Internet 2030

Towards a New Internet for the Year 2030 and Beyond

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For ITU-T, SG 13

This White Paper demonstrates future use cases and requirements beyond IMT2020 and provides thoughts for the Focus Group NET-2030 work.

Executive Summary

Fast forward to year 2030. Fueled by the 5G ecosystem, society has already undergone a bulk of digital transformations. By this time, the Internet is capable to meet the economies of diverse services requiring varying parameters of performance, to deliver end to end service level objectives. The promise of smart city infrastructures has been delivered. Although telesurgery is not common yet, remote patient monitoring is a reality. The AR/VR ecosystem is flourishing with variety of immersive media displays swarming the consumer markets and large volume of AR/VR content made available and distributed over the networks.

Our lifestyle will continue to push the technology boundaries even in post 5G era. When we try to imagine future life, a few things come to mind immediately, (a) that there will be a lot more automation; as machines perform tasks on our behalf, information will be collected and generated from multiple sources, creating humungous amounts of data, (b) more things will operate at system level, not in isolation; and will demand even tighter delivery guarantees than 5G at the same time coordinating distributed intelligence all over the connectivity fabric, (c) the lines between real and digital will get even fuzzier. We will advance from virtual, augmented, and mixed, immersive realities to a holographically rendered world in which communication networks will make distances immaterial.

The IMT-2020 study of 5G technologies is a tremendous effort that gave clear set of recommendations on how to enable futuristic technologies in mobile and telecommunication networks. This clarity also begs a question of what effect it will have on the network protocols? Specifically, will the incumbent suite of Internet Protocols (IP) and its architecture in fixed networks (which did not change in IMT-2020) will continue to remain so? If 5G delivers 1ms latency with 10Gbps data rates, the future applications will only be more demanding of shorter latency and higher capacity. How can then the Internet of today based on best effort, deliver such services? What may seem too advanced today will become relevant in next 10-15 years. In this preparation, we ask how to bridge the gap between technological advancements of 2030 and protocols that will carry them? How to ensure that the protocols will be ready when the time comes to meet qualitative and quantitative communications nuances of digital services like advanced holographic teleconferencing, autonomous digital twins in factories, accident free societies and humungous data movement – all operating with absolute security.

Network 2030 is such an initiative that looks at network capabilities to support what lies ahead of the 5G vision. It provides an even tighter integration between communications and human life and identifies key future scenarios that should appear in the period 2030-2035. Network 2030 questions how to deliver strict guarantees with the IP, which has been the incumbent in its original form since the beginning of the Internet. More importantly it explores on-the-wire communication mechanisms from many broader perspectives not restricted by pre-existing notions of layers etc. to any particular form of technology.

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1 Introduction

The reality of 5G technology enabled world will be upon us soon. That promise of it is on its way, from a concept to trials and to mass adoption of 5G applications. From 2020 and in the following years, most of the things and applications are expected to be either have a connected 5G-interface already or will be equipped with it. By then, realization of 5G use cases would have happened, which includes interplay of smart sensors to monitor and control electric meters; automatic operation of street lights in smart city infrastructure; realization of high bandwidth delivery of AR/VR multimedia applications with desired latency; proliferation of edge compute applications for smart homes infrastructure and higher distribution of localization centric information.

IMT-2020 introduced integrated requirements related to both fixed and wireless elements in consideration to the growth of mobile networks to support enhanced broadband, with ultra-reliable and low latency services requirements in an agile and reusable manner by softwarization means of technologies such as SDN and NFV. While IMT-2020 created a framework for new connected services and applications, it does not effectively address the role of the Internet Protocols (IP) which is the fundamental carrier of information in modern networks. The next-generation of applications will be designed with strict resource requirements; therefore, networks will need to perform carefully close to application requirements.

In this regard, we ask ourselves the following question: what should be the network protocol for 5G as well as future applications? Will the IP architecture be suitable for future applications? If yes, how and if not why? It is important to investigate this now and build on the foundations of IMT-2020. Without going into the limitations or specifics of current architectures, this document ventures into the use cases a few years further ahead. We elaborate upon particularly challenging scenarios that are not necessarily possible in the realm of incumbent infrastructures. Therefore, the goal of this document is to create excitement and motivation and foster focused studies and investigations relating to network architectures. This initiative is called Network 2030.

We define the vision of Network 2030 as a progression of the capabilities of network infrastructures at the present and in IMT-2020, which are then extrapolated into the needs of future applications circa 2030. The new paradigms of Network 2030 are described in the next section along with a description of salient requirements which will help disseminate study items for this initiative.

2 Market Driving Factors

Network 2030 builds upon the achievements IMT2020. The technological growth will not stop with 5G. In fact, 5G lays down foundations upon which new innovations will take place, reaping further benefits from it across different sectors. Fueled by hyper connectivity, the key driving factors for next generation of networks are seen to be:

- High density data movement
- Holographic avatars
- Striving for even more realistic personal communications
- Security through trustworthy systems
- Self-governing independent network systems

2.1 High Density Data Movement

Everything that is connected produces some usable data for both immediate and later use. The data is often neither discarded nor forgotten; instead it is consumed, trained and processed for action and to build machine learning models. Huge amount of data generation is one of the biggest side effects of connected devices that are no longer single entities by themselves but in fact are often a dense network of sensors. The Table 1 below shows data generated by various types of connected devices individually in gigabytes transmitted over a snapshot of small period of times. At scale, several of these devices will produce a complex data set with millions of data points (parameters, inputs etc.) in the order of petabytes. The data will be delivered to cloudified applications which in turn perform system-wide optimizations through control loops between the devices and analytics. It is inferred that a large capacity networks will be needed to handle such data movements.

Table 1: Scale of raw data generated on an hourly basis

	Massive Amount of Data
Self-driving cars	1000 CPUs, 100 sensors, 10 GB per mile[1]
Lytro (Light field) camera	300 GB per second
Formula 1 car	200 sensors, 200 GB of data[2]
Twin Jet engine-based airplanes	5000 sensors, 10 terabytes per 30 minutes per plane. 5000 planes in US[3]

Undoubtedly, there is plenty of evidence that not all generated data is useful. The effective, meaningful data is the result of several steps of aggregation, deriving intelligence, insights and analysis of operational impacts and outcomes. These steps may be executed anywhere in the cloud or in the network path. Therefore, the role communication networks play may have to be more than raw exchange at high speed. In addition to their traditional role of ensuring that data was delivered reliably and securely, networks have to become more sensitive to the precise specifications of an application such as, what kind of bounded low latency or bandwidth is need, how the functionality is distributed in the cloud and what kind of data needs quantitative vs qualitative treatment etc. When computing and networking converge, it is easy to imagine that in-transit data can be changed due to in-network computations and processing without affecting the resulting delivery to the end point.

