10 Mobile Evolution to 5G

Felix EDELMANN
Helix IT Consulting e.U., Austria

10.1 Abstract

This paper attempts to show the mobile evolution from 1G to 5G, describe the key features of 5G, outline the activities in Europe defined by EU 5G PPP Public-Private Partnership, look into the current 5G activities in Austria and the Austrian 5G Roadmap. From the various technologies used in 5G massive MIMO and beamforming will be pointed out. It will close with use cases for 5G networks.

Keywords: 5G Technology, Speed GB/s, 5G Scenarios, MIMO, Beamforming

10.2 Introduction

If data transfer lasts not more than a blink of an eye. Mobile data radio is about to make a quantum leap: From 2020, 5G technology will be available as the basis for comprehensive digitization for business and society. Visions like autonomous driving or intelligently networked production should become reality by 2025, see figure 1.

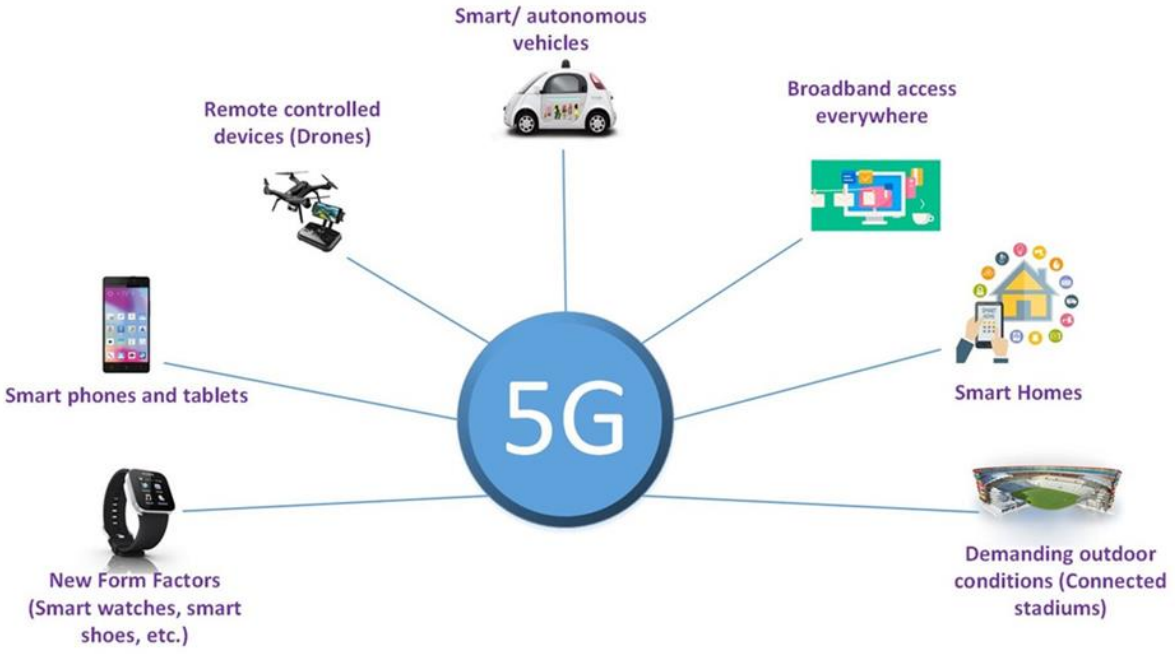

Figure 1: *Various 5G scenarios*
Source: https://5g-ppp.eu/

Innsbruck, 09 th February 2018. Two radio cells in the network of T-Mobile Austria are already showing the future of communication. The plants in Innsbruck are the first in Austria and among the first in Europe, which already work to the greatest extent according to the new 5G standard. With this pre-version of the final 5G standard, the network in Innsbruck creates record transmission rates of two gigabits per second and a latency of only three milliseconds. Super short response time of the network and extremely high bandwidths are major advantages of 5G, which was demonstrated in the Tyrolean capital for the first time.

10.3 Mobile Technologies from 1G to 5G

1G system: Frequency 800 MHz and 900 MHz, Bandwidth: 10 MHz (666 duplex channels with bandwidth of 30 kHz), Analogue switching, Modulation: Frequency Modulation (FM), Voice only, Access technique: Frequency Division Multiple Access (FDMA).

2G system GSM: This standard could support up to 14.4 to 64kbps (maximum) data rate which is sufficient for SMS and email services. On December 3rd 1992, the engineer Neil Papworth sent the first short message from the Short Message Service with the text "Merry Christmas" from a PC to a mobile phone. Twenty years later - in 2012 - 59 billion SMS have already been sent.

