5G Prospects
– Key Capabilities to Unlock Digital Opportunities –

by NGMN Alliance

Version:	**1.1**
Date:	**01-07-2016**
Document Type:	**Final Deliverable (approved)**
Confidentiality Class:	**P - Public**
Authorised Recipients: (for CR documents only)	

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Abstract

To ensure that the capabilities delivered by 5G are meaningful and timely, this paper uncovers the mutual implications of technology and business drivers, highlighting the key capabilities that 5G must deliver, as well as key issues in realising the 5G vision as stipulated by the NGMN 5G White Paper. Insights are presented for the three major service categories, enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable and low latency communications (uRLLC):

- **eMBB** – 5G should enable integration of various deployment and business models to facilitate availability of large bandwidths cost efficiently. An identity abstraction and control layer is essential to provide consistent user experience in highly heterogeneous environments.
- **mMTC** – 5G should bring down the costs of provisioning for various mMTC connectivity solutions addressing individual business needs, through a standardized modular framework. Differentiation and competition should drive realization of various IoT benefits, closely working together with stakeholders.
- **uRLLC** – 5G should push down the cost curve to unlock new uRLLC use cases. Cross-industry debate needs to be facilitated to reduce uncertainties around external dependencies to determine a sensible capabilities target for 5G and their market availability timing.

The scope of services envisioned to be supported by 5G poses a challenge for global harmonization and capability prioritization. Hence, 5G should be designed in a modular manner to efficiently accommodate various demands and strategies. The technology design should allow operators to focus investments depending on market contexts and business opportunities, while leveraging existing assets.

Document History

Date	Version	Author	Changes
06/06/2016	V 1.0	Mikio Iwamura, NTT DOCOMO	Initial version for board approval
22/06/2016	V 1.1	Mikio Iwamura, NTT DOCOMO	Reflected board feedback

Contents

LIST OF ACRONYMS

5G	Fifth generation mobile communication system
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
B2B	Business to Business
B2C	Business to Consumer
CAGR	Compound Annual Growth Rate
cmW	Centimetre Wave
CSG	Closed Subscriber Group
DSL	Digital Subscriber Line
eMBB	Enhanced Mobile Broadband
EPC	Evolved Packet Core
FTTH	Fibre-to-the-Home
HD	High Definition
IAM	Identity and Authentication Management
ICT	Information and Communication Technology
IMS	IP Multimedia Subsystem
IoT	Internet of Things
IPR	Intellectual Property Rights
ITU-R	International Telecommunications Union Radiocommunication Sector
KPI	Key Performance Indicator
L1	Layer 1
L2	Layer 2
LAA	License-Assisted Access
LPWAN	Low-Power Wide Area Network
LTE	Long Term Evolution
MEC	Mobile Edge Computing
MIMO	Multiple Input Multiple Output
mMTC	Massive Machine-Type Communications
mmW	Millimetre Wave
MNO	Mobile Network Operator
MSISDN	Mobile Station International Subscriber Directory Number
MVNO	Mobile Virtual Network Operator
NB-IoT	Narrowband IoT
NDA	Non-disclosure Agreement
NFV	Network Function Virtualization
OTT	Over-the-Top
PoS	Point of Sale
QoE	Quality of Experience
RAT	Radio Access Technology
RCS	Rich Communication Services
ROI	Return on Investment
RTT	Round Trip Time
SDN	Software Defined Networking
SLA/R	Service Level Agreement/Report
SME	Small and Medium-Sized Enterprise
SINR	Signal-to-Interference-and-Noise Ratio
TTI	Transmission Time Interval
U/I	User Interface
UGC	User Generated Content
uRLLC	Ultra-Reliable and Low Latency Communications
VoLTE	Voice over LTE
VR	Virtual Reality
XaaS	Everything-as-a-Service

1 INTRODUCTION

Rapid growth of the digital eco-system is transforming our society, changing how contexts are exchanged among people and things. To unlock the digital opportunities, the underlying telecom layer needs to expand its capabilities and flexibility to accommodate various applications. This calls for new technologies, often collectively referred to as "5G" [1]. While many technology concepts are on proposition, such as massive MIMO, control-/ data-plane split, and virtualization, they each have business implications and require investment. Conversely, changes in the business environment, such as access/ service separation, commoditization, and the Internet of Things (IoT), have implications on what technology should deliver. This paper uncovers such mutual implications, highlighting the essential issues that need to be addressed to substantiate digital opportunities.

In an abstract view, 5G can be described in two ways, as also illustrated in Figure 1:

- **Expanded network capabilities** – 5G will push the performance envelope in all directions, e.g., data rates, capacity, latency, reliability, and supported number of devices. This will be enabled mainly by new radio access technology (utilizing wider spectrum, massive MIMO, etc.) and architecture design (dual-connectivity, mobile edge computing (MEC), etc.).
- **Intelligent "poly-morphic" system** – 5G will enable fast and cost efficient provisioning of various network slices by means of software. Virtualization of network functions (NFV) and control-/ data-plane split (utilizing software defined networking (SDN)) will enable agile morphing of the network capabilities, tailoring to the dynamic needs of concurrent applications, thereby facilitating new businesses through open innovation.

These two engines will enable new applications in various directions that can be largely categorized into three groups [2]:

- Enhanced mobile broadband (eMBB)
- Massive machine type communications (mMTC)
- Ultra-reliable and low-latency communications (uRLLC)

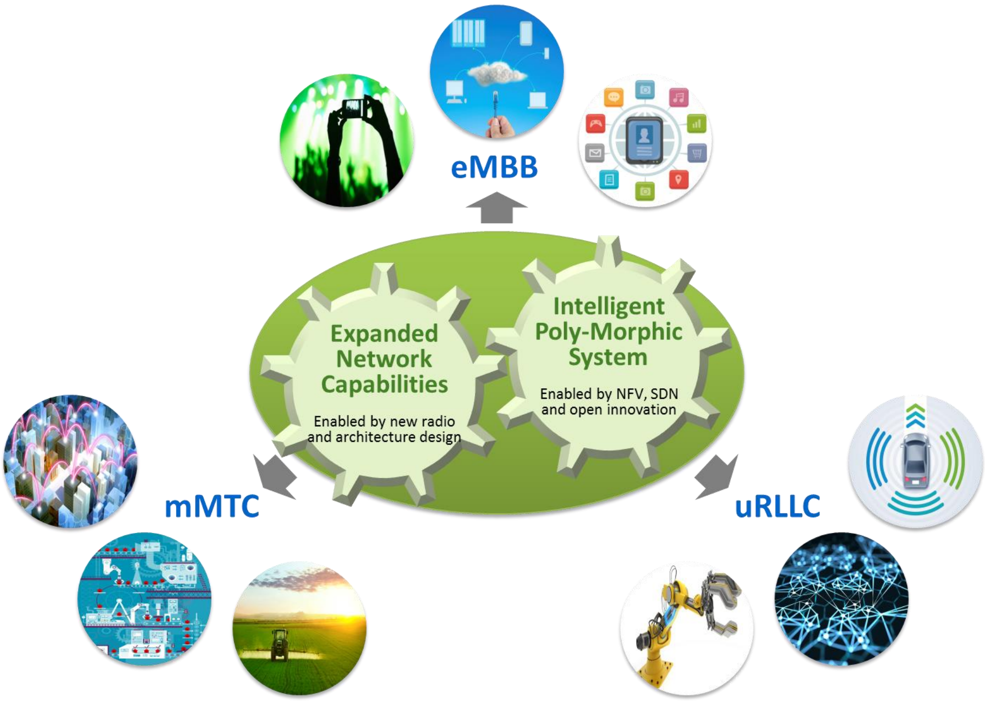

Figure 1: An abstract view of 5G.

