TELECOM INFRA PROJECT

Quantifying Mobile Network Requirements by Use Case in the Outdoor Urban Environment

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Introduction

An understanding of the trends in demand (number of users, bandwidth, latency) due to the growth in existing mobile use cases and the emergence of new ones is important for the planning of mobile network deployments. This is particularly important in the outdoor urban environment where there are few alternative connectivity solutions.

The purpose of this study is to identify the existing and emerging connectivity-dependent use cases that are, or will be, heavily used in the next 2-5 years, and evaluate whether they require a significant connectivity upgrade.

We study both existing and emerging use cases. Growth in existing use cases will, in itself, justify upgrades in the mobile network infrastructure and consequently provide a connectivity environment conducive to the rollout of emerging use cases. Within emerging use cases, the characteristics of each may have different effects on the evolution of the mobile network.

History of exponential mobile traffic growth

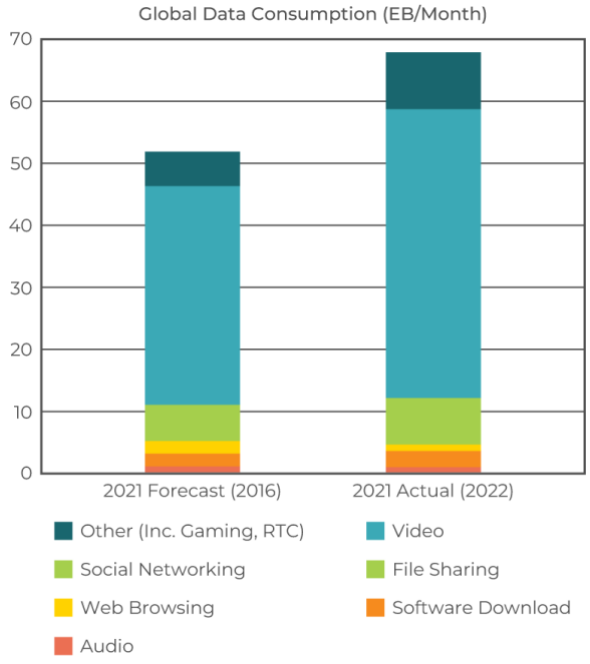
Mobile data consumption has increased exponentially in recent years. It is particularly difficult to forecast in an exponential growth environment, but the industry has provided remarkably consistent and accurate forecasts. Using different methodologies, the Ericsson Mobility Report[1] and Cisco Visual Networking Index[2] published in 2016 both forecast mobile data consumption of ~50 ExaBytes / month in 2021. The actual 2021 consumption estimated by the Ericsson Mobility Report published in 2022 was ~67 Exabytes / month, which is a difference of only 6% CAGR. This gives us some confidence in the demand forecast methodologies.

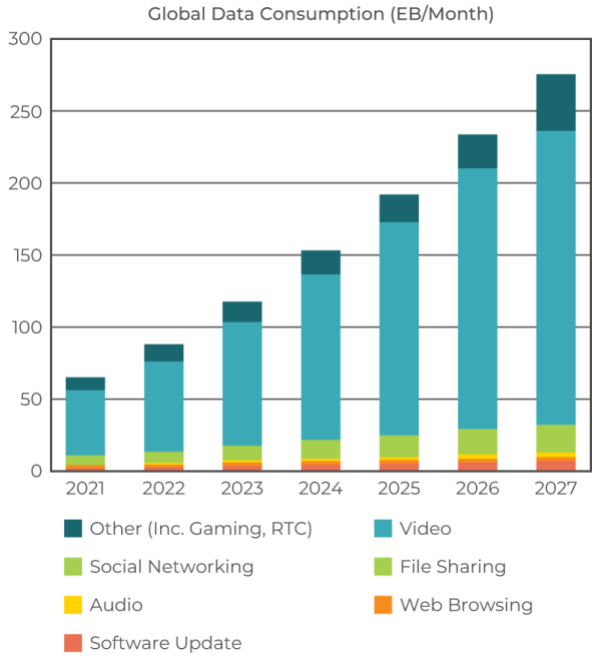
[1] Ericsson Mobility Report, 2016

[2] Cisco Visual Networking Index, 2016

The difference between forecast and actual data consumption was due to the greater than forecast growth in the Video and Other (Gaming, Real-Time Communications and emerging applications) categories. The historic forecast for these categories is conservative. The actual data consumption for the 'Other' categories was almost exactly as forecast.