Another emerging high-density high velocity data trend includes the secure movement of personal digital information. With mobile phones being ubiquitous, people are used to capturing their personal lives through videos and photographs. Even a basic camera technology now captures high resolution pictures

[1] https://www.hitachivantara.com/en-us/pdf/white-paper/hitachi-white-paper-internet-on-wheels.pdf

[2] https://blogs.gartner.com/simon-walker/2017/01/05/motorsports-has-been-doing-iot-big-data-real-time-analytics-for-decades/

[3] https://gigaom.com/2010/09/13/sensor-networks-top-social-networks-for-big-data-2/

and videos. Other forms of personal data such as digital books, government issues documents, school/ work notes, medical records and so on also needs storage. Even though these digital records are generally accessible through individual sources (content providers) in the cloud, end users always prefer to maintain a personal copy at a single place.

Powered by edge-compute and edge-storage concept in 5G, a personalized my-cloud service could be a promising future application. My-cloud helps resolve two primary issues; first, it allows all personal records in one place and secondly, it provides a scale-out alternative to physical storage capacity which will most certainly reach its limits with at home physical storage. Furthermore, my-cloud is bound to a person; that is, it moves with that person from one edge to the other without leaving any trace in the previous edge. The obvious benefits are increased trust and faster access as the data always remains close to the user. It also brings a greater sense ownership, privacy and protection of personal data with an explicit control over sharing personal information.

The challenge of realizing my-cloud means that as tens of thousands of people in a region move around with their my-cloud, the networks transmit terabytes of data very fast and over short distances. My-cloud is a use case for future networks; it builds on edge storage concept. It may seem inefficient to move data in this manner today, but it is fundamental to protection, privacy and ownership of data in digital form because my-cloud can ensure there is no third-party or administrators between users and their my-cloud.

2.2 Holographic Avatars

Today's AR/VR[4] applications target the retail, entertainment, health and gaming industry amongst others. What follows is viewing video images in three dimensions as holograms[5]. In comparison to AR/VR, holograms create more interesting, engaging and exploratory visualizations in the field of education, information and sectors that use design and modeling techniques such as architecture, blueprints, floor plans, medical imaging, navigation maps etc. by rendering information objects in 3D with more accurate light intensity, form and texture.

Holographic avatars thus, are multi-dimensional information replicas of a true scene or real objects therein, or virtualized objects that will be rendered at the remote end. Early adoption of such avatars is first anticipated in entertainment then in personal communications and later in industry automation and remote operations. However, presentation of holographic information, especially for objects in motion transmission is a challenge that is pushing the capabilities of current technology.

Similar to AR/VR, the quality or resolution of a hologram depends on effective pixel count for a given unit surface area. The size of continuous moving 3D hologram images will grow with increase in display sizes as well as frame rate. Thus a service provider's network will need to accommodate for orders of terabytes

[4] Virtual Reality (VR), simulates physical presence in virtual worlds. Virtual reality can recreate sensory experiences, which include virtual taste, sight, smell, sound, touch, etc. Augmented reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data (from Wikipedia).

[5] a hologram is a photographic recording of a light field. Holography is a technique to construct three-dimensional images (holograms) to be made. It involves capturing of, light intensity so that as the object's view changes with the orientation of the viewer (Wikipedia).

of bandwidth to transmit multiple hologram images. One study[6] computed that a raw full parallax, 4"x4" size of a holographic tile needs local display rate of 30 Gbps at 30 fps. Network level transmission rates are then derived from this data using different mechanisms of encoding and compression. There are many factors that determine what gets to be transmitted: computational algorithm and method, pixel resolution, compression ratio, display size, and even rendering optimizations are possible[7]. A raw extrapolation of these numbers yields that to render a life size hologram would require an order of

Table 2: Raw and compression data rate of holograms

	Dimensions	Bandwidth	100:1 compression
Tile	4 x 4 inches	30 Gbps	37.5 Mbps
Human	77 x 20 inch	4.62 Tbps	5.7 Gbps

Number of human holograms Flows	Approx. Bandwidth Requirement
1000	5.7 Tbps
10000	57 Tbps
100000	570 Tbps

terabytes of data per second as seen in Table 2, using a relaxed 100:1 compression with a small scale of 1000 of flows will need bandwidth in the order of terabytes[8].

Indeed, ongoing research[9] has put lot of focus in reducing the size of a hologram. In years to come technological advances will determine the sweet spot between hologram transmission rate efficiency and quality, without compromising the end-user experience having "very-real" remote communications.

The holographic future communication challenge remains in determining how networks can support a high quality, real-time, interactive transmission of video holograms for live video conferencing type applications. It requires capacity, balance between compute vs compression overheads, differential reliability (some data must not be dropped while other is ok to drop in congestion), and information adjusting to meet application specific latency.

2.3 Near-Real Personal Communications and Experiences

One of the greatest gift of telecommunications is to enable people at different locations to communicate in real-time. At first, it allowed two people to talk to each other over telephones, then exchange emails, images and texts instantly. Video conferencing is possible now and in near future we will see AR/VR based communications. We are gradually approaching the point where the lines between virtual and real aspects of communications are beginning to blur. To put it in context, AR/VR simulates a remote environment in

[6] reference: N. Peyghambarian, University of Arizona

[7] https://www.microsoft.com/en-us/research/project/holoportation-3/, https://www.sciencealert.com/microsoft-s-new-holoportation-tech-lets-you-jump-into-someone-else-s-reality

[8] Certain techniques can compress Compression ratio for animated holography can range from 100:1 to 2000:1, depending on nature of the hologram and algorithms selected.

[9] [I] 3D Holographic Display and Its Data Transmission Requirement 2011 (https://ieeexplore.ieee.org/abstract/document/6122872/), Holographic image transmission using blue LED visible light communications 2016 (http://www.apsipa.org/proceedings_2016/HTML/paper2016/234.pdf)

order to make visual conversation look more natural, as if the both sides people are at same place. However, in terms of experience there is still an awareness of distance or remoteness.

In order to eliminate the awareness of being remote and reach the ultimate near real experience of communications, the first step is to capture information in three-dimensions and render them as holograms. Then, there is no limitation on how and from which angle a remote object is viewed. But, this by itself is not sufficiently immersive; the next step would then be to embed other sensory stimulations – the touch, smell, taste and perhaps emotions as well. As an example, in a holographically rendered remote scene say near a tropical waterfall, in addition to immersive sound (such as water flowing) there may be a sense touch or texture (temperature and moisture) as well as the smell (pertaining to where water is flowing). A commercial application of such capability would be to render flavor or aroma of a particular dish in food industry.

The innovative idea of transporting multi-informational holograms is to associate both objective as well as subjective attributes about the objects along with it. To look at an object not just as raw encoded data (message, video frame or sound-track) but also in terms of several other properties associated with it. For communication purposes, such objects require artefacts beyond bandwidth, latency and path guarantees and an altogether different paradigm information transmission. In fact, current transport mechanisms do not have such capabilities, therefore, a new transmission method is proposed to be devised: 'information teleportation'. The teleportation technique carries rendering of information at source in a manner that it can be replicate exact and holistic experiences at the remote end in a manner that the objects get rendered or consumed as required by the applications.

