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DIGITAL ENABLER

JILID 12

E-KLIPING

Kumpulan informasi teknologi, regulasi, dan trend digital

MASYARAKAT TELEMATIKA INDONESIA
2025

Daftar Isi

Daftar Isi

01.

Penguatan Keamanan Siber dalam Era IPv6 dan Transformasi Jaringan 5.5G: Mewujudkan Infrastruktur Digital Aman dan Terpercaya - Direktorat Kebijakan Teknologi Keamanan Siber dan

#bangga melayani bangsa

Penguatan Keamanan Siber dalam Era IPv6 dan Transformasi Jaringan 5.5G: Mewujudkan Infrastruktur Digital Aman dan Terpercaya

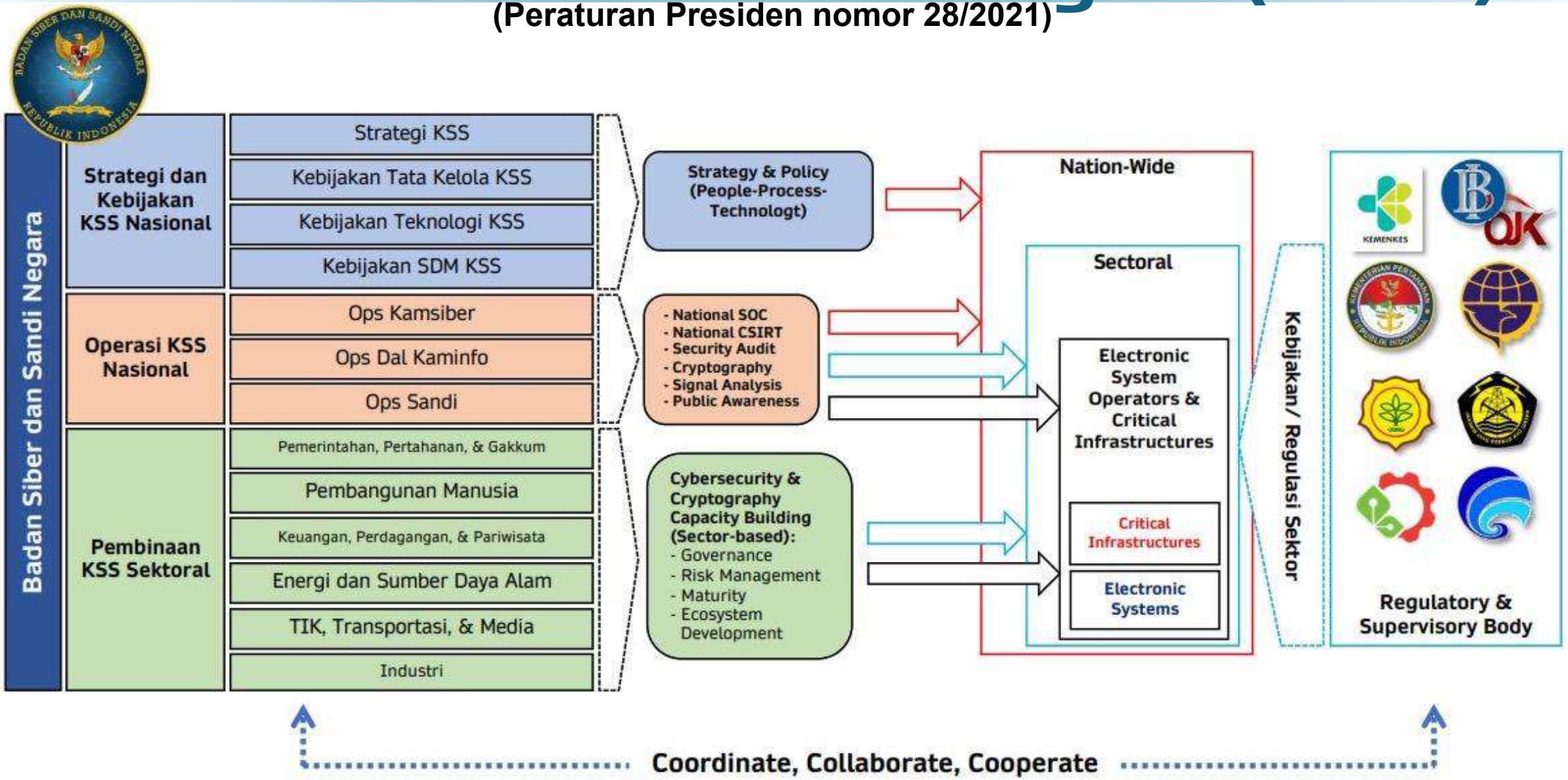
Direktorat Kebijakan Teknologi Keamanan Siber dan Sandi

Deputi I – BSSN

2024

Badan Siber dan Sandi Negara (BSSN)

(Peraturan Presiden nomor 28/2021)



Roadmap Keamanan Siber Indonesia 2045

Dalam rangka mencapai siber Indonesia yang berdaulat, BSSN bersama dengan pemangku kepentingan menyusun suatu peta jalan (roadmap) 2019-2045 demi "Mewujudkan Kedaulatan Siber Indonesia Berkelas Dunia 2045"

Roadmap dibagi dalam 3 (tiga) periode waktu mengikuti RPJP yang merupakan rencana strategis pembangunan di Indonesia:

Periode Stabilisasi 2019 2025

TARGET: Stabilisasi Teknologi Siber dan Sandi Nasional

Sasaran:
- Penguatan Regulasi Kamsiber.
- Kompetensi dan kapabilitas SDM.
- Litbang dan sertifikasi teknologi.
- Peningkatan Nilai Kematangan siber.
- Pembentukan Budaya Kamsiber.

Periode Integrasi 2026 2035

TARGET: Integrasi Teknologi Siber dan Sandi Nasional

Sasaran:
- Implementasi Regulasi di bidang ekonomi.
- Ekstensifikasi Secure Smart Government.
- Penguatan kemitraan nasional dan internasional.

Periode Kemandirian 2036 2045

TARGET: Kemandirian Teknologi Siber dan Sandi Nasional

Sasaran:
- Identifikasi dan eksplorasi beragam perkembangan masa depan dunia siber secara realistis.
- Kemandirian yang berkelanjutan dan terarah.

FOKUS AREA

1. Tata Kelola
2. Manajemen Risiko
3. Kesiapsiagaan dan Ketahanan
4. Pelindungan IIV
5. Kemandirian Kriptografi Nasional
6. Pembangunan Kapabilitas & Kapasitas
7. Kebijakan Keamanan Siber
8. Kerja Sama Internasional

REN. AKSI

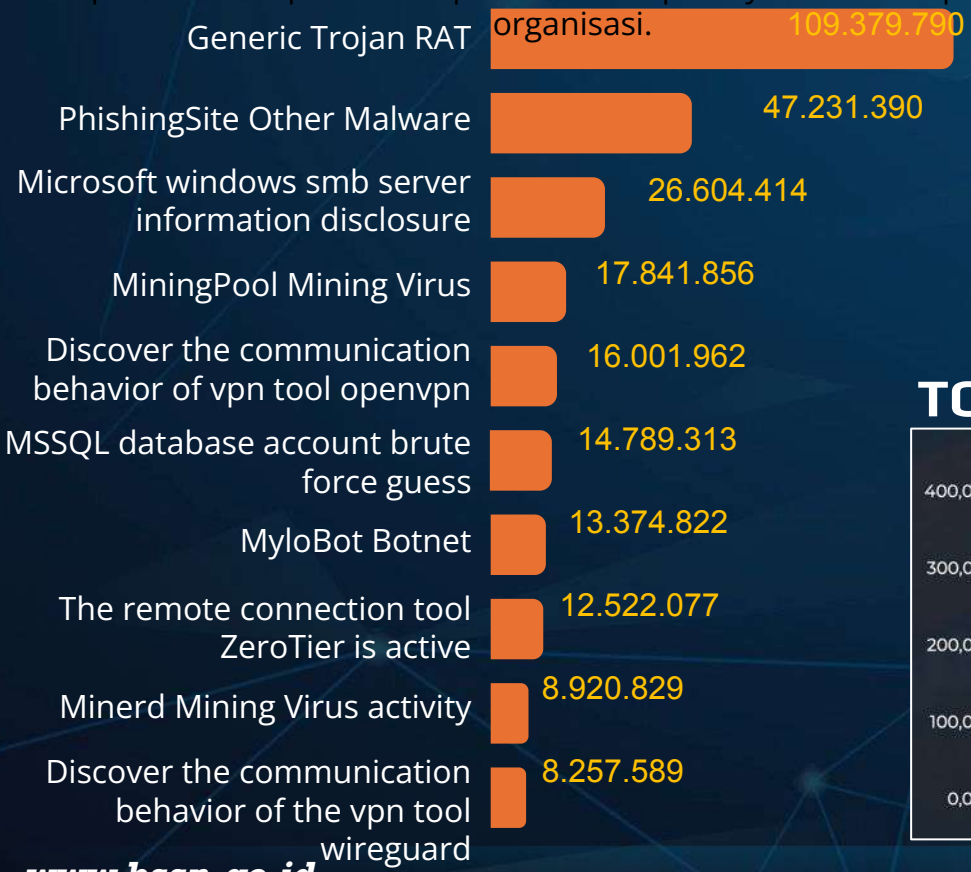
Upaya terencana dan terukur berbasis kolaborasi

- Penyelenggara Negara
- Pelaku Usaha
- Akademisi
- Komunitas / Masyarakat

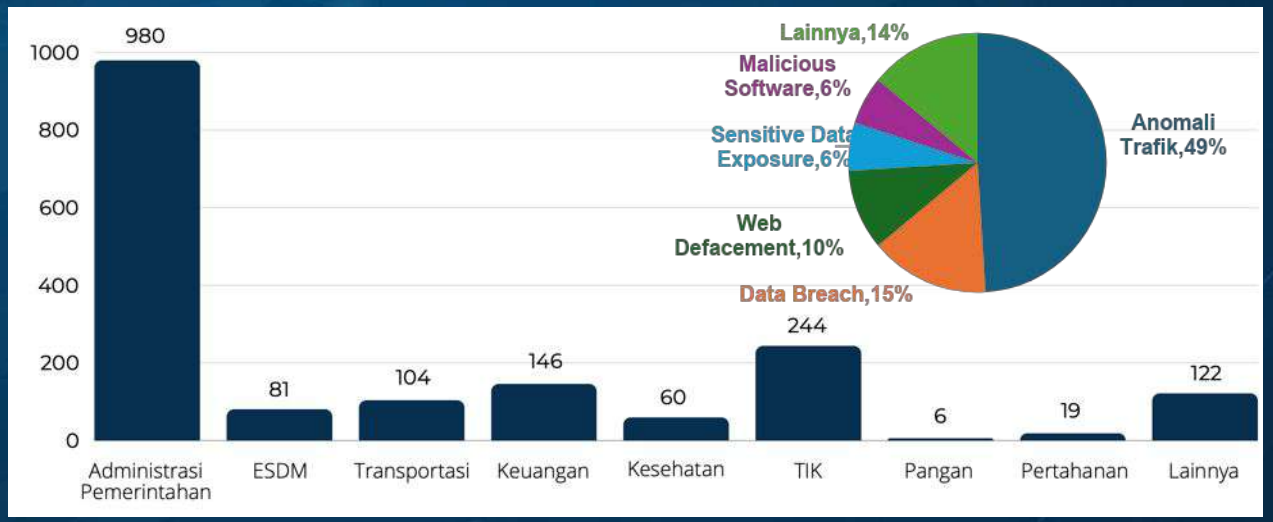
STRATEGI KEAMANAN SIBER NASIONAL (PERPRES 47/2023)

TANTANGAN KEAMANAN SIBER INDONESIA

Total **trafik anomali** di Indonesia selama tahun 2023 adalah **403.990.813 anomali**. Anomali trafik tertinggi terjadi pada bulan Agustus dengan jumlah 78.464.385 anomali, sedangkan anomali terendah terjadi pada bulan November dengan jumlah 19.296.439 anomali. Aktivitas anomali trafik ini dapat berdampak pada penurunan performa perangkat dan jaringan, pencurian data sensitif, hingga perusakan reputasi dan penurunan kepercayaan terhadap suatu organisasi.

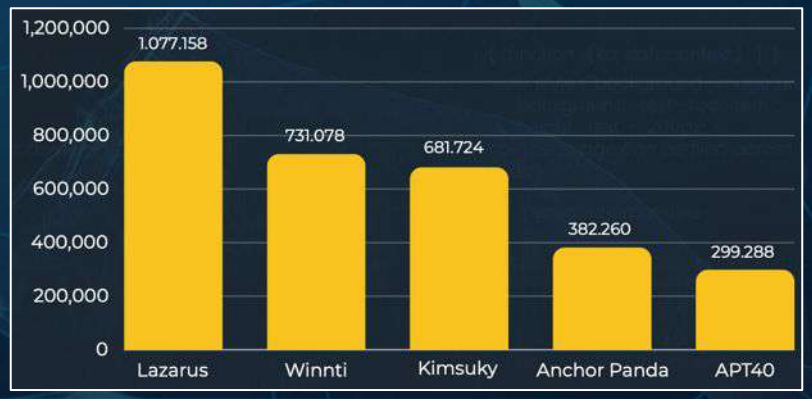


NOTIFIKASI INSIDEN SIBER



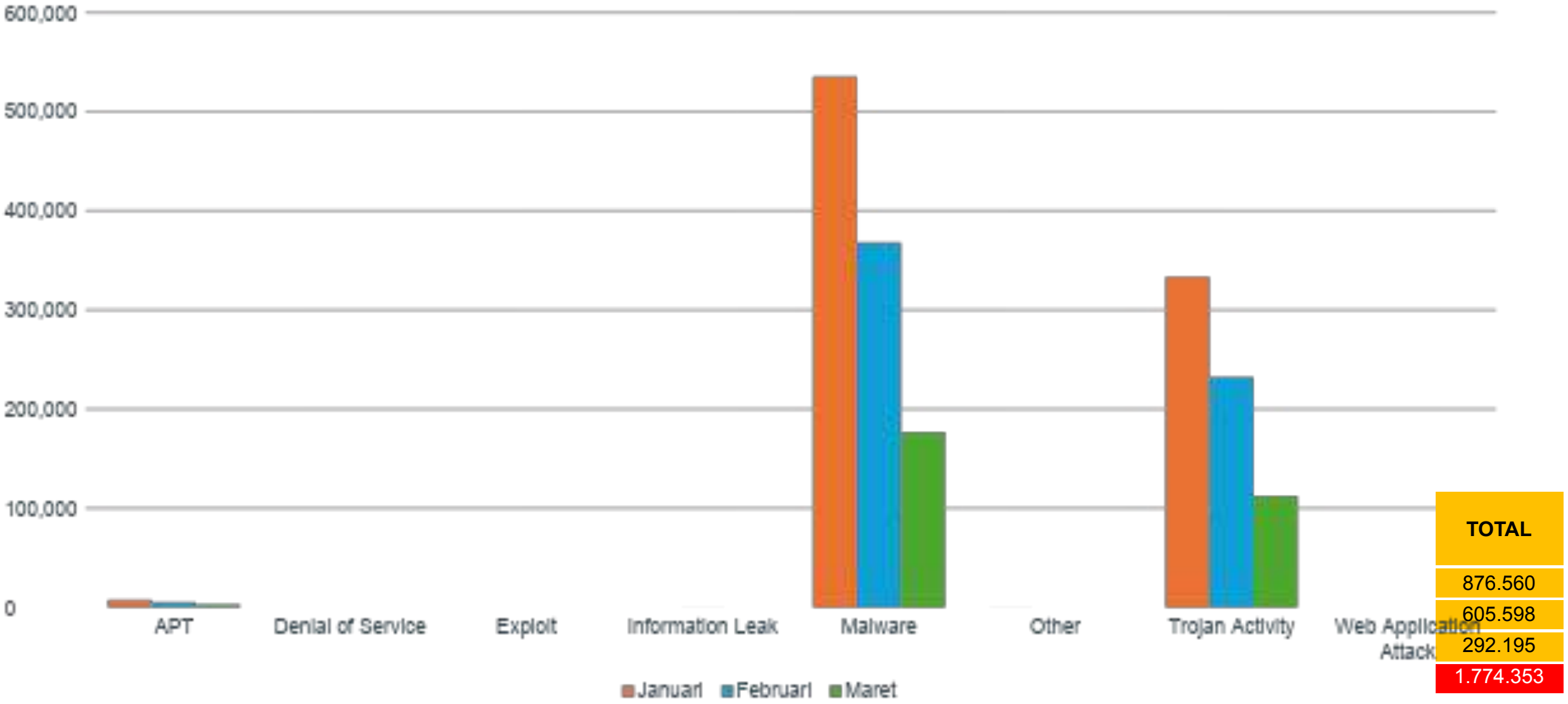
TOP 5 RANSOMWARE

TOP 5 APT

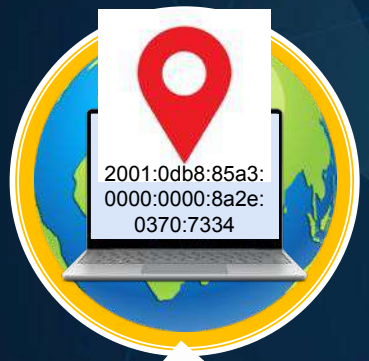


Sumber: BSSN. Lanskap Keamanan Siber Indonesia 2023.

ANOMALI IPv6 (Januari – Maret 2024)

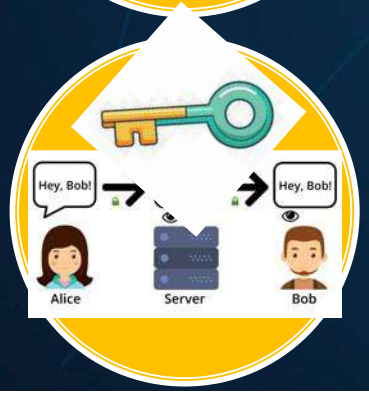


KEUNGGULAN IPv6



Kapasitas alamat yang besar

IPv6 menyediakan ruang alamat hingga 340 undecillion (3,4 x 10^38) alamat IP, memungkinkan miliaran perangkat untuk terhubung tanpa konflik. Mendukung pertumbuhan ekonomi digital dan IoT, termasuk di wilayah terpencil.



End-to-End Encryption Bawaan

IPv6 mendukung enkripsi langsung antar perangkat tanpa memerlukan NAT (*Network Address Translation*). Untuk perlindungan data dapat mengurangi risiko intersepsi data, melindungi komunikasi sensitif seperti transaksi keuangan dan layanan medis.

Penyempurnaan Routing dan Mobilitas

IPv6 mengoptimalkan routing, mengurangi latensi dalam komunikasi jaringan. Mendukung mobilitas perangkat, memungkinkan perangkat bergerak antar jaringan tanpa kehilangan koneksi.

TRANSFORMASI TEKNOLOGI SELULER

Setiap sepuluh tahun, *International Telecommunication Union* (ITU) memperkenalkan teknologi seluler baru. Saat ini, jaringan 4G adalah yang paling umum digunakan. Namun, 5G tentunya akan membawa kemampuan baru yang lebih canggih dari 4G.

0G
Komunikasi Nirkabel Terbatas
Sebelum 1980

1G
Jaringan Komunikasi Analog untuk Panggilan Suara
1980

2G
Penambahan Jaringan Komunikasi Digital untuk Mendukung SMS
1990

3G
Mobile Broadband, MMS, *Mobile* TV, Panggilan Video
2000

4G
Improved Mobile Broadband, Jaringan IP, HD *Video Streaming*, *Mobile Gaming*
2010

5G
eMBB, uRLLC, mMTC, *Network Softwari-zation*, VR, AR, MR, *Autonomous Vehicles*, IoT, Industri 4.0
2020

6G
2030

- Merujuk hasil riset dari Institut Teknologi Bandung (ITB), pengembangan 5G di Indonesia berpotensi menyumbang <Rp 2.800T (9,5% dari PDB) pada 2030, bahkan bisa meningkat hingga Rp 3.500T (9,8% dari PDB) pada 2035.
- Secara global, studi IHS Markit memproyeksikan, pada 2035, 5G akan berkontribusi sebesar $13,2T bagi perekonomian dunia:
  - Setara dengan hampir seluruh belanja konsumen Amerika Serikat pada 2018 □ $13,9 triliun
  - Gabungan belanja konsumen di Tiongkok, Jepang, Jerman, Inggris, dan Prancis pada tahun 2018 □ $13,4 triliun
- Di era Revolusi Industri 4.0, Arthur D. Little memperkirakan nilai pasar IoT berbasis 5G akan mencapai USD 1,5 triliun pada 2030.

LANSKAP KEAMANAN

5G adalah bentuk konvergensi antara dunia telekomunikasi dan Teknologi Informasi (TI), sehingga banyak isu keamanan baru yang tadinya hanya dikenal di dunia TI kini juga menjadi tantangan dalam pengamanan 5G.

1G

- Physical Attacks e.g. Eavesdropping
- No Security and privacy guaranteed

AMPS, NMT, TACS

2G

- Illegal devices e.g. Spam Rouge Base Stations
- One-way authentication

D-AMPS, GSM/GPRS, cdmaOne

3G

- IP traffic security issues e.g. Virus, Spyware, Malware
- Encryption key issues

CDMA2000/EV-DO, WCDMA/HSPA+, TD-SCDMA

4G

- MAC layer threats e.g. Mobileware, APT/Ddos, Malicious Apps

LTE, LTE Advance

5G

- Cyberwafare and critical infrastructure threats
- SDN/NFV threats
- Cloud computing and related threats

NR, SDN, NFV, NS

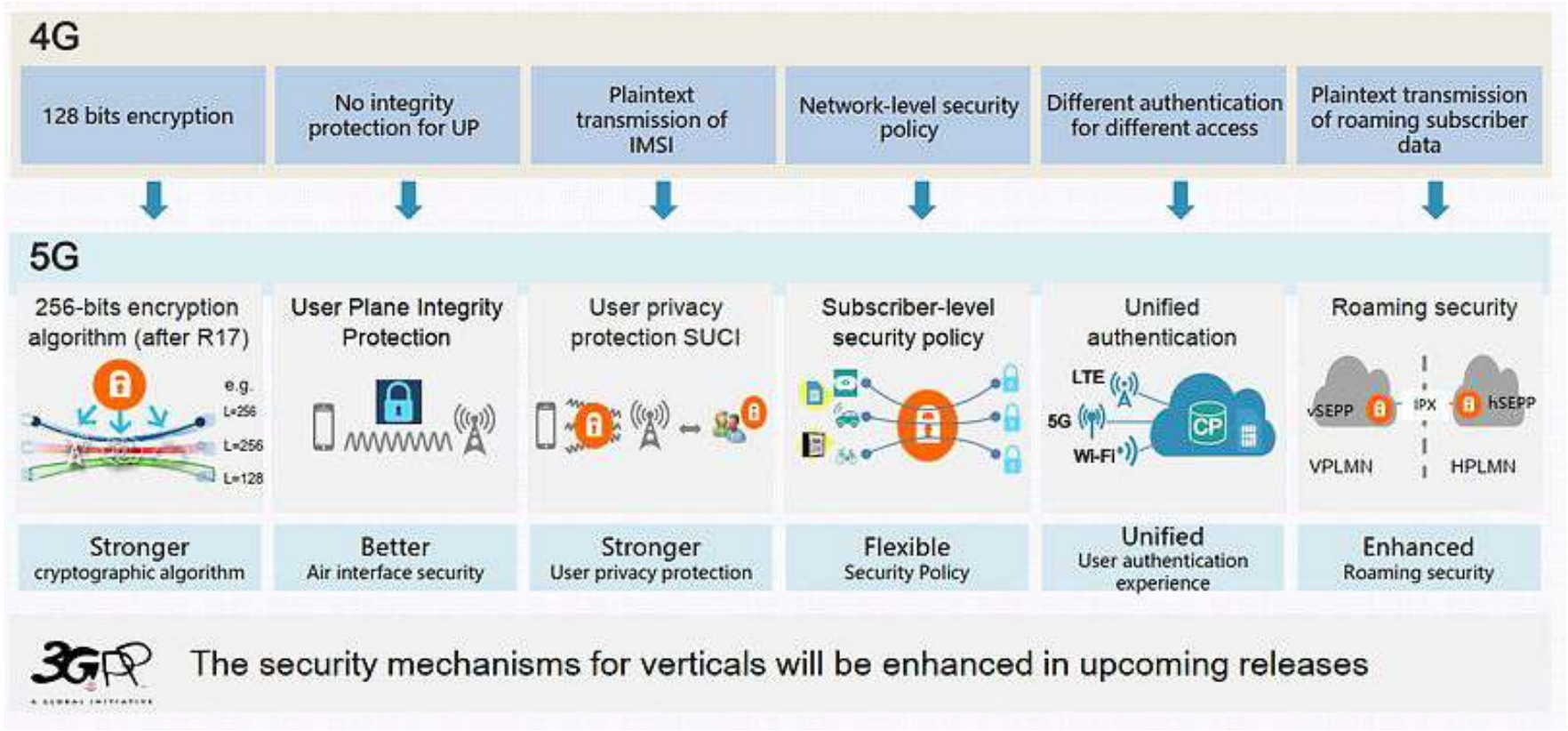
6G

- AI/ML based intelligent attacks
- Quantum attacks
- PHY layer attacks for VLC, THz, etc