Using the same methodology, Ericsson forecasts 5x data consumption growth in the Video category and a 3x data consumption growth in Other over the 2021-2027 forecast period.



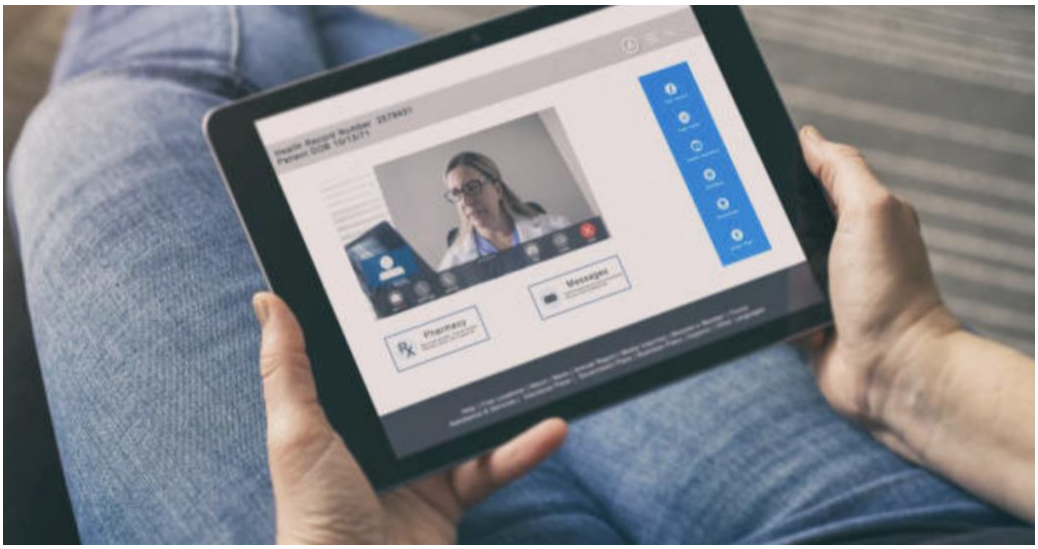


Drivers of video traffic growth

Increases in mobile video traffic are driven by a number of trends. Mobile video services are not additive, as multiple video services cannot be sensibly consumed simultaneously on the same device. However, video is an increasingly important component of each service, and the delivery of the video becomes more demanding as resolution and latency improve.

Video on every property, on every screen

Websites that are most visited by consumers such as news, health, and personal finance, have long used video on their desktop properties. They are adding video to enrich their mobile platform and make it more engaging.



These videos are generally in windows, short, and their individual bandwidth is low. In aggregate it adds to the demand placed on the mobile network.

Growth of high data rate streaming video

Short and long-form streaming video distributed by independent (for example, Netflix, Amazon Prime) and studio-linked (for example Disney+) streaming services is a major component of mobile video data consumption.

These are usually “big screen” television experiences but approximately 10% of consumption is on mobile devices[3] - and up to 40% in some regions. Bigger devices

[3] Global streaming viewing time by device 2021

with larger screens have generated greater quality expectations, which are satisfied with higher resolution and frame rate.

Application[4]	Consumption (MB/hour)	Average Daily Usage (minutes)
Netflix	3000	80
Amazon Prime	3000	60
YouTube	3000	11

While a large proportion of this traffic is transported over Wi-Fi in households that have broadband, the increasing number of mobile-only households implies that a part of this traffic will be carried by mobile networks. Streaming video is also consumed in a variety of outdoor locations such as public and private transportation, parks and other outdoor venues, where the traffic will mostly be carried by mobile networks.