2.4 Overhauling End-to-End Security

Network connectivity and security infrastructure have studied disjointly with very little coordination between the two. Proliferation of in-cloud data storage and the growth in data digitization makes the gap look wider to both industry verticals and consumers alike. In addition, new emerging infrastructures such of connected vehicles and smart cities, bring new security and privacy challenges and service providers are generally unsure about how to prepare against future threats.

A survey conducted by Cato Network[10] about the top networking security challenges, highlights the limitations that arise from the lack of holistic network security architectures. Connecting remote sites securely is a tradeoff between cost (related to L2/L3 MPLS etc.), complexity (scattered appliance placements) and performance. Firewall and admission control policies can become out of sync across different sites of an enterprise and thus be broken into or hacked easily. The cost of reactive patches and synchronizing them in branch offices and the cloud has become a prohibitive overhead. Network security is in dire need of an embedded security architecture.

Another important aspect of network security is the growing discomfort regarding user data privacy and a lack of clarity about who preserves and protects that data. This calls for investigating new ways of

10 Top Networking and Security Challenges In the Enterprise; Planned Network Investments in 2017. http://go.catonetworks.com/rs/245-RJK-441/images/Top-Networking-and-Security-Challenges.pdf?aliId=12188640

preserving user identities and data through techniques of data obfuscation and anonymity and mechanisms for end users to retain a degree of control over their data.

Encryption of data in transit prevents it from "man in the middle" attacks and all major web sites and content providers have adopted security protocols (TLS, SSL etc.). The ciphertexts generated using cryptographic algorithms have public keys (for encryption) and private-keys for decryption. The algorithm strength is determined by the kind of attack it can repeal and the length of time required to carry out the attack (like obtaining private keys). Public and private keys are related by integer factorizations and in future, potential of quantum computing with rapid factoring capabilities could perform these calculations that today would take billions of years on classical computers in a few seconds[11]. There is a need to research other approaches; post-quantum cryptography being one them. Or instead of relying on encryption for data protection, other holistic system level approaches maybe explored.

Applying security isolates people by building walls and barriers and demanding strong control. Internet security methods are a tradeoff between the level of security and inconvenience. Inconvenient because of having to prove who you are – a number of login usernames, identities, passwords, security questions and delegate to third party. The use of software to store and remember this information compromises security of sensitive information.

Today security model is based on Zero-trust. Often solutions to complex problems are unintuitive and achieved indirectly. For example, in order to prevent misuse of user data, instead of building layers and layers security methods on zero-trust systems, users become citizens of trusted systems. Alternately, what if things, people and systems were made trustworthy? What if good will and reputation builds through mutual benefits and incentives. A holistic approach that safeguards against attack vectors in enterprise and vertical markets, along with privacy and protection of data in transit is much needed. Perhaps, thinking of alternate ways of cooperative approaches built on trust model could be an approach to intrinsic security.

3 Infrastructure Driving Factors

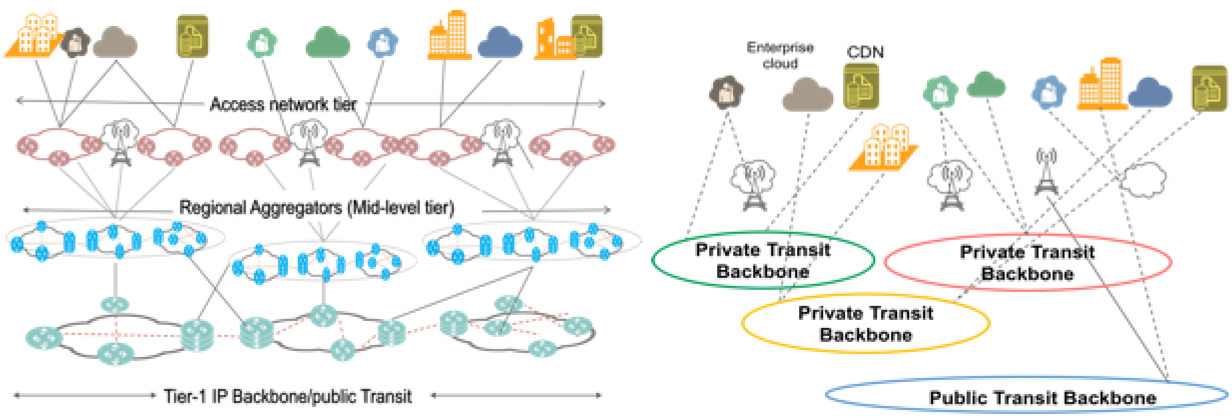
Along with the features of future applications, network infrastructures are evolving as well to support many current changes related to cloudification. The extent of those changes (cooperative, public cloud infrastructures) will have a huge impact on how future applications will be deployed.

3.1 Self-governing Infrastructures

The Internet backbone is formed by interconnection. It is a complex and dynamic interconnection of more than 60000 Autonomous Systems (ASes). The Internet has always been an association of organizations or companies that offer peering or interconnection for traffic to pass through their network or AS for the purpose of access, use and participation in the Internet.

[11] [11] https://csrc.nist.gov/csrc/media/publications/conference-paper/1997/10/10/proceedings-of-the-20th-nissc-1997/documents/128.pdf

The Internet service providers (ISP) are solely responsible for carrying data from one regional location to the other. They establish business agreements with other ASes in order to exchange traffic under various constraints. ISPs form a hierarchical structure of access, aggregators and tier 1 transit networks (see Figure 1). Tier-1 networks connect with every other tier-1 network to form the Internet backbone. The business relations among the ISPs have a heavy economic impact, affecting the profitability of the ASes.



Recently, the economic effects of content growth and the popularity of public cloud are seen in terms of increased infrastructure investments made by cloud/content service providers[12]. More and more cloud

Figure 1: Traditional and new structure of the Internet

service providers are leaning towards creating private transits across different geographies; as a result, the public transit backbone is beginning to trim down. The same cloud providers have also begun to invest in satellite networks. When content providers will own both terrestrial and space transits, it will have a huge impact on the structure of the Internet as we know it.

We have to confront the possibility that the Internet may manifest itself into multiple autonomous Internets with the global public Internet becoming only a tiny small part of it. Barring economic effects, it is important to investigate what will be the global Internet of future. How it will exist and how different Internets will allow data movement from one cloud to the other. A further study on new type of routing paradigm will be necessary to allow for sharing data across these clouds and more importantly allowing support for use cases described in Section 2. A satellite-based global routing system that cooperates with ground-based networks will also be new topic of study for interoperation of space to space network domains and space to ground networks.

