

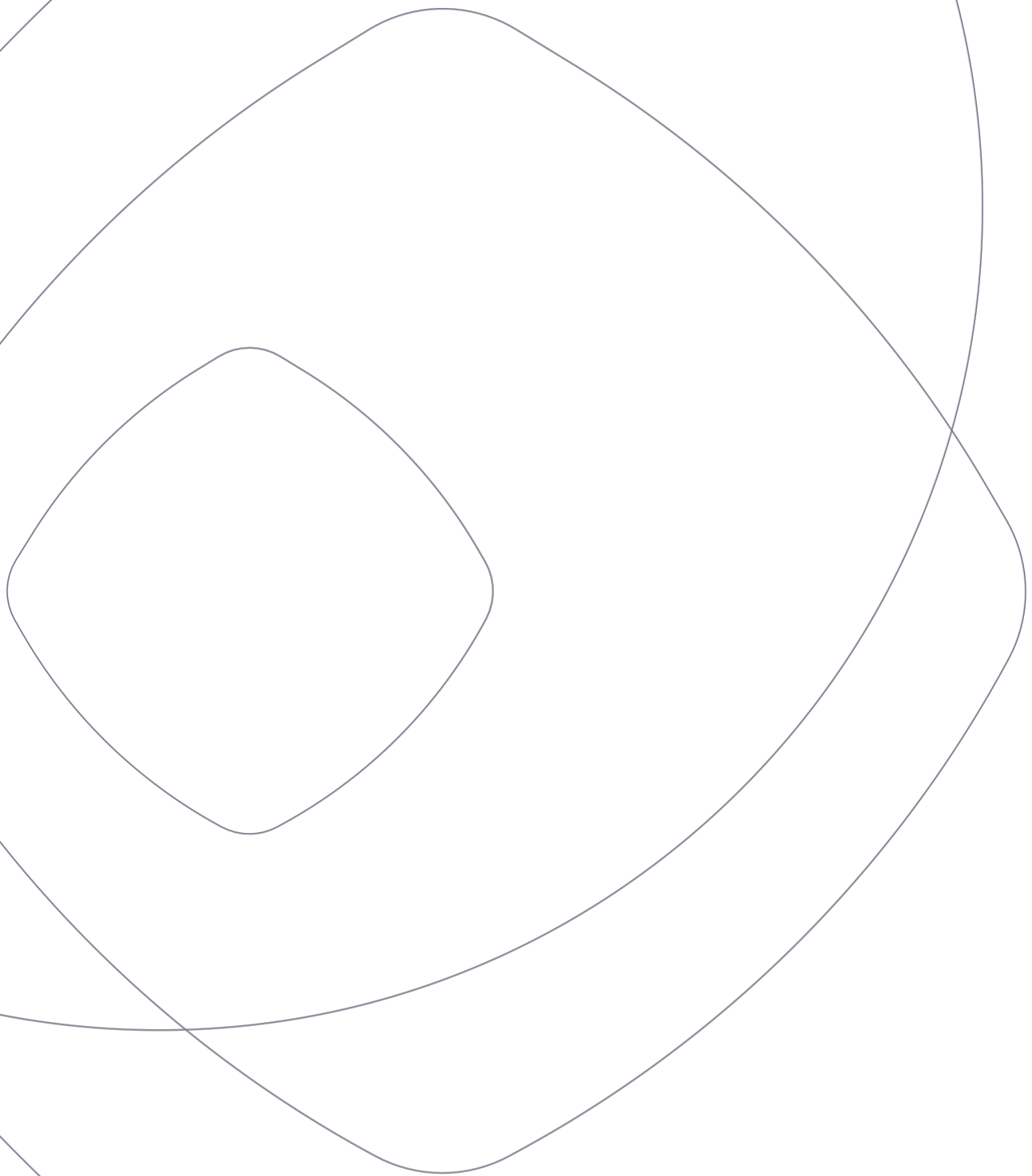
The use of 5G networks for fixed wireless point-to-multipoint high- speed access (FWA)

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**Národní
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obnovy**



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List of abbreviations and explanatory notes

Abbreviation	Full form (in English)	Explanation
2G	Second Generation	Second generation of mobile networks
3G	Third Generation	Third generation of mobile networks
3GPP	3rd Generation Partnership Project	An organisation developing technical specifications for mobile telecommunications, including 3G, 4G and 5G standards
4G	Fourth Generation	The fourth generation of mobile networks
5G	Fifth Generation	Fifth generation of mobile networks
5G BC	Fifth Generation broadcast	Fifth generation mobile networks Broadcast
5G NR	Fifth Generation New Radio	Fifth generation mobile networks new radio
6G	Sixth Generation broadcast	Sixth generation mobile networks
AAS	Active Antenna System	Active antenna systems
AMF	Access and Mobility Management Function	A component of the 5G network core that manages access and mobility for user devices
ATO	Association of Television Organisations	Association of Television Organisations
BSC	Base Station Controller	Base Station Controller
BTS	Base Transceiver Station	Base Transceiver Station
CA	Carrier Aggregation	A technique that allows several frequency bands to be combined into a single channel, resulting in increased overall bandwidth
CDMA	Code Division Multiple Access	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations	European Conference of Postal and Telecommunications Administrations
CPE	Customer Premises Equipment	Customer Premises Equipment.
ČTU		Czech Telecommunications Office
DESI	Digital Economy and Society Index	Digital Economy and Society Index
DVB-T2	Digital Video Broadcasting – Second Generation Terrestrial	
ECC	Electronic Communications Committee	Committee on Electronic Communications.
EECC	European Electronic Communications Code	European Electronic Communications Code
eNodeB	evolved Node B	Enhanced base station type (for 4G)
EPC	Evolved Packet Core	Evolved Packet Core
ETSI	European Telecommunications Standards Institute	European Telecommunications Standards Institute
EU	European Union	European Union
FDD	Frequency Division Duplex	Frequency Division Duplex
FS	Fixed Service	Fixed service
FSS	Fixed Satellite Service	Fixed Satellite Service
FUP	Fair Use Policy	Fair Use Policy
FWA	FWA	Fixed Wireless Access

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GHz	Gigahertz	Unit of frequency
gNodeB	Next Generation Node B	Next-generation base station (for 5G)

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GSM	Global System for Mobile Communications	Global System for Mobile Communications
HSS	Home Subscriber Server	Home Subscriber Server
IEEE	Institute of Electrical and Electronics Engineers	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications	International Mobile Telecommunications
ITU	International Telecommunication Union	International Telecommunication Union
LTE	Long Term Evolution	Long Term Evolution
LTE/5G	LTE/5G	Combination of LTE and 5G standards
MFCN	Mobile/Fixed Communication Networks	Mobile/fixed communication networks
MME	Mobility Management Entity	Mobility Management Entity
NEF	Network Exposure Function	Network Exposure Function
NodeB	Node B	Base station (for 3G)
NSA	Non-Standalone	Independent mode
P_GW	Packet Gateway	Packet Gateway
PCF	Policy Control Function	Policy Control Function
PCRF	Policy and Charging Rules Function	Policy and Charging Rules Function
PVRS	Public Voice Radio Service	Public Voice Radio Service
RAN	Radio Access Network	Radio Access Network
RLAN	Radio Local Area Network	Radio Local Area Network
RNC	Radio Network Controller	Radio Network Controller
RRL	Radio Relay Link	Radio relay link
RSPP	Radio Spectrum Policy Programme	Radio Spectrum Policy
SA	Standalone	Standalone mode
S-GW	Serving Gateway	Service Gateway
SMF	Session Management Function	Session Management Function
TDD	Time Division Duplex	Time Division Duplex
TRP	Total Radiated Power	Total Radiated Power
UDM	Unified Data Management	Unified Data Management
UPF	User Plane Function	User Plane Function
UWB	Ultra-Wideband	Ultra-wideband transmission
VHCN	Very High Capacity Network	Very High Capacity Network
WCDMA	Wideband Code Division Multiple Access	Wideband code division multiple access
WiFi	Wireless Fidelity	A type of wireless technology for wireless LAN based on IEEE 802.11 standards
WiGig	Wireless Gigabit	Wireless gigabit technology
WiMax	Worldwide Interoperability for Microwave Access	Worldwide Interoperability for Microwave Access
xDSL	Digital Subscriber Line	Digital subscriber line
XPIC	Cross-Polarization Interference Cancellation	Cross-polarization interference cancellation
XR	Extended Reality	Extended Reality

1 Executive Summary

From a global, European and Czech perspective, Fixed Wireless Access (FWA) networks are an integral part of the technological environment of the access layer for the provision of electronic communications services. Modern wireless access technologies for electronic communications networks represent the final link in the chain, with the assumption that the higher layers of the network – the access and backbone layers – are implemented using high-speed data transmission technologies, most commonly optical fibre.

The aim of this study is to analyse the potential and development of the wireless access layer, whether based on 5G technologies or on technologies with similar or higher performance based on licensed or unlicensed bands. To achieve the study's objectives, it is necessary to quantify the current and future requirements of households and businesses regarding connection capacity and reliability. A secondary objective of the study is to analyse the usability of FWA networks for content distribution via specialised protocols, such as 5G Broadcasting.

2 Management summary

Fixed wireless access (FWA) networks are, from a global, European and Czech perspective, an integral part of the technological environment of the access layer of electronic communications service provision. Modern technologies of wireless access to electronic communications networks represent the final link in the connection chain, whilst it is assumed that the higher layers of the network – backhaul and backbone – are implemented by high-speed data transmission technologies, most often by optical fibre.

The aim of this study is to analyse the potential and evolution of the wireless access layer, whether based on 5G technologies or on technologies with similar or higher performance utilising licensed or unlicensed bands. To meet the objectives of the study, it is necessary to quantify the current and future capacity and reliability requirements of households and businesses. A secondary objective of the study is to analyse the applicability of FWA networks for content distribution via specialised protocols such as 5G Broadcasting.

3 Introduction

The use of 5G networks for fixed wireless broadband (FWA) has become a key element of the modern technological environment in recent years. This approach enables the provision of high-speed connectivity in areas where the deployment of wired infrastructure is economically, technically, legislatively or otherwise challenging. The aim of this study is to analyse in detail the current and future potential of FWA based on 5G networks, with a focus on the Czech electronic communications market, within the context of the EU's Single Market framework.

5G technology, which delivers a significant increase in transmission speeds and a reduction in latency, offers FWA unique opportunities to extend broadband services to areas with limited availability of cable connections. In the Czech context, where coverage by cable and, in particular, optical infrastructure is not sufficient everywhere, FWA provides a suitable solution for ensuring high-quality internet access. This study focuses on assessing the technological developments and regulatory environment influencing the development of FWA networks, and analyses how 5G technologies can meet the growing capacity needs of the radio access network (RAN).

An important aspect of this analysis is the assessment of the current situation, where an increasing number of households and businesses require high-capacity and reliable connections. In this context, the study will examine not only the potential of 5G FWA to provide broadband access, but also the factors influencing its development, such as technological barriers, spectrum availability and investment costs. A secondary objective is to reassess the use of FWA for new applications, such as content distribution via specialised protocols, for example 5G Broadcast.

Last but not least, the study will focus on the expected evolution towards 5G Advanced technologies and future generations, such as 6G, and their potential impact on ensuring connectivity and the development of the digital economy.

4 Fixed Wireless Access

4.1 Technology description and characteristics

FWA represents an effective solution for providing high-speed internet in areas where cable infrastructure is not readily available. Compared to cable infrastructure, connectivity via wireless technologies is more expensive to operate; however, the costs of setting up the infrastructure are significantly lower. Fixed wireless networks are therefore the technology of choice for investors in areas with limited cable infrastructure. However, the term 'limited cable infrastructure' should not be understood in a blanket sense, for example as covering only rural areas. Limited availability of cable infrastructure can also occur in urban neighbourhoods of detached houses, in suburban areas with new individual housing developments, which were built after the area had been covered by cable network investors. A wireless service connection is also a solution for businesses as a backup to cable infrastructure. FWA supports the deployment of high-speed connectivity, particularly in areas where the construction of traditional infrastructure would be costly or complex. Furthermore, it enables the rapid expansion of broadband services without extensive investment in cable networks, which is important for meeting the demand for fast internet access.

The investment costs involved in setting up fixed cable infrastructure, or even just a connection, are not limited to the monetary cost; they may also face obstacles in the form of obtaining consent for the installation of a connection from property owners or co-owners – whether of buildings or adjacent land. Even in countries with high cable network penetration, a high percentage of FWA users remains, mainly due to the simplicity of setting up the service. In the Czech Republic, the use of FWA is widespread¹. Fixed LTE/5G services are used by 11.1% of users, wireless access in unlicensed bands (labelled as WiFi in the table) by 27.2% of households, with the WiFi category also including 60 GHz millimetre-wave technologies; 0.2% of users rely on FWA technologies in licensed bands without mobile network technologies (e.g. WiMax). The total share of wireless fixed technologies in the fixed-line market in the Czech Republic is 38.5%.

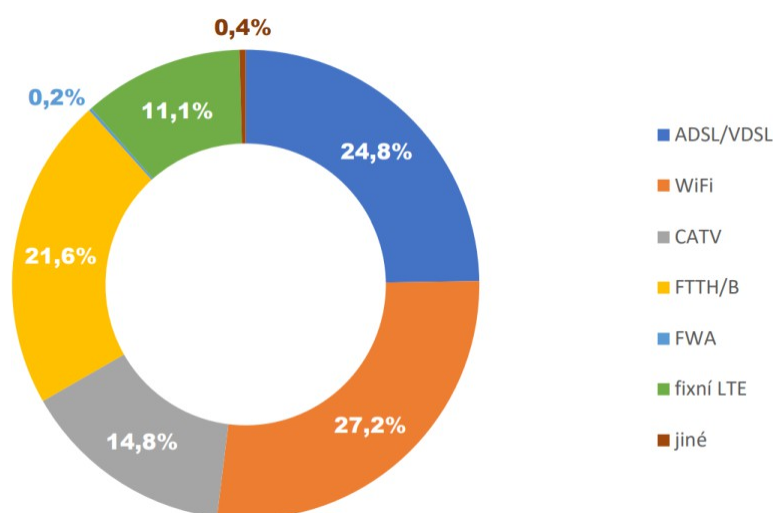


Figure 1 Share of high-speed access by individual technological solutions (including fixed LTE and 5G services) from the Report on the Development of the Electronic Communications Market with a Focus on 2023

¹ Report on the Development of the Electronic Communications Market with a Focus on 2023, page 52, Chart 41: Structure of fixed-location internet access services by access technology in 2023, https://ctu.gov.cz/sites/default/files/obsah/stranky/472017/soubory/zovt_2023.pdf

There are many scenarios for the development of wireless fixed infrastructure; it is important to avoid perceiving wireless infrastructure as a solution suitable only for sparsely populated areas, as evidenced by the high proportion of FWA in the total number of access points. For the purposes of further analytical assessment, however, it should be emphasised that it is precisely remote areas and the countryside that are the most typical locations for the development of FWA.

