented reality, remote surgery, and the potential of the Internet of Things—and no doubt many use cases will emerge which haven't even been thought of yet—initial 5G deployments will better enable existing use cases and familiar industries.

Broadcast and Media

The exponential growth of video over IP is changing broadcasting needs, processes, and deliverables—and the growing consumption of high-quality video through both traditional channels and new media, such as social platforms, is driving 5G to the forefront of industry discussions and projects.

Unsurprisingly, the broadcast industry has taken an active role in contributing to 5G standards.[5]

While upload speeds will vary by spectrum, provider, and region—for instance, mid-band consumers in the United States have reported nearly 500 Mb/s, while carriers in China and South Korea are delivering mid-band peaks of around 600-900 Mb/s—5G is expected to offer more reliability to send more data, more quickly, thereby enabling more HD and 4K/UHD live video transmissions.[6]

But the benefits extend far beyond resolution. For example, 5G may allow broadcasters to expand their use of spectrum for data services, with the most likely initial use cases being those which leverage broadcasting's unique ability to efficiently reach many recipients at the same time and which require a wide geographic reach.

5G also has the potential to deliver more ambitious solutions which may enable the deployment of multicamera, remotely-operated outdoor broadcasts.

Finally, whether through higher bandwidth or reduced congestion, 5G is expected to deliver better connectivity with improved reliability. Higher bandwidth, especially through extremely high-frequency mmWave spectrum, can also strengthen or enable broadcast use cases like remote production.

Major Use Cases

Remote Contribution: Broadcast live and send recorded content from remote locations virtually anywhere—in particular, we expect MIMO to play a significant role in improving reliability and performance

Remote Production: Perform production activities in a remote location by leveraging the high throughput provided by mmWave service—plus, if some remote production processing can be performed at the edge then it will benefit from edge compute and reduced latency

Content Distribution: Cost-effectively distribute content to network affiliates, group stations, or to other broadcasters and media organizations

Return Video: Send low-latency return video and teleprompting feeds to live broadcast production teams in the field and view feeds simultaneously on tablets and mobile devices

Remote Connectivity: Access media assets and newsroom systems remotely, quickly transfer files back and forth, and more easily collaborate and communicate with field personnel

Disaster Recovery: Keep broadcasts on air and retain content distribution capabilities in the event of damage to broadcast facilities or studios

[5] For example, see Helping To Unlock the Potential of 5G for Content Production, from the European Broadcasting Union.

[6] For an aggregation of real-world experiences, see VentureBeat's The definitive guide to 5G low, mid, and high band speeds

Public Safety

Major Use Cases

Mobile Command: Provide reliable connectivity to enable connected command vehicles to send and receive data from cameras, sensors, and edge devices to and from the cloud

Fleet Connectivity: Send live video back to command centers and enable "mobile precincts" to help make appropriate response decisions or retrieve vital data in the field to keep teams safe and respond faster—for instance, a mobile camera could capture a license plate and send to the edge for instant analysis to alert an officer if action should be taken

Real-Time Video: Ensure central command has real-time video to support decision-making during sporting events, parades, protests, and other events which draw large, mobile crowds

UAS Situational Awareness: Provide real-time video from the safety of the sky to improve situational awareness for law enforcement and fire service commanders

First responders must be able to quickly and reliably get the information they need to make life-saving decisions.

From enabling mobile commanders and field personnel to send and receive video and data from the field, to enhancing situational awareness and communication and enabling "mobile precincts," reliable and fast connectivity can make a life-saving difference.

As public safety departments around the world increase their use of video—from body cameras and surveillance cameras to dash cams and unmanned aerial systems (UAS)—the amount of video which law enforcement agencies produce and ingest is soaring.

5G has the potential not only to enable transmission of more and higher-quality video, but to allow public safety organizations to leverage edge computing resources to pre-process feeds to prioritize immediately actionable or especially valuable information, while storing secondary feeds for later transmission.

The introduction of 5G could also help drive down wireless broadband deployment costs, leading to better coverage of rural and underserved areas—aiding first responders as well as consumers and businesses.