4 The Evolution of Network Capabilities

Generations in communications technology play an interesting part in clearly differentiating between the capabilities of a previous generation to the next one. We often describe fixed communication network generations (ATM, IP, MPLS, etc.) separately from 3GPP generations (3G, 4G, 5G etc.). The 3GPP

[12] https://www.theregister.co.uk/2017/10/31/facebook_amazon_finance_jupiter_trans_pacific_submarine_cable,

generation are far more structured in describing their bounded capabilities via network parameters like bandwidth, latencies, reliability along with frequency spectrum mostly because they do not overlap like the fixed systems. During the IMT-2020 initiative, for the first time, the combined impacts of both cellular and wireline network was studied jointly. Thus, in the quest for the next generation of integrated networks IMT-2020 is a first. To put this achievement in perspective, we discuss below how capabilities are evolving from the present to the near future and use this information to extrapolate into the long-term future.

4.1 Capabilities of Today (pre-5G)

The present-day Internet of the 2000s evolved from the innovations in web, content distribution and mobile device applications. Since the launch of the world wide web, a tremendous growth has happened, a digital transformation, with the rise of e-commerce, e-retail, e-readers, online publications and many other sectors. Early web users had mainly low expectations in regards to experience, mainly due to the awe-factor in realizing that several tasks could be done online, but also due the fact that there were no prescribed criteria or awareness to enforce the performance requirements of an applications. Later, with the growth of multimedia streaming, it created specific market segments that would generate, produce and share content over the Internet; it was apparent that the best-effort model was not a suitable approach for services that needed specific patterns and behavior in transmissions. Hence mechanisms

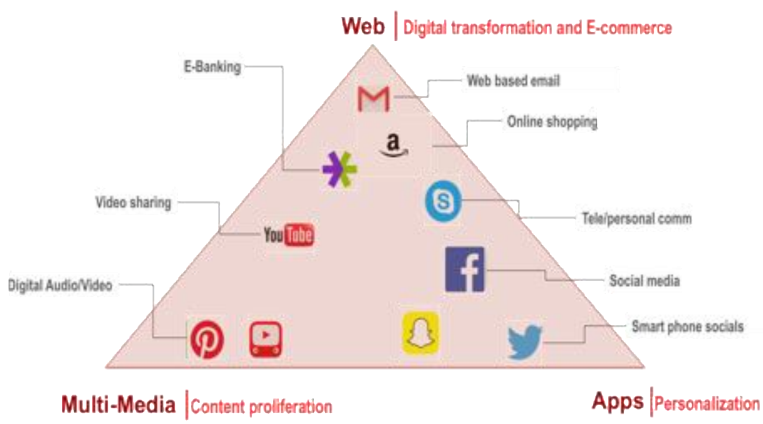


Figure 2: Current Internet Capabilities

that are used today to provide high quality video were developed especially in the DVB and W3C SDOs. Now we are in an era of 'Apps' and the focus is on on how to personalize and customize the experience of a particular application.

A capability perimeter of the current Internet is illustrated in Figure 2[13]. Today, applications try to achieve service response times in the lower order of milli-seconds to seconds depending on the app, capacity in a few tens of megabytes because of the prohibitive price of data plans especially in the US, reliability through path replication and forward error correction and personalization through user account policies and localized features. This works for most market segments within the perimeter of this triangle but the

[13] Courtesy Huawei technologies

infrastructures are already beginning to feel the stress of new higher quality services; this is what helped drive 5G development.

4.2 IMT-2020 capabilities

5G started with a goal of achieving a speed 20 times faster and 10 times lower latency than 4G. It also, brought attention to the networking impact of breakthroughs in emerging markets (AR/VR, IoT, car automation etc.). Especially, it helped emphasize the role of mobile networks in achieving ubiquitous connectivity (of anything from anywhere). In addition, it lays as much importance on wireline networks as on cellular systems in order to flexibly provide end-to-end service delivery as WIFI is essentially a wireline technology. IMT-2020 focused particularly on SDN/NFV technologies and the overall softwarization of network elements and the overall systems. The capability perimeter of IMT2020 forecasted support for billions of connections, latency at a millisecond and bandwidth of up to 20GBps. Several applications shown in the triangle will fall within the bounds of these figures.

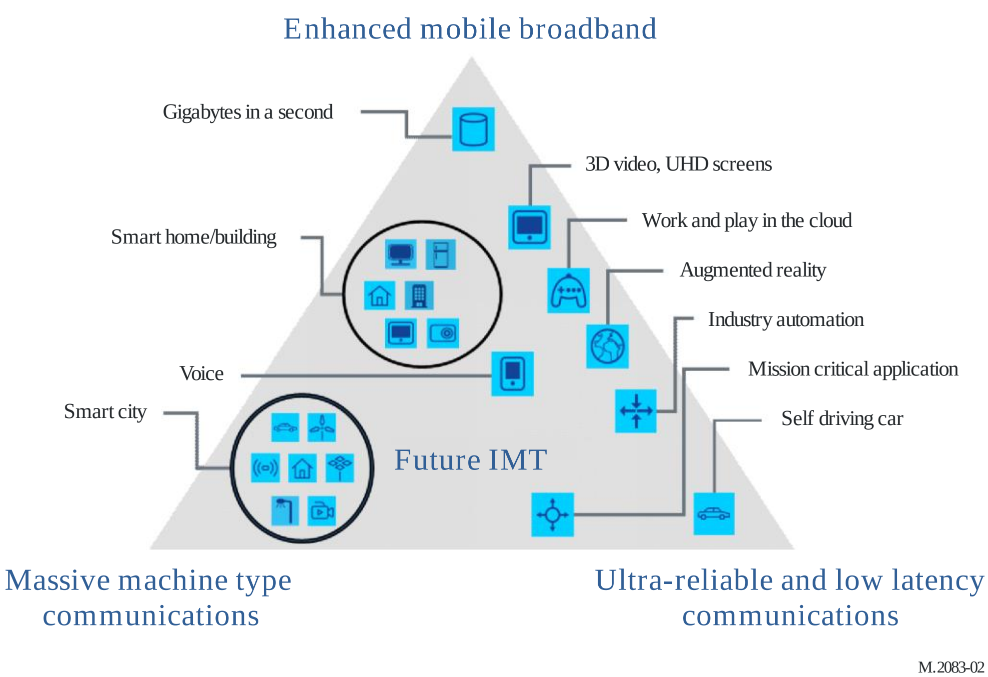


Figure 3: 5G Network Capability Requirements[14]

4.3 Leapfrogging into 2030 (post 5G era)

With 5G now a given, we can interestingly ask how future communications will evolve. It is reasonable to extrapolate on known feature of 5G and the current trends in emerging technologies. The art of perfecting near-real communications has become the latest obsession among technologists from different field of study/research.