The topology of the wireless access network is similar to that of cable networks at higher layers. The wireless part forms the access layer of the network, representing the technological solution for connecting users to the network access point (Access Point, Base Station). The access point is connected, much like a distribution point in a wired network, most often using fibre-optic technology or a point-to-point high-capacity radio link. This description is necessary to understand the capacity capabilities of FWA infrastructure. These are hybrid networks utilising wireless access to address the 'last mile'. From a user experience perspective, well-dimensioned and properly designed FWA networks are a satisfactory solution.

4.2 FWA in mobile infrastructure

FWA in mobile infrastructure offers flexibility, rapid deployment and lower costs, which is crucial for operators in optimising their 5G investments and expanding coverage in sparsely populated areas where FWA fixed connectivity can be provided at minimal additional cost. Operators often utilise the unused capacity of local infrastructure, frequently using mobile network access frequencies. In this way, they make effective use of existing higher-level network infrastructure. The MFCN² infrastructure development concept envisages both the use of traditional mobile network frequency allocations and the use of frequencies that are technically more suitable for connecting subscribers at a fixed location, perceived for mobile services as a capacity layer with the ability to provide coverage over short distances. According to the Report on the Development of the Electronic Communications Market with a Focus on 2023³, 11.1% of subscribers, or 453,600 connections, use fixed wireless infrastructure via the mobile network. Wireless access via so-called fixed LTE/5G refers to internet access services provided via mobile networks, which are, however, tied in their use either to a specific location or, in the case of a nomadic nature, to multiple locations⁴. From the Report on the Development of the Electronic Communications Market, the following can be cited to assess the distribution of individual speed profiles:

"The speed category $\geq 10 < 30$ Mbit/s accounted for the dominant share of the total number of 453,600 accesses throughout the period 2019–2023; despite a downward trend, it retained a majority (53.7%) of accesses in 2023, amounting to 243,500. The second-largest category in terms of the number of connections, the < 10 Mbit/s category, which has been steadily declining, accounted for 11.1% of the total in 2023, amounting to 50,300 connections, having fallen by almost 40% from its original level over the period under review. The growing share of connections with higher advertised speeds amounted to 25.7% (116,600 connections) in 2023 for the category $\geq 30 < 100$ Mbit/s, and 9.5% (43,200 connections) for speeds of ≥ 100 Mbit/s < 1 Gbit/s. Both of these categories also recorded a significant year-on-year increase of 13.6% and 34.9%, respectively, compared to the previous year."

² MFCN (Mobile/Fixed Communications Network), as defined by 3GPP (3rd Generation Partnership Project), refers to a network that encompasses both mobile and fixed communication technologies, with the aim of providing integrated services including voice, data and multimedia. MFCN comprises radio communication systems that support both mobile and fixed users, and utilises shared frequency spectrum and infrastructure to ensure a seamless transition between fixed and mobile services. This network also forms the basis for technologies such as 5G, where the emphasis is on high capacity, low latency and efficient spectrum utilisation

³ Report on the Development of the Electronic Communications Market with a Focus on 2023, published by the Czech Telecommunications Office (ČTÚ) in 2024, available online: https://ctu.gov.cz/sites/default/files/obsah/stranky/472017/soubory/zovt_2023.pdf

⁴ The publicly available offer from O2 Czech Republic a.s. does not restrict the availability of the fixed wireless internet service to a specific address, although it is advertised as a home connection. Available online: <https://www.o2.cz/osobni/internet/bezdratovy-internet#c-podrobne-informace-o-bezdratovem-internetu-a98082>

The shares of all speed categories in the total number of active connections in 2023 are shown in the following chart.

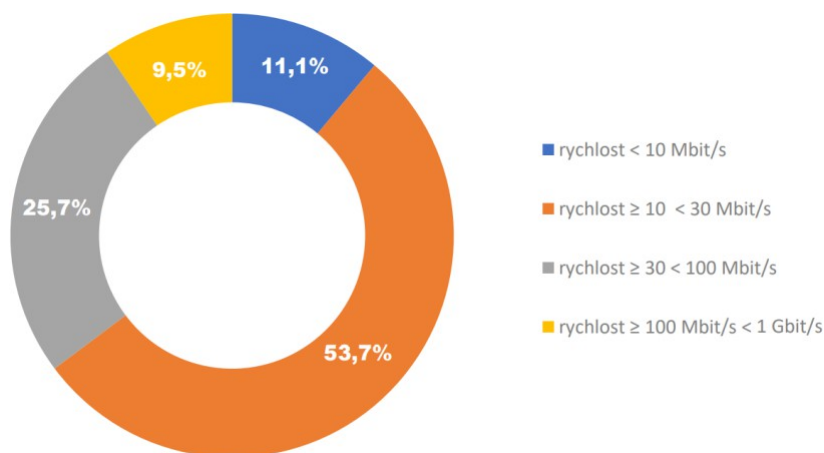


Figure 2: Chart No. 62 from the Report on the Development of the Electronic Communications Market with a focus on 2023⁵ ; Structure of internet access via fixed LTE/5G by advertised speeds in 2023

The chart in Figure 3 shows the trend in the number of internet accesses via wireless technologies operating in licensed FWA bands by advertised access speed. Note the decline in the number of advertised accesses offering speeds in the range ≥ 100 Mbit/s < 1 Gbit/s between 2019 and 2023.

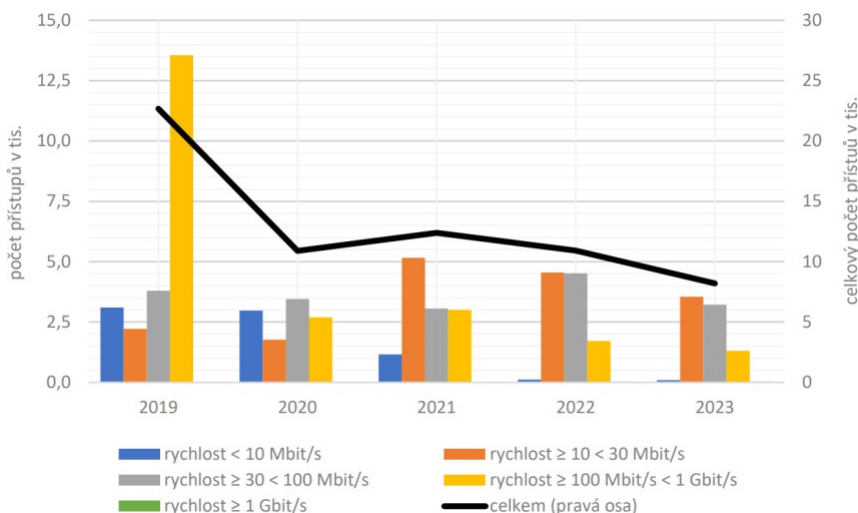


Figure 3: Chart No. 65 from the Report on the Development of the Electronic Communications Market with a focus on 2023; The chart shows the development of the number of internet connections via wireless technologies operating in licensed FWA bands by advertised access speed.

4.3 FWA in licensed bands not using mobile network infrastructure

A typical example of wireless access technology in licensed bands specifically designated for fixed-location connections was WiMax in the 3.5 GHz band. Technology based on the IEEE 802.16 standard did not see significant uptake in the Czech Republic, nor indeed worldwide. The main barrier to the expansion of this otherwise promising technology was the undermining of the fundamental prerequisites for FWA networks – low acquisition costs with acceptable operating costs, albeit higher than those of cable fibre-optic networks. The speeds achieved were in the tens of Mbit/s per access point, i.e.

⁵ https://ctu.gov.cz/sites/default/files/obsah/stranky/472017/soubory/zovt_2023.pdf

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aggregated among connected users. Commission Implementing Decision (EU) 2019/235 amended the harmonised use of spectrum, providing for further development in this band based on 5G technologies. A similar fate befell the previously promising development of point-to-multipoint systems in the 24 to 26 GHz band, originally intended for fixed point-to-multipoint links within FWA networks operated by ^{licence holders}⁶.

The current technological needs of businesses providing wireless connectivity in licensed bands are primarily met through point-to-point links in licensed bands. Such a solution enables the provision of high-speed data transmission services, including internet connectivity; however, due to its high cost, it is intended either for connections in the corporate client segment or for providing access to households, particularly those sharing connections within multiple residential buildings. Just over 8,000 connections via licensed FWA were reported in 2023.

The shift in the number of connections after 2020 is likely linked to the release of the new 60 GHz band for unlicensed use, and the gradual decline in prices of infrastructure equipment for the 80 GHz band, which led operators to restructure their networks and switch to solutions that do not require regular payments for individual licences. This is particularly evident in the decline in the speed category \geq

100 Mbit/s $<$ 1 Gbit/s. The relative stability in the number of connections with lower speed profiles is likely linked to the greater distance of user devices from network access points, for which millimetre-wave bands are unsuitable. Lower speed profiles do not require the use of high-bandwidth channels, which has meant there has been no cost pressure to change the technological solution. Another factor inhibiting the retention of solutions in the licensed band may be the requirements for high availability, which can be guaranteed in licensed bands.

4.4 FWA in unlicensed bands

Fixed wireless access in unlicensed bands has long been the most widely used fixed-location internet access service, including all cable technologies (see Figure 1). In 2023, operators reported approximately 1.115 million wireless access connections in unlicensed bands.⁷

The technological infrastructure for FWA in unlicensed bands consists primarily of WiFi technology based on the 5 GHz bands, and to a lesser extent on the 2.4 GHz band. Depending on the deployment type and generation of WiFi technology, delivered transmission speeds range from the high tens of megabits per second to the low hundreds of Mbit/s. The second most common method of connection is the use of technologies in the 60 GHz band (IEEE 802.11ad and IEEE 802.11ay), commercially known as WiGig. A fundamental advantage of millimetre-wave bands in general is their ability to provide speeds of up to one gigabit. The spread of WiGig technology is indicated by the number of registrations on the [ran.ctu.cz](https://www.ran.ctu.cz) portal, where operators must register WiGig devices operating in the 57–66 GHz band. There were almost 133,000 registration records available in Q4 2024. The registration requirement ^{does not apply} to the remaining part of the available band in the 66–71 GHz ^{range}⁸; the total number of actively operated technologies in the 60 GHz band is higher. The expansion of the 60 GHz band has been significantly supported by the mass production of components and the availability of this gigabit technology to businesses providing electronic communications services. A disadvantage of WiGig is its limited propagation capability in the environment, which strictly limits the ability to connect users located further away from network access points.

Less common connection methods include the use of point-to-point radio relay technologies in unlicensed bands. In particular, derivatives of professional infrastructure links designed for the 10.5 ^{GHz}⁹, 17 ^{GHz}¹⁰ or 80 ^{GHz}¹¹ frequency bands provide high-capacity connections for users, most commonly corporate clients. From the perspective of customer segmentation, however, services provided to households clearly dominate in the licence-exempt FWA sector.

⁶ Part of Radio Spectrum Utilisation Plan No. PV-P/2/03.2006-4 for the 24.25–27.5 GHz frequency band, pages 3–5, Section 2, Fixed service, available online at: <https://ctu.gov.cz/sites/default/files/obsah/clanky/66423/soubory/telekomunikacni-vestnik-07-2006-1142585856.pdf>

⁷ Report on the Development of the Electronic Communications Market, CTU website, published in 2024, page 57, available online: https://ctu.gov.cz/sites/default/files/obsah/stranky/472017/soubory/zovt_2023.pdf

⁸ General Authorisation No. VO-R/12/11.2021-11 for the use of radio frequencies and the operation of equipment for broadband data transmission in the 2.4 GHz to 71 GHz bands, General Authorisation issued by the Czech Telecommunications Office, page 2, available online at: https://ctu.gov.cz/sites/default/files/obsah/vo-r_12-112021-11.pdf

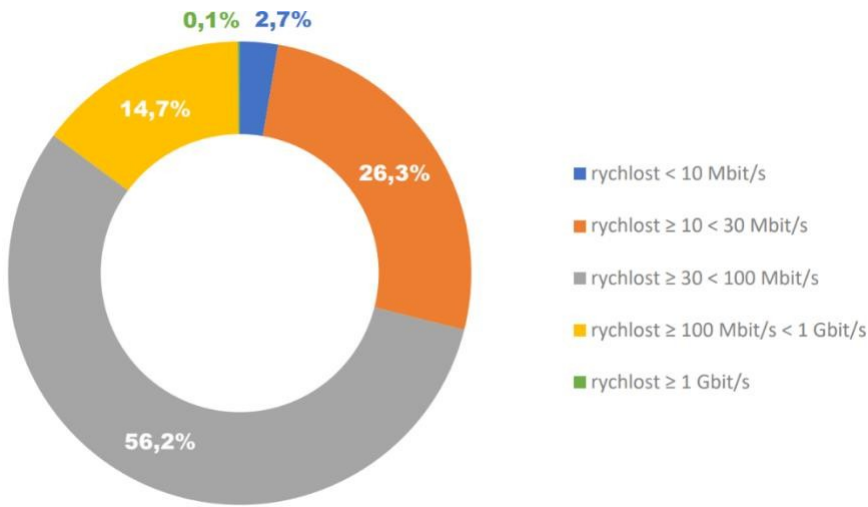
⁹ General Authorisation No. VO-R/14/05.2020-7 for the use of radio frequencies and the operation of equipment in the 10 GHz frequency band, OOP issued by the CTU, available online at: <https://ctu.gov.cz/sites/default/files/obsah/ctu/vseobecne-opravneni-c.vo-r/14/05.2020-7/obrazky/vo-r-14-052020-7.pdf>

¹⁰ General Authorisation No. VO-R/12/11.2021-11 for the use of radio frequencies and the operation of equipment for broadband data transmission in the 2.4 GHz to 71 GHz bands, OOP issued by the CTO, page 2, available online at: https://ctu.gov.cz/sites/default/files/obsah/vo-r_12-112021-11.pdf

¹¹ General Authorisation No. VO-R/23/06.2024-4 for the use of radio frequencies and the operation of fixed service equipment in the 71–76 GHz and 81–86 GHz frequency bands, General Authorisation issued by the Czech Telecommunications Office, available online at: <https://ctu.gov.cz/sites/default/files/obsah/vo-r23-062024-4.pdf>

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Figure 4: Chart No. 50 from the Report on the Development of the Electronic Communications Market with a Focus on 2023; Chart showing the structure of access via wireless technologies operating in unlicensed bands by advertised speeds in 2023.