Transit

Many public transit operators require fast and reliable connectivity for their bus and rail fleets on the move.

5G is poised to make a major impact on fleet connectivity use cases in particular, by enabling richer passenger services, supporting data-heavy fleet management applications, and using edge computing resources to analyze telemetry in real time.

As autonomous vehicles and systems gain traction, the lower latency and edge computing within 5G can allow vehicles to communicate with the outside world and external systems—potentially leading to considerably more efficient and safer use of existing road infrastructure.

Major Use Cases

Fleet Connectivity: Enable on-board systems such as passenger infotainment and Wi-Fi, payment systems, fleet management, and telematics

Autonomous Vehicles: Provide low-latency vehicle-to-vehicle and vehicle-to-everything connectivity

Real-Time Video: Improve the safety and security of passengers and operators with real-time video monitoring at a central location, allowing faster response to incidents

Enterprise

Major Use Cases

Branch Connectivity: Enable remote branches with reliable connectivity to cloud services, data centers, and headquarters

Mobile Connectivity: Ensure reliable connectivity for mobile workforces when and where it's needed—especially in areas where cellular coverage from a single carrier may be weak or unavailable

Temporary Connectivity: Provide connectivity for days, weeks—or even months—to support short-term needs at tradeshows, events, construction sites, and other projects

Drone Inspection: Deliver real-time video and data to experts anywhere the world to facilitate collaboration and enhance efficiency

Live Video Streaming: Stream video from a remote location, for instance to support product launches, all-hands meetings, and site visits

Today's organizations are dependent on reliable access to the Internet to run their business.

Without connectivity, access to cloud services, private networks, and data centers comes to a halt, mission-critical communication and data-exchange between branch locations and head offices can be severed, and mobile workforces lose productivity.

If 4G was about mobile broadband, then we might look back upon 5G as the dawn of the truly mobile cloud. But whether the mobile cloud becomes a defining characteristic of 5G or more of a secondary use case, we still expect to see enterprises embrace 5G through private networks which offer higher security and lower latency than Wi-Fi, and with 5G-enabled laptops which take advantage of the decreased latency and increased speeds promised by 5G.

Beyond 'traditional' branch applications, today's enterprises are using wireless networks to enable a whole host of use cases which require fast and reliable connectivity. 5G has the potential to enhance these use cases by supporting live video, powering faster data transfers, and providing network slices tailored to the needs of particular industries and large organizations.

Practical Realities

Despite the excitement and meaningful milestones, the first wave of broad 5G coverage will be sub-6 GHz and will offer only marginal improvements over 4G LTE-Advanced. It will be at least a few years until 5G networks are approaching being able to live up to the promises and potential which are driving the hype.

> "Despite the hype, the first wave of 5G coverage will be sub-6 GHz and will offer only marginal improvements over 4G LTE-Advanced."

Ultimately, 5G's manifestation in the real world is dependent upon a number of factors, including:

- **Spectrum allocation:** Spectrum discussions, auctions, and re-allocations/re-farmings are ongoing and status is changing rapidly. In early 2019 the European Union announced that member states would harmonize across the 3.6 GHz spectrum for 5G deployments by the end of 2020.[7] In the United States, legislation to publicly auction at least 280 MHz in the C band spectrum (which falls in the medium frequency range) by the end of 2020 was introduced in December 2019 and in January 2020 the FCC authorized full commercial deployment in the 3.5 GHz band, while Canadian spectrum auctions for similar spectrum will occur in early 2020[8]

- **Operational 5G networks:** Upgrading the RAN with new equipment is a prerequisite for 5G connectivity. Beyond the RAN, enabling advanced capabilities like end-to-end network slicing will require core and backhaul upgrades; however, it is unlikely that these investments will occur ahead of the established upgrade schedule (based largely on the lifecycle of existing components within today's 3G and LTE networks), and due to the significant costs involved many operators will only upgrade other backhaul and core elements where and when there is an expected return on investment (unless compelled to do so by government incentives). Plus, concerns about national infrastructure security have the potential to delay investments[9]

> "Concerns about national infrastructure security have the potential to delay 5G investments."

