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International Telecommunication Union
Standardization Sector

Recommendation

ITU-T L.1391 (01/2024)

SERIES L: Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

Energy efficiency, smart energy and green data centres

Specification of IMT-2020 network sharing and co-construction adapting to climate change mitigation

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Recommendation ITU-T L.1391

Specification of IMT-2020 network sharing and co-construction adapting to climate change mitigation

Summary

Recommendation ITU-T L.1391 specifies IMT-2020 (also known as 5G) network sharing and co-construction (NSCC) and their contribution to climate change mitigation, identifies their key technologies and specifies how to assess NSCC in their adaptation to climate change. Recommendation ITU-T L.1391 also addresses the cost-benefit analysis and best practice for IMT-2020 NSCC.

Mobile network operators around the world are facing unprecedented difficulties in IMT-2020 deployment. Restricted by expensive spectrum resources, the need for high investment and high energy consumption of IMT-2020, the profit gap between operators and equipment manufacturers is growing, and a large number of problems related to business increment with no increase in revenue are arising. Methods of reduction in the cost of network construction and operation, adaptation to climate change mitigation and enablement of the rapid benefits of IMT-2020, especially in underdeveloped communications regions, present major challenges to the global industry and operators.

History *

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Introduction

IMT-2020 (also known as 5G) is the most advanced cellular technology in commercial deployment of our era. While IMT-2020 offers much faster speed, massive connections and much lower latency, and has the potential to enable a much bigger variety of new applications for both people's lives and vertical industries, it does increase the energy consumption of mobile networks.

More importantly, sustainability has risen to the top of the agenda for many industries, including telecommunications. Mobile network operators (MNOs) need to rethink the usage of energy and its impact on the environment, and this will have a profound effect on the way they plan and deploy next generation networks. Thus, collaborative network deployment among devices, sites, networks and even MNOs will become an inevitable trend.

IMT-2020 network sharing and co-construction can effectively improve utilization efficiency of scarce spectrum resources and rapidly establish advanced mobile networks, thus circumventing the aforementioned problems. Via the quick construction of IMT-2020 full coverage networks from cities to counties, towns, and rural areas to realize universal IMT-2020 services and narrow digital gaps, this approach helps more people shake off poverty, pushing forward the UN 2030 agenda for sustainable development goals [b-UN SDG].

Recommendation ITU-T L.1391

Specification of IMT-2020 network sharing and co-construction adapting to climate change mitigation

1 Scope

This Recommendation specifies IMT-2020 (also known as fifth generation (5G)) network sharing and co-construction (NSCC) and their contribution to climate change mitigation, identifies their key technologies and specifies how to assess NSCC in their adaptation to climate change. This Recommendation also addresses the cost-benefit analysis and best practice for IMT-2020 NSCC.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T F.743.15] Recommendation ITU-T F.743.15 (2022), *Requirements for multi-operator core network enabled multimedia services*.

[ITU-T L.1210] Recommendation ITU L.1210 (2019), *Sustainable power-feeding solutions for 5G networks.*

[ITU-T L.1410] Recommendation ITU-T L.1410 (2014), *Methodology for environmental life cycle assessments of information and communication technology goods, networks and services*.

[ITU-T L.1430] Recommendation ITU-T L.1430 (2013), *Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects*.

[ETSI ES 203 700] ETSI Standard ETSI ES 203 700 V.1.1.1 (2021), *Environmental engineering (EE); Sustainable power-feeding solutions for 5G network.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 carbon dioxide equivalent; CO_2e [b-ISO 14064-1]: Unit for comparing the radiative forcing of a GHG to that of carbon dioxide.

NOTE – The carbon dioxide equivalent is calculated using the mass of a given GHG multiplied by its global warming potential.

3.1.2 emission factor [ITU-T L.1430]: A factor linking GHG emissions to a level of activity or a certain quantity of inputs, products or services (e.g., tonnes of fuel consumed or units of a product).

NOTE – An electricity emission factor is commonly expressed as tonnes of CO_2e per MWh. For example, an electricity emission factor of 1.3 means 1.3 t CO_2e is emitted by consuming 1 MWh of electricity.

3.1.3 environmental impact [ITU-T L.1410]: Impact including positive and negative aspects on the environment.

3.1.4 greenhouse gas; GHG [b-ISO 14064-1]: Gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds.

NOTE 1 – For a list of GHGs, see the latest Intergovernmental Panel on Climate Change (IPCC) Assessment Report.

NOTE 2 – Water vapour and ozone are anthropogenic as well as natural GHGs, but are not included as recognized GHGs due to difficulties, in most cases, in isolating the human-induced component of global warming attributable to their presence in the atmosphere.

NOTE 3 – GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

3.1.5 greenhouse gas emission; GHG emission [b-ISO 14064-1]: Release of a GHG into the atmosphere.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 environmental impact assessment: A process of evaluating the positive and negative environmental impacts of a proposed project or development.