5 Current status and technological development of 5G FWA

Fixed wireless access (FWA) 5G/LTE within the MFCN concept, i.e. for connecting households via broadband, is leading to a significant increase in the volume of data transmitted over mobile networks as it develops and its usage grows. In the past, the FWA concept, primarily utilising LTE technology, was mainly used where there was insufficient provision of broadband via other technologies (including wireless connections in unlicensed bands) and where sufficient capacity was available in the access network. However, these synergistic effects began to reach market limits due to the development of other fixed broadband technologies – even in rural and remote areas. Such developments in the competitive market environment are forcing mobile operators, in areas where their infrastructure permits, to modernise their networks with 5G FWA technology. Only 5G FWA makes it possible to offer tariffs in the range of ≥ 100 Mbit/s to < 1 Gbit/s.

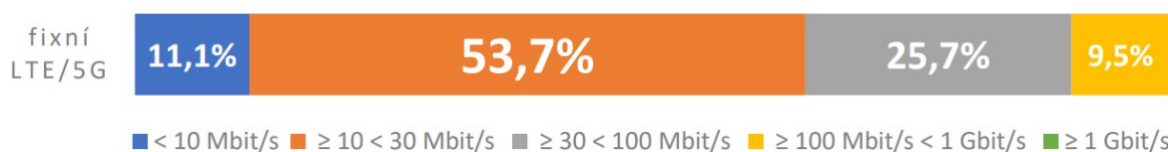


Figure 5: Structure of speed categories according to advertised speeds from the Report on the Development of the Electronic Communications Market with a focus on 2023, published by the Czech Telecommunications Office.

When comparing with competing technologies, we must also take into account upload speeds, which may vary depending on the available frequency of the mobile network covering the specific location. FWA LTE tariffs in operators' public offers operate with a download/upload ratio of 10:1; in other words, a tariff with a download speed of 20 Mbit/s offers 2 Mbit/s for uploading data. This apparent technological disadvantage compared to other technologies may disappear over time with the transition to newer generations of 5G NR 3GPP standards. Such a transition and the massive increase in data load on the MFCN infrastructure significantly raise the cost of investment and operating expenses for fixed-line tariffs.

As William Webb wrote in his book 'The End of Telecom ^{History}(12), *fixed wireless access technology is unlikely to succeed in competition with fixed cable connections. A high-quality fixed cable connection should be faster, more reliable and have lower long-term costs than a mobile connection.*

Will FWA LTE5G be competitive? Due to the gradual roll-out of fibre-optic cable networks, particularly fully optical FTTH/B infrastructure, but also the shortening of distances between the fibre-optic access network and the connection points of other competitors' access technologies (xDSL network access exchanges, FWA based on unlicensed bands), market aspects other than the availability and quality of the offer will also play a role in consumers' decision-making. The main reason for acquiring a fixed wireless LTE/5G connection will be the flexibility of the connection – for example, for users who rent a flat, or for users who want to take their connection with them. We can therefore expect the greatest expansion of FWA via LTE/5G in areas that are not served by adequate cable infrastructure and/or where there is a high cost barrier to the roll-out of fully optical networks to the home – that is, to households that have so far been using fixed wireless FWA networks based on unlicensed frequency bands. The competitive advantage of LTE/5G FWA over unlicensed FWA lies in dedicated frequencies – and the technical capability to utilise greater bandwidth at frequencies below 6GHz, which are suitable for covering larger areas (covering a wider area with a signal from a base station). For frequencies below 6GHz, unlicensed fixed access providers have only the shared WiFi band at their disposal, where service quality depends on the level of interference. Unlicensed FWA providers therefore resort to more extensive

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¹² William Webb, The End of Telecom History, 2024, ISBN-13:9798328402729

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use of the 57–71 GHz WiGig band under General Authorisation VO/R-12, where 14,000 MHz of bandwidth is available and spectrum collisions are unlikely. Millimetre-wave bands (tens of GHz) are suitable for unlicensed provision with gigabit parameters. Depending on the type of area, landscape profile, population density and other factors, the technological competition between licensed and unlicensed types of wireless connectivity can be very close. This is primarily due to economic factors, such as the costs of network operation and maintenance – these factors directly influence the price, which is the deciding factor for the subscriber/consumer. In the case of FWA LTE/5G, nationwide 4G and 5G network frequencies are available, which differ in their physical propagation characteristics depending on the frequency used, offering greater flexibility and range from the network's base stations. It is necessary to take into account the load on the available mobile network access frequencies caused by purely mobile devices and the available bandwidth of individual 4G and 5G infrastructure frequencies, which affect the quality of the FWA LTE/5G services provided, whereas with a purely fixed wireless infrastructure, you know the number of connected households at any given moment and can tailor the network precisely to transmission requirements.

Providing connections for high-speed data transmission via mobile frequencies also shared with fixed services, at relatively greater distances from the base station, has technical and economic limitations. Frequencies with sufficient capacity to provide a service competitive with cable infrastructure – where more frequency spectrum is available – are, from a purely mobile service perspective, utilised for mobile communications due to their spatial propagation characteristics. On the other hand, for the widespread use of frequency allocations suitable primarily for the provision of FWA services within the MFCN concept, it would be necessary to build and maintain a significantly denser infrastructure of access points compared to the current situation, which would inevitably have to be interconnected via multi-gigabit access infrastructure.

According to data, the average monthly data consumption of a fixed infrastructure connection is 332 GB per active connection (CTU Market Report, 2024), whilst for mobile services it is approximately 33 times ^{less}¹³ (9.7 GB per month per SIM with a data plan). **The average load on a mobile network connection is therefore around 3% of the average load on a fixed infrastructure connection.**

What exactly is the MFCN (Mobile Fixed Communication Networks) concept? It represents the future development of a 'mobile' fixed wireless network. It is a hybrid telecommunications network that combines elements of both mobile and fixed communication technologies, with the aim of providing broadband, reliable and, for part of the offering, installation-friendly electronic communications services. Imagine MFCN as an optical network that serves directly connected users, but also connects parts of the mobile network and fixed wireless access (FWA).

Key components of MFCN:

Mobile network component: The mobile part of MFCN comprises infrastructure typical of mobile networks, such as base stations (BTS, NodeB, eNodeB, gNodeB) and backbone networks that support mobile devices across a wide geographical area. The mobile component is optimised to support user mobility, including services available whilst on the move, such as voice communication, high-speed data connections and roaming. Mobile technologies that can form part of an MFCN include 4G LTE and 5G networks utilising mobile network frequencies, or higher frequencies directly suitable for high-capacity data transmission due to their bandwidth.

Fixed network component: The fixed part of the MFCN relies on physical infrastructure, in particular optical fibre cables with sufficient data throughput. Such a network architecture enables the development of data-intensive FWA, which provides broadband connectivity to locations due to its high data throughput. Even frequencies that are physically more suitable for use in fixed wireless access (FWA) networks can, in justified cases, be used for mobile data connectivity – for example, to provide coverage in areas such as public gathering places. The fixed component of MFCN predominantly utilises bands such as 3400–3800 MHz or the candidate 26 GHz band, whilst the mobile component operates predominantly in bands such as 700 MHz, 800 MHz, 1800 MHz and 2600 MHz. MFCN supports both Time Division Duplex (TDD) and Frequency Division Duplex (FDD), which provides flexibility in the use of frequency resources. In TDD mode, the same frequency is used for both uplink and downlink, but at different time intervals, whilst FDD uses separate bands for each direction of transmission.

3 400 – 3 800 MHz, part of PVRS ^{PV-P/714}, harmonised in accordance with ECC/DEC/(11)⁰⁶¹⁵, intended for networks with fixed, nomadic or mobile terminals. The size of the allocated blocks is a multiple of 5 MHz. The duplex mode of operation is TDD. Coexistence with other services – Fixed service (FS), Fixed Satellite Service (FSS) – is regulated in CEPT ECC Report ²⁵⁴¹⁶

¹³ CTU Annual Report, available online: https://ctu.gov.cz/sites/default/files/obsah/stranky/487450/soubory/VZ%20%C4%8C%C3%9A%202023_0.pdf

¹⁴ Part of Radio Spectrum Utilisation Plan No. PV-P/7/02.2022-3 for the 2700–4200 MHz frequency band, OOP issued by the CTU, available online: <https://ctu.gov.cz/sites/default/files/obsah/ctu/sdeleni-o-vydani-opatreni-obecne-povahy-casti-planu-vyuziti-radioveho-spektra-c.pv-p/7/02.2022-3-for-the-2700-4200-mhz-frequency-band/images/pvrs7p.pdf>

¹⁵ ECC Decision (11)06, Harmonised frequency arrangements and least restrictive technical conditions (LRTC) for mobile/fixed communications networks (MFCN) operating in the 3400-3800 MHz band, available online at: <https://docdb.cept.org/download/1531>

¹⁶ CEPT ECC 254; Operational guidelines for spectrum sharing to support the implementation of the current ECC framework in the 3600-3800 MHz range, available online at: <https://docdb.cept.org/download/1276>

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Frequency blocks enabling the use of LTE Band 42 (3400–3600 MHz) and LTE Band 43 (3600–3800 MHz), 5G NR Bands n77/n78. Given the total size of the allocation, significant bandwidth should be available in contiguous frequency blocks to enable a competitive offering of high-speed connectivity services with parameters meeting the needs of the majority of users¹⁷. Commission Implementing Decision (EU) 2019/2351¹⁸ set as one of its objectives the task of creating a sufficiently wide contiguous block of communication channels:

‘With regard to Article 54 of the European Electronic Communications Code, Member States should strive to defragment the 3 400–3 800 MHz frequency band in order to provide access to large contiguous blocks of spectrum in line with the gigabit connectivity objective. This includes facilitating the trading and/or leasing of existing rights of use. Large contiguous blocks of spectrum, ideally 80–100 MHz, facilitate the effective deployment of 5G wireless broadband services, e.g. using active antenna systems (AAS), services with high transmission speeds, high reliability and low latency, in line with the policy objective of gigabit connectivity. This objective is particularly significant for defragmentation.’

The current situation does not fully correspond to the objectives of the Implementing Regulation. In the first FWA spectrum auction in 2017, the Czech Telecommunications Office (ČTÚ) allocated frequencies in the 3600–3700 MHz band between the two existing mobile operators – Vodafone Czech Republic and O2 Czech Republic a.s. Other auction winners were providers without mobile services – PODA a.s. and Nordic Telecom a.s. Frequency blocks of 40 MHz were auctioned; the bidder Nordic Telecom acquired two frequency blocks, i.e. 80 MHz. Furthermore, PODA a.s. won 40 MHz, O2 CZ 40 MHz and Vodafone CZ 40 MHz. In 2017, the 5G NR specification was not yet fully developed; under the service development conditions, the CTU did not require the use of 5G NR technologies.

Table 1: First auction of the 3.6 GHz band

Winner of the FWA 4G auction	Allocated radio frequency bands in the 3 600 – 3 800 MHz band	Total allocation of 200 MHz
PODA a.s.	3600 – 3640 MHz	40 MHz
Nordic Telecom 5G a.s.	3720 – 3800 MHz	80 MHz
O2 Czech Republic a.s.	3640 – 3680 MHz	40 MHz
Vodafone Czech Republic a.s.	3680 – 3720 MHz	40 MHz

In the second auction of 5G frequencies, auction blocks were awarded to Nordic Telecom 5G a.s.; CentroNet, a.s.; T-Mobile Czech Republic a.s.; Vodafone Czech Republic a.s. and O2 Czech Republic a.s.

Table 2: Second auction of the 3.6 GHz band

2021 auction winner	Allocated radio frequency bands in the 3 400 – 3 600 MHz band	Total allocation of 200 MHz
CentroNet, a.s.;	3400 – 3480 MHz	80 MHz
Nordic Telecom 5G a.s.	3580 – 3600 MHz	20 MHz
O2 Czech Republic a.s.	3540 – 3560 MHz	20 MHz
T-Mobile Czech Republic a.s.	3480 – 3540 MHz	60 MHz
Vodafone Czech Republic a.s.	3560 – 3580 MHz	20 MHz

The terms and conditions of the 2020 5G auction already describe the technical requirements as “the 5G NR (New Radio) access radio network standard in an architecture that meets the requirements of specifications ETSI TS 123 501 (3GPP TS 23.501) and ETSI TS 138 401 (3GPP TS 38.401) or later versions”. The 2020 5G spectrum auction, in addition to the MFCN allocation of 3600–3800 MHz, allocated frequency blocks in the 700 MHz band.

¹⁷ The most commonly used tariffs across technologies lie in the range of ≥ 100 Mbit/s; due to the limitations of the technologies with the largest market share – xDSL and WiFi FWA – tariffs with a download speed of 100 Mbit/s can be considered sufficient for the needs of most households in 2024.

¹⁸ Commission Implementing Decision (EU) 2019/235, see Recital (10), available online at: <https://eur-lex.europa.eu/legal-content/CS/TXT/PDF/?uri=CELEX:32019D0235&from=EN>

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At one point, in addition to the three mobile operators, there were three other fixed-line operators on the market, namely PODA a.s., Nordic Telecom a.s. and CENTRONET a.s. (frequency allocation transferred to Incrate s.r.o.).

PODA a.s. transferred the rights to the frequencies to VODAFONE Czech Republic a.s. in 2023¹⁹. Vodafone ČR a.s. now has a 100 MHz block at its disposal.

Incrate s.r.o. transferred its frequencies to T-Mobile Czech Republic a.s. in 2023²⁰. T-Mobile Czech Republic a.s.'s total allocation now stands at 140 MHz.

Nordic Telecom a.s., which has developed the most extensive provision of FWA services through its LTE/5G frequency allocation, has become a subsidiary²¹ of O2 Czech Republic a.s. The latter therefore directly controls the remaining frequencies from the total 400 MHz range of the 3400–3800 MHz allocation, i.e. 160 MHz.

In 2024, market consolidation and the reallocation of FWA LTE/5G frequencies among existing mobile operators were completed, enabling them to fully utilise the MFCN network concept. They have sufficiently large frequency allocations available for the provision of VHCN services via fixed infrastructure. A factor hindering the faster development of 5G NR services appears to be the obsolescence of pure LTE infrastructure using channels allocated in 2017. Infrastructure equipment is being gradually replaced, partly through natural replacement – however, as with any generational upgrade, the roll-out of more modern services is slowed down by the roll-out of customer premises equipment (CPE). In any case, the coherence of available frequency blocks is a key factor for the development of 5G NR. The refarming of radio frequencies in 2021 seems to have predetermined the direction of future market consolidation; the frequency blocks are contiguous.