[14] https://www.itu.int/rec/R-REC-M.2083-0-201509-I/en

Not long ago, it was sufficient to do real-time video chat capabilities yet today it is not at all beyond imagination to experience taste, smell, and touch by means of communication services. Several chemical and energy sensors are being developed that can be incorporated to compose an entire 5-sensory experience. This will be defined as *holographic type communication or HTC* as introduced in Section 2 Holographic communications will be about describing a piece of information along with its different attributes across multi-dimensions and also as something in need of very large bandwidths to achieve its

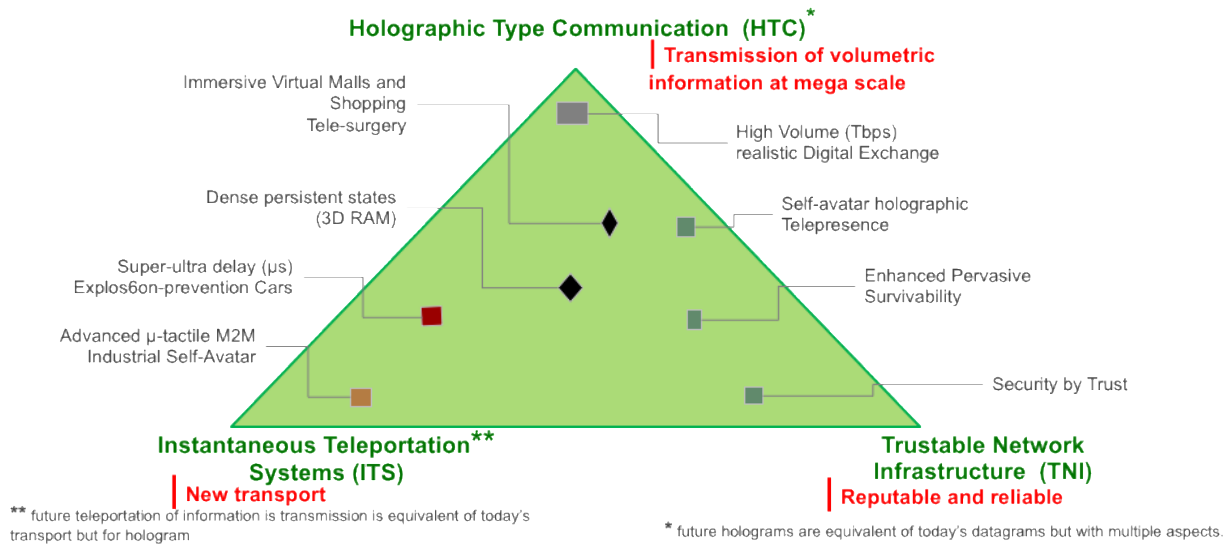


Figure 4: Capabilities for the Future applications

goals (see section 2.2).

As 5G goes mainstream, especially in regards to machine to machine communication, automation will take over many traditional command/controls systems. This is especially relevant in emergency or disaster first response where decisions have to be taken in an instant. Many use cases of even lower than ultra-low latency could emerge in post 5G era. One of the applications is μ-tactile industrial cyber physical systems (CPS) performing operations with the highest possible precision in manufacturing plants. These will be a part of what defined previously as *Instantaneous teleportation systems (ITS)*. ITS combines the concept of distributing multi-attribute holographic information at sub millisecond latency together. Thus, HTC describes end to end aspects of a holographic content and ITS is concerned with forwarding it with appropriate specifications while considering different processing attributes inside the network.

At the same time, the connected societies that aim to function autonomously and yet cooperate by information sharing, have to build a trustable system together and covered under Secure and *Trustable Network Infrastructure (TNI)*. Possibly, blockchain technologies and smart contracts indicate a path to a viable and scalable solution.

The Network 2030 initiative is a combination of HTC, TNI and ITS network capabilities (Figure 4) that together enable some of the applications that will be current in 15 years from now. The technologies needed to build the Network-2030 systems with these capabilities are not yet formally defined but we are confident that they will be be feasible. Therefore, Network 2030 must be studied from many different perspectives, not siloed or restricted by pre-existing notions of layers, protocol, infrastructures etc. We believe such an effort needs new networking paradigms as discussed in the next section.

5 New Paradigms of Internetworking

The IMT2020 networks specifications underlined softwarization of components because SDN/NFV are the emerging trends. This in itself may not be sufficient to meet many quantitative goals of bandwidth and low latency. The 5G new radio (NR) protocol stack allows 1 ms subframes for low latency delivery[15], and the new PDCP[16] enables reliability and new spectrum (1-6 GHz) for high bandwidth and capacity. No similar effort has been taken in fixed IP networks to supplement these guarantees. We emphasize that a new Internetwork paradigm should be defined in the IP world to make networks end to end capable of delivering emerging services deterministically when needed.

5.1 Holographic Type Communication

What get sent over Internet transmission networks is a raw stream of packets. At lower layers we see bits. In the future, we anticipate a communication of a new type: Information holograms or holo-objects (see section 2). Holo-objects can be seen as user defined objects with their own attribute matrix to represent a specific information base. These holo-objects will get rendered on receiver's side based on how they get used. The holographic communication between two parties is shown in Figure 5 below to highlight that information attributes are also sent on the wire.

What Figure 5 shows is analogous to 3D-holograms because the object at source is captured from different angles, the viewing angle at the destination selects the rendered shape, light intensity and texture to the object. The HTC extends this idea to not only visual and sound but to other sensory forms (touch, taste and smell) as well.

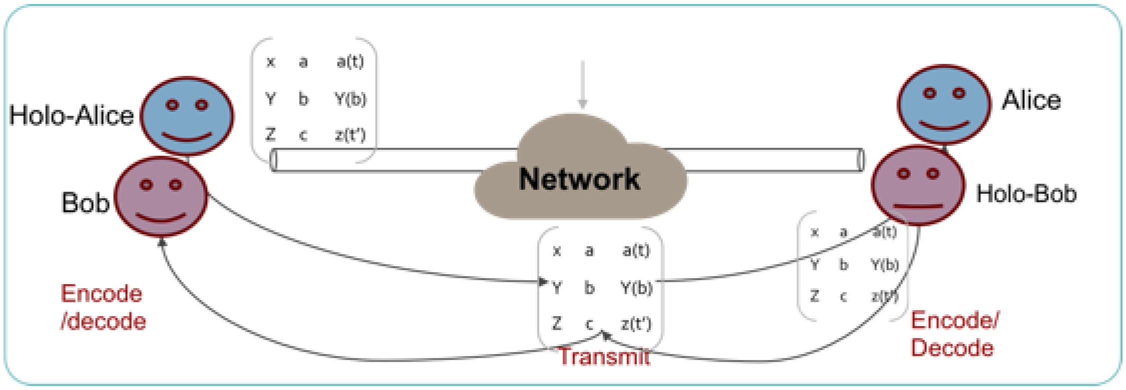
Encapsulating volumetric and other information in this manner (through an attribute matrix) and making it meaningful to the networks allows the networks to selectively choose what part of the data in transit may be dropped in an event of congestion and still be able to reconstruct the information on the other side. Such data discriminations within a holographic flow is acceptable because different levels of information attributes will have varying degrees of reliability. As an example, when transmitting a

Figure 5: Holographic Type Communication

[15] TR 38.802 and TR 38.804
[16] TR 38.323

hologram video in a telepresence setting, it may be acceptable to drop details of the background or some fine-grained skin or hair texture, in favor of text to be clearly readable.