3.2.2 network infrastructure: All the active equipment and passive items needed to realize a network.

NOTE 1 – Examples of active equipment are radio access network elements, like antennae, base transceiver stations and radio network controllers.

NOTE 2 – Examples of passive elements of network infrastructure can be: masts; containers; towers; power supply; and air-conditioning equipment.

3.2.3 network sharing and co-construction: A collaborative approach in which multiple individuals or organizations come together to jointly build and share network infrastructure or resources.

NOTE 1 – Network sharing and co-construction involve active participation and contribution of all stakeholders to create and maintain the network, with the aim of achieving common goals and benefiting from shared resources and expertise.

NOTE 2 – The sharing concept is often applied in areas such as telecommunications, transportation, and information technology, where the pooling of resources and knowledge can lead to more efficient and cost-effective solutions.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

4G fourth Generation

5G fifth Generation

6G sixth Generation

AI Artificial Intelligence

CA Carrier Aggregation

CAPEX Capital Expenditure

DSS Dynamic Spectrum Sharing

EF Emission Factor

EIA Environmental Impact Assessment

FAST Fusion-Assisting Super Time division duplexing

HPLMN	Home Public Land Mobile Network
ID	Identifier
IMT-2020	International Mobile Telecommunications-2020
IMT-2020C	IMT-2020 Core
MNO	Mobile Network Operator
MOCN	Multi-Operator Core Network
NR	New Radio
NSA	Non-Standalone
NSCC	Network Sharing and Co-Construction
RAN	Radio Access Network
RAT	Radio Access Technology
RB	Resource Block
SA	Standalone
SRS	Sounding Reference Signal
SUL	Super Uplink
TDD	Time Division Duplexing
TTI	Transmission Time Interval

5 Conventions

None.

6 Challenges of IMT-2020 network development

Over the past few decades, mobile communications have experienced a huge development from first generation to IMT-2020. Mobile communication networks update every 10 years, which constantly brings breakthroughs in mobile communication capabilities. Every intergenerational leap and technological progress have greatly promoted industrial upgrade, as well as economic and social development, and have changed the way we live and work like never before. From analogue to digital communications, from voice to data services, the traffic throughput has increased hundreds of times, and mobile communication networks have created a prosperous Internet economy.

As a new generation of mobile communication network, IMT-2020 not only solves the ultimate service experience that provides users with more immersive and extreme business experiences, such as augmented reality, virtual reality and ultra-high-definition video, but also solves the problem of communication between people and things, things and things, and meets the application needs of vertical industries such as mobile medical, Internet of vehicles, smart home, industrial control and environmental monitoring. With the rapid infiltration of IMT-2020 network into all walks of, IMT-2020 infrastructure construction has become the key to support digitalization and networking, as well as intelligent transformation of the economy and society.

At the same time, the development of IMT-2020 networks for global operators is facing unprecedented difficulties and challenge, such as insufficient coverage, large investment in construction difficulties and high operating expenses. As of 2022, the global use of mobile services reached 5.3 billion, accounting for 67% of the world's total population, the proportion of IMT-2020 connections in the total number of connections is estimated to increase from 8% in 2021 to 25% in 2025 [b-GSMA 5G], it is expected that the number of IMT-2020 connections will account for one quarter of the total number of mobile connections in 2025; however, there is still no mobile communication signal coverage in underdeveloped regions and countries in the world. The main problem and challenge is how to enable billions of people in underdeveloped regions, e.g., in Africa, Latin America, the Middle East and West Asia, to enjoy mobile communications and experience the convenient life made possible by IMT-2020. Mobile communication signal coverage needs to be improved in these areas by the global communications industry and universal economic and social development programmes.

Operator revenue will increase from $1.08 trillion in 2021 to $1.16 trillion in 2025, with operator capital expenditure (CAPEX) expected to reach $620 billion from 2022 to 2025, of which 85% will be spent on IMT-2020 development [b-GSMA 5G]. In addition to the purchase of expensive wireless spectrum, due to the use of higher frequency bands and larger bandwidth, the site density of IMT-2020 base stations is at least three times those of the fourth generation (4G). The power consumption and construction cost of a single station are each about three times that of one of 4G, which makes IMT-2020 construction and operation and maintenance (O&M) costs rise significantly, while the site selection of new IMT-2020 base stations is difficult, and the greater demand for transmission networks with large bandwidth will make the overall investment in IMT-2020 more than four times that of 4G. In addition, common problems faced by global operators that urgently need to be solved include methods for: reduction in "scissors difference" profit between operators and equipment manufacturers; modification of the "increment without income increase" situation of operators; and reduction in IMT-2020 network construction and operating costs.

7 Benefit of IMT-2020 network sharing and co-construction

From the current stage, implementation of sharing and co-construction in IMT-2020 is the most effective way to solve the problems mentioned in clause 6; such an approach cannot only reduce network-duplicated investment, but also accelerate the construction of IMT-2020 networks, leading to fast introduction of IMT-2020 services.