Table 3 Consolidation of the 3.6 GHz band

Radio frequency allocation holder 2021	Allocated radio frequency range
incrate s.r.o. (now TMCZ)	3400–3480 MHz
T-Mobile Czech Republic a.s.	3480–3540 MHz
Vodafone Czech Republic a.s.	3540–3600 MHz
PODA a.s. (now VDF CZ)	3600–3640 MHz
O2 Czech Republic a.s.	3640–3700 MHz
Nordic Telecom 5G a.s. (now O2 CZ)	3700–3800 MHz

Nationwide frequency allocations of 3400–3800 MHz for 5G NR for MFCN are now assigned to three commercial entities – mobile operators – and technological development is expected within the framework of a hybrid usage concept for fixed and, additionally, mobile services. Further development of MFCN based on the principle of non-nationwide allocations in the C-band (i.e. local networks, industrial networks, etc.) can therefore potentially be directed only to the 3800–4200 MHz band. However, according to the Radio Spectrum Utilisation Plan²³, this band is allocated in 2024 to point-to-point fixed service links in accordance with ITU-R Recommendation²⁴. According to the CTU database, the point-to-point fixed service in the Czech Republic utilises 96 allocated Individual Authorisations for each frequency. Given that only duplex links with a bandwidth of 29 MHz are permitted, the number of active duplex links in the band is 43. **A band of potential national significance, with the technological potential for gigabit infrastructure, is almost entirely unused.** The 3400–4200 MHz band may also be used by the Fixed Satellite Service (FSS). However, downlink allocations from telecommunications satellites to coordinated ground stations are not utilised in the Czech Republic. As essential for the further development of mobile networks and

¹⁹ According to information on the transfer of radio frequency allocations; ČTÚ; online at: <https://ctu.gov.cz/infromace-o-prevodu-ridelu-56836-2022>

²⁰ According to information on the transfer of radio frequency allocations; ČTÚ; online at: <https://ctu.gov.cz/infromace-o-prevodu-ridelu-12519-2023>

²¹ Press release from Nordic Telecom a.s., available online at: <https://nordictelecom.cz/pro-media/12/prodej-nordic-O2/>

²² INFORMATION on changes to radio frequency allocations in the 3400–3800 MHz frequency band, issued by the CTO, available online at: <https://ctu.gov.cz/refarming-3600/rozhodnuti>

²³ Part of the Radio Spectrum Utilisation Plan No. PV-P/7/02.2022-3 for the 2700–4200 MHz frequency band, February 2022, available online at: <https://ctu.gov.cz/sites/default/files/content/ctu/notice-on-the-issuance-of-a-general-measure-part-of-the-radio-spectrum-utilisation-plan-no-pv-p/7/02.2022-3-for-the-2700-4200-mhz-frequency-band/images/pvrs7p.pdf>

²⁴ ITU-R Recommendation F.382-8 – Radio/frequency channel arrangement for radio/relay systems operating in the 2 and 4 GHz bands.

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Local networks in the 3800–4200 MHz band may also conflict with the aeronautical mobile service. The 4200–4400 MHz band is used by airborne radio altimeters²⁵.

The draft Frequency Spectrum Management Strategy²⁶ of the Czech Telecommunications Office (ČTÚ), therefore, based on the European Commission's Mandate for CEPT²⁷, works with a national intention not to terminate the existing operation of the fixed service and its further development, but to seek conditions for sharing with potential new users of the band, i.e. MFCN local networks (both public and non-public). From a business perspective, the band would also be of interest for specific purposes and modes of communication in industry. However, the draft CEPT technical conditions are not yet finalised. However, a further 400 MHz suitable for FWA services (MFCN) could significantly influence the future development of the business environment in the electronic communications market. The availability of equipment, the method of authorising access to the spectrum, and the level of fees for its use will also be important. Non-public use of frequencies refers to the operation of a completely independent private network, free from any influence by a third party. This highly specific method of communication is particularly suitable for large manufacturing enterprises, warehousing, mining operations or other industrial applications. In future, the need to build private networks must not be overlooked in the Strategies. It should be noted that the most significant technological difference between the operation of nationwide MFCN networks and private/local networks based on 5G NR technologies will be the STAND ALONE principle, i.e. operation independent of the traditional network core with separate time slot control. More on this in the chapter on Technological Trends.

Another 'candidate' frequency allocation for MFCN networks is the 26 GHz band. The future of the 24.25–27.5 GHz frequency band is, in accordance with Commission Decision (EU) No 28 and ECC Decision No 29, designated on a non-exclusive basis³⁰ for use by electronic communications broadband service systems (IMT). The use of the lower 24.25–26.5 GHz band by the mobile service currently prevents its use by the fixed service (FS), particularly for point-to-point links with wider channel bandwidths. The need to protect satellite services must also be taken into account.

Technical conditions for experimental use specified for the 26.5–27.5 GHz band in the ²⁰²⁰ Czech Spectrum Utilisation Plan³¹: key conditions:

- Five adjacent blocks with a bandwidth of 200 MHz are defined in the band.
- Operation is TDD
- The total radiated power (TRP) of the base station antenna is no more than 25 dBm/200 MHz
- The use of the specified blocks or blocks of a multiple of their width is permitted up to a total bandwidth of 1 GHz
- Base stations with a TRP higher than 5 dBm that are installed outdoors must be equipped with the capability to synchronise the time frames of the transmission and reception modes (TDD). The Authority may recommend or impose an obligation for time synchronisation.
- Base stations installed inside buildings must be installed in such a way that radiation outside the building is minimised and that, at locations of base stations installed outdoors, a signal-to-noise ratio of at least 30 dBm is maintained.
- In the case of base stations installed outdoors, operating at the maximum permitted ^{TRP32} power and using non-synchronised operation, the basic geographical separation is 3 km when using the same channel in the case of direct line-of-sight between stations, or 1.6 km where the antenna is located at a height of up to 6 m above ground level in an environment with obstacles (e.g. an urban environment). In the case of adjacent channels

²⁵ ERC Report No. 25: European Table of Frequency Allocations and Applications in the frequency range 8.3 kHz to 3000 GHz, Rev. 2020, [ERC Report 25: European Table of Frequency Allocations and Applications in the frequency range 8.3 kHz to 3000 GHz, rev. 2020].

²⁶ Draft Spectrum Management Strategy, published in October 2024, available online at: https://ctu.gov.cz/sites/default/files/obsah/ctu/vyzva-k-vyjadreni-se-k-navrh-u-strategie-spravy-radioveho-spektra/obrazky/241010_navrh_strategie_spravy_spektra-corr.pdf

²⁷ EC mandate to CEPT 'Mandate to establish technical conditions for the shared use of the 3.8–4.2 GHz frequency band for terrestrial wireless broadband systems providing local area network connectivity in the Union', available online at: <https://ec.europa.eu/newsroom/dae/redirection/document/82230>

²⁸ Commission Implementing Decision (EU) 2020/590 of 24 April 2020 amending Decision (EU) 2019/784 on the harmonisation of the 24.25–27.5 GHz frequency band for terrestrial systems providing wireless broadband electronic communications services in the Union

²⁹ Decision ECC/DEC/(18)06 – Harmonised technical conditions for Mobile/Fixed Communications Networks (MFCN) in the 24.25–27.5 GHz band.

³⁰ A non-exclusive basis for the allocation of radio frequencies means authorisation not through nationwide allocations, i.e. unlike the method of allocating rights to use frequencies in the 3 400–3 800 MHz band.

³¹ Current section of the Radio Spectrum Utilisation Plan No. PV-P/2/10.2020-10 for the 24.25–27.5 GHz frequency band, available online at: <https://ctu.gov.cz/sites/default/files/obsah/ctu/sdeleni-o-vydani-opatreni-obecne-povahy-casti-planu-vyuziti-radioveho-spektra-c.pv-p/2/10.2020-10-for-the-24.25-27.5-GHz-frequency-band/images/pvrs-2p.pdf>

³² Total Radiated Power.

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The separation for adjacent channels is 1.5 km and 0.9 km respectively. The Office may adjust the geographical separation on a case-by-case basis according to specific conditions.

- Base stations are equipped with active antenna systems. The main radiation beam must be directed below the horizon.
- The use of frequencies by base stations and terminals is only permitted on the basis of an individual licence to use radio frequencies for experimental purposes.

In 2020, the Office established these specific requirements for the experimental use of equipment in the 26.5–27.5 GHz band, both in accordance with harmonised conditions and to gain operational experience and gauge industry interest. Pilot projects, for which data on their progress has been published³³, indicate industry interest in using narrower transmission channels of 50 MHz and 100 MHz multiples, particularly due to the cost of fees for individual authorisations to use frequencies. The available data indicates that delivered capacities per user reach the order of several hundred megabits per second. The 5G NR channel n258, in its technical specification 3GPP TR 38.815, Rel. 15, supports the use of a channel arrangement of 50 / 100 / 200 / 400 MHz.

ECC Decision (18)06 (1)³⁴ in Annex 1 states explicitly:

- The frequency arrangement is a TDD arrangement with a block size of 200 MHz;
- This block size may be adjusted to narrower blocks (multiples of 50 MHz) adjacent to other users in order to make full use of the spectrum where necessary;
- If blocks need to be shifted to accommodate other uses, this shift should be carried out in 10 MHz steps.

The current regulations for the allocation of experimental frequencies in the 26 GHz band in the Czech Republic do not currently provide for the use of channels narrower than 200 MHz. The calculation of the fee is based on Regulation of the Government of the Czech Republic No. 154/2005 Coll. on the determination of the amount and method of calculation of fees for the use of radio frequencies. Frequencies may be allocated on a non-exclusive basis, i.e. in the form of Individual Authorisations, in accordance with Chapter A 3.1:

A 3.1 Terrestrial systems for the provision of wireless broadband electronic communications services in the 24.25–27.5 GHz and 40.5–43.5 GHz frequency bands.

CZK per year as calculated

$$C = \sum_{i=1}^n S4_i$$

where

C is the fee for the use of a single radio frequency n is

the number of individual base stations

S4 is the fee for the use of a radio frequency by individual base stations depending on the allocated bandwidth

Table 4: S4 fee in CZK by bandwidth

Bandwidth (MHz)	0 MHz	200 MHz	400 MHz	600 MHz	800 MHz
	<=	<=	<=	<=	<=

³³ ISP Futuretec 2022 Conference, presentation by Jakub Rejzek, 5G – FWA 26GHz – the future of high-capacity PtMP?; available online at: <https://www.isp-konference.cz/isp-futuretec-2022/main-programme>, Samsung case study / KKDS Plzeň 2023 Conference, lecture by Jan Stejskal, conclusions from the Cambium Networks pilot project, available online at: <https://www.isp-konference.cz/sites/default/files/obsah/konference/program/soubory/prezentacejanstejskal.pdf>, recording of the lecture available online: https://www.youtube.com/watch?v=bfgfw_dYEvY.

³⁴ ECC/DEC/(18)06 of 6 July 2018 on the harmonised technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band 24.25–27.5 GHz, last amended on 20 November 2020 (ECC#54), available online at: <https://docdb.cept.org/document/3361>

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	200 MHz	400 MHz	600 MHz	800 MHz	1,000 MHz
S4 fee (CZK)	3,000	6,000	9,000	12,000	15,000

Given that the operation of MFCN infrastructure under individual licences is subject to a fee based on the total number of allocated frequencies;

and given that a channel spanning the 50 MHz and 100 MHz bands is sufficient for providing very high-capacity services in the case of frequency allocations in the 3400–3800 MHz band, for the future development of MFCN wireless infrastructure, particularly in rural areas with low subscriber numbers, the ability to allocate narrower channels will be key to the economic scalability of commercial service offerings.

The utility of the 26 GHz band in MFCN networks is broader than expected. For example, the US company Verizon uses a similar 28 GHz band for Ultra WideBand (UWB) transmissions when providing 5G UWB services. Using the 5G NR n257 channel in the suburbs of US cities, it offers tariffs with speeds of 85–1000 ^{Mbit/s}³⁵ as FWA. Millimetre-wave infrastructure is also usable in the US for direct mobile phone connections. Some higher-end mobile phone models on the US market support direct communication with 5G NR channels n258 for the 26 GHz band and n261 for the 28 ^{GHz band}³⁶.

In rural areas, the use of the millimetre band for FWA offers the possibility of connecting users who are further away from the network base station. Data from pilot projects show that, assuming the use of a fixed CPE installation with a 1-foot diameter parabolic gain antenna, it is possible to provide tariffs with speeds in the hundreds of megabits per second at distances of up to 5 km from the base station's sector antenna (100 MHz). With further technological developments, utilising the full potential of 5G NR, a significant increase in transmission capacities can be expected. Other candidate 5G NR millimetre bands include the 42 ^{GHz band}³⁷.

³⁵ <https://www.cnet.com/home/internet/verizon-5g-home-internet-vs-t-mobile-home-internet/>

³⁶ <https://www.youtube.com/watch?v=OCyGkeH6vxA>

³⁷ Analysis of current and future use of the 42 GHz band, Ministry of Industry and Trade of the Czech Republic, available online at <https://www.mpo.gov.cz/assets/cz/e-komunikace-a-posta/studie-k-narodnimu-planu-obnovy/2024/6/Studie-3.pdf>

6 Current status of 5G technology deployment and technological trends in mobile networks

The basic division of a traditional nationwide network is into the network core (CORE), the network backbone (BACKBONE), the network backhaul (BACKHAUL) and the network access (ACCESS).

The CORE of mobile infrastructure has evolved alongside generations of mobile networks, including its physical form. Currently, there is a move away from specialised hardware solutions, and the modern CORE is taking the form of virtualisation and multiple network cores located in data centres. This is particularly important for the development of 5G NR infrastructure, as it allows the network cores of **Stand Alone** solutions to be brought closer to users. The 5G core is designed on the principle of cloud-native technologies. It utilises microservices and containerisation (e.g. Kubernetes) for scalability and efficiency. This means that individual network functions can run as separate microservices that can be easily modified, deployed or scaled as required. The 5G core can be optimised for massive connectivity and its resources scaled to optimise the provision of MFCN networks so as to fully utilise the capabilities of 5G FWA technologies as part of the MFCN infrastructure.

A description of the core networks of Czech mobile operators is important for understanding the current state of 5G infrastructure development. At ^{present³⁸} (2024), the transition from Non-Stand-Alone (NSA) core networks to Stand-Alone (SA) core networks is underway. NSA networks rely on existing 4G infrastructure (Evolved Packet Core – EPC). 5G radio frequencies (New Radio – NR) are used for data transmission, but control functions (the so-called control plane) are managed via the 4G LTE infrastructure. This is a transitional solution in which the 4G core still plays a key role and is used primarily to facilitate the easier and faster deployment of 5G technologies in the radio access network (RAN). Only a fully independent 5G MFCN network with a new core and all the benefits of 5G technology can deliver on all the promised features of 5G infrastructure.

Key components (functions) of the 5G CORE:

- Access and Mobility Management Function (AMF): Manages user registration and connection allocation.
- Session Management Function (SMF): Manages the setup and management of user data connections (session management).
- User Plane Function (UPF): Ensures the transmission of user data, separate from the control plane.
- Network Repository Function (NRF): Maintains information on available network functions and enables their dynamic interconnection.
- Policy Control Function (PCF): Manages the rules and conditions for providing services to users.
- Unified Data Management (UDM): Manages user data, such as authentication and authorisation.
- Network Exposure Function (NEF): Enables external applications to access network services and resources via APIs.

