5G (+ 6G)

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INTRODUCTION

AI-kommissionens

Färdplan för Sverige

26/11/2024

AI-kommissionens *Färdplan för Sverige*

AI-kommissionen och de vi mött

200 möten - 1000 personer

Massor av inspel

Stor förväntan, iver att komma igång

Sverige har under ett sekel legat i framkant när det gäller utbyggnaden av telekom, både avseende senaste teknologi och täckning. En illustration av detta är att Sverige har **ett relativt väl utbyggt fibernä**t, vilket ger en bra grund för att erbjuda AI-lösningar.

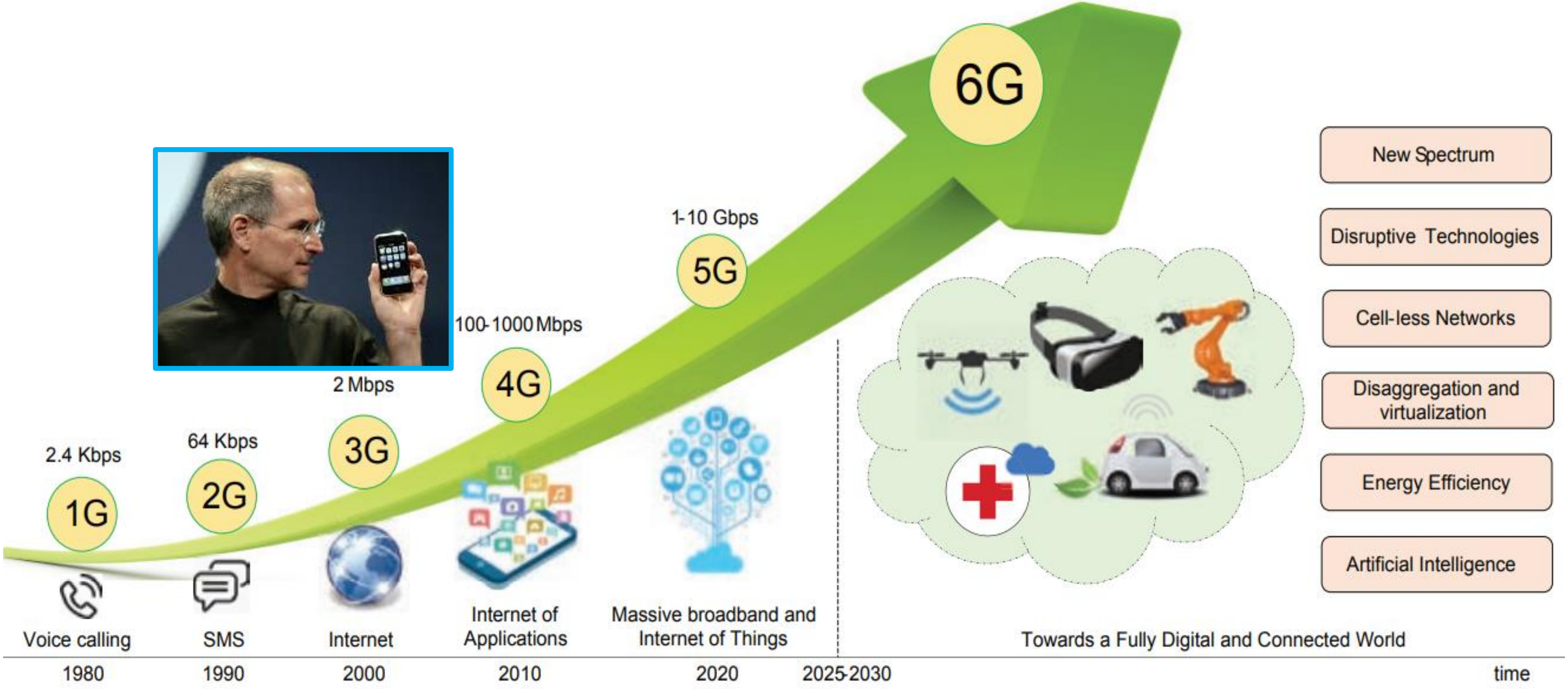
I kontrast står sig Sveriges mobilnät sämre vid en internationell jämförelse. **Utbyggnaden av 5G** har skett tidigare och snabbare i USA och Asien än i Sverige.

Enligt den senaste upplagan av GSMA:s 5G-konnektivitetsindex **hamnar Sverige på plats tjugoett.** Våra nordiska grannar Norge, Finland och Danmark tillhör alla de sju bästa i världen. Likaså placerar sig de stora AI-nationerna Kina och USA före Sverige.

5G-teknik gör AI möjlig

5G-tekniken gör AI möjlig genom snabbare och mer robust dataöverföring. Den ökade hastigheten och kapaciteten i 5G-nätverk skapar nya förutsättningar för AI-baserade system som bygger på att bearbeta stora mängder data i realtid. 5G SA (stand alone) ger operatörer möjlighet att avsätta specifik nätverkskapacitet baserat på individuella kunders behov. Denna flexibilitet gör att kunder med höga krav på stabilitet och pålitlighet kan få en anpassad uppkoppling, vilket inte var möjligt med tidigare nätverksgenerationer där resurserna delades lika mellan alla användare.

Evolution of cellular networks 1G → 6G



6G will revolutionize the wireless evolution from "connected things" to "connected intelligence".

Generations of cellular mobile systems

Gen	Year	Name	Technology	Frequence	Data rate	Application
1G	(1980 -)	NMT	analogue	400 MHz - 950 MHz	2.4 kbit/s	voice
2G	(1992 -)	GSM	digital	900 MHz - 1.8 GHz	64 kbit/s	voice, SMS
3G	(2004 -)	UMTS	digital	900 MHz - 1.8 GHz	2 Mb/s	multimedia, internet
4G	(2010 -)	LTE	digital	500 MHz - 2.5 GHz	>100 Mb/s	internet, apps
5G	(2020 -)		digital	400 MHz - 40 GHz	>1000 Mb/s	IoT
6G	(2030-)		digital	400 MHZ - > 1 THz	>1000 Gb/s	sky´s the limit brave new world

4G - 5G - 6G parameters

Issue	4G	5G	6G
Per Device Peak Data Rate	1 Gbps	10 Gbps	1 Tbps
End-to-End Latency (E2E)	100 ms	10 ms	1 ms
Maximum Spectral Efficiency	15 bps/Hz	30 bps/Hz	100 bps/Hz
Mobility Support	Up to 350 km/hr	Up to 500 km/hr	Up to 1000 km/hr
Satellite Integration	No	No	Fully
AI	No	Partial	Fully
Autonomous Vehicle	No	Partial	Fully
XR (Extended reality)	No	Partial	Fully
Haptic Communication	No	Partial	Fully
THz Communication	No	Very limited	Widely
Service Level	Video	VR, AR	Tactile
Architecture	MIMO	Massive MIMO	Intelligent Surface
Maximum Frequency	6 GHz	90 GHz	10 THz

1G

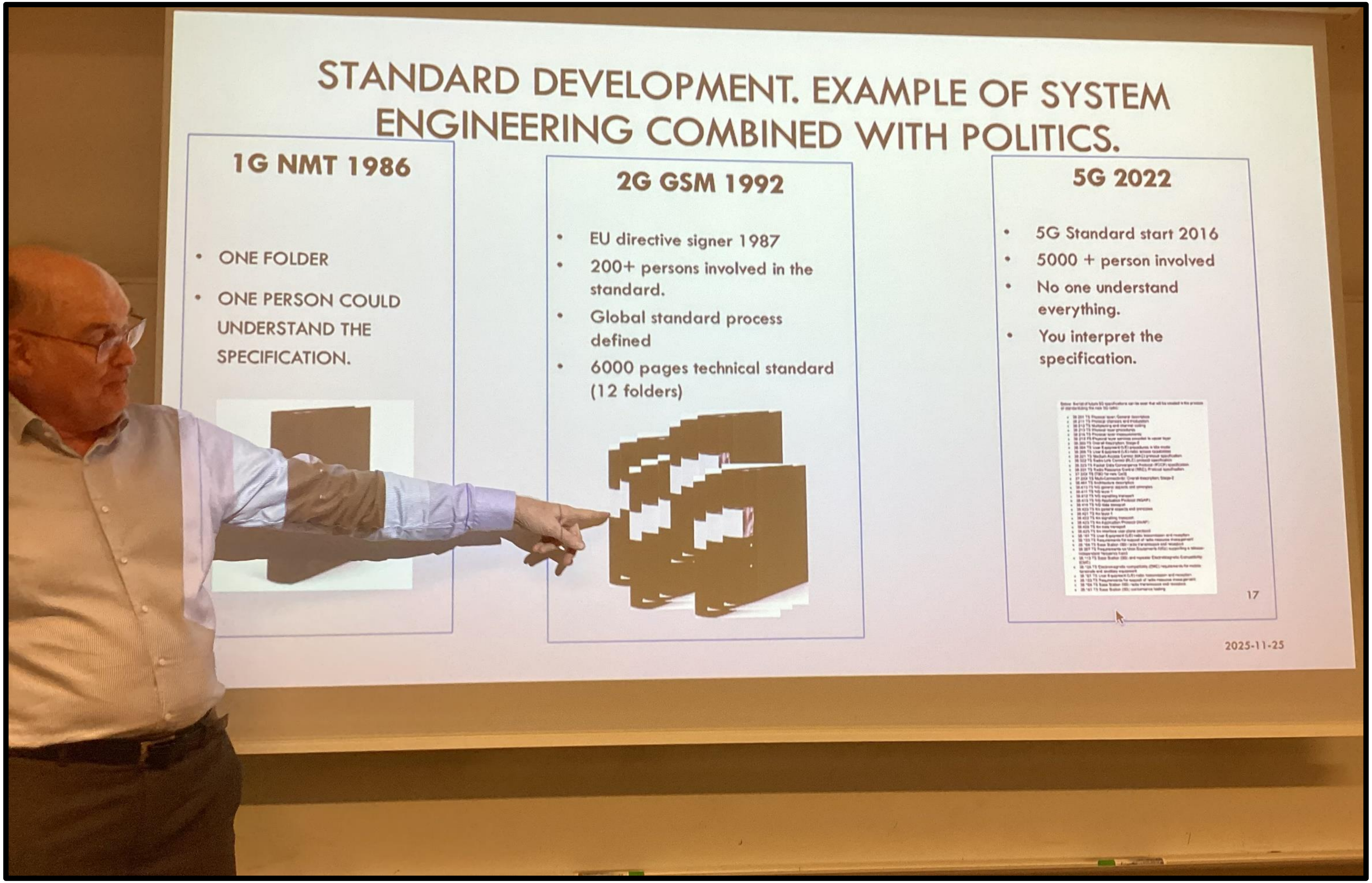
2G

3G

4G

5G

Ett pussel med motiv från färgstarka Djungeln. Märke: Jumbo Tillverkare: Jumbo Antal bitar: 500 XL bitar Mått på pussel: 68 x 49 cm


STANDARD DEVELOPMENT. EXAMPLE OF SYSTEM ENGINEERING COMBINED WITH POLITICS.
1G NMT 1986
ONE FOLDER
ONE PERSON COULD UNDERSTAND THE SPECIFICATION.
2G GSM 1992
EU directive signer 1987
200+ persons involved in the standard.
Global standard process defined
6000 pages technical standard (12 folders)
5G 2022
5G Standard start 2016
5000 + person involved
No one understand everything.
You interpret the specification.
17
2025-11-25


6G!!!

What is special with 5G

5G technology is not just the next version of mobile communications, evolving from 1G to 2G, 3G, 4G, but it provides **a new approach** giving **ubiquitous connectivity**.

5G technology is very different. **Previous systems** had evolved driven more by what could be done with the latest technology. **The new 5G technology has been driven by specific use cases and applications.**

5G is able to provide **much greater flexibility** and therefore it is able to support a much wider range of applications, from **low data rate** IoT requirements through to very **fast data rate** and very **low latency** applications.

MARKETING OF 5G (2022)

Dagspress - Svensk operatör X förklarar

Teknikerna i mobilnätet brukar delas in i generationer där 4G och 5G står för fjärde och femte generationens mobilnät. 4G gav helt nya förutsättningar för videosamtal och livestreaming men är inte rustat för framtidens **extrema mängder uppkopplade enheter**. Det är här 5G kommer in i bilden.

Vad är skillnaden mellan 4G och 5G?

De största skillnaderna som **vi som surfar kommer** märka är att **5G går snabbare** och har **kortare svarstid än 4G,** det vill säga tiden från klick till respons. Det här beror på att 5G-nätet har större bandbredd och kan hantera större mängder data än 4G. Båda dessa är såklart stora fördelar, vem har tid eller tålamod att vänta?

Varför är 5G snabbare än 4G?

Enkelt sagt består täckning av signaler som skickas via olika frekvenser i mobilnätet. **Låga frekvenser når långt men kan inte hantera så mycket data medan höga frekvenser kan hantera mer data men når inte lika långt.** De är alltså varandras motsatser. Det trevliga med 5G är att tekniken kan använda både högre och lägre frekvenser än 4G vilket gör att det både **når längre** OCH **går snabbare**. Ja tack säger vi!

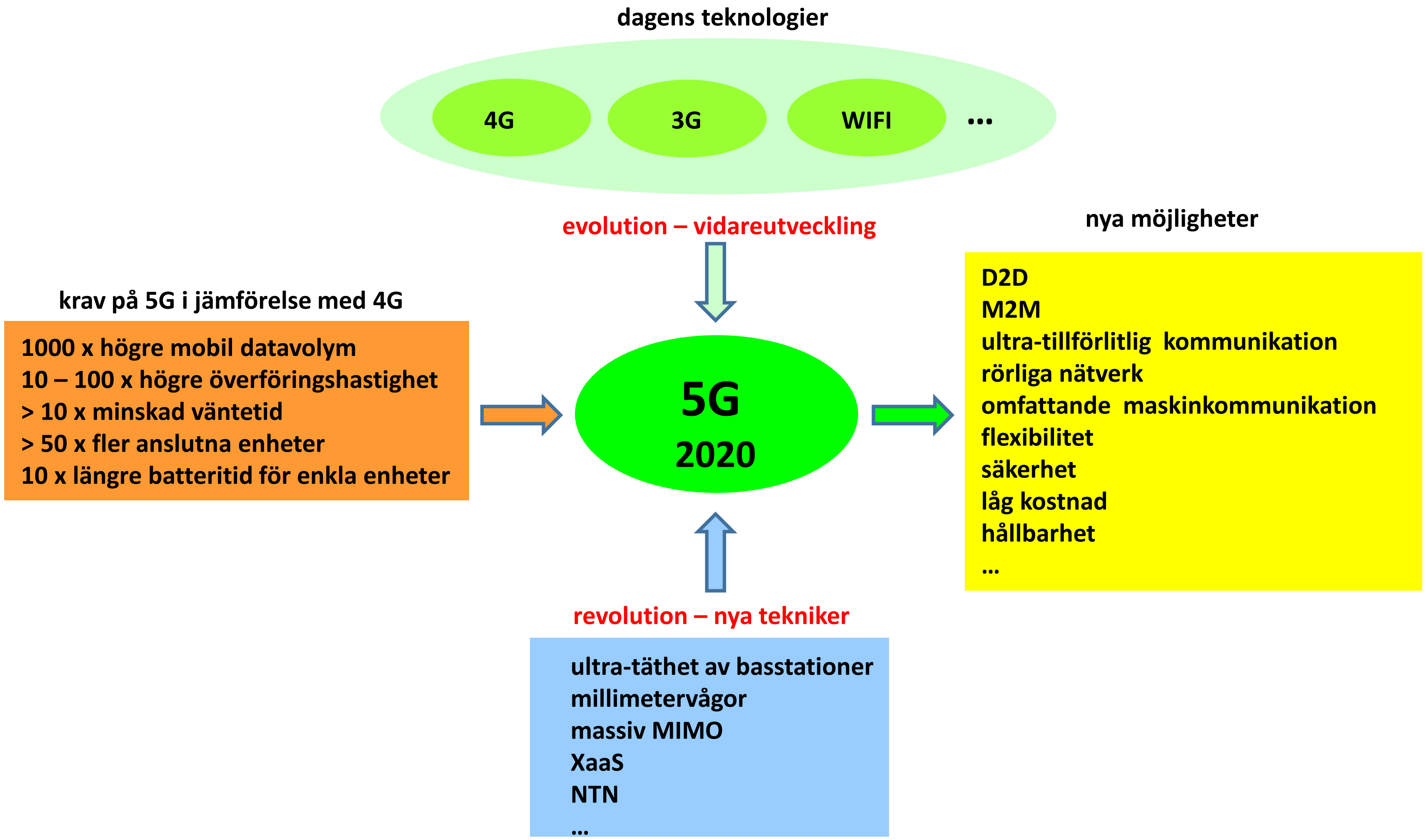
5G har kortare svarstid än 4G

Svarstid, eller **ping** som det också kallas, är tiden från klick till action. Från att du trycker like till att det visas på Instagram eller från att du trycker ”hoppa” till att din gubbe i spelet faktiskt hoppar. Inom just gaming är svarstider extremt viktigt och kan vara skillnaden mellan att vinna och förlora. Med 5G kommer svarstiderna vara så korta att det **om några år** kommer gå att spela alla typer av spel överallt där det finns bra mobiltäckning.

NATIONALENCYKLOPEDI OCH 5G

2015 IK ☺

Behovet av snabba, tillförlitliga och bredbandiga mobila kommunikationstjänster ökar ständigt. Vissa av dessa behov kan tillfredsställas med stegvis förbättring och vidareutveckling av dagens tekniker som 3G, 4G och trådlösa lokala nätverk (WiFi). Framtida tillämpningar ställer dock mycket högre krav än vad dessa tekniker kan uppfylla. Ett **revolutionärt steg** i utvecklingen av kommunikationsteknologin är därför nödvändigt för 5G.



De mest uppenbara skillnaderna mellan 5G och de tidigare generationerna kommer att vara dels antalet, dels typen av användare.
I framtiden kommer vi att bevittna en övergång från människocentrerad kommunikation (som är dominerande i 3G, 4G och WiFi) till kommunikation mellan många olika fasta och mobila enheter där människor som användare är i minoritet.

En storkonsument av 5G-systemens tjänster blir det snabbt växande området **M2M** (machine to machine) som innebär kommunikation mellan teknisk utrustning utan mänsklig inblandning. En annan ofta använd akronym är **D2D** (device to device) där två eller flera enheter utbyter data med varandra direkt och 5G nätverket endast har en kontrollfunktion.

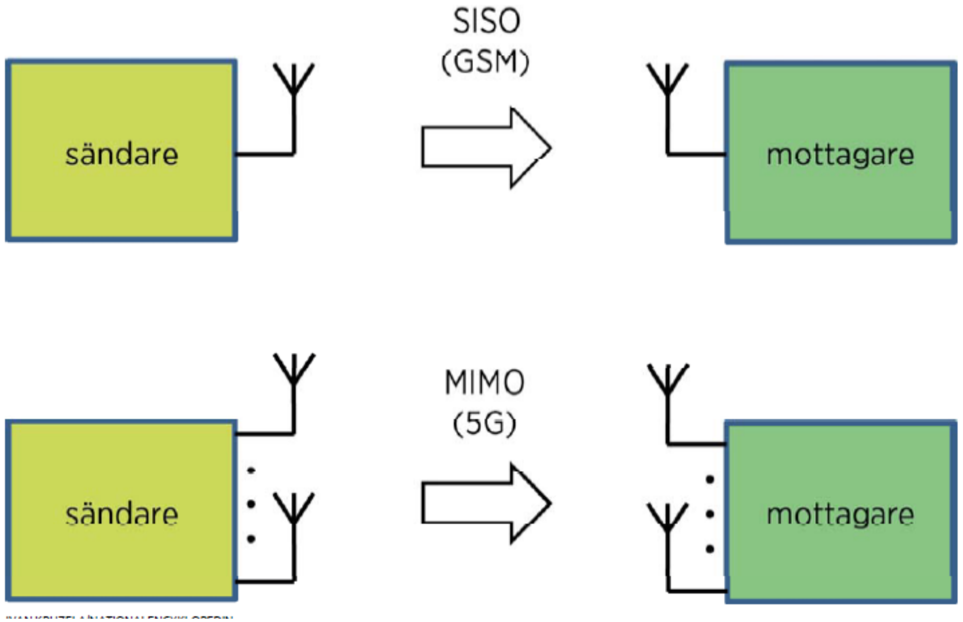
NE - nya tekniker

Stark förtätning av basstationer.
Ett intuitivt uppenbart sätt att öka den i framtiden nödvändiga accesskapaciteten är att minska cellstorleken och öka antalet. I stället för en basstation som täcker ett område (cell) med radien 1 km och har en begränsad mängd tillåtna frekvenser och därmed ett begränsat antal användare, kan man inom samma område installera 100-tals små basstationer med låg signalstyrka och räckvidd under 100 m.

Millimetervågor.
Tidigare generationer av mobila nät använder frekvenser inom området **hundratals MHz till några GHz**, med våglängder **mellan 50 och 5 cm**. Detta område närmar sig gränsen för möjligt utnyttjande. En möjlig lösning på problemet är att använda nya spektralområden. En relativt oanvänd del av radiospektrum, **30–300 GHz** med våglängder från **10 till 1 mm**, erbjuder möjligheten till nya kommunikationskanaler med **hög överföringshastighet**. Högre frekvenser betraktades tidigare som olämpliga för mobila system på grund av nackdelar som hög dämpning av signalen i atmosfären, signalabsorption i regndroppar och behovet av fri sikt mellan sändare och mottagare (signalen blockeras av hinder som byggnader).

Massiv MIMO.

MIMO (**multiple input multiple output**) är en teknik där både den sändande och den mottagande enheten använder flera antenner. En vanligare teknik som har används i till exempel GSM, är **SISO** (single input single output) med endast en sändande och en mottagande antenn. Syftet med massiv MIMO är att öka tillförlitligheten (minska känsligheten för störningar), öka överföringskapaciteten (antalet överförda bitar per sekund) samt spektrumeffektiviteten (mer konservativ användning av det för tillfället tillgängliga spektrumet). Tekniken är speciellt fördelaktig vid användning av millimetervågor eftersom en stor mängd antenner av millimeterstorlek kan få plats i mobila enheter.



XaaS.
Traditionellt är ett kommunikationsnätverk en ganska oflexibel lösning som utgörs av en mängd integrerade delar, till exempel transmissionskomponenter, gateways, växlar och routrar. **I framtiden kommer nätverket att vara en enbart för tillfället och för en konkret situation skapad tjänst där uppkoppling och inställningar av all ingående utrustning kommer att göras av programvara på en server.** Metoden kallas **mjukvarudefinierat nätverk**.
XaaS (**anything as a service**) är ett begrepp som används i sammanhanget, och som har sitt ursprung i datormolntekniken, är som innebär att allt i framtidens nät blir en tjänst.