Most likely, such types of multidimensional object require high volume of data, in all likelihood higher



than AR/VR scenarios as described in section 2.2. Such communications are not possible in today's TCP framework and new communication protocol and algorithms, encoding schemes are needed.

5.2 Instantaneous Teleportation System

Information must be available always and instantaneously within the bounds of time when it is needed. Earlier sections touched upon the volume of data being generated these days. This much information can be used to mimic situation models (almost like digital twin of entire system) corresponding to different events and when they turn catastrophic, instant real-time decisions can be transmitted to various entities in the system under duress. Networks 2030, should then be able to discriminate the purpose and urgency of this data so as to transmit accordingly.

Today's Concept		Future Concept	
Datagram	A self-contained routable entity with destination address in packet switched networks	Hologram	A representation of routable entity and its attributes (latency, b/w, metadata, behavior etc.), chained to previous and next hologram
Transport	A one-dimensional information carrier over network. Behavior captured E2E.	Teleport	Different dimensions of information containers carrier over networks Transmits at extremely near-real-time (sub ms)

Figure 6: Future Information Teleportation

Today communication systems consist of basic unit of datagram (see Figure 6) which we then transport from source to destination. The vision of information teleportation is to be able to make information encoded as a hologram available to the other end. Our concept of "hologram" as a multi-dimensional unit was described in sections 2, 3 and 4 with a description of it's different elements of information. Hologram-type encodings (attribute matrix in section 5.1) becomes relevant both on endpoints as well in the networks. The attribute assisted knowledge allows networks to understand the service level objectives in exactly the form they are intended to be and at the end points to delivers the ultimate user experience.

For example, the need for such communications becomes obvious in a large-scale factory. In the case of an accident occurrence, the command center needs to know the entire plan of the factory with latest workers' locations; it should then guide each worker through its individual evacuation path plan to various safe locations. The accident could be severe and factory floor is densely populated, entire modeling, computation and communication need to take place in an extremely short time, perhaps under a ms.

5.3 Intrinsic Trustable Security

Earlier, we asked if things, people and systems can be made trustworthy mainly because layer by layer security causes overheads, fragmented solutions and un-delivered promised. The idea of trust is counter-intuitive to security but it can provide a different perspective. In a trusted system, users exchange information safely protected by the system hosting them. The system holds users accountable. I.e. they are penalized for breach of trust and are rewarded by following the guidelines. Trust can also be quantitatively associated with business objectives of different systems that could be used to improve or reduce the credibility.

Decentralization is one of the emerging technologies that implements proof of trust using blockchains but applying it to overall holistic network security is yet to be studied thoroughly.

Assuming a trustworthy model is in place, several functional benefits become apparent. For example, domain-based trust can be represented as a function of time and credibility score from number of other domains. This is computed by verification of correctness and that data remained unimpaired while transiting a domain. New routing paradigms (and corresponding business incentives) could emerge as now domains may choose to transit through systems that are better in trust-scores. A side effect of such approach will be finding a balance of cost and security within the network.

We recognize there are several challenges in this approach that calls for further study to define scope and how to building holistic trustworthiness systems.

6 Exploring Requirements for Network 2030

The current softwarization trends have given rise to cloudification and the SDN/NFV infrastructure. The cloud platforms provide location agnostic access to large amount of content and high computational processing power for applications. However, many applications such as AR/VR and IoT impose huge constraints on transmission networks in terms of both latency and bandwidth that result from physical distance amongst other. This led to the development of edge computing platforms or edge datacenter concepts where content is location aware and placed closer to the user. Edge data centers are still IP based networks and can fall short of reliability, latency and bandwidth assurances. Even for short distances, current IP networks do not have built-in mechanisms to monitor and take actions to reduce packet loss and maintain a consistent flow of content.

6.1 The New IP

These is an obvious limitation in the current Internet because of this many future applications will only deliver to the capability of what current IP protocol suite can do. Therefore, we need to think about a New Internet Protocol or quite simply the New IP. This will be the network protocol for the Network 2030 (and even IMT 2020) initiative. The Internet has been a great success and it works well for the general-purpose resource demands of this time and age. The New IP technology should evolve the existing Internet to a next generation with a focus on requirements of near-term and future applications.

The New IP embodies the network protocol of tomorrow and makes communications possible for all the future application scenarios described earlier. Network 2030 then enables an ecosystem that delivers applications based on New IP, helps design network architecture, framework and infrastructure.

6.2 Relevance of Tighter service requirements

Figure 7 illustrates how over the decades, services level objectives are becoming more constraining in terms of their performance guarantees.