- **Devices which support 5G:** As of early 2020, only a handful of devices support 5G. Mass adoption requires widespread device availability, plus enough time for upgrade cycles to create sufficient market penetration. Initially, 5G is expected to consume more power than LTE, resulting in shorter device battery life; however, this behavior should improve over time. Additionally, integrating mmWave capabilities into portable devices is a significant challenge because the high frequencies involved cause problems with directionality and attenuation

- **5G data plans/SIMs:** Customers and telecom providers must 'agree' on commercial models which make sense. Initially, many operators will likely offer 5G data as an optional, paid upgrade to existing LTE data plans. Plus, consideration

[7] There are pockets of early availability in cities and communities across Finland, Spain, Switzerland, and the UK.; trials are proceeding elsewhere, with commercial launches expected in France, Germany, Norway, Sweden, and the Netherlands in 2020

[8] For more information, see Mobile World Live's coverage at US errs towards public C-Band sale and the FCC's statement at FCC Authorizes Full Commercial Deployment in 3.5 GHz Band

[9] For instance, see US warns Boris Johnson that UK secrets are at risk, in the Financial Times and Why Canada Should Not Let Huawei Into Our 5G Networks: Debunking Five Myths, by the Macdonald-Laurier Institute

must be given to determining appropriate data allowances (Figure 5): the adoption of LTE led to widespread awareness of "bill-shock", and 5G speeds could make the problem even more acute

- **A willingness to pay:** The path to 5G is an expensive one, and many of the expected economic benefits remain only theoretical until proven otherwise. Especially at the outset, 5G equipment and air time are likely to be more expensive than LTE. Plus, even after equipment costs decline, operators will have little financial incentive to extend high- and medium-frequency coverage to rural areas (let alone remote locations)

> "Even after equipment costs decline, operators will have little financial incentive to extend high- and medium-frequency coverage to rural areas—let alone remote locations."

Mobile access adoption lifecycles

5G rollouts won't happen everywhere all at once. The first 5G services will be limited to densely populated urban areas or municipalities which are friendly to the zoning requirements associated with small cell deployments. Moreover, 5G won't replace 4G (which has replaced 2G and will ultimately replace 3G); instead, 5G and 4G will work in a complementary fashion to handle different types of traffic and to address different use cases.

> "The first 5G services will be limited to densely populated urban areas or municipalities friendly to the zoning requirements associated with small cell deployments"

As noted previously, 5G technology is expected to transform the role that telecommunications technology plays in society. Therefore, it's no coincidence that many governments—particularly in advanced economies like South Korea, Japan, Singapore, and the United States—are aggressively pursuing and supporting 5G initiatives.

Nevertheless, the history of telecommunications reveals a clear pattern in upgrade cycles.

Progress is measured over decades

Understanding 5G: Perspectives on future technological advancements in mobile, published by GSMA Intelligence, states that "Historically, cellular technologies have adhered to an approximate 20-year cycle from launch to peak penetration, with around ten years between the launch of each new technology."

> "Historically, cellular technologies have adhered to an approximate 20-year cycle from launch to peak penetration"—GSMA

With focus always on the next or new thing, it's easy to overlook just how long it takes a new access generation to reach widespread adoption and, ultimately, to peak. To put things in perspective, consider that May 2001 marked the first commercial 3G offering, by NTT DoCoMo; however, 3G connections are not forecast to peak until 2020 or even 2021. The GSMA tells us that:

> The first commercial LTE networks went live in 2009 and based on historical precedent we would not expect the technology to reach a peak level of connections until around 2030.
>
> In reality, the adoption of LTE is proceeding at a faster rate than its predecessor technologies, yet we still do not expect LTE connections to peak until well into the next decade.

> The first commercial 3G offering launched in May 2001. Almost 20 years later, 3G connections still haven't reached their peak.

The Mobile Economy 2019, also published by the GSMA, further explains that:

Figure 5 — The BBC's inaugural live 5G broadcast, in May 2019, ran into trouble when they immediately reached their data cap[10]

In 2018, 4G overtook 2G to become the leading mobile technology across the world, with 3.4 billion connections accounting for 43% of the total (excluding licensed cellular IoT). With growth continuing apace, particularly across developing markets, 4G will soon become the dominant mobile technology, surpassing half of global mobile connections in 2019 and reaching 60% in 2023.