5G SPEKTRUMBAND

Spektrumband för 5G och deras egenskaper

Lågband (600-900 MHz)
+ Större täckningsyta
+ Bra inomhuspenetration
- Låg kapacitet (bandbredd)

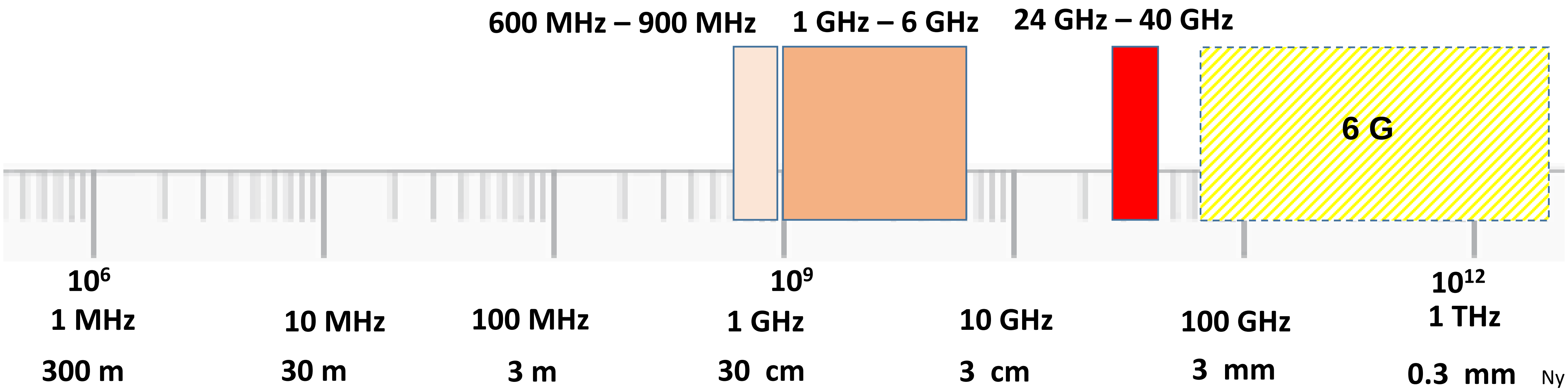
Massiv maskintypskommunikation, Täckning av stora områden. IoT

Mellanband (1-6 GHz)
+ Högre kapacitet
+ Lägre fördröjning
- Mindre täckningsyta

Mobilt bredband. Fast trådlöst tillgång (fixed wireless acces), Streaming applications.

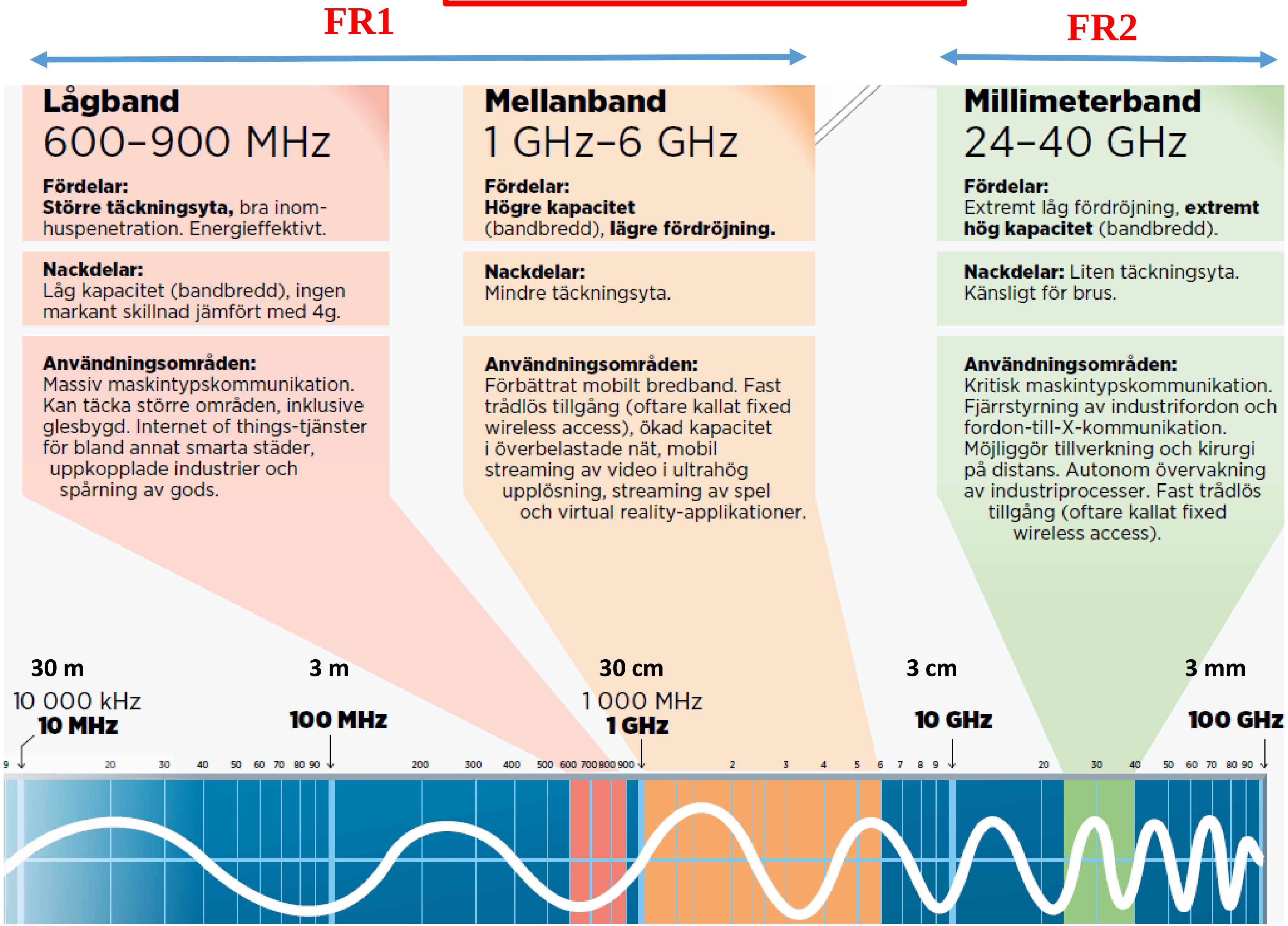
Millimeterband (24-40 GHz)
+ Extremt låg fördröjning
+ Extrem hög kapacitet
- Liten täckningsyta
- Känslig för brus

Kritisk maskintypskommunikation. Fordon till X kommunikation. Kirurgi på distans.

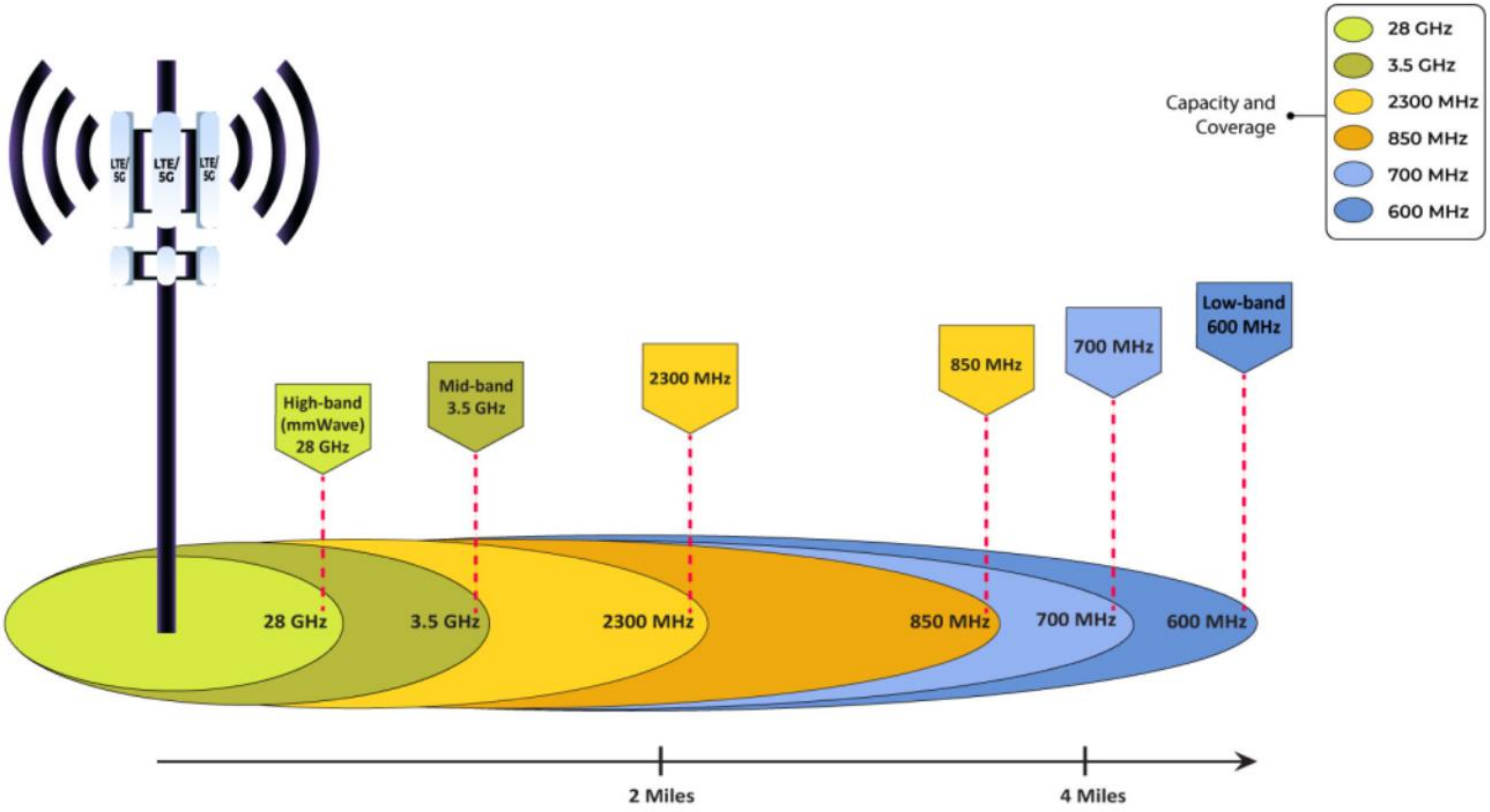


Ny Teknik

5G Spektrumband



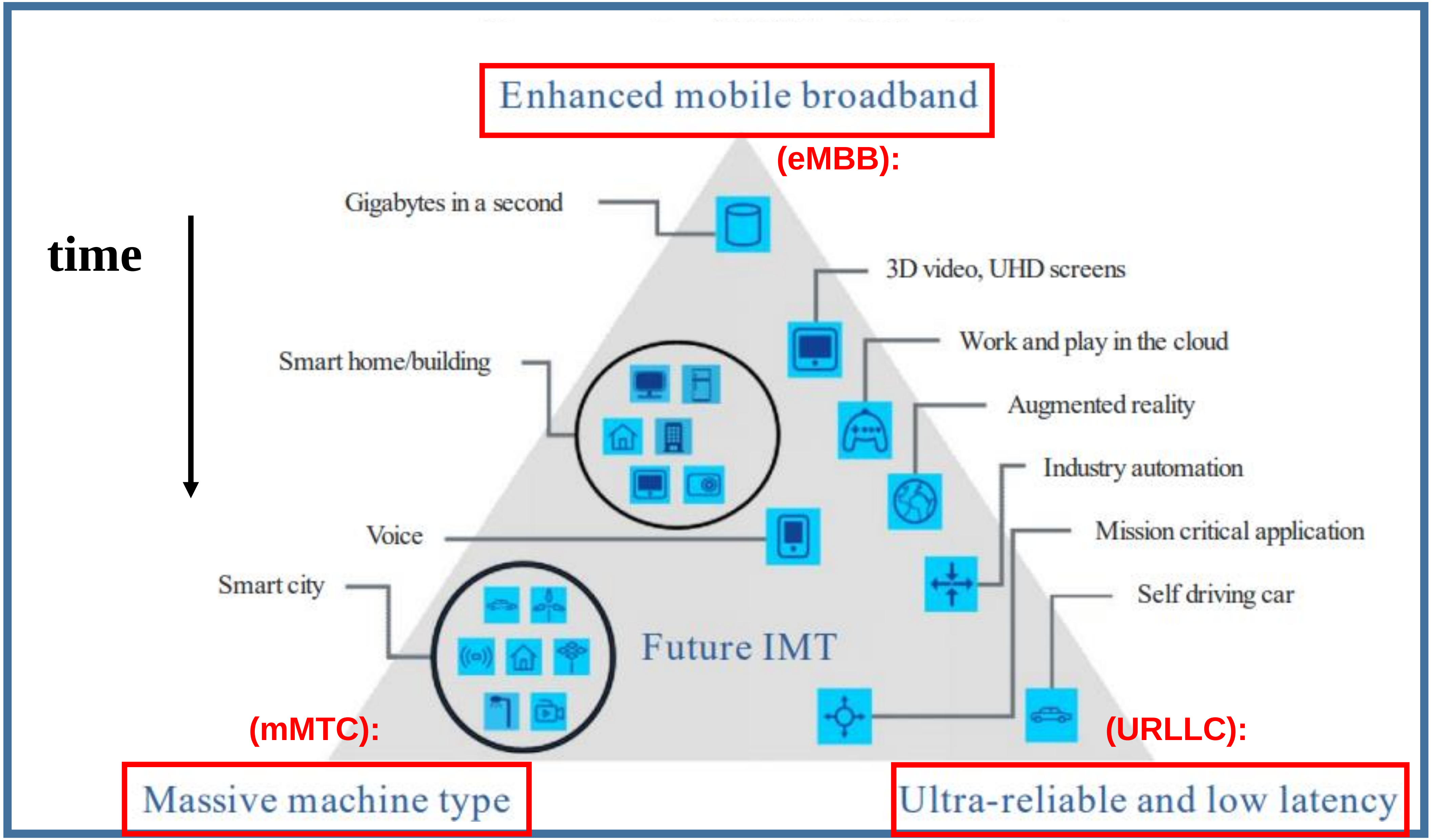
5G Spektrumband - täckning



https://nybsys.com/5g-bands/

USAGE SCENARIOS

5G usage scenarios



Unlike previous systems (3G, 4G) that attempted to provide a “one size fits all” solution, the 5G system is expected to satisfy a wide range of applications and services, which can be grouped into **three use case families**:

Enhanced Mobile Broadband (eMBB): describes the **high data rate** and **high capacity** aspects of 5G with the goal of providing a mobile broadband experience on cellular phones and other connected devices mostly focused on **high definition video streaming, virtual meetings, augmented reality and cloud computing**.

Massive Machine-Type Communications (mMTC): is the evolution path for today’s IoT air interfaces. It enables **high density**, **high coverage**, and **low power** use cases, such as **asset tracking, sensor networks, smart cities, smart buildings, health care monitoring and wearables**.

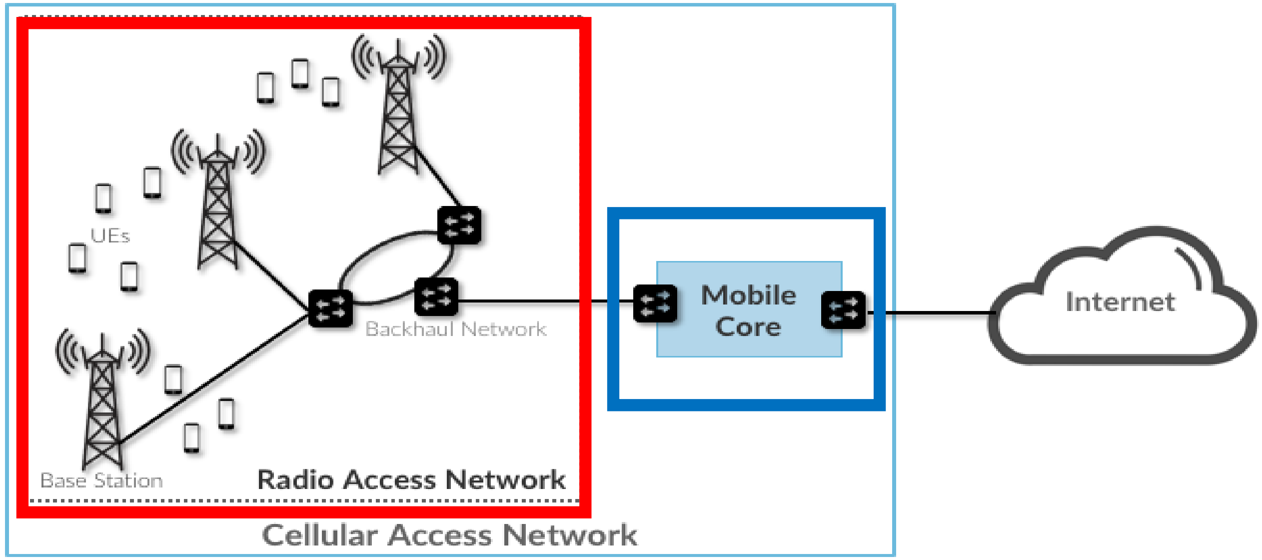
Ultra-Reliable Low Latency Communication (URLLC): opens 5G to new mission-critical applications reliant on **ultra-low latency** communication and **high reliability**. It will enable applications focused on **public safety, industrial control, health, unmanned vehicles and autonomous driving**.

5G - SYSTEM ARCHITECTURE

3GPP TS 123.501 (570 pages)

3GPP TS 138.401

Basic architecture of 5G



The **5G cellular network** consists of the **Radio Access Network (RAN)** and the **Mobile Core**.

The **RAN** manages the radio spectrum, making sure it is used efficiently and meets the quality-of-service requirements of every user

The **Mobile Core** is a bundle of functionality that serves several purposes.

- Provides Internet (IP) connectivity for both data and voice services.
- Tracks user mobility to ensure uninterrupted service.
- Tracks subscriber usage for billing and charging.

- https://5g.systemsapproach.org/

High-level representation of networks: User, Control and Management plane

A **plane** is a representation of an aspect of a network. **User plane**, **Control plane** and **Management plane** - can be thought of as **different areas of operations**.

Each plane carries a different type of traffic and is conceptually (and often in reality) an overlay network (a telecommunications network that runs independently on top of another one, although supported by its infrastructure).

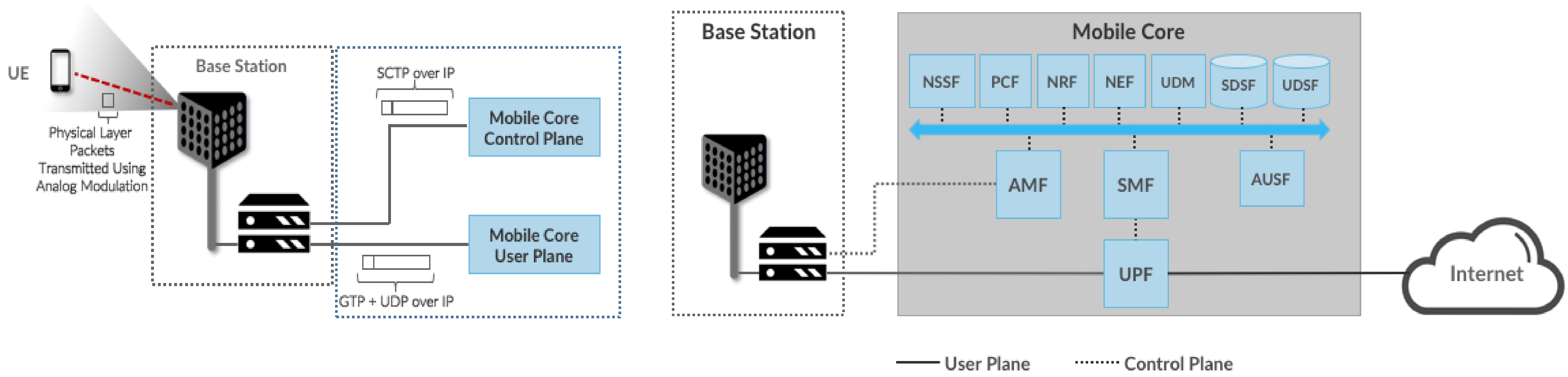
User plane, also called the Data Plane, carries the network **user traffic**.

Control plane is the part of a network that carries **signaling traffic**.

Management plane is the element within a system that configures, monitors, and provides **management**.

https://www.dialogic.com/ https://www.techtarget.com/

Mobile Core - 5G



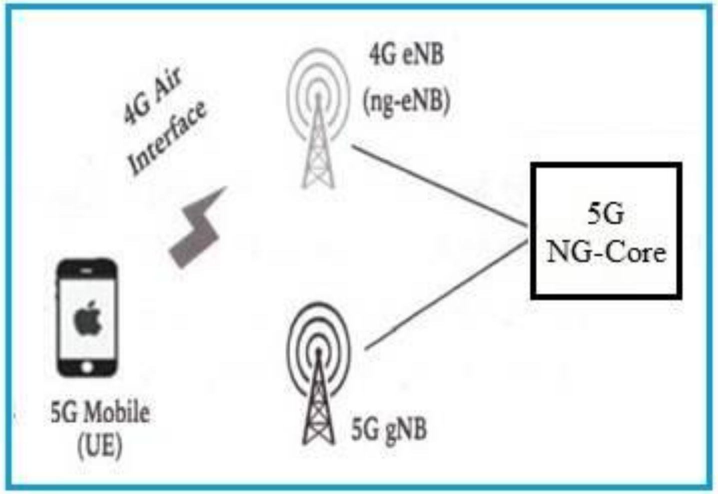
UPF (User Plane Function): Forwards traffic between RAN and the Internet. In addition to packet forwarding, it is responsible for policy enforcement, traffic usage reporting, and QoS policing.

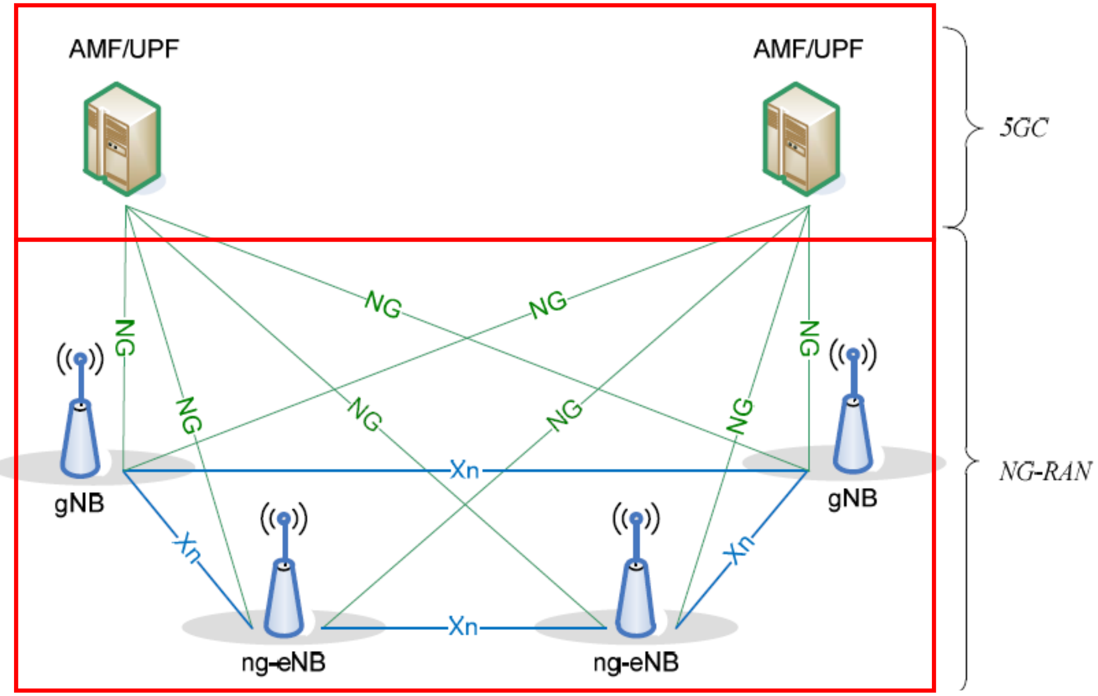
AMF (Core Access and Mobility Management Function): Responsible for connection and reachability management, mobility management, access authentication and authorization, and location services.

SMF (Session Management Function): Manages each UE session, including IP address allocation, selection of associated UP function, control aspects of QoS, and control aspects of UP routing.

https://5g.systemsapproach.org/

The 5G RAN architecture





An NG-RAN node **gNB** or **ng-eNB** (*4G*) provide NR user plane and control plane protocol terminations towards the **UE** and is connected via the **NG interface** to the 5GC.