AI/ML, DLT, VLC, THz, Quantum computing

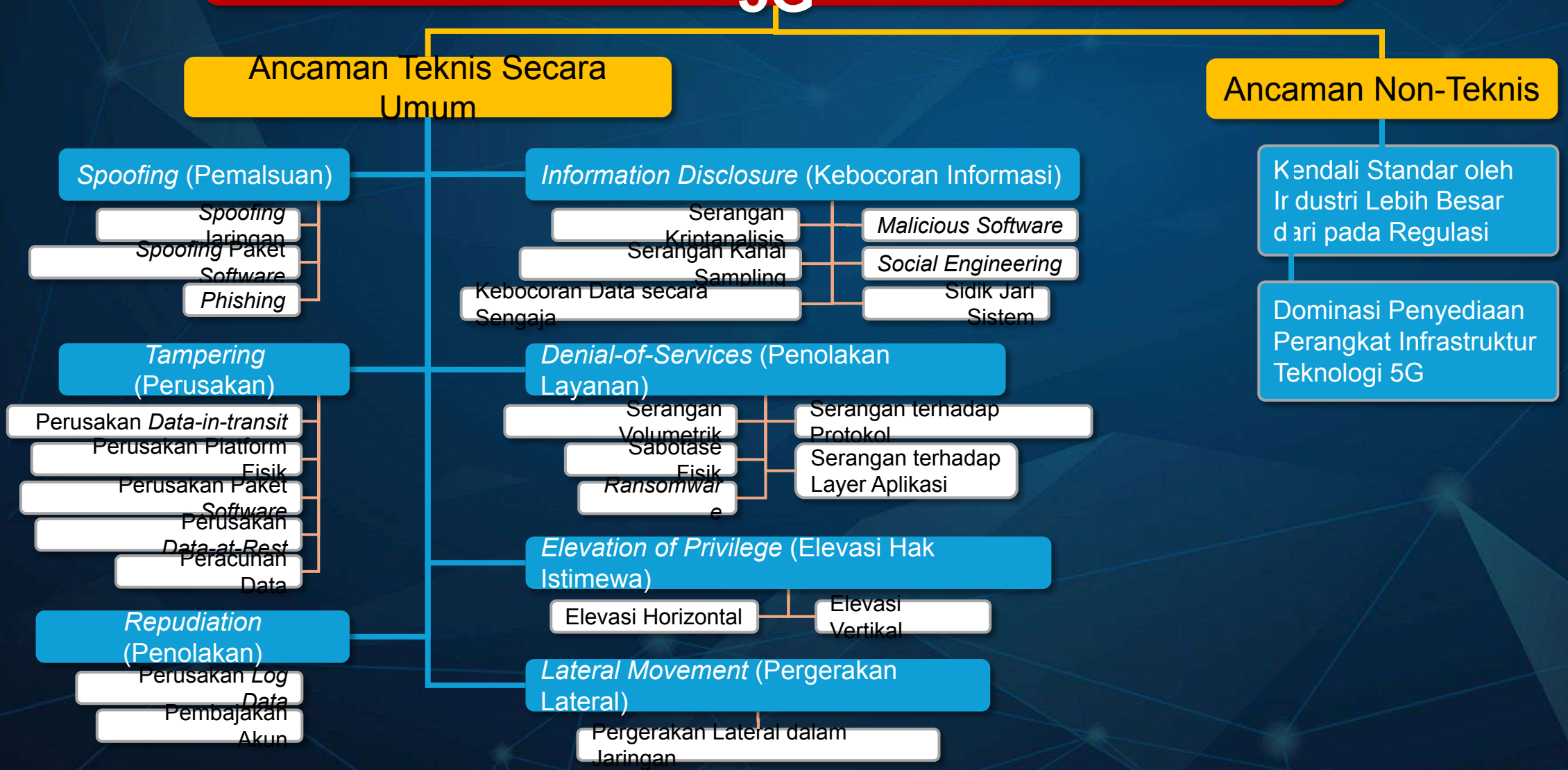
MEKANISME KEAMANAN 5G

Teknologi 5G dikembangkan dengan pendekatan *secure by design* di atas fondasi teknologi 4G/LTE dengan mekanisme dan peningkatan keamanan yang lebih maju.



Peningkatan tersebut antara lain: penggunaan algoritma kriptografi yang lebih kuat, keamanan *air interface* yang lebih baik, proteksi privasi pengguna yang lebih kuat dengan Identitas Tersembunyi Langganan (*Subscription Concealed Identity* - SUCI), kebijakan keamanan yang lebih fleksibel pada level pelanggan, autentikasi yang lebih menyatu, juga peningkatan keamanan pada saat *roaming*.

ANCAMAN KEAMANAN TEKNOLOGI 5G



KONTROL KEAMANAN TEKNOLOGI 5G

Domain Kontrol Keamanan digunakan untuk mengelompokkan praktik keamanan berdasarkan sifatnya dikaitkan dengan tantangan keamanan yang akan dimitigasi.
Domain kontrol yang digunakan dalam kajian ini sebagai berikut:

1. **Kontrol Teknis**
2. **Kontrol Fisik**
3. **Kontrol Operasional**
4. **Kontrol SDM, dan**
5. **Kontrol Kelembagaan**

Jenis Kontrol menjelaskan ketika metode kontrol keamanan tertentu digunakan sehubungan dengan terjadinya insiden keamanan informasi. Hal ini mencakup jenis-jenis kontrol berikut ini:

1. **Preventif**: kontrol yang diimplementasikan sebelum insiden diketahui untuk mencegah terjadinya insiden keamanan.
2. **Detektif**: kontrol yang diimplementasikan secara terus menerus selama pengoperasian sistem untuk mengidentifikasi insiden keamanan ketika terjadi.
3. **Korektif**: kontrol yang diterapkan selama dan setelah terjadinya insiden, misalnya untuk meminimalkan dampak insiden keamanan dan untuk pulih dari situasi yang merugikan.

KONTROL TEKNIS - UMUM

No	Kontrol	Prioritas	Tindakan Pengendalian	Penanggung-jawab
1	*System Engineering* yang Aman	Kritikal	Prinsip-prinsip desain dan pengembangan sistem yang aman harus diintegrasikan ke dalam proses rekayasa organisasi. Harus dipastikan bahwa prinsip-prinsip desain dan pengembangan sistem yang aman diintegrasikan ke dalam proses rekayasa organisasi.	Pemasok
2	*Network Engineering* yang Aman	Kritikal	Disarankan untuk memastikan bahwa prinsip-prinsip desain jaringan yang aman diintegrasikan ke dalam proses engineering (rekayasa) organisasi	Operator
3	Algoritma Kriptografi yang Aman	Kritikal	Algoritma kriptografi yang aman harus digunakan untuk melindungi informasi dalam perjalanan dan penyimpanan	Operator
4	Manajemen Identitas dan Akses	Kritikal	Sebaiknya dibuat satu sumber informasi tunggal yang tepercaya untuk identitas digital yang digunakan untuk mengoperasikan dan memelihara sistem 5G, kredensial dan izin yang terkait	Operator
5	Manajemen Kunci	Kritikal	Informasi rahasia untuk enkripsi yang digunakan oleh sistem 5G harus dikelola dan disimpan dengan aman	Pemasok dan Operator
6	Prosedur *Boot* yang aman	Kritikal	Keakuratan firmware tingkat rendah dan komponen OS selama boot-up harus dipastikan	Pemasok dan Operator
7	Pemantauan integritas sistem	High	Disarankan untuk memastikan keakuratan informasi yang disimpan secara lokal selama pengoperasian sistem	Pemasok dan Operator
8	Komunikasi manajemen yang Aman	Kritikal	Harus dipastikan bahwa semua alat operasional dan protokol menyediakan autentikasi timbal balik antara rekan-rekan komunikasi, kerahasiaan dan integritas data yang dikirimkan	Operator
9	Koleksi *log file* dan *storage* yang aman	Kritikal	Disarankan untuk memastikan perlindungan data log sistem selama pembuatan, pemindahan, dan penyimpanan di tempat penyimpanan pusat	Operator

REGULASI KSS DI INDONESIA

UU 1/2024 - Perubahan UU 11/2008 tentang ITE | UU 27/2022 - PDP | UU 23/2014 - Pemda

PP 71/2019 - PSTE

Perpres 47/2023 tentang Strategi Keamanan Siber Nasional

1. Per. BSSN 2/2024 - Manajemen Krisis Siber
2. Per BSSN 5/2024 - Rencana Aksi Nasional SKSN

Per. BSSN 8/2020 - Sistem Pengamanan dalam PSE

Perpres 82/2022 - Pelindungan IIV

1. Per. BSSN 7/2023 - Identifikasi IIV
2. Per. BSSN 8/2023 - Kerangka Kerja IIV
3. Per. BSSN 9/2023 - Peningkatan Kapasitas SDM
4. Per. BSSN 10/2023 - Pengukuran Maturitas Keamanan Siber
5. Per. BSSN 1/2024 - Pengelolaan Insiden Siber

Perpres 53/2017 dan 28/2021 - BSSN

Per. BSSN 10/2019 - Pelaksanaan Persandian untuk Pengamanan Informasi di Pemda

Per. BSSN 7/2020 - Pemberian Rekomendasi dan Pemberian Register LSP Bidang Keamanan Siber

Per. BSSN 8/2021 - Penyelenggaraan Penilaian Kesiapan Penerapan SNI/ISO 27001 menggunakan Indeks KAMI

Per. BSSN 7/2024 - Penyelenggaraan Penilaian Kesesuaian Kriteria Umum untuk Evaluasi Keamanan Teknologi Informasi Indonesia

Per. BSSN 11/2024 - Penyelenggaraan Algoritma Kriptografi Indonesia dan Penilaian Kesesuaian Keamanan Modul Kriptografi

PP 12/2017 - Pembinaan dan Pengawasan Penyelenggaraan Pemda

Perpres 95/2018 - SPBE

Per. BSSN 4/2021 - Pedoman Manajemen Keamanan Informasi SPBE dan Standar Teknis dan Prosedur Keamanan SPBE

Per. BSSN 8/2024 - Standar dan Tata Cara Pelaksanaan Audit Keamanan SPBE

STRATEGI DAN KEBIJAKAN TEKNOLOGI DALAM MENJAGA KEAMANAN SIBER DI INDONESIA

SNI di bidang Keamanan Informasi, Keamanan Siber, dan Perlindungan Privasi

- BSSN melalui Komite Teknis 35-04 menyusun Rancangan Standar Nasional Indonesia (RSNI) di bidang Keamanan Informasi, Keamanan Siber, dan Perlindungan Privasi.
- Badan Standardisasi Nasional (BSN) menetapkan RSNI yang diajukan oleh Komite Teknis 35-04 menjadi Standar Nasional Indonesia (SNI).

Kajian Keamanan Teknologi Terkini

- Pesatnya perkembangan teknologi meningkatkan risiko keamanan, sehingga BSSN melakukan kajian mendalam terhadap keamanan teknologi-teknologi terkini dalam rangka penyusunan kebijakan untuk melindungi dari ancaman siber.

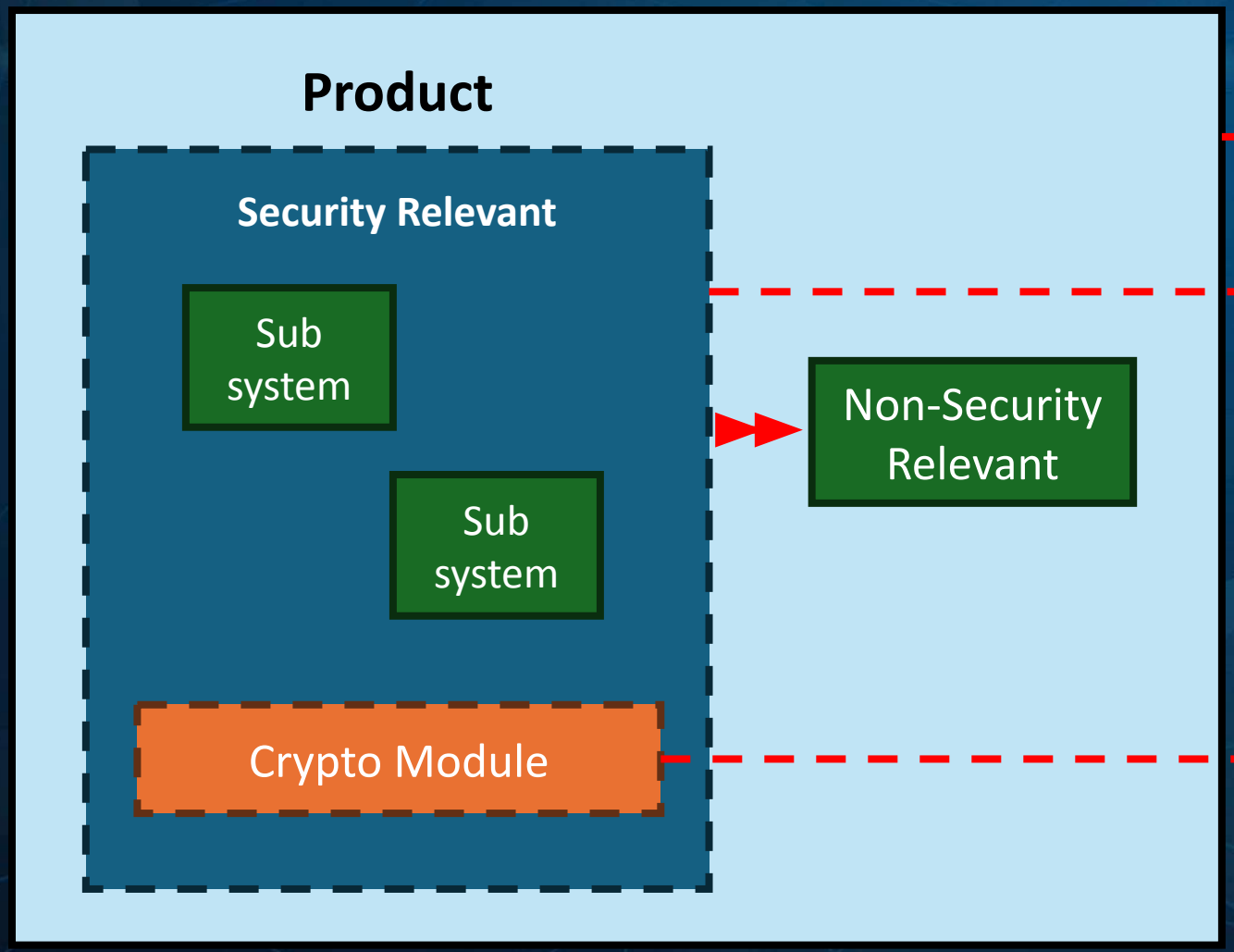
Sertifikasi Produk Teknologi Keamanan Siber dan Sandi

- BSSN menetapkan Peraturan BSSN No 7 Tahun 2024 tentang Penyelenggaraan Penilaian Kesesuaian Kriteria Umum untuk Evaluasi Keamanan Teknologi Informasi Indonesia.
- LSPro dan Laboratorium Uji BSSN melakukan sertifikasi keamanan terhadap produk teknologi informasi.

Standar Algoritma Kriptografi Indonesia

- BSSN menetapkan Peraturan BSSN No 11 Tahun 2024 tentang Penyelenggaraan Algoritma Kritografi Indonesia dan Penilaian Kesesuaian Keamanan Modul Kriptografi.
- BSSN akan menerbitkan Peraturan tentang Daftar Algoritma Kriptografi Indonesia yang dapat diimplementasikan oleh Penyelenggara Sistem Elektronik.

SECURITY BOUNDARY PRODUK SIBER DAN SANDI



EKOSISTEM JAMINAN KEAMANAN PRODUK SIBER DAN SANDI

PRODUSEN

PRODUK SIBER DAN SANDI

PEMERINTAH

PERATURAN/ KEBIJAKAN PENILAIAN KESESUAIAN KEAMANAN PRODUK SIBER DAN SANDI

PENYELENGGARA

Lembaga Sertifikasi Produk BSSN

Laboratorium Pengujian Badan Siber dan Sandi Negara

Laboratorium Pemerintah/Swasta

KAN

PENGUJIAN DAN SERTIFIKASI KEAMANAN PRODUK SIBER DAN SANDI

PEMERINTAH

KOMTEK 35-04

STANDAR/KRITERIA

SNI ISO IEC Common Criteria

PENGGUNA

PRODUK SIBER DAN SANDI YANG TERSERTIFIKASI KEAMANAN

bangga melayani bangsa

Terima Kasih

Direktorat Kebijakan Teknologi Keamanan Siber dan Sandi,
Deputi I – BSSN
2024

02.

Strategy for Sustainable Digital Infrastructure Development through IPv6 and 5.5G Networks - Amalia Adininggar Widyasanti (Kementrian PPN/Bappenas)

Kementerian PPN/
Bappenas

INDONESIA EMAS 2045

Strategy for Sustainable Digital Infrastructure Development through IPv6 and 5.5G Networks

Amalia Adininggar Widyasanti

Deputy Minister for Economic Affairs
Ministry of National Development Planning/BAPPENAS

Kementerian PPN/ Bappenas

INDONESIA EMAS 2045

Achievements of Indonesia's Digital Infrastructure from 2020 to 2024

Spectrum & Mobile Broadband

- **Total allocated spectrum** is expected to be up to **2047 Mhz** until 2024.
- Average Mobile download speed is **29.05Mbps** as of July 2024, global ranking of **82** *(source: Speedtest)*

Data Center

- Data center capacity is estimated to **reach 210 MW in 2024**
- Indonesia's data centers are spread across **23 cities**, with **107 centers** from **39 providers**

Fixed Broadband

- Number of **Fixed subscribers 14.7 million** in 2023
- Ave. **fixed broadband download speed of 31.75 Mbps** as of July'24, global ranking of 121 *(source: Speedtest)*

Cyber Security

- No of recorded **cyber attacks reached > 360 million** in the first ten months of 2023 *(source BSSN)*
- Indonesia's **cyber security index in 2023 is 63.64** out of 100 points, placing in **49th place out of 176 countries**

Indonesia's Digital Competitiveness in ASEAN

In digital infrastructure, Indonesia lags significantly behind its neighboring countries.

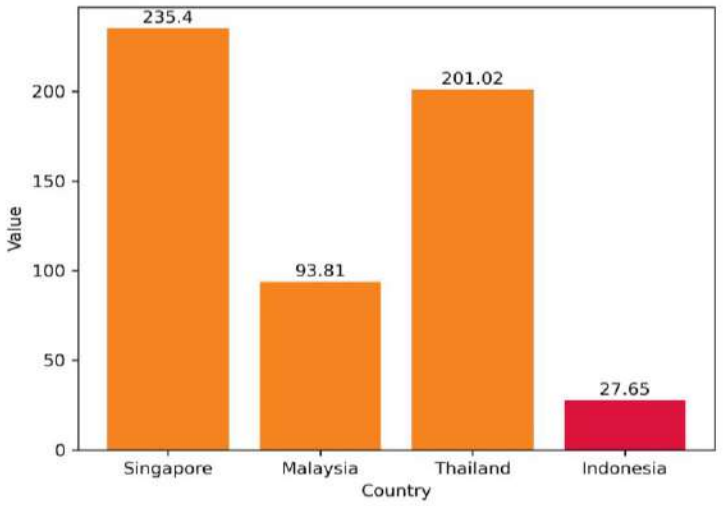
>40% **No.1** Indonesia accounts for more than 40% of ASEAN's **population, economic volume, and digital economy capacity.** However, the relatively backward infrastructure is out of balance with its economic and social status.

Digital Economy

- Indonesia became Southeast Asia's **second-largest digital investment destination** in 2023,
- Digital economy investment was nearly US$22 billion, second only to Singapore (US$141 billion)

Despite the digital economy's great potential and strong growth, Indonesia's digital facilities and services have been **constrained by its sub-optimal digital infrastructure**

Fixed Broadband Download Speed in some ASEAN Countries



Source: Ookla, 2023

Digital Infrastructure

- **Rural areas have not been fully covered with 4G,**
- **5G network deployment is stagnant,**
- Fixed broadband coverage and download rates are **far behind** those in neighboring countries such as Singapore, Malaysia, and Thailand.
- The speed (rate) is still around 30 Mbps or **ranked below the top 100** in the world,
- Fiber optic coverage **still below 30%,**
- 12,548 villages (15%) **not yet covered by a broadband internet network** (4G),
- From 5,950 populated islands in Indonesia the **fiber optic network has not yet reached** around 654 islands (11%).

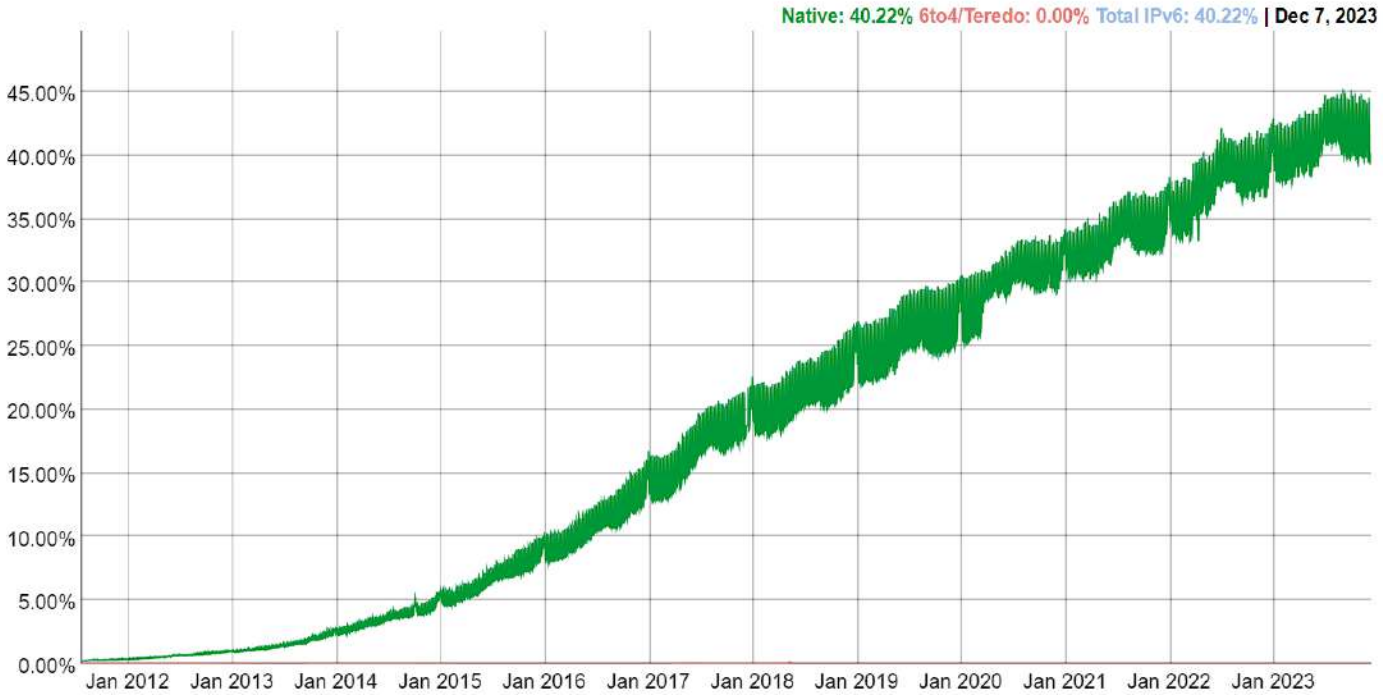
Source: ITU

Global IPv6 adoption is increasing exponentially. Compared to Its Neighbors, IPv6 Adoption in Indonesia Relatively Slow

IPv6 adoption is increasing exponentially over year. As of December 7, 2023, IPv6 adoption in the world has reached 40.22 percent.