From the perspective of investment, sharing and co-construction allow decreases, effectively reducing CAPEX in the process of IMT-2020 network construction. The higher network performance of IMT-2020 is associated with high investment costs, and it is difficult to achieve large-scale IMT-2020 network coverage in a short period of time by relying on the strength of a single operator. Through co-construction and sharing, existing network resources, for example, of two operators are coordinated to provide better network performance and achieve the effect of $1 + 1 > 2$, which will greatly reduce repeated investment and construction of IMT-2020 networks.

From the perspective of high-quality development requirements, sharing and co-construction are additive. Sharing and co-construction is conducive to combining the operator's own advantages with those of high-quality resources of all parties and exerting maximum efficiency.

From the perspective of meeting the needs of users, sharing and co-construction should ensure that there is improvement in coverage and quality of IMT-2020 services. With the continuous development of the digital economy, industry and consumers are full of expectations of IMT-2020, but there is a gradual process of coverage, application and IMT-2020 network service nationwide. Through network co-construction and sharing, respective users of each party will use IMT-2020 services for a shorter period of time; the significant reduction in infrastructure construction expenditure will also help to reduce the level of IMT-2020 tariffs and to further promote speed-up with cost reduction. As the IMT-2020 service demonstration effect becomes more prominent, and 4G users continue to migrate to IMT-2020 networks, development will be promoted of IMT-2020 networks that are faster and better, and stable and high-quality IMT-2020 services realized for users.

Sharing and co-construction can effectively reduce carbon emissions of base stations and thereby significantly increases social and economic benefits. IMT-2020 network sharing has proportionately decreased the number of devices deployed in the network, improved the utilization rate of equipment, and provided more services without increasing energy consumption. This therefore effectively reduces network power consumption, promotes green innovation and development, and promotes carbon peaking and carbon neutrality in a much faster manner.

8 Classification of network sharing and co-construction

From the perspective of operation and management, there are two modes of sharing and co-construction. One is where operators build their own networks and share network resources through commercial agreements. The other is where operators set up a joint venture company for independent operation, especially one that is responsible for wireless network construction or maintenance.

From the perspective of shared network resources, network sharing is divided into passive and active types. Passive sharing refers to the sharing of physical infrastructure, excluding active devices. Sharing part or all of the active equipment of the radio access network, including access network sharing, gateway core network and core network roaming, is referred to as active.

Passive sharing is quite mature, while active sharing requires closer coordination between operators, making technical solutions more complicated. Therefore, this guideline mainly analyses active sharing.

9 Key technologies of IMT-2020 sharing and co-construction

9.1 Standard evolution of mobile network sharing and co-construction

The evolution of mobile NSCC can be related to the work done by the 3rd Generation Partnership Project (3GPP) [b-3GPP TS 23.251] [b-3GPP TS 23.501] [b-3GPP TS 29.573] [b-3GPP TS 37.471] [b-3GPP TS 37.472] [b-3GPP TS 37.473]. IMT-2020 multi-operator core network (MOCN) radio access network sharing has been supported since 3GPP Release 15 [b-3GPP-TR 21.915], which standardized radio access network sharing in terms of network architecture, air interface, next generation interface and Xn interface protocol. The operator-level information object class adaptation to multi-cell identifier (ID) scenario was added in Release 17, and further research on sharing and co-construction management architecture is being carried out in Release 18 to specify better O&M management. [ITU-T F.743.15] specifies the requirements for MOCN-enabled multimedia services, i.e., using network-sharing capabilities to improve the quality of conventional multimedia services.

9.2 Key technologies for IMT-2020 network sharing

9.2.1 Radio access network sharing

The architecture of sharing of radio access networks (RANs) shall allow different core network operators to connect to them, including two kinds of sharing mode, MOCN with shared carrier and multi-operator RAN network (MORAN) with dedicated carrier.

In the non-standalone (NSA) phase, the core network is deployed separately by operators, while the IMT-2020 new radio (NR) carrier is shared and 4G anchor carrier is shared as required, resulting in relatively complicated architecture. There are two modes of anchor cell: two dedicated anchor cells or one shared anchor cell.

During the promotion phase from NSA to standalone (SA), the evolution path from NSA mode to NSA/SA dual mode and then to SA mode is generally recommended.

In the SA phase, only IMT-2020 node B shall be connected to both IMT-2020 core (IMT-2020C) networks. Decoupled from the 4G network, no anchor cell solution is needed. With standard processing of 4G and IMT-2020 mobility management, both 4G and IMT-2020 user experience can be guaranteed.

9.2.2 Inter-network roaming for IMT-2020

In the IMT-2020 inter-network roaming scenario, the sharing base station only connects to the core network of the main operator. The core network for a home public land mobile network (HPLMN) and visited public land mobile network shall be connected when user service flow can pass both core networks. The bearer networks shall also be connected to each other.