The subsequent sections discuss the prospects for each of eMBB, mMTC and uRLLC, incorporating both technology and business viewpoints. The key capabilities and issues are uncovered to make the 5G vision reality.

2 ENHANCED MOBILE BROADBAND (EMBB)

2.1 eMBB drivers

Enhanced mobile broadband (eMBB) applications are largely driven by

- **Traffic demand** – In many markets traffic has been growing at 1.5-2.0 CAGR since the introduction of smartphones, although recent trends indicate a growth decline, e.g., to 1.2 CAGR, in developed markets. As a result some markets observe 10-15 GB of traffic being consumed per user and month on average, on flat rate LTE tariffs. It has been reported that over 80% of cellular Internet traffic is consumed indoors and the majority of Internet traffic is video. Users are demanding higher throughputs e.g., to meet various video needs, such as HD video streaming.
- **Operator competition** – Operators are endeavouring to provide more competitive, attractive data plans, while service propositions are being eroded by over-the-top (OTT) alternatives. Competition is mainly in two directions, i.e., to offer cheaper rates, often focusing on particular customer segments as pursued by many MVNOs, or to offer value-add, exemplified by larger data caps, faster data rates, and bundling, with for example, zero-rated videos (as seen in the US).
- **Incentives to improve attractiveness of countries, cities and premises** – Many governments and municipalities see enhanced broadband availability as a key to future productivity and economic growth (enriching the life of citizens, attracting more tourists, and facilitating businesses) and are leading initiatives to improve broadband environments. Similarly, building owners have incentives to invest into connectivity provisioning to sustain property value. The same applies to any kind of space, e.g., to airports, hotels, shopping malls, coffee shops, public transport, and even cars and airplanes. The cost for connectivity provisioning is often paid by indirect sources, making the cost invisible to the end user.

In a nutshell eMBB is to make higher data rates available wherever and whenever needed at sustainable cost models. Using two KPIs, namely, *user experienced data rate* and *availability*, the eMBB space can be depicted as in Figure 2. Availability encompasses both coverage and time aspects, i.e., it is a probability that a user can experience a certain data rate.

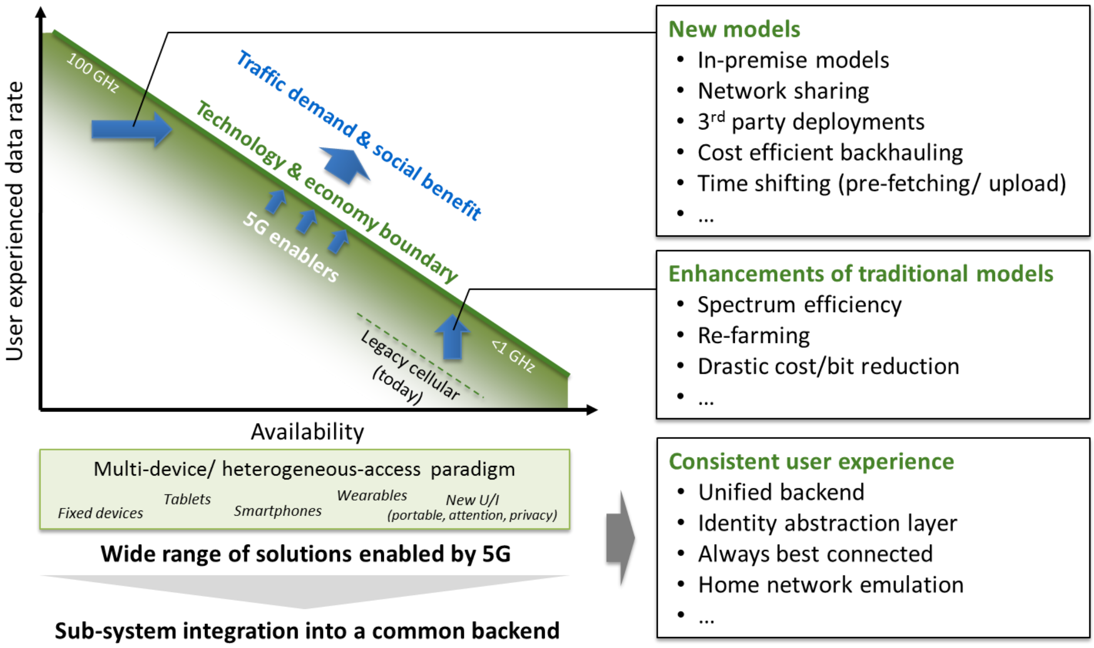

Figure 2: eMBB prospects.

With wide recognition of the power of mobile broadband and social demand, ITU-R WRC-15 identified a range of new spectrum for potential mobile use, up to the millimetre wave (mmW) range. The broad range of spectrum (<1 GHz to 100 GHz), with diverse propagation properties, implies that a single model (technology design, deployment model, business model, etc.) may not be efficient and sustainable. The aim is to push the achievable boundary by technology and business means, or “5G enablers”, desirably unlocking new revenue streams to leverage investments (note that such a boundary may not be linear in reality – the figure is merely conceptual).

2.2 Device perspective

Customers tend to use the most suitable device for the situation, e.g., a tablet at home, a laptop at office, and a smart watch on the move, thereby leading to a multi-device per user paradigm. This indicates that a single form factor is not optimal for various environments. Applications are being increasingly designed to fit the form factor and user interface (U/I). As such, the type of devices and applications used will have strong correlation to the circumstance, e.g., indoor/ outdoor, private/ public, or stationary/ active. There seem to be several decisive factors:

- **Portability** – Form factors and battery capacity define the portability of a device. Devices also need to be fashionable to be carried outdoors. Wearable devices that could exploit availability of large bandwidth/ data rates are also being developed (e.g., virtual reality (VR) glasses and other head-mounted displays). However, it is not obvious if the current designs can achieve similar mainstream adoption as smartphones.
- **Attention** – The level of attention drawn by the use of U/I will define what devices and applications are used under what circumstances. Richer contents and complex manipulations capture more attention and thus limit the environments in which they can be safely used. For example watching a video or typing a search query while walking, driving, or cycling will draw away the attention required to watch the road. Hence, such usage will require the user to be more or less stationary.
- **Privacy** – Privacy of the environment, including the ability of the U/I to seclude and the nature of content, imposes barriers to what devices and applications may be used. It is hard to imagine work-related video conferencing in public crowds, and typing emails or browsing private

contents under exposure may not be comfortable for many. Use of display filters improves privacy and expands the usable space, but such solutions are add-ons rather than inherent design.
- **Urgency** – A user may take actions to use certain devices or applications in an urgency. For instance, a user may make a phone call in a train, if the train is running late to attend a business meeting. A user may watch a live sports game in a train on his/ her tablet that he/ she does not normally carry when going out. As such, urgency has some influence to the priorities among different factors (portability, attention, and privacy).