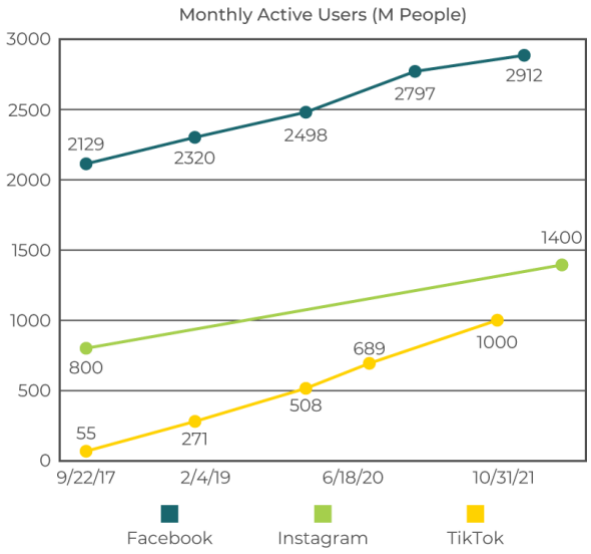
Streaming of non-live (pre-recorded) can tolerate high latency - in fact, latency is introduced through buffering to compensate for jitter (variations in latency) in the network so that the presentation of the video is smooth. The maximum “time to content” - that is, the start of the video presentation, or navigation within the video stream - sets the limit on the latency that can be tolerated. Some of the effects of latency during navigation can be mitigated through faster access to index frames.

Streaming of live video is much more sensitive to latency when the video is consumed at the event that is live streamed, and especially so when the streams may be seen side by side. In the context of urban connectivity, this is in locations such as stadiums where network performance can be more tightly controlled, but also in the public realm such as parks and squares.

[4] We answered the question how much data is enough data?

Reorientation of social media platforms to video

Social media platforms such as Facebook[5], Instagram and TikTok[6] continue to grow, as their adoption increases across different user segments and regions.



Social media has been primarily a text-first medium but a reorientation to video-first has recently emerged. Instagram has added Reels as a feature within the platform while TikTok is a video-only platform. According to Meta[7], Reels now accounts for over 20% of the time that users spend on Instagram and video makes up 50% of the time that users spend on Facebook.

Application[8]	Consumption (MB/hour)	Average Daily Usage (minutes)
TikTok	840	53
Instagram	720	145
Snapchat	160	30
Facebook	100	145

[5] Facebook MAU worldwide 2022

[6] TikTok reveals detailed user numbers for the first time

[7] Meta - Q1 2022 earnings

[8] We answered the question how much data is enough data?

The duration of social video clips is also growing. The maximum run time for Instagram Reels clips has increased from 15 seconds at launch in 2019, 30 seconds shortly thereafter, 60 seconds May 2022, to 90 seconds currently for some users[9]. Likewise, TikTok run time has expanded from 15 seconds to 60 seconds, to 3 minutes and to 10 minutes in February 2022[10]. This contributes to greater engagement.

The reorientation towards video and increased penetration of video across user segments, combined with the large numbers of users of these platforms is driving significant growth in video consumption and creation.

Consumer-sourced live events and social media creation must be ingested in near-real time to be available for consumption with low delay and to avoid exceeding the capacity of the consumer device.

The emergence of casual multiplayer video gaming

The number of mobile game players is increasing quickly even as individual titles gain and lose popularity rapidly.

Game Type[11]	Monthly Active Users (M)	CAGR (Q1 2018 - Q2 2021)
Shooter	45	39.3%
Action	20	28.7%
Strategy	17	6.5%
Role Playing	9	8.1%

As platforms such as Roblox and Player Unknown: Battlegrounds (PBUG) migrate from the desktop to mobile, the more complex gameplay results in longer playing times and

[9] Meta for Creators

[10] TikTok expands max video length to 10 minutes, up from 3 minutes

[11] The State of App Engagement 2021 - SensorTower

greater engagement. The games drive both the capabilities of the playing device and the required network connectivity. Phone screens have reached resolutions that are HD (1080x1920 pixels) and above and frame rates that are as high as 120 Hz.

Most mobile games are "snackable", with playing time of 4-5 minutes per session[12]. Top multiplayer games have an average playing time of ~9 minutes per session and an average of 4 sessions per day.

Application	Consumption (MB/hour)	Average Daily Usage (minutes)
Clash Royale	16[13]	30
PUBG	50	30
Roblox	300[14]	156[15]

There isn't a definitive specification for network latency in multiplayer action games, but recommendations[16][17] from industry participants suggest that 15~50 millisecond latency is acceptable.

The extension of mobile multiplayer games into the metaverse is expected to manifest itself as both AR and VR experiences in the urban environment. In the former case, AR will result in the gamification of a rich visual background. In the latter case, VR experiences will provide an escape for consumers on public transportation, in streets and parks and within public buildings.