In the NSA phase, only IMT-2020 NSA users are allowed to roam while other subscribers will only connect to the home network through a 4G evolved packet core. The management of users, billing and strategy control are separated in both core networks. The IMT-2020 network is constructed by the HPLMN with geographic separation.

In the SA phase, with a new IMT-2020C deployed and connected, only SA users are allowed to roam. All 4G users whenever roaming will fall back to access the home network. SA users of the secondary operator can access the IMT-2020 network with a new public land mobile network.

9.2.3 Spectrum sharing

Convenient and fast deployment has been the main focus of operators from the beginning of IMT-2020, and dynamic spectrum sharing (DSS) enables low investment and fast deployment with smooth evolution of Sub3G (i.e., spectrum resources below 3 GHz).

However, DSS performance is not as expected due to inter-radio access technology (inter-RAT) interference; an innovative spectrum sharing solution is required for higher NR performance, called hybrid DSS. Based on the current 20 MHz long-term evolution network, an IMT-2020 carrier with large bandwidth can be rapidly deployed. A cluster DSS solution and dynamic resource sharing at the base station cluster level, which limits inter-RAT interference at the cluster boundary, improve the IMT-2020 user experience and network efficiency without impact on 4G performance.

9.2.4 Coverage enhancement

A super uplink (SUL) solution with decoupled uplink and downlink, which has been incorporated into 3GPP Release 16, solves the bottleneck of NR carrier uplink coverage. The uplink data is transmitted over the time division duplexing (TDD) spectrum and SUL spectrum, which greatly increases the available uplink resources for IMT-2020 subscribers.

An innovative fusion-assisting super TDD (FAST) solution combines a middle or low band carrier in accordance with the framework of carrier aggregation (CA), with the addition of an innovative uplink TDM CA mode. By taking full consideration of the terminal implementing differentiation and the network strategies of operators, FAST can flexibly adapt to different capabilities of the terminal to maximize system performance.

Power pooling and dynamic sharing have been introduced for unified and flexible scheduling of the output power of modules, which improves the downlink experience by 5% to 20% with lower carbon.

9.2.5 Capacity improvement

Super frequency fusion technology, which has been incorporated into 3GPP Release 18 for IMT-2020-advanced, greatly improves the spectrum efficiency, system capacity and user experience through simplified control channels for multi-carrier, spectrum pooling for multi-carrier and unified scheduling.

Three dimensional beam coordination with time, frequency and space domain, achieves the best average user experience in the whole network with scheduling of full-band multi-beam formation and collaboration of multi-bands, solving the problem of unbalanced service or user distribution.

Sounding reference signal carrier switching improves the secondary carrier experience by 30% with sounding reference signal (SRS) dispatch via a secondary carrier for self-contained timeslots and SRS dispatch via a primary carrier for other timeslots.

9.2.6 Interference suppression

Passive interference of multi-frequency co-existence in the antenna feeder system is a difficult problem in the industry. By new architecture of multi-level cancellation, both linear and non-linear passive interference can be counteracted. The coverage has been improved by 20% with over 10 dB passive intermodulation cancellation. The technology is called **ultra-wideband passive interference self-cancellation**.

In a macro-macro intra-frequency network, the interference between neighbouring cells has been decreased with **intelligent beam forming power coordination**. User speed rate increases by about 15% through coordination frequency scheduling of neighbouring cells.

9.2.7 Operation and dispatch

The shared operation and dispatching platform, based on block chain technology, addresses three issues of operation: key parameters verification; configuration permissions of sharing network elements; and intelligent scheduling of contract resources. The platform empowers the whole procedure of sharing network construction, application, operation and optimization with cloud-deployment, cloud-chain and heterogeneous-cloud coordination. At the time of publication, the platform has been applied for over 600,000 sites with operation efficiency doubled.

An energy-saving platform, powered by artificial intelligence (AI), big data and network controlling technologies, has been deployed in 31 provinces in China with over 15% energy saving for IMT-2020 sharing network.

9.2.8 Business-to-business private sharing network

A multi-mode resource block resource reservation strategy, with a statistical level and transmission time interval level resource block (RB) reservation strategy, matches the differentiation requirements of services. Meanwhile, IMT-2020 user speed rate and latency have been guaranteed, especially for ultra-reliable low latency communication scenarios with RB management and scheduling. The technology has been incorporated into [b-3GPP TS 28.541]. **Multi-logic cell management of a shared carrier** is an innovative sharing solution that ensures the differentiated requirements of IMT-2020 verticals of different operators. Not only are vertical applications independently operated, but also the security of industry data can be guaranteed.

9.3 IMT-2020 standalone international roaming under core network sharing

Currently, [b-3GPP TS 23.501] only supports the sharing architecture of IMT-2020 MOCN. It is necessary to increase the research on IMT-2020 SA international roaming technology under core network sharing. It is recommended that the research and standard support of long-term architecture be increased. Accordingly, [b-3GPP TS 29.573] also needs to be reviewed to support the interconnection of a long-term security and edge protection proxy. In addition, [b-GSMA NG.113] is a guideline for IMT-2020 SA roaming, and it is recommended that support for long-term shared architecture be also added.