Key components of the traditional network core (using 4G LTE EPC as an example):

- MME (Mobility Management Entity): Manages user registration, authentication and location tracking. It also controls handover between cells.
- HSS (Home Subscriber Server): A central database containing information about users, including their identities, subscription services and authentication keys.
- S-GW (Serving Gateway): Routes user data between base stations and the P-GW.

³⁸ Vodafone Czech is preparing to switch to a fully-fledged new 5G mobile network core at a cost of hundreds of millions, an article on the LUPA.cz website, by Jan Sedlák, available online at: <https://www.lupa.cz/aktuality/cesky-vodafone-za-stovky-milionu-chysta-prechod-na-plnohodnotne-nove-jadro-mobilni-site-5g/>

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- P-GW (Packet Data Network Gateway): Acts as an entry point between the mobile network and external networks, such as the internet. It handles IP address allocation and data routing.
- PCRF (Policy and Charging Rules Function): Controls which services users can access and sets the rules for service billing.

Older generations of CORE (2G, 3G) mobile networks are not relevant for MFCN network usage.

BACKBONE, the backbone of the network: in telecommunications, these are the main communication routes that interconnect various regional and local network nodes and form the backbone of the entire network. These networks serve as a central transport system for the transmission of large amounts of data between different locations, both nationally and internationally. Backbone networks are designed for high capacity, low latency and high reliability – the robustness of the entire infrastructure.

A key feature of a backbone network is high capacity, usually based on fibre-optic technologies. An alternative to optical cable may be, albeit more or less exceptionally, infrastructure-grade microwave links. Low latency and infrastructure robustness are also important parameters for backbone networks. Infrastructure robustness is achieved primarily through the geographical redundancy of backbone routes. Redundancy ensures that communication is not interrupted even if one part of the network fails.

The backbone network is a critical infrastructure to which all smaller networks are connected. The capacity of the backbone infrastructure in the Czech Republic is sufficient for the operation of telecommunications services; exceptions can be found in more remote regions, such as municipalities located away from major transport routes (for example, outside the railway network). Thanks to technologies for increasing throughput, such as

DWDM³⁹ and other technologies, it is often possible to increase the capacity of the existing physical infrastructure to the order of terabits per second. The data throughput of a single Ethernet⁴⁰ port using the most advanced commercially available technology is 400 Gbit/s.

In telecommunications, **BACKHAUL** refers to the part of the network that connects smaller networks or local nodes, such as base stations or network access points, to the main backbone network. The backhaul network ensures data transmission from the local level. Optical fibre technology has, of course, been successfully adopted in backhaul networks, as has infrastructure microwave link technology. In the Czech Republic, a significant percentage of mobile towers are connected via **microwave links**, particularly in areas where it is not feasible to simply lay optical fibre, such as in remote or rural locations. Approximately ^{30–60%}⁴¹ of mobile network base stations are connected via microwave links. Microwave links are popular due to their ease of installation and lower acquisition costs compared to optical cables, particularly where building physical infrastructure is expensive or technically complex. Although the transmission capacities of radio relay microwave links (RRL) have improved significantly over the last decade, they present a potential bottleneck in a fully converged MFCN network. As with any other form of radio communication, the transmission capabilities of radio links depend on the bandwidth utilised. In the case of traditional licensed bands – i.e. technologies authorised to operate in the frequency spectrum under individual licences – only frequency bands offering the possibility of using a channel with a bandwidth of at least 100 MHz (110 / 112 MHz) or multiples thereof (220 / 224 MHz). The capacity of a radio link with single polarisation and a channel bandwidth of 112 MHz / 4096 QAM is just over 1 Gbit/s⁴² (full-duplex operation). In the Czech Republic, some bands can be coordinated with a bandwidth of up to 224 MHz, which corresponds to a transmission speed of 2 Gbit/s. If the link utilises XPIC (Cross Polarization Interference Cancellation), a technology employing both horizontal and vertical polarisation within a single transmission channel, the transmission capacity of radio links in traditional frequency bands increases to a maximum value approaching 4 Gbit/s in both directions. Traditional licensed bands therefore represent a bottleneck in 5G infrastructure and are suitable for connecting remote parts of the network or rural areas. The advantage of traditional bands is the ability of radio waves to propagate over longer distances and the possibility of using antenna systems with large-radius parabolic antennas. The gain of a parabolic antenna increases with the diameter of the reflector and the higher frequency used. Conversely, higher frequencies suffer from high additional attenuation in rain or fog. For long-distance links, typically up to tens of kilometres, operators primarily use the 11 GHz band. The 18 GHz band is popular; higher bands are already competing with unlicensed 80 GHz millimetre-wave technologies (E-band)⁴³. Unlicensed use of the 71–76 GHz and 81–86 GHz bands addresses the problems of limited network infrastructure capacity based on traditional

³⁹ Dense Wavelength Division Multiplexing (DWDM)

DWDM is a technology that significantly increases the capacity of a single optical fibre by enabling the transmission of multiple wavelengths (channels) simultaneously. Each channel transmits its own data stream at a different wavelength of light, effectively creating several parallel 'paths' for data within a single fibre.

⁴⁰ Ethernet is a networking technology used to interconnect devices in networks using standardised protocols for data transmission. It is the fundamental transport layer of most modern data networks.

⁴¹ An informed estimate based on the Analysis of the issues surrounding the connection of mobile network base stations to the backbone network in the period 2018–2022 with an outlook to 2027, by Jiří Vodrážka and Zdeněk Brabec, CTU, available online at: <https://ctu.gov.cz/sites/default/files/obsah/ctu/vyzva-k-uplatneni-pripominek-k-predbezne-analyze-trhu-mobilniho-backhaultu/obrazky/backhaul201724provk.pdf>

⁴² Calculation table by VanCo.cz, available online at: <https://www.vanco.cz/vypocet/>

⁴³ General Authorisation No. VO-R/23/06.2024-4 for the use of radio frequencies and the operation of fixed service equipment in the 71–76 GHz and 81–86 GHz frequency bands, issued by the CTO in 2024, available online at: <https://ctu.gov.cz/sites/default/files/obsah/vo-r23-062024-4.pdf>

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licensed bands, is, however, limited to a few kilometres due to the physical properties of millimetre waves. On the other hand, it is precisely the significantly poorer propagation of radio waves in the millimetre bands and the narrow radiation patterns of antenna systems that protect radio communications from the effects of harmful interference. Modern RRL links in the E-band achieve transmission capacities in excess of 40 Gbit/s, which is entirely sufficient for interconnecting even larger sections of the access network.

Table 5: Overview of licensed bands and channel widths for fixed point-to-point links in the Czech Republic

Band GHz	Range	Max. channel bandwidth (MHz)	CEPT/ERC/REC Recommendation
4	3 810 – 4 197 MHz	29	ITU-R F.382-7
6	5925–6425 MHz	29.65	ERC/REC 14-01
7	6425–7125 MHz	40	ERC/REC 14-02
7.5	7425–7725 MHz	14	ITU-R F.385-7
11	10.7–11.7 GHz	112	ERC/REC 12-06
13	12.75–13.25 GHz	56	ERC/REC 12-02
15	14.5–15.35 GHz	28	ERC/REC 12-07E
18	17.7–19.7 GHz	220	ERC/REC 12-03
23	22.0–22.6/23.0–23.6 GHz	224	ERC/REC T/R 13–02
26	24.773–25.445/25.781–26.453 GHz	112	ERC/REC T/R 13–02
32	31.8–33.4 GHz	112	ERC/REC/(01)02
38	37.093–38.178 / 38.353–39.438 GHz	224	ERC/REC T/R 12–01

One of the reasons why MFCN networks with high-capacity 5G NR technologies will only very gradually expand the availability of gigabit tariffs in rural areas is precisely the infrastructure bottlenecks in the access network. **Building a dense network of base stations connected via fully optical infrastructure is not economically viable in smaller municipalities – and these make up the majority in the Czech Republic.** A prerequisite for the development of MFCN infrastructure is the removal of network bottlenecks by bringing optical infrastructure closer to the network's base stations, so that additional base stations (network access points) can be served by radio relay links operating, for example, in unlicensed millimetre-wave bands.

Another significant inhibitor to the development of FWA infrastructure in remote or rural areas is the level of fees set by Government Regulation No. 154/2005 Coll. Licence fees paid to the state via the Czech Telecommunications Office (ČTÚ) depend on the occupied bandwidth, the power used and the operating frequency of the radio relay link. For example, the annual licence fee for a device with a 4 Gbit/s transmission capacity, a transmission power of 20 dBm and a 220 MHz XPIC is CZK 71,280, or CZK 5,940 per month. Together with the associated operating costs and equipment depreciation, it is not economically viable to connect even municipalities with 500 permanent residents via a licensed link.⁴⁴ In the case of small municipalities, providers' pricing policies must also take into account the economic aspects of operation, not just the technical ones. The quality parameters for fixed networks, set by the CTO in General Authorisation No. VO-S/1/12.²⁰²¹⁻¹⁴⁴⁵, do not permit providers of fixed FWA services within the MFCN to allow a drop in service quality due to aggregation below the limit set by the Authority. For economic, technical and regulatory reasons, the range of tariffs available in areas distant from the central network node is therefore limited.

With a population of⁴⁴500 and an average household size of 2.3 people, this equates to 217 connectable users per rural household; given a typical 30% market penetration due to the competitive environment, the investment will be spread across 65 users.

⁴⁵ General authorisation to provide electronic communications networks and services No. VO-S/1/12.2021-14, issued by the Czech Telecommunications Office (ČTÚ), available online at: <https://ctu.gov.cz/sites/default/files/obsah/stranky/36864/soubory/vos1uznaweb.pdf>

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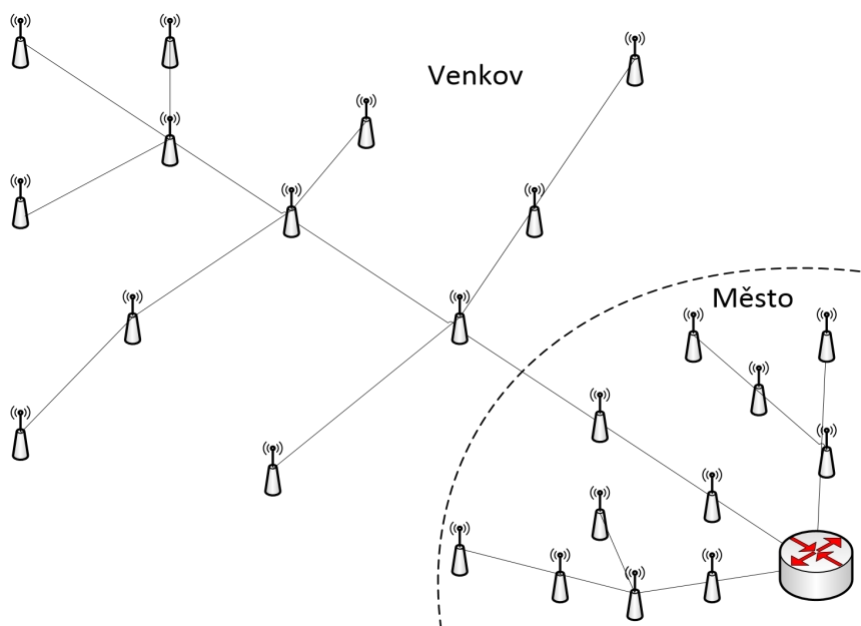


Figure 6: Typical MFCN backhaul topology

ACCESS network, access network. The RAN (Radio Access Network) is a key component of mobile infrastructure, ensuring the connection of end devices to base stations and, thereby, to higher-level network elements. Base station controllers (BSC/RNC) manage radio resources, allocate channels and, in the case of mobile services, control handover between individual cells. Mobile networks use different frequency bands depending on the generation of technology (2G, 4G, 5G). The 3G network was gradually switched off during 2021 in favour of 4G LTE and 5G.

Main frequencies of mobile operators' infrastructure (access frequencies) used in the Czech Republic, according to [vportal.ctu.gov.cz](https://portal.ctu.gov.cz):

- 2G (GSM): 900 MHz, 1800 MHz
- 4G (LTE): 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2600 TDD MHz, 2600 FDD MHz
- 5G: 700 MHz, 1800 MHz, 3500 MHz, 26 GHz (being prepared for future deployment)

Frequencies below 1 GHz are used as the base coverage layer; in mobile infrastructure, an important characteristic is the frequency band's ability to penetrate buildings. The 1–3 GHz bands are used as the mid-capacity layer, with somewhat more limited ability to penetrate buildings. However, they can be used for LTE / 5G FWA services. Frequencies above 3 GHz have limited ability to penetrate building envelopes, but are very well suited for MFCN, where, particularly in line-of-sight modes between the terminal and the base station, they provide high-speed, low-latency connections.

4G LTE and, of course, 5G networks can combine the capacity of the frequency channels used via a technique known as Carrier Aggregation (CA). This feature allows several frequency bands to be combined into a single channel, leading to an increase in total bandwidth and, consequently, the network's data capacity. CA enables LTE and 5G RAN networks to utilise multiple bands (e.g. 800 MHz, 1800 MHz, 2600 MHz in the case of 4G) simultaneously, which improves transmission speed and connection stability.

It should be emphasised, however, that the total usable bandwidth for a mobile operator's access network in the sub-3 GHz bands does not exceed tens of MHz. There are sufficient IMT frequency bands designated for widespread coverage with good range from base stations for the purposes of connecting mobile services in the true sense of the word. There is no scope in the 700 MHz – 3 GHz bands for the development of converged FWA services with very high capacity.

The CTU visualisation portal⁴⁶ provides an overview of how nationwide frequency allocations are utilised. The portal is divided into individual modules according to service type. It contains data obtained from field measurements carried out by ČTÚ staff and other types of data, e.g. the results of coverage calculations based on data obtained regarding the parameters of transmitting stations and base stations

⁴⁶ CTU Telecommunications Services Visualisation Portal, available online at: <https://vportal.ctu.gov.cz/intro?!=cs>

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in trial operation, transmitters, an overview of compliance with development criteria, etc. Individual frequency bands and technologies used can be clearly filtered when using the portal. The availability of individual services can be specified down to the level of a specific location. The V-Portal can thus be used for assessment – coverage simulations for individual frequency allocations at 2600 TDD and 2600 FDD for all three mobile operators on the V-Portal indicate low utilisation of these bands. We are also only at the beginning of developing the potential of MFCN technologies in the C-band (3400–3800 MHz).

7 Private 5G networks

A private 5G network is a wireless communication infrastructure built on 5G technology, which organisations deploy and manage for their own needs within a closed location, such as a factory, campus or warehouse complex. Unlike a public 5G network, which is provided by operators to the general public, a private network is intended exclusively for the needs of a specific organisation or company. This makes it possible to fully tailor the network to the requirements of a specific operation.