[12] Mobile Game Session Length: How to Track & Increase It

[13] How much Internet data does Clash Royale use?

[14] How much Internet data does Roblox use?

[15] Roblox Corporation SEC Form S-1 p.3

[16] Internet Requirements for Gaming in 2022, Streamscheme

[17] How to improve your gaming latency, Centurylink

Augmented Reality

Increasing number of AR users

Augmented reality is becoming an important part of the mobile experience, across a variety of . In Q1 2022, over 250 million Snapchatters engaged with augmented reality every day on average, out of 330 million Daily Active Users[18].
While large in number, these experiences have for the most part been individual and independent of location.

AR drives shared outdoor experiences

Geolocation ties experiences to specific locations and introduces social interaction. A user can, for example, find out more about a location, activity or event, while sharing it with the user's social connections.

Shared experiences can create more complex interactions. Pokemon Go has 80 million average monthly players[19]. Gameplay consumes a few 10s kilobits per second[20]. The wide distribution of these players means that the load at any point in the network is not particularly high.

However, aggregating players in a small area has a profound effect on network performance. Niantic hosted a Pokemon Fest event at Westfalen Park, Dortmund, Germany in 2019, which attracted 100,000 people. Even with a substantial deployment of 4G small cells around the park, the network was overwhelmed[21].

[18] Snap Inc. Announces First Quarter 2022 Financial Results

[19] Pokemon Go Live Player Count and Statistics

[20] Pokémon GO Isn't a Mobile Data Hog—and This Data Proves It

[21] Gamesbeat interview with Verizon and Niantic

Gaming is the first and most obvious application of consumer AR. Beyond gaming, Snap reports[22] that 83% of surveyed consumers are interested in accessing AR maps that help navigate, 80% of consumers are interested in exploring the world with AR. The diversity of urban locations where AR experiences are available will increase - starting from stadiums and event halls and growing to encompass parks, tourist attractions and public transportation.

The experience is increasingly a shared, as opposed to an individual, experience. This drives the need for greater coordination between users and hence lower inter-user as well as system latency[23]. Multiplayer games such as Niantic's Codename: Urban Legends[24] require specific network optimizations for bandwidth and latency.

Photorealism in AR drives network capacity and edge compute

The current generation of dedicated XR devices require a large amount of computing power and, if mobile, a correspondingly large battery. In order to achieve costs that are suitable for a consumer product and therefore support broad adoption, it is necessary to significantly reduce the application burden on the device by moving compute from the device into the network.

In 2013 Oculus, now Meta Reality Labs, established a threshold for system latency ("motion to photons") of 20 milliseconds that has been generally adopted as standard[25]. Recently, Meta Connectivity has suggested a target system latency of 25 milliseconds and throughput of 25 Mbps[26]. The latter is also assumed in the Ericsson Mobility Calculator.

[22] Augmentality Shift

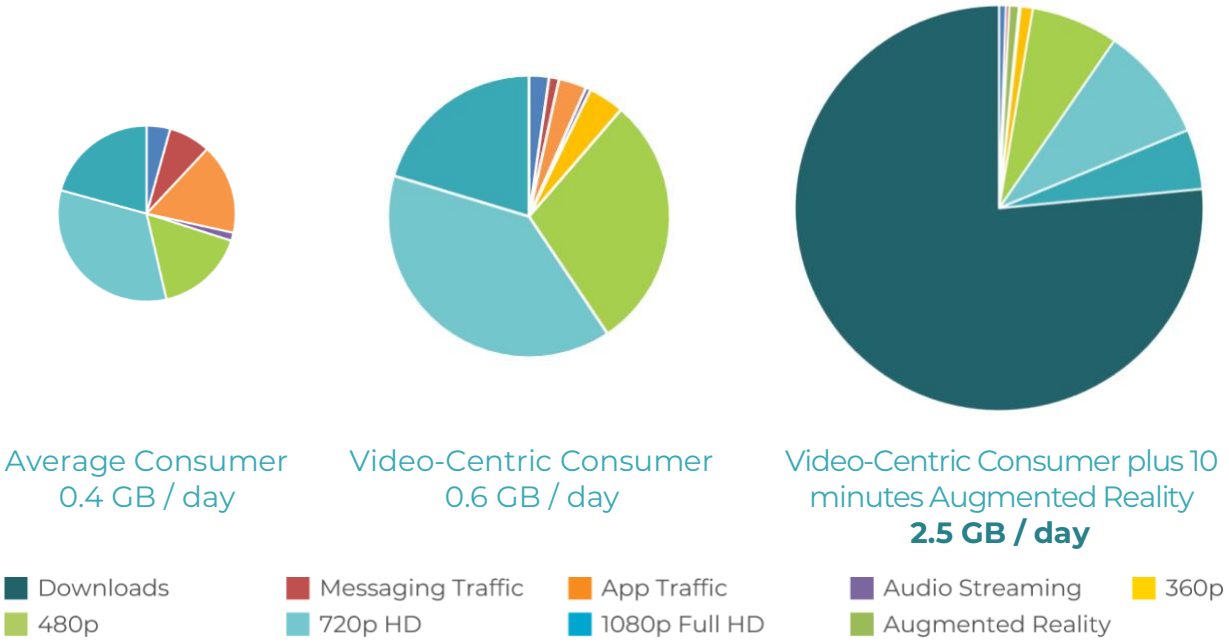
[23] Network performance requirements of Augmented Reality Systems