2.5G and 2.75G system: General Packet Radio Service (GPRS) was introduced and successfully deployed. GPRS was capable of data rate up to 171kbps, EDGE – Enhanced Data GSM Evolution also developed to improve data rate for GSM networks. EDGE was capable to support up to 473.6kbps.

3G system: UMTS – Universal Mobile Terrestrial / Telecommunication Systems. Data rate of 384kbps is supported. 3G mobile communication system and smart phones became popular. Specific APPs handles multimedia email, social media and healthcare.

3.5G to 3.75 systems: HSDPA – High Speed Downlink Packet access and HSUPA – High Speed Uplink Packet Access came into play. 3.5G network can support up to 2mbps data rate. 3.75 system is an improved version of 3G network with HSPA+ High Speed Packet Access plus. Later this system will evolve into more powerful 3.9G system known as LTE (Long Term Evolution).

4G system: Simultaneous transmission of voice and data is possible with LTE system which significantly improve data rate. All services including voice services are transmitted over IP packets. Complex modulation schemes and carrier aggregation is used to multiply uplink / downlink capacity.

5G system: 5G will be using advanced technologies to deliver ultra-fast internet and multimedia experience for customers. Current LTE advanced networks will transform into supercharged 5G networks in future. To achieve higher data rate, 5G technology will use millimeter waves and unlicensed spectrum for data transmission. Complex modulation technique has been developed to support massive data rate for Internet of Things IoT. [1]

Generation	Speed	Technology	Key Features
1G (1970 –1980s)	14.4 Kbps	AMPS,NMT, TACS	Voice only services
2G (1990 to 2000)	9.6/ 14.4 Kbps	TDMA,CDMA	Voice and Data services
2.5G to 2.75G (2001-2004)	171.2 Kbps 20-40 Kbps	GPRS	Voice, Data and web mobile internet, low speed streaming services and email services.
3G (2004-2005)	3.1 Mbps 500- 700 Kbps	CDMA2000 (1xRTT, EVDO) UMTS and EDGE	Voice, Data, Multimedia, support for smart phone applications, faster web browsing, video calling and TV streaming.
3.5G (2006-2010)	14.4 Mbps 1-3 Mbps	HSPA	All the services from 3G network with enhanced speed and more mobility.
4G (2010 onwards)	100-300 Mbps. 3-5 Mbps 100 Mbps (Wi-Fi)	WiMax, LTE and Wi-Fi	High speed, high quality voice over IP, HD multimedia streaming, 3D gamming, HD video conferencing and worldwide roaming.
5G (Expecting at the end of 2019)	1 to 10 Gbps	LTE advanced schemes, OMA and NOMA	Super fast mobile internet, low latency network for mission critical applications, Internet of Things, security and surveillance, HD multimedia streaming, autonomous driving, smart healthcare applications.

www.rfpage.com

Table 1: *Comparison of 1G to 5G technology, speed and key features*
Source: https://www.rfpage.com/

10.4 The 5G Infrastructure Public-Private Partnership

The 5G Infrastructure Public Private Partnership [1] (5G PPP) is a joint initiative between the European Commission and European ICT industry (ICT manufacturers, telecommunications operators, service providers, SMEs and researcher Institutions). The 5G-PPP is now in its second phase where 21 new projects were launched in Brussels in June 2017. The 5G PPP will deliver solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade. The challenge for the 5G Public Private Partnership (5G PPP) is to secure Europe's leadership in the areas where Europe is strong or where there is potential for creating new markets such as smart cities, e-health, intelligent transport, education or entertainment & media, see figure 2. The 5G PPP initiative will reinforce the European industry to successfully compete on global markets and open innovation opportunities. [2]

Figure 2: *The 5G Infrastructure Public Private Partnership (5G PPP)*
Source: https://5g-ppp.eu/

10.5 Mobile in Austria from 1974 to 2018

B network: 1974 Austria started the B network, and the public land mobile radio went in operation. However, one still had to know in which call zone the interlocutor was. 1995 the B network was shut down after almost 21 years.

C network: 1984 the B network approached its capacity limits with 1.770 subscribers. The cellular C network (450 MHz, NMT) went in operation. This was the first time under a country-wide unified area code an uninterrupted transfer of calls in another geographical cell was possible. In June 1985 already 5.000 subscribers could be reached under the area code 0663. 1997 the C network was discontinued.

D network: 1990, the analogue D network (E-TACS, 900 MHz band) was put in operation. The higher frequencies made smaller mobile phones possible. With the same area code as the C network, but with a six-digit number, mobile telephony has now become affordable. 2002 the D network was discontinued.