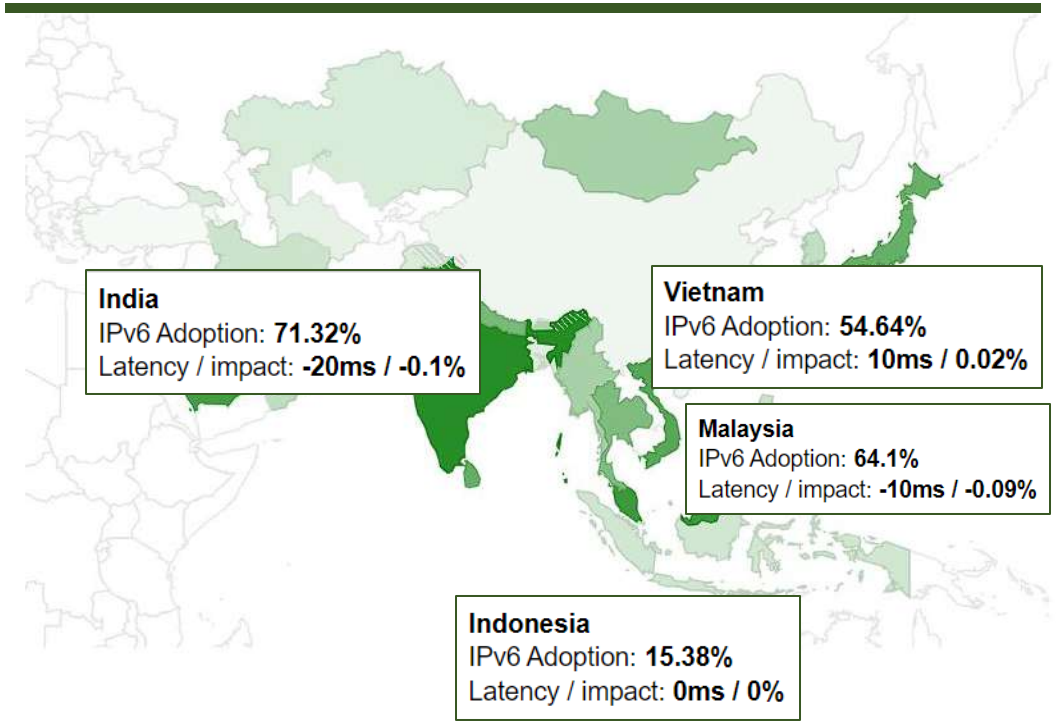
IPv6 Adoption

The graph shows the percentage of users that access Google over IPv6.



Source: Google, 2023

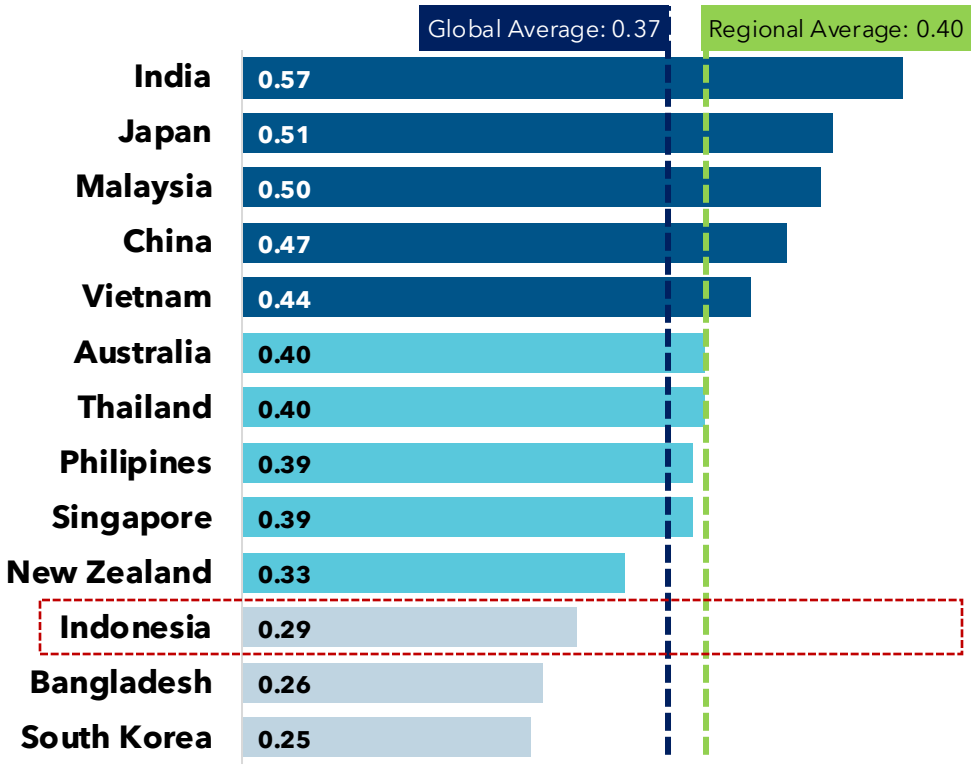
IPv6 Adoption in Asia Pacific



Regions where IPv6 is more widely deployed **(the darker the green, the greater the deployment)** and users experience infrequent issues connecting to IPv6-enabled websites.

IPv6 Deployment Status in Indonesia is in Medium Level

Country ranking of global IPv6 Development Index – Asia Pacific



Source: Roland Berger, 2023

Indonesia faces weak incentives from leading ISPs and content providers to migrate to IPv6.

However, Indonesia is one of the leading countries in the world in implementing the latest IPv6 technology.

Indonesia ranks 74 in 92 countries, with a score of 0.29, and is grouped as an adopter. This means that IPv6 deployment status in Indonesia is in medium level.

	Overall score	IPv6 penetration				Performance	Innovation
		Planning	Network	Content	Users	Performance	Overall rating based on standards, policy, academics and application
Front-runners	0.50	0.38	0.40	0.38	0.90	0.47	0.44
Adopters	0.36	0.39	0.38	0.38	0.27	0.38	0.36
Starters	0.26	0.33	0.31	0.35	0.04	0.25	0.31
Indonesia **Ranking**	0.29 **(74)**	0.33 **(63)**	0.31 **(84)**	0.30 **(88)**	0.21 **(51)**	0.21 **(75)**	0.39 **(41)**

Source: Roland Berger, 2023

The Transition to IPv6 will Encourage Digital Transformation

Widespread IPv6 deployment is crucial for an intelligent, **connected world in the digital economy.** Active implementation of innovative IPv6 applications is essential for **higher-quality development and improved capabilities in the 5G and cloud era.**

Necessity of Developing IPv6 and IPE

Necessity of Transition to IPv6

The booming digital economy boost strong demand for IP addresses

Balance digital power and provide equal access for all

Alternative technologies and more sustainable than IPv4

Importance of IPv6 Enhanced Innovation

Technological capabilities support digital transformation of various industries

Improve network efficiency and performance, reduce operation and maintenance costs

Ensure network security, making cloud and IoT services safer and more reliable

Source: Roland Berger analysis

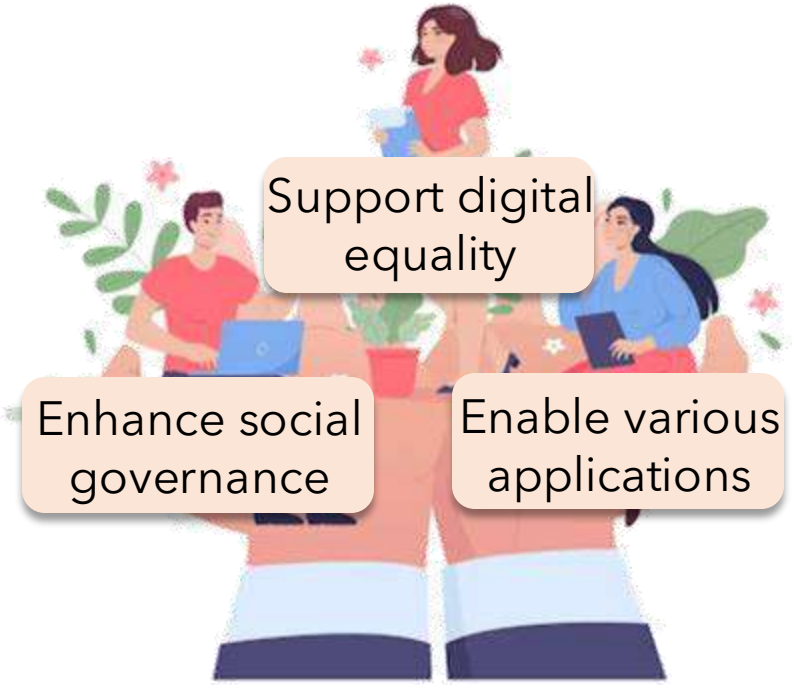
IPv6 Enhances Innovation and Brings Economic and Social Benefits

Economic and Social benefits of IPv6

Promotes Sustainable Economic Growth

- Empower digital economy transformation
- Drive innovation and entrepreneurship
- Improve quality and efficiency
- Improve security and optimize costs

Improves Society and Well being



Source: Roland Berger analysis

How IPv6 and IPv6+ affects the Industries?

Cost reduction

Derived from:

- ✓ preventing data security issues of different types
- ✓ the impact of improved efficiency

Value creation

created by innovative technologies and their application scenarios.

Impact Valuation from using IPv6 and IPv6+

Potential global value
on multiple industry sectors
$10.8 trillion
in 2030

4.8%
of the total real industry output
in 2030

Source: Roland Berger analysis

Quantitative and Qualitative Impact of IPv6 and IPv6+ on Industry Sectors

	IPv6 and IPv6+ Qualitative impact					IPv6 and IPv6+ Quantitative impact	
			Empower innovation				
Industry	Improved security	Increased efficiency	5G	IoT	Cloud	Value [bn]	% of industry sales
Information & communication	●	●	●	○	●	769	6.4%
Public service & utilities	●	●	●	●	●	1,160	5.9%
Manufacturing	●	●	●	●	●	4,408	5.8%
Transport. & storage	○	●	●	●	●	535	5.6%
Hospitality & entertainment	●	○	○	●	○	309	5.4%
Health & social work	●	●	○	○	●	479	5.0%
Education	●	○	○	○	●	300	4.6%
Prof. services & finance	●	○	○	○	●	1,223	4.3%
Energy	●	○	●	●	●	177	4.0%
Wholesale & retail	●	○	●	○	○	708	3.7%
Ag., forestry & fishing	○	○	●	●	○	180	2.7%
Construction & real estate	○	○	○	○	●	636	2.3%
Total						10,882	4.8%

Low impact ○ ○ ● ● High impact

The industries most affected by the use of IPv6 and IPv6+ quantitatively and qualitatively are the **Information & Communications and Public Services & Utilities industries.**

The Estimated Impact of IPv6 on Indonesia's Industries

In Indonesia, the use of IPv6 and IPv6+ will have high impacts on the Information & Communication sector through the use of 5G and on the Education sector through the use of the Cloud.

Potential value
of IPv6 deployment
across multiple industries
$78 billion
by 2025

3%
of the total real industries output
in 2025

Estimated Impact of IPv6 and IPv6+ on Various Sectors in Indonesia

	Qualitative impact by IPv6					Quantitative impact by IPv6	
	Infrastructure of digital economy			Improved security	Increased efficiency		
Industry	5G	IoT	Cloud	Improved security	Increased efficiency	Value [mn $]	% of industry sales
Health & social work	○	○	●	○	●	1,333	4.8%
Public service & utilities	●	○	○	○	●	7,191	4.8%
Manufacturing	●	●	●	○	○	18,983	4.6%
Information & communication	●	○	○	○	○	5,652	4.5%
Transport. & storage	●	○	●	○	○	5,773	3.5%
Education	○	○	●	○	○	2,339	3.3%
Prof. services & finance	○	○	●	○	○	6,378	3.3%
Hospitality & entertainment	○	○	●	○	○	3,402	3.2%
Wholesale & retail	○	○	●	○	○	9,019	2.8%
Energy	○	○	○	○	○	3,611	2.4%
Construction & real estate	○	○	○	○	○	9,190	1.7%
Ag., forestry & fishing	●	○	○	○	○	4,923	1.7%
Total						77,794	3.0%

Low impact ○ ○ ● ● High impact

Source: Desktop research; Roland Berger analysis

The Impact of IPv6 and IPv6+ on Industry Sectors

Impact of IPv6 and IPv6+ on Various Sectors

Industry	Application (some examples)	Improved security	Increased efficiency	Innovation
Manufacturing	**Smart manufacturing**: production visualization, remote operation			
Info. & communication	**Intelligent operations**: predictive maintenance, intelligent detection			
Wholesale & retail	**Smart shelves**: environment monitoring, automatic warning			
Public service &utilities	**Smart water system**: real-time monitoring of pipe network operation			
Prof. services & finance	**Risk control platform**: warning, identification and prevention			
Transport. & storage	**Driverless**: responsive navigation and operation with low latency			
Health & social work	**Telemedicine**: remote physician coaching operations			
Ag., forestry & fishing	**Smart agriculture**: remote monitoring, real-time data analysis			
Construction& real estate	**Operations security**: wearable devices monitor workers' moving line			
Energy	**Smart drilling system**: soil detection, automatic adjustment of drilling			
Education	**Smart classroom**: interactive distance learning, AR classroom			
Hospitality & entertainment	**Mobile games**: real-time interaction and enhanced experience			
		Low impact		High

Source: Expert interview, desktop research; Roland Berger analysis

The Information and Communication sector has the highest impact from IPv6 and IPv6+ through reduced efficiency

Ex: Implementation of intelligent operations (predictive maintenance, intelligent detection).

The Public Services and Utilities sector has the highest impact from IPv6 and IPv6+ through reduced efficiency

Ex: Use of smart water system (real-time monitoring of pipe network operation).

The Transportation and storage sector has received the highest impact from IPv6 and IPv6+ through innovation

Ex: Implementation of driverless (responsive navigation and operation with low latency).

The Health and Social work sector has seen the greatest impact from IPv6 and IPv6+ through security improvements

Ex: Implementation of telemedicine (remote physician coaching operations).

The Hospitality and Entertainment sector has seen the greatest impact from IPv6 and IPv6+ through security improvements

Ex: Implementation of mobile games (real-time interaction and enhanced experience).

Besides IPv6, The 5.5G Network is Expected to Have a Significant Impact on The Economy in Several Ways

Digital economy

Drive the development of the digital economy by providing the bandwidth and low latency needed for computationally intensive processes.

Industry innovation

Enable more efficient and insightful operations across industries, such as manufacturing, urban development, and the Internet of Things (IoT).

AI capabilities

Support the expansion of AI capabilities by facilitating large-scale automation and data analysis.

Autonomous driving

Improve autonomous driving networks, making them 10x more intelligent.

Energy efficiency

Reduce CO_2 emissions transmitted on mobile networks by 10x.

Urban infrastructure

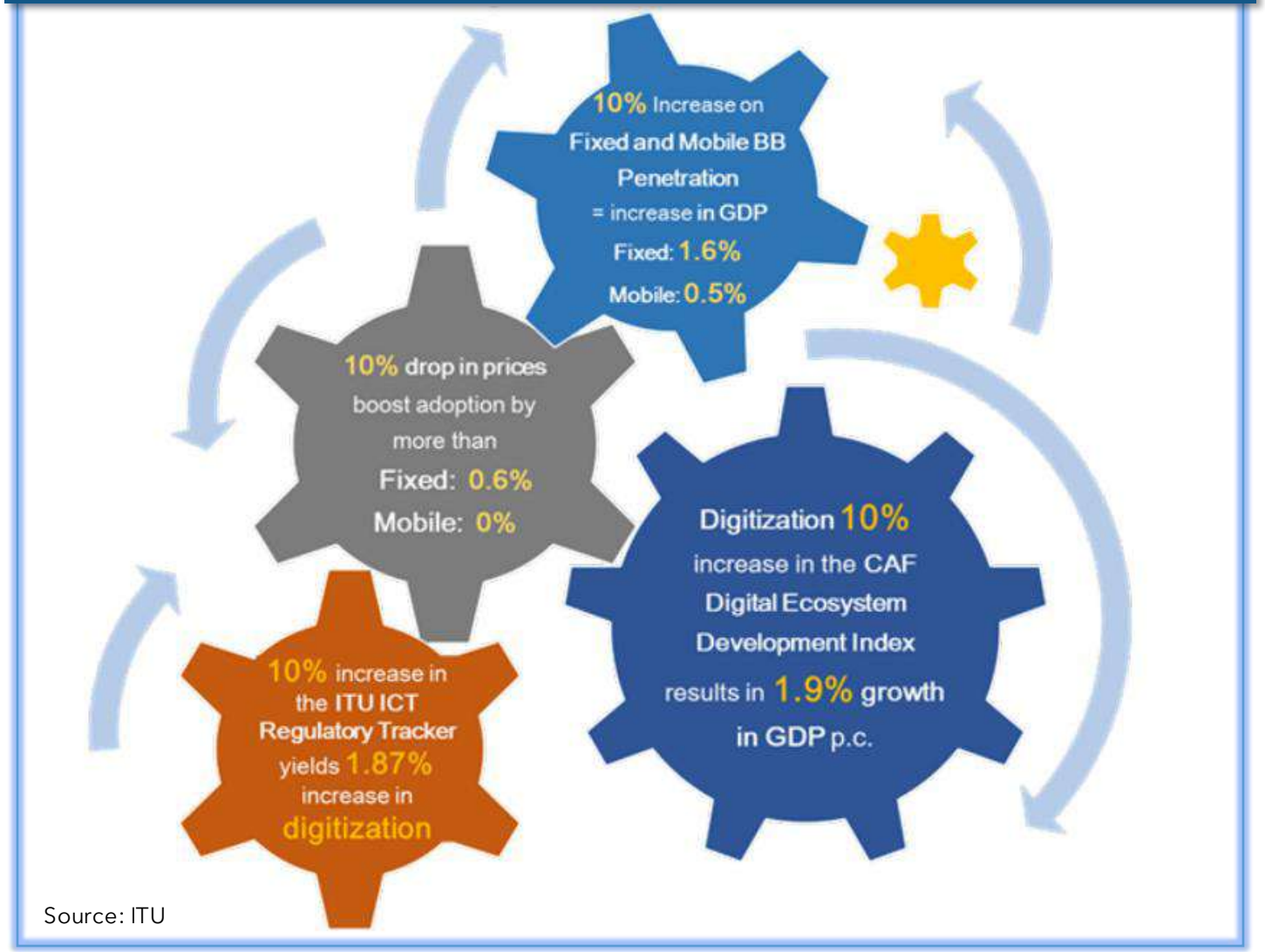
Make urban infrastructures more intelligent by automatically detecting road obstacles and notifying drivers in advance.

Telemedicine

Reduce hospital stay lengths, increase consultations, and enhance patient quality of life.

Increased Broadband Penetration in Indonesia is Expected to Have a Significant Impact on Economic Growth 2025 - 2030

Asia and Pacific: Economic Impact of Fixed and Mobile Broadband and Digitization, 2019



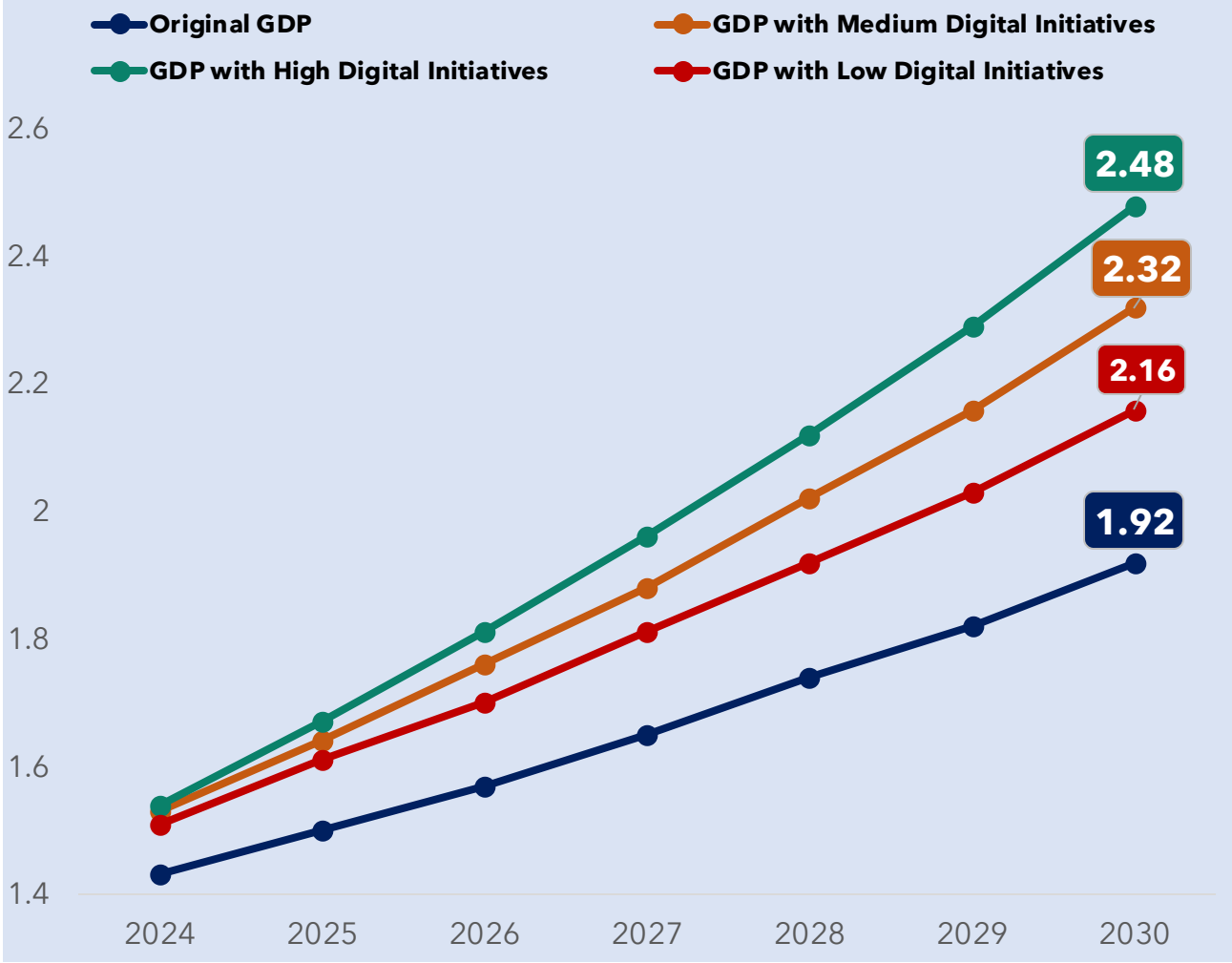
Source: ITU

Increasing broadband penetration in Indonesia is expected to significantly impact GDP Growth from 2025 to 2030

- **10% increase** in **broadband penetration** can lead to a **1% to 1.5% increase in GDP per capita.**
- This impact can be even more pronounced for developing economies like Indonesia, **with potential GDP growth increases of up to 1.38% for every 10% rise in broadband penetration**

IPv6 and 5.5G can drive Digital Transformation to Boost Indonesia's GDP

GDP Growth with Digital Initiative 2024 – 2030 (Trillion USD)



Highlight

Original GDP (without additional digital initiatives)
If there is no significant effort in digital transformation, GDP continues to grow naturally but more slowly. By 2024, GDP is projected to be **1.43 Trillion USD** and increase to **1.92 Trillion USD** by 2030.