These fundamental properties suggest:

- With the proven concept of "Internet in your pocket", smartphones will continue to be the central personal device. The existing form factors and U/I configurations of smartphones are designed to comply with human usage patterns (carrying the smartphone in a trouser pocket) or limitations (image resolution property of the human eye). This implies applications may remain more or less similar or limited to rather straight forward enhancements, and this could lead to saturation of traffic growth in developed markets.
- Many of the bandwidth demanding applications envisioned for 5G, such as high resolution videos (HD, 4K, 8K) and VR applications, are likely to stay mostly indoors, or restricted under conditions where the user is stationary, e.g., when sitting in a train.

Therefore, disruption in the eMBB domain will largely depend on potentials for new U/I devices[1]. A new U/I device may unlock new applications and usage models, if it conveys the following properties:

- Fashionable, compact and battery efficient to be portable;
- Change the level of attention required to manipulate/ use the device; and
- Change the level of privacy afforded when using the device.

A new U/I device may also call for new operating systems, and this could open opportunities for an eco-system change. Nevertheless, a new U/I device is only a prerequisite, and attractive applications need to be developed to drive further industry growth. In this context augmented reality (AR) seems to be an interesting area, having the potential to address portability, attention, and privacy. AR services can be used anywhere, including outdoors where cellular systems are anticipated to sustain relevance. However, mainstream adoption will require the eventual availability of killer apps for which people are willing to pay.

Another aspect to consider is penetration of shared devices. The concept of shared devices has long been understood for desktop systems, and is expanding toward mobile devices. Shared devices are penetrating beyond personal/ home or business use, and are on offer at many places, like hotels, libraries, and cafes, while personalization is enabled by cloud services. The multi-device paradigm, including shared devices, implies recognition of the end user is more prevalent than the device itself, and per user revenue streams more relevant than per device.

2.3 Access perspective

Mobile network operators (MNOs) need to address the growing traffic and have incentives to invest into eMBB as their sustained core business. In this regard the access part has a major role, but the level of investment will largely depend on the revenue opportunities. As users are increasingly reluctant to pay for the amount of data, when data volumes continue to grow, drastic reduction of cost-per-bit will be crucial.

The cellular model (investing into macro cellular deployments and collecting returns by B2C) was cost-effective using low frequencies (<2 GHz). Since "availability" can be efficiently achieved using low

[1] Note this encompasses two aspects, i.e., new U/I (which may be realized to some extent by application design) and new devices that facilitate the use of new U/I.

frequencies at existing sites, the main direction for improvement with the legacy cellular model will be to increase the "user experienced data rate" (i.e., the right-bottom part of Figure 2). Given the scarce spectrum at low frequencies and near Shannon performance of LTE (for a given signal-to-interference and noise power ratio (SINR)), a viable approach will be to improve the overall geographic distribution of SINR, e.g., using higher order MIMO, interference cancellation/ management, and densification, that is, to spatially pack more channels. However, these approaches will likely incur considerable costs, and densification by means of additional outdoor sites may lead to radio overdose, i.e., too much interference that may negate signal strength and capacity gains.

Thus, new spectrum opportunities at higher frequencies, up to the millimetre wave (mmW) range, is sought for. Since the signal generator noise alone will destroy the LTE signal at frequencies above 10 GHz, a new radio access technology (RAT) will be needed to unlock such spectrum. However, higher frequencies will suffer larger path loss (although large beam gains of massive MIMO can compensate to some extent) and will not penetrate indoors. Hence, relevance of investments into the traditional cellular model will strongly depend on the achievable coverage, especially the outdoor to indoor penetration, using higher frequencies at existing sites.

The ability of the traditional cellular model to satisfy user demands (in terms of data rates and caps) will have strong impacts on the end user incentive to purchase their own last mile solution (e.g., FTTH, DSL, Wi-Fi/ Wi-Gig). In this regard femto and closed-subscriber group (CSG) concepts were never successful, partly due to regulations (the need to register base stations for spectrum license and ensure operation at the spot, etc.) but largely due to misbranding. That is, customers are reluctant to pay for connectivity provisioning, when they expect this as an operator responsibility. Meanwhile, Wi-Fi has been gaining popularity in the residential space. In Japan more than 70% of households with fixed broadband contracts (FTTH or DSL) operate their own Wi-Fi access point.

A challenge in utilizing higher frequencies will be to improve the "availability" of large data rates that can be brought by the available spectrum bandwidth (i.e., the left-top part of Figure 2). While there are certainly technical challenges to unlock the new spectrum, significant challenges also seem to lie ahead in the economics. To efficiently improve "availability", new models need to be considered:

- **Network sharing** – Densification will segment the 3D space, leading to loss of statistical multiplexing gains, that is, the load per cell will highly vary (e.g., due to demographics, applications, peak time). Hence, lower return on investment (ROI) may be anticipated, and ways to reduce cost will be crucial, including site loan fees, equipment procurement, maintenance, and energy bills. This calls for network sharing models. Sharing models may also be relevant considering that public networks, using lamp posts and street furniture, are likely to be commissioned by a single operator. For this purpose operators may form joint ventures, or a third-party operator may deploy such networks and lease capacities to multiple operators. A user will appreciate an "always best connected" experience, aggregating use of multiple networks. Technology needs to support these scenarios.

- **In-premise models** – Building owners have incentives to invest into connectivity provisioning to sustain property value. Office buildings need to support frequent change of tenants, as SMEs are being facilitated by ICT. Shopping malls also need to adapt to change of tenants, as each may pose different applications, e.g., point of sale (POS) systems, or personalized ads and coupons based on analytics. University campuses require virtually separated networks e.g., for students, faculty, visitors, and departments. Hence, various virtual secure networks need to be dynamically created and managed, desirably using the same physical network to save costs. Such in-premise solutions will require:
    - Deployment (ownership) is possible by the property owner;
    - Cost efficient deployment (e.g., simplified mounting and installation) and back-/ front-hauling (e.g., using Ethernet, wireless);
    - Accessibility can be controlled by the owner/ client; and

o Service level agreements/ reports (SLA/ SLR) can be flexibly updated.

To address these requirements, NFV and SDN will be essential, alleviating the need to manually configure physical network equipment.

The current indoor cellular solutions are too expensive and inflexible to address these requirements. License-assisted access (LAA) has potentials to resolve some of the issues and use of the so called “side-links” is also interesting, i.e., to reuse the mass-produced chipsets for user equipment also at small cells. Nevertheless, these will compete against Wi-Fi and Wi-Gig, both of which are also evolving.

It should be highlighted that the access technology itself is not the essential issue. A question is rather what technology is successful in creating a compelling eco-system (Wi-Fi already has an established eco-system), with the right branding, scale, and business models. An operator can choose to employ the best technology that meets their needs.

- **Backhaul models** – Indoor networks require a backhaul to connect to a wider network. To cope with larger bandwidth and traffic demands in the indoor space, backhauls also need more capacity. A possibility for 5G is that a new RAT provides such backhauls, using mmW and massive MIMO. This could be beneficial especially where fibre is not widely available. In addition, wireless backhaul will be essential for vehicles. With the advent of highly automated transport systems (e.g., autonomous driving), in-vehicle connectivity demand will increase. Vehicles are anticipated to be increasingly equipped with on board access points. 5G could make strong business cases for cost effective provisioning of broadband and reliable mobile wireless backhaul solutions for those on board access points.

- **Time shifting** – Significantly higher throughput under limited new RAT coverage (e.g., mmW RAT) and increased memory capacity on end user devices (e.g., potentially in the terabyte order beyond 2020, considering falling memory prices) may imply different deployment/ usage models, e.g., pre-fetching all library-type contents relevant for the user at certain touch points, e.g., when crossing new RAT small cell coverage. A similar approach can be considered for uploading user generated contents (UGC). Train stations and airports can be sought for such deployments, but where to place those small cells and how to charge the user needs careful consideration. Time shifting can be a way to improve the effective “availability” for non-realtime data.