9.4 Planning and construction

To ensure the smooth implementation of sharing and co-construction, all parties should fully collaborate with each other in planning, construction, operation and optimization to achieve common goals, it is recommended that cooperative operators establish a joint working mode.

The cooperative operators should establish an end-to-end sharing and co-construction long-term cooperation mechanism based on the information support platform, including: the organization guarantee mechanism; the evaluation system of planning, construction, maintenance and optimization; and the mechanism of assessment and incentive.

9.4.1 Planning

In terms of joint network planning, the following are required.

Planning principle: In response to differences in network resources and objectives of planning and construction, unification of the objectives, processes, planning, guidelines, templates and methods.

Planning methodology: Jointly sort out the current situation; jointly judge trends, unified planning objectives, unified coordination of resources; and jointly review planning.

9.4.2 Construction

In terms of joint network construction, the following are required.

Construction principle: Full sharing and information equivalence; joint planning review, unified construction priority evaluation criteria, joint acceptance of engineering projects, and regular management to ensure information equivalence and timely response to sudden and changing demands.

Construction step: Network construction is divided into four stages: solution review; infrastructure reconstruction; construction implementation; and engineering acceptance.

9.5 Regulation and accounting or settlement

Regulatory and security mechanisms shall be established.

At the same time, it is necessary to study inter-network accounting or settlement, including inter-network settlement requirements and settlement principles.

9.6 Operation and optimization

In terms of network operation and optimization, exploration is required of strategies of cooperative operation, including: service resource strategy; mobility strategy; operation data sharing; collaborative network ID; network management sharing; and unified key performance indicators.

10 Environmental impact assessment of network sharing and co-construction

The environmental impact assessment (EIA) is a crucial process that evaluates the potential environmental impacts of various projects. The IMT-2020 mobile construction is one such project that has raised concerns about its environmental impact. In this clause, the EIA of IMT-2020 mobile construction and its potential environmental impact are briefly discussed.

The EIA of IMT-2020 NSCC is a crucial aspect that needs to be considered before implementing this technology. IMT-2020 networks have the potential to revolutionize the way we live and work, but at the same time, they can have a significant impact on the environment.

One primary concern regarding IMT-2020 NSCC is the amount of energy that will be required to power these networks. The increased speed and bandwidth of IMT-2020 networks will require more energy to operate, which could lead to an increase in GHG emissions and other environmental impacts.

Another concern is the impact that IMT-2020 networks could have on wildlife and ecosystems. The installation of new infrastructure, such as cell towers and antennas, could disrupt wild habitats and migration patterns, leading to negative impacts on local wildlife populations.

To address these concerns, an EIA should be conducted before implementing IMT-2020 NSCC projects. An EIA is a process that evaluates the potential environmental impacts of a proposed project and identifies ways to mitigate those impacts.

The EIA process shall involve a thorough analysis of the potential energy consumption and GHG emissions associated with IMT-2020 NSCC. This analysis should consider the energy requirements of the new infrastructure, as well as the energy required to power the increased data traffic on these networks.

The EIA shall also assess the potential impacts on local wildlife populations and ecosystems. This assessment should consider the potential disruptions to habitats and migration patterns caused by the installation of new infrastructure, as well as the potential impacts of increased electromagnetic radiation on wildlife.

Based on the results of the EIA, measures shall be taken to mitigate any potential negative impacts of IMT-2020 NSCC. These measures can include: using renewable energy sources to power the new infrastructure (see [ITU-T L.1210] or [ETSI ES 203 700]); minimizing the number of new cell towers and antennas; and implementing measures to reduce electromagnetic radiation.

In conclusion, the EIA of IMT-2020 NSCC is a critical step in ensuring that this technology is implemented in a way that minimizes its impact on the environment. By conducting a thorough EIA and implementing appropriate mitigation measures, we can ensure that we reap the benefits of IMT-2020 networks while minimizing their negative environmental impacts.

For the assessment of project impact for GHG effects and energy effects, see [ITU-T L.1430].

For detailed information on the EIA methodology for good (equipment) networks and services, see [ITU-T L.1410].

11 The contribution of IMT-2020 network sharing and co-construction to climate change mitigation

The contribution to climate change from IMT-2020 NSCC is mainly in terms of reduced infrastructure construction, reduced consumption of raw materials, and GHG emissions from energy consumption during operation. Table 1 shows the calculation of carbon-reduction by NSCC during operation. Table 2 provides an illustration of calculation of carbon-emission in the manufacturing phase.