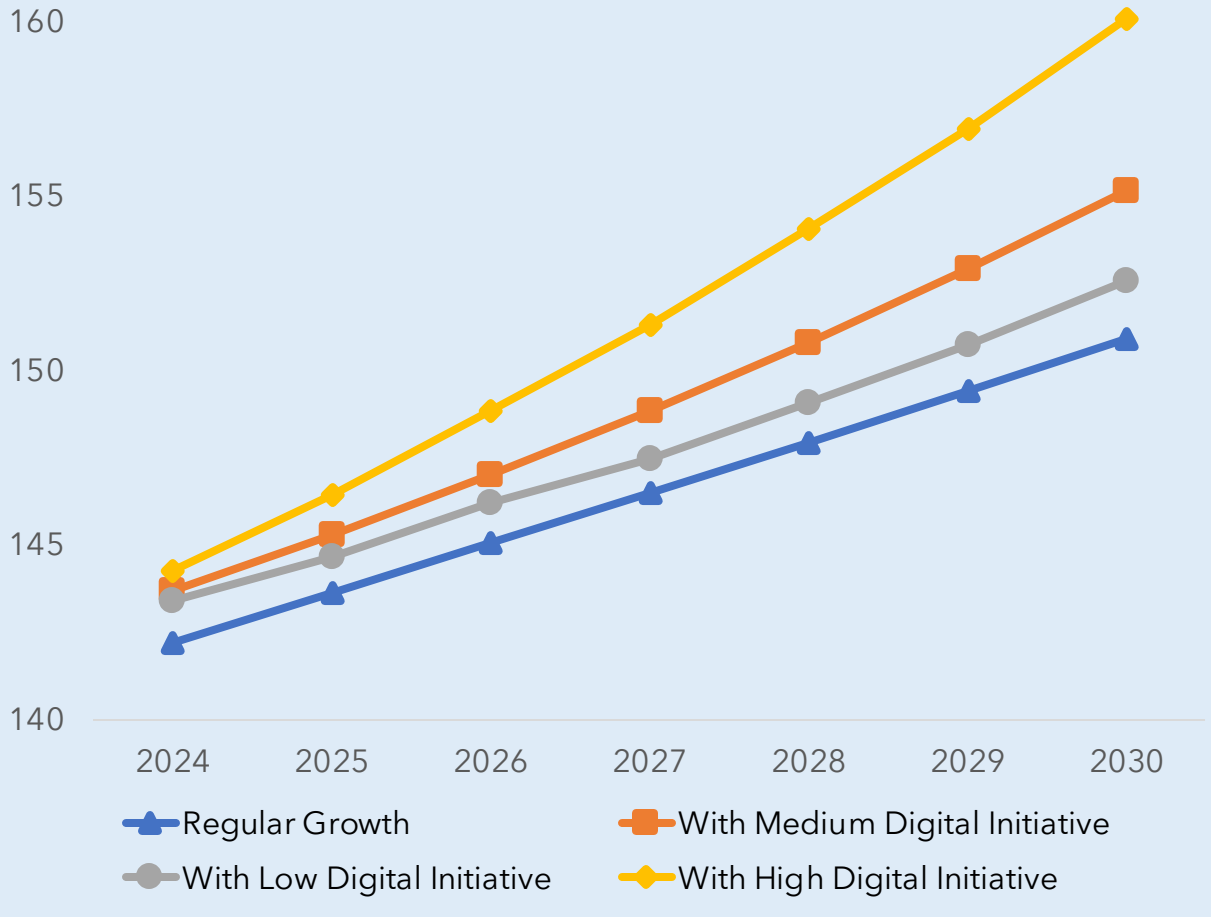
High Digital Initiatives
GDP **grows the fastest** in this scenario. By 2024, GDP is projected to be **1.54 Trillion USD**, and by 2030 it will reach **2.48 Trillion USD**.

Medium Digital Initiatives
GDP grows moderately, higher than the baseline scenario (Original GDP). By 2024, GDP is projected to be **1.53 Trillion USD** and reach **2.32 Trillion USD** in 2030.

Low Digital Initiatives
GDP growth is slower than in the medium and high digital scenarios. GDP in 2024 is **1.51 Trillion USD**, and in 2030 it is **2.16 Trillion USD**.

IPv6 and 5.5G also Encourage Digital Transformation to Create Substantial Employment Opportunities

Job Creation with Digital Initiative 2024-2030 (Millions People)



Highlight

- **The digital transformation is anticipated to create substantial employment opportunities.** Indonesia will need approximately nine million digital sector workers over the next 15 years, digitalization initiative impact in 2030 will push the workers number from 150.9 million towards 152.2 million (low scenario) up to 160 million (high scenario).
- **This surge in demand** for digital skills will not only reduce unemployment but also enhance the overall quality of the workforce

The Lingkage of Digital Sector Development in the Redesign of Indonesia's Economic Transformation

Digital Sector Planning Map in Economic Transformation

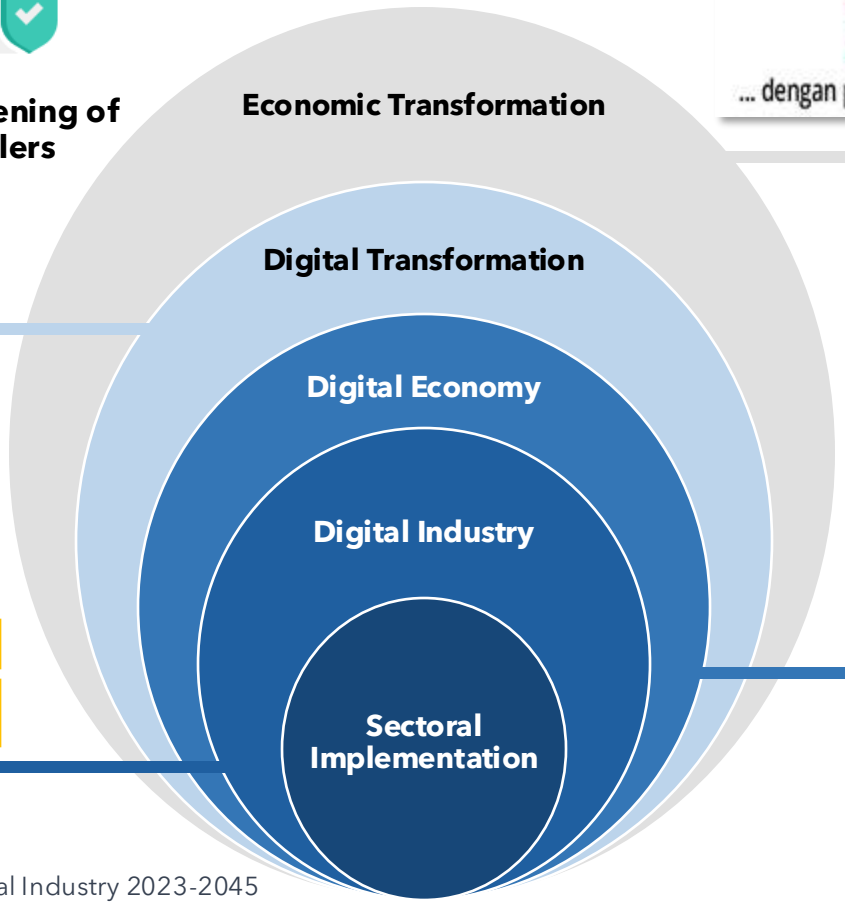
Digital Infrastructure

Utilization of ICT Infrastructure: Government, Public Services, Social Assistance, Education, Healthcare, Trade, Industry

Strengthening of Enablers

Focused on 6 Priority Areas as Catalyst

Governance	Healthcare	Trade
Education	Procurement & Logistics	Industry 4.0



Redesigning Indonesia's Economy to Achieve Inclusive and Sustainable Growth in line with Indonesia's Vision 2045

Strategies:

- Acceleration of Business and Industry Digitization
- Enhancement of Digital Capacity and Connectivity
- Cross-Sector and Cross-Institution Coordination

8 Focus Sectors:

Agriculture and Fisheries; Manufacturing; Trade; Education; Healthcare; Finance; Tourism; MSMEs

Source: Master Plan for the Development of Indonesia's Digital Industry 2023-2045

Digital Transformation is Part of Economic Transformation

IPv6 and 5.5G Implementation will Support Digital Transformation

ECONOMIC TRANSFORMATION

- **IE 4** Science and Technology, Innovation and Economic Productivity
- **IE 5** Green Economy Implementation
- **IE 6** Digital Transformation
- **IE 7** Domestic and Global Economic Integration
- **IE 8** Urban Areas as Centers of Economic Growth

Economic transformation requires mainstreaming digital transformation through:

1. Super platform digital
2. Regulation and institution
3. Digital talent production
4. Digital infrastructure and technology
5. Data enablement
6. Financing technologies
7. R&D

Strategic Issue and Policy Direction for Implementing Digital Transformation

Strategic Issues

- Limited and inadequate digital infrastructure or internet access in rural and remote areas
- Lack of digital skills among the workforce and broader society is also a significant challenge
- Cyberattacks, data theft, and information leaks are real risks
- It is necessary to have a clear policy framework to address issues such as data protection, privacy, e-commerce, and technological innovation

2045 Goal **TOP 20** **Global digital competitiveness index (ranking)**

Policy Direction for Digital Transformation

- Establishment of regulations and institutions (Law) for the basis of digital transformation development
- Supply Side Development (such as the development of digital infrastructure and services in an equitable, quality, and inclusive manner)
- Development of Digital Utilization
- Proficiency in digital technology based on digital research and innovation
- Development of finance and incentive systems that support digital transformation
- Data integration (through Satu Data Indonesia)
- Strengthening Cyber Security
- Establishment of Indonesia Digital Super Platform
- Digital Industry Development to strengthen the supply side of digital transformation

Transformation in The Digital Field to Support Efficiency and Productivity

- Development of fiber optics up to the village/village level
- Improved broadband connectivity
- Development of national data centers
- Provision of digital infrastructure in special regions

Infrastructure

- Provision of HR scholarships
- Increase the number of qualified ICT workers
- People's digital literacy
- Strengthening ICT Education

Human Resources

- Accelerated support for Industry and Agriculture 4.0
- Increase in e-commerce transactions
- Digital Security Development

Digital Economy

Digital Government

- Digitalizing public services
- Smart Cities Acceleration
- Administration integration and Public service

R & D Digital

- Financing support Digital R&D
- Providing incentives for Local Developers

Kementerian PPN/ Bappenas

BAPPENAS has Prepared Digital Industry Development Masterplan to Support Consolidation of the Digital Economy in Economic Transformation

The implementation of digital transformation needs to be ensured to be benefited as much as possible by domestic businesses through opportunities that open up to respond to market potential and strengthen the digital industry supply chain.

2022 - 2024

1

Consolidation of Indonesia's Digital Industry

Planning and implementation of initiatives related to the development and compliance of Indonesia's digital industry

Outcome:

1. Strengthening the market contribution of the digital economy
2. Providing easy access to internet and digital goods to certain segments of society
3. Equitable internet quality in Indonesia
4. Establishment of regulations and policies related to the development of the digital industry

2025 - 2029

2

Strengthening Base and Accelerate Digital Industry

Acceleration and development of supporting aspects of Indonesia's digitalization

Outcome:

1. Strengthening Digital Economy Market from Six Priority Sector
2. Affordable internet in all parts of Indonesia
3. All Citizen have access to digital hardware
4. Strengthening the National Digital Industry

2030 - 2034

3

Strengthening the Digital Industry's Contribution to Economic Growth

Strengthening the role of the digital industry in Indonesia's economic growth

Outcome:

1. The digital economy market has positive contributions to economic growth
2. Affordable high-speed and high-quality Internet across Indonesia
3. The National Digital Industry dominates the national market
4. Increasing quantity and quality of digital industries

2035 - 2039

4

Increasing Competitiveness of Digital Industry

Strengthening Indonesia's Digital Industry for national and global competitiveness

Outcome:

1. The digital economy market highly contribute to economic growth
2. Increasing TKDN Value in the ICT Sector
3. Global competitiveness of Indonesia's digital industry human resources

2040 - 2045

5

Dominance and Sustainability of the Digital Industry

Maintaining the sustainability of Indonesia's digital industry infrastructure

Outcome:

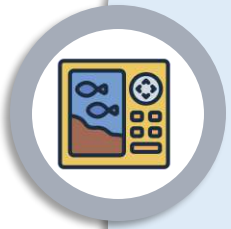
1. Investing value in ICT Sector has grows and contributes positively on economic growth
2. ICT Sector trade balance surplus
3. The National Digital Industry dominates the regional market

Source: Indonesia Digital Industry Development Master Plan 2023-2045, Bappenas/Ministry of National Development Planning

5G+ Strategy: Encouraging and Promoting Digital Application

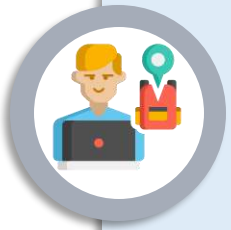
5G+ Industrial Internet

- **Promoting the integration of 5G with industrial terminals** such as AR/VR devices, remotely-controlled devices machine vision devices, and AGVS accelerate smart manufacturing and industrial intranet transformation.
- Applications in key areas like production, operations, and human-computer interaction, with scalable models for various industries.



5G+ Smart Oceans

- **Driving the application of the 5G/F5G technologies that will enhance** remote control of cargo-handling, automated port operations, and personnel safety, while driving the digitalization of ports and offshore facilities.
- Applications will include unmanned inspections, self-driving container trucks, smart aquaculture, and intelligent monitoring for marine industries.



5G+ Tourism

- **Increasing the application of enhance AR/VR content and 4K/8K Video to offer immersive, multi-view virtual tourism experiences.**
- Scenic spots and museums will provide cloud-based services and interactive digital experiences, promoting new tourism models like customized and immersive travel.

Country Examples: Implementation of 5.5G Network in China

China is a leader in 5.5G network development, with Beijing at the forefront

- China Unicom and Huawei have built a large-scale 5.5G network in Beijing that covers 70% of the city's 4th urban ring road.
- The network includes coverage in stadiums, metro stations, tunnels, residential areas, scenic spots, business districts, and universities.

The benefits of 5.5G networks:

- **Improved capacity and efficiency allow for the simultaneous connectivity of many devices.**
- **Enables businesses and governments to collect and analyze large amounts of data.**
- **Improve user experiences, drive innovation, and enhance productivity.**
- **Bridge the gap between 5G and 6G, and address issues like lag, reliability, and power consumption.**

Country Examples: Implementation of IPv6 in the China

- The **Chinese government** has achieved significant results in **driving the IPv6 transition among operators, content service providers, and key device manufacturers**
- This action was carried out through a set of **multi-level and highly binding policies**

Implications

The **Digital China strategy** outlined in the 14th Five-Year Plan is considered an example.

Recommended that governments **embrace strategy** for the digital society, government, and economy

Operators are most prone to policy influence and play the largest role in driving the deployment at the network and users' end.

The **active deployment of IPv6** can have a substantial effect in the national networks.

IPv6 Industry Sector Impact

The potential value created by deploying IPv6 across multiple industries

Total $578 bllion by 2025
(equivalent to **1.7 %** of the gross value of these industries in 2025)

IPv6 Development Status

The ranked **12** out of 92 countries with a score of **0.47**

Category of Frontrunners

China is considered a leader in development of IPv6

Source: Global IPv6 Development Report 2022

Country Examples: Implementation of IPv6 in Germany

- **Germany** is at the **forefront of IPv6 implementation globally**
- The users' natural demand for IP addresses becomes a **potent driver for IPv6 transition**
- Germany began the **deployment process early and the active public sector** has contributed significantly to the promotion of IPv6

Implications

The **government should take the lead in deploying IPv6** and then encourage the private sector to make the appropriate change.

The modernization of digital infrastructures in major industries (e.g., manufacturing) is projected to generate enormous demand for IPv6 capabilities

Governments should integrate IPv6 into industrial settings (such as smart manufacturing) and support pilot projects for its implementations

IPv6 Industry Sector Impact

The potential value created by deploying IPv6 across multiple industries

Total $288 bllion by 2025
(equivalent to **4.2 %** of the gross value of these industries in 2025)

IPv6 Development Status

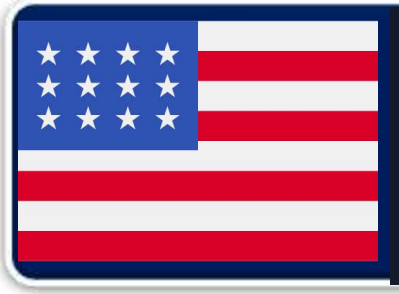
The ranked **4** out of 92 countries with a score of **0.53**

Category of Frontrunners

Germany is considered a leader in development of IPv6

Source: Global IPv6 Development Report 2022

Country Examples: Implementation of IPv6 in United States



- **The United States** is a **digitalization pioneer** and now has a **highly developed digital industry**, resulting in high demand for IP addresses
- Possesses a huge number of IPv4 addresses, whereas the setup of **IPv6 native equipment and services has not yet been optimized**, and it will take time for the relative penetration of IPv6 (in comparison to IPv4) to increase

Implications

The legislative priorities of early adopters with a **healthy digital economy** must be forward-looking, such as making the connection between IPv6 and other emerging technologies such as 5G and IoT

The **growth of the digital economy** is the driving force behind the **development of IPv6**.

Enforcing end-to-end IPv6-only networks for government services, healthcare, and education, etc., considerably increases the implementation of IPv6

IPv6 Industry Sector Impact

The potential value created by deploying IPv6 across multiple industries

Total $2.4 trillion by 2025
(equivalent to **5.2 %** of the gross value of these industries in 2025)

IPv6 Development Status

The ranked **7** out of 91 countries with a score of **0.53**

Category of Frontrunners

USA is considered a leader in development of IPv6

Source: Global IPv6 Development Report 2022

Kementerian PPN/
Bappenas

INDONESIA EMAS 2045

Thank you

03.

IPv6 Implementation & Roadmap 5.5 G in Telkom Group - Telkom Indonesia

IPv6 Implementation & Roadmap 5.5 G in Telkom Group

Jakarta, 19 December 2024

Telkom Indonesia

OUTLINE:

1. IPv6 Implementation Journey
2. IPv6 Key Aspect
   (Challenge & Solution)
3. IPv6 Lesson Learned & Recommendation
4. Roadmap Towards 5.5 G

1 IPv6 Implementation Journey

Telkom created **IPv6 Acceleration Implementation Task Force** since Q1 2021, with objective :

1. Scale up & accelerate IPv6 Implementation in Telkom customer (especially IndiHome) by maintaining its customer experience.
2. Contribute to improve IPv6 Capable Indonesia.

Preparation, Trial, and Exploration

2016 - 2020

Implement **Native IPv6** to New Customer Nationally

2021

20K IPv6 Subscribers

Based on the evaluation that native IPv6 was too risky for CX, Telkom changed its strategy to dual stack implementation.

Implement Dual Stack IPv6 to New Customer & Existing Customer (Migration)

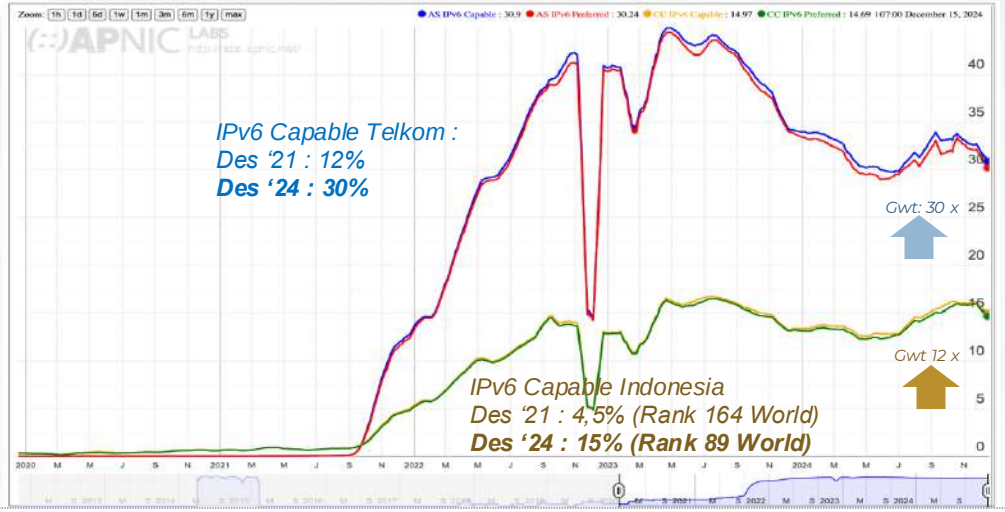
Q4 2024

~7M IPv6 Active Subscribers

Telkom commit and fully support to accelerate IPv6 implementation in Indonesia

IMPACT

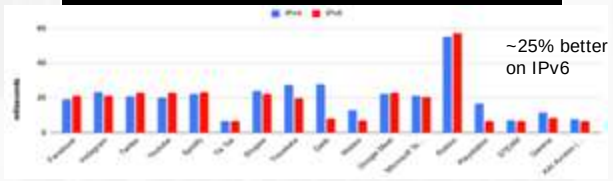
1 IPv6 implementation Telkom acceleration in last 3 year contributing IPv6 Capable Indonesia improvement significantly.



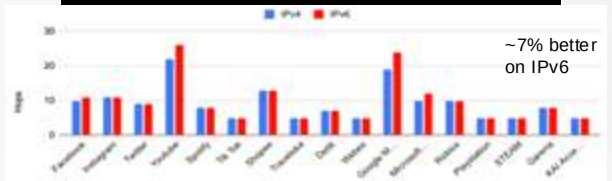
2 CX Improvement :

- ***Solving customer pain point regarding "Slow & Unstable Internet Access" caused by IPv4 NAT issue.***
- Better latency (~25%) & hop (~7%) in accessing IPv6 ready content (compare to IPv4).

Performance Comparison - Latency

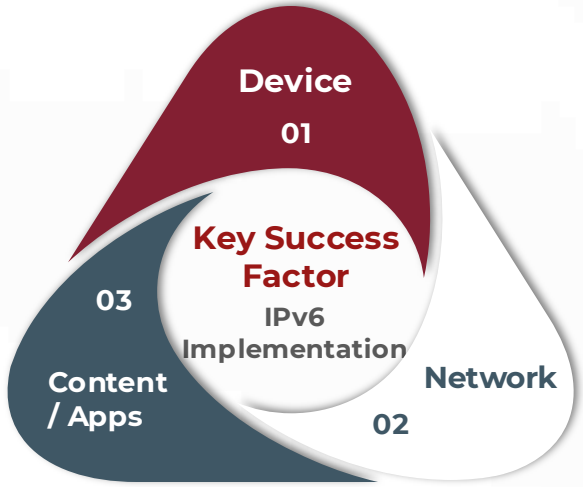


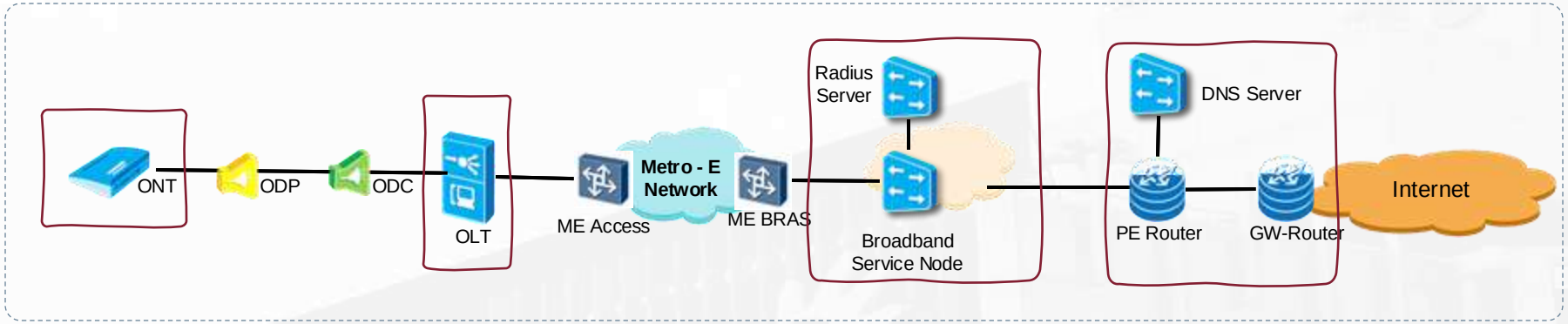
Performance Comparison - Hops



3 Business Continuity (serving ~9 M Telkom subscribers) and Cost Saving (No invest in CGNAT anymore ~ Rp 50 Billion / year).

2 IPv6 Key Aspect (Challenge & Solution)





COMPONENT	CHALLENGE	SOLUTION
ONT	▪ Old type ONT by default not support IPv6 ▪ If already support IPv6, need change configuration ONT on customer premises to IPv6 Dual Stack massively	▪ Using ACS & OSS to massively change configuration by remote and systemized. ▪ Design IPv6 enabled systemized using TR-069 ACS & OSS ▪ Mandatory requirement new type ONT supported IPv6 by default.
OLT	▪ Many types OLT, old type by default not support IPv6	▪ OLT modernization for type that not support IPv6. Mandatory requirement new type OLT supported IPv6 by default.
Broadband Service Node	▪ Old type BRAS by default not support IPv6 ▪ IPv6 usage accounting	▪ Modernization BRAS with BNG supported IPv6 ▪ Reconfiguration Radius to be able to account IPv6 usage
PE & GW Router	▪ Configure IP Prefix & BGP v6 in all Router including with external peers (CDN, IX, Upstream Transit)	▪ Coordinate intensively with external peers (CDN, IX, Upstream Transit) to updating IP Prefix v6 continously

3 IPv6 Lesson Learned & Recommendation

Lesson Learned IPv6

Perlunya **pemahaman & awareness IPv6 pada semua unit yang terlibat dalam value chain delivery layanan** internet, khususnya **strategi komunikasi yang proper kepada pelanggan** yang masih menggunakan device not support IPv6.