[24] Niantic Planet-Scale AR Alliance Accelerates Social AR Future in Codename: Urban Legends

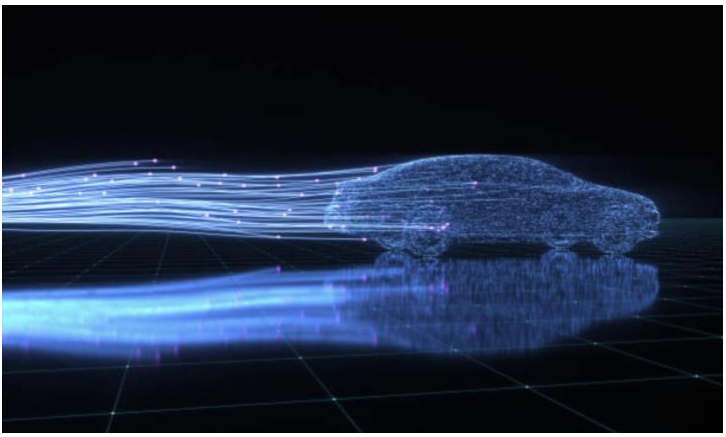
[25] Latency mitigation strategies (originally at http://www.altdevblogaday.com/)

[26] FWA is a success. Now the hunt is on for the next big 5G use case

In a modest scenario of 10 minutes of AR usage a day, data consumption reaches 2.5 GB a day, 4 times that of the video-centric user and greater than 6 times that of the average user.



Non-consumer use cases



Connected Vehicles

The environment for mobile connectivity to vehicles is complex - vehicle manufacturers, infrastructure providers, operators and a very large number of jurisdictions (cities, counties, etc) must collaborate to create an end-to-end service which must comply with the regulatory framework.

Mobile connections to vehicles are currently used by the vehicle manufacturer for predictive diagnosis; that is, to determine whether a single vehicle is likely to fail, or a model of vehicle is collectively demonstrating a mode of failure. The data is non-safety critical and non-time sensitive. The mobile connection may also be used for calls to a helpline for on-road or roadside assistance.

The first class of driving-oriented safety communications to be deployed are infrastructure to vehicle (I2V) messages that communicate the state of the environment to the driver; that is, traffic light status (time to green, turning red), slowing traffic and hazardous weather conditions. These convenience messages aid the driver in interpreting the driving conditions, reducing stress and increasing safety. An example of this is the collaboration between Audi, Traffic Technology Services and several municipalities in the US[27] to deploy traffic-light information services.

The second class of driving-oriented safety communications provide information about the state of the vehicle; that is, speed, direction, lane changes and proximity of other objects.

Safety communication relies on messages (for example, basic safety message (BSM) in the US, cooperative awareness message (CAM) in the European Union) that are of the order of a few hundred bytes. While convenience messages are generally non-real time, safety messages are real-time with message intervals of 100 milliseconds or so. While the traffic associated with an individual vehicle is low, the traffic in aggregate in areas of high vehicle density becomes high and compliance with latency requirements becomes challenging.