Advantages of private 5G networks

- **Control and security:** Private 5G networks allow full control over security and data traffic, which is crucial in industries and sectors where data is sensitive or regulated. Within a company, this enables network segmentation for individual applications or even departments.
- **Low latency:** 5G technology with an SA network core and extremely low latency enables the operation of applications that require rapid data processing, such as autonomous systems, robotics or augmented reality.
- **Flexibility and customisability:** Private network users can precisely control its settings, capacity and signal range according to their specific requirements.
- **Separation from the public network:** As a result, private networks are less prone to congestion or outages caused by public traffic.

The reason for mentioning private networks in this study on FWA connectivity is the need for businesses and institutions to establish private networks in the future. In 2024, those interested in establishing private networks will have the opportunity to request cooperation from holders of nationwide licences – mobile operators⁴⁷ – whilst some are subject to a wholesale obligation to provide spectrum on a sharing basis. The candidate band for spectrum allocation independent of existing holders of 5G frequency allocations is the 3800–4200 MHz band⁴⁸. In the future, it may also be appropriate to make frequencies in this band available to undertakings providing publicly available electronic communications services, in particular for the purpose of using 5G technologies as the access layer of a fixed wireless network.

⁴⁷ Example of application: Vodafone has launched a private 5G mobile network at ŠKODA AUTO, available online at: <https://www.vodafone.cz/nejen-pro-media/tiskove-zpravy/vodafone-spustil-mobilni-privatni-5g-sit-ve-skoda->

⁴⁸ EC mandate to CEPT 'Mandate to establish technical conditions for the shared use of the 3.8–4.2 GHz frequency band for terrestrial wireless broadband systems providing local area network connectivity in the Union', available online at: <https://ec.europa.eu/newsroom/dae/redirection/document/82230>

8 Outlook for 5G Advanced and 6G technologies

8.1 Efficiency and economics

Technical development continues even within a single generation of mobile networks. After all, the abbreviation LTE in 4G stands for Long Term Evolution. The very name of the technology suggests the need for investors in telecommunications technologies – to develop infrastructure that meets user demand and maintain it at least until it becomes obsolete, or until it reaches the end of its technical life and reaches the point where renewal is necessary.

The first digital, secure and widely usable mobile infrastructure was GSM, referred to as 2G. The GSM infrastructure was first launched in 1991 in Finland; in the Czech Republic, the 2G network was introduced by EuroTel in 1996. In 2000, the International Telecommunication Union specified the standards for 3G mobile networks in document ITU-R M.¹⁴⁵⁷⁴⁹. The role of the next generation was to significantly increase data transmission speeds from the inadequate GPRS and EDGE. The ITU required a 3G download speed of 384 kbit/s for users in motion and up to 2 Mbit/s for users at rest or moving slowly. 3G technologies such as **WCDMA (UMTS)** and **CDMA2000** were developed based on the IMT-2000 specifications and became the foundation for subsequent generations of mobile technologies, leading up to 4G in IMT-Advanced. The basis for 4G networks was 3GPP Release 8, published in 2008, with the first commercial deployment taking place in 2009. “Basic 4G provided 100 Mbit/s for downloads and 50 Mbit/s for uploads. 4G Release 10 from 2011 brought the first true 4G standard, with significantly higher download speeds (up to 1 Gbit/s) and support for carrier aggregation, i.e. combining multiple channels to increase bandwidth. In 2016, 4G **Release 13** 3GPP LTE-Advanced Pro was introduced, which incorporated certain features paving the way for 5G, such as higher carrier aggregation and improved network management. The first 5G networks in the Czech Republic were established in 2020 in the form of pilot projects; following the 5G spectrum auction in 2021, there has been a gradual and significant expansion of 5G Non-Standalone (NSA) infrastructure. It is not until 2024 that reports begin to emerge regarding the planned transition by Czech mobile operators to the 5G Stand Alone (SA) core, which supports certain benefits associated with full 5G infrastructure.

⁴⁹ ITU-R Document M.1457 specified the standards for third-generation mobile networks under the name IMT 2000.

⁵⁰ The IMT-Advanced document, which specifies standards for 4G, is designated ITU-R M.2134. This document was published by the ITU and contains technical requirements and parameters for networks complying with the 4G standard.

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In contrast, the GSMA Association⁵¹, in its document '5G-Advanced: Shaping the future of operator services marketing paper', anticipates the finalisation of Release 18 – the 18th edition of the 3GPP standard – in 2024. This represents a further advancement in the capabilities of MFCN infrastructure. Meanwhile, in February 2024, in the same year, the GSMA Association publishes the "6G Terminal Vision White Paper"⁵², describing the IMT-2030 (6G) Vision developed by ITU-R WP⁵³.

Key benefits of 5G – Advanced; 3GPP R18, taken from the GSMA White Paper:

- They enable a fundamental change in network capacity and flexibility, giving operators much greater scope to tailor 5G connectivity to the needs of individual businesses or specific applications.
- Utilise new spectrum and extremely large antenna arrays to provide Fixed Wireless Access (FWA), capable of delivering 10 Gbit/s throughput to homes and businesses.
- To provide significantly greater automation, AI-driven analytics and programmability, enabling businesses to track and monitor the vast number of resources used across various industries.
- Coordinate artificial intelligence (AI) across the network, devices and the cloud/edge to optimise available connectivity for demanding applications such as image recognition and conversations with automated personal assistants.

Deploy Integrated Sensing and Communication (ISAC) devices and Reconfigurable Intelligent Surfaces (RIS) to ensure the capacity for large numbers of people to enjoy reliable connectivity at major events such as the Asian Games and the Olympic Games.

The main stated goal of 6G is to significantly improve transmission speeds, latency and capacity. The technology companies behind the development and promotion of the next generation of wireless communication claim that further developments will enable even more advanced applications beyond 5G, which are not yet feasible today.

Some examples of such communication include:

- extended sensory reality (XR)
- artificial intelligence directly integrated into the network
- real-time holographic communication
- virtual worlds connected to the real world (metaverse)
- digital twin representations of entire urban areas
- sensor and communication networks at the molecular level
- autonomous transport

The pace of technological development and technological possibilities is accelerating rapidly, yet the expectations of technology companies investing significant resources in research and development do not match the pace of telecommunications infrastructure development. After all, in the pivotal year of 2024 – the year of the rollout of 5G-Advanced and the announcement of 6G^{infrastructure} pilot projects⁵⁴ – Czech mobile operators are only now announcing the acquisition of technology for operating the 5G SA core(s) of their networks. But what can entrepreneurs and investors in new

⁵¹ 5G-Advanced: Shaping the future of operator services marketing paper, available online at: https://www.gsma.com/solutions-and-impact/technologies/networks/gsma_resources/5g-advanced-shaping-the-future-of-operator-services/

⁵² 6G Terminal Vision White Paper, published by the GSM Association, 2024, available online at: <https://www.gsma.com/about-us/regions/greater-china/wp-content/uploads/2024/02/6G-Terminal-Vision-White-Paper-en-0223-1.pdf>

⁵³ IMT towards 2030 and beyond (IMT-2030), ITU, available online at: <https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Pages/default.aspx>

⁵⁴ Article "6G networks promise terabit internet over the air. The West fears China, which has announced its first progress", LUPA.cz website, author Jan Sedlák, 3 May 2023, available online at: <https://www.lupa.cz/clanky/site-6g-slibuji-terabitovy-internet-vzduchem-zapad-se-obava-ciny-ktera-oznamila-prvni-pokrok/>

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technology? The vision for the development of 6G ^{infrastructure55} speaks of an “ubiquitous internet” in 6G infrastructure, accessible from terrestrial, satellite and mobile base stations within an interconnected infrastructure.

However, it is necessary to realistically examine the feasibility of these ambitious visions, set against the backdrop of 2030 and the following decade:

Question 1: Do these ambitious visions correspond to the reality of the requirements of network subscribers, who finance infrastructure development through their fees?

If you offer a network subscriber high-speed connectivity for their mobile device anywhere, regardless of their current location, with very low latency and other features, they will naturally welcome such ‘better’ connection parameters. At the same time, however, it is necessary to examine their willingness to pay extra for such network performance. The generally applicable economic law of supply and demand also applies in telecommunications. Of course, it could be argued that supply can, to a certain extent, create demand, and that the transition from 3G to 4G mobile infrastructure brought a whole range of ‘killer applications’, such as multimedia, social networks, online gaming and dozens of other possibilities with significant impacts on the mass user. However, the use of widely adopted applications, including multimedia ones, does not require a connection with top-of-the-range specifications. Professor William Webb, in his book ‘The End of Telecoms History’⁵⁶, in the chapter 3, ‘User requirements are nearly met’, calculates that a connection speed of 50 Mbit/s is sufficient for the average user of a fixed home connection. **W. Webb considers a speed sufficient if it does not restrict the user during normal use of the internet connection and therefore, from the perspective of transactional decision-making, does not provide sufficient benefit to justify changing the provider or access layer technology.** Even in the case of FWA, such a connection speed corresponds to the technical capabilities of the 3GPP 4th generation.

5. The 4th generation brings operators further measurable technological benefits, in the form of better utilisation of the available frequency spectrum and a reduction in aggregation load in areas with significant demand for the service – that is, in conurbations with insufficient cable connectivity. Based on the Report on the Development of the Electronic Communications Market with a Focus on 2023 by the Czech Telecommunications Office (CTO)⁵⁷, the data indicates that unlimited mobile data tariffs are the key factor influencing the steadily growing consumption of mobile data. Currently, these tariffs are used on 23.5% of SIM cards with mobile internet access, which corresponds to 17.3% of the total number of active SIM cards. Their average monthly data consumption in 2023 was almost seven times that of users with limited mobile data access, including ad hoc access and access with a data limit. Mobile internet users with unlimited access consume an average of 27.9 GB per month. Ad hoc users or those with a data limit (FUP), by contrast, show a monthly average of 4 GB. By simple calculation, 76.5% of mobile phone users with a data plan in 2023 do not feel the need to change their usage behaviour and switch to mobile data plans with an FUP.

For a more detailed analysis, it would be useful to know the usage patterns of mobile service customers with unlimited data plans. Mobile operators also stratify their range of plans without FUPs according to available connection speeds. Vodafone Czech Republic a.s. promotes, in its publicly available range of plans⁵⁸, unlimited data with speed limits of 4 Mbit/s and 20 Mbit/s, as well as a plan with unlimited network speed at a given location. A similar offer from O2, at a higher base price, offers the lowest tariff at 10 Mbit/s. No data is available on which tariffs network users choose or on the dynamics of changes in purchasing behaviour.

By contrast, according to the same “Report on the Development of the Electronic Communications Market with a Focus on 2023, page 53”, fixed-line users, regardless of the technology used, consume an average of 332.5 GB per month. FWA, WiFi and xDSL technologies have the largest market share, and these generally do not provide services with VHCN ^{parameters59} or gigabit speeds.

Conclusion No. 1: The key requirement for the majority of electronic communications service users is a single fee for a connection with sufficient speed and quality to meet household needs, with the option to add any number of connected devices. Although 5G network coverage gradually increased up to 2021, reaching a total of 95.1% of the Czech Republic’s territory by the end of 2023, this increase in 5G coverage did not result in a measurable slowdown in the growth of data consumption on fixed networks, nor in a significant increase in the number of mobile service users without a fair usage policy (FUP). Nor have the price expectations or purchasing behaviour of service users changed in any way, which leaves no scope for investors to increase the pace of investment.

⁵⁵ ‘European Vision for the 6G Network Ecosystem’, published by 5G PPP, available online at: <https://5g-ppp.eu/european-vision-for-the-6g-network-ecosystem/>

⁵⁶ William Webb, The End of Telecom History, 2024, ISBN-13:9798328402729

⁵⁷ Report on the development of the electronic communications market with a focus on 2023, available online at: https://ctu.gov.cz/sites/default/files/obsah/stranky/472017/soubory/zovt_2023.pdf

⁵⁸ Vodafone.cz, My Mobile Tariff 2024, available online at: <https://www.vodafone.cz/tarify-2024/>

⁵⁹ BEREC Guidelines on Very High Capacity Networks (2023), published by BEREC in 2023, available online at: <https://www.berec.europa.eu/en/document-categories/berec/regulatory-best-practices/guidelines/berec-guidelines-on-very-high-capacity-networks-2023>

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A gradual increase in coverage and market availability of 5G NR MFCN services in FWA mode can be expected. Fixed-location connectivity via a wireless access layer has good prospects of becoming a competitive service in the Czech Republic. This assertion can be further supported by the high number of FWA connections in unlicensed bands (more than 1.12 million ^{users}⁶⁰). The main bottleneck for FWA, regardless of technology, will be the capacity of the access infrastructure – on which, however, both fixed and mobile services in MFCN networks will depend.

Question 2: Are these ambitious visions technically feasible in the current regulatory environment, given the need to maintain other services utilising the frequency spectrum?

The development of the next generation of wireless communications and mobile networks would be feasible using existing frequency allocations, or at the expense of frequency bands currently used for other purposes. For physical reasons, the frequency bands used for traditional mobile telephony, which require seamless nationwide coverage, must use frequency allocations below 1 GHz, with a nationwide capacity layer in the 1–3 GHz band. Higher frequency bands (3600–4200 MHz, 26 GHz and other candidate bands) are particularly suitable for connecting fixed network points and providing coverage in areas with high user density; however, they also entail increased investment in the construction of new base stations or, at the very least, the upgrading of bottlenecks in the access network. Adapting spectrum regulation is difficult in itself; the spectrum is a scarce resource also used by other sectors – for example, the telecommunications sector for other types of use, terrestrial television broadcasting, satellite communications services, space research, meteorology, transport services, aviation and the defence sector. Although the development of IMT services is important, the needs of various stakeholders must be balanced. An important principle enabling further discussion on the future use of spectrum is the exploration of spectrum sharing between individual ^{services}⁶¹. The 2012 EU Radio Spectrum Policy Programme (RSPP)⁶² establishes a framework based on the principle that spectrum should be used efficiently and managed effectively. In the interests of increasing efficiency and flexibility, it requires Member States, in cooperation with the Commission, to promote collective and shared use of spectrum where appropriate. **According to the 2018 European Electronic Communications Code (EECC)⁶³, the promotion of shared use of radio spectrum is considered a key driver for achieving the Code's main objectives**, namely the promotion of competition, the internal market, the interests of citizens and businesses, and connectivity. In accordance with the Code, Member States shall promote the sharing of radio spectrum between similar or different types of use, whilst respecting competition law. They should facilitate the sharing of radio spectrum on the basis of general authorisations and limit the granting of spectrum usage rights to individual users only in specific cases, which may include the need to maximise efficient use in view of demand or to minimise harmful interference issues. In both cases, Member States should, where possible, take into account the development of reliable conditions for radio spectrum sharing and the combination of general authorisations and individual rights of use. They should ensure the efficient and effective use of radio spectrum and also promote coverage.