GSM, 2G: 1994 was the start of the first GSM 900 MHz in Austria. Early 1996, Mobilkom Austria had 120,000 subscribers. Originally expected a maximum of 200.000 users, in March 2000 there were 2.400.000. 1995 max. mobil started in Austria.1998 Austria's 1800 MHz network was started by Connect Austria.

3G: 2002 Mobilkom Austria (A1) launched the first European UMTS network - a new generation of mobile communications had begun in Europe. 2005 HSDPA was launched, allowing downlink data rates of up to 14.4Mb/s. 2006, T-Mobile finally became the first Austrian provider to put HSUPA into operation.

4G: At the end of 2009, the 4th generation mobile radio standard was introduced. With LTE and later LTE-Advanced. The main goal of LTE was a unified architecture that enables transmission based on Internet Protocol IP.

Austria gets a 5G test region. September 2018, companies in Carinthia are to test their applications for the next mobile generation. Self-driving cars, billions of networked devices, robots, video streaming. Current technologies are not sufficient for these requirements. The LTE successor 5G is expected to start in 2020. Austria is currently trying to set the course to play in the front. The Ministry of Infrastructure has given the go-ahead for a 5G test region in Carinthia.

10.6 IMT-2000 to IMT 2020 - 4G/5G

The framework of standards for International Mobile Telecommunications (IMT), encompassing IMT-2000 and IMT-Advanced, spans the 3G and 4G industry perspectives and will continue to evolve as 5G with IMT-2020 See figure 3. [3]

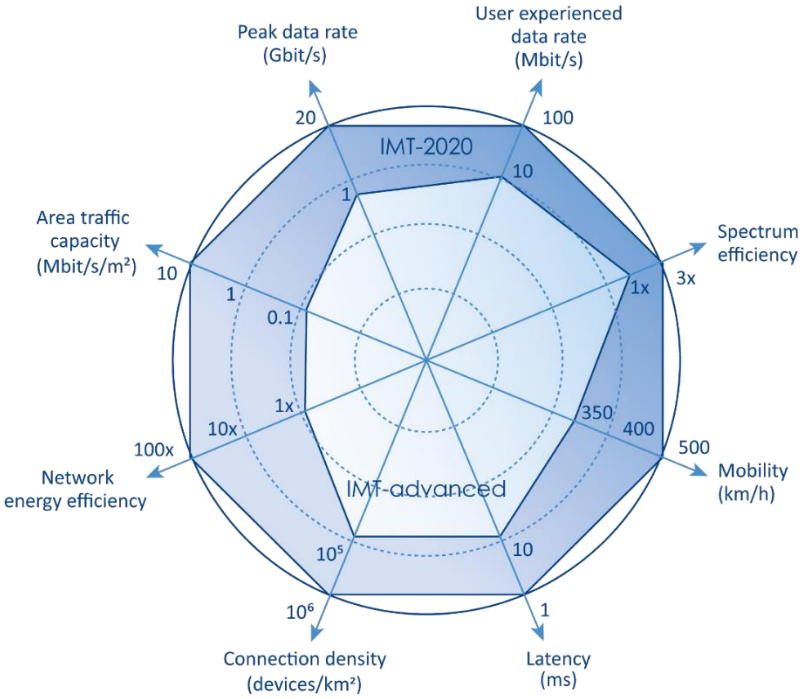

Figure 3: *Enhancement of key capabilities from IMT-Advanced to IMT-2020 [4]*
Source: https://www.researchgate.net

10.6.1 5G Roadmap for Austria

The Austrian federal government underscored the urgent priority of digitization, expanding broadband networks and rolling out the 5G standard. The government also recently presented its '5G Strategy' to the public. Austria should lead 5 G in Europe, 2020 5G in each capital city, use cases for E-Government, E-Health, autonomous driving, industry 4.0, 2025 5G full coverage, 20 times more efficient, far more intelligent then 4G.

10.6.2 5G Activities in Austria

T-Mobile Austria: Innsbruck, 09 th February 2018. With Europe's first 5G drone flight, T-Mobile is demonstrating with Huawei that next-generation mobile is fast enough to control a drone in real-time and transmit a high-resolution camera image of the drone.

A1 Telekom Austria: June 08 th 2018, mobile operator A1 shows "real" 5G in Vienna. A1 set up a complete 5G network in the technology centre in Vienna's Arsenal. Transmission speed of 1.4 Gbit/s were achieved and latencies down 4 ms were measured. A1 CEO Marcus Grausam gave a preview of the technology that will be launched in 2020.