TS 138.300

Generation	**Radio Technology**	**Base Station Name**
2G	GSM	BTS (Base Transceiver Station)
3G	UMTS	NodeB
4G	LTE	eNB (Evolved NodeB)
5G	NR (New Radio)	gNB (Next Generation NodeB)

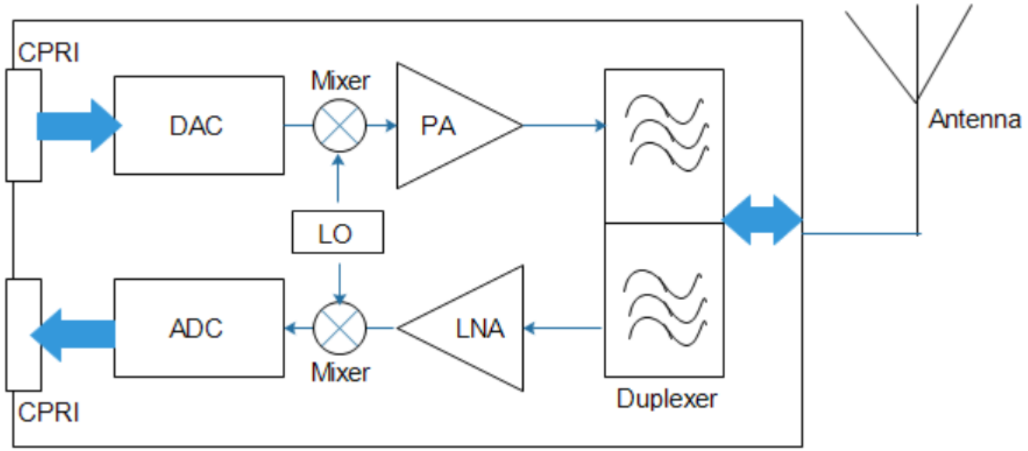
Example of gNB functions

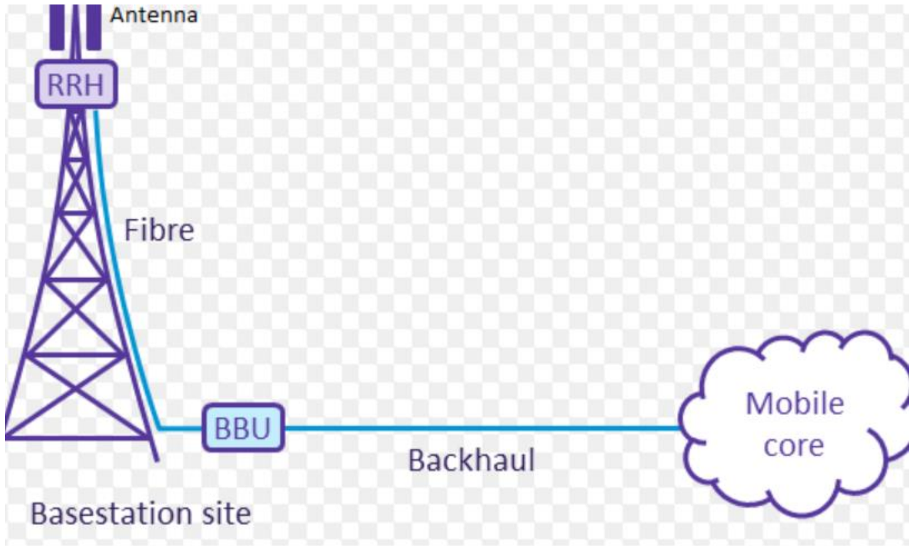
- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection
- **Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);**
- **Routing of User Plane data towards UPF(s);**
- **Routing of Control Plane information towards AMF;**
- **Connection setup and release;**
- Scheduling and transmission of paging messages;
- Scheduling and transmission of system broadcast information (originated from the AMF);
- **Measurement and measurement reporting configuration for mobility and scheduling;**
- Session Management;

Remote Radio Head (RRH)

RRH is sitting on top of cell tower and performs following functions:

- Convert optical signal to electrical signal and vice versa using CPRI
- In transmitter section of RRH, it converts digital signal to RF and amplifies that signal to the desire power level and Antenna connected to it, radiates the RF signal in air
- In Receiver section of RRH, it receives the desired band of signal from antenna and amplify it and convert RF signal back to digital signal in the receiver chain.

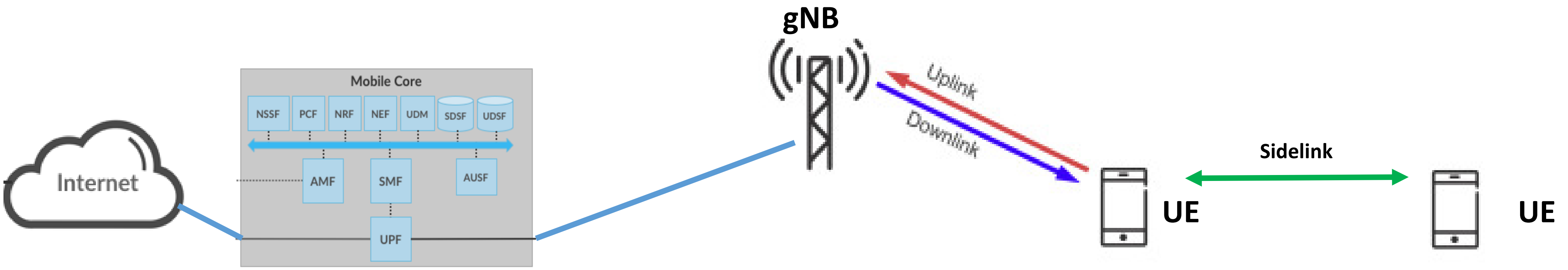




The **Common Public Radio Interface (CPRI)** standard defines an interface between Baseband Unit (BBU) and Remote Radio Head (RRH)

https://www.techplayon.com/?s=rrh

Downlink / Uplink / Sidelink



There are two main components in 5G NR network: **UE** (User Equipment) and **gNB** (base station). gNBs are connected with 5G Mobile Core.

Connection from gNB to UE is known as **downlink**

Connection from UE to gNB is known as **uplink**

Connection between UEs is known as **sidelink**

https://rfwireless-world.com/Articles/5G-NR-Physical-Layer.html

DATA CHANNELS

5G Data Channels: Physical, Transport & Logical

In order to be able to carry the data across the 5G radio access network, the data and information is organized into a number of **data channels**.

As there are many different types of data that need to be transferred - **user data** obviously needs to be transferred, but so does **control information** to manage the radio communications link, as well as data to provide synchronization, access and the like. All of these functions are essential and require the **transfer of data** over the radio access network.

The use of these 5G channels provide a **method for organizing the data flow** over the radio interface of the 5G communications network. Using channels enables the communications system to recognize the type of data that is being sent, and to deal with it accordingly.

Three types of data channels used in 5G

- **Logical channel:** Logical channels can be one of two groups:

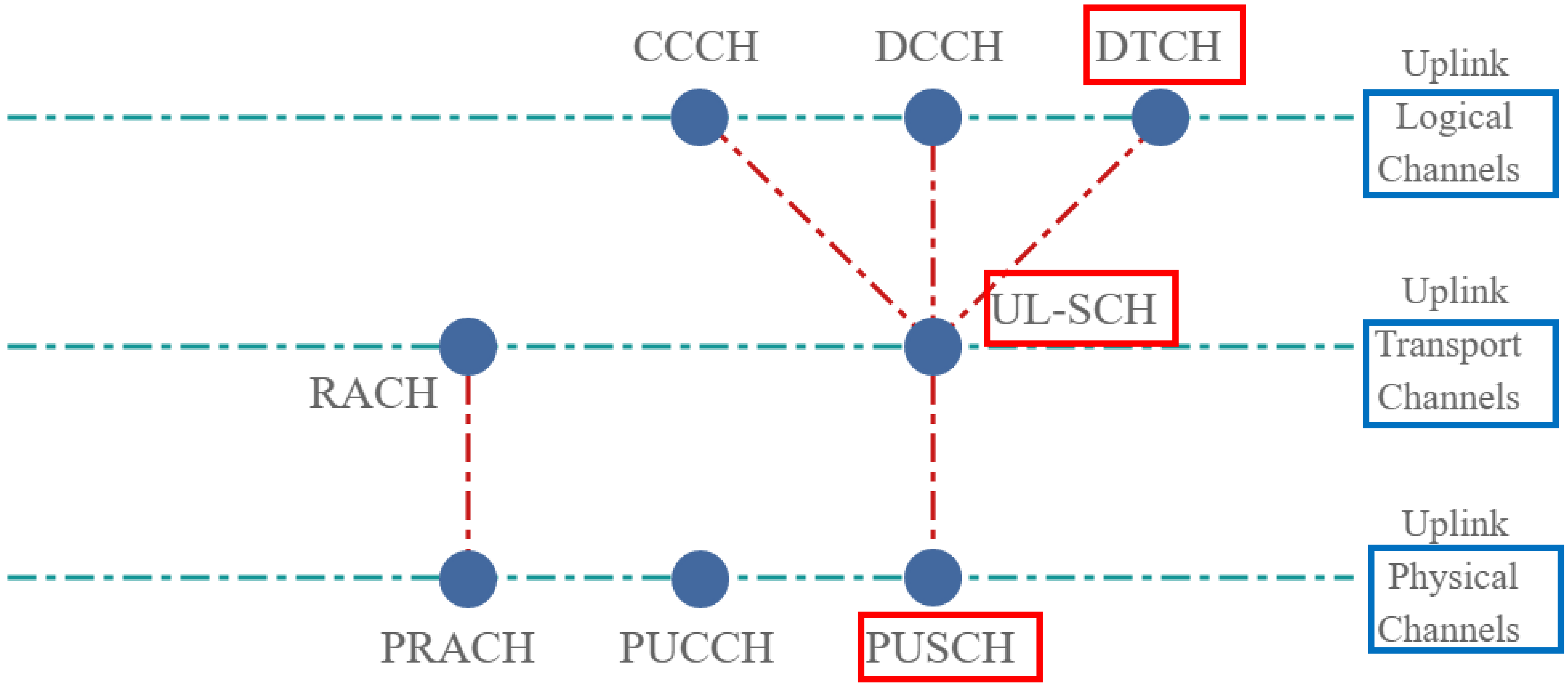
  - ***Control channels*:** The control channels are used for the transfer of data from the control plane
  - ***Traffic channels:*** The traffic logical channels are used for the transfer of user plane data.

- **Transport channel:** Is the **multiplexing** of the logical data to be transported by the physical layer and its channels over the radio interface.

- **Physical channel:** The physical channels are used to carry the data over the radio interface. They have the transport channels mapped into them, but they also include various physical layer data required for the maintenance and optimization of the radio communications link between the UE and the base station.

TS 138.213

5G NR uplink logical, transport & physical channel mapping

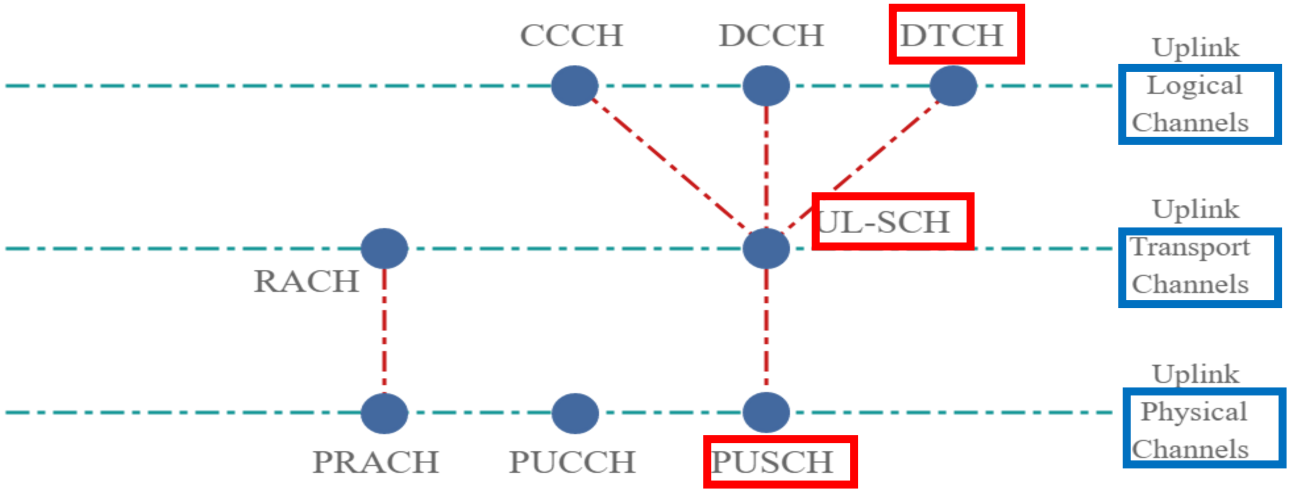


5G NR logical channels - uplink

- ***Common Control Channel, CCCH:*** This channel is used on both the downlink and uplink for transmitting control information to and from UEs. The channel is used for initial access.

- ***Dedicated Control Channel, DCCH:*** The DCCH is used to carry dedicated control information between the UE and the network.

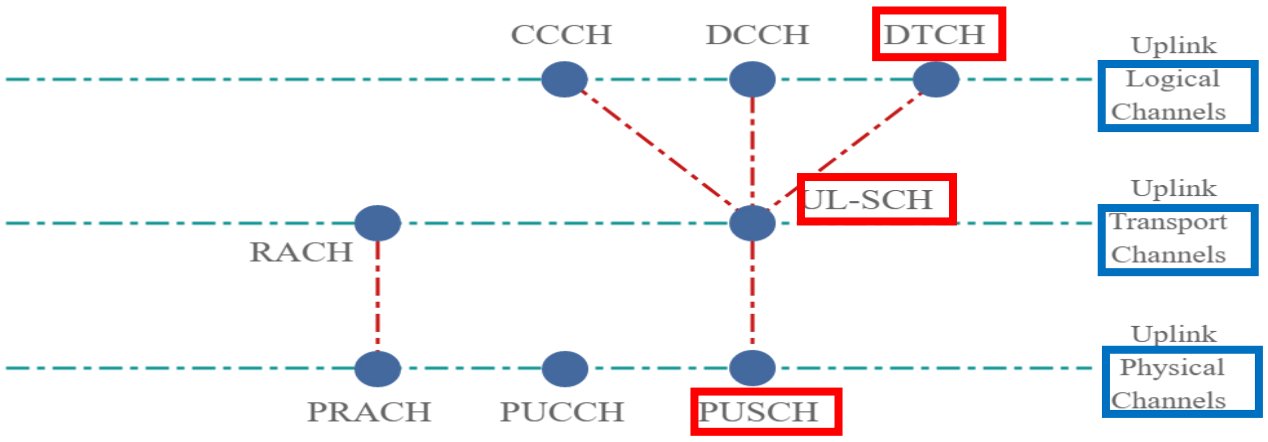
- ***Dedicated Traffic Channel, DTCH:*** This channel is dedicated to one UE and is used for carrying user information to and from a specific UE and the network.



5G NR transport channels - uplink

- ***Uplink Shared Channel, UL-SCH:*** This is the uplink transport channel used for transmission of uplink data.

- ***Random-Access Channel, RACH:*** The RACH is a transport channel, which is used to overcome the message collisions that can occur when UEs access the system simultaneously.

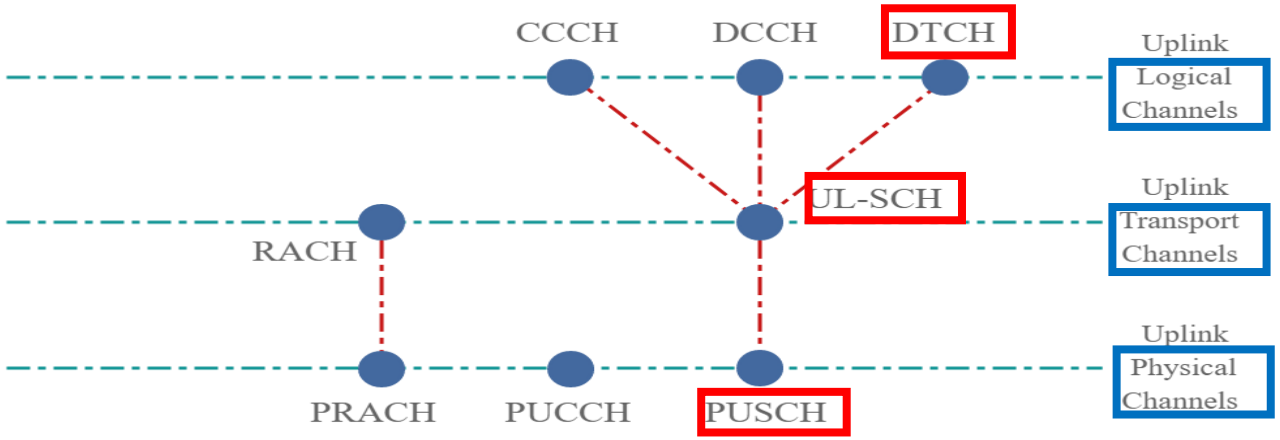


5G NR physical channels - uplink

•***Physical random access channel, PRACH:*** It is used for channel access.

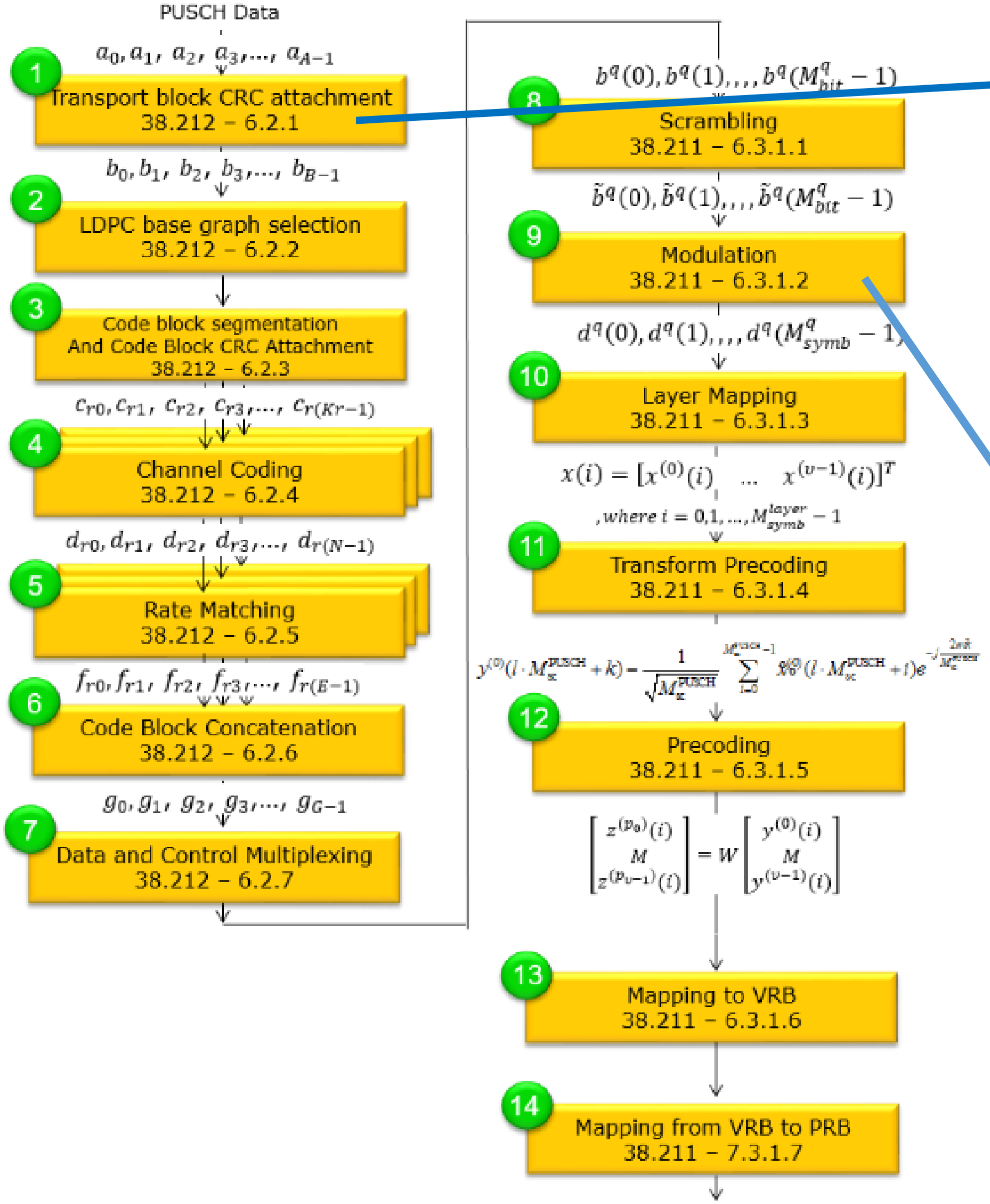
•***Physical uplink shared channel, PUSCH:*** It is used to carry data from the UL-SCH and its higher mapped channels on a frequency and time-shared basis.

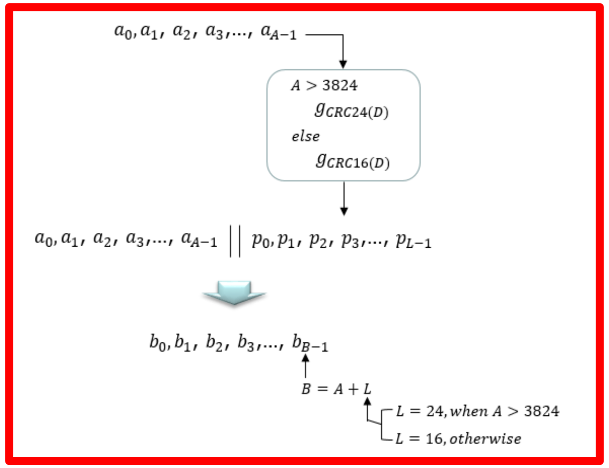
•***Physical uplink control channel, PUCCH:*** It carries the uplink control data.