6. The 3GPP generation is intended to deliver previously unfeasible applications and increase transmission capacity, improve latency and other network parameters compared to previous-generation networks; however, it does not have access to substantially different frequency resources within the traditionally occupied part of the frequency spectrum. The solution that presents itself is to shift focus away from traditional frequency bands – into the millimetre-wave range. In the range of the higher tens to hundreds of GHz, sufficient frequency bands (with adequate bandwidth) are available for wireless communication at 'optical' speeds. In its study "6G standardisation – an overview of timeline and high-level technology ^{principles}"⁶⁴, Ericsson identifies fixed wireless access (FWA) infrastructure as one of the key examples of utilising the capabilities of 3GPP Release 21 for 6G. It is worth noting that it envisages the use of 5G infrastructure elements for the operation of the 6G RAN portion of the network. The use of millimetre bands provides a good basis for licence-free operation of RAN infrastructure, thereby reducing key operational costs. However, the development of networks based on millimetre bands is hampered by the need for base station densification and the need to build out high-capacity access infrastructure.

Conclusion No. 2: Sixth-generation networks will represent a significant capacity shift for traditional mobile networks only if they can sufficiently justify taking part of the spectrum away from other services or if effective mitigation techniques enabling spectrum sharing are found. However, regulatory authorities must also take into account the maintenance of a competitive environment and the interests of other businesses and institutions interested in using the spectrum on the basis of individual licences or licence-exempt use. A new approach to current technological possibilities for the use of millimetre-wave bands may, however, present an opportunity for FWA within the MFCN. Economic indicators may argue against investment in millimetre-wave-based RANs – high acquisition costs and relatively low demand for services with gigabit speeds. The draft proposals in the 'Vision for 6G'⁶⁵ work with entirely new

⁶⁰ CTU Annual Report for 2023, Chapter 1.2 Fixed High-Speed Access Services, available online at: <https://ctu.gov.cz/rok-2023-0>

⁶¹ Promoting the shared use of Europe's radio spectrum, Shaping Europe's digital future, available online at: <https://digital-strategy.ec.europa.eu/en/policies/shared-use-spectrum>

⁶² <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32012D0243>

⁶³ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L1972&qid=1632310399854>

⁶⁴ 6G standardisation – an overview of timeline and high-level technology principles, Ericsson 2024, available online at: <https://www.ericsson.com/en/blog/2024/3/6g-standardization-timeline-and-technology-principles>

⁶⁵ The European Commission is working to prepare Europe for 6G and ensure we are ready for the next generation of communications, available online at: <https://digital-strategy.ec.europa.eu/cs/policies/6g>

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spectrum sharing approaches, in particular band sharing with existing users. Technological developments allow data streams to be combined across many separate frequency bands.

Question 3: Does connecting a user's device via an MFCN network based solely on 3GPP standards offer the user any particular advantage?

Data published by Adaptive Spectrum and Signal Alignment, Incorporated (ASSIA®)⁶⁶ and cited in the Dynamic Spectrum Alliance white paper⁶⁷, it appears that as much as 92% of data traffic in fixed networks in Europe is transmitted to end devices via WiFi wireless networks (IEEE 802.11 standard) – which corresponds to fixed network end devices. This figure in the Czech Republic does not differ significantly from the global average. The year-on-year increase in data consumption across both mobile and fixed data networks is undeniable, with the clear focus of this growth being on fixed electronic communications service connections. If we consider the behaviour of individual users, i.e. those on mobile tariffs – specifically the low uptake of mobile internet without a Fair Usage Policy (FUP) – the vast majority of data is consumed within the home. That is, a location with a shared connection for all members of the household and their devices connected via the home Wi-Fi network.

Conclusion No. 3: The data do not indicate any transactional preference among network users based on the technology used. The decisive factor is meeting the subscriber's needs at the lowest possible cost and with the lowest possible transaction costs.

⁶⁶ State of Wi-Fi Reporting, Reliably Fast Broadband & Wi-Fi for the Home, Adaptive Spectrum and Signal Alignment, Incorporated (ASSIA®) available at: <https://dynamicspectrumalliance.org/wp-content/uploads/2021/06/ASSIA-DSA-Summit-Presentation-v7.8.pdf>

⁶⁷ How do Europeans connect to the internet 2022. Dynamic Spectrum Alliance, available at: <https://6ghz.info/wp-content/uploads/2022/06/DSA-White-paper-How-do-Europeans-connect-to-theInternet.pdf>

8.2 Potential for the use of 5G Broadcast

5G Broadcast (5G BC) technology represents a possible future development in radio and television broadcasting, whereby a set of video and audio streams is transmitted from a single powerful transmitter in selected parts of the 5G (UHF, 470–694/698 MHz), not used for mobile network data transmission, a set of video and audio streams is broadcast from a single powerful transmitter intended for a wide area, similar to DVBT-2 terrestrial television. 5G Broadcast was defined in 3GPP Release 16 and R. 1768. The main objective and reason for the existence of 5G BC is primarily to enable the operation of a broadcast network compatible with the receiving modems of standard mobile networks, e.g. with slightly modified 5G phones.

The first theoretical advantage of 5G BC is that the signal can be transmitted from a single data stream to an unlimited number of devices. It is therefore analogous to DVB-T2 terrestrial linear broadcasting. According to the EBU TR 064 technical report, 5G BC operates with a maximum bandwidth of 8 MHz (10 MHz is also being considered); in terms of capacity, it is a system similar to DVB-T2 (10 MHz). 5G BC offers no measurable benefits to viewers of terrestrial broadcasting, but it may offer advantages to viewers who use mobile devices to watch television. 5G BC television broadcast data does not count towards a mobile data allowance and does not utilise the mobile operator's data network services at all. Basic 5G BC does not offer the benefits of IPTV, which lie primarily in the possibilities of time-shifted viewing. In mixed mode, it is technically possible to extract a separate data stream (unicast) from linear broadcasting; however, this is already dependent on the subscriber's data tariff.

A second theoretical advantage of 5G BC is the possibility of reallocating part of the UHF band to benefit 5G IMT services. The 5G BC broadcasting system could be introduced alongside traditional television broadcasting, and later as a replacement for it. This would represent a sort of 'Next' digital dividend, and in the case of replacement rather than supplementation, it would also entail a change in DVB-T2 terrestrial broadcasting technology. In both cases, this involves a Single Frequency Network (SFN).

Conclusion: In the case of 5G BC, this is a long-discussed possible scenario for the development of terrestrial broadcasting. With the exception of the interest in the UHF band and the possibility of reception via a 5G modem, the technology paradoxically has little in common with 5G infrastructure. The future of 5G BC is linked to the future of terrestrial broadcasting as such. České Radiokomunikace launched a pilot broadcast on 24 October 2024 covering Prague and Central Bohemia⁷⁰. In its press release, it highlights the benefits for emergency broadcasting outside the reach of mobile networks, the availability of TV broadcasting for young people accustomed to watching content on mobile devices, and improving support on available mobile devices. However, the crisis situations arising from the floods in 2024, as well as the war in Ukraine, highlight above all the need to maintain the operation of data networks and two-way communication. Communication following extensive damage to infrastructure in Ukraine was, and continues to be, provided by the Starlink satellite constellation⁷¹.

The Association of Television Organisations (ATO) confirms in its press release⁷² that a still dominant 89% of time spent in front of the television screen in 2023 was accounted for by traditional linear, live viewing. However, the same article confirms the growing share of IPTV platforms (42%).

⁶⁸ The 5G Broadcast specification is set out in ETSI TS 103 720, available online at: https://www.etsi.org/deliver/etsi_ts/103700_103799/103720/01.02.01_60/ts_103720v010201p.pdf

⁶⁹ Article "The Future 5G Broadcast TV Standard: The Journey from Mobile Phones to 5G BC TV", Televizniweb.cz website, author Václav Udatný, 2022, available online at: <https://www.televizniweb.cz/2022/12/budouci-standard-tv-vysilani-5g-broadcast-cesta-od-mobilu-k-televizorum-s-5g-bc/>

⁷⁰ CRA presents TV reception on mobile phones for the first time in the Czech Republic using new 5G Broadcast technology without a mobile network or Wi-Fi connection, CRA press release, 2024, available online at: <https://www.cra.cz/press-centre/television-and-broadcasting/cra-presents-television-reception-on-mobile-phones-for-the-first-time-in-the-czech-republic-using-the-new-5g-broadcast-technology-without-a-mobile-network-or-wifi-connection>

⁷¹ Huawei Ukraine presentation: Experience in ensuring the functionality, operation and security of mobile networks under the emergency conditions of war at the 'Where are digital networks heading? Olomouc 2023' conference, available online at: <https://www.isp-konference.cz/kam-kraci-digitalni-site-olomouc-2023/program> from 13:00

⁷² Article "New ATO data for 2023 confirms TV's dominance: 92.6% of households watch TV programmes, IPTV share is growing", ato.cz website, 2024, available online at: <https://www.ato.cz/2024/nova-data-ato-za-rok-2023-potrzuji-dominanci-tv-926-domacnosti-sleduje-tv-porady-roste-podil-iptv/>

8.3 Regulatory environment FWA technologies based on unlicensed bands

A significant provider of fixed Internet access in the Czech Republic consists of businesses using technologies based on unlicensed bands in their access networks, collectively referred to somewhat inaccurately as WiFi. According to data⁽⁷³⁾ from the Czech Telecommunications Office (ČTÚ), the share of unlicensed bands in the fixed-line market is 27.2% of the total number of connections, which corresponds to approximately 1.12 million connections reported in the regular data collection. The number of connections operated using an unlicensed radio access layer has remained stable over the long term and reflects both the ability of unlicensed bands to provide services of satisfactory quality – otherwise the user base would not be stable – and the insufficient coverage by high-quality cable networks in remote and rural areas.

In its regular data collection, the CTO includes among wireless accesses in unlicensed bands, including WiFi (labelled as WiFi in the graph), all wireless technologies based on unlicensed bands, i.e. also connections not based on the IEEE 802.11 standard (2.4 GHz, 5 GHz, 60 GHz), for example in the unharmonised 10.5 GHz band operated under General Authorisation VO-R/14⁷⁴ or other unlicensed bands, the most significant of which is the 80 GHz millimetre band operated under General Authorisation VO-R/23⁷⁵.

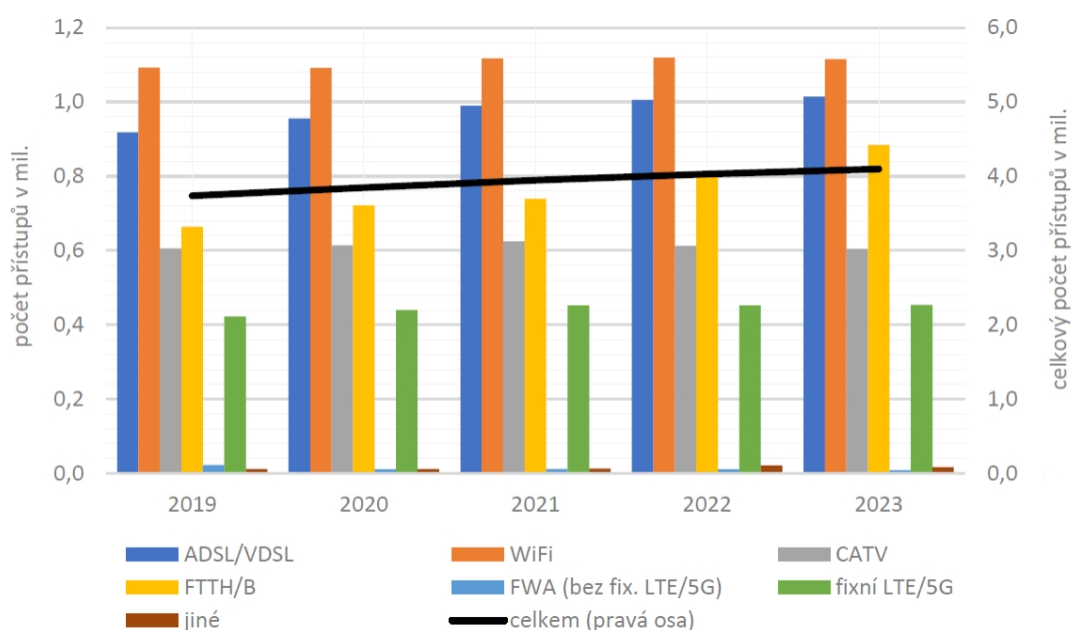


Figure 7: Development of the number of fixed internet access services by technology

According to the CTO Guidelines⁷⁶, connections that are partially implemented using metallic or optical cable are also reported as WiFi wireless connections; however, the predominant connection technology is a wireless link in an unlicensed band – regardless of its actual capacity.

This highlights the truly variable possibilities for utilising FWA wireless access networks, and even MFCN, as well as the flexibility of businesses in meeting the demand for electronic communications services. There is no single universal access network topology; many networks are built from the outset as hybrid networks in the sense of the creative use of optical fibres and the use of combinations

⁷³ Report on the development of the electronic communications market with a focus on 2023, page 51, available online at: https://ctu.gov.cz/sites/default/files/obsah/stranky/472017/soubory/zovt_2023.pdf

⁷⁴ General Authorisation No. VO-R/14/05.2020-7 for the use of radio frequencies and the operation of equipment in the 10 GHz frequency band, available online at: <https://ctu.gov.cz/sites/default/files/obsah/ctu/vseobecne-opravneni-c.vo-r/14/05.2020-7/obrazky/vo-r-14-052020-7.pdf>

⁷⁵ General Authorisation No. VO-R/23/06.2024-4 for the use of radio frequencies and the operation of fixed service equipment in the 71–76 GHz and 81–86 GHz frequency bands, available online at: <https://ctu.gov.cz/sites/default/files/obsah/vo-r23-062024-4.pdf>

⁷⁶ Guidance on completing geographical data in the annexes to Section 2 of form ART 232, available online at: <https://ctu.gov.cz/elektronicky-sber-dat-esd-elektronicke-komunikace>

both licensed and unlicensed bands to meet user needs. From this perspective, **however, it is difficult to report some even gigabit connections for data collection purposes as connections meeting all the criteria of** ^{the VHCN⁷⁷} (Very High Capacity Network) **definitions**, which are decisive for the Czech Republic's position in the DESI (Digital Economy and Society Index; DESI is now part of the State of the Digital Decade Report and is no longer tracked separately)⁷⁸, in the section on Internet Infrastructure Development.

It is crucial to understand that the definition of unlicensed FWA does not mean WiFi in the sense of the shared 5GHz band, but is much broader.