Hutchison Drei Austria: April 19 th 2018, together with the city of Vienna, Drei was launching a kind of precursor to 5G technology. CEO Jan Trionow sees the push as a bridge to 5G. During 2018 the rollout is planned throughout Vienna - and in Austria "where it is needed".

10.7 Technologies used in 5G networks

SDN, Software-defined networking is set to be an integral part of the proposed 5G networks and is the only solution to manage 5G complex networks.

NFV, Network functions virtualization is to decouple software from hardware. With NFV, service providers can deploy various network functions in days instead of months.

cRAN, Cloud Radio Access Network. Current radio access networks (RANs) need to evolve to the growing number of connected devices and increasing data rates for the upcoming 5G era.

Massive MIMO and beamforming allows to go beyond what has been done in the past. It takes all the antenna elements to work together. Beamforming is where the beam focuses the “transmit” and/or “receive” in one specific area to avoid interference from outside sources and to increase gain and throughput. See figure 9. This focuses the beam both vertically and horizontally. It increases coverage and densification without moving an antenna or dropping in a small cell. [5]

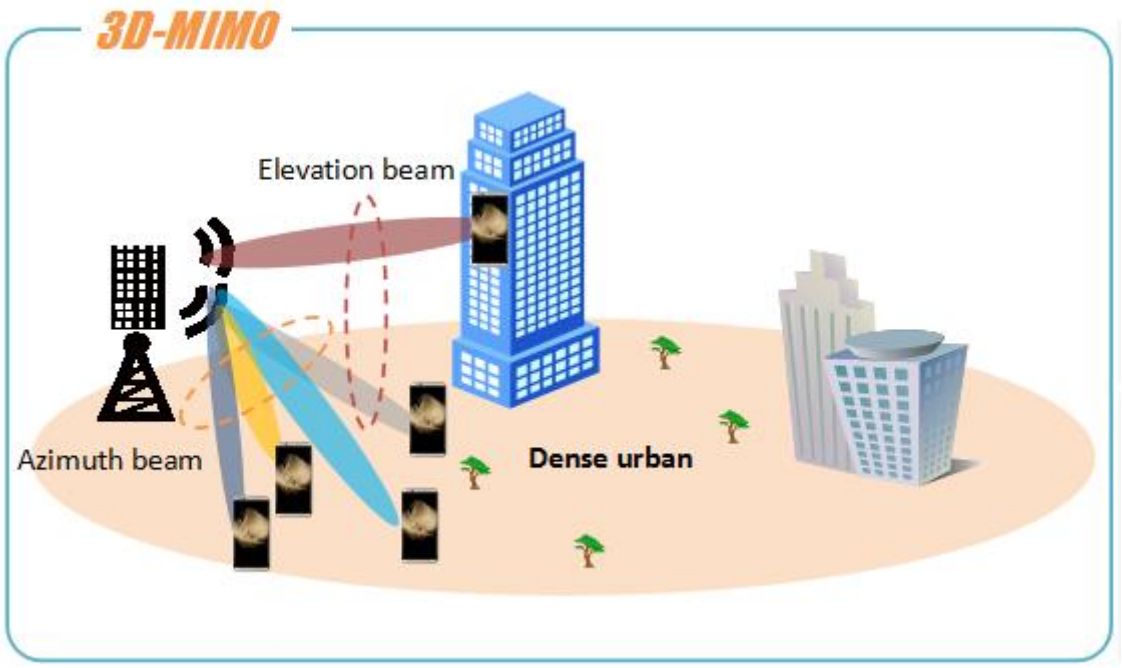

Figure 4: *Massive MIMO 3D beam forming*
Source: http://telecoms.com/

10.8 Top use cases for 5G

Fixed Wireless: One of the top 5G use cases will be fixed wireless access. Fixed wireless will provide Internet access to homes using wireless network technology rather than fixed lines.

Enhanced Mobile Broadband: The 5G standard will take mobile computing performance to the next level with high-speed, always-on, always-connected Internet links with real-time responsiveness. This category includes virtual reality (VR) and augmented reality (AR) experiences.

Massive IoT: One of the most anticipated 5G use cases is the ability to seamlessly connect everything. Industrial IoT is one area where 5G will play a major role, from smart cities to asset tracking, to smart utilities, to agriculture.