It should also be highlighted that eMBB is not only for B2C, but also for B2B/ B2B2C. Various applications will benefit from eMBB, e.g., surveillance cameras, digital map update for navigation systems, virtual classrooms, and VR/ AR assistance at construction sites. Unforeseen applications may call for new models and requirements beyond the ones listed above. 5G will need to cater for any unknown applications that may arise beyond our imagination today. The foundation will be to have the right toolset to address different spaces, cost efficiently. Depending on the traffic properties and usage environment (e.g., data rate and availability requirements, public vs private, mobile vs stationary), an operator can choose what tools to apply.

When a new RAT is introduced, an operator has to ensure that the value proposition (e.g., user experienced data rates) is attractive such that customers are willing to pay. It is anticipated that LTE-Advanced will continue to be widely deployed, aggregating more bands in the process. To ensure attractive value proposition in this context and to allow for smooth migration, the capability to aggregate the new RAT and LTE will be essential for the following reasons:

- A new RAT could be introduced either on re-farmed spectrum or some new band. If the new RAT is deployed on considerably narrower bandwidth compared to the aggregated bandwidth available for LTE-Advanced, the new RAT “alone” may not outperform LTE-Advanced, unless new deployments (e.g., densification) are considered.

- Provision of seamless new RAT coverage from day one is unlikely, especially for deployments utilizing higher frequency bands.

Still, stand-alone operation of the new RAT could also be envisioned in markets where spectrum (either re-farmed or new) and deployment could achieve sufficient coverage (e.g., to cope with signalling traffic from legacy fall back/ interworking).

2.4 Backend perspective

The previous discussions suggest a foreseeable future that is highly heterogeneous, with multi-device, multi-access, and diverging range of services. This is natural as segmentation and tailoring follows market theory, when a market is maturing. A challenge is to provide consistent and seamless user experience under such a paradigm.

It is clear that an abstraction layer is needed to control various networks and devices with a global view. The overall system should be able to steer customers over various networks (sub-systems), based on the user and network context, e.g., device and application under use, mobility, available sub-systems, load conditions, realtime quality of experience (QoE), and personal preferences (e.g., cost considerations), to ensure an "always best connected" experience. The sub-systems could include wide and local area networks, some of which may be third-party operated. NFV and SDN will play essential roles to provide the flexibility and agility to address dynamic demands. Data analytics could help optimise control, having in mind that growing use of end-to-end encryption may affect the effectiveness of such optimizations and need careful consideration.

Considering diverse applications and the need to tailor network functionalities (by means of network slicing), a single charging model is clearly insufficient to address all the needs. The charging mechanisms need to be extended beyond time and volume information, to include context specific elements, for example, differentiating traffic patterns/ profiles (users vs objects, broadband vs narrowband, mobile vs static, peak vs off-peak), state of the network (level of cell congestion, licensed vs unlicensed spectrum, traffic terminated locally vs centralized routing) and the actual delivered performance (level of compliance with given availability and reliability commitments). One time service charging should also be enabled, similar to many Wi-Fi services on offer. Operators will be responsible to make the charging models transparent to the user, as they have been with legacy.

Involving various connectivity providers, various SLAs may need to be managed, and control policies need to be crafted ensuring user transparency. This could lead to complex policies and implementation, especially when different networks involve different price models. Ambient control over multiple networks (e.g., cellular and Wi-Fi) by smartphones, without the user consent, has created user complaints and led to some lawsuits in the US. In relation, one of the difficulties of LAA (including Wi-Fi aggregation) is establishing a clear charging model, when the user cannot distinguish (and does not really care) how much traffic is transported by unlicensed spectrum (which has been perceived as free) or licensed spectrum. It is also difficult for the network to count such traffic (if possible at all) anyway, with complex L2 transport. Thus, pricing models will have to be simplified, for example, to a flat rate to get data rate boosts by certain sub-systems (LAA, new mmW RAT, etc.) or in the extreme case, a complete flat rate over all accesses, if an operator chooses to play integration/ aggregation models. The charging model clearly impacts the control design, and given that price models may change depending on market dynamics, the control needs to reside in the network side. This applies also when aggregation models across multiple operator networks (e.g., Google Fi) is considered.

A critical component in this context is identity and authentication management (IAM). The above discussion clearly indicates that an IAM abstraction layer is needed, linking a user identity to multiple devices, services, and accesses, and recognizing the user under all circumstances. Such an IAM layer could facilitate various applications, alleviating cumbersome credential management by the user. The IAM layer may sit over-the-top or in-between the connectivity and service layers. Although numbering schemes like MSISDN could be considered, with billions of users already connected and the anticipated growth (also considering IoT), numbering alone may not be sufficient and scalable. In any case some standardized approach may be needed to ensure interoperability, especially if operators need to address identity portability.

2.5 Key points

From the above discussion, the key points for eMBB can be summarized as follows:

- Fundamentally, eMBB is to improve the user experienced data rate and the availability of those data rates across time and space.
- Disruption in the eMBB domain will largely depend on potentials for new U/I devices, which are portable while changing the level of attention drawn and privacy afforded in using the device.
- New spectrum needs to be exploited to address traffic growth, and new models (e.g., network sharing, in-premise models, backhaul models, and time shifting) need to be considered to make large bandwidth systems available cost efficiently.
- A common IAM and control layer, putting the user identity as the central key, is needed to ensure consistent user experience under highly heterogeneous environment (multiple devices, access sub-systems, and services).

3 MASSIVE MACHINE TYPE COMMUNICATIONS (MMTC)

3.1 mMTC drivers

Massive machine type communications (mMTC) applications are largely driven by

- **Business precision and efficiency** – Various industries are recognizing the value of data-oriented optimization of business processes and resource usage. This includes the areas of production, logistics, customer services, energy consumption, and maintenance. Environment and human knowledge is increasingly digitized to assist decisions, thereby increasing the precision and efficiency of value delivery, while at the same time improving sustainability of the environment.
- **Technology** – Latest advances in technology (e.g., in sensors/ actuators, access technology, data storage, cloud computing, big data, and artificial intelligence (AI)) are making ICT solutions in this domain feasible and affordable. Besides, ICT players are positioning themselves in the emerging IoT value space, promoting both solutions and platforms.

3.2 Directions and issues

A high level view of the mMTC and IoT space is depicted in Figure 3. Note the difference between these two terms: IoT in this context is understood as the end-to-end ecosystem, including the application and value-adds from various data insights, etc., whereas mMTC is understood as the connectivity part of the IoT ecosystem. The mMTC space is the foundation that involves telecom infrastructure and requires standardization to ensure interoperability and scale. Additional value-added propositions in the IoT space can be offered by various players (including mobile operators) on top of the mMTC foundation.