8.4 Overview of the regulatory framework for the use of unlicensed bands suitable for the provision of fixed wireless access (FWA) services in the Czech Republic

The share of individual unlicensed technologies in the total number of connections can only be estimated from data published by the CTO. In its ^{Market} Development Report⁷⁹, the CTO published the share of advertised speeds in the total number of unlicensed FWA connections. For only 14.7% of active connections do operators offer speeds in the range ≥ 100 Mbit/s < 1 Gbit/s, and 0.1% of connections exceed 1 Gbit/s. In the range above 100 Mbit/s, it can be assumed that technologies other than WAS/RLAN are used, i.e. 5 GHz WiFi. The same document offers a different perspective in its breakdown of the proportion of available ^{connections⁸⁰}. Here, operators report the possibility of providing services with speeds in the range of ≥ 100 Mbit/s < 1 Gbit/s for 51.4% of all covered address locations and the possibility of providing connections above 1 Gbit/s for 1.3% of covered address locations.

Active connections are connections that are actively in use. Available connections are connections that are either installed or, in practice, not yet installed but can be set up without significant cost within 4 weeks of ordering. The precise definition can be found in the Guidelines for Data Collection.

The former complete reliance of businesses offering access via unlicensed FWA in the WAS/RLAN bands, i.e. Wi-Fi in the 2.4 GHz and 5 GHz bands, is now distributed roughly equally between Wi-Fi and millimetre-wave access technologies. As with MFCN networks, the need to build a much denser infrastructure of network access points and to strengthen their connection capacities is becoming a barrier to the development of infrastructure in the millimetre bands.

8.5 Comparison of the regulatory framework with international approaches and general technological trends

Radio communication theory recognises only four methods of mitigating mutual interference. These are spatial separation, frequency separation, time division, separation by opposite polarisation, and coding protection. All these mitigation methods are utilised in the telecommunications infrastructure of unlicensed bands.

For spatial separation, the relationship holds that the higher the frequency, the more effective this mitigation method can be. This fact must be taken into account when assessing the suitability of individual frequency bands for the reliable provision of electronic communications services.

⁷⁷ BEREC Guidelines on Very High Capacity Networks (2023), published by BEREC in 2023, available online at: <https://www.berec.europa.eu/en/document-categories/berec/regulatory-best-practices/guidelines/berec-guidelines-on-very-high-capacity-networks-2023>

⁷⁸ The State of the Digital Decade reports published by the European Commission; DESI is part of this report; for 2023, available online at: <https://digital-strategy.ec.europa.eu/cs/library/2023-report-state-digital-decade>

⁷⁹ Report on the development of the electronic communications market with a focus on 2023, page 59, Figure 50: Structure of internet access via fixed wireless technologies in unlicensed bands by advertised speeds in 2023.

⁸⁰ Report on the development of the electronic communications market with a focus on 2023, page 60, Figure 52: Available Wi-Fi connections by effective download speed in 2023

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2.4 GHz band

The 'original' Wi-Fi band in the 2 400 – 2 483.5 MHz range is of little significance in FWA infrastructure. The band's advantage, namely the acceptable degree of electromagnetic field penetration through obstacles, is at the same time a key disadvantage when using this frequency in telecommunications network infrastructure. The total bandwidth of 83.5 MHz, combined with the widespread use of the lower band by domestic WiFi routers, makes the licence-exempt band released under General Authorisation VO-R/12 ideal for use in home networks. The new generation of the IEEE 802.11be WiFi 7 standard supports the combination of available 2.4 GHz and 5 GHz bandwidth capacity via the Multi-link operation feature, similar to networks based on 3GPP standards, and improves the spectral efficiency of the 2.4 GHz band.

FWA applications utilising the 2.4 GHz band are deployed only in specifically justified cases where it is necessary to connect a single location with a requirement for low transmission capacity, corresponding to a maximum bandwidth of 20 MHz (at a maximum value of around 40 Mbit/s).

5 GHz band

From an FWA infrastructure perspective, the 5 GHz WiFi band (5 GHz RLAN) may only be used in frequency bands that do not conflict with other uses in the spectrum (particularly FS and FSS). According to General Authorisation VO-R/12, the following bands may be used:

5150 – 5250 MHz (100 MHz) for outdoor use as well, subject to registration, with a maximum transmission power of 200 mW e.i.r.p.⁸¹

5250–5350 MHz (100 MHz) band, restricted to indoor use only, with a maximum transmission power of 200 mW e.i.r.p.

5470–5725 MHz (255 MHz) band, also for outdoor use without geographical restrictions, without registration requirement, with a permitted maximum power of 1 Watt e.i.r.p.

5725–5850 MHz (125 MHz) band, also for outdoor use subject to geographical restrictions to protect priority services, with a registration requirement, with a maximum permitted power of 1 Watt e.i.r.p.

5945–6425 MHz (700 MHz) band for use inside buildings or for portable stations, with a maximum transmission power of 23 dBm e.i.r.p. (200 mW).

It is clear from the above figures that 480 MHz of usable spectrum is available in non-contiguous blocks for use in infrastructure FWA. The basic channel bandwidth of 5 GHz RLAN is 20 MHz, and its multiples are also usable. In the latest iteration of IEEE 802.11 WiFi 7, equipment manufacturers report data rates of 200 Mbit/s for a 20 MHz channel in a line-of-sight environment. The spectral efficiency of the latest WiFi 7 generation approaches that of 3GPP 5G NR networks. The standard supports the use of 16×16 MU-MIMO and a modulation scheme of up to 4096 QAM. It also introduces entirely new methods of spectrum access and advanced techniques for mitigating mutual interference.

A major drawback for the provision of services based on the 5 GHz frequency is spectrum sharing in a relatively low-frequency band. Sharing the frequency band among many types of users (businesses, households) does not bode well for the growth of capacity and service quality in densely populated areas. Although mitigation techniques improve with each new generation of Wi-Fi, their main benefits lie in improving connection parameters up to 100 Mbit/s. In rural, remote areas, however, they can undoubtedly deliver surprisingly high capacity ^{improvements⁸²} up to the level of hundreds of megabits per second. Through modern channel capacity aggregation functionalities (Multi-Link Operation), even significantly better connection parameters can be expected in the future – which is similar to 5G infrastructure in licensed bands. It is worth noting that 3GPP standardised 5G NR unlicensed for Stand Alone network operation in the 5 GHz and 6 GHz bands in 3GPP Release 16.

Discussions are currently underway regarding possible changes to the use of the 6 GHz band, i.e. the lower 6 GHz band for 5925–6425 MHz and the upper 6 GHz band for 6425–7125 MHz. At present, these two sub-bands are reserved for point-to-point fixed service links. As the use of fixed-service links is not intensive in some European Union countries, including the Czech Republic, the debate regarding the 6425–7125 MHz band is moving towards sharing the frequency spectrum for the development of 5G networks and the expansion of ^{WAS/RLAN⁸³} (WiFi) bands. Regarding a specific scenario

⁸¹ e.i.r.p. E.I.R.P. (Equivalent Isotropically Radiated Power) is a measure of power that indicates how much energy an isotropic antenna (a theoretical antenna that radiates energy uniformly in all directions) would have to radiate to achieve the same signal strength in a given direction as an actual antenna. Put simply, it expresses the total radiated power, including the gain of the antenna system.

⁸² Article on the LUPA.cz website, by Jakub Rejzek and Jan Stejskal, 2024, available online at: <https://www.lupa.cz/clanky/test-wi-fi-7-vs-wi-fi-6-dalsi-zvysemi-rychlosti-obzvlast-v-zarusenem-prostredi/>

⁸³ WAS/RLAN (Wireless Access Systems / Radio Local Area Network) is a term used for wireless access systems and radio local area networks, which include technologies such as WiFi.

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There is no consensus in 2024. Some countries, such as the US and Canada, have already opted for licence-free use of one of the 6 GHz sub-bands⁸⁴.

The demand from FWA providers for frequency allocations is also reflected in declarations of interest in the future use of the 3800–4200 MHz band on a non-exclusive basis. A candidate band that has the potential to significantly supplement or completely replace 5 GHz WiFi in FWA infrastructure is the 26 GHz 5G band with non-exclusive licensing.

10.5 GHz, 17 GHz, 24 GHz bands:

The 10.5 GHz band is a specific Czech non-harmonised use of frequency segments based on VO-R/14. For the frequency bands 10 301 – 10 420 MHz and 10 476 – 10 588 MHz, the maximum bandwidth is set at 56 MHz. Use is limited to point-to-point applications. The predominant mode of use is the ‘retuning’ of fixed-link infrastructure technologies with frequency duplex and the connection of network access points of lesser capacity significance with connection speeds of 400 Mbit/s FDD. With a permitted power of 2 dBm into the antenna system, ranges of up to twenty kilometres are achievable. Systems based on the 10.5 GHz band are also used to connect end-users, often as backup systems for licensed links.

The 17 GHz band in the 17.1–17.3 GHz range is designated for broadband data transmission under VO-R/12. The transmit power of systems based on the 200 MHz band is limited to 100 mW e.i.r.p., which restricts its widespread use. Nevertheless, 17 GHz systems are used by businesses, most commonly for point-to-point links. The available transmission capacity is 1000 Mbit/s with an asymmetric duplex channel configuration.

The 24 GHz band in the 24–24.25 GHz range, in accordance with VO-R/10 and based on the SRD Recommendation CEPT/ERC/REC 70-03, with a power of 100 mW e.i.r.p. offers similar possibilities to those in the 17 GHz band. The use of both SRD bands at low power reflects the need for businesses to operate affordable technologies based on principles similar to those of licensed links, with high data transmission quality regardless of the type of service. The main technological competitors are the 60 GHz and 80 GHz bands, which were released later.

The 60 GHz and 80 GHz bands:

The 60 GHz band in the 57–71 GHz range is effectively another WiFi band, albeit with the modified designation WiGig. It is a global standard based on IEEE 802.11ad and 802.11ay. Although the technology is relatively new, the band was introduced for outdoor use in the period 2019–2020; the earlier proliferation of silicon components for industrial purposes and gigabit home routers enabled virtually immediate mass production of devices intended for the telecommunications infrastructure of wireless fixed networks. On the basis of the harmonised document CEPT/ERC/REC 70-03, the Office extended General Authorisation VO-R/12 and introduced a registration requirement for equipment in the 57–66 GHz band, in order to protect fixed service equipment operated in accordance with ETSI 302 217. As of October 2024, approximately 134,000 devices using the 57–66 GHz band are registered on the registration portal rlan.ctu.gov.cz. In the 66–71 GHz band, where there is no registration requirement, the numbers may be similar or rather lower due to the later development of devices supporting the full frequency range in accordance with the harmonised standard ETSI 303 722.

The high frequencies of the millimetre bands provide technology users with a high degree of isolation between systems due to the narrow radiation characteristics of their antenna systems, where, aided by beamforming functionality, they contribute to the mutual isolation of co-located systems. The ability to steer the radio beam using phase shifting of the antenna array significantly contributes to ease of assembly and installation costs. The adoption of the band for broadband data transmission in FWA was also aided, from the perspective of a ‘traditional’ network, by a paradoxical physical property. The energy of the electromagnetic field in the millimetre bands diminishes rapidly as it propagates through space, thereby substantially reducing the high risk of mutual interference in the 5 GHz band between otherwise relatively distant network transmission points.

The 57–71 GHz frequency band provides 14 GHz (sic!) of available bandwidth, which allows for mutual self-coordination among network operators. The 60 GHz millimetre band thus fulfils two physical principles of mutual radio isolation – frequency isolation and spatial isolation. The permitted power in the band is either 40 dBm e.i.r.p. for low-gain antennas, or 55 dBm e.i.r.p. for antennas with higher (average) gain. The basic transmission channel bandwidth is 2,160 MHz. WiGig gigabit technology has a solid foundation for providing fixed wireless access (FWA) services beyond 2035 and beyond. However, it does not form a basic capacity layer capable of serving subscribers further away from the base station – the network access point.

The 80 GHz band in the 71–76 GHz and 81–86 GHz sub-bands is designated for the operation of fixed point-to-point links. The harmonisation of the band is based on document ECC/REC/(05)07 from 2005; it is therefore one of the first applications of millimetre-wave technology intended for the construction of infrastructure with very high transmission capacity. Equipment for the 80 GHz band is available in the Czech Republic

⁸⁴ 6GHz.cz server, Wireless Communications Union, document ‘Use of the 6 GHz band in the Czech Republic’, Annex 1, available online at: <https://6ghz.cz/>

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under General Authorisation VO-R²³⁸⁵ with a basic bandwidth of 250 MHz, or in a selected section with even finer granularity of 62.5 MHz and 125 MHz. In both cases, multiples of the basic channel, i.e. 500 / 1000 / 2000 MHz. Both frequency division duplex (FDD) and time division duplex (TDD) modes are permitted. A total of 10 GHz of bandwidth is available, with a permitted maximum radiated power of 85 dBm e.i.r.p. When using the 80 GHz band, users were subject to a notification (registration) obligation until 2024,⁸⁶ which comprises nearly 14,500 records of fixed service link installations. This obligation was abolished on 1 August 2024. From point 3 of the explanatory memorandum:

“The Office has recorded a negligible number of cases (three in total) of harmful interference. This in itself does not necessarily mean that this situation will persist if the notification requirement is abolished (see the significance of self-coordination), but it contributes to the conclusion that no dramatic change in current practice can be expected. It is also possible to take into account the fact that the vast majority of respondents to the questionnaire stated that they had not been affected by interference in the relevant bands in practice (and without themselves actively using the option of self-coordination using data from the portal) – see below.”

From the perspective of assessing the suitability of millimetre bands operated under a General Authorisation, the CTO's data are highly significant. It appears that even with high utilisation of the band, tens of thousands of devices can be successfully operated, even with relatively high power, with a range of several kilometres and with a capacity sufficient even when connecting to busy base stations of MFCN networks or FWA access points of fixed network providers. The prospective use of higher frequencies within, for example, 3GPP 6th generation networks can be safely operated on the basis of licence-exempt spectrum access authorisation. It is primarily the user who will benefit from such access – low operating costs help to overcome the barrier to the development of high-speed infrastructure for providing internet access in sparsely populated areas, such as rural and remote areas.

⁸⁵ General Authorisation No. VO-R/23/08.2017-6 for the use of radio frequencies and the operation of fixed service equipment in the 71–76 GHz and 81–86 GHz frequency bands, issued by the Czech Telecommunications Office (ČTÚ), available online at: <https://ctu.gov.cz/sites/default/files/obsah/vo-r23-062024-4.pdf>

⁸⁶ Technical specifications for point-to-point fixed radio systems in the 71–76 GHz and 81–86 GHz bands, available online at: <https://ctu.gov.cz/vyhledavaci-databaze/technicke-udaje-pevnych-radiovych-systemu-typu-bod-bod-v-pasmech-71-76-ghz-a-81-86-ghz/kompletni-prehled?page=1>

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