Ultra-Reliable Low-Latency Communications URLLC: This category includes new services that will transform industries with ultra-reliable/available low-latency links, such as remote control of critical infrastructure, and (popularly) self-driving vehicles. The level of reliability and latency will be vital to smart-grid control, industrial automation, robotics, drone control and coordination, and so on. [6]

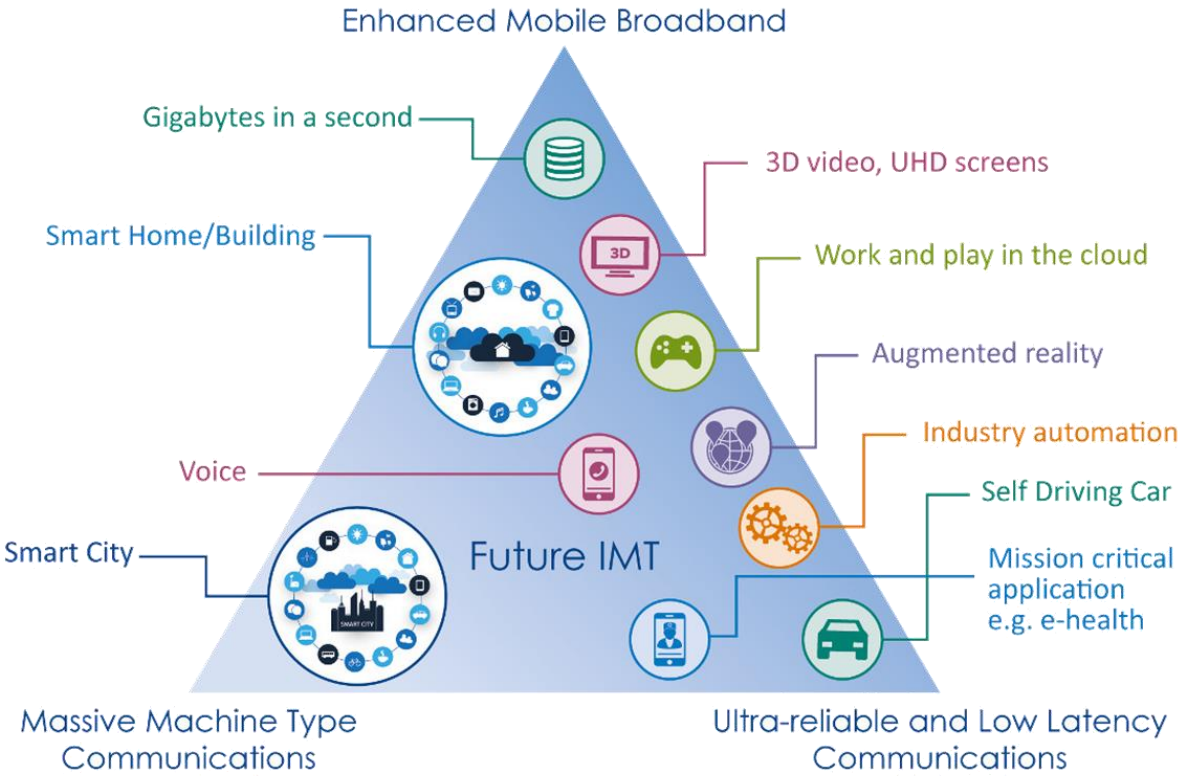

Figure 5: *Top use cases for 5G*
Source: https://www.testandverification.com/

10.9 Use case smart city, Kolumbus, Norway

https://www.zdnet.com/article/scandinavia-gets-its-first-autonomous-public-buses-but-theres-a-big-catch/

To find this website easy just google “Kolumbus Norway 5G”. Look at the Video: Norway's 5G pilot will have driverless buses, drones, and real-time medical diagnoses.

10.10 Conclusion

Wireless technology has been continuously evolving to meet increasing demands and higher requirements. Since the deployment of first generation mobile networks, the telecommunication industry is facing new challenges in terms of technology, efficient utilization of spectrum and most importantly security to end users. Future wireless technologies will provide ultra-fast, and highly secure mobile networks. 5G will revolutionize the mobile

experience with supercharged wireless network, which can support up to 20 GB/s download speed with latency down to 1 ms.

10.11 References

[1] Mobile Technologies from 1G to 5G. Retrieved from https://www.rfpage.com/evolution-of-wireless-technologies-1g-to-5g-in-mobile-communication/

[2] The 5G Infrastructure Public-Private Partnership. Retrieved from https://5g-ppp.eu/

[3] IMT-2000 to IMT 2020 - 4G/5G. Retrieved from https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx

[4] Key capabilities from IMT-Advanced to IMT 2020. Retrieved from https://www.researchgate.net/figure/Enhancement-of-key-capabilities-from-IMT-Advanced-to-IMT-2020_fig2_313486542

[5] Massive MIMO and beamforming. Retrieved from https://wade4wireless.com/2018/01/29/about-massive-mimo-beamforming/

[6] Top use cases for 5G. Retrieved from https://www.sdxcentral.com/5g/definitions/top-5g-use-cases/