Table 1 – Calculation of carbon-reduction by network sharing and co-construction

Category	No.	Item	Unit	Annual values
IMT-2020 SCC Stations	[1]	Total number of IMT-2020 SCC base stations	thousand	*X*
	[2]	Average power of an IMT-2020 base station[1]	kW	*Y*
	[3]	Total power savings of IMT-2020 SCC stations{=[1]*[2]*365day*24h}	MWh	*X***Y**365*24
	[4]	Carbon emission factor (see Note 2)	tCO_2e/ MWh	*EF*
	[5]	Calculated values for total carbon reduction{=[1]*[2]*[3]*[4]}	tCO_2e	*X***Y**365*24**EF*
4G SCC Stations	[1]	Total number of 4G SCC base stations	thousand stations	*X*
	[2]	Average power of a 4G base station (see Note 1)	kW	*Y*
	[3]	Total power savings of 4G SCC stations{=[1]*[2]*365 day*24 h}	MWh	*X***Y**365*24
	[4]	Carbon emission factor (see Note 2)	tCO_2e/ MWh	*EF*

Table 1 – Calculation of carbon-reduction by network sharing and co-construction

Category	No.	Item	Unit	Annual values
	[5]	Calculated values for total carbon reduction{=[1]*[2]*[3]*[4]}	tCO_2e	$X*Y*365*24*EF$
NOTE 1 – The average power of an IMT-2020/4G base station will vary from year to year, due to the use of new materials, new manufacturing processes or new model equipment, or with the software use of emerging energy-saving technologies or AI management tools, etc. NOTE 2 – The carbon EF is the amount of carbon emissions per unit of energy produced during the combustion or use of each energy source. Based on the assumptions of the IPCC, it can be assumed that the carbon EF for a given energy source is fixed. However, this EF will vary from one country or region to another, depending on the year and regional differences.				

Table 2 – Calculation of carbon emissions in the manufacturing phase of IMT-2020 stations and 4G stations

Category	No.	Item	Unit	Annual values
IMT-2020 Stations	[1]	Total number of IMT-2020 base stations	thousand	X
	[2]	Average energy consumption in the manufacturing phase of IMT-2020 base stations (see Note 1)	kWh	Y
	[3]	Average accessories (see Note 2) usage in the manufacturing phase of IMT-2020 base stations	kg	Z_i
	[4]	Carbon EF of grid	kg CO_2e/ kWh	EF_1
	[5]	Carbon EFs for the production of accessories	kg CO_2e/ kg	EF_{ia}
	[6]	Carbon EFs for the volatilization of accessories (see Note 3)	kg CO_2e/ kg	EF_{ib}
	[7]	Calculated values for total carbon emission{=[1]*{[2]*[4]+ Σ [3]*{[5]+ [6]}}}	tCO_2e	$X*[Y*EF_1+\sum_{i=1}^{n} Z_i*(EF_{ia}+EF_{ib})]$
4G Stations	[1]	Total number of 4G base stations	thousand	X
	[2]	Average energy consumption in the manufacturing phase of 4G base stations (see Note 1)	kWh	Y
	[3]	Average accessories (see Note 2) usage in the manufacturing phase of 4G base stations	kg	Z_i
	[4]	Carbon EF of grid	kg CO_2e/ kWh	EF_1
	[5]	Carbon EFs for the production of accessories	kg CO_2e/ kg	EF_{ia}
	[6]	Carbon EFs for the volatilization of accessories (see Note 3)	kg CO_2e/ kg	EF_{ib}
	[7]	Calculated values for total carbon emission{=[1]*{[2]*[4]+ Σ [3]*{[5]+ [6]}}}	tCO_2e	$X*[Y*EF_1+\sum_{i=1}^{n} Z_i*(EF_{ia}+EF_{ib})]$

Table 2 – Calculation of carbon emissions in the manufacturing phase of IMT-2020 stations and 4G stations

Category	No.	Item	Unit	Annual values
NOTE 1 – The energy consumption in the manufacturing phase of IMT-2020 stations and 4G stations mainly comes from the energy consumption of production line assembly and the energy consumption of software and hardware testing. NOTE 2 – Accessories include solder paste, cleaning agent and flux. NOTE 3 – The volatile ratio of volatile organic compounds has been included in EF_{ib}.				

12 Prospect of global mobile communication network sharing and co-construction

In terms of the future development direction of sharing network with global partners, the following are required.

Deepening IMT-2020 network sharing and co-construction cooperation: The future evolution direction of IMT-2020 NSCC can be analysed from multiple dimensions such as technology route, geographical range, number of partners, working frequency bandwidth and technology systems.

Future technological evolution of sharing and co-construction: Millimetre wave sharing and co-construction, multi-access edge computing sharing and co-construction and sixth generation (6G) NSCC.

Appendix I

The practice of IMT-2020 network sharing and co-construction in China

(This appendix does not form an integral part of this Recommendation.)

In 2019, China Telecom and China Unicom launched a joint project to build and share an IMT-2020 lifecycle network. Since then, both parties have made significant breakthroughs in IMT-2020 sharing technologies, components, equipment, networking and operations, and have built one physical network, two logical networks and multiple customized private networks. As the first and the largest, this IMT-2020 SA shared network has realized large-scale industrial application and ensured good user experience.