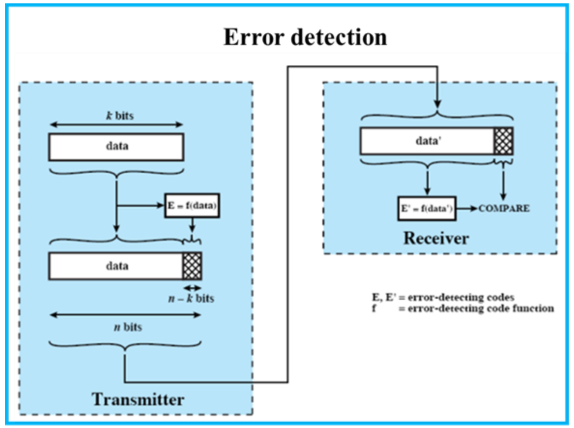


PUSCH Transport process

PUSCH is the physical uplink channel that carries user data







$\tilde{b}^{(q)}(0),\ldots,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$: Binary Sequence

38.211-Table 6.3.1.2-1

Transform precoding disabled		Transform precoding enabled	
Modulation scheme	Modulation order Q_m	Modulation scheme	Modulation order Q_m
		π/2-BPSK	1
QPSK	2	QPSK	2
16QAM	4	16QAM	4
64QAM	6	64QAM	6
256QAM	8	256QAM	8

$d^{(q)}(0),\ldots,d^{(q)}(M_{\text{symb}}^{(q)}-1)$: Complex Number Sequence

TS 38.211 https://www.sharetechnote.com/html/5G/5G_PUSCH.html

NUMEROLOGY

3GPP TS 38.211

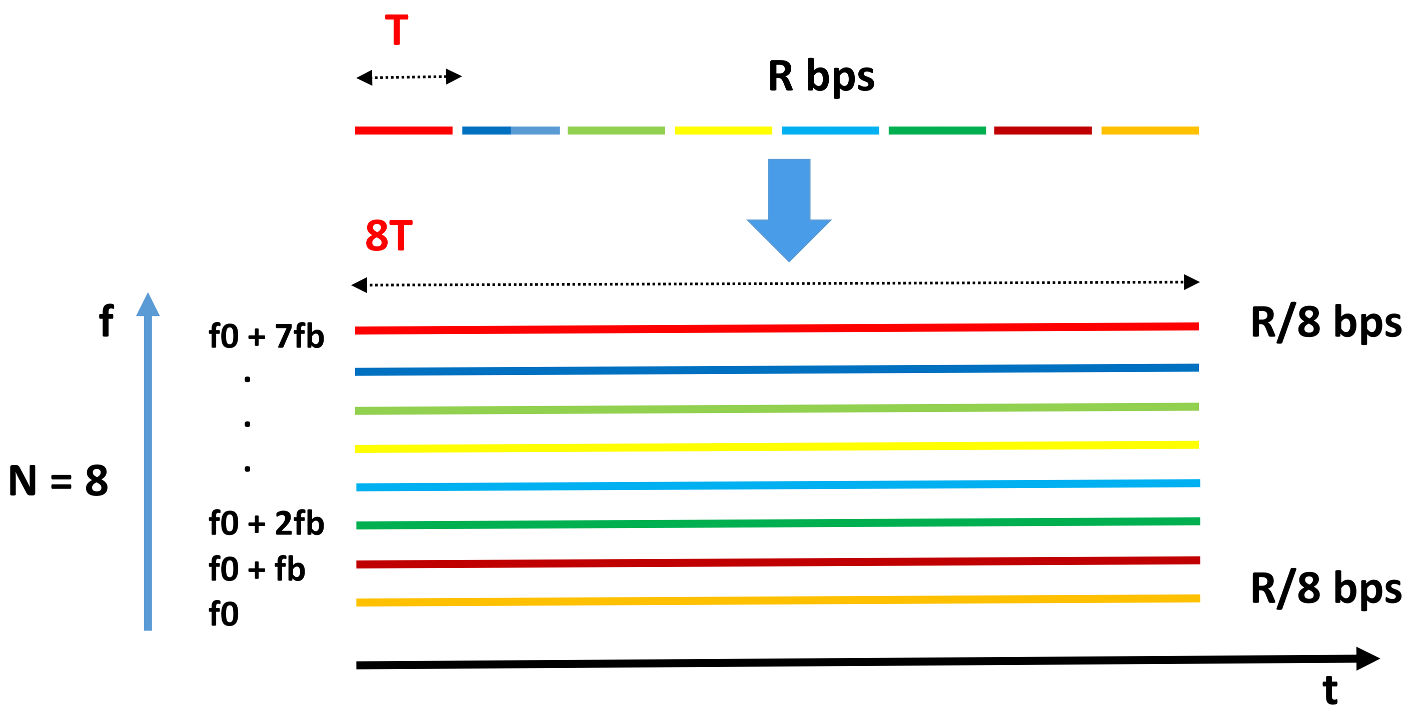
Numerology

Numerology is any belief in the divine, mystical relationship between a number and one or more coinciding events. It is also the study of the numerical value of the letters in words, names and ideas. It is often associated with the paranormal, alongside astrology and similar divinatory arts. – Wikipedia

In 5G/NR multiple numerologies (waveform configuration like subframe spacing) are supported and the radio frame structure gets different depending on the type of the numerology. However, regardless of numerology the length of one radio frame and the length of one subfame is same. The **length of a Radio Frame** is always 10 ms and the **length of a subframe** is always 1 ms.

https://www.sharetechnote.com/html/5G

OFDM - Princip



Transmission scheme - Frequency domain structure

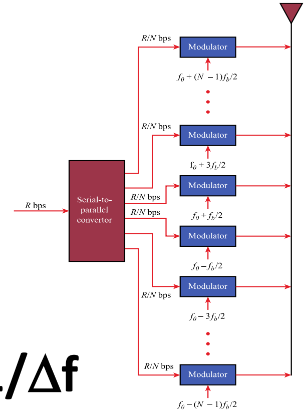
Table 4.2-1: Supported transmission numerologies.

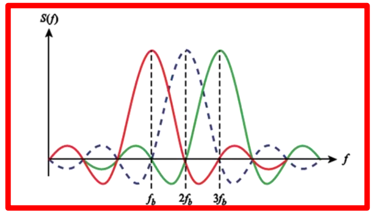
μ	$\Delta f = 2^{\mu} \cdot 15\,[\mathrm{kHz}]$	Cyclic prefix
0	15	Normal
1	30	Normal
2	60	Normal, Extended
3	120	Normal
4	240	Normal

600 MHz-6 GHz **FR1**

24 GHz-40 GHz **FR2**

OFDM





Ts = 1/Δf

1/15 kHz = 66,7 μs

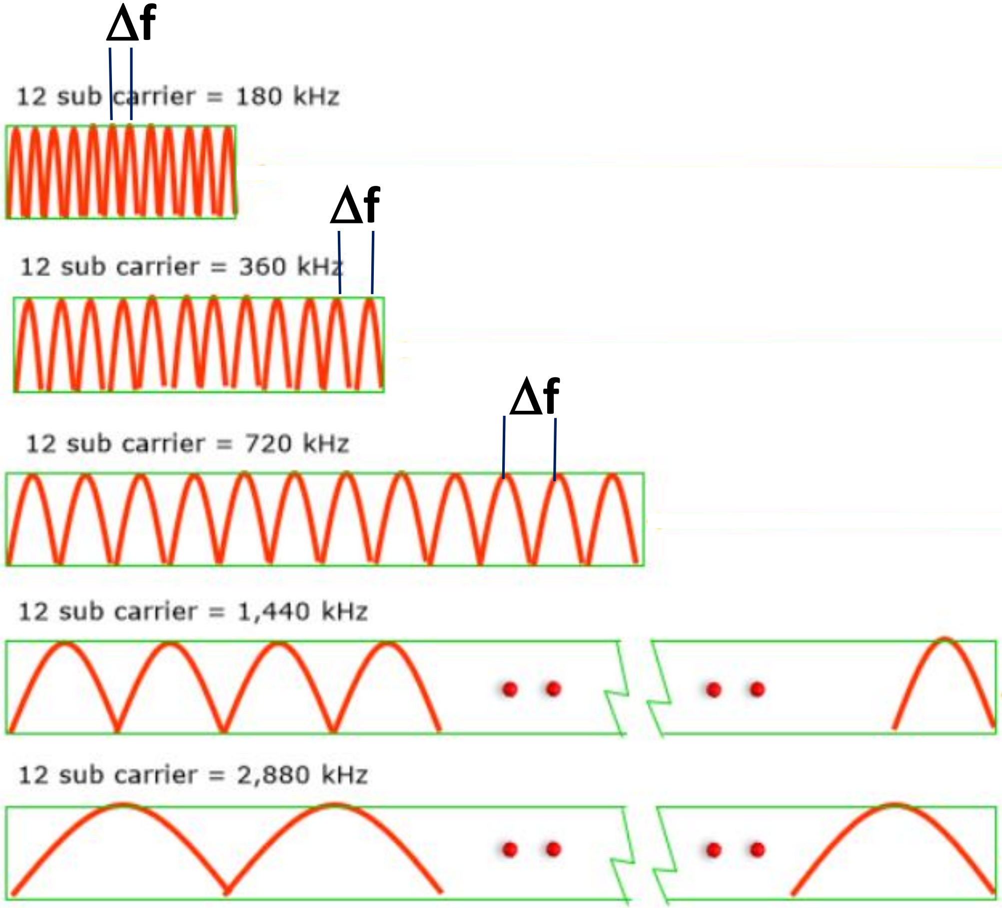
LTE **Δf = 15 kHz**

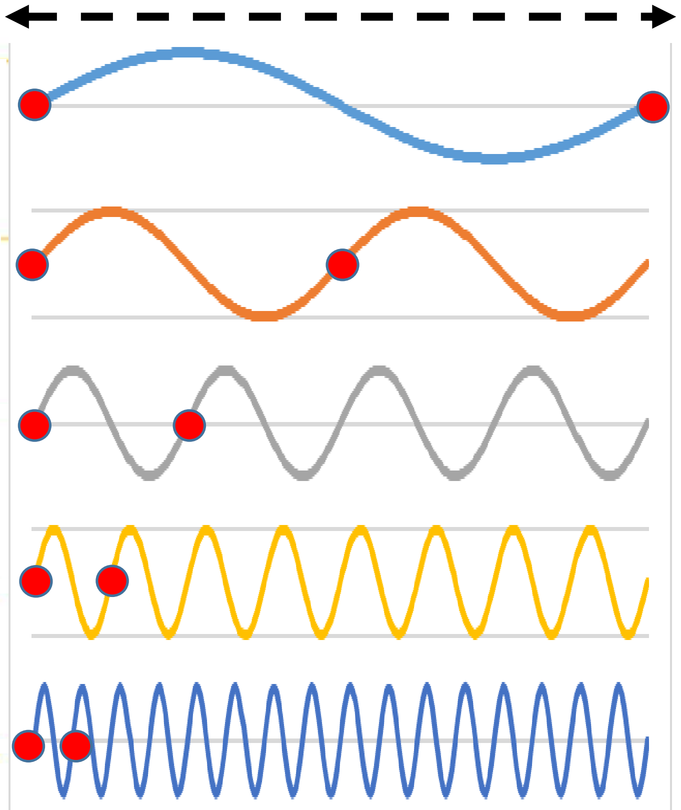
Δf = 30 kHz

Δf = 60 kHz

Δf = 120 kHz

Δf = 240 kHz





Symbol time

15 66,7 μs

30 33,3 μs

60 16,7 μs

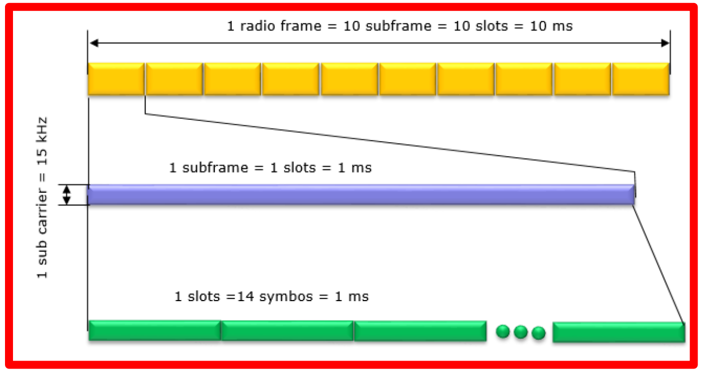
120 8,33 μs

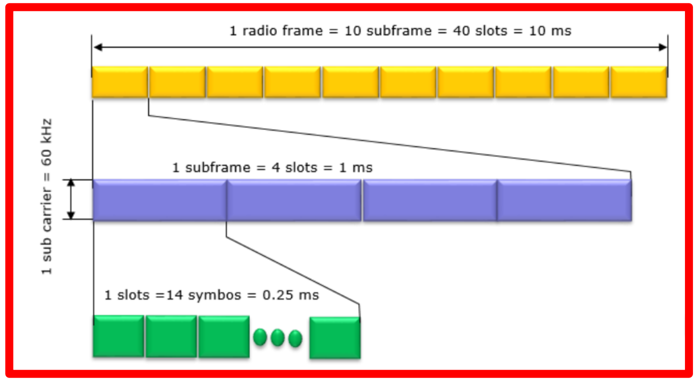
240 4,17 μs

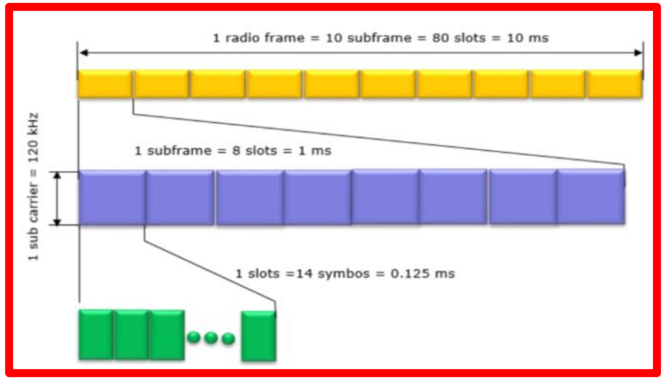
TS 138 211

Transmission scheme - Time domain structure

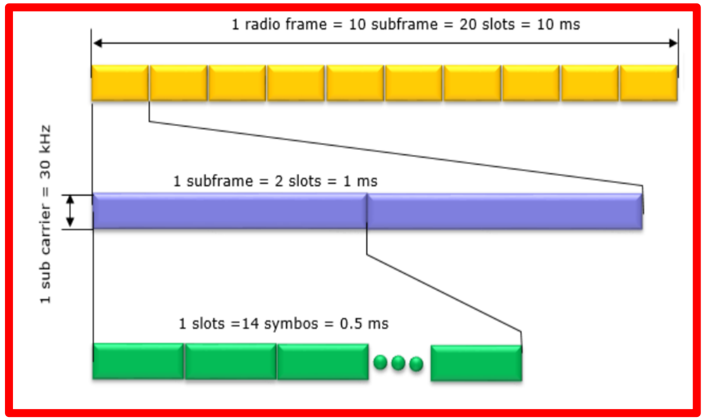
Downlink and uplink transmissions are organized into **frames** with 10 ms duration, consisting of 10 **subframes**, 1 ms each. A subframe is divided into **slots** (1, 2, 4, 8, 16) with 14 OFDM symbols each



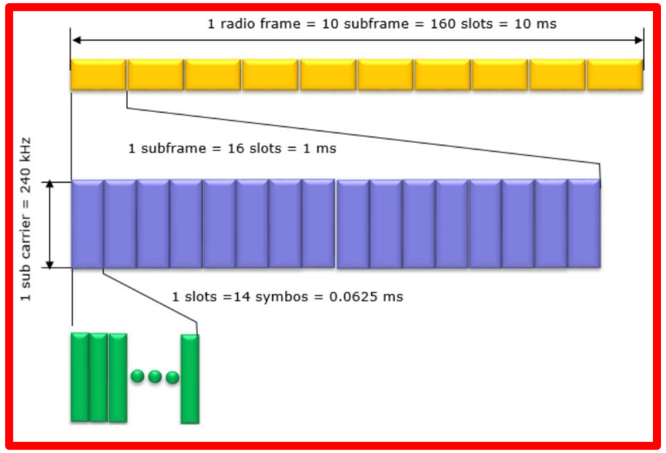




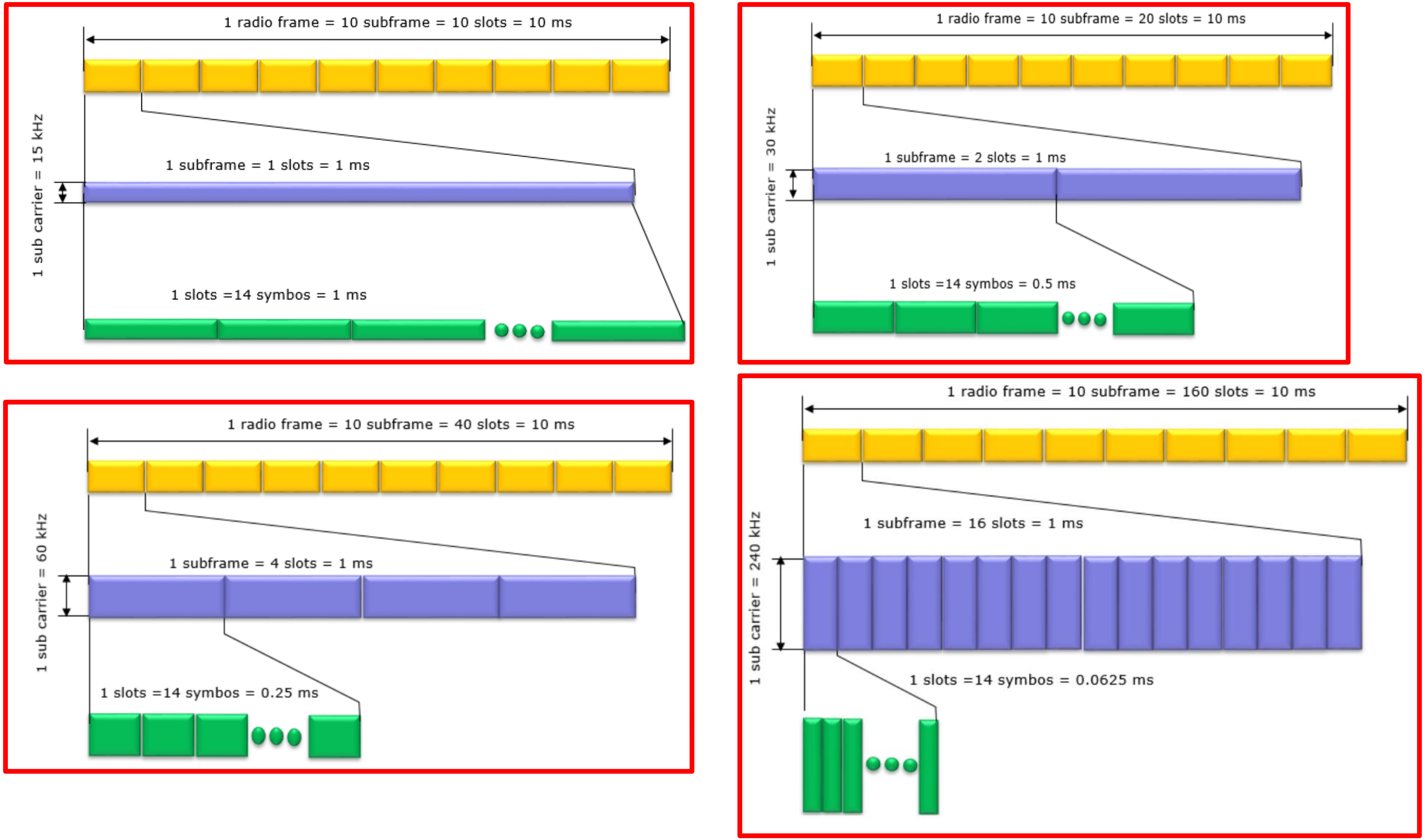
Parameter	LTE	NR
Radio frame length	10 ms	10 ms
Subframe length	1 ms	1 ms
No. of OFDM symbols in a slot	14	14
No. of slots in a subframe	2	Numerology dependent



μ	SCS	No. of slots per subframe = 2^{μ}	No. of slots per radio frame = 10 * 2^{μ}	slot duration (*ms*)
0	15 kHz	1	10	1
1	30 kHz	2	20	0.5
2	60 kHz	4	40	0.25
3	120 kHz	8	80	0.125
4	240 kHz	16	160	0.0625

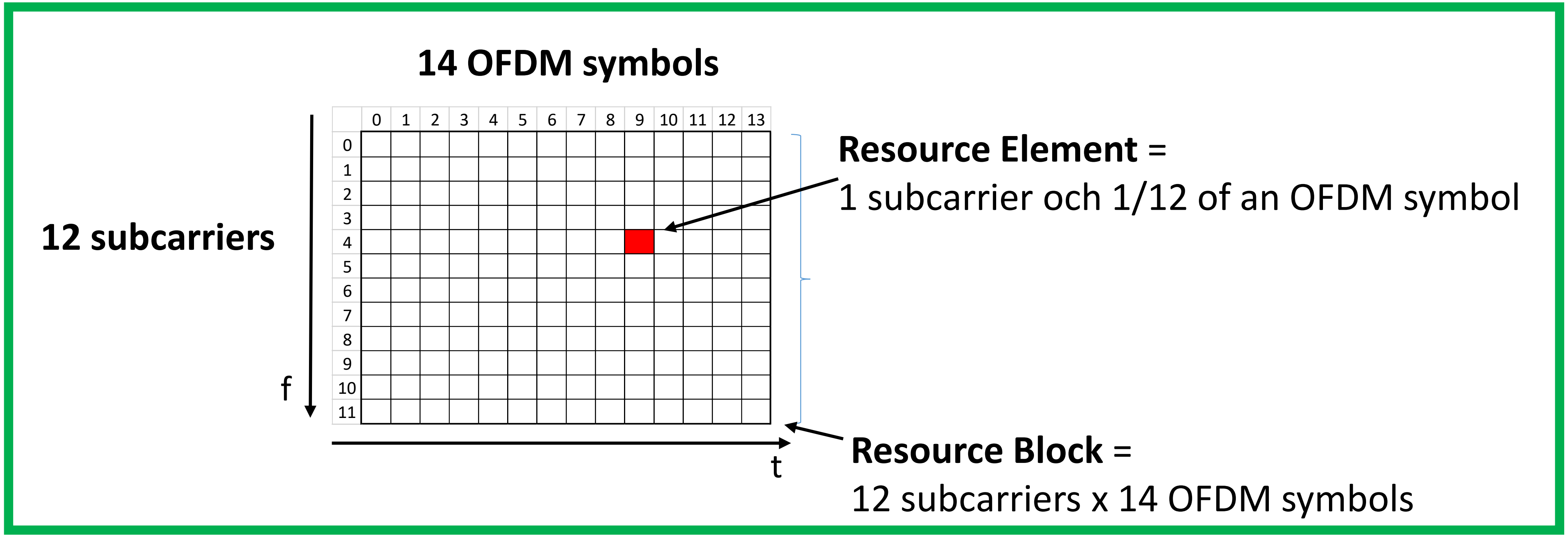


https://www.sharetechnote.com/html/5G


1 radio frame = 10 subframe = 10 slots = 10 ms
1 sub carrier = 15 kHz
1 subframe = 1 slots = 1 ms
1 slots =14 symbos = 1 ms
1 radio frame = 10 subframe = 20 slots = 10 ms
1 sub carrier = 30 kHz
1 subframe = 2 slots = 1 ms
1 slots =14 symbos = 0.5 ms
1 radio frame = 10 subframe = 40 slots = 10 ms
1 sub carrier = 60 kHz
1 subframe = 4 slots = 1 ms
1 slots =14 symbos = 0.25 ms
1 radio frame = 10 subframe = 160 slots = 10 ms
1 sub carrier = 240 kHz
1 subframe = 16 slots = 1 ms
1 slots =14 symbos = 0.0625 ms

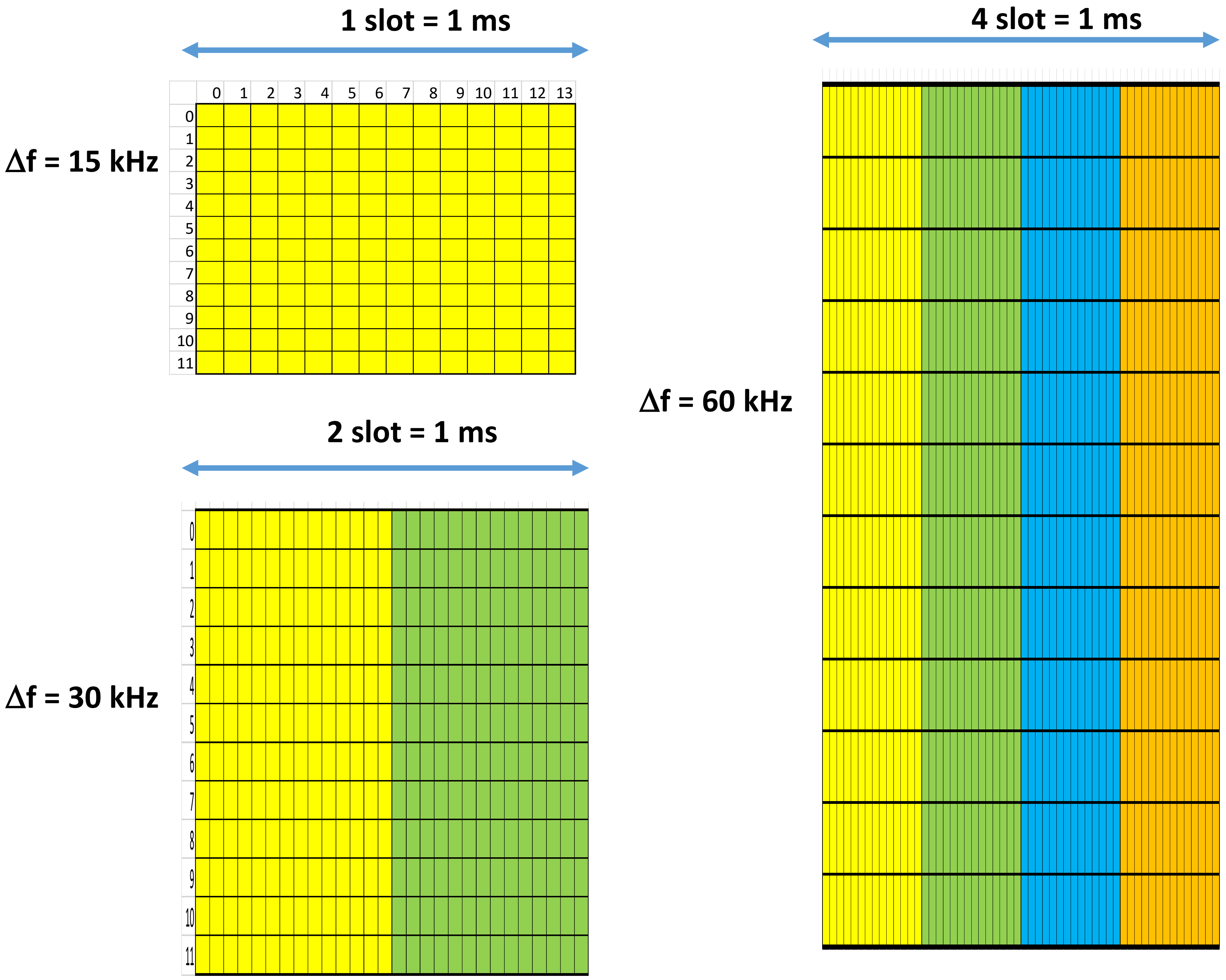
5G Resource Grid

A resource block (RB) is the smallest unit of resources that can be allocated to a user.