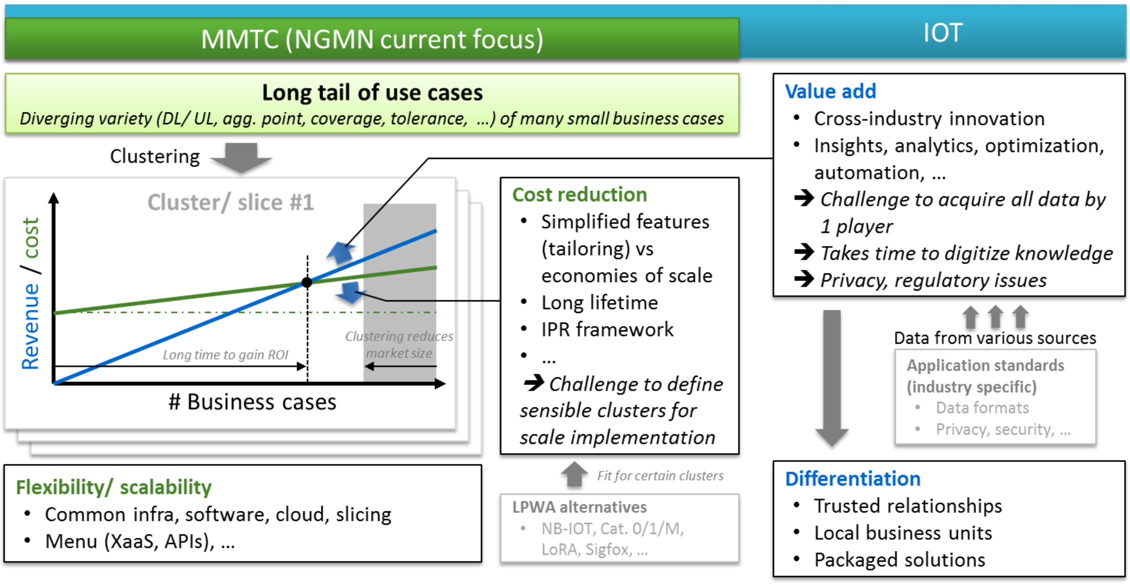

Figure 3: mMTC prospects.

The use cases supported by mMTC are generally B2B (or B2B2C), having a long tail, i.e., with each having potentially very different requirements, e.g., in terms of downlink vs uplink, relevance of aggregation points, required coverage, tolerance against failures, etc. This implies that a single solution cannot address (or will be far too expensive for) all use cases, and clustering is important to achieve sufficient scale. That is, to cluster use cases into groups with similar requirements, and providing a tailored solution (e.g., data rate, latency) for each of those groups.

A fundamental challenge of mMTC is that revenue per device is generally small; it may well be only 1% of the revenue typically provided by smartphones. Hence, many business cases need to be accumulated – which translates to a long time – to gain ROI. Therefore, cost reduction is critical to bring down the breakeven point. A number of approaches can be considered to bring down the cost:

- **Simplify (tailor) the features depending on the business case** – Removal/ simplification of mobility management and session management features could help reduce the cost. Restricting transmission modes and buffer sizes may also help reduce the cost, as well as removing duplex capabilities or even the downlink or the uplink completely. Device costs in the order of few dollars need to be achieved. However, tailoring (or clustering) reduces economies of scale, and clustering reduces the potential business cases that can be supported by a cluster.
- **Enduring solution** – This includes device lifetime, battery lifetime, etc. The difference between vertical industry speed (product lifecycle) and telecom industry speed (generation cycle) becomes an issue, i.e., spectrum re-farming and migration can be detrimental for certain business cases and need careful consideration. In addition, the sheer number of devices may make keeping track of device locations difficult, and this will create significant challenges for migration. Hence, transmissions by devices should be controlled by the network, as otherwise, early solutions may restrict the spectrum use, and any future enhancements may be bound by backward compatibility. Regulations could help in this regard.
- **IPR framework** – IPR licensing models need to be established to ensure IPR license fees do not prevent the necessary cost reduction, while giving sufficient incentives for developers.
- **Use common infrastructure** – This is perhaps the most essential approach to bring down the cost curve, especially the fixed cost. Dedicated and specialized solutions may be hard to finance. Trunking gains and economies of scale should be sought for by centralizing network functions (as well as operations and management), unless the use case requires stringent latency or a local in-premise solution for other reasons, e.g., security. Yet, to cope with diverging requirements, a software-oriented network design will be fundamental and network slicing

should be able to flexibly address different business needs. Through the definition of relevant APIs, everything-as-a-Service (XaaS) models should be enabled, thereby fostering open innovation.

A key challenge for mMTC is therefore to define the sensible clusters. Low power wide area network (LPWAN) technologies (e.g., NB-IoT, Cat. 0/1/M, LoRa, Sigfox, Ingenu) may address some of these clusters with some overlaps resulting in a potential market fragmentation. As B2B contracts for mMTC are typically long lasting, e.g., in the order of 10 years, migration opportunities may only come at long cycles. Hence, migration may be a big challenge. Nevertheless, to address potential long-term convergence and use cases not sufficiently covered by the existing LPWANs and their evolutions, 5G should be designed to encompass various clusters cost efficiently, with the built-in flexibility.

Another approach to bring down the breakeven point is obviously to push the revenue curve upwards. This could be achieved by providing various value-adds, such as insights, optimization and automation, through big data analytics, or by providing a platform to support such data analytics. Value creation from data has several challenges:

- Acquiring all useful data by one player may be difficult, as relevant data may be spread across different platforms and companies/ organizations. Even if one player is managing various relevant pieces of information, they may be spread across various business cases. Furthermore, non-disclosure agreements (NDAs) may prohibit cross-utilization of data.
- Regulatory issues around privacy may prohibit from deriving useful insights from personal data pertaining to an individual.
- It takes long time to develop data insights for value creation. Such value-adds are basically prediction using data trends, and requires reliable history of data. In many cases value-adds (e.g., efficiency) can be achieved by digitizing human knowledge, i.e., digitizing the decision making process. This requires sufficient amount of data to be correlated with human knowledge and to gain statistical confidence. For example, agriculture has annual routines that imply years of data correlation to digitize knowledge.

While the mMTC part has interoperability issues that necessitate standardization, the value-add part generally does not require interoperability and could be considered as a differentiation zone. As simple replacement of existing eco-systems (e.g., by digitization, automation, etc.) may be rather destructive to the vertical industry, IoT should aim at creating new businesses and markets to benefit the overall economy, and hence, cross-industry innovation is sought for to create new values. For the value-add part in the IoT chain, the following strategies will be fundamental:

- **Building trusted relationship** – As IoT business is basically B2B (or B2B2C), establishing trusted relationships with the business partners is crucial. The ability of operators to engage local businesses in face will be valuable in this respect.
- **Packaged solutions** – mMTC connectivity solutions alone may promise very low margins with only a minor fraction of the entire IoT value space. Packaged solutions (e.g., with access to data analytic toolsets, consultation, automation) could be more attractive for the customer, and having the platform (either alone or through partnerships e.g., with AI service providers) will be essential.

However, stepping into the value-add part means that the player is stepping into the vertical industry itself, as it needs to build expertise around the concerning vertical industry.

The difficulty of IoT uptake is due to the long time to gain profit – the fact that the revenue curve is very gradual, the time it takes to develop sufficient scale, and the time it takes to gain data insights for value creation. As such, the industry needs to be prepared for the long term business. A key for success is to suppress the cost of provisioning, by leveraging a common (or existing) infrastructure. If mMTC is enabled by simple software upgrade in the network side, operator assets, such as wide area coverage, interoperability and roaming models, and security and authentication management systems could be leveraged, making solutions more affordable to unlock various business cases.