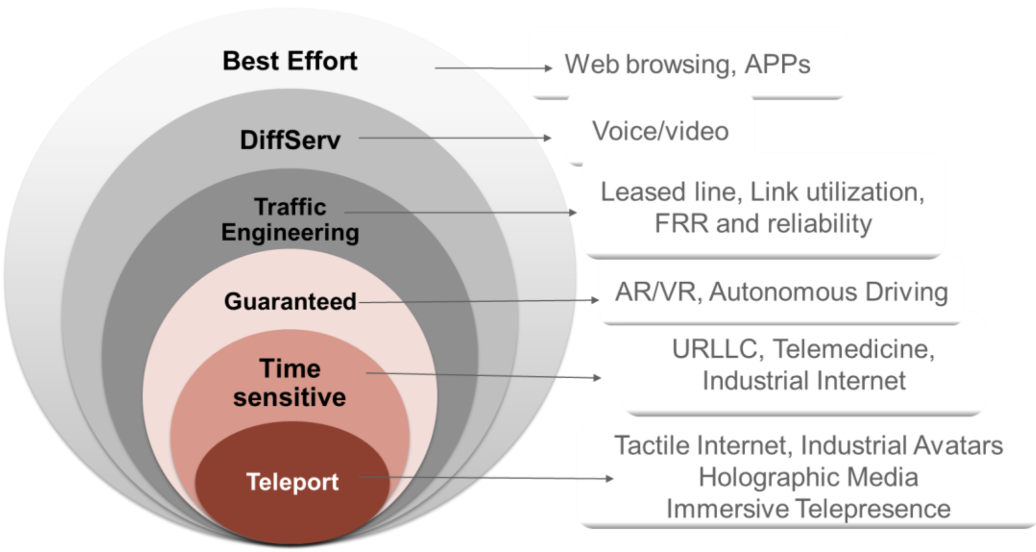


Figure 7: Tighter Service Level Objectives

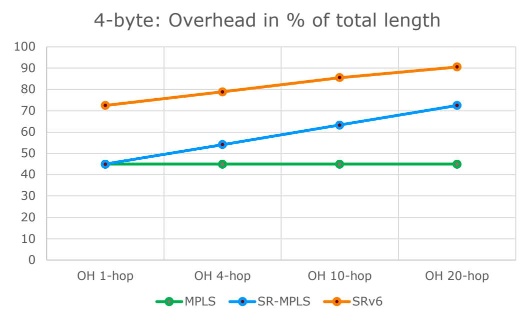
For instance, the web-based interface of the 1990s is based on the client-server model, client generally waits until the server replies, however long it may take (often multiple attempts in TCP). Original voice and video conferencing brought the concept of real-time but still the delay tolerance was high. Then with enterprise networks, there was rise in multitude of services with varying performance objectives for each service (document access, mail, multimedia, lab, applications, voice-conference, VPN access, etc.). These objectives got implemented using resource reservation and path redundancy techniques that are becoming more and more complex and challenging at scale.

The future applications landscape covers use cases like administering medicine or closely monitoring a patient remotely as well as Industry 4.0. These services have to be specially customized with high precision at a finer granularity than enterprise services hence Time Sensitive Networking (TSN) is gaining traction. We extrapolate this landscape to get stingier with service level objectives for information teleportation of holographic objects. The current TCP/IP does not have methods to deal with such information objects.

6.3 Protocol Efficiency

The IP-protocol suite is the predominant protocol site of the current network era and IMT2020 does not challenges this position. When the IMT2020 network goes live, most part of the architecture will still be fixed wireline network and for the reasons cited above, it is often not suitable to meet the service level objectives of IMT2020 (1 ms latency, reliability and high bandwidth in Gbps).

MPLS	bytes	MPLS-SR	bytes	SRV6	bytes
				IPv6 Encap	40
				SRH header	8
Transport Labels	4 to 12	Transport Labels	4 x SID count (upto 30)	transport SID	16 x SID count (upto 30)
Service Label	4	Service Label	4		
Outer IPv4 (for GTP)	20	Outer IPv4 (for GTP)	20	Service SID	16
UDP Hdr	4	UDP Hdr	4	UDP Hdr	8
GTP	12	GTP	12	GTP	12
Inner User IP	20	Inner User IP	20	Inner User IP	20
User Transport	4	User Transport	4	User Transport	4
User Payload	4 to 1200	User Payload	4 to 1200	User Payload	4 to 1200



$$transport\ OH\ \% = \frac{(Path_{oh})}{(Std_{hdr} + Path_{oh} + Pl)}$$

Observations

1. With Segment routing TE (MPLS or V6) overheads go up with No of hops.
2. General overhead for 4-byte packet is very high (with Std TCP/IP hdr included)
3. Segment routing TE vs MPLS has control plane complexity trade-offs

Figure 8: Transport backhaul protocol overheads

Both incumbent and new approaches of resource constrained path stitching in IP networks use overlay label or path information (MPLS, MPLS-SR and SRV6) to assure service performance. There are overhead trade-offs between control plane complexity and data plane payload tax. The easiest way to understand this is through understanding the transport backhaul in mobile networks. Instant messaging over mobile phone is a way of life today and often chat starts with a ‘Hi’ greeting that is four bytes message at most. The transport overhead over IP networks is shown below in Figure 8.

6.4 Federated Networks

In section 3 the changing nature of infrastructure was discussed. The growth of private networks is undeniable. The content owning organizations also own network infrastructure as well. This is unprecedented until now; yet there will be a need to provide data from one private network or cloud to the other. Therefore, the public backbone support may or may not be required and the definitions of global Internet may change to federated networks; How the infrastructure evolves and how private content owners support this model is an item of study.

It may require new routing and networking (addressing) paradigm, new trust-building models, more autonomic service level agreements. These are some of the topics of interest in this regard. It needs to be understood what kind of protocol is more suitable to form federations.

6.5 Achieving Network 2030

The Network2030 builds a bottom up foundation of the new Internet that works for both present and future applications. The new Internet has to be an extremely forward-looking architecture to build a new network that works for both machines (support CPS, digital twin communication) and humans (holographic teleportation). One of the instrumental part of Network 2030 is the New IP. First and foremost, formal definition and scope description through architecture and framework will be an important first step. Several enabling technologies may not be available yet; other new protocols may need to be created and some may need to be redefined. Anchoring on new IP, the following topics must be evaluated with details in the scope of Network 2030.

- ***Holographic Avatar Centric Communications***: This has been covered thoroughly in section 5.1.
- ***µ low-latency***: Covered in 5.2. allowing general purpose network technologies to be used as an enabler of industry 4.0 use cases.
- ***New data plane***: In order to support HTC and ITS, a new type of data plane techniques may be required. Such data planes should be backward compatible, because several applications in the current Internet can continue to be best-effort. The new data plane will need at least two new capabilities over existing IP. First, it must be able to carry a new kind of holographic-payloads and second, make the corresponding attributes available to network nodes to perform differential treatment of information. The data plane needs to evolve to dynamically adapt to different modes of operation, this is extremely difficult to achieve today.
- ***New control plane***: Control planes serve dual purpose, they act upon information from network operators (configurations, monitoring etc.) and participate in routing protocols. The self-configuration of networks requires autonomic, zero-touch configurations. The new techniques for telemetry and possibly mini machine learning and/or time-based algorithms can be incorporated in several control planes. Yet another control information with clear format of service level objectives for future application must be studied. The control plane must remain transparent to centralized or distributed modes of control.
- ***Security by trust***: Explained in section 5.3. the establishment of trust control plane or routing protocols must happen prior to bringing upon changes in order to be intrinsically secure. Also, periodic verification through "proof of trust" may be established.
- ***Protocol efficiency***: Allow data planes to be capable of compressing or shrinking partially or all of the flow information, in order to save total bits on wire. This may comprise of flexible headers, addressing, chained flow techniques. This is not an isolated data plane or control plane activity and must be coordinated at the architecture level.
- ***Factors for reliability***: The new data plane protocols must clearly be able to describe what is most reliable and what could be other levels of reliability.
- ***New routing technologies:*** These should emerge as a consequence of the new data plane, and also due to the fact that the Internet is getting redefined. The control artefacts of different type of applications (IoT, V2X, end user applications, enterprises, critical communications etc.) will vary. Identification of methods to uniformly capture these artefacts for protocol flexibility and extensibility can be done in the scope of Network 2030.

- ***Architectures & Infrastructures***: Discussed in section 6.4, it will worth studying the impact of Infrastructure changes to the network architectures as to allow heterogenous type and access agnostics communications.