> "4G will soon become the dominant mobile technology, surpassing half of global mobile connections…reaching 60% in 2023"—GSMA

With that being said, the promise of 5G is such that there's a general expectation within the industry and governments that things will move a bit faster this time around, but "a bit faster" is relative in telecommunications. On 5G, *The Mobile Economy 2019* forecasts that:

> The number of 5G connections will reach 1.4 billion by 2025 – 15 per cent of the global total. By this point, 5G is forecast to account for around 30 per cent of connections in markets such as China and Europe, and around half of the total in the US.

[10] See Rory's first 5G live broadcast;—and the BBC is not alone: in Newsrooms begin tinkering with 5G, Axios outlines the 5G activities of several leading news organizations

The Role of Dejero *Smart Blending Technology*

As showcased by the demonstration with Vodafone, Dejero products are already 5G-proven through the use of external 5G modems; as integrated 5G modems become commercially available, we will incorporate them into our products. With limited 5G coverage in most locations, supporting existing wireless network technologies will remain key.

> "With limited 5G coverage in most locations for the foreseeable future, supporting existing wireless network technologies will remain key."

Dejero's *Smart Blending Technology* enables broadcasters to blend connections from multiple providers and different wireless technologies. This connection diversity will remain key—even in a 5G world—to delivering the reliability which tomorrow's connected organizations need.

Dejero *Smart Blending Technology* is a novel approach to connection or link aggregation which delivers both improved reliability and faster aggregate connection speeds compared to other techniques—ultimately enabling important and valuable use cases for broadcast and media companies, public safety organizations, transit services, and enterprises.

Smart Blending Technology achieves these outcomes by overcoming the technical challenges limiting most traditional connection aggregation solutions.[11]

Broadly, 'traditional' connection aggregation solutions can provide sufficient quality for stationary applications using wired broadband technologies including fiber, DSL, and cable. But because these solutions don't dynamically manage connections or latency, even in this scenario the aggregation doesn't make efficient use of the network resources—negatively impacting connection reliability, speed, and efficiency.

Unfortunately, the limitations of traditional solutions are exacerbated by wireless technologies, which often exhibit significantly variable latency and major differences in bandwidth capacity (which itself varies over time)—and for remote, mobile, or nomadic sites, the aggregated connection might depend entirely upon these less reliable (compared to fixed access), more variable technologies.

Dejero *Smart Blending Technology* is a novel approach to connection or link aggregation which delivers both improved reliability and faster aggregate connection speeds compared to other techniques—ultimately enabling important and valuable use cases for broadcast and media companies, public safety organizations, transit and services, and enterprises.

Smart Blending Technology lets organizations leverage the full combined potential of their individual links—even when those links have different and variable characteristics.

[11] For more information about how Dejero *Smart Blending Technology* works, please see our Technical Showcase Dejero *Smart Blending Technology*: Delivering reliable connectivity, anywhere

By automatically and dynamically managing network latency and connections, *Smart Blending Technology* delivers significant advantages, including:

1. Achieving high link utilization and performance even with only a single flow, and even with unreliable connections
2. Enabling particularly demanding applications, like low-latency constant-bitrate video streaming
3. Simplifying operational management and improving failover performance
4. Administratively configured connection priorities that dynamically and adaptively use the available links (in priority order) to achieve the target blended bitrates; this Priority Routing feature allows customers to use lower-cost connections (for instance, fixed broadband) whenever possible, only blending over the more expensive wireless networks as needed to ensure reliable connectivity

These characteristics combine to allow Dejero *Smart Blending Technology* to deliver reliable, lower-cost connectivity while still meeting demanding quality of service needs, and 5G—even when it's commonplace—doesn't remove the underlying problems addressed by *Smart Blending Technology*.

Ultimately, ensuring reliable and high-quality connections requires the ability to blend 5G with 4G LTE and satellite connections, without loss of connectivity or IP addressing changes.