3.3 Key points

The key points are summarized below:

- mMTC is understood as the connectivity part of the IoT ecosystem, whereas IoT is understood as the end-to-end ecosystem, including the application and value-adds from various data insights, etc.
- The difficulty of IoT uptake is due to the long time to gain ROI – the fact that the revenue curve is very gradual, the time it takes to develop sufficient scale, and the time it takes to gain data insights for value creation.
- Cost reduction is critical for mMTC – clustering (tailoring) of features, endurable solution, IPR framework, and the use of a common infrastructure are crucial to suppress the cost of provisioning, operations, and management.
- Differentiation and competition should drive value creation in the IoT space, where trusted relationship with local business partners will be crucial.

4 ULTRA-RELIABLE AND LOW-LATENCY COMMUNICATIONS (URLLC)

4.1 uRLLC drivers

Ultra-reliable and low latency communications (uRLLC) applications are largely driven by

- **Technology** – New technology concepts such as new RAT (where L1 numerology is expected to scale towards shorter TTI to match the wider bandwidths available in the cmW/ mmW range) and MEC, as well as advances in device processing power, will enable considerably lower transmission latency. This is creating new value propositions in the uRLLC direction.
- **Vertical industry applications** – The automotive industry is undergoing transformation with the advent of autonomous and cooperative driving. Factories are transforming to improve production efficiency by use of cooperative machines that are highly configurable to adapt to fast changing and individual customer demands. uRLLC is a critical component to enable these transformations.

4.2 Directions and issues

uRLLC is often considered as one potential direction that can create new applications and unlock new revenue sources for operators. uRLLC heavily depends on the configuration and performance of the network and cannot be realized by an OTT approach. Moreover, uRLLC is hard to realize by use of unlicensed spectrum, as performance may not be guaranteed. Hence, uRLLC can be a strong and exclusive value proposition of operators. uRLLC is also attractive for operators who do not own backhaul networks, as its values are realized largely by the assets around the network edge.

However, it is important to emphasize that uRLLC does not come for free. Absolute zero latency and/ or 100% reliability can never be achieved due to inherent physical properties of wireless data transmission. Thus, the cost for reducing latency and improving reliability is expected to grow exponentially and diverge[2]. The cost pertains to the need to distribute network functions to reduce latency from traversing distances, the need for redundant systems, and the need for local engineers to manage the distributed network. While the telecom industry will endeavour to make uRLLC affordable, the extent to which uRLLC can be achieved will strongly depend on the business potential (revenue projections) that contains many uncertainties. This high level view is depicted in Figure 4.

[2] The fact that absolute zero latency and 100% reliability is physically impossible implies that the cost needs to diverge. This implies that the cost for reducing latency and increasing reliability is expected to grow exponentially. Physics implies that there will be an achievable limit for latency/ reliability with given resources (e.g., bandwidth, transmission power). Beyond such a limit, parallel transmission/ processing (doubling resources) can be considered. However, the number of parallel streams (or resources) will grow exponentially as latency/ reliability requirement is tightened.

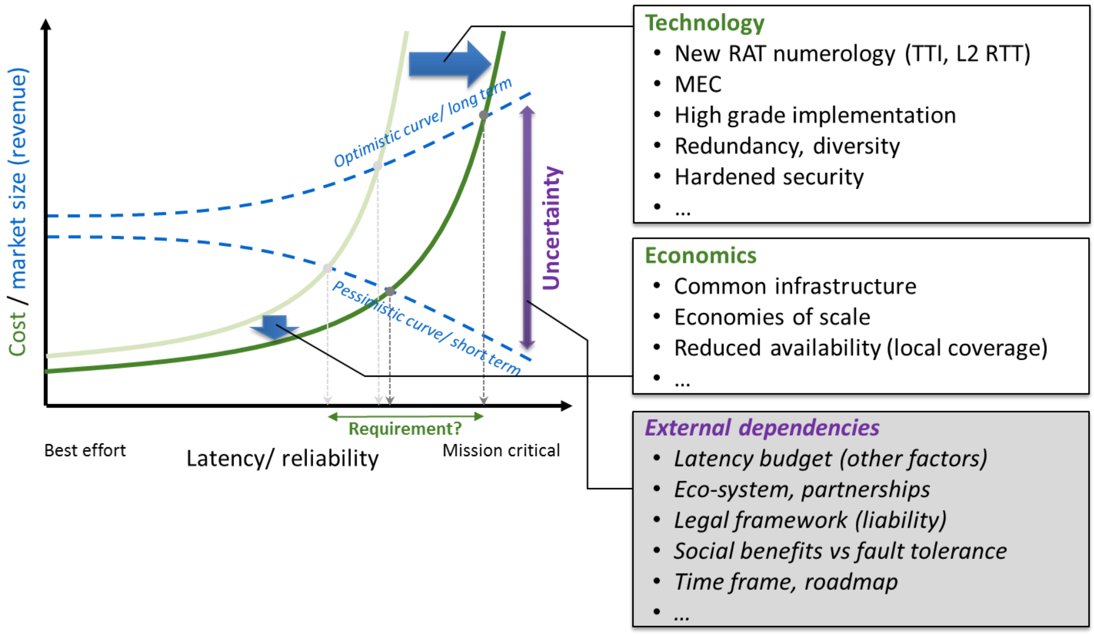

Figure 4: uRLLC prospects.

The cost curve can be reduced by

- **Technology design** – New RAT numerology (TTI, L2 RTT, etc.) and MEC can enable lower latencies. High grade implementation, redundancy, diversity, and hardened security can improve reliability. Redundancy across multiple networks may have to be considered, if the required reliability is higher than the level achievable with a single network.
- **Economics** – uRLLC will likely require more distributed deployments compared to eMBB and mMTC, diminishing pooling gains. Yet, use of common infrastructure (among different use cases, as well as with eMBB and mMTC) is essential to reduce costs. Another possible approach is to reduce availability of uRLLC services, e.g., to a limited local environment, as providing seamless nationwide coverage certainly seems too costly and unrealistic. Nevertheless, this will limit applications and viable business cases.

Since operators will share higher risks, the revenue per device/ user for uRLLC is expected to be considerably higher than eMBB. However, the revenue curve contains uncertainty that seems to increase as uRLLC is pushed towards mission critical requirements (uncertainty decreases toward best effort, since best effort is basically eMBB, i.e., extension of the business we know today). Such uncertainty is largely due to external dependencies:

- **Latency budget** – The prospects for other latency factors should be clarified. It may not make sense to provide sub-millisecond radio access latency or integrate compute power right into base stations to save few milliseconds in physical propagation time, when other factors, e.g., processing, sensor/ actuator control periodicity, etc. are not anticipated to be comparably faster.
- **Eco-system, partnerships** – For many of the vertical applications, relevant eco-systems need to be established to make those applications economically viable. Thus, the right technology should be seen as only the first step and not an end in itself. Other significant challenges will lie in establishing the right ecosystems and partnerships to realize the foreseen applications.
- **Legal framework (liability)** – Some of the uRLLC applications are set in scenarios for which the legal framework still needs to be established. For example, liability needs to be clarified in case an accident occurs as a result of network failure in an autonomous (cooperative) driving or remote surgery use case. It is unlikely that significant investments will flow to support a business case for which the legal framework remains uncertain. Thus, technology development should

also take into account the anticipated progress in the legal framework in timing the availability of key capabilities.