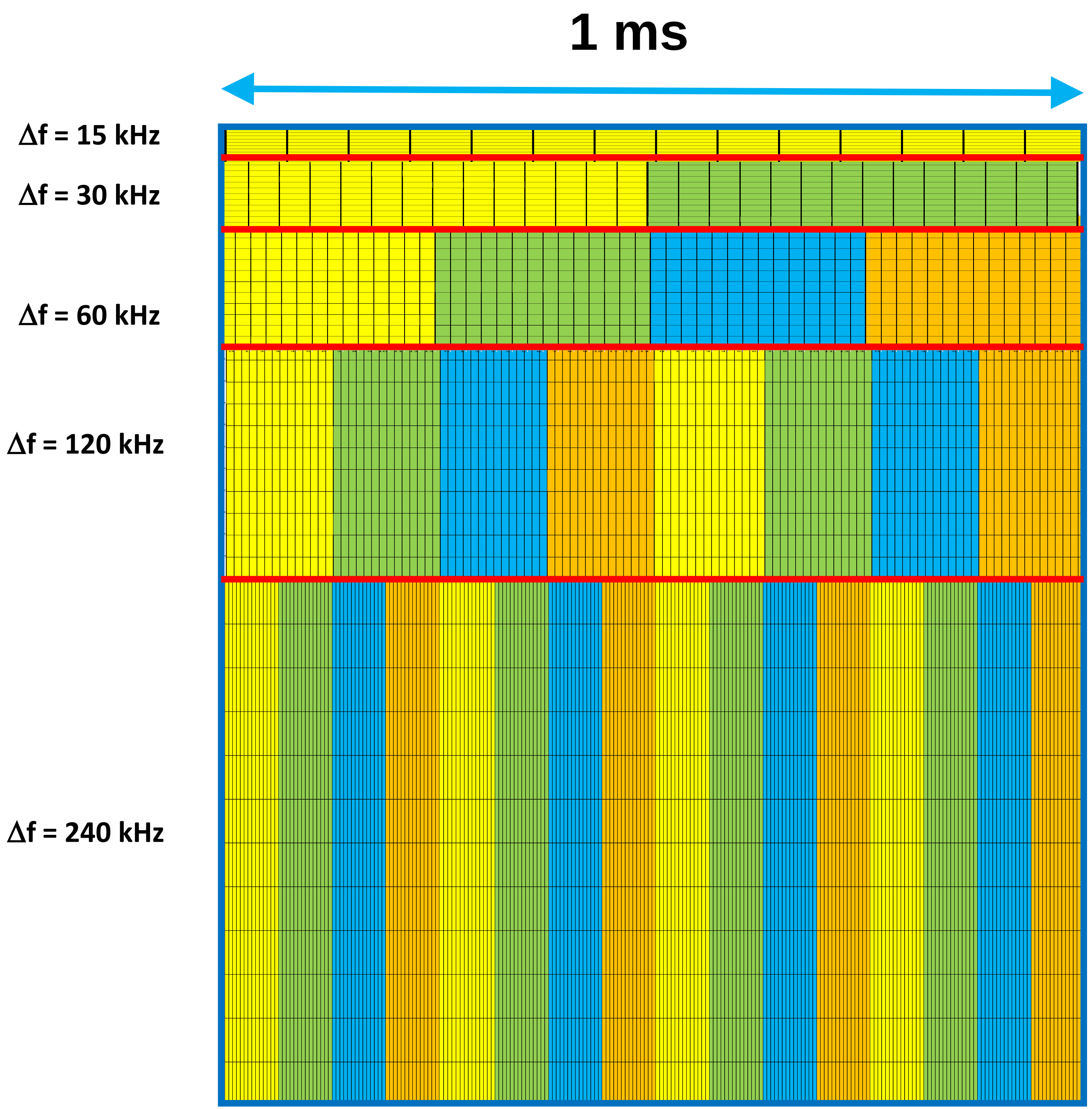


Each user is allocated a number of resource blocks in the time and frequency grid. The more resource blocks a user gets, the higher the bit-rate. Which resource blocks and how many the user gets at a given point in time depend on **advanced scheduling mechanisms in the frequency and time dimensions**.

https://www.gaussianwaves.com/2022/02/5g-nr-resource-block/



1 slot = 1 ms
Δf = 15 kHz
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 1 2 3 4 5 6 7 8 9 10 11
2 slot = 1 ms
Δf = 30 kHz
0 1 2 3 4 5 6 7 8 9 10 11
4 slot = 1 ms
Δf = 60 kHz



Resource elements

12 subcarriers x 14 OFDM symbols = 168 resource elements

12 x 28 = 336

FR1

FR2 (> 6 GHz)

12 x 56 = 672

12 x 112 = 1344

12 x 224 = 2688

NON-TERRESTRIAL NETWORKS (NTN)

Non-Terrestrial Networks (NTN)

Terrestrial networks are currently focusing on delivery of 5G services to areas already being served by existing cellular technologies, but the unique capabilities of non-terrestrial networks can help expand the reach of 5G technology in the realization of new use cases.

Satellites are complimentary to 5G and improve the value of 5G networks by addressing coverage challenges and complex use-cases that ground-based infrastructure alone cannot address.

3GPP TR 38.811 V15.4.0 (2020-09)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on New Radio (NR) to support non-terrestrial networks
(Release 15)

A GLOBAL INITIATIVE

3GPP TR 38.821 V16.1.0 (2021-05)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Solutions for NR to support non-terrestrial networks (NTN)
(Release 16)

A GLOBAL INITIATIVE

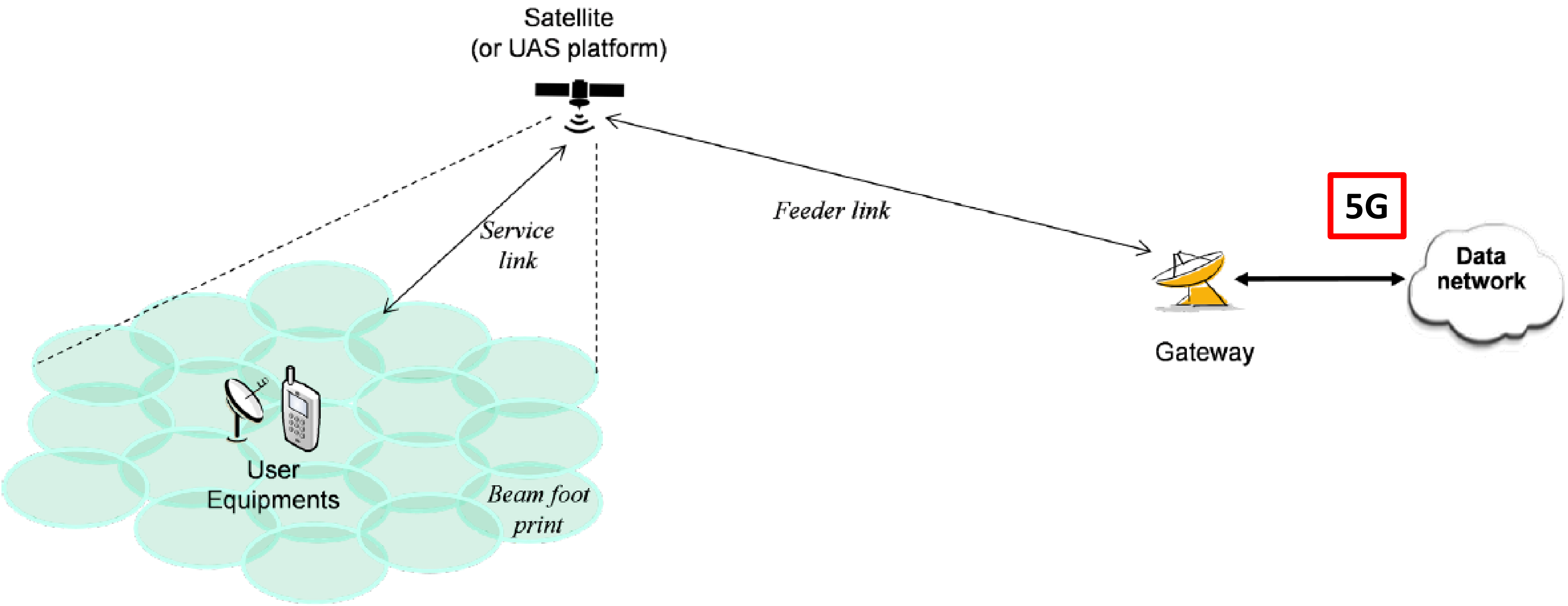
Three main categories of use cases for satellite-based NTN

Service Continuity: Use cases where 5G services cannot be offered by terrestrial networks alone and a combination of terrestrial and nonterrestrial networks combined provides service continuity for such cases. Some **examples** are airborne platforms (e.g., a commercial or a private jet) and maritime platforms (e.g., a maritime vessel).

Service Ubiquity: Use cases address unserved or under-served geographical areas, where terrestrial networks may not be available. **Examples** of ubiquity use cases are IoT (e.g., agriculture, asset tracking, metering), public safety (i.e., emergency networks), and home access.

Service Scalability: Use cases that leverage the large coverage area of satellites and uses multicasting or broadcasting a similar content over a large area. An **example** of such use case is the distribution of rich TV content (i.e., Ultra High-Definition TV).

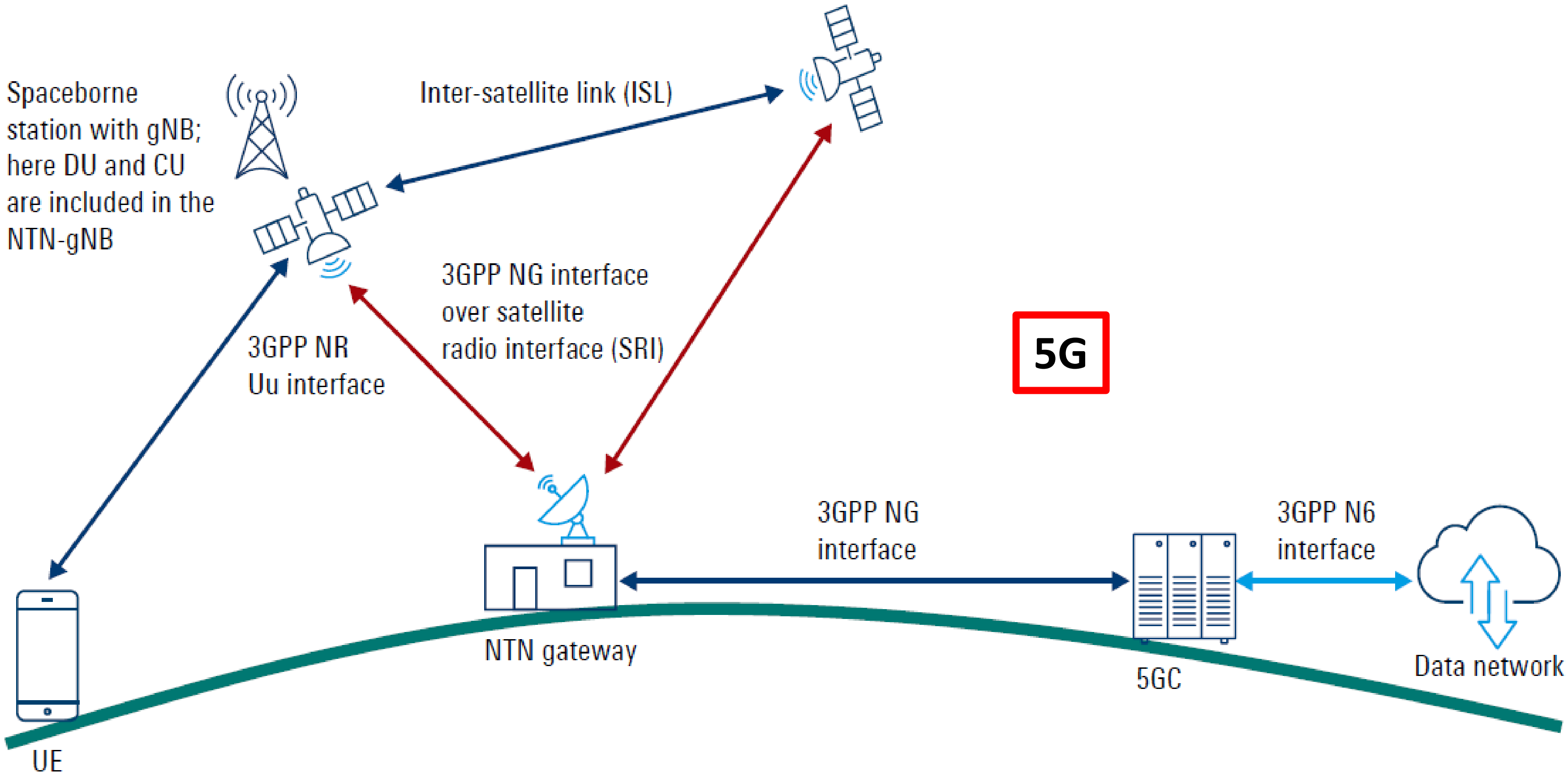
Satellite 5G scenario based on transparent payload



A transparent payload: Radio frequency filtering, frequency conversion and amplification only at the satellite. Hence, the waveform signal repeated by the payload is unchanged.

UAS Unmanned Aircraft System

Satellite 5G scenario based on regenerative payload



A regenerative payload: Radio frequency filtering, frequency conversion and amplification as well as demodulation/ decoding, switch and/or routing, coding/modulation at the satellite. This is effectively equivalent to having all or part of base station functions (e.g. **gNB**) on board the satellite.

EDGE COMPUTING

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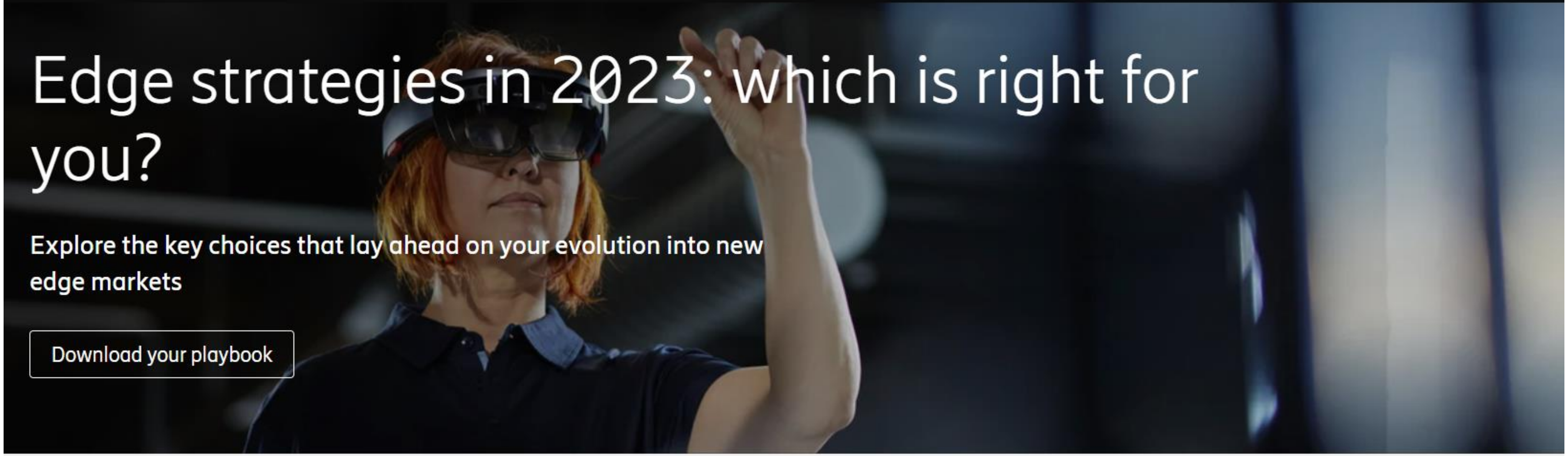

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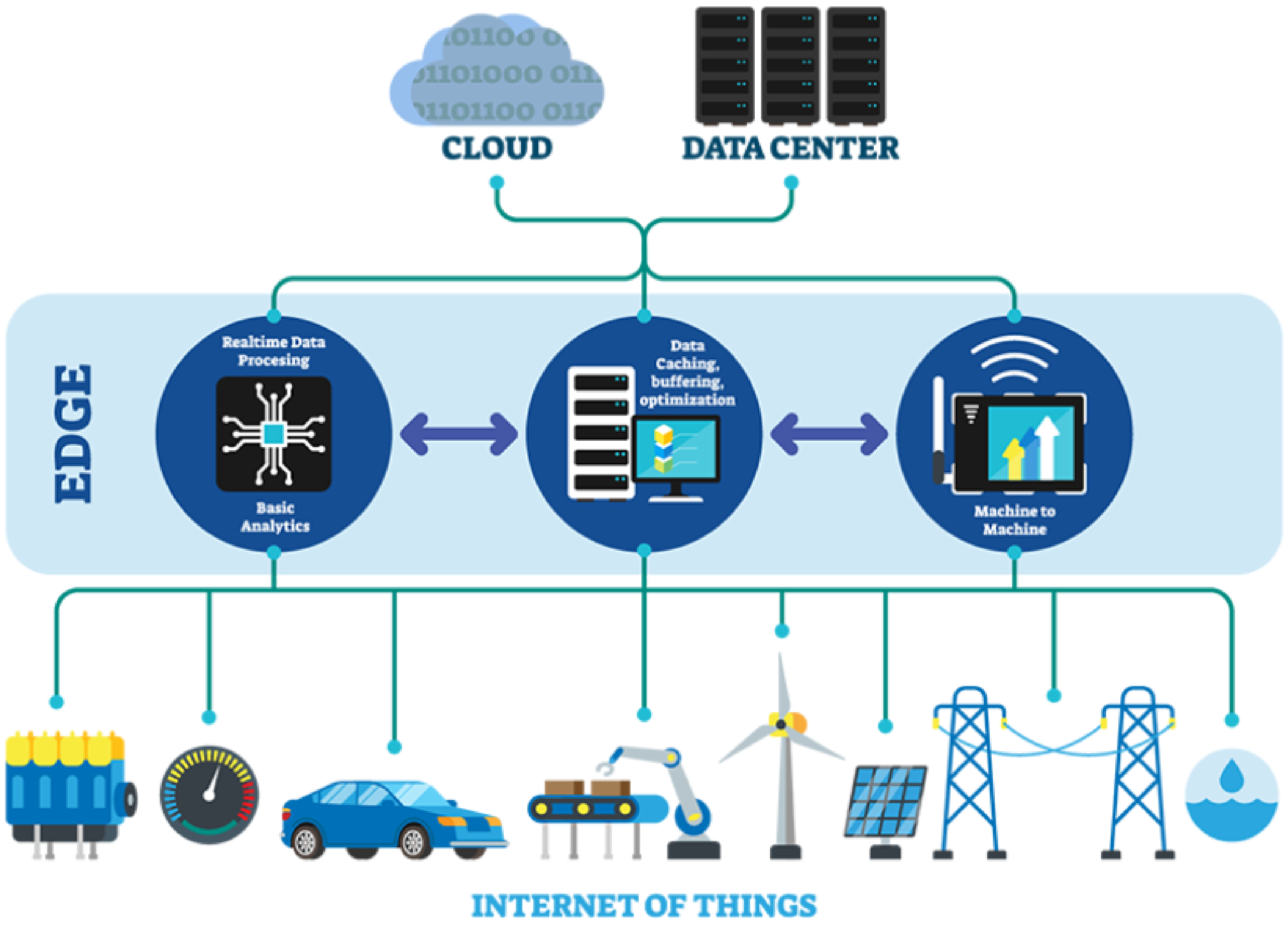
HOME > EDGE COMPUTING

Edge computing - a must for 5G success

5G and edge computing are opening a world of new revenue opportunities across manufacturing, gaming and entertainment, healthcare, retail and more. How can communications service providers (CSPs) gain an edge ahead of competitors? Find out everything you need to know below

What is Edge computing?



Managing the deluge of IoT-generated data makes proper processing near impossible. Traditional cloud computing has serious disadvantages, including data security threads, performance issues, and growing operational costs. In many instances, it would be beneficial to handle data close to device where it's generated.

Edge computing, the concept of computing as close as possible to where data is created and commands are executed helps decentralize data processing and lower dependence on the cloud. The **main benefits** are **low latency and high bandwidth.**

https://innovationatwork.ieee.org/real-life-edge-computing-use-cases/

Edge computing use cases

Edge computing could potentially be on the **client device itself** – such as a smartphone, surveillance camera, drone, or autonomous vehicle – or it may be performed **a few hops away**, such as on a **locally connected server** next to a cell tower or in **a small, local data center**.

Autonomous Vehicles: The decision to stop for a pedestrian crossing in front of an autonomous vehicle must be made immediately. Relying on a remote server to handle this decision is not reasonable. Additionally, vehicles that utilize edge technology can interact more efficiently because they can communicate with each other first as opposed to sending data on accidents, weather conditions, traffic, or detours to a remote server first. Edge computing can help.

Healthcare Devices: Health monitors can keep an eye on chronic conditions for patients. It can save lives by instantly alerting caregivers when help is required. Additionally, robots assisting in surgery must be able to quickly analyze data in order to assist safely, quickly, and accurately. If these devices rely on transmitting data to the cloud before making decisions, the results could be fatal.

Security Solutions: Because it's necessary to respond immediately to threats, security surveillance systems can benefit from edge computing technology. Security systems can identify potential threats and alert users to unusual activity in real-time.