> "5G—even when it's commonplace—doesn't remove the underlying problems addressed by Dejero's *Smart Blending Technology*. Ultimately, ensuring reliable and high-quality connections requires the ability to blend 5G with 4G LTE and satellite connections, without loss of connectivity or IP addressing changes."

Creating reliability through network diversity

With initial high-frequency/high-speed coverage limited to dense urban areas and restricted to micro-cells, weak or unreliable coverage will be the norm; thus, the added reliability realized by smart blending across multiple networks will continue to provide significant benefits—especially in mobile and nomadic applications where users may be moving in and out of different coverage pockets.

> "Even within an all-5G environment there will still be a need for network blending to gain security through carrier diversity."

Creating reliability through carrier diversity

Even when 5G services are commonplace, network operators are unlikely to offer guaranteed coverage for demanding applications like video streaming. Consequently, within an all-5G environment there will still be a need for network blending to gain security through carrier diversity.

And on that note, it's important to recognize that network slicing—once it becomes available and affordable—will be provided on a per-carrier basis, which does nothing to help with scenarios where carrier diversity is required. Plus, operators will be motivated to pursue returns on their investment: if an operator were to choose between enabling an autonomous driving use case or a broadcast use case, then the former may be favored.

Conclusions

5G is likely to result in demands for more data and more content. However, since 5G will take some time to be deployed and coverage will be limited, we believe that blending multiple connections will offer a compelling advantage—both during the transition and once 5G is firmly established—regarding reliability and throughput, especially in mobile and nomadic applications.

But cellular networks don't reach everywhere and 5G isn't the only new generation of communication technology poised to come online.

> "Using *Smart Blending Technology* to blend these satellite connections with terrestrial networks will open up even more opportunities for live content generation and other important use cases."

Speaking more broadly about telecommunication, on-demand satellite connectivity will also remain a critical element for connectivity. Operators are putting the latest generation of high throughput satellites into service, ensuring access for all from any location or environment. Using *Smart Blending Technology* to blend these satellite connections with terrestrial networks will open up even more opportunities for live content generation and other important use cases.

Dejero in a 5G world

For Dejero, 5G is simply a new ingredient in our blending recipe, joining 4G, satellite, Wi-Fi, and broadband connections.

> "For Dejero, 5G is simply a new ingredient in our blending recipe"

With patented (and patent pending) *Smart Blending Technology*, we are embracing the transition as 5G, LTE, GEO satellites and emerging connectivity options (for example, LEO satellites) come online, and we're proud to have played an important role in proof-of-concept projects which illustrate the potential of 5G.

Our technology has always been optimized for fast data rates. Our GateWay appliance mobile connectivity solution, for example, has been proven to reliably deliver in excess of 200 Mb/s upload and download with LTE modems while maintaining seamless connectivity.

Importantly, our video encoders feature adaptive bitrate encoding, content adaptive techniques, and dynamic scaling of resolution to provide superior picture quality when the transmission bandwidth is limited, which are vitally important to enabling superior quality video transmissions.[12]

For our customers, the improved reliability and reduced latency achieved by blending networks with 5G will continue to expedite workflows, simplify operations, and enable new use cases.

[12] For more information about the importance of encoding, please see our Whitepaper High-Performance Video Encoding Considerations for delivering high-quality, low-latency live video from field environments

Glossary

5G
5G is the fifth generation of cellular network technology; the requirements for 5G are specified in International Mobile Telecommunications-2020 (IMT-2020), issued by International Telecommunication Union Radiocommunication Sector (ITU-R).

5G Evolution (5G E)
5G E is a marketing term from AT&T used to denote devices which are capable of supporting 4×4 MIMO, 256 QAM, and License Assisted Access (LAA) technologies which are made available via the LTE-A or LTE Advanced specification

5G NR
5G NR (New Radio) is a radio access technology developed by 3GPP for the 5G mobile network. 5G NR uses two frequency ranges:

- Frequency Range 1 (FR1), which includes sub-6 GHz frequency bands
- Frequency Range 2 (FR2), which includes frequency bands in the mmWave range (24–100GHz)

Initial 5G NR launches will depend on existing 4G LTE infrastructure in non-standalone (NSA) mode; subsequent deployments are expected to operate in standalone (SA) mode with the 5G core network.

beamforming
Beamforming is a technique which focuses a wireless signal towards a specific receiving device, rather than having the signal spread in all directions from a broadcast antenna, to improve speed and reliability.