Untuk tetap menjaga **Customer Experience** selama proses implementasi IPv6, dilakukan **E2E Experience Test untuk setiap tipe konfigurasi** sebelum implementasi secara massive.

Pelanggan **mendapatkan latency yang lebih baik** pada konten yang sudah support IPv6 bila dibandingkan dengan IPv4 (solving issue related to NAT).

Dengan mengimplementasikan IPv6, Telkom **dapat menghemat CAPEX untuk CGNAT,** dan akan lebih optimal lagi benefitnya jika end user device dan content sudah support IPv6 seluruhnya.

Telkom's Recommendation

"KEBIJAKAN AKSELERASI IMPLEMENTASI IPv6"

berlaku untuk seluruh ekosistem internet (end user device player, service provider, content provider),

Target Pencapaian & Evaluasi Implementasi IPv6

Sehingga target yang ingin dicapai oleh Pemerintah untuk akselerasi implementasi IPv6 di Indonesia dapat tercapai.

Pemberian Stimulus dari Pemerintah

kepada pemain ekosistem internet (end user device player, ISP, NAP, Siskomdat, dan Konten) yang berhasil mengakselerasi implementasi IPv6.

IPv6 support enable as mandatory requirement

Standar bagi end user device player, service provider, maupun content provider yang menjalankan bisnisnya di Indonesia.

4 Roadmap Towards 5.5 G

Source: https://www.nokia.com/networks/5g/5g-advanced/

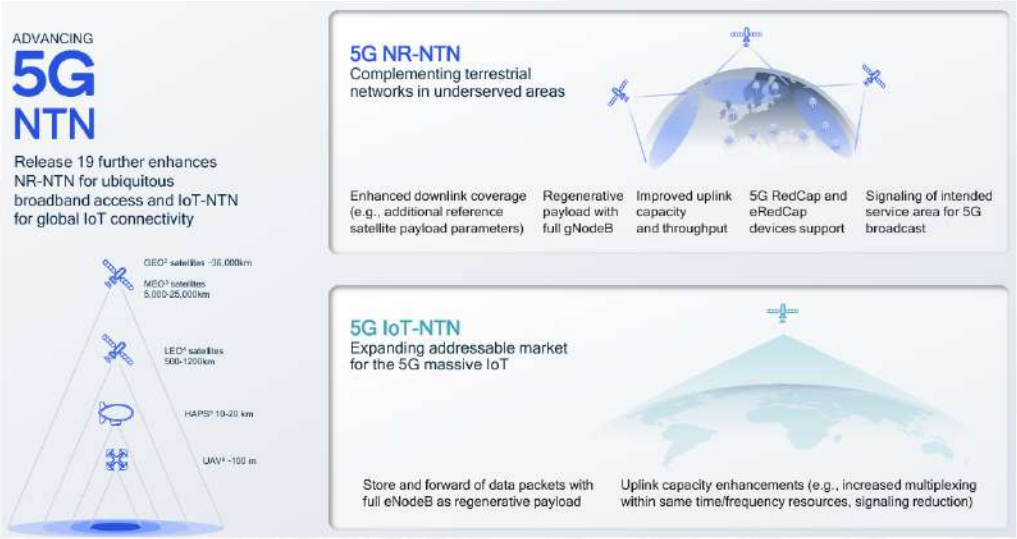
5G Advanced Rel 18 Focus

Source: 3GPP

China Unicom Beijing & Huawei Resmikan Jaringan Pintar 5G-Advanced Terintegrasi dan Berskala Besar yang Pertama di Dunia

Jumat, 22 November 2024 20:05 WIB

5G Advanced Rel 19 Focus



5G Advanced merupakan improvement dari 5G dimana terjadi peningkatan: a) Performansi: Peningkatan Massive-MIMO, penurunan waktu handover, peningkatan spectral efficiency, dan Non-terrestrial Network. b) New Service: Support Enhanced XR, Support RedCap (NR-light) device, Enhanced positioning dan time-critical support. c) Efisiensi Energi: Intent-based energy saving dan New 3GPP lean methodology Intelligent Automation: AI-based RAN, AI-based air interface. d) Menjadi enabler untuk implementasi use case 5G NR & 5G IoT pada Non-Terrestrial Network.

we appreciate your time and attention.

THANK YOU!

04.

Connected Nations, UK Report 2024 - Ofcom

Connected Nations

UK Report 2024

Published 5 December 2024

Contents

Section

1. Overview

This year's Connected Nations report provides updated data on the coverage and usage of fixed broadband and mobile networks within the UK. This includes updates on take-up of services on full-fibre and gigabit-capable networks, reporting on the further development of 4G networks and progress on the rollout of 5G networks.[1]

In addition, we report on network security and resilience, including providing an update on our monitoring programme under the Telecoms (Security) Act 2021 (TSA).

Full-fibre network availability has risen sharply, reaching over two-thirds of households

The coverage of full-fibre networks continues to expand rapidly with full-fibre now available to 69% or 20.7 million of the UK's 30.1 million households. This is an increase of 12 percentage points or 3.6 million premises between September 2023 and July 2024. Residential premises in urban areas are more likely to have full-fibre coverage than in rural areas, at 71% and 52%, respectively.

Full fibre is also available to the majority of small and medium-sized businesses (SMEs). As of July 2024, 63% of SMEs in the UK were within reach of a full-fibre network, an increase of 12 percentage points from September 2023.

Gigabit-capable coverage has expanded to 83%

The coverage of gigabit-capable broadband networks – which includes hybrid fibre coaxial (HFC) cable in addition to full fibre – has grown to reach 83% or 25 million residential premises in the UK by July 2024. This suggests the Government's target of 85% coverage by 2025 is likely to be reached.

Take-up of broadband services is increasing, as are the speeds they offer

More residential and business customers are taking up services on full-fibre networks. The take-up of services on full-fibre networks where available has risen to 35% or 7.5 million premises as of July 2024, up from 28% of all premises in May 2023.

Take-up of full fibre is notably higher in rural areas than in urban areas. Of premises with full fibre access, 52% of premises in rural areas have taken full fibre, compared to 32% in urban areas.

In a new sub-section of the report this year, we provide performance data for broadband services on different networks. Customers are moving to higher speed services, with UK average maximum download speeds up from 170 Mbit/s in 2023 to 223 Mbit/s in 2024.

[1] The topics covered in this year's report differ in some cases from our previous annual reports. For example, we are not setting out our analysis on 'crowdsourcing' as a means of measuring mobile network performance, nor are we including a chapter on climate change and telecoms networks as in last year's report. Such matters continue to be areas of interest to Ofcom, and we will consider returning to them in future Connected Nations reports or other publications.

Take-up of superfast broadband services reaches 75% threshold for review of broadband USO

The take-up of broadband services with download speeds of at least 30 Mbit/s, at premises (residential and business) across the UK, has increased from 72% to 75%. This meets a statutory threshold for Government to ask Ofcom to review specific aspects of the broadband universal service obligation (USO). We will continue to engage with Government on the broadband USO.

Fewer premises have no access to decent broadband, while satellite broadband connections are growing

Although gigabit-capable services are available to most people across the UK, there remains a small number of customers without access to a decent broadband connection from either a fixed-line or Fixed Wireless Access (FWA).[2] 58,000 or 0.2% of premises (residential and small businesses) have no access to decent broadband, a reduction from 61,000 in 2023.

Meanwhile, satellite services are expanding as a new option for people and businesses to access broadband. In 2024, there were 87,000 connections across the UK, a more than doubling from 42,000 in 2023. The majority of these customers are in rural areas, with relatively high numbers (8%) of these premises in areas with no access to decent broadband from fixed lines or FWA services.[3]

Mobile availability continues to grow

Mobile operators are steadily deploying 5G networks

The availability of mobile 5G continues to expand, with mobile network operators (MNOs) coverage ranging between 61% and 79% outside premises.[4] However, 5G coverage where all MNOs are present outside premises remains low, at 38% for our High Confidence level. We continue to see significant differences across the UK, with 5G deployed in 42% of sites in urban areas, compared with 16% of sites in rural areas.

The deployment of mobile 5G standalone sites has increased to around 3,300 sites this year, representing just below 15% of reported mobile 5G sites. These sites carry 14% of the total 5G monthly traffic representing around 3% of overall monthly mobile traffic in the UK.

4G remains the most used technology and geographic coverage has expanded

4G remains the primary technology for mobile users, reaching outside more than 99% of UK premises and carries 78% of total mobile data traffic. 4G coverage where it is available from at least one MNO has now reached 95% of the UK landmass (delivering early on one of the key targets for the Shared Rural Network programme), with 4G geographic coverage across individual MNOs in the UK rising from a range of 80-87% last year to 88-89% this year. We note the 4G geographic coverage improvements because of the Shared Rural Network programme.[5]

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[2] FWA services can be delivered by MNOs or Wireless Internet Service Providers. See page 17 of the report.
[3] UK legislation defines 'decent broadband' as providing at least 10 Mbit/s download and 1 Mbit/s upload speeds.
[4] At our High Confidence level.
[5] Ofcom, Mobile coverage obligations.

We are working to improve our mobile reporting

Current coverage reporting at national and local level (mobile coverage web-checker), based on existing signal strength predictions from the MNOs, has some limitations and does not always reflect consumers' lived experience. We are improving our coverage and performance reporting over the next 12 months, including overhauling our mobile web-checker in the summer.

Mobile traffic continues to grow at a slower pace

Total monthly mobile traffic overall has grown by 18% this year to 1069 PB[6], at a slower pace compared to the 25% growth observed between 2022 and 2023. Traffic carried on 5G represents around 21% of total monthly traffic, however it has seen the highest increase by approximately 50%, from 151 PB in 2023 to 227 PB in 2024.

The phasing out of legacy mobile networks has begun

MNOs have begun phasing out their 3G networks, with two operators having completed the process, and have committed to shutting down their 2G networks by 2033. The number of customers using devices reliant on 2G or 3G connectivity has fallen from 2.4 million to 2.1 million.[7]

We are stepping up our monitoring of network security and resilience

In this report, we provide an update on our TSA monitoring programme. We observe significant investment by providers to align their processes with their new legal obligations. We note the importance of this work, given the increased number of actors and capabilities posing a threat to telecoms infrastructure.

Meanwhile, there has been an increase in the number of significant network resilience incidents reported to us. This includes a 45% rise in incidents regarding the legacy public switched telephone network (PSTN), though there was a 55% decrease in the number of PSTN service hours lost, as increasing numbers of customers have moved to digital voice services.

Nations and interactive reports

Alongside this UK report, we are also publishing separate reports for each of the UK's four nations, including updates on fixed and mobile availability in these nations. Additionally, we publish an interactive report that allows users to explore the data in further detail, including looking at network coverage in their local area and tracking trends over time.

These reports support our objective of making communications work for everyone and promoting high-quality, reliable and widely available networks. It also fulfils Ofcom's legal duty to report on the status of the UK's telecommunications infrastructure and services.

[6] 1 PB (Petabyte) is equivalent to 1,000,000 GB (Gigabyte).

[7] The 2.1 million figure only includes direct customers of MNOs and MVNOs. It does not include third-party devices, such as smart meters or devices using roaming SIMs.

2. Fixed broadband and voice

Introduction

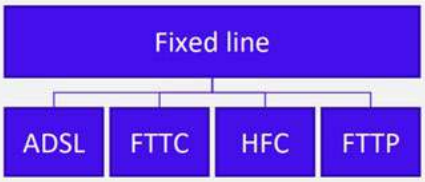
This section presents our latest findings on the roll-out of full-fibre networks and other fixed-line networks, and reports on the take-up of services over these networks. We also provide an update on the deployment of Fixed Wireless Access networks and take-up of satellite broadband services, that now offer alternative means to secure broadband connectivity for some customers. While the majority of premises now has access to a high-speed network, we provide the latest data on the small number of properties that do not yet have access to a decent broadband service. In addition, we provide data on average speeds for broadband services and report on the continuing migration of residential customers from the traditional voice network to digital voice services.

Highlights

- **Over two-thirds of the UK's 30.1 million residential premises now have access to full-fibre networks.** As of July 2024, full fibre is available to 69% or 20.7 million premises, an increase of 12 percentage points or 3.6 million premises compared to September 2023. Gigabit-capable broadband covers 83% of households or 25 million premises.
- **Take-up of services on full-fibre networks by residential and business customers has risen.** Take-up as a proportion of premises where full fibre is available is up from 28% in May 2023 to 35% in July 2024. This equates to an increase of 2.9 million new full-fibre connections for a total of 7.5 million connections.
- **As a proportion of all UK premises, the take-up of superfast broadband services has reached 75%.** This meets a statutory threshold for Government to ask Ofcom to review specific aspects of the broadband universal service obligation (USO). We will continue to engage with Government on the broadband USO. Meanwhile, the vast majority of people have access to superfast broadband from fixed lines, which is now available at 98% of premises, up from 97% last year.
- **Consumers continue to move to higher speed broadband services, with average download speeds increasing by 31%.** The average speed in 2024 is now 223 Mbit/s, up from 170 Mbit/s in 2023. This reflects customers moving onto new full-fibre networks as they become increasingly available, combined with a move to higher speed packages.
- **Some customers are taking up alternative broadband options delivered over fixed wireless and satellite networks.** The number of satellite connections has more than doubled from 42,000 to 87,000 in the last year.
- **The number of premises (both residential and small businesses) without access to decent broadband has fallen to around 58,000.** This is down from the 61,000 premises last year that were unable to access decent broadband from either fixed-line or FWA networks. We estimate that around 10,000 of these premises will be connected via publicly funded schemes by December 2025 leaving only about 48,000 premises without access to decent broadband.
- **Consumers continue to move from legacy voice services towards digital landlines.** As the switch-off of the legacy public switched telephone network (PSTN) progresses, PSTN connections now account for just over a quarter of all residential landline connections (27%).

Background: fixed-line broadband services

Fixed connections provide broadband access at specific locations, such as residential or business premises. Fixed-line broadband technologies can be broken down into different technology types.



There are **four** primary types of fixed-line connections for fixed broadband access:

- **ADSL**[8] – Copper (telephone) cables are used to connect the exchange to each premises. Maximum download speed is up to 24 Mbit/s. Actual speeds delivered diminish with length of cable from exchange to the premises.
- **Fibre to the cabinet (FTTC)** – FTTC involves fibre to the street cabinet, with copper cables connecting the cabinet to the premises. FTTC uses 'very high-speed digital subscriber line' (VDSL) technology. [9] As with ADSL, speeds diminish with length of cable, but as cabinets are generally located close to premises, maximum download speed is normally up to 80 Mbit/s.
- **Hybrid fibre coaxial (HFC) cable** – With HFC, there is fibre to a street cabinet and coaxial cable from the cabinet to the premises. Because coaxial has less signal loss compared to telephone copper wires, HFC can deliver higher speeds over longer distances. Cable broadband in the UK is provided by Virgin Media O2, and its cable network can deliver gigabit speeds.[10]
- **Full fibre or 'fibre to the premises' (FTTP)** – The connection from the exchange to the premises is provided entirely over fibre. Generally, distance to the premises does not affect the speed delivered. Full fibre can deliver gigabit speeds.[11]

We categorise fixed broadband connections based on the download speed they can provide:

- **Decent** – can provide at least 10 Mbit/s download and 1 Mbit/s upload speeds.[12] It can be delivered by ADSL, FTTC, HFC cable or full fibre. Decent broadband provides sufficient speeds for making a high-definition video call. Over minimum decent broadband, downloading a one-hour HD TV episode (1 GB) would take almost 15 minutes.
- **Superfast** – can provide download speeds of at least 30 Mbit/s and can be delivered by FTTC, HFC cable or full fibre. Superfast broadband provides sufficient speed for one person streaming 4K/UHD video. Downloading a one-hour HD TV episode would take under four and a half minutes and several devices can work simultaneously.
- **Gigabit-capable** – can offer download speeds of 1 Gbit/s and above. It can be delivered by HFC cable or full fibre. With gigabit-capable broadband, it is feasible to download a full 4K film (100 GB) in under 15 mins, or a one-hour HD TV episode in eight seconds.

[8] ADSL: Asymmetric Digital Subscriber Line.
[9] Another technology known as G.fast is also sometimes deployed at, or near, a limited number of cabinets offering higher speeds than VDSL.
[10] Cable broadband HFC access networks are shared between a large number (usually hundreds) of premises.
[11] Most full-fibre access networks utilise Passive Optical Network (PON) approaches where capacity in the downstream and upstream direction is shared between around 30 to 60 users.
[12] The UK Government defines the characteristics of 'decent broadband'. This is the level of connection currently deemed necessary for consumers to participate in a digital society.

Figure 2.1 Summary of broadband coverage at a fixed location across the UK and nations

	Gigabit-capable (residential)	Full fibre (residential)	Superfast (residential)	Unable to get decent (all properties)
UK	83%	69%	98%	0.2%
Scotland	77%	62%	96%	0.5%
Northern Ireland	94%	93%	98%	0.2%
Wales	74%	68%	96%	0.5%
England	84%	69%	98%	0.1%

Source: Ofcom analysis of provider data (July 2024).

Coverage and take-up of full-fibre & other gigabit-capable networks continue to rise

Full-fibre broadband is now available to over two-thirds of UK residential premises

There has been a further significant expansion in the availability of full-fibre networks. As of July 2024, 69% or 20.7 million residential premises across the UK had access to a full-fibre broadband network (Table 2.1 below).[13] This is an increase of 12 percentage points, or 3.6 million premises, compared to September 2023.

Residential premises in urban areas across the UK are more likely to have access to full-fibre network coverage (71% for urban areas). But even in rural areas over half of households (52%) now have access to full fibre.

Coverage in each of the four nations has risen, most significantly in England and Wales where both nations had a 13 percentage point increase (to 69% and 68% respectively). Meanwhile, Northern Ireland has the highest level of full-fibre coverage of the four nations at 93%, while there was a 9 percentage point increase in Scotland to reach 62%.

[13] Where providers have indicated that coverage of their fixed broadband network has not changed, we have used their most recent previous submitted data in our analysis.

Table 2.1: Residential full-fibre and gigabit-capable network coverage

	Full fibre			Gigabit capable		
	Total	Urban	Rural	Total	Urban	Rural
England	69% (17.3m)	71% (15.6m)	52% (1.7m)	84% (21.1m)	88% (19.4m)	54% (1.7m)
Northern Ireland	93% (0.8m)	96% (0.6m)	86% (0.2m)	94% (0.8m)	97% (0.6m)	86% (0.2m)
Scotland	62% (1.7m)	67% (1.5m)	42% (0.2m)	77% (2.1m)	85% (1.9m)	43% (0.2m)
Wales	68% (1.0m)	74% (0.8m)	48% (0.2m)	74% (1.1m)	81% (0.9m)	49% (0.2m)
UK	**69% (20.7m)**	**71% (18.5m)**	**52% (2.2m)**	**83% (25.0m)**	**88% (22.7m)**	**54% (2.3m)**

Source: Ofcom analysis of provider data (July 2024).

Gigabit-capable broadband is now available to 83% of UK residential premises

Gigabit-capable broadband can be delivered over both full-fibre and HFC technologies; therefore, the increase in full-fibre coverage has also resulted in an increase in the number of premises able to access gigabit-capable broadband. By July 2024, 83% or 25 million residential premises across the UK had access to a gigabit-capable broadband network. This is an increase of 5 percentage points, or an additional 1.8 million residential premises compared to September 2023.

As of July 2024, 14 million or 47% of all residential premises had access to more than one gigabit-capable network. This is a substantial increase from September last year when 35% or 10.5 million residential premises had access to more than one gigabit-capable network. Furthermore, 12% of all residential premises have a choice of three or more gigabit-capable networks.

Most small and medium-sized enterprises can now access full-fibre networks

Access to high-speed broadband is important for many small and medium-sized enterprises (SMEs). In 2024, the availability of both full-fibre and gigabit-capable broadband for SMEs has risen.

As of July 2024, 63% of SMEs in the UK had access to a full-fibre network (Table 2.3), which represents an increase of 12 percentage points from September 2023. Seventy-nine per cent of SMEs in the UK had access to a gigabit-capable network, an increase of five percentage points from September 2023.

Coverage remains highest for micro businesses, which are often based in residential areas and can make use of residential services. Our coverage data does not include networks used to deliver point-to-point FTTP businesses leased lines, so coverage may be higher than indicated in Tables 2.2 and 2.3 below, particularly for medium-sized businesses.

As with residential broadband, SMEs in Northern Ireland have the greatest availability of full-fibre and gigabit-capable networks, followed by England (Table 2.3).

Table 2.2: SME full-fibre and gigabit-capable network coverage by size of business

	Full fibre		Gigabit capable	
	Sept 2023	July 2024	Sept 2023	July 2024
Micro (1-9 employees on site)	52%	63%	75%	80%
Small (10-49 employees on site)	45%	56%	65%	71%
Medium (50-249 employees on site)	**42%**	**52%**	**61%**	**67%**

Source: Ofcom analysis of operator data (July 2024).

Table 2.3: SME full-fibre and gigabit-capable network coverage by nation

	Full fibre			Gigabit capable		
	Total	Urban	Rural	Total	Urban	Rural
England	63%	64%	51%	80%	84%	53%
Northern Ireland	85%	86%	84%	88%	91%	84%
Scotland	55%	59%	38%	71%	78%	40%
Wales	61%	66%	47%	66%	73%	47%
UK	**63%**	**64%**	**51%**	**79%**	**84%**	**53%**

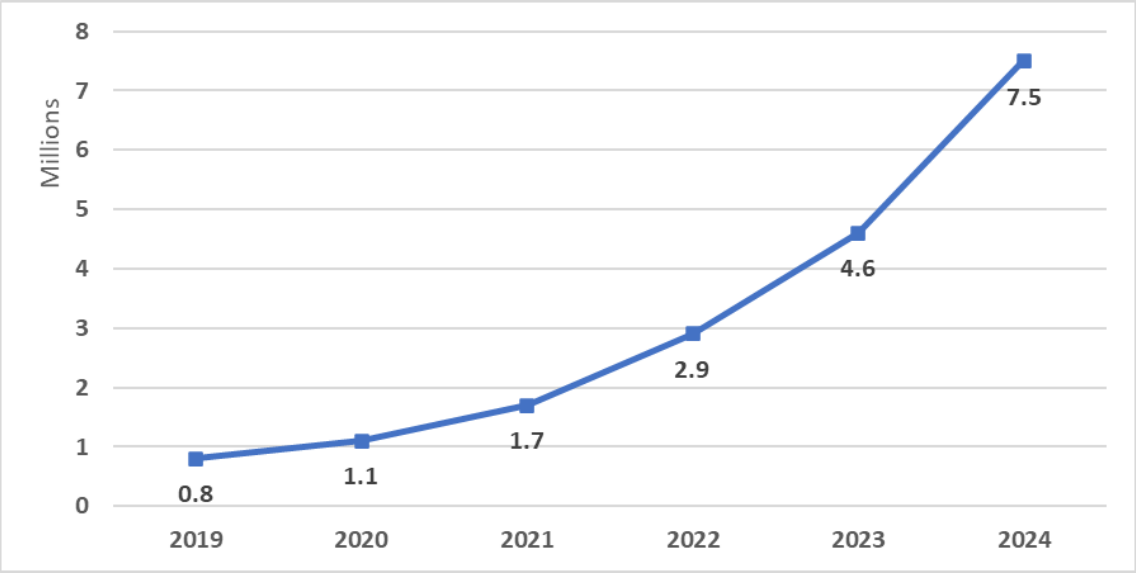
Source: Ofcom analysis of operator data (July 2024).

Take-up of services on full-fibre networks is rising

An increasing number of customers are using broadband services on full-fibre networks as their coverage expands. In May 2023, we reported that across the UK approximately 28% of premises where full fibre was available had taken it up. In July 2024, take-up of services on full-fibre networks at all premises (residential and commercial), where available, was 35% or 7.5 million premises (Figure 2.2, Table 2.4). This is an increase of seven percentage points in take-up over the last year.

There have been 2.9 million new full-fibre connections in the period since May 2023, with the total rising from 4.6 million to 7.5 million connections in July 2024.

Figure 2.2: Estimated total full-fibre broadband connections, 2019-2024



Source: Ofcom analysis of provider data (July 2024).

Meanwhile, our data indicates that take-up of services on gigabit-capable networks, where they are available, is now at 49%. There has been an increase of 7 percentage points in take-up from 42% reported last year.