NETWORK SLICING

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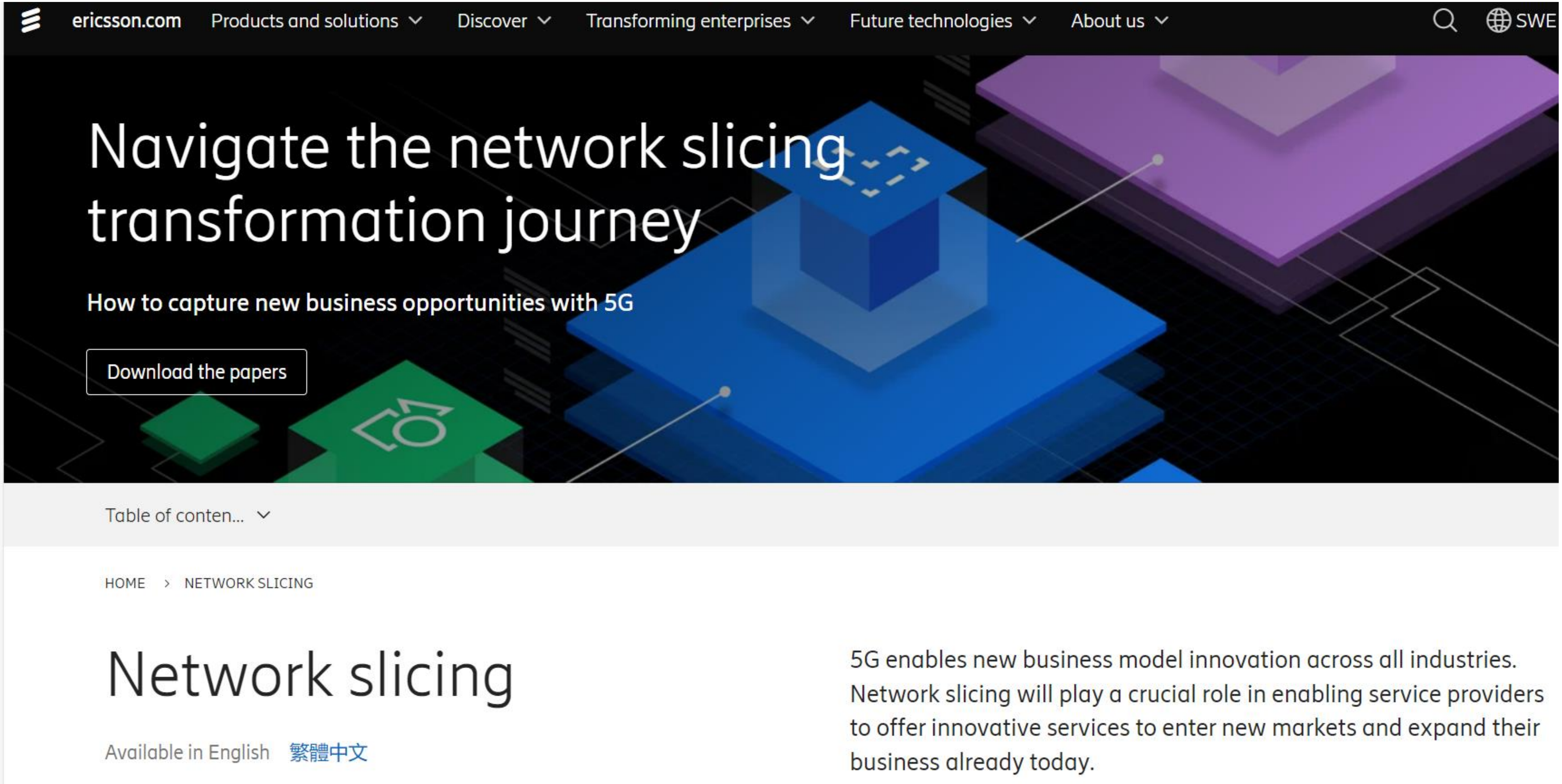
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Navigate the network slicing transformation journey

How to capture new business opportunities with 5G

Download the papers

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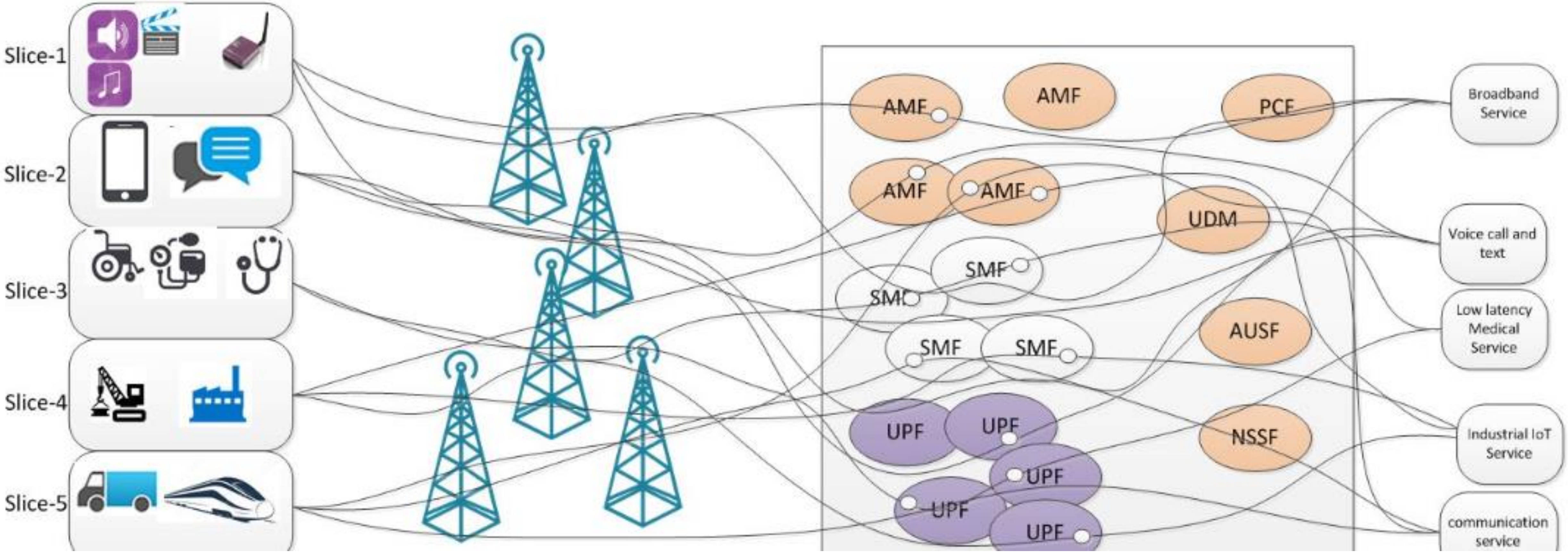
HOME > NETWORK SLICING

Network slicing

Available in English 繁體中文

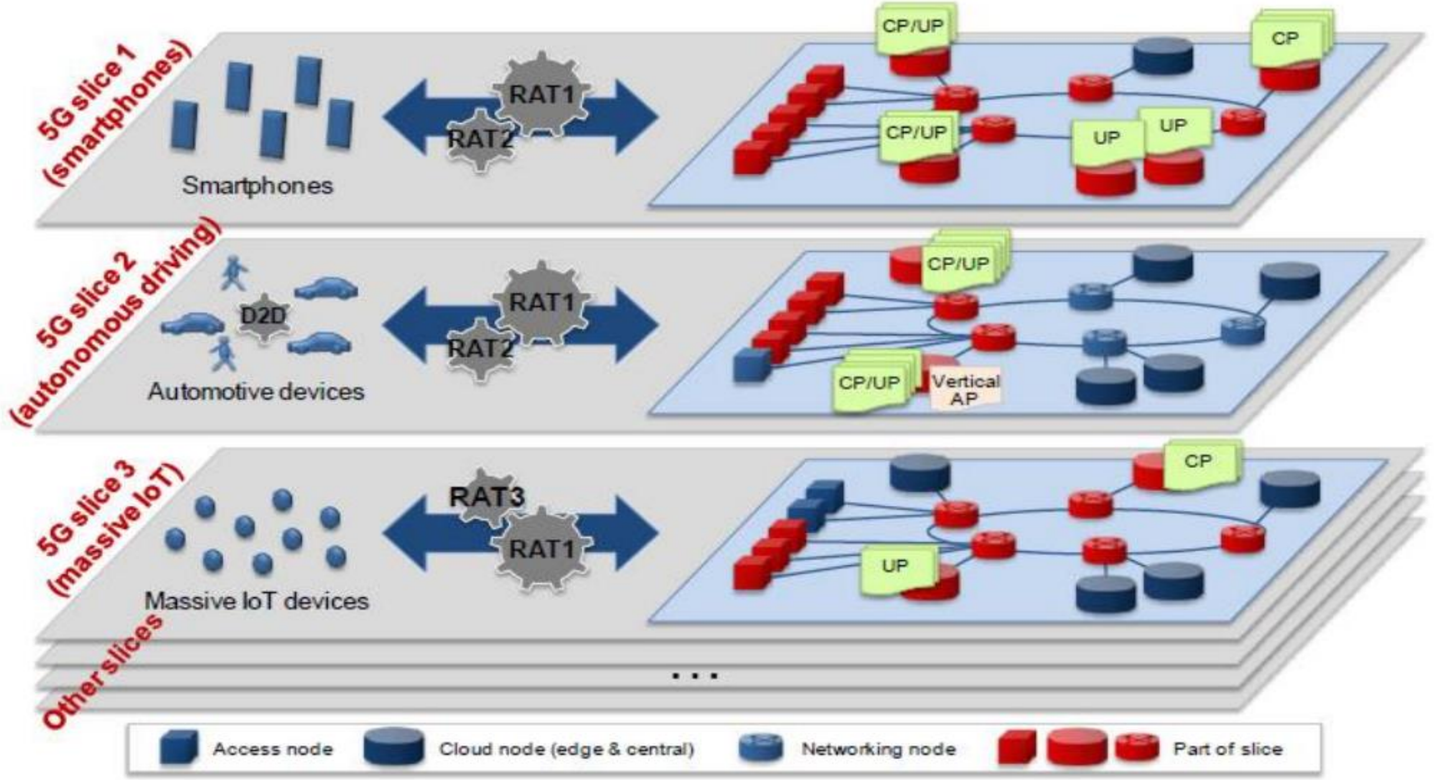
5G enables new business model innovation across all industries. Network slicing will play a crucial role in enabling service providers to offer innovative services to enter new markets and expand their business already today.

Under 5G, there will no longer be "one size fits all network" **but multiple virtual networks running simultaneously on the same common infrastructure.** The advantage: These networks, so-called **slices**, can have different characteristics tailored to meet the specific requirements of a particular application or user group.



https://www.5gblogs.com/5g-network-slicing-concepts/

The **network slice** is a logically separated, self-contained, independent and secured part of the network, targeting different services with different requirements on speed, latency and reliability. Network slice characteristics are for example low latency, high bandwidth and ultra-reliability for a critical IoT use case or higher latency and lower bandwidth for a massive IoT use case.



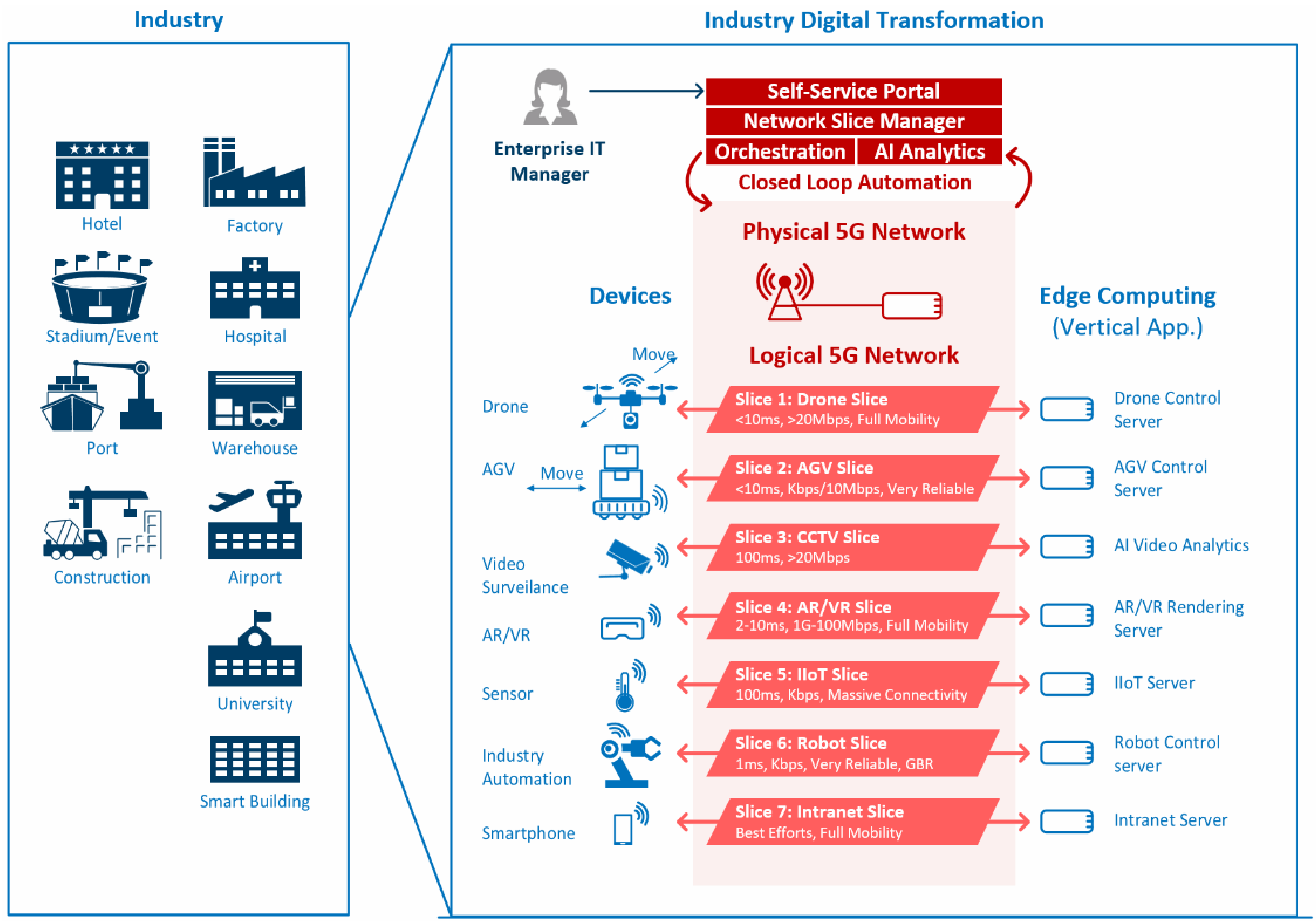
eMBB

uRRLC

mMTC

A network slice can be dedicated to one enterprise customer, or shared by multiple tenants.

The way to achieve a sliced network is to transform it into **a set of logical networks** on top of a **shared infrastructure**. Each logical network is designed to serve a defined business purpose and comprises of all the required network resources, configured and connected end-to-end.


Industry
Hotel
Factory
Stadium/Event
Hospital
Port
Warehouse
Construction
Airport
University
Smart Building
Industry Digital Transformation
Enterprise IT Manager
Self-Service Portal
Network Slice Manager
Orchestration
AI Analytics
Closed Loop Automation
Physical 5G Network
Devices
Edge Computing (Vertical App.)
Logical 5G Network
Move
Drone
Slice 1: Drone Slice
<10ms, >20Mbps, Full Mobility
Drone Control Server
AGV
Move
Slice 2: AGV Slice
<10ms, Kbps/10Mbps, Very Reliable
AGV Control Server
Video Surveilance
Slice 3: CCTV Slice
100ms, >20Mbps
AI Video Analytics
AR/VR
Slice 4: AR/VR Slice
2-10ms, 1G-100Mbps, Full Mobility
AR/VR Rendering Server
Sensor
Slice 5: IIoT Slice
100ms, Kbps, Massive Connectivity
IIoT Server
Industry Automation
Slice 6: Robot Slice
1ms, Kbps, Very Reliable, GBR
Robot Control server
Smartphone
Slice 7: Intranet Slice
Best Efforts, Full Mobility
Intranet Server

PRIVATE 5G NETWORKS

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Imagine endless possibilities with a private network

Industries like manufacturing, ports, mining, airports and energy are going through change driven by digitalization. One that will require a modern communication backbone to support the adoption, use and scaling of new and emerging, data-driven technologies.

Industry 4.0 requires a high-performance communications foundation that is reliable and secure. Private networks are the preferred way to power digital transformation by connecting devices, industrial sites and augmenting workers.

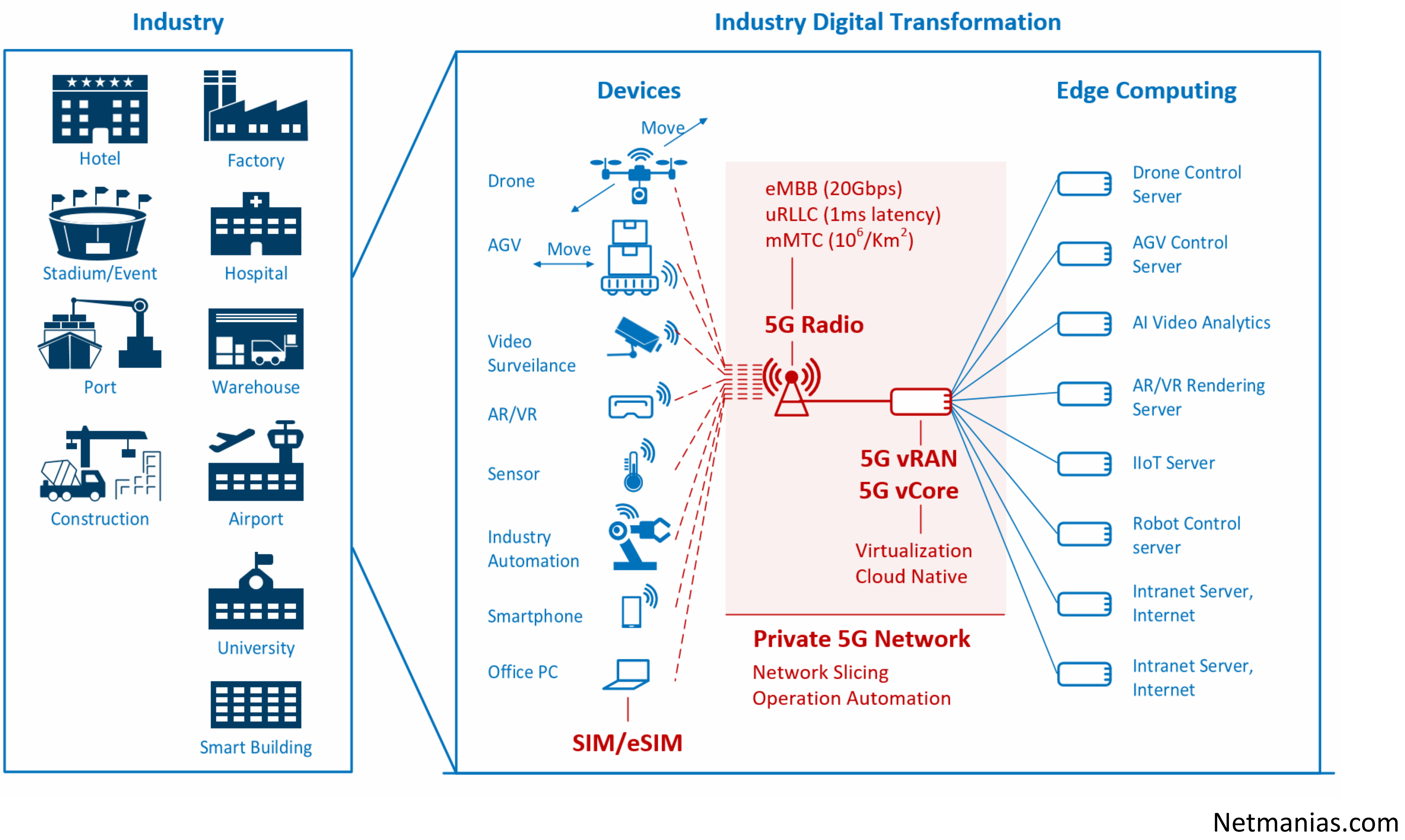
Ericsson Private 5G is a next-generation, private network, tailored to drive Industry 4.0, the modernization and digitalization of infrastructures and business process operations. Organizations gain secure and powerful 4G/LTE and 5G Standalone (SA) connectivity allowing them to optimize and simplify business operations through data creation, collection, and analysis.

Private 5G networks

Private 5G mobile network is **technically the same as a public 5G network**, but which allows the owner to provide communication connections to people or things belonging to a specific enterprise and provides specific services necessary for the business of the enterprise. This can be beneficial when deploying private wireless networks at facilities where **coverage**, **speed**, and **security** capabilities are needed beyond those offered by Wi-Fi and other network technologies.

Reduced latency and **increased reliability** makes private 5G especially interesting for industrial applications.

An example could be a large manufacturing site, where reliable connectivity is needed inside the shop floor, but also outside. Think of autonomous guided vehicles moving parts from one shop floor to the other. With private 5G, they can connect reliably, and machines can be instrumented with more sensors quicker and cheaper without the need for re-wiring.



Industry
Hotel
Factory
Stadium/Event
Hospital
Port
Warehouse
Construction
Airport
University
Smart Building
Industry Digital Transformation
Devices
Move
Drone
AGV
Move
Video Surveilance
AR/VR
Sensor
Industry Automation
Smartphone
Office PC
SIM/eSIM
eMBB (20Gbps)
uRLLC (1ms latency)
mMTC (10^6/Km^2)
5G Radio
5G vRAN
5G vCore
Virtualization
Cloud Native
Private 5G Network
Network Slicing
Operation Automation
Edge Computing
Drone Control Server
AGV Control Server
AI Video Analytics
AR/VR Rendering Server
IIoT Server
Robot Control server
Intranet Server, Internet
Intranet Server, Internet
Netmanias.com

5G → 6G

Road to 5G / 6G

NGMN Next Generation Mobile Networks Alliance

. . . .

6G Flagship

Companies / Research institutions / Universities

3GPP A GLOBAL INITIATIVE 3rd Generation Partnership Project

ITU International Telecommunication Union

The **3rd Generation Partnership Project** (**3GPP**) is an umbrella term for a number of standards organizations which develop protocols for mobile telecommunications.

Vision
Use cases
Requirements

R&D
Solutions
Prototypes

Formulates Standard

Approves Standard

https://www.6gflagship.com

Next Generation Mobile Networks Alliance

https://www.ngmn.org/

VISION

The vision of the NGMN Alliance is to provide **impactful guidance** to achieve innovative and affordable mobile telecommunication **services for the end use**r with a particular focus on supporting **5G's** full implementation, Mastering the Route to Disaggregation, Sustainability and Green Networks, as well as **6G.**

Operators requirements - 2015

17-February-2015

125 sidor

5G VISION

"5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models."