The original Internet architecture was a clean slate, it did not have predecessors; in terms of security it did not anticipate any kind of attack vectors or exploitation of user data techniques. One of the important activities to come out of Network 2030 will be the investigation of and a proposal for new data planes and control planes. These activities will exploit strengths of SDN/NFV, centralized and distributed approaches altogether instead of favoring one over the other. Of course, Network 2030 sits on the shoulders of the giant IMT2020. Without the vision of IMT 2020, Network 2030 would have been impossible. How use cases, market drivers and scenarios differ between or evolve from IMT2020 and/to 2030 are shown below in Figure 9.

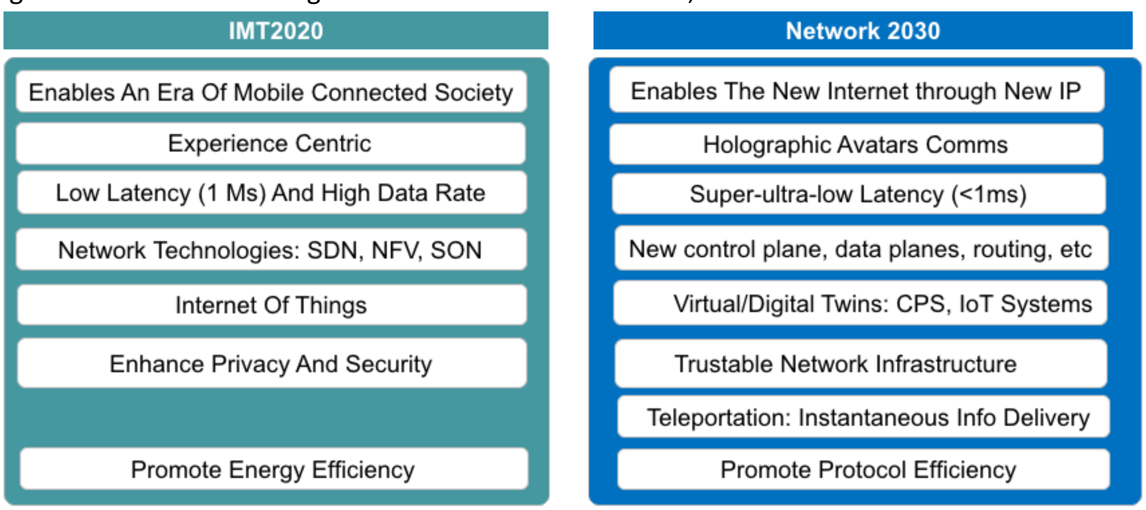


Figure 9: From IMT2020 to Network 2030

7 Research Map (study topics)

The vision of Network 2030 is presented below. It shows applications and technologies with in IMT2020 scope as well as Network 2030 along with technology enablers and New IP as the foundation.

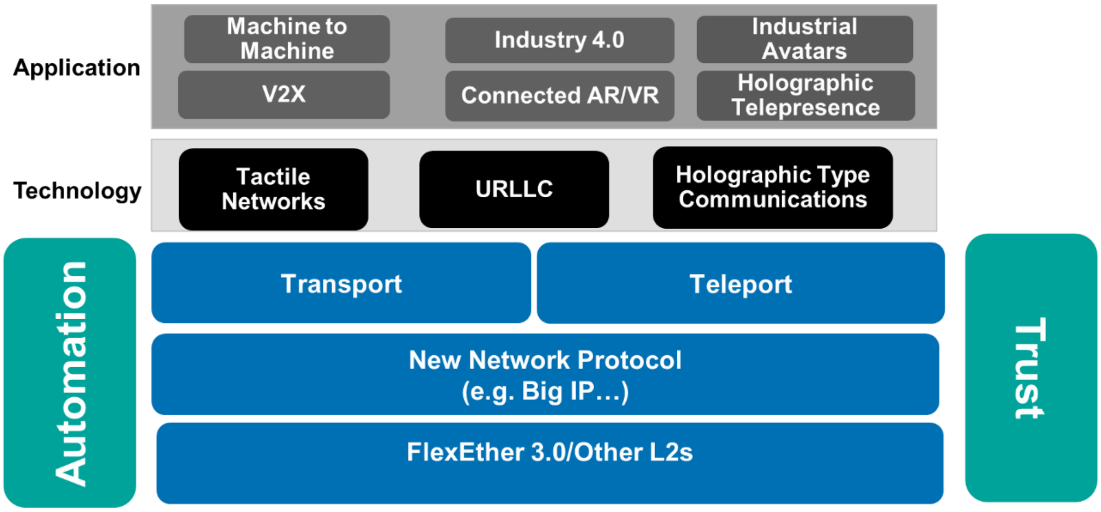


Figure 10: Network 2030 Framework

Based on the discussion, suggested topics in the scope of Network 2030 are

- Proposal for evolution network layer protocols applicable to both IMT2020 and Network 2030
- Study of holographic type communications
- Study of mechanisms for information teleportation
- Study and proposals for trust based intrinsic security
- Federation network communications and protocols
- Study of techniques that provide efficiency in network protocols

8 Conclusion

Network 2030 is a planning for network architectures for future applications. The vision and directions provided by IMT-2020 helps us understand a landscape of what kind of services and infrastructures greater significance will have going forward. The next wave in networking applications, such as the Industrial Internet, the Tactile Internet, or Augmented Reality, have placed unprecedented demands on the network in terms of extremely low latency, jitter, bandwidth, and loss. At the same time, inherent security and support for seamless mobility are not considered as optional but are expected as organic. We are approaching the year 2020, and it is understood that the fundamental construct – the Internet Protocol (IP) may not nearly be ready to support these constraints.

What is needed first and foremost to establish goals – that communications technologies should work for the safety of and the making of better human life. A new way of approaching the network resources and constraints needs discussion. This paper was its introduction.

In this paper, we discussed the capability perimeter roadmap towards 2030. From there we laid out three properties that will be necessary for the future networks: augmented holographic type communications, instantaneous teleportation and trustable network infrastructures. These capabilities allow networks to aim to implement innovative networking algorithms that can be used for the novel schemes that will vastly improve network performance, security, mobility, and overall user experience. Network 2030 should make existing services better. Network 2030 will have a new IP protocol suite that combines best effort and high-precision. It will deliver on the demands of the next wave of networking applications.

All this requires a bold and necessary rethinking of fundamental internetworking concepts. To emphasize this, in this document we presented a vision of the relevant future use cases that our society would like to see and will benefit from. We also brought in focus current scenarios that need to be re-examined for the way they are deployed today.

Network 2030 means nothing without cooperation, collaboration, buy in from service providers, vendors and application developers. Without proper standardization and common vision, Network 2030 will not be possible. We invite active participation, study contribution and candid review of this document as well the work that will follow.

Please join us in this journey to Network 2030.

This document serves as supporting material for ITU-T, FG-NET-2030. It is a vision document to rationalize need for study pertaining to communications and future applications.