Full-fibre take-up rates are highest in Northern Ireland and in rural areas

Across the four nations, take-up of services on full-fibre networks where available is highest of the four nations in Northern Ireland at 53%. It is lower in England (33%) and Scotland (35%), though both nations have recorded marked increases in take-up rates (6 percentage points in England, 7 percentage points in Scotland). There was an 8 percentage point increase for take-up in Wales (from 31% to 39%).

Table 2.4: Estimated full-fibre broadband take-up as a percentage of premises where full-fibre networks are available by nation: 2021-2024

	2021	2022	2023	2024
England	25%	25%	27%	33%
Northern Ireland	19%	25%	39%	53%
Scotland	22%	23%	28%	35%
Wales	24%	28%	31%	39%
UK	**24%**	**25%**	**28%**	**35%**

Source: Ofcom analysis of provider data (July 2024).

To date, take-up of full fibre has been notably higher in rural areas than in urban areas. Of premises with full fibre access, 52% of premises in rural areas have taken a full-fibre service, compared to 32% in urban areas.

As a proportion of all premises in the UK (including those that do not yet have access to full-fibre networks), full-fibre take-up is now 23%. Of the four nations, Northern Ireland has the highest proportion of all premises taking up full fibre at 49%. We have published updated data on take-up rates at the local authority level in our Connected Nations performance open data files.

Time elapsed since build impacts on take-up rates

We continue to find that the longer fibre has been available in a particular area, the higher the take-up. For example, where full fibre has been available at a property for more than four years then there is a 53% probability that services on a full-fibre network will have been taken up. By contrast, if full fibre has only been available for one year or less, there is only a 12% probability of take-up.

Table 2.5: Likelihood of full-fibre take-up with respect to length of time it has been available

Years full fibre has been available at the property	Probability that the property has taken full fibre
One year or less	12%
Greater than one year, up to two years	27%
Greater than two years, up to three years	37%
Greater than three years, up to four years	47%
Greater than four years	53%

Source: Ofcom analysis of provider data (July 2024).

The vast majority of people have access to superfast broadband services

Most residential premises in the UK have access to superfast broadband. This is defined as a broadband connection that can provide download speeds of at least 30 Mbit/s. Our 2024 data shows that the proportion of residential premises that have access to superfast broadband has increased by one percentage point and has now reached 98% of (or roughly 29.4 million) UK residential premises (Table 2.6). This includes the 25 million premises that have access to faster, gigabit-capable networks as discussed above. An increase in superfast broadband coverage in rural areas of Scotland of four percentage points (from 79% to 83%) has contributed to this increase.

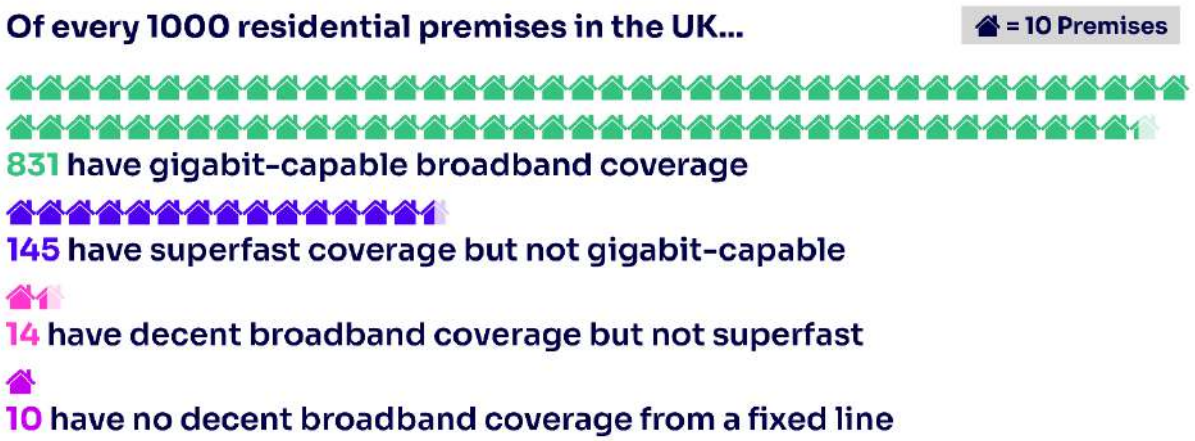
Table 2.6: Residential superfast coverage by nation

	Total	Urban	Rural
England	98%	99%	90%
Northern Ireland	98%	99%+	95%
Scotland	96%	99%	83%
Wales	96%	99%	87%
UK	**98%**	**99%**	**89%**

Source: Ofcom analysis of operator data (July 2024).

Looking at all fixed-line coverage for residential premises (Figure 2.3), around 831 in every 1,000 premises in the UK have gigabit-capable coverage, while an additional 145 premises have superfast but not gigabit-capable coverage. Of the remaining residential premises, 14 have decent broadband but not superfast, while 10 do not have access to decent broadband connection from a fixed-line.

Figure 2.3: Residential fixed-line broadband availability in the UK



Source: Ofcom analysis of provider data (July 2024).

Broadband performance

This sub-section provides insights on broadband performance experienced by consumers and builds on the coverage and take-up of services described earlier. It includes information on data usage, speeds across different technologies, the range of different speed packages taken by consumers, and how performance is affected in network 'busy times'.

Data usage over fixed broadband is higher over full-fibre connections

Our 2024 data shows an average monthly data usage of 531 GB per connection across all technologies, and an average of 766 GB for full-fibre connections only (see Table 2.8). This higher usage figure may reflect consumers with higher data needs choosing full fibre as well as some consumers making more use of data intensive applications once they have moved to these higher speed technologies.

Table 2.8: Average monthly data usage per connection GB (gigabytes)

	Average monthly data usage per connection (GB)	
	All connections	Full-fibre connections
England	539	805
Northern Ireland	510	589
Scotland	480	627
Wales	508	646
UK	**531**	**766**

Source: Ofcom analysis of provider data (July 2024). Data usage is the total data downloaded and uploaded over the broadband connection during July 2024. Due to a change in methodology, this usage data is not directly comparable with usage data reported in previous years.[14]

Broadband download speeds continue to rise

As full-fibre networks are rolled out, more customers are moving to higher speed broadband services. This is reflected in a 31% increase in UK average maximum download speeds, up from 170 Mbit/s in 2023 to 223 Mbit/s in 2024.[15] A similar increase in average maximum download speeds can also be seen for all the nations (Table 2.9).

Out of the four nations, Northern Ireland has the highest average maximum download speed of 259 Mbit/s compared to the UK average of 223 Mbit/s (Table 2.9 below). This higher average is likely to reflect the greater availability and take-up of full-fibre broadband in Northern Ireland.

Table 2.9: Average maximum download speed by nation

	Average maximum download speed (Mbit/s)	
	2023	2024
England	173	225
Northern Ireland	191	259
Scotland	155	215
Wales	136	181
UK	**170**	**223**

Source: Ofcom analysis of provider data (July 2024).

Download speeds delivered to consumers differ from the maximum speed potentially available

The maximum download speed to consumers, as recorded by providers, may be less than the maximum speed potentially achievable on a given technology. This is because the maximum speed (as recorded)

[14] For 2024, we collected data usage measurements aggregated at the Optical Line Terminal (OLT) or headend, rather than on a 'per line' data usage basis as in previous years.

[15] This is the average (i.e. mean) across each of the nations of the maximum download speeds delivered to the customers' premises (e.g. the router) as reported by the providers' systems. Information on how speeds are analysed are set out in more detail in the methodology annex.

will vary depending on a range of factors including the type of package purchased by consumers and the technology used (i.e. ADSL, FTTC, HFC, FTTP).

Table 2.10: Average maximum download speed by technology

Technology	Average maximum download speed delivered[16] (Mbit/s)		Maximum speed of the technology
	2023	2024	
ADSL	13.3	14.8	24 Mbit/s
Fibre to the Cabinet (FTTC)	58	58	80 Mbit/s
Hybrid fibre coaxial cable (HFC)	322	437	Gigabit capable
Full fibre (FTTP)	362	406	Gigabit capable
All connections	**170**	**223**	**N/A**

Source: Ofcom analysis of provider data (July 2024). Maximum technology speeds assume an unimpaired, uncongested access connection, with actual speeds dependent on line length for ADSL and FTTC which use copper cables or wires – see also the Background to fixed-line broadband services for a more detailed description of the different technology types.

For technologies such as full fibre (FTTP) and HFC cable, the difference between the maximum download speeds (as recorded) and the maximum speeds potentially available is more likely to reflect the fact that some consumers purchase broadband service packages with lower speeds than the highest speed available over a technology. For example, 17% of FTTP customers are taking packages with speeds of less than 100 Mbit/s even though the maximum speed over that technology could be up to 1 Gbit/s or over (see next sub-section).

The differences in the average download speed for FTTP and HFC (406 Mbit/s and 437 Mbit/s respectively) reflect differences in the mix of speed packages taken by consumers across these technologies, both of which can potentially deliver speeds of 1 Gbit/s or more (i.e. gigabit capable).

For older technologies relying on copper wires, broadband speeds to consumers (as recorded) will also be lower than the maximum speed potentially available. This difference will vary depending on the technology used (e.g. ADSL or FTTC) as well as the length and quality of the copper lines. A clear example of this is for ADSL, where the average download speeds delivered across all these broadband lines is 14.8 Mbit/s even though ADSL can potentially deliver up to 24 Mbit/s (Table 2.10).

There is variation in speed packages taken by customers on full-fibre networks

While increasing numbers of customers are moving from legacy broadband technologies to full fibre, not all customers taking up services on full-fibre networks will need or want the packages that offer the

[16] We asked providers to submit for each of their customer connections the maximum recorded download speed and, for technologies other than FTTP, the average recorded download speed as well. The methodology for 2024 uses maximum download speeds to ensure a comparison across service providers and technologies, so is not comparable with previous reports which relied on average speeds. To enable a year-on-year comparison, the 2023 data has been re-analysed using the 2024 methodology, which is described in more detail in the methodology annex.

fastest speeds that these networks can actually provide.[17] However, between 2023 and 2024, we observed a general move by customers towards higher speed packages.

For example, we find that 17% of customers are taking a speed package with a download speed of less than 100 Mbit/s, a decrease from 29% in 2023 (Table 2.11). In contrast, 27% of consumers on full fibre are taking advantage of speeds from 300 Mbit/s up to 600 Mbit/s in 2024 compared to 18% in 2023. The overall effect of this change in the mix of all the speed packages taken by customers is an increase in the average maximum download speed for services on full-fibre networks from 362 Mbit/s in 2023 to 406 Mbit/s in 2024 (see Table 2.10 above).

Table 2.11: Take-up of services on full-fibre networks by advertised download speed

Advertised download speed	Take-up	
	2023	2024
<100 Mbit/s	29%	17%
>=100 & <300 Mbit/s	39%	39%
>=300 & <900 Mbit/s	18%	27%
>=900 Mbit/s	14%	17%

Source: Ofcom analysis of provider data (July 2024).

Download speeds reduce slightly at peak times

Download speeds across the network "from router to internet" at peak times (8pm to 10pm for residential users) is between 98.7% and 99.7% when compared to the average across the day. This varies slightly depending on the technology (Table 2.12). These slightly lower peak time speeds reflect factors such as congestion within the network or across the internet at these peak times.[18] The largest difference between peak times and the average across the day is on the older ADSL-based technology (98.7%).

Table 2.12: Time of day speed variations by technology

Technology	Average 8-10pm peak-time download speed as a % of average 24-hour download speed
ADSL	98.7%
Fibre to the Cabinet (FTTC)	99.3%
Hybrid fibre coaxial (HFC)	99.7%
Full fibre (FTTP)	99.4%

Source: Ofcom analysis of four providers' embedded test data on a sample of consumer lines (March 2024). Peak time performance for an individual consumer may therefore differ from the average results

[17] Our broadband coverage checker shows the estimated fastest speeds and operators that are available at a particular address.

[18] The connection experienced by consumers using devices connected to the provider's router will be impacted by a range of factors including Wi-Fi performance, the quality of any in-home wiring, in-home congestion as well as the performance of servers within the internet that deliver content.

shown in this table. An explanation of how the data was processed is available in the methodology annex.[19, 20]

Broadband services can be delivered over wireless and satellite networks

Background to wireless networks and satellite services

In addition to existing fixed-line connection technologies, it is also possible to receive fixed broadband via wireless networks and satellite.

Fixed Wireless Access (FWA) can be delivered by:

- **Mobile network operators (MNOs)** – Fixed Wireless Access on mobile networks is offered on licensed 4G and 5G networks, usually to an indoor router. These services share the network capacity with mobile users, meaning that the capacity of the network must be carefully managed between the demands of existing mobile users and FWA customers. There may be areas of high mobile demand where a reliable FWA service cannot be offered.
- **Wireless internet service providers (WISPs)** – The majority of these services are delivered over wireless networks that communicate via a wireless link between a provider's mast site and an external antenna fixed to a customer's premise. These networks mostly use spectrum under licence exemption or light licence authorisation. We are beginning to see some use of 5G technology specifically for Fixed Wireless Access services, which is enabling WISPs to provide superfast and above speeds much more widely. The performance of services may be impacted by line of sight issues, which can become more significant at higher frequencies (WISPs have a range of frequency options, with choice informed by capacity and performance requirements, as well as technology and kit available in a given band).[21]

Fixed broadband can also be delivered over satellite and there are two types of satellite services:

- **Geostationary orbit (GSO) satellites** – These orbit the earth at about 36,000 km and have traditionally been the primary way of delivering satellite communications services. GSO

[19] This 'time of day' analysis is based on a sample of data from four large providers, meaning that 'time of day' speed for other providers may vary from the data presented in the table.
[20] Only embedded data collected from the main four internet service providers (ISPs) is used for calculating 'time of day' speed differences, and this calculation does not use 'SamKnows' data (provided by volunteers with a hardware monitoring unit connected to their broadband router) as used in previous Home Broadband Performance (HBP) reports. That circumstance, together with other differences such as sample size, means the 'time of day' data in this report is not directly comparable with the HBP reports published by Ofcom until 2023. We are continuing to explore the use of alternative data sources, including ISPs' 'embedded' test data and how it might be used in future reports.
[21] Ofcom introduced its Shared Access framework in 2019 to support local spectrum access for local networks. The framework includes the 3.8-4.2 GHz band and part of the 26 GHz band that are suitable for the provision of high-speed networks based on 5G technology.

providers can provide satellite broadband to most premises across the UK, including some in the most remote areas, but the connection's performance can be limited by its higher latency.

- **Low Earth orbit (LEO) satellites** – These satellite constellations are now also available offering residential and business broadband to UK customers. LEO satellites can deliver lower latency services due to their lower orbit (below 2,000 km), enabling a more seamless use of applications such as two-way video calling and gaming.

FWA (both that provided by MNOs and by WISPs) and satellite fixed broadband connections can also provide decent and superfast speeds and, under certain conditions, may be gigabit capable, but this will be dependent on the specific deployment, available capacity at the site, and the number and location of users.

Broadband services are available across large parts of the UK using fixed wireless networks

Fixed Wireless Access via mobile networks

FWA services from the MNOs are provided primarily over 5G networks and advanced 4G networks (LTE-A). Based on information from the MNOs about their coverage levels, we estimate that 95% of all UK premises have access to decent broadband through an MNO FWA service (Table 2.9), in line with the coverage we reported last year. [22]

FWA services offered over 4G and 5G networks share the network capacity with mobile users, meaning that capacity has to be carefully managed between the demands of existing mobile users and FWA customers. As such, there may be areas of high mobile demand where a reliable FWA service cannot be offered, and elsewhere the reliability of FWA services may fluctuate as demand for mobile services does. MNO FWA services are typically sold as 'plug and play' indoor routers.

The performance of the broadband FWA connection is dependent on the quality of the mobile signal that is received indoors. Some operators have offered or are offering solutions to improve the quality of the signal received indoors for example through a pre-configured external antenna combined with an internal router designed for self-installation by customers. This then makes use of the stronger outdoor mobile signal to provide for an improved broadband experience.[23]

Additionally, the availability of higher spectrum frequencies provides the capability to support higher speeds. However, the coverage that can be achieved with higher frequencies, with less range, is reduced so necessitating a greater number of masts to achieve coverage at higher speeds. At the same time, advances in the technology such as the use of massive MIMO are allowing better (i.e. more efficient) use of the spectrum. [24]

[22] Our reporting here is based on data from EE and Three – see the annex for further information on the methodology.
[23] For example, Three have recently launched what is called a '5G Outdoor hub'.
[24] MIMO (Multiple Input, Multiple Output) system is an advanced antenna array technology that improves spectral efficiency and increases the amount of data transferred over wireless links.

Fixed wireless access via wireless internet service providers

This year we collected data from 20 WISPs (compared to 21 in 2023).[25] Based on estimates from these WISPs, around 7% of all UK premises (residential and SME) have decent broadband coverage from a WISP network (Table 2.13), unchanged from the previous year.[26]

FWA provided by WISPs has been primarily over the 5 GHz band. The availability of the additional spectrum in the 3.8-4.2 GHz band, primarily considered to be a 5G band, is allowing WISPs greater flexibility in the deployment of higher speed services over 5G standard equipment. This may allow for the availability of higher speed services in places where fibre has not yet been deployed, and where FWA services may be more cost effective than satellite services.

Table 2.13: Coverage of MNO and WISP FWA networks with at least decent broadband (all premises)

	MNO FWA	WISP FWA
England	96%	6%
Northern Ireland	84%	3%
Scotland	95%	2%
Wales	93%	22%
UK	**95%**	**7%**

Source: Ofcom analysis of provider data (July 2024).[27]

MNOs continue to provide fibre backhaul to a number of masts across the UK that deliver mobile and FWA services. These masts have the potential to support higher speed FWA services in the future.

Take-up of satellite broadband is increasing and may offer an alternative for customers in poorly served areas

Satellite technologies continue to evolve, and Low Earth Orbit (LEO) satellite constellations particularly could potentially help to serve parts of the UK which are harder to reach through more traditional technologies.

LEO satellite constellations can offer high-speed, lower latency services relative to traditional geostationary orbit (GSO) satellites. The LEO retail market is at an early stage of development and take-up remains low compared to terrestrial broadband services, though it is increasing.

Starlink currently offers the only direct-to-consumer LEO service in the UK through its retail product. This offers nationwide broadband coverage, including in harder-to-reach areas. In addition, business-to-business (B2B) services are available from OneWeb. At the time of writing, we have authorised a total of 6 LEO operators to provide broadband services in the UK so we expect further development in both

[25] See the methodology annex for further information.
[26] The analysis for WISPs includes SME and residential users.
[27] Several factors may impact on coverage figures, for example, some WISPs are migrating customers to their full-fibre networks and withdrawing some wireless sites, and one WISP indicated a change in their reporting model, thus potentially impacting figures on overall WISP coverage, for example, in Wales.

business-to-consumer (B2C) and business to business (B2B) markets as these operators start to launch satellites and services in the coming years.[28]

The data provided to us by Starlink indicates that around 87,000 connections in the UK in June 2024 make use of LEO satellites for their broadband service (up from 42,000 in August 2023). This includes both residential and business packages, and our analysis of the location of these customer connections suggests that:

- The majority of these premises are in rural areas.
- Around 8% of these premises are in areas with no decent broadband, compared to a UK average of only 0.2% of premises with no decent broadband.
- Just over 24% of these premises have access to full fibre, compared to a UK average of 67% of premises with access to full fibre.

Relative to UK premises as whole, premises with a satellite broadband connection are therefore more likely to be in a rural area, and less likely to have access to a decent fixed-line or FWA broadband service.

Although satellite services do not typically guarantee any minimum speeds on their packages, in the data submitted to Ofcom, Starlink indicate average download speeds of over 160 Mbit/s in 2024, slightly down from over 170 Mbit/s in 2023. Starlink reported average upload speeds on their connections to be around 18 Mbit/s in 2024.

Some premises still cannot access decent broadband coverage

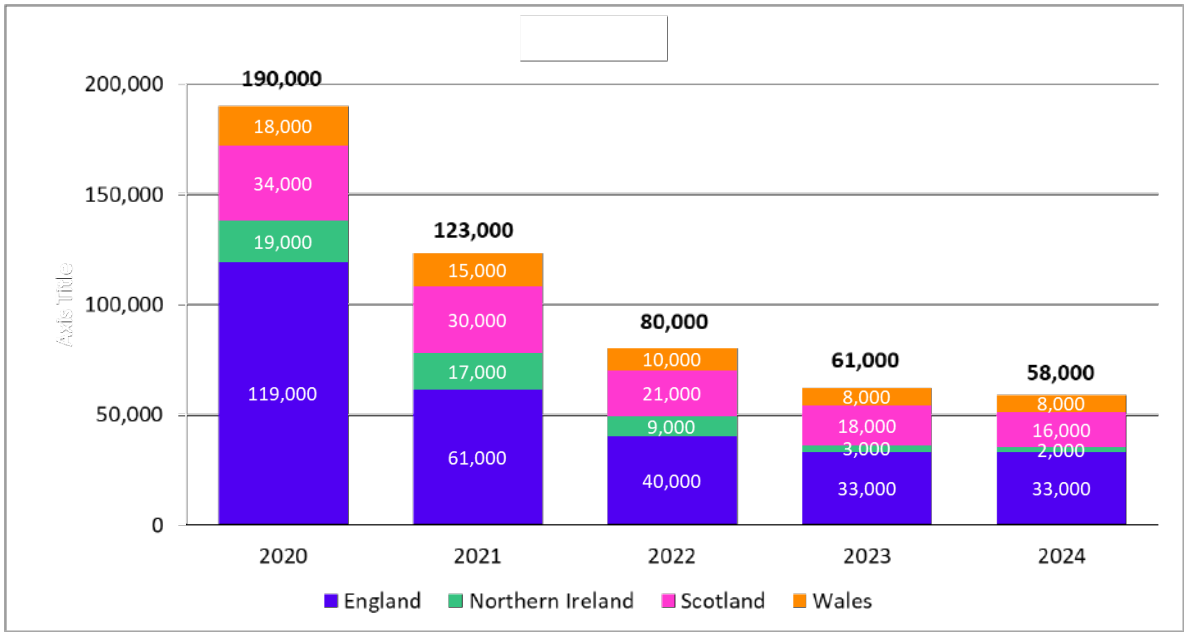
The number of premises unable to access decent broadband via a fixed connection has fallen

We estimate that 1% of all UK premises, residential and commercial, cannot access decent broadband, which is defined as connections which provide at least 10 Mbit/s download speed and 1 Mbit upload speed, from a fixed-line connection. This is around 385,000 premises in July 2024, a drop of 25,000 since September 2023, when we reported that around 410,000 premises did not have decent broadband via a fixed-line.

Of those premises that do not have decent broadband via fixed lines, a large share is able to access decent broadband via FWA services offered by MNOs or WISPs. Taking account of the coverage available from FWA, we estimate that this leaves around 58,000 or 0.2% premises in the UK without a decent broadband service from either fixed-line or FWA (Figure 2.5). The remaining number of premises without access to a decent broadband service has therefore fallen by around 3,000 from the approximately 61,000 premises we reported last year. These figures have dropped significantly in the past five years, from 190,000 in 2020 to 58,000 in 2024.

[28] Information about LEO satellite constellations which are licensed in the UK can be found on Ofcom's website. This page also includes information about applications from LEO satellite constellations and other Non-GSO (NGSO) satellite systems.

Figure 2.5: Approximate number of premises without access to a decent broadband service from either a fixed or Fixed Wireless Access network, 2020-2024[29]



Source: Ofcom analysis of provider data (July 2024)

We estimate that around 10,000 of these premises will be connected via publicly funded schemes by December 2025, meaning that the number of premises remaining without a decent broadband from a fixed-line or FWA could be around 48,000 by the end of 2025.

The universal service obligation (USO) can offer decent broadband to some premises currently without access

The broadband USO provides all premises with the right to request a broadband connection with a download speed of at least 10 Mbit/s and an upload speed of 1 Mbit/s (as well as several other specific technical characteristics).[30]

Where an affordable service with these characteristics is not available, or due to become available in the next 12 months under a publicly funded scheme, the customer is eligible for the USO if the costs of providing the connection are below £3,400.[31] Where the costs are above £3,400, the customer has the option to pay the excess costs to get a USO connection. BT is the universal service provider for the UK (excluding Hull), and KCOM for the Hull area. They are required to provide the USO and to report at six monthly intervals on delivery.[32]

[29] All figures have been rounded to the nearest 1,000.
[30] In particular, these characteristics are: (i) a contention ratio of no more than 50:1; (ii) latency which is capable of allowing the end user to make and receive voice calls effectively; and (iii) the capability to allow data usage of at least 100 GB a month.
[31] In March 2020, we specified in the USO conditions that an affordable service was one that costs £45 per month, rising annually by CPI. This has now risen to £56.20 per month in line with CPI.
[32] BT, USO Reports. KCOM, USO Reports. To date, we understand that KCOM has not received any eligible USO orders.