I.1 Global best practice of IMT-2020 network sharing and co-construction in China

China Telecom and China Unicom are the pioneers and practitioners of IMT-2020 sharing and co-construction technology. In September 2019, China Telecom and China Unicom signed an IMT-2020 NSCC framework cooperation agreement, which clearly stated that they would build a joint IMT-2020 access network nationwide, sharing the IMT-2020 frequency resources, and building IMT-2020 core networks independently. After area demarcation, the companies build, invest, maintain and operate separately. In the subsequent implementation of IMT-2020 co-construction and sharing, China Telecom and China Unicom continue to innovate in technical solutions, cooperation models, management mechanisms, etc., which accelerates the construction of IMT-2020 networks. On 2020-09-30, the first and largest IMT-2020 sharing network finished its phase I construction and commercial deployment, which promoted IMT-2020 network construction and completed the end-to-end network evolution of the SA mode.

By 2021-12-31, China Telecom and China Unicom had deployed about 700 000 base stations in IMT-2020 networks, accounting for more than 40% of the world's built IMT-2020 base stations, and built the world's first and largest IMT-2020 SA shared network, realizing large-scale industrial applications. Meanwhile, it has promoted the sharing of 4G access networks between the two partners, saving more than CNY 210 billion in network construction investment, CNY 20 billion in network operating costs, more than 10 GWh of electricity, and reducing carbon emissions by 6 Mt every year.

China Telecom and China Unicom have proposed 12 international standards for IMT-2020 co-construction and sharing, forming the first national standard for wireless sharing technology, filling the gaps in wireless system sharing technology and standards, and leading a leap forward in global mobile communication network sharing.

In the past three decades, a universal system has been forming in the information and communications technology industry, whose main characteristics are: alignment of standards; globalization of technologies, products and supplies; and free flow of data. Unbalanced data flow will lead to differences in the pace of network construction, fragmentation of telecommunication standards, and fragmentation of supply systems. The co-construction and sharing advocated by China coincides with the vision of the Internet of everything pursued by the telecommunication industry. The co-construction and sharing of China Telecom and China Unicom in the world's largest IMT-2020 network will greatly promote the unification of industry standards, globalization of supply chains, digitization of society, free flow of data and circulation of capital within the industry.

China Telecom and China Unicom are the first in the world to carry out nationwide IMT-2020 full life cycle network co construction and sharing. With a series of innovative practices in products, technology and O&M and management, China Telecom and China Unicom have promoted sharing and co-construction and accelerated the implementation, providing Chinese experience for the global telecommunications industry.

IMT-2020 sharing and co-construction technology. Practising in many aspects for different modes of NSA and SA, e.g., various networking schemes, coverage enhancement technology, capacity improvement, interference suppression, DSS technology, key technologies of sharing and co-construction management and scheduling strategy, shared to business private network and international roaming scheme.

Taking the use case of China Telecom and China Unicom as an example, the IMT-2020 spectrum of 3.5/2.1 GHz is adjacent band, and only one set of equipment is required to support 2.1 GHz 55 MHz, 3.5 GHz 200 MHz broad bandwidth, providing better network performance. At the same time, the network resources of the two operators are highly complementary in the southern and northern regions of China. Through nationwide cooperation, an IMT-2020 joint access network will be quickly built and shared efficiently to rapidly achieve full network coverage nationwide, form IMT-2020 service capabilities, enhance the market competitiveness of IMT-2020 networks, improve network and asset operation efficiency, and achieve mutual benefit and win-win results.

IMT-2020 sharing and co-construction management. Establishment of rules, regulations, supervisions and settlements. All partners have set up joint working organizations, established rules and regulations, reinstituted processes, ensured the operation quality of the network and the consistency of the business and user perceptions of all partners through a series of innovative solutions. Moreover, promotion of the full life cycle and whole process penetration. and coordination of planning, construction, maintenance and optimization.

IMT-2020 co-construction and shared operation. The principle of planning, construction, maintenance and optimization runs through the whole process and cooperation. All partners have introduced dual north faced resource scheduling, slicing resource allocation, blockchain technology, and full-time shared AI energy-saving technology to further improve operational efficiency, build a mutual trust mechanism, and realize transparent, visible and efficient collaboration of all partners' operations.

Follow up evolution of co-construction and sharing. Looking forward to the future and continuing to deepen co-construction and sharing. Such as technical route, geographical scope, number of partners, operating frequency band, technical system and other dimensions, IMT-2020 sharing and co-construction are analysed. Facing the future problems of sharing millimetre waves, chambers, edge computing and 6G, which will also continue to explore innovation and practice.

I.2 Calculation of carbon-reduction by network sharing and co-construction in China Telecom and China Unicom

Table I.1 lists steps in the calculation of the electricity savings for 4G and IMT-2020 base stations by NSCC and the estimated amount of carbon reduction for China Telecom and China Unicom in 2020, 2022 and 2025.