C band
The C band is a designation by the IEEE for a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 4.0 to 8.0 gigahertz (GHz). The medium frequency range of 5G spectrum overlaps with the C band.

Today, the C band is used for many satellite communications transmissions, some Wi-Fi devices, some cordless telephones as well as some surveillance and weather radar systems.

edge computing
In the context of 5G architecture, edge computing refers to locating applications—and the generalpurpose compute, storage, and associated switching and control functions needed to run them—relatively close (on the access edge) to end users and/or IoT endpoints. Edge computing is a requirement for achieving 5G's latency goals.

Evolved Packet Core (EPC)
The Evolved Packet Core (EPC) is a framework for providing converged voice and data on a 4G LTE network. The key components of EPC are:

- Mobility Management Entity (MME)
- Serving Gateway (S-gateway)
- Packet Data Node Gateway (PGW)
- Policy and Charging Rules Function (PCRF)

IMT-2020
International Mobile Telecommunications-2020 (IMT-2020 Standard) are the requirements issued by the ITU-R in 2015 for 5G networks, devices, and services.

Long Term Evolution (LTE)
LTE is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It was specified in 3GPP's Release 8 document series, with enhancements described in Release 9.

Although LTE has been promoted as "4G LTE," it does not meet the technical criteria 4G and is also described as 3.95G.

LTE-Advanced (LTE-A)
LTE-A is an enhancement of the LTE standard. It was standardized as 3GPP Release 10.

mmWave
mmWave generally refers to a specific part of the radio frequency spectrum between 24 GHz and 100 GHz, which has a very short wavelength.

In a literal meaning, mmWave refers to frequencies in the range of 30 GHz to 300 GHz, which have a wavelength between 1 mm and 10 mm. In the context of 5G communications, mmWave often (but not always) refers specifically to the spectrum band between 26 and 28 GHz.

network slicing
5G network slicing is a network architecture which enables multiplexing of virtualized and independent logical networks on the same physical network infrastructure. Each network slice is an isolated end-to-end network tailored to fulfill specific and varied requirements.

The GSMA's *5G Spectrum – GSMA Policy Position* explains that "network slicing will allow operators to create virtual sub-network slices with tailored features for specific types of user or usage requirement. Each slice can have a tailored set of network resources including spectrum bands and channels, radio access, and core network features including security. For example, ultra-low latency and high availability slices are a good fit for automated manufacturing, connected cars and remote surgery. Contrastingly, IoT networks with vast numbers of sensors and devices like streaming video cameras can be allocated a slice that is tailored for uplink heavy communications."

Non-Standalone (NSA)
A 5G deployment model in which the NR radio cells are combined with LTE radio cells using dualconnectivity to provide radio access and the core network may be either EPC or 5G Core depending on the choice of operator. This scenario is attractive to operators who wish to leverage existing 4G deployments, combining LTE and NR radio resources with existing EPC.

Standalone (SA)
A 5G deployment model in which the 5G NR or the evolved LTE radio cells and the core network are operated alone. This model means that the NR or evolved LTE radio cells are used for both control plane and user plane. The standalone option is a simple solution for operators to manage and may be deployed as an independent network using normal inter-generation handover between 4G and 5G for service continuity.

Wi-Fi 6
Wi-Fi 6 is the marketing term for 802.11ax which, along with 802.11ay, is termed High Efficiency Wireless.

Dejero

About Dejero

Driven by our vision of reliable connectivity anywhere, Dejero delivers fast and dependable connectivity required for cloud computing, online collaboration, and the secure exchange of video and data.

With our global partners, Dejero supplies the equipment, software, connectivity services, cloud services, and support to provide the uptime and bandwidth critical to the success of today's organizations.

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