As of September 2024, BT had received just over 2,000 USO orders since the launch of the USO in March 2020. Each order requires network build that can serve multiple premises, and therefore these orders will lead to full-fibre connections being built that can serve over 10,000 premises.[33]

Table 2.14: USO orders and number of premises built by nation

2024	Number of USO Orders	Total premises passed by resulting build
England	1,558	7,478
Northern Ireland	89	726
Scotland	115	540
Wales	247	1,334
UK	**2,009**	**10,078**

Source: Ofcom analysis of BT data (September 2024).

The increase in the number of USO orders since last year's Connected Nations report was very small (around 40 new orders up to September 2024). Data analysis by BT has indicated that the cost of connecting more than nine out of ten of the remaining premises without access to decent broadband are likely to exceed the £3,400 threshold. In these cases, customers will receive excess cost quotes that may be quite high and, in most cases, unaffordable for customers. Those premises that are the most expensive to connect are likely to need alternative solutions.

To ensure the broadband USO remains relevant, a review provision was included in the legislation and the process to review is likely to be triggered when superfast broadband is taken up by at least 75% of all premises.[34] As of July 2024, 75% of all premises have taken up superfast broadband.

In October 2023, the Government consulted on a review of the broadband USO and we will continue to engage with Government on the future approach to the USO.

Private sector investment is spearheading rollout of faster networks; and public schemes support harder-to-reach areas

Estimated expenditure on telecoms infrastructure totalled £9.9bn

We collect network investment information to better understand how the UK's largest fixed and mobile telecoms operators are investing in network infrastructure.[35] The information collected relates to

[33] BT's public reporting shows a slightly lower number of total confirmed orders. This is because it only covers orders prior to, and during, network build; whereas the 2,009 figure also includes orders made once build has completed.

[34] Under the Communications Act 2003, the Secretary of State is likely to issue Ofcom with a direction to review the broadband USO if it appears to them that, on the basis of information we have published, take-up of superfast broadband has reached at least 75% of all UK premises.

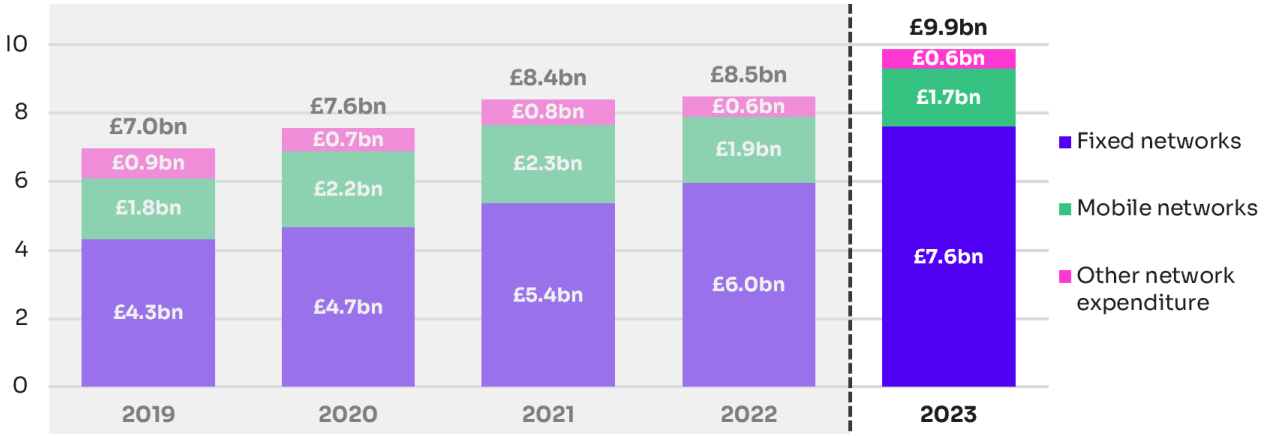
[35] Only capital expenditure required to provide and operate network infrastructure in the UK is included; figures exclude VAT and expenditure on retail activities (e.g. retail billing or marketing systems). Figures include capital expenditure on tangible and intangible assets, including capitalised staffing and labour expenditure, and expenditure on assets in the course of construction (AICC). Figures exclude expenditure on assets that have been

providers' annual financial reporting periods, and the information received is pro-rated to estimate calendar year figures.[36]

The figures include public funding provided to support the rollout of better fixed and mobile connectivity, such as UK Government funding, funding provided via the governments of the devolved nations and local authority funding. This year, we have received data for around 20 additional full-fibre network operators (resulting in data collection from around 50 providers). While this means our analysis better represents spend on fixed telecoms networks (and total telecoms network investment), a consequence is that the 2023 total and fixed telecoms figures are not directly comparable to those for previous years.

We estimate that UK operators invested a total of £9.9bn in network infrastructure in 2023. Fixed network investment totalled £7.6bn during the year (77% of the total) with mobile network investment accounting for £1.7bn (17% of the total). A further £0.6bn related to 'other network expenditure', i.e. investment in infrastructure used to provide both fixed and mobile services.

Figure 2.6: Estimated telecoms network capital expenditure: 2019 to 2023



Source: Ofcom analysis of operator data.
Notes: Adjusted for CPI (2023 prices); 2023 fixed network data is not directly comparable to previous years.

Fixed telecoms network infrastructure investment was estimated to be £7.6bn

We estimate that UK operators invested £7.6bn in fixed telecoms network infrastructure in 2023. Most investment in fixed network infrastructure during the year related to access networks (£7.1bn, or 93% of the total) with the remaining £0.5bn (7% of the total) being investment in fixed core and backhaul networks.

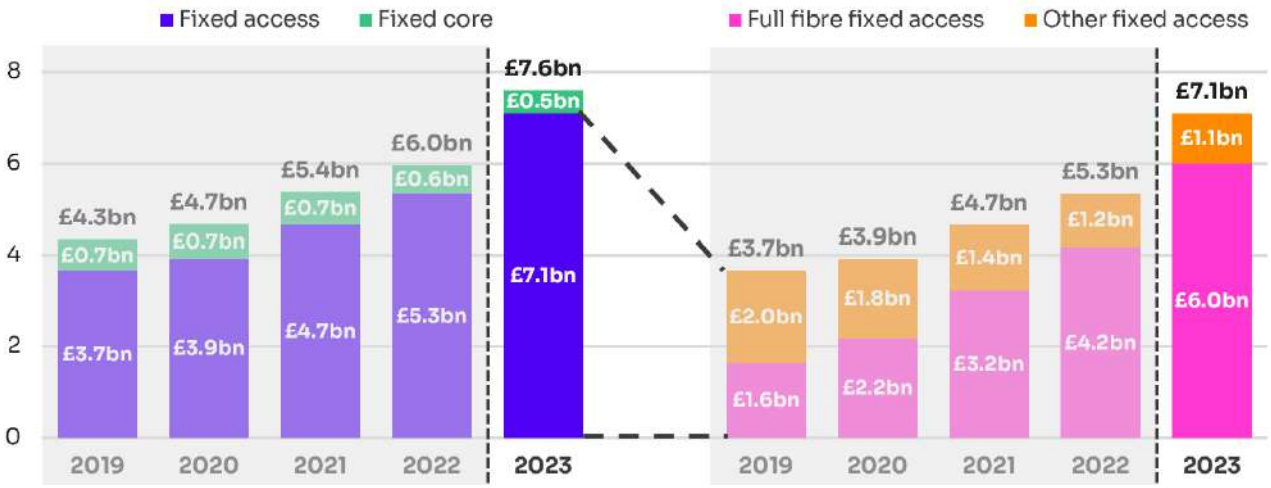
Full-fibre access networks was estimated at £6.0bn in 2023, representing 79% of all fixed network investment and 61% of total telecoms network investment. Additionally, some of the £1.1bn that was

added to a balance sheet through adoption of the IFRS16 accounting standard, or assets held for sale, and the costs of maintenance contracts purchased alongside hardware. Expenditure associated with asset transfers and leasing follows the same guidelines the Office for National Statistics provides when requesting information in its quarterly acquisitions and disposals of capital asset survey. While the figures shown have been rounded, any percentage changes shown are calculated using the unrounded data.

[36] The most recent period for which we hold network infrastructure investment data is 2023 as, unlike much of the other data in this report, this data covers the whole of the calendar year and is not a snapshot taken at a point in 2024.

invested in other fixed access infrastructure may be used to support the rollout of future full-fibre services where it relates to physical infrastructure upgrades (such as fibre deployment in fibre-to-the-cabinet networks).

Figure 2.7: Estimated fixed telecoms network capital expenditure: 2019 to 2023



Source: Ofcom analysis of operator data.
Notes: Adjusted for CPI (2023 prices); 2023 data is not directly comparable to previous years. Our September Planned network deployment update set out industry's estimated progress over the next 3 years.

The availability of full-fibre and gigabit-capable networks is expected to continue to increase over the next few years. A range of network operators plan to continue deploying new infrastructure, using varying business models.

Ofcom gathers stated deployment plans from network operators. In September 2024, we published our latest forward-looking update on planned network deployments. This update is based on operators' deployment plans within three years from May 2024, for both full-fibre and Fixed Wireless Access networks, and includes plans that are funded privately or supported through public funds.

The proportion of residential premises expected to have full-fibre coverage in 2027 could be as high as 96% (29 million properties), while gigabit-capable coverage could be in excess of 97%.

Our estimates indicate that there could be 26,000 premises that continue to be without access to decent broadband from fixed-line or fixed wireless networks by May 2027.

Table 2.15: Estimated number of remaining premises unable to access decent broadband by May 2027

	May 2027
England	14,000
Northern Ireland	1,000
Scotland	7,000
Wales	4,000
UK	**26,000**

Source: Ofcom analysis of operator data (May and July 2024).

Physical infrastructure access continues to play an important role in the deployment of new networks

Significant investment and engineering resources are required to deploy new networks. Many providers reduce the cost and timeframes for deployment if they roll out parts of their network using Openreach's network, which is made up of approximately 496,000 km of duct and 4.1 million poles. Since 2019, our rules have allowed easier access to Openreach's physical infrastructure (PIA). As of the end of September 2024, 172 providers had registered with Openreach as customers of PIA, and 140 of these had already built network using PIA or had placed orders to do so. Providers have ordered around 176,000 km of duct routes (101,000 km of which has been delivered) and approximately 1.2 million attachments to poles (750,000 of which have been delivered) to deploy networks.[37]

Public sector investment has a key role in achieving connectivity, particularly in hard-to-reach areas

Governments across the UK continue to supplement commercial rollout. This includes an August 2024 announcement from the new UK Government regarding the latest stages of the Project Gigabit initiative, including the first contract under Project Gigabit to boost connection in Wales. In the recent Budget, the Government said the wider Project Gigabit plan will make £800 million available to deliver gigabit connections across Great Britain, and it added that it was on track to achieve full gigabit coverage by 2030.[38]

Further information is available on projects led by the devolved governments in the individual nations reports.

Migration from legacy voice services to digital voice services

The retirement of the legacy public switched telephone network is progressing

The UK's traditional landline voice services continue to undergo a substantial transition as network operators retire their legacy systems (referred to as the public switched telephone network, or 'PSTN') and replace them with modern systems.

BT and Openreach are now looking to retire BT's PSTN network and the Openreach wholesale services that deliver PSTN by January 2027, and we understand that other providers are following a broadly similar timescale.[39]

To make sure landline services continue to be available to their customers, providers of legacy telephony networks have started delivering landline calls over a broadband connection, using a digital technology called Voice over Internet Protocol (VoIP). This is commonly known as a digital landline. BT has also developed an interim solution, called 'pre-digital phone line', for certain complex or difficult to migrate customers such as landline-only or critical national infrastructure customers. This will allow those customers to move off the PSTN without the need to install a broadband connection or change legacy equipment.[40]

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[37] Multiple communications provider customers may build on the same piece of Openreach infrastructure.
[38] HM Treasury, Autumn Budget 2024, 30 October 2024.
[39] BT, BT Group refines its digital switchover programme for the UK's full fibre future, 20 May 2024.
[40] BT, BT Group refines its digital switchover programme for the UK's full fibre future, 20 May 2024.

The industry has made steady progress over the last few years in migrating customers off the PSTN, mainly through a combination of customers choosing to move to IP (customer-led migrations) and providers actively moving them onto IP (provider-led migrations). The latter has mainly been used by BT, VMO2 and to a lesser extent Zen, KCOM and Vodafone.

While progress has been steady, migration numbers slowed significantly in 2024 due to an agreement between the UK Government and all the main providers to temporarily pause provider-led migration of customers until additional steps are taken to protect vulnerable consumers through the transition.[41]

While moving from the PSTN to digital landlines should be smooth for most customers, these changes can be more complex and raise potential risks for some groups of customers – for example, those with additional needs or vulnerabilities, landline-dependent customers and users of non-voice devices that rely on the PSTN such as telecare/security alarms and smart meters.

We continue to monitor the migration closely and engage with providers to ensure that disruption is minimised and vulnerable customers are protected from harm.[42]

Customers with landlines are increasingly using VoIP

We collected data from seven of the largest providers of retail voice services to residential customers. We found PSTN connections now account for just over a quarter of residential landline connections (27%). Around 5.2 million residential landline customers still use the PSTN.

The remainder of customers with a landline have either switched to VoIP (8.6 million landline connections) or use emulated PSTN, which has similar features to the PSTN but does not rely on PSTN technology.

Table 2.16: Number and share of residential landline customers by technology[43]

	Approximate number of customers	Share of all landlines
PSTN	5.2 million	27%
VoIP	8.6 million	45%
Emulated PSTN	5.3 million	28%
Total	**19.1 million**	**100%**

Source: Ofcom analysis of provider data (July 2024).

In the year to July 2024, 1.8 million residential customers who previously had a PSTN line migrated to a VoIP service. 53% (970,000 lines) of these were as a result of a provider-led migration, while the remaining 47% (870,000 lines) were as a result of customer-led migrations.

[41] Public Switched Telephone Network charter, 18 December 2023. Network operators such as Openreach also signed a similar voluntary charter in early 2024.
[42] Ofcom, Protecting customers during the migration to digital landlines, 18 December 2023.
[43] This table only captures retail residential landlines and is not comparable with landline data from last year's Connected Nations report.

Switching to broadband-only lines

We also found that just over a million households ceased their landline in favour of a broadband-only service in the year to July 2024. Last year we reported that just under half a million households ceased their landline in the year to September 2023.

As households cease their landline services, some consumers may be making use of personal online communication services (OCS), such as Skype or WhatsApp, to make voice and video calls and / or relying on their mobile phones for voice calls.

3. Mobile, data and voice

Introduction

Mobile connectivity has become an integral part of modern living; it enables effective communication, provides access to information and services, enhances productivity, and supports various aspects of daily life.

This section provides an update on the progress MNOs are making with their 5G mobile rollout plans, while continuing to report on the broader availability of 4G mobile coverage outside and inside premises, across the UK's landmass and on roads. In addition, we provide updates on 2G and 3G coverage and MNOs' switch-off plans. We also report on investment in, and the take-up of mobile services, reflected in the continuing growth of mobile traffic.

Our current approach to mobile reporting, which is based on existing signal strength predictions from the MNOs, has limitations. It does not necessarily reflect consumers' lived experience, particularly in the context of trying to determine coverage at a local level, which we provide on our mobile coverage web-checker.

We have a work programme in place (which we set out in the sub-section entitled 'Approach to mobile reporting') to update how we report on coverage and performance and, to deliver improvements at the local level in our web-checker. These changes will be designed and implemented throughout next year and beyond, starting with our first round of web-checker improvements. Until this work is implemented, mobile coverage reported in this report will be based on the same approach and criteria as that used in previous Connected Nations reports.

Highlights

- **The availability of 5G mobile continues to grow steadily** with MNOs' coverage ranging between 61% and 79% outside premises.[44] 5G coverage outside premises where it is available from at least one MNO has increased to 90-95%, up from 85-93% in 2023 (across a range covering Very High and High Confidence levels).[45] MNOs' 5G predictions indicate that BT/EE has the most extensive outside premises coverage at both our High Confidence level (79%) and Very High Confidence level (76%).
- **There has been further deployment of 5G standalone sites for mobile.** Last year, we reported that the deployment of commercial 5G mobile standalone sites had begun, and this year, this has increased to over 3,300 sites accounting for just below 15% of 5G sites. 5G mobile standalone now carries 14% of the total monthly 5G traffic (around 3% of overall monthly mobile traffic in the UK).
- **4G continues to be the main technology for mobile users.** 4G remains the primary technology for mobile users, reaching outside more than 99% of UK premises and carries 78% of total monthly mobile data traffic. 4G geographic coverage where it is available from at least one MNO has now reached 95% (delivering early on one of the key targets for the Shared Rural Network programme), with 4G geographic coverage across individual

[44] The coverage ranges here refer to the span between the MNO with the least coverage, and that with the most coverage at our High Confidence level.

[45] Please refer to our 'Background to mobile technologies' section in this chapter where these levels are defined.

MNOs in the UK rising from a range of 80-87% last year to 88-89% this year. We note the 4G geographic coverage improvements as a result of the Shared Rural Network programme.[46]

- **Mobile traffic continues to grow, though at a slower pace,** with overall monthly traffic levels increasing by around 18% to 1069 PB this year compared to the c.25% growth between 2022 and 2023. Monthly 5G traffic has seen the highest increase from 151 PB in 2023 to 227 PB in 2024, an increase of around 50%.[47]
- **MNOs have started switching off their 3G networks, with two of them having already completed the process.** MNOs have also committed to switching off their 2G networks by 2033 at the latest. The number of customers using devices reliant on 2G or 3G connectivity has fallen from 2.4 million down to 2.1 million.[48]

Figure 3.1: Overview of voice and data coverage across the UK and UK nations[49]

	5G outside premises (MNO range)	4G outside premises (MNO range)	4G geographic (MNO range)	4G total not spots	Voice and text total not spots
UK	61-79%	99-99+%	88-89%	5%	3%
Scotland	54-76%	99-99+%	77-80%	11%	7%
Northern Ireland	36-90%	98-99%	89-95%	2%	<1%
Wales	16-80%	98-99%	83-89%	5%	3%
England	65-81%	99-99+%	94-96%	1%	1%

Source: Ofcom analysis of MNO predictions (September 2024)

Background to mobile technologies

Mobile services described in this section include:

- **5G, the current generation of wireless technology,** is faster than previous generations of wireless technology, as it offers greater capacity, allowing an increased number of devices to be connected at the same time in a small area. It is also more responsive by reducing latency which is the time between instructing a wireless device to perform an action and that action being completed.

[46] Ofcom, Mobile coverage obligations, 20 February 2024.
[47] 1 PB (Petabyte) is equivalent to 1,000,000 GB (Gigabyte). Additionally, traffic reported in this section, except for MNO IoT traffic, is rounded up to the nearest whole number.
[48] The 2.1 million figure only includes direct customers of MNOs and MVNOs. It does not include third-party devices, such as smart meters or devices using roaming SIMs.
[49] The coverage ranges in this figure refer to the span between the MNO with the least coverage and that with the most coverage on a given measure. For 5G outside premises, the coverage range is based on our High Confidence level, rather than the Very High Confidence level which we also use in this report.

• **5G non-standalone (5G NSA)** involves deploying 5G radio equipment alongside existing 4G and is supported by the 4G core network. This delivers an increase in capacity and allows MNOs to support demand as it continues to grow, without the congestion and degradation of service quality that would otherwise result.

• **5G standalone (5G SA**) involves the deployment of a new 5G core network. This could enable new use cases such as Augmented Reality (AR)/Virtual Reality (VR) and robotics, supported by the broader capabilities of 5G including ultra-low latency, advanced virtual network (slicing) functions,[50] and potentially improved coverage.[51] 5G SA referred to in this chapter is specifically in relation to mobile standalone deployment.

When reporting on 5G mobile availability predictions, we refer to confidence ranges reflecting the likelihood of on the ground coverage for consumers as: [52]

• **High Confidence** associated with a signal strength (-110 dBm), to equate to at least an 80% confidence level.

• **Very High Confidence** associated with a higher signal strength (-100 dBm), to equate to a circa 95% confidence level.

• **4G, 3G and 2G** are older generations of mobile standards with specified features. In particular, 3G supported the use of data applications such as web browsing, while 4G has supported more data intensive activities such as streaming and gaming.

Mobile coverage

Approach to mobile reporting

The mobile coverage data in this report is based on signal strength predictions provided to us by the MNOs. To evaluate the accuracy of the information provided, we undertake regular testing to ensure that the predictions are suitable for national and regional reporting.[53]

However, this approach to reporting on coverage has limitations. In particular, signal strength predictions - while generally reasonable for determining average coverage over a wide area - come with significant uncertainty when trying to determine coverage in a specific location, particularly where the signal strength is low.

[50] Network slicing is a feature of 5G SA networks that allows an MNO to create multiple virtual networks (slices) on top of its common shared physical infrastructure. The virtual networks are then customised to operate with specific quality of service and meet the specific needs of applications, services, devices, customers or operators.
[51] Augmented Reality (AR): an enhanced version of the real physical world that is achieved through the use of digital visual elements, sound, or other sensory stimuli delivered via technology. It overlays digital content, which could include a combination of sound, video, text, and graphics, onto a real-world environment using a headset or a device with a camera, such as a mobile phone.
Virtual Reality (VR): use of a headset to access a virtual experience, which could be digitally created or a captured 360° photo or video.
[52] Signal strength measured on the 4G common reference signal and 5G secondary synchronisation block – for further detail see our Methodology annex.
[53] For more information on this, please see the Methodology annex.

So we are working to improve our mobile coverage and quality reporting. Set out below is our programme of improvement:

- We are planning to use higher signal strength thresholds when presenting local predictions
- We will overhaul our website in the summer and provide clearer explanation of the issues and the specific functions of the web-checker
- We will assess predicted signal strength information at a more granular level (50 or 25 square metres instead of the current 100 square metres) to determine if it is possible to reduce the local uncertainty to some extent.

We will also look to use measured data, including crowdsource data, to build on the coverage predictions, providing more insight into where and when the consumers can expect a good experience. We acknowledge the limitation of data sampling for crowdsource data, but we consider it could help consumers understand which MNO would best suit their needs in a given area.

Following implementation of our current programme of work, we will consider undertaking a larger-scale performance measurement programme to complement coverage predictions and enhance our mobile reporting.

We will continue to engage with Government and MNOs, over the next 12 months, to improve reporting of mobile coverage and performance.

5G standalone deployment

We are seeing an increase in reported 5G mobile standalone (SA) deployments. Last year, we reported around 2,000 5G SA sites. This year, a total of over 3,300 sites was reported, representing just below 15% of reported 5G mobile sites and 14% of the total 5G traffic (c.3% of overall mobile traffic in the UK).[54]

5G mobile services are still mostly being delivered in non-standalone (NSA) mode. This means that services can be delivered over 5G alone or a mix of 4G and 5G but supported by existing 4G infrastructure. We report 5G mobile coverage as merged 5G NSA and SA. We aim to explore ways with MNOs to report on 5G SA and 5G NSA separately as mobile networks evolve.