5G use case families:

Broadband access in dense areas

PERVASIVE VIDEO

Broadband access everywhere

50+ MBPS EVERYWHERE

Higher user mobility

HIGH SPEED TRAIN

Massive Internet of Things

SENSOR NETWORKS

Extreme real-time communications

TACTILE INTERNET

Lifeline communications

NATURAL DISASTER

Ultra-reliable communications

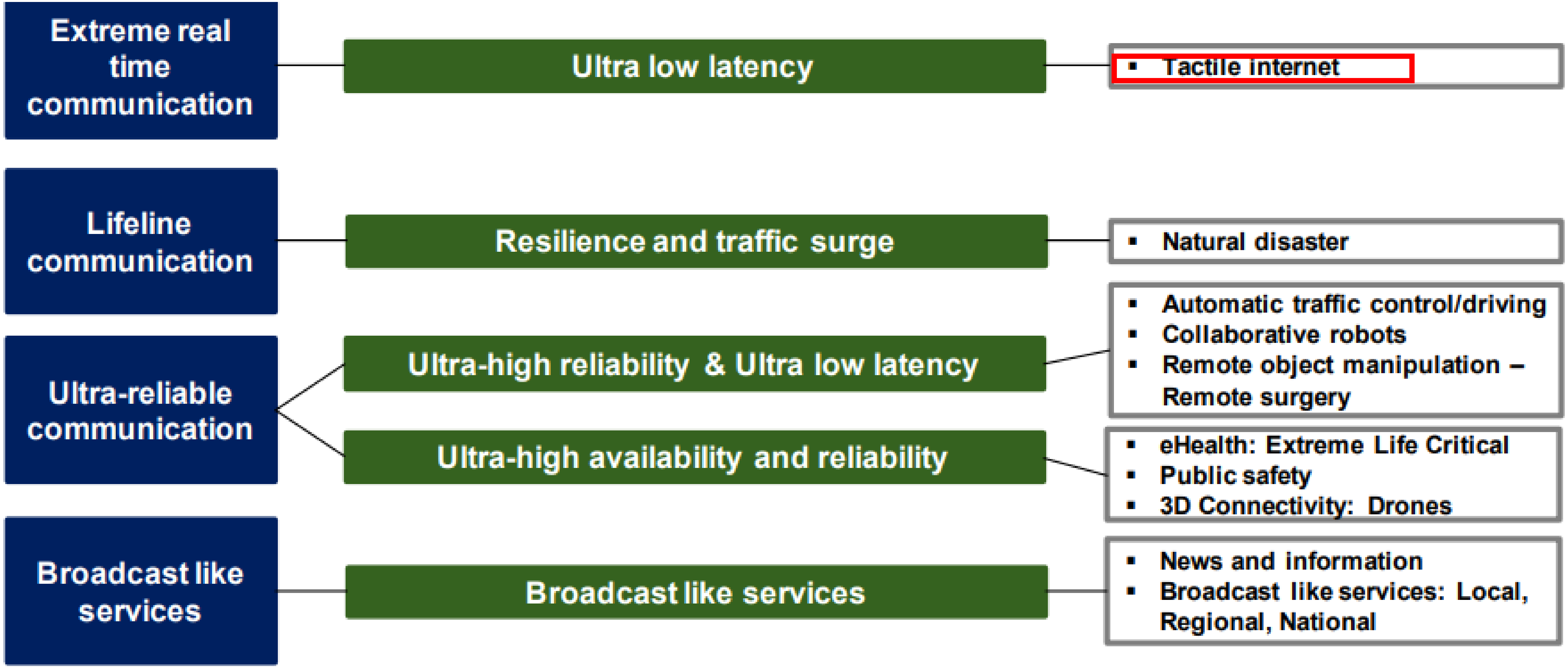
E-HEALTH SERVICES

Broadcast-like services

BROADCAST SERVICES

5G use case categories

Families	Categories	Use Cases
Broadband access in dense area	Broadband access in dense area	Pervasive video; Operator cloud services; Dense urban society
	Indoor ultra-high broadband access	Smart Office
	Broadband access in a crowd	HD video/photo sharing in stadium/open-air gathering
Broadband access everywhere	50+ Mbps everywhere	50 Mbps everywhere
	Ultra low-cost broadband access for low ARPU areas	Ultra-low cost networks
High user mobility	Mobile broadband in vehicles	High speed train; Moving Hot Spots; Remote computing
	Airplanes connectivity	3D Connectivity: Aircrafts
Massive Internet of Things	Massive low-cost/long-range/low-power MTC	Smart wearables (clothes); Sensor networks
	Broadband MTC	Mobile video surveilance


Extreme real time communication
Ultra low latency
▪ Tactile internet
Lifeline communication
Resilience and traffic surge
▪ Natural disaster
Ultra-reliable communication
Ultra-high reliability & Ultra low latency
▪ Automatic traffic control/driving
▪ Collaborative robots
▪ Remote object manipulation – Remote surgery
Ultra-high availability and reliability
▪ eHealth: Extreme Life Critical
▪ Public safety
▪ 3D Connectivity: Drones
Broadcast like services
Broadcast like services
▪ News and information
▪ Broadcast like services: Local, Regional, National

Broadband Access in Dense Areas

This family highlights the broad range of growing and new use cases of the fully connected society. The **focus** is service availability in densely-populated areas (e.g., multi-storey buildings, dense urban city centres or events).

Communications are expected to be pervasive and part of everyday life. Augmented reality, multi-user interaction, three-dimensional (3D) services will play an increasingly significant role in the 2020+ timeframe. This family includes the **following use cases**:

- **Pervasive Video**
- **Smart Office**
- **Operator Cloud Services**
- **HD Video/Photo Sharing in Stadium/Open-Air Gathering**

Tactile Internet

The International Telecommunication Union (ITU) defines the **Tactile Internet** as an internet network that combines ultra low latency with extremely high availability, reliability and security.

Use case

In **healthcare**, medical expertise is still largely confined to the location of the physician, but in the world of the Tactile Internet it will be available anywhere and at any time. The physician will be able to command a tele-robot at the patient’s location, allowing remote physical examination including **telesurgery** with full AV and haptic feedback.

27th July 2020

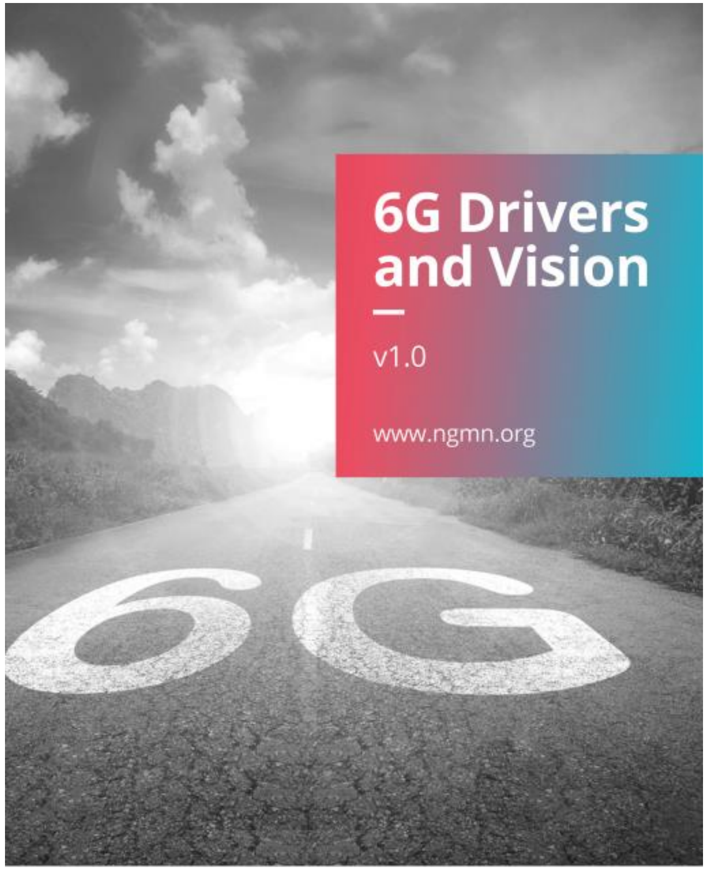
Executive Summary

Since the publication of the first NGMN 5G White Paper, the first phase of 5G standards has been completed, initial 5G services have been launched, and much more is underway to increasingly realize the potential of 5G.

Whilst the initial standards and launches have mostly focused on **enhanced Mobile Broadband**, 5G is expected to increasingly enable new business models and countless new use cases, in particular those of **massive Machine Type Communications** and **Ultra-reliable** and **Low Latency Communications**. **(eMBB → mMTC, URLLC)**

The first NGMN 5G White Paper provided a 5G vision, describing the business context and identifying several **use cases** and **business models**. It defined **detailed requirements** based on this vision, reviewed technology trends, identified potential technology building blocks and proposed an architecture for the 5G system. This **second White Paper** builds on the first 5G White Paper, extending the vision, use cases and enablers.

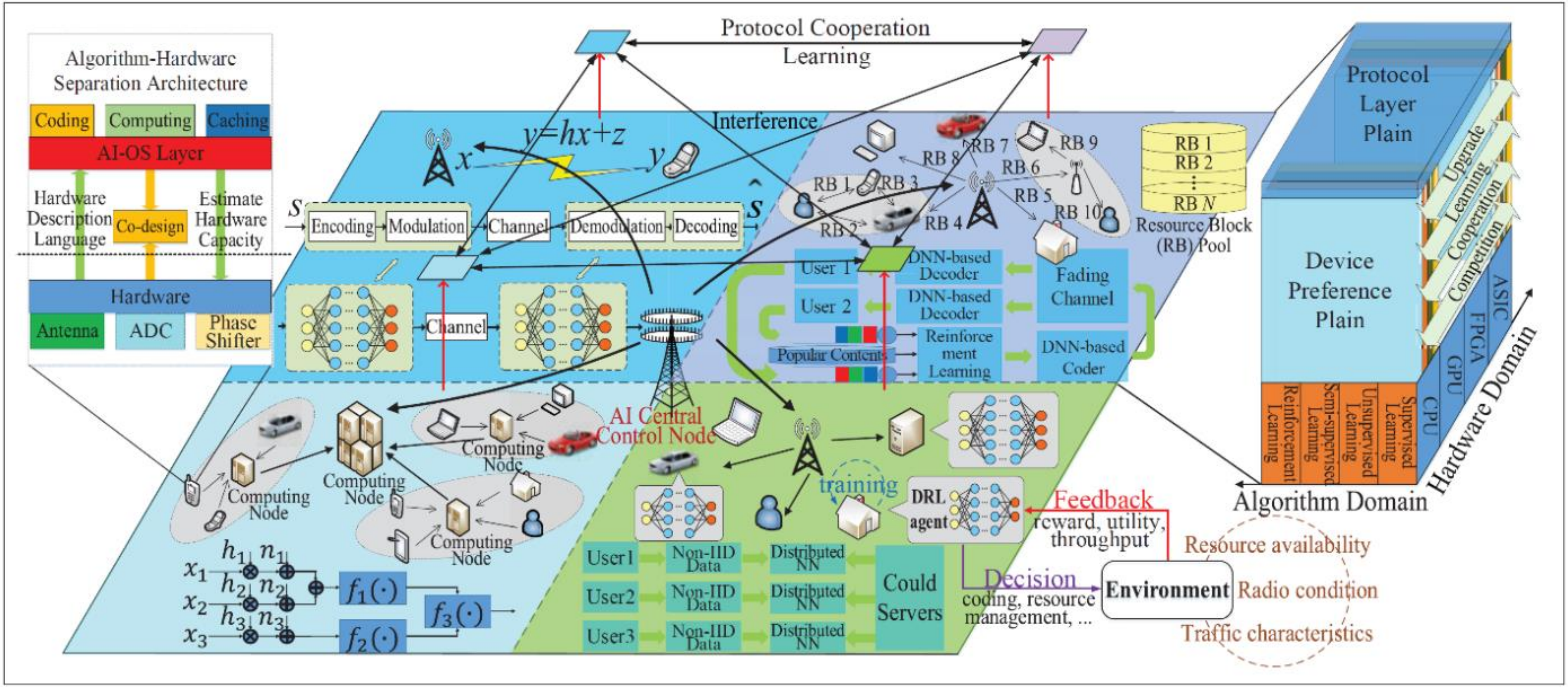
Requirements comparison of 6G with 4G and 5G

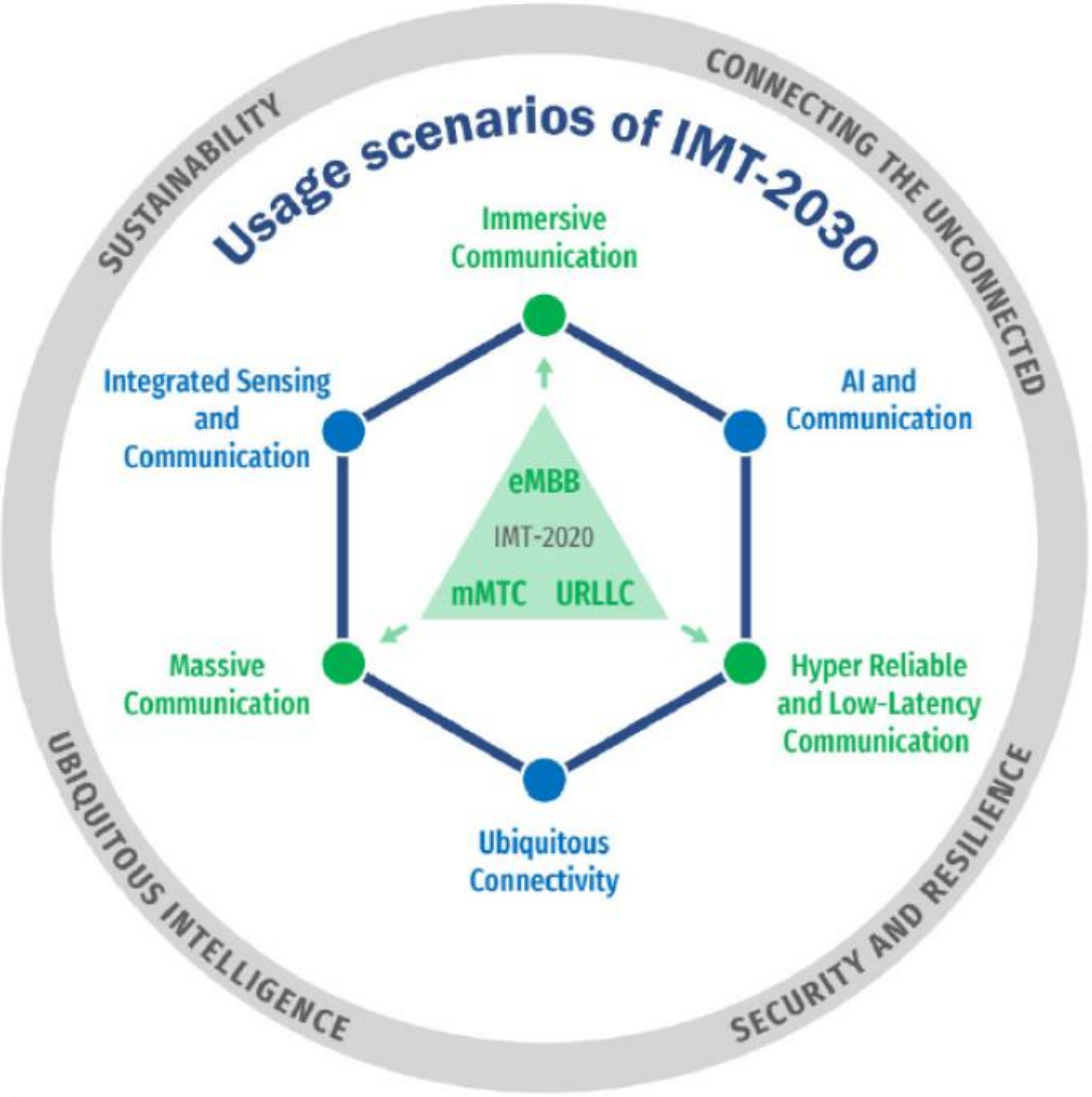


Issue	4G	5G	6G
Per Device Peak Data Rate	1 Gbps	10 Gbps	1 Tbps
End-to-End Latency (E2E)	100 ms	10 ms	1 ms
Maximum Spectral Efficiency	15 bps/Hz	30 bps/Hz	100 bps/Hz
Mobility Support	Up to 350 km/hr	Up to 500 km/hr	Up to 1000 km/hr
Satellite Integration	No	No	Fully
AI	No	Partial	Fully
Autonomous Vehicle	No	Partial	Fully
XR (Extended reality)	No	Partial	Fully
Haptic Communication	No	Partial	Fully
THz Communication	No	Very limited	Widely
Service Level	Video	VR, AR	Tactile
Architecture	MIMO	Massive MIMO	Intelligent Surface
Maximum Frequency	6 GHz	90 GHz	10 THz

1 k =10^3 1 M = 10^6 1 G = 10^9 1 T = 10^{12}

Potential vision of the system architecture for 6G





Ubiquitous Connectivity - use cases include IoT and mobile broadband communication in rural, remote, and sparsely populated areas.

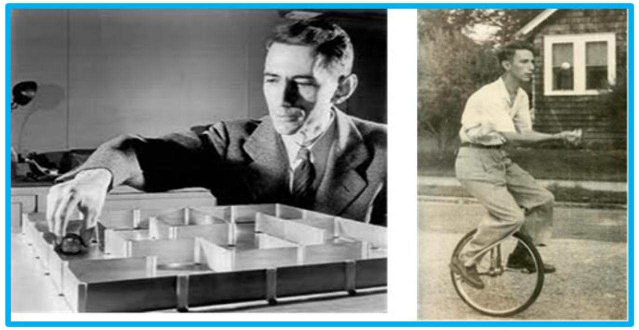
AI and Communication- use cases include assisted autonomous driving, autonomous collaboration between medical devices, offloading intensive computations across devices and networks, creating and predicting digital twins, and assisting collaborative robots.

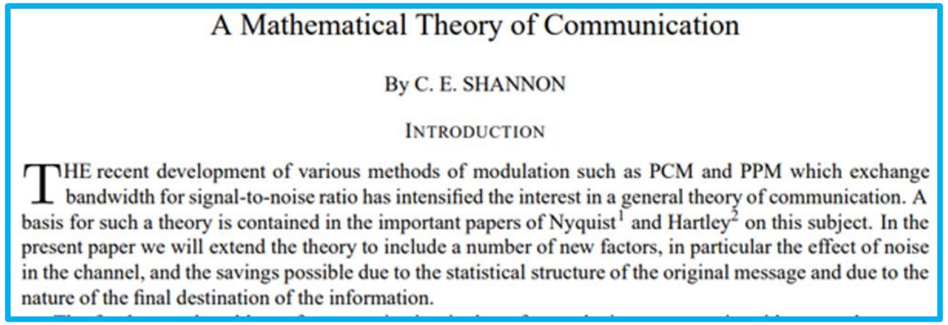
Integrated Sensing and Communication – use cases include wide-area multidimensional sensing, offering spatial information about unconnected devices and spatial information about connected devices, movement, and the surrounding environment.

TWO NEW TECHNOLOGIES IN 6G

1) Semantic communication

1948 Shannon publishes his Theory of Communication





A Mathematical Theory of Communication

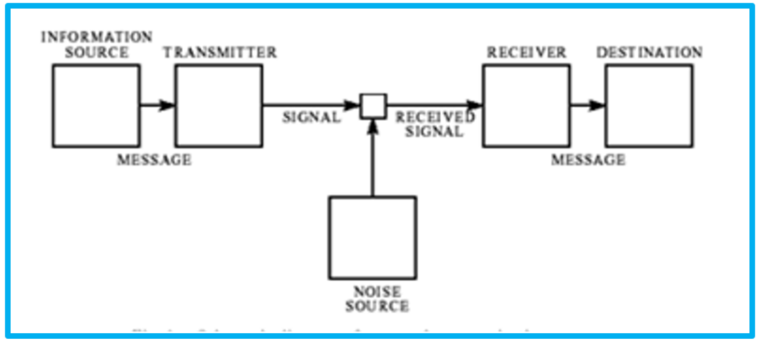
By C. E. SHANNON

INTRODUCTION

THE recent development of various methods of modulation such as PCM and PPM which exchange bandwidth for signal-to-noise ratio has intensified the interest in a general theory of communication. A basis for such a theory is contained in the important papers of Nyquist[1] and Hartley[2] on this subject. In the present paper we will extend the theory to include a number of new factors, in particular the effect of noise in the channel, and the savings possible due to the statistical structure of the original message and due to the nature of the final destination of the information.

Claude Shannon (1916-2001). American mathematician and electrical engineer who laid the theoretical foundations for digital circuits and information theory.

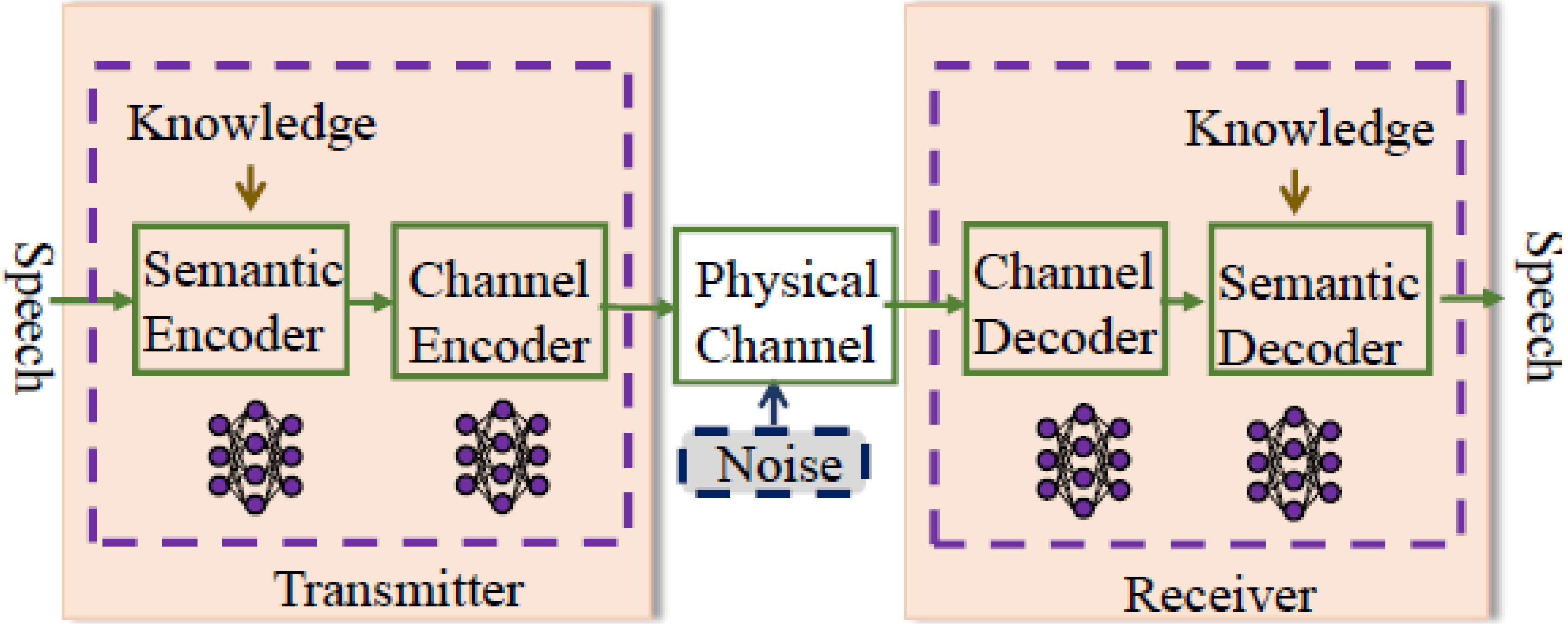
Shannon separated the technical problem of delivering a message from the problem of understanding its meaning. This separation allows the communication engineers to concentrate on the problems of message delivery.