Two architectures are considered for the communication of low-latency messages: peer-to-peer and node-to-hub-to-node. The former requires the allocation of dedicated spectrum or sidelink transmissions in spectrum licensed to mobile operators. The latter requires guaranteed quality of service through allocated network capacity.
Autonomous vehicle operation requires the processing of large amounts of sensor data with very low latency and a very high quality of service guarantee. It is unlikely that any part of the processing loop will be conducted outside of the vehicle.
Most autonomous vehicle control systems rely on machine learning (ML) models. The models are trained with data obtained from driving experience. The data must be offloaded to the ML training system, and new models must be loaded to the vehicle.

[27] Audi brings Traffic Light Information to Los Angeles, New York, and San Francisco

This data can be voluminous but the transfers have no time dependency and they can be made when the vehicle is not in use. These transfers are not expected to create a significant load on the mobile network.

An intermediate step to fully-autonomous vehicles might be semi-autonomous vehicles with remote operator assistance. In this scenario, video from different viewpoints must be available to the operator.

Significant load from passenger cars is unlikely during the forecast timeframe; however, the load from trucks, buses and other vehicles with a more constrained operating environment may become significant.

Delivery by drone

Delivery by drone is an attractive alternative to conventional delivery methods for high-value / weight and time-sensitive items such as medical supplies and fast foods. Drones will initially serve suburban and rural locations until the logistics of serving multi-floor buildings can be addressed.

Drone flights are restricted by regulation to visual line of sight under the control of a dedicated operator. Coordinated flight management systems are being developed to eliminate the need for a human operator per flight, which will lead to the removal of this restriction and significantly reduce the operating cost.

Drones cruise at an altitude of 40 - 60 meters. Flight destinations are within a 2 kilometer radius of a hub for the highest efficiency. Drone flights can be effectively served by a mobile network macrocell, with the exception of coverage gaps caused by shadowing.

Telemetry processing is undertaken on the drone. Data traffic between the drone and ground control is primarily telemetry information for the drone operator. Coordinated

flight management systems would allow the offloading of telemetry processing from the drone, which would reduce the size and weight of the electronics sub-system. This would not substantially increase the data traffic but it would increase the required level of link reliability.

Analyses by Airbus[28] and the Delft University of Technology[29] forecast drone flight densities in the approximate range of 1~5 flights per square kilometer in urban areas in the early 2030s. This is similar to Manna Aero's estimate of 20 drones per 2-kilometer radius cell.

The data rate of drone telemetry is ~1 Mbps. The estimates of drone density above suggest that the aggregate data demand at the macrocell will not be significant. However, the need for high quality-of-service and relatively low latency imply that a differentiated service is required from the mobile network operator.

Conclusion

In this study, we looked at various use cases and predicted their impact on the mobile network in the 2022-2027 timeframe.

Consumer use cases will continue to drive the bulk of the growth in network traffic. The increasing prevalence of video on all types of sites, the increasing resolution of streaming video services and the reorientation of social media towards video are all contributing factors.

The growth in multiplayer games provides a foretaste of the latency challenges that network operators will face from emerging applications. Latency requirements of 50 milliseconds or less stress existing 4G LTE networks.

[28] The Blueprint for the Sky: The Roadmap for the Safe Integration of Autonomous Aircraft

[29] Estimation of traffic density from drone-based delivery in very low level urban airspace, Journal of Air Transport Management, Volume 88, 2020

The transition to 5G addresses some of the shortcomings. Niantic[30] has found that a 5G small cell coupled with edge compute can deliver a 3x improvement in latency, 2.5x improvement in spectrum capacity and a 1.5x improvement in battery efficiency over 4G LTE.

AR in particular will have a profound effect on the mobile network. 10 minutes of AR use at an average throughput of 25 Mbps will quadruple the average video-centric user's data consumption, and consistent service will be required across the network, even at the cell edge. System latency of 25 milliseconds or less will require architectures that deploy compute resources close to the edge, not in remote data centers. The metaverse implies a metanetwork.

Non-consumer use cases such as connected vehicles and delivery by drone will have an impact later in the forecast period and mainly on the macrocell layer, which may drive the need for greater capacity at the small cell layer. More substantial impact on the network will occur if remote monitoring by a human operator is required.

[30] Niantic, "Evolution and Reach of 5G Gaming", MWC 2022