Table I.1 – Calculation of carbon-reduction by network sharing and co-construction

Category	No.	Item	Unit	Values for 2020	Values for 2022	Values for 2025
IMT-2020 SCC Stations	[1]	Total number of IMT-2020 SCC base stations	thousand	400	1000	[1400]
	[2]	Average power of an IMT-2020 base station (see Note 1)	kW	1.45	1.45	[1.45]
	[3]	Total power savings of IMT-2020 SCC stations{=[1]*[2]* 365 day*24 h}	MWh	5 080 800	12 702 000	17 782 800

Table I.1 – Calculation of carbon-reduction by network sharing and co-construction

Category	No.	Item	Unit	Values for 2020	Values for 2022	Values for 2025
	[4]	Carbon EF (see Note 2)	tCO_2e/ MWh	0.581	0.581	[0.581]
	[5]	Calculated values for total carbon reduction{=[1]*[2]* [3]*[4]}	tCO_2e	2 951 944.8	7 379 862	10 331 806.8
4G SCC Stations	[1]	Total number of 4G SCC base stations	thousand stations	240	1120	[1700]
	[2]	Average power of a 4G base station(see Note 1)	kW	0.5	0.5	[0.5]
	[3]	Total power savings of 4G SCC stations{=[1]*[2]* 365 day*24 h}	MWh	1 051 200	4 905 600	7 446 000
	[4]	Carbon EF (see Note 2)	tCO2e/ MWh	0.581	0.581	[0.581]
	[5]	Calculated values for total carbon reduction{=[1]*[2]* [3]*[4]}	tCO_2e	610 747.2	2 850 153.6	4 326 126
NOTE 1 – The average power of an IMT-2020/4G base station will vary from year to year, due to the use of new materials, new manufacturing process or new model equipment, and with the use of emerging energy-saving technologies or AI-based management tools, etc. NOTE 2 – The carbon EF is the amount of carbon emissions per unit of energy produced during the combustion or use of each energy source. Based on the assumptions of the IPCC (United Nations Intergovernmental Panel on Climate Change), it can be assumed that the carbon EF for a given energy source is fixed. However, this EF will vary from one country or region to another, depending on the year and regional differences.						

Table I.2 lists steps in the calculation of carbon emission in the manufacturing phase of IMT-2020 station and 4G station (station mode: one baseband unit (BBU) plus three active antenna units (AAUs) or remote radio units (RRUs).

Table I.2 – Calculation of carbon emissions in the manufacturing phase of IMT-2020 stations and 4G stations

Category	No.	Item	Unit	Values for 2020	Values for 2022	Values for 2025
IMT-2020 Stations	[1]	Total number of IMT-2020 base stations	thousand	400	1 000	1 400
	[2]	Average energy consumption in the manufacturing phase of IMT-2020 base stations (see Note 1)	kWh	/	26.45	/
	[3]	Average accessories (see Note 2) usage in the manufacturing phase of IMT-2020 base stations	kg	/	Z_1 = 0.082	/
	[4]	Carbon EF of grid	kg CO_2e/ kWh	/	0.791	/
	[5]	Carbon EFs for the production of accessories	kg CO_2e/ kg	/	EF_{1a} = 3.915	/
	[6]	Carbon EFs for the volatilization of accessories (see Note 3)	kg CO_2e/ kg	/	EF_{1b}= 0	/

Table I.2 – Calculation of carbon emissions in the manufacturing phase of IMT-2020 stations and 4G stations

Category	No.	Item	Unit	Values for 2020	Values for 2022	Values for 2025
	[7]	Calculated values for total carbon emission{=[1]*{[2]*[4]+ Σ [3]*{[5]+[6]}}}	tCO_2e	/	21 243	/
4G stations	[1]	Total number of 4G base stations	thousand	240	1 120	1 700
	[2]	Average energy consumption in the manufacturing phase of 4G base stations (see Note 1)	kWh	/	24.50	/
	[3]	Average accessories (see Note 2) usage in the manufacturing phase of 4G base stations	kg	/	Z_1 = 0.078	/
	[4]	Carbon EF of grid	kg CO_2e/ kWh	/	0.791	/
	[5]	Carbon EFs for the production of accessories	kg CO_2e/ kg	/	EF_{1a} = 3.915	/
	[6]	Carbon EFs for the volatilization of accessories (see Note 3)	kg CO_2e/ kg	/	EF_{1b} = 0	/
	[7]	Calculated values for total carbon emission{=[1]*{[2]*[4]+ Σ [3]*{[5]+[6]}}}	tCO_2e	/	22 047	/

NOTE 1 – The energy consumption in the manufacturing phase of IMT-2020 stations and 4G stations mainly comes from the energy consumption of production line assembly and the energy consumption of software and hardware testing.

NOTE 2 – Accessories include solder paste, cleaning agent and flux.

NOTE 3 – The volatile ratio of volatile organic compounds has been included in EF_{ib}.

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