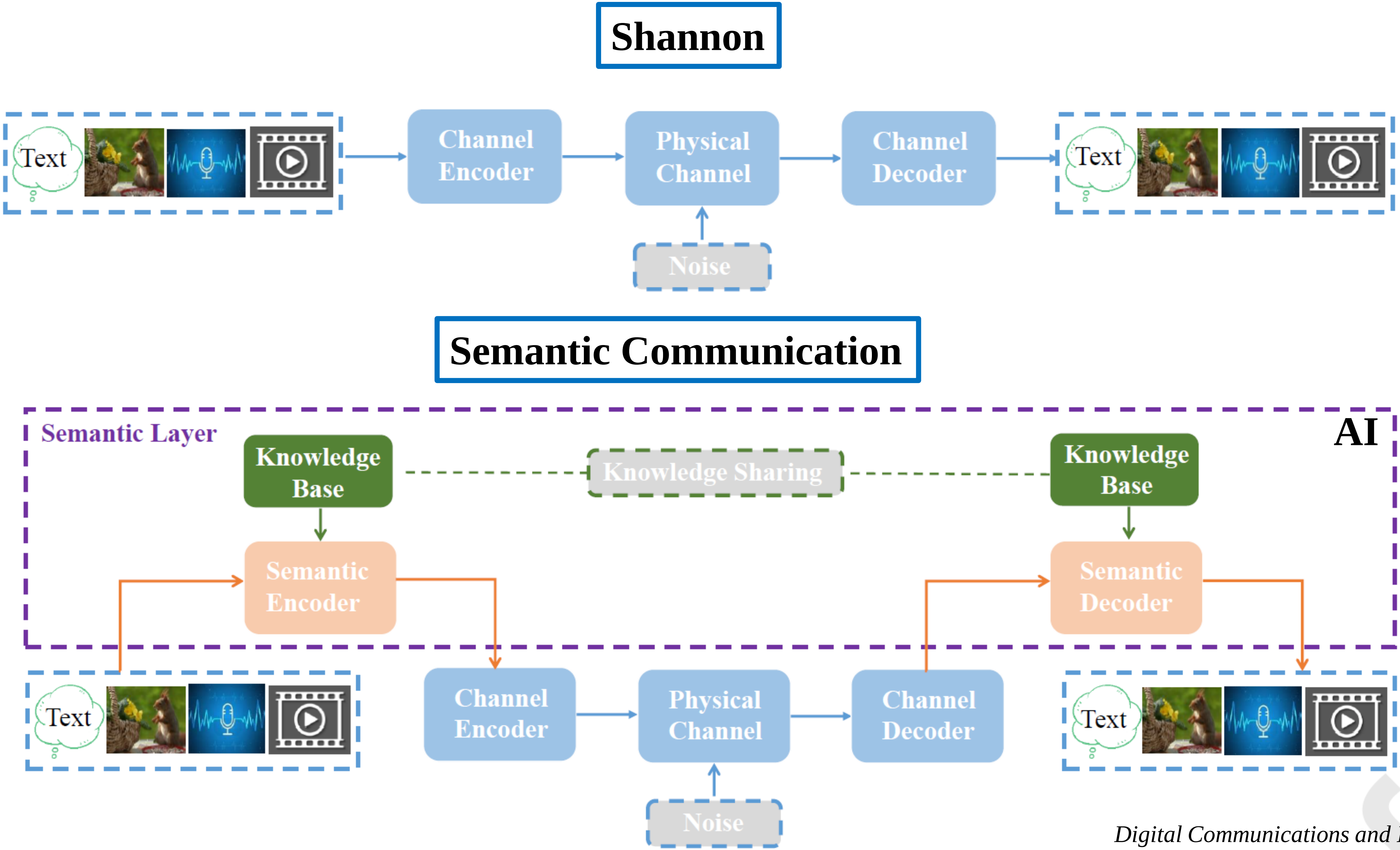


The key issues in the paper were the establishment of the most efficient encoding of a given message in a noiseless environment and the understanding of coding in the presence of noise. According to Shannon, the information content of a message is related to the probability of its occurrence.

In contrast to the Shannon paradigm whose underlying principle is to guarantee the correct reception of each single transmitted packet regardless of its meaning, **semantic communication** is concerned with the problem of how transmitted symbols convey a desired meaning to the destination, as well as how effectively the received meaning affects the action in a desired way.

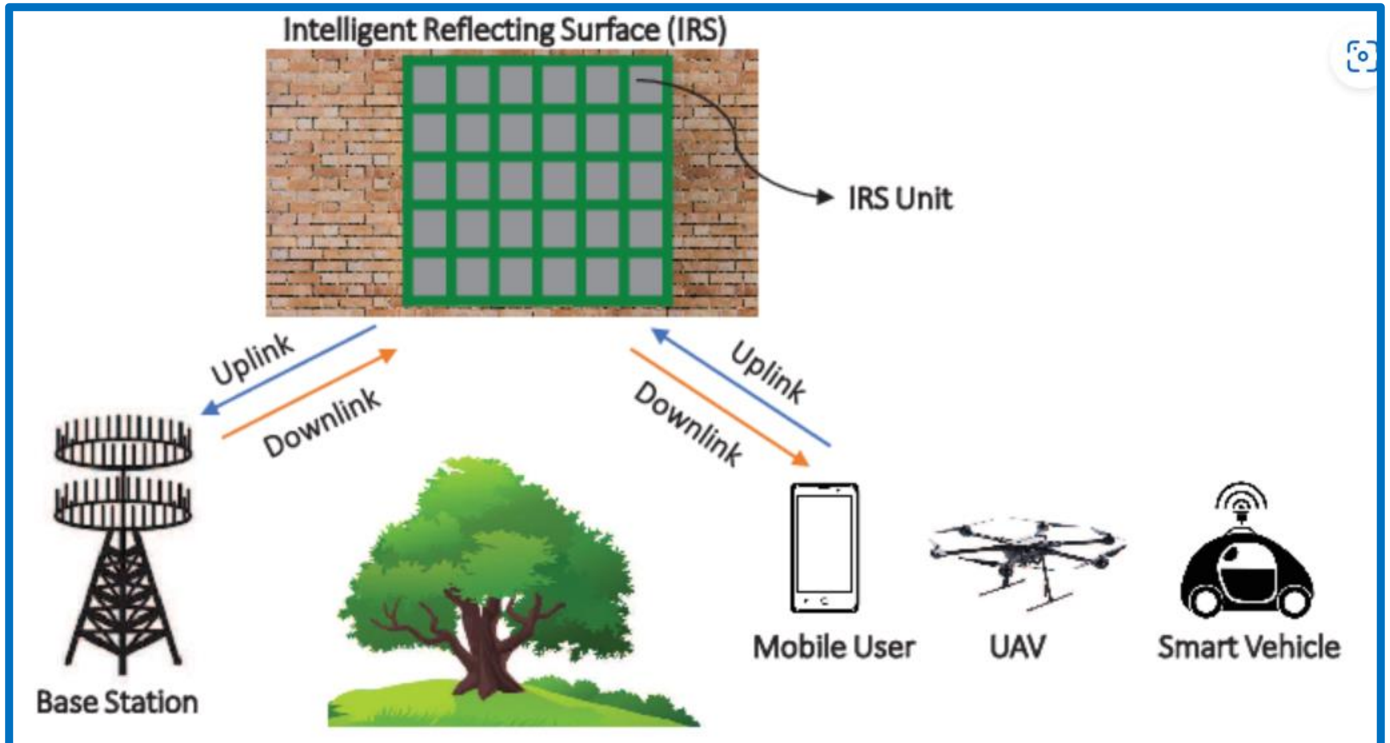
By communicating the meaning or semantics of the data, semantic communication holds the promise of making wireless networks **significantly more energy-efficient, robust and sustainable.**



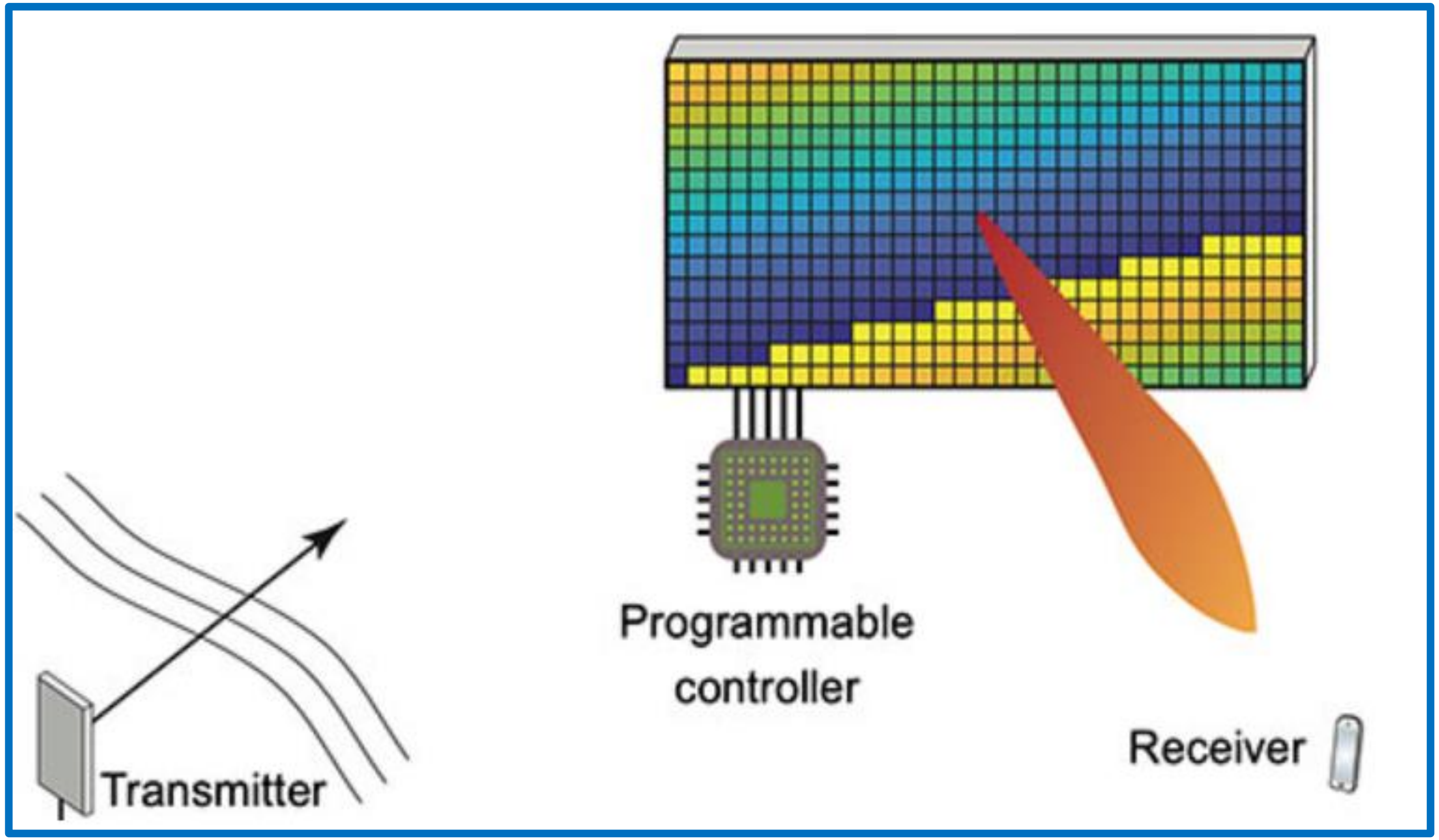

Shannon
Text
Channel Encoder
Physical Channel
Channel Decoder
Text
Noise
Semantic Communication
Semantic Layer
AI
Knowledge Base
Knowledge Sharing
Knowledge Base
Semantic Encoder
Semantic Decoder
Text
Channel Encoder
Physical Channel
Channel Decoder
Text
Noise

2) Reconfigurable intelligent surfaces

A Reconfigurable Intelligent Surface (RIS) is a programmable surface structure that can be used to control the reflection of electromagnetic (EM) waves by changing the electric and magnetic properties of the surface. These surfaces can be strategically placed in the radio channel between a transmitter and receiver to control the way the signal reflects off a surface in its propagation path. Reconfigurable Intelligent Surfaces can be used to steer signals to the receiver resulting in better reception or link quality.

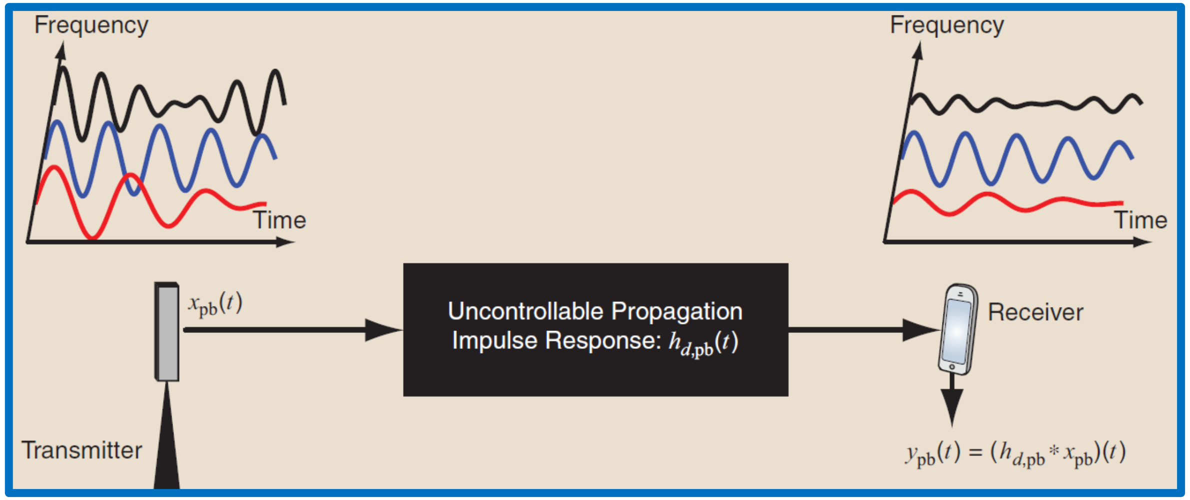


Reconfigurable intelligent surfaces would first absorb a signal that is directed towards it, which then would be processed by a microcontroller and then reproduced again and transmitted in a specific direction using antenna arrays. Thus they can be used to **increase availability of cellular in areas where they are not naturally accessible.**

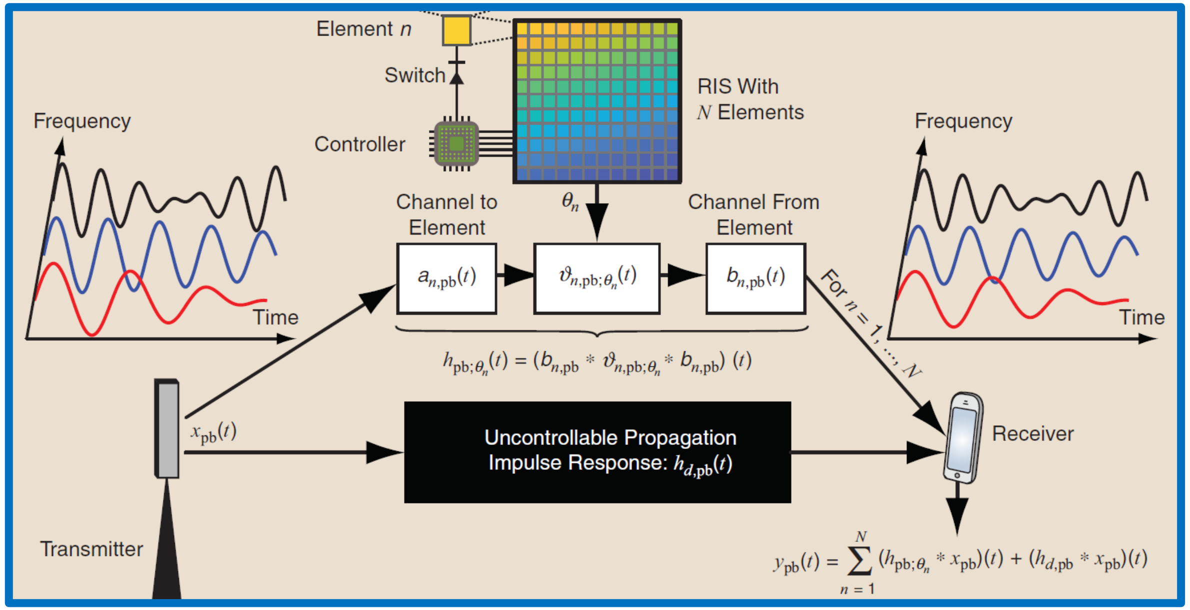


https://www.everythingrf.com

Without RIS



With RIS



The surface consists of an array of discrete elements, (where each color represents a certain amplitude and phase response curve). A controller and switch determine which curve to utilize on a per-element or group-of-elements level.

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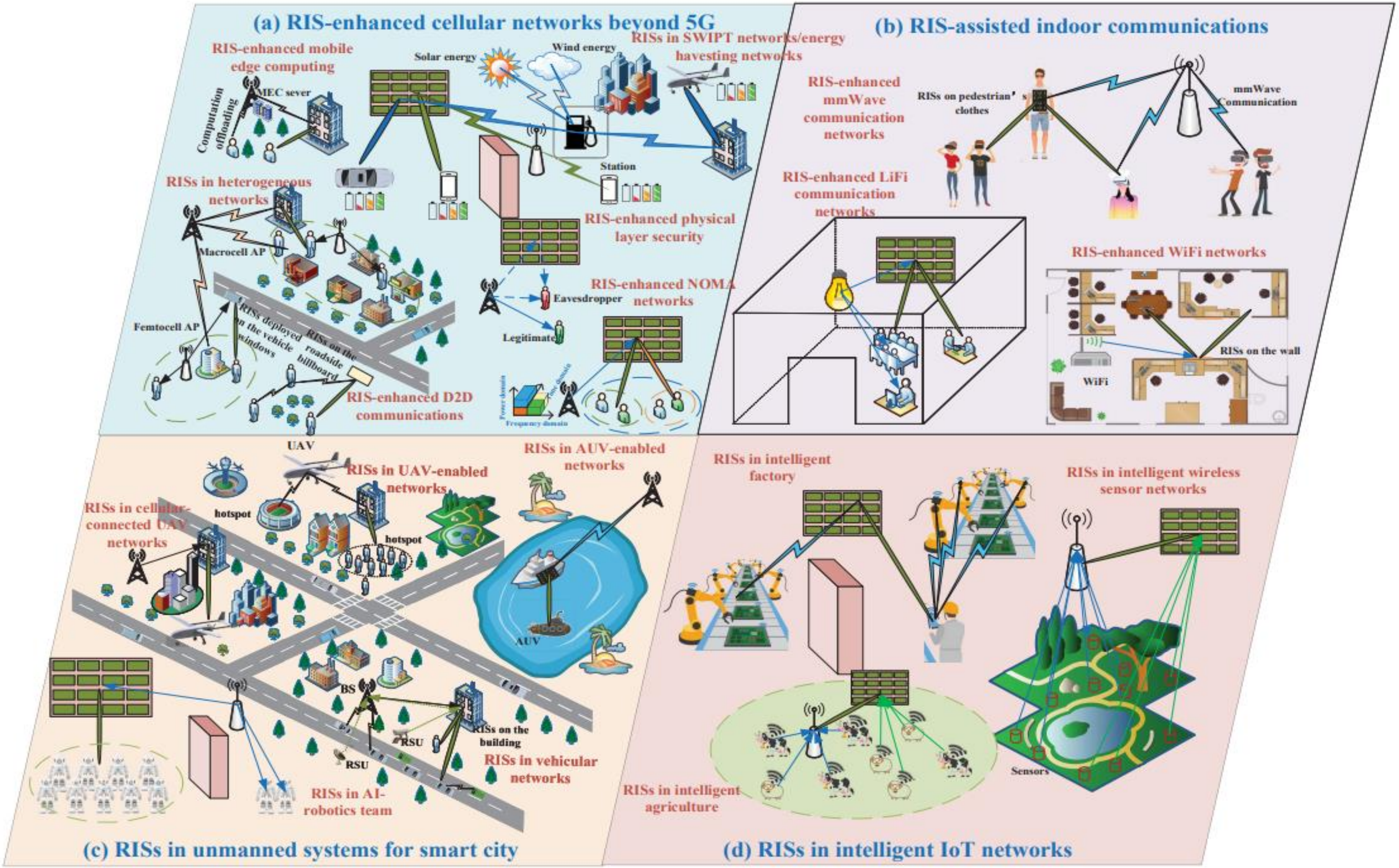
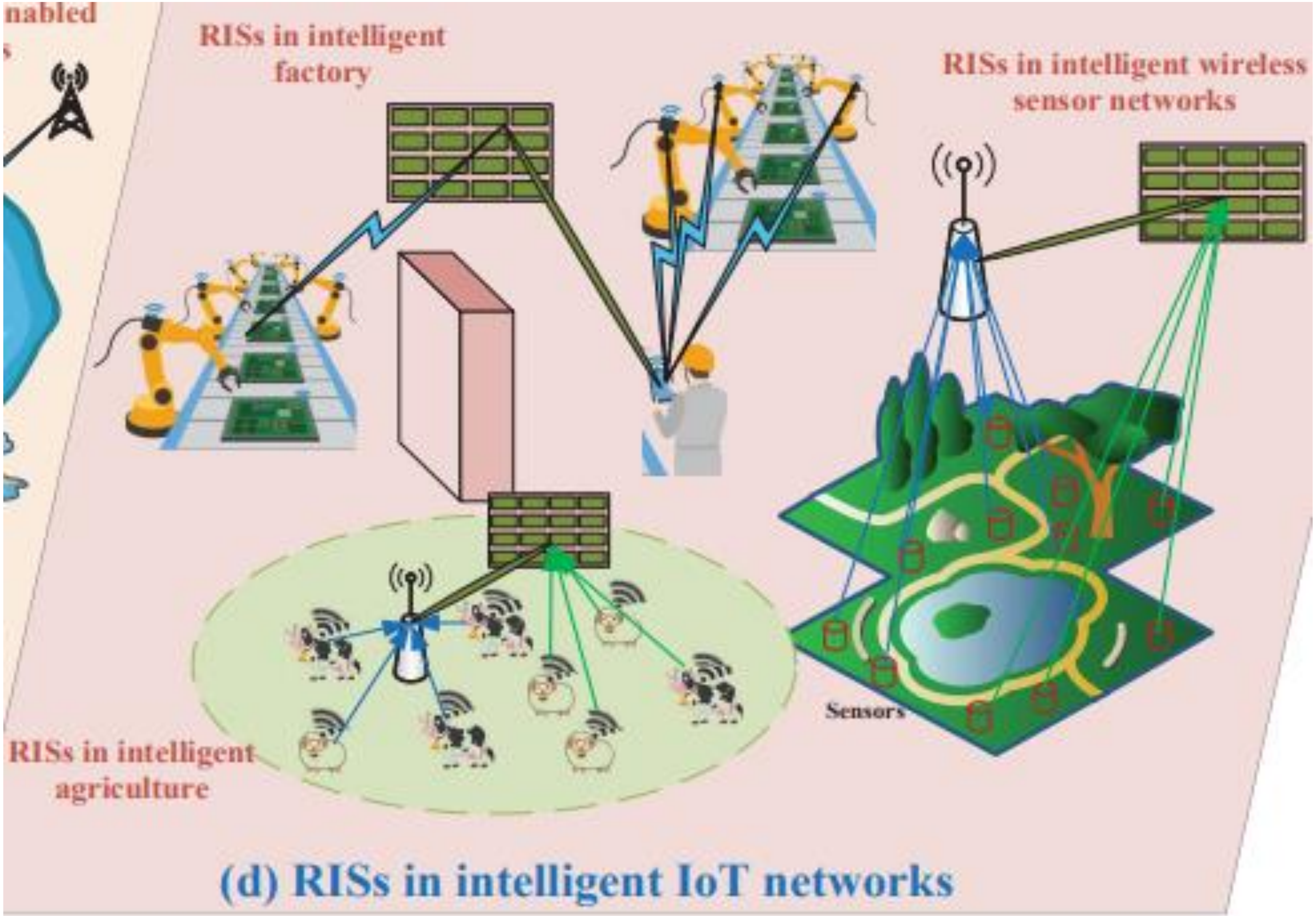


https://www.researchgate.net



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RISs in intelligent factory
RISs in intelligent wireless sensor networks
Sensors
RISs in intelligent agriculture
(d) RISs in intelligent IoT networks