- **Social benefits vs fault tolerance** – Network failures for mission critical services may imply new types of social impacts, e.g., complete breakdown of a transport system. The society needs to appreciate the value propositions of the overall application over the seldom failure impacts.
- **Time frame, roadmap** – It is hard for vertical industries to take into account 5G in their product roadmap, when the 5G specification is yet undefined and the cost models are unclear. It may not be until the telecom industry starts providing sufficient network coverage and mass-produced devices that vertical industries start to consider 5G in their product design (e.g., cars). Hence, it may be further beyond 2020 when vertical applications start to proliferate.

It is essential that these uncertainties are reduced. The only way to achieve this is through engaging the related vertical industries, i.e., through rounds of communications. The reasonable design target will depend on the balance between the revenue projections and the exponential cost.

4.3 Key points

The key points are summarized below:

- uRLLC can be a strong and exclusive value proposition of operators. Since operators will share higher risks, the revenue per device/ user should be considerably higher than eMBB.
- As absolute zero latency and/ or 100% reliability can never be achieved, the cost for reducing latency and improving reliability is expected to grow exponentially and diverge.
- Technology design (new RAT numerology, flexible architecture design, etc.) and economics (use of common infrastructure, reduced availability) may push down the cost curve.
- The business potential of uRLLC contains many uncertainties. These need to be reduced through discussions with the relevant vertical industries. Examples of those uncertainties are latency budget, eco-system, legal framework (liability), social benefits vs fault tolerance, and roadmap.

5 PRIORITIES AND MIGRATION

5.1 Modular design to accommodate various strategies

From various sources it is clear that different regions have different market priorities and commercialization plans for 5G. Initial deployments are advocated for 2020 or even earlier. Nevertheless, for a new generation system to be successful, the surrounding eco-system (e.g., content providers, application developers, distribution channels, business partners, and customers) needs to be prepared to embrace the new capabilities.

5G will enable and encompass various services. However, it is unlikely that an operator will introduce all eMBB, mMTC and uRLLC services at the same time. An operator will set priorities and roadmaps based on the market context and business opportunities. An operator will also try to leverage existing assets as long as they are relevant. Since those contexts are different per region and operator, the strategy will most likely be different for each operator, thus leading to many scenarios for 5G rollout and migration. For example, an operator may decide to deploy a 5G new RAT to boost eMBB. Another operator may decide to rollout a wide area stand-alone 5G network to support mMTC services, or choose to provide in-premise uRLLC solutions using a new 5G system. The sheer fact that 5G will unlock many applications will mean that the potential scenarios may also be many.

Thus, technology design must allow for the modular introduction of new capabilities, leveraging existing assets where it makes economic sense. This will lower the hurdle for 5G introduction, thereby helping the eco-system to be established quickly. Nevertheless, it is important to achieve economies of scale through global harmonization of spectrum and timing of key capabilities/ features. Commonality should be achieved in the technology design as far as possible, avoiding niche optimization for corner cases which could lead to fragmentation. The industry should continue to strive for a unified standardized solution.

5.2 Migration of telco services

Telco services like voice and messaging have long been a core business of operators. However, OTT alternatives to these services are often free for the user and create strong competition. For example, messaging services have been overtaken by the likes of WhatsApp and LINE. Furthermore, the way people communicate is also changing, due to heavy use of emails, blogs, and tweets. Thus, legacy modes of communication like phone calls are fading in favour of services provided e.g., by Google, Facebook, and Twitter. Even in cases where phone/ video calls are relevant, they are being replaced e.g., by Skype and Facetime. While these trends may not be favourable for many operators, the facts need to be embraced for a sustainable future. The question is how to evolve from here, moving on to 5G.

It is clear that different operators are reacting differently to these trends. Some operators are taking strategies to sustain telco services through various value-added services, e.g., using RCS or bundling with other services. To this end adoption of Jibe by Google may facilitate RCS support in Android devices. Use of telco services through WebRTC may also be interesting to expand applications, e.g., into the IoT domain. Whether these efforts prove successful or not is yet premature to judge, but some fundamentals are worth reviewing.

One of the key strengths of telco services is the “global reachability”. That is, regardless if the user has a smartphone, feature phone, or even fixed phone, the user can be reached via just his/ her phone number. However, as phone numbers are stored on smartphone (or feature phone) memories, the number itself is becoming increasingly invisible. Then, the competition is a matter of having a good U/I design. Another strength of telco services is that QoS can be guaranteed. However, operators are facing a dilemma that by increasing the capacity after each generation, while most communication services are merely narrowband, QoS is reducing its value for communication services. Best effort is simply good enough in many cases.

Yet in emergency situations, like natural disaster events, people rely strongly on telco services. With the optimised congestion control, telco services could provide far better availability in such extraordinary situations. These benefits may not be so obvious in countries where natural disasters rarely occur, but in countries that suffer from natural disasters, this property is highly valuable. In addition, telco services adhere to all regulations, such as emergency call support and legal intercept. It will be hard to achieve these with OTT services, unless regulations evolve with IP premise.

While the path to take is entirely up to discretion of each operator, one clear point is that there is no need to proactively terminate telco services, as long as the cost model is sustainable. It should also be noted that fixed phone services have not been terminated either, despite the mobile shift. The key is to reduce the cost of running these services. This means that operators will avoid investments into new design, if it does not bring additional values or significantly reduce the total cost.

One implication of this is that impacts on IMS should be avoided. That is, additional options and variations in IMS implementation to cope with the new network design should be avoided, thus minimizing impacts on existing VoLTE agreements. It is crucial to establish VoLTE as a global interworking solution for voice to sustain telco relevance in communication services and the identity management footprint, when OTT alternatives are gaining market penetration over IP. Telco fragmentation needs to be avoided by having different service platforms deployed for the same service.

As a single operator will not be able to cover globally wherever a user may travel, interconnect and roaming models continue to be needed for seamless service continuity. However, new jurisdictions, e.g., in Europe, implies roaming revenues will inevitably decrease. This, together with the access/ service split and all-IP paradigm, invokes a discussion on the relevance of traditional interconnect and roaming models. While pure IP peering may not be able to meet the seamless service continuity requirement, the legacy model has been expensive with the complexities of data-/ finance-clearing house. A potential middle ground may be to emulate home networks at visited networks, using virtualization, so that traffic is handled locally. That is, home network functionalities can be instantiated at visited network clouds, so that roaming users can be served by network slices emulating home networks. This however invokes many challenges and will need further study e.g., on scalability, cost, mobility across slices, SLAs, software updates, interoperability testing, security and charging models. Technology should desirably support such schemes, so that an operator can choose to apply them to cases that make sense.

5.3 Key points

The key points are summarized below:

- The fact that 5G will unlock many applications will mean that the potential scenarios for rollout and migration may also be many. Technology design must allow for the modular introduction of new capabilities, leveraging existing assets where it makes economic sense.
- Commonality in the technology design should be achieved as far as possible, and global harmonization of spectrum and timing of key capabilities/ features should be sought for, to achieve economies of scale and to avoid fragmentation. The industry should continue to strive for a unified standardized solution.
- Standardization should focus on essential features that require interoperability. Open source approaches should be explored for features that can be implemented by software.

6 CONCLUSIONS

Many concepts have been proposed for 5G in various fora and papers, highlighting their advantages and potential applications. To substantiate the benefits of these concepts, their technical and business implications need to be well understood, in light of economic reality. It is about time that realities of 5G need to be understood, because in the end, standardization is not enough, implementation is not enough, and deployment is not enough to realize a successful telco generation. The entire eco-system (including content providers, application developers, distribution channels, business partners, and customers) needs to be prepared to embrace the true capabilities of 5G, so that all stakeholders benefit from the new generation. This paper merely serves as one small step to build a common understanding on what to anticipate from 5G, and this discussion will need to continue.

From the analyses in this paper, eMBB, mMTC, and uRLLC prospects can be summarized as follows:

- **eMBB** – 5G should enable integration of various deployment and business models to facilitate availability of large bandwidths cost efficiently. An identity abstraction and control layer is essential to provide consistent user experience in highly heterogeneous environments.
- **mMTC** – 5G should bring down the costs of provisioning for various mMTC connectivity solutions addressing individual business needs, through a standardized modular framework. Differentiation and competition should drive realization of various IoT benefits, closely working together with stakeholders.
- **uRLLC** – 5G should push down the cost curve to unlock new uRLLC use cases. Cross-industry debate needs to be facilitated to reduce uncertainties around external dependencies to determine a sensible capabilities target for 5G and their market availability timing.

As 5G will enable various applications, global harmonization on capability prioritization and roadmap is very difficult to achieve. While the telecom industry will endeavour to achieve harmonization through continued debates, 5G should be designed in a modular manner to efficiently accommodate various demands and strategies. The technology design should allow operators to focus investments depending on market contexts and business opportunities, while leveraging existing assets. Building on the virtualized foundation, open source approaches should be explored to improve scalability and agility.

With the expanded network capabilities and intelligent poly-morphic system design, 5G will encompass various vertical applications cost efficiently utilizing a common platform. Operators' ability to engage various enterprises locally in face will be a key strength in fuelling enterprises and the society with the power of ICT. The ability to accommodate the real needs with flexibility and agility, under a trusted relationship, will be the key to unlock the digital opportunities.

7 REFERENCES

[1] NGMN 5G White Paper, Mar 2015.

[2] Recommendation ITU-R M.2083.

8 APPENDIX

Breakdown of eMBB services and their expected used environments are shown in Table 1. The table also shows mapping of different scenarios to the NGMN use cases defined in the NGMN 5G White Paper, as well as whether the scenario is considered as a target design scenario for 5G.

Table 1: eMBB services, used environments, and mapping to NGMN use cases.

Service	Example	Service requirements	Target (Yes/No) ===== Corresponding NGMN use cases	Environment								
				Indoor			In-vehicle			Outdoor		
				Residential	Office	Public	Private	Public	Civil aviation	Private	Dense outdoor	Rural outdoor
				house, apartment ≤ 3 km/h	office, factory, hospital ≤ 3 km/h	airport, mall, concert hall ≤ 3 km/h	car ≤ 250 km/h	bus, train ≤ 500 km/h	jets, airplanes ≤ 1,000 km/h	garden, balcony ≤ 3 km/h	plaza, stadium, high street ≤ 3 km/h	park, roads ≤ 3 km/h
Basic internet access	Information access, entertainment (incl. video download), communications, data logging (incl. UGC upload)	Best effort (NGMN WP: 10~50 Mb/s, 10~50 ms depending on environment)	Target (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
			50+ Mpbs everywhere (DL 50 Mb/s, UL 25 Mb/s, 10 ms, ≤ 100 km/h)	X	X	X	X	X	X	X	X	X
			Ultra low-cost broadband for low ARPU areas (DL 10 Mb/s, UL 10 Mb/s, 50 ms, ≤ 50 km/h)	X	X	X	X	X		X		X
			Broadband access in a crowd (DL 25 Mb/s, UL 50 Mb/s, 10 ms, pedestrian)			X					X	
			Mobile broadband in vehicles (DL 50 Mb/s, UL 25 Mb/s, 10 ms, ≤ 500 km/h)				X	X				
			Airplane connectivity (DL 15 Mb/s, UL 7.5 Mb/s, 10 ms, ≤ 1,000 km/h)						X			
Enterprise intranet access	Office/enterprise cloud access, VPN	Requirements depend on SLA Security critical	Target (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
			In addition to "basic internet access" cases: Indoor ultra-high broadband access (DL 1 Gb/s, UL 500 Mb/s, 10 ms, pedestrian)		X	X						
Video streaming (progressive downloading of library type contents)	4K/ 8K/ 3D, multi-view, movies, news archive, YouTube	* 4K (2160/60/P): 30~40 Mb/s * 8K (4320/60/P): 80~100 Mb/s * HD H.265/HEVC: ~20 ms	Target (Yes/No)	Yes	Yes	Yes	Yes (may be limited to 50 Mb/s*)	Yes (may be limited to 50 Mb/s*)	Yes (may be limited to 50 Mb/s*)	Yes	Yes	No
			Broadband access in dense areas (DL 300 Mb/s, UL 50 Mb/s, 10 ms, ≤ 100 km/h)	X	X	X	X	X			X	
Realtime video (live contents)	* DL: live streaming, sports betting * UL: surveillance, UGC uploading in stadium * DL+UL: video conf.,	* 4K (2160/60/P): 30~40 Mb/s * 8K (4320/60/P): 80~100 Mb/s * HD H.265/HEVC: ~20 ms	Target (Yes/No)	Yes	Yes	Yes	Yes (may be limited to DL 50 Mb/s, UL 25 Mb/s*)	Yes (may be limited to DL 50 Mb/s, UL 25 Mb/s*)	Yes (may be limited to DL 50 Mb/s, UL 25 Mb/s*)	Yes	Yes	No
			Indoor ultra-high broadband access (DL 1 Gb/s, UL 500 Mb/s, 10 ms, pedestrian)	X	X	X						
VR	Real-time 3D gaming	Depends on rendering (server or client) * 4K (2160/60/P): 30~40 Mb/s * 8K (4320/60/P): 80~100 Mb/s * HD H.265/HEVC: ~20 ms	Target (Yes/No)	Yes	Yes	Yes	Yes (may be limited to 50 Mb/s*)	Yes (may be limited to 50 Mb/s*)	Yes (may be limited to 50 Mb/s*)	Yes	No	No
			Indoor ultra-high broadband access (DL 1 Gb/s, UL 500 Mb/s, 10 ms, pedestrian)	X	X	X						
AR	Realtime virtual product demo, realtime guides (e.g., tourism)	Depends on rendering (server or client) * 4K (2160/60/P): 30~40 Mb/s * 8K (4320/60/P): 80~100 Mb/s * HD H.265/HEVC: ~20 ms	Target (Yes/No)	Yes	Yes	Yes	Yes (may be limited to 50 Mb/s*)	Yes (may be limited to 50 Mb/s*)	Yes (may be limited to 50 Mb/s*)	Yes	Yes	Yes
			Indoor ultra-high broadband access (DL 1 Gb/s, UL 500 Mb/s, 10 ms, pedestrian)	X	X	X						
Mobile wireless backhaul	For cars, buses, trains, ships, airplanes, etc.	Depends on assumed services and environment, e.g., 5 Gb/s per train wagon to provide 50 Mb/s per passenger	Target (Yes/No)	No	No	No	Yes	Yes	Yes	No	No	No
			(No corresponding NGMN use case)									

Yes	NGMN targets to support - could possibly be served by legacy, e.g., 4G
Yes	NGMN targets to support - some challenges potentially requiring 5G
Yes	NGMN targets to support - high challenges potentially resulting in some restrictions even with 5G under certain conditions e.g., rural, high mobility, etc. (hence the notion "may be limited…")
No	NGMN does not target to support, i.e., will not design 5G for that