5G availability continues to grow steadily

5G continues to reach a growing number of consumers, with around 50% of mobile handsets now 5G capable and notable increases in coverage observed across the UK.[55]

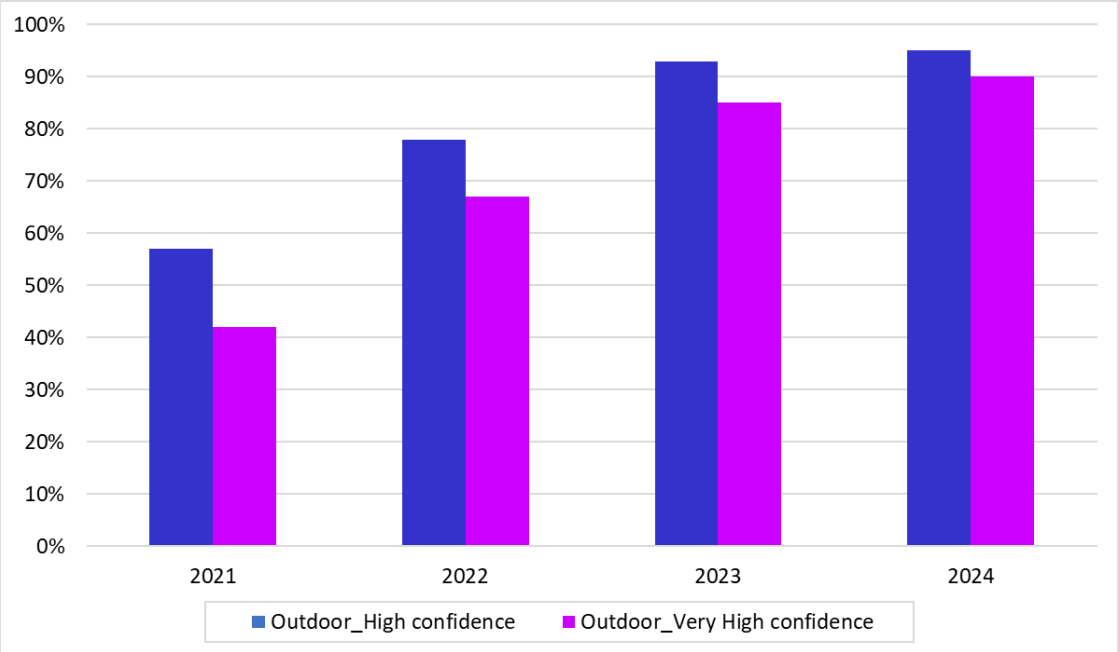
The availability of 5G, where consumers are likely to connect to a 5G network, continues to grow, although it varies by MNO and geography. In 2024, there has been an increase in 5G coverage across the UK, with 95% (High Confidence) and 90% (Very High Confidence) 5G coverage in areas outside of

[54] The total traffic and number of 5G sites reported here are likely to be slightly lower than the actual figures. This is because one of the MNOs has underreported its site count and, consequently, the associated traffic due to data issues with its performance reporting tool.

[55] Based on analysis of operators' data. The methodology for calculating the total number of devices varies across MNOs, making this figure an approximation rather than an exact figure. Additionally, we note that not all 5G capable devices may be enabled with a 5G subscription.

premises where it is available from at least one MNO.[56] This is an improvement from 93% and 85% respectively in 2023 (see Figure 3.2).[57]

Figure 3.2: 5G coverage outside UK premises where it is available from 'At least one MNO' (2021 - 2024)



Source: Ofcom analysis of operator data (September 2024)

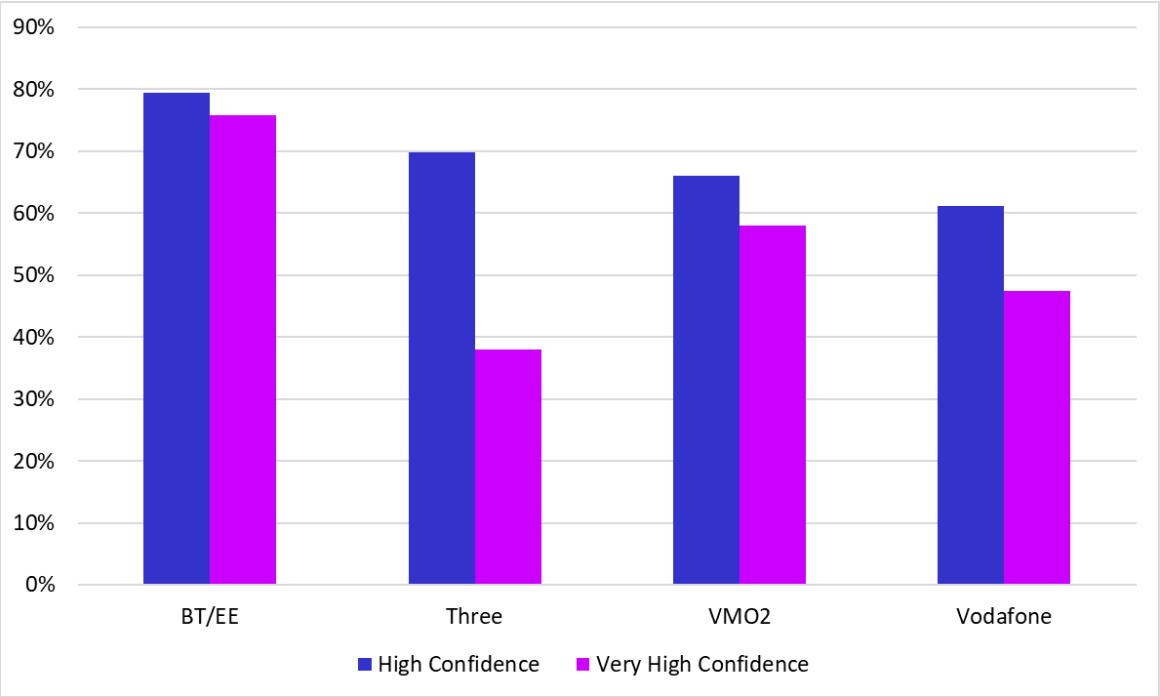
The footprint where all MNOs provide 5G coverage remains considerably lower. However, it has increased, now covering outside 38% of premises at the High Confidence level and 19% at the Very High Confidence level, up from 25% and 16% respectively last year.

Across individual MNOs, 5G coverage outside premises varies across UK Nations as follows: 65-81% for England; 54-76% for Scotland; 16-80 % for Wales; and 36-90% for Northern Ireland (all based on the High Confidence level). BT/EE leads in 5G coverage outside premises at both our Very High Confidence and High Confidence levels extending to around 76% and more than 79% respectively (see Figure 3.3).

[56] 5G coverage figures reported in this chapter are slightly lower than the actual 5G coverage due to data inconsistencies affecting 5G standalone reported by one of the MNOs during the later stages of our publication process. We are looking into the effect of this at both the UK and nations level to determine if an update is needed.

[57] By 'coverage outside premises', we mean that coverage is predicted in a 100x100m area in which a dwelling is located, which can be seen as a proxy for outdoor coverage of populated areas in the UK. By 'At least one MNO', we mean the combined coverage that would be available if the total coverage of each MNO was included in an aggregated coverage footprint.

Figure 3.3: MNO 5G coverage outside UK premises, at Very High and High Confidence levels[58]



Source: Ofcom analysis of operator data (September 2024)

The expansion of 5G landmass coverage by individual MNOs is progressing, albeit at a modest pace. Currently, coverage ranges from 15% to 42% of the UK landmass at the High Confidence level, and from 8% to 35% at the Very High Confidence level. This marks an increase from last year's figures of 11% to 38% and 6% to 26%, respectively.[59] BT/EE leads in 5G landmass coverage in the UK reaching around 35% (at Very High confidence) and 42% (at High Confidence).

These increases in coverage have been driven by additional 5G deployments, with over 23,100 5G sites now operational across roughly 81,000 sites in the UK, up from around 18,500 reported in 2023 (c.24% increase).[60] 84% of these sites are in England, 9% in Scotland, 4% in Wales and 2% in Northern Ireland, consistent with previous years and mirroring the national distribution of mobile traffic.[61] Urban areas have seen the most significant deployment with 42% of sites in urban areas now equipped with 5G, compared to 29% in suburban areas and 16% in rural regions, an increase from 34% for urban, 20% for suburban and 10% for rural reported last year.[62]

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[58] The data we have received from Three shows a drop in its 5G coverage compared to our reporting in last year's Connected Nations report from September 2023. Three has stated that this is mainly due to configuration changes in their network and some minor adjustments in their prediction model for a handful of sites, but that these changes do not have an adverse impact on the overall 5G experience for their customers.

[59] The coverage ranges refer to the span between the MNO with the least coverage and that with the most coverage on a given measure.

[60] These deployments do not necessarily equate to a total of individual sites across all MNOs. For example, two MNOs may be offering coverage from the same site. Also, this encompasses the various 5G mobile deployment types i.e. 5G NSA, 5G SA and Dynamic Spectrum Sharing (DSS).

[61] Note that the percentages do not add up to 100% due to rounding to the nearest whole number.

[62] The aggregated number of sites, represented by the percentages in both rural and urban classifications and the nations split of sites, is slightly less than the total sites. This is because not all sites could be spatially mapped onto the UK due to limitations in the ONS 2021 Census National Statistics Postcode Lookup (August 2023) and Locale

4G coverage

While 5G coverage is expanding, it is important to note that most people still use voice and data services over 4G. Below we outline 4G coverage from different MNOs.

Outdoor premises coverage remains high

As in previous years, individual operators maintain 4G coverage outside more than 99% of UK premises. Additionally, 99% of premises enjoy outdoor 4G coverage from all MNOs, an increase of 1 percentage point from last year's figure of 98%. Voice and text service coverage remains robust, with each MNO providing outdoor voice call coverage at around 99%+.[63]

In rural areas, individual operator 4G coverage outside premises ranges from 97% to 98%, an improvement from last year's 94% to 98%. In contrast, each MNO continues to cover 99%+ of urban premises. Outdoor voice coverage across the UK remains at 99%+, unchanged from 2023.

Indoor coverage continues to be widely available

The coverage that people receive indoors depends on a range of factors including the thickness of walls, building materials used in construction and where in a building people are using their phone.[64] Consequently, there may be differences between MNOs' predicted indoor coverage data and the actual coverage available in some premises.[65]

Indoor 4G coverage now serves 94-96% of premises across different MNOs, a small change from last year's 93-96%. Indoor voice call availability remains the same as last year estimated at 96-99%+, although we note that all MNO voice coverage has decreased by around 2 percentage points this year. Some notable differences remain between indoor 4G and voice coverage in rural and urban areas, as shown in Table 3.1 below.

Table 3.1: 4G and voice indoor coverage across MNOs in rural and urban areas

	4G		Voice	
	2023	2024	2023	2024
Urban	96-98%	97-99%	99-99%+	99-99%+
Rural	73-82%	78-84%	81-97%	82-98%
Total	93-96%	94-96%	96-99%	96-99%+

Source: Ofcom analysis of operator data (September 2023 and September 2024)

Where indoor coverage is poor or unreliable, other solutions can improve the user experience. These include broadband-based voice or video calls on services such as WiFi calling, online communications

classification files, which we used to generate the classifications and geographical boundaries. However, this should not have a significant impact on figures reported as the number of sites affected is minimal.

[63] The MNOs' coverage is rounded up to the nearest percentage point.

[64] Ofcom's Mobile Coverage Checker provides information on the likelihood of there being indoor coverage in buildings at different locations and explains more about the factors that affect mobile signal indoors. This Ofcom produced map uses MNOs' coverage predictions indicating signal levels at every location in the UK.

[65] Ofcom determines indoor coverage by applying an average building entry loss of 10dB across buildings. We acknowledge this approach provides only a simplified view of indoor coverage and that the real experience depends heavily on the types of building material and insulation in a specific building.

services such as instant messaging and calling applications, or femtocell.[66] All MNOs offer WiFi calling, although not all phones are configured to support this. The percentage of voice over WiFi calls reported by three of the MNOs ranges between 9% and 17% across individual MNOs.[67]

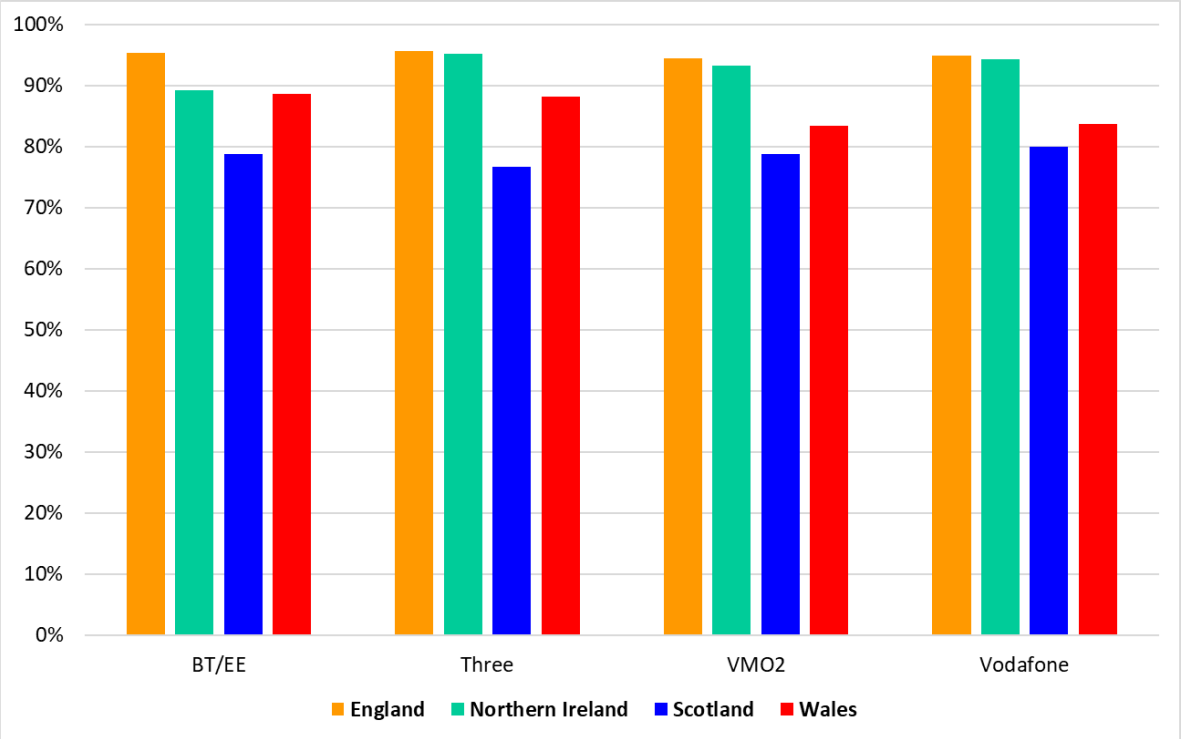
4G geographic coverage

Overall, 4G geographic coverage across individual MNOs in the UK has increased significantly since 2023, rising from a range of 80-87% to 88-89% this year. From the data reported to us, the percentage coverage by MNO is 89% (up from 87% in 2023) for BT/EE, 88% (up from 82% in 2023) for Virgin Media O2, 89% (up from 80% in 2023) for Three, and 89% (up from 83% 2023) for Vodafone. 4G geographic coverage where it is available from at least one MNO has now reached 95% compared to 93% in 2023. As the majority of the UK landmass is rural, rural coverage levels are similar to overall UK levels, while urban areas report moderately higher geographic coverage.

As of September 2024, MNOs' predicted geographic coverage in UK's nations ranged from 94-96% (compared to 92-95% in 2023) in England; 89-95% (compared to 88-92% in 2023) in Northern Ireland; 77-80% (compared to 59-76% in 2023) in Scotland; and 83-89% (compared to 73-85% in 2023) in Wales (Figure 3.4). This means that compared with 2023, the coverage range for England and Northern Ireland had modest increases at both lower and upper bounds, ranging from 1 to 3%. Scotland experienced a substantial increase in coverage range rising by 18 percentage points at the lower bound and 4 percentage points at the upper bound. Similarly, Wales coverage range increased significantly, with an increase of 10 percentage points at the lower bound and 4 percentage points at the upper bound. However, significant differences remain in 4G geographic coverage across the UK's nations.[68] We note the 4G geographic coverage improvements as a result of the Shared Rural Network programme.[69]

[66] WiFi calling is the ability to make and receive a call and text/SMS over a WiFi network. A femtocell is a small low-power cellular base station connected to the phone network over the internet.
[67] One of the MNOs was unable to differentiate between overall voice calls that are made over Wi-Fi (voWiFi) and overall voice calls that are delivered via VoLTE (VoLTE) on its network.
[68] This coverage is reported to the nearest full integer (whole number), consistent with past publications. We note that, in assessing the coverage obligations for the Shared Rural Network, we report MNOs progress against their commitments to one decimal place, providing a more detailed view of each MNO's level of progress for that purpose.
[69] Ofcom, Shared Rural Network (SRN) coverage obligations, 20 February 2024.

Figure 3.4: Differences in 4G geographic coverage in England, Northern Ireland, Scotland and Wales



Source: Ofcom analysis of operator data (September 2024)

Update on Shared Rural Network (SRN)

On 9 March 2020, the UK Government announced that it had entered into an agreement with the four MNOs to grant funding for a Shared Rural Network (SRN).[70] Under the terms of this agreement, each of the four MNOs has committed to provide good quality 4G data and voice coverage to 88% of the country's landmass by 30 June 2024, and 90% by 31 January 2027.[71]

On 12 September 2024, Ofcom published an update on the compliance of UK's MNOs with their SRN coverage obligations and confirmed that BT/EE, Vodafone and VMO2 had met the 88% UK-wide threshold and their individual thresholds for each UK nation.[72] We reported that, as of 30 June 2024, their UK wide 4G coverage levels were 88.9%, 88.7 % and 88.1%, respectively. We said we would undertake a further assessment of new information provided by Three and published a further update on 6 November 2024.[73] This confirmed that Three had subsequently met its outstanding UK-wide and Scotland coverage obligation thresholds, reaching 88.6% 4G geographic coverage.[74] This assessment was informed by coverage predictions submitted by the MNOs for the time these obligations fell due, and Ofcom's subsequent measurement work.[75]

[70] The SRN programme is detailed on our Mobile Coverage Obligations website: Mobile coverage obligations - Ofcom

[71] Good quality coverage is defined as the ability to sustain a 90 second voice call and access data speeds of at least 2 Mbps, with a methodology to assess this based on a 4G signal of at least -105 dBm.

[72] Shared Rural Network Coverage Obligations – Assessing the mobile network operators' compliance with their geographic coverage obligations.

[73] Shared Rural Network (SRN) Coverage Obligations - 2024 assessment update

[74] 4G geographic coverage where it is available from at least one MNO has now reached 95.3% (Source: Ofcom analysis of operator data, September 2024).

[75] 2020 coverage obligations - Notice of compliance verification methodology

Road coverage

4G coverage is predicted to be available inside vehicles[76] on motorways and A roads[77] across individual MNOs in a range of 89-92%. This falls to a range of 80-83% for B roads. Outside vehicles, 4G coverage on motorways and A roads ranges between 98-99% across individual MNOs (compared to 94-98% in 2023), and between 95-96% for B roads (compared to 90-95% in 2023).

Coverage of in-vehicle mobile voice services on motorways and A roads ranges between 90-98% across individual MNOs (91-97% in 2023).[78] This falls to a range of 80-95% for B roads (81-92% in 2023). Voice call coverage outside vehicles on motorways and A roads ranges from 99-99+% across individual MNOs, compared to 98-99% in 2023. Coverage for voice calls outside vehicles on B roads ranges from 96-99% across individual MNOs (compared to 94-97% in 2023).

Rail

We currently do not report on rail coverage or quality. In December 2019, we published open data on mobile signal strength along UK railways based on measurement equipment temporarily installed on 'yellow trains' or maintenance stock.[79] We also provided advice to Government in 2018 and 2020 on improving rail passenger access to data services.[80]

Since then, we have continued to explore the feasibility of reporting on coverage on trains in a relevant way. We currently consider that a new approach is needed to report mobile coverage and quality on trains. While our existing methods, including coverage prediction data from MNOs, provide reasonable estimates of aggregate coverage outside of trains, they fall short in accurately predicting quality on trains. The challenges of external mobile signals penetrating trains, combined with the substantial variance between predicted and measured signal strength, highlight the inadequacy of current prediction data for this purpose.

The high volume of concentrated mobile service demand on moving trains may cause capacity and service challenges which cannot be characterised using signal strength alone. Additionally, while some measurements might be sufficient to determine the availability of mobile services at a particular location, more in-depth measurements are often necessary. These measurements may need to consider factors such as the time of day, the location within the carriage, and the type of rolling stock to provide a comprehensive understanding of mobile service performance.

We are continuing work to explore alternative measurement and data collection methods to provide information on mobile quality on trains. We expect to provide an update in Connect Nations 2025.

Switch-off of 3G and 2G networks

3G switch-off is underway

All MNOs made a commitment to the Government to switch off their 2G and 3G networks by 2033 at the latest. This will result in improved network efficiency and enable more spectrum to be used for 4G and 5G services.[81]

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[76] Ofcom determines inside vehicle coverage by applying a 10 dB attenuation of outdoor signals.
[77] Motorways and A roads are collectively referred to as 'major roads' in our interactive report.
[78] Mobile voice services through 2G, 3G and 4G.
[79] Mobile signal strength measurement data from Network Rail's engineering trains
[80] Advice to Government on improving rail passenger access to data services
[81] A joint statement on the sunsetting of 2G and 3G networks and public ambition for Open RAN rollout as part of the Telecoms Supply Chain Diversification Strategy

In February 2023, we set out a number of expectations on mobile providers on 3G and 2G switch-off, which are designed to ensure that customers are treated fairly and any disruption to customers is minimised.[82]

The MNOs are responsible for their own switch-off timetables for these legacy technologies, with 3G being switched off first. This year, Vodafone and EE both completed their respective 3G switch-offs.[83] Ofcom has received very few complaints from customers about the impact of 3G switch off, and MNOs have not reported any significant disruption related to the switch to Ofcom. Three is in the process of switching off 3G, and Virgin Media O2 plans to switch off its 3G services in 2025.[84] We will continue to closely monitor these switch-off processes through to completion.

Over 2 million devices remain reliant on 2G/3G networks

Our latest estimates from MNOs about mobile providers' direct customers suggest there are 2.1 million devices reliant on 2G/3G networks, decreasing from 2.4 million in 2023.[85] Of the 2.1 million devices reliant on 2G/3G networks, the number identified by MNOs as residential devices (for example mobile devices such as handsets) stands at around 1 million.

There has been a rise in voice traffic being carried on 2G networks in 2024. Given that two MNOs have already completed 3G switch off, it appears that more calls may be being made over 2G because some customers are relying on devices which do not have the capability to make calls over 4G/5G networks.

This highlights the need for mobile providers to continue their efforts in contacting customers ahead of 2G switch off to ensure that they upgrade to 4G/5G VoLTE devices and can continue to access the services they need.

Virgin Media O2 is the only MNO to have announced plans for changes to its 2G network. It intends to start moving customers off its 2G network in 2025, other than for certain uses such as emergency calling and smart energy meters.[86]

In addition to mobile providers' direct customers, third-party devices that operate on 2G, including some telecare, fire and security alarms, will also require upgrading ahead of changes to 2G networks. The supply chain for these services can be complex, but we expect MNOs to make a sustained commitment to raising awareness so that suppliers have sufficient time to update their devices and their customers do not lose access to vital services.

There are additional key services that rely on 2G, such as smart meters and eCall, that will require efforts led by Government to ensure a smooth transition, and Ofcom will continue to offer support on this.

Emergency calling via 4G VoLTE, and the ability to roam onto another network using VoLTE are becoming increasingly important as MNOs continue phasing out their 3G networks. As of July 2024, all UK MNOs, except for VMO2, had already integrated emergency calling via VoLTE.

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[82] Ofcom's expectations of mobile providers for 2G and 3G switch-off

[83] Vodafone UK successfully switches off 3G across the UK - boosting 4G and 5G
We're Switching Off Our 3G Network

[84] Our plans to switch off 3G
Virgin Media O2 to begin switching off 3G in 2025 with enhanced customer experience as network evolves

[85] 2.1 million figure only includes direct customers of MNOs and MVNOs and does not include third-party devices such as smart meters or devices using roaming SIMs.

[86] Mobile network evolution: meeting customer needs now and for future

Mobile performance

Mobile performance explores various aspects of the connectivity that people experience, including upload, download speeds and latency, which extend beyond basic signal strength measured by coverage metrics. Signal strength alone does not necessarily correlate with the service performance experienced by users. Capturing performance parameters requires significantly more effort than measuring coverage and is also more variable, depending on factors such as the time of day.

Mobile performance using crowdsourced data

Ofcom's latest Mobile Matters Report provides analysis of mobile data service experiences across the UK.[87] The report, which uses crowdsourced data collected between October 2023 and March 2024, focuses on several key areas.

In our Connected Nations: UK Report 2023, we provided an initial snapshot of mobile performance, informed by crowdsourced data and we also identified the limitation of the dataset due to the availability of data points across the UK.

We are currently exploring the role innovative measured data, including crowdsource data, might play in providing an improved localised view of performance. We plan to provide further insights into mobile performance and quality reporting in the next 12 months.

Mobile traffic

Gradual slowdown in mobile traffic growth with rising 5G share

The growth in monthly mobile traffic as a whole has been slower, though absolute growth remains significant. Total monthly traffic has risen from 905 PB to 1069 PB,[88] [89] an annual increase of c.18%, compared to a c.25% increase in 2023.[90] This aligns with other reports on mobile traffic internationally over the last year. We will continue to report on these traffic levels in future years to allow any long-term changes to be observed.

5G traffic has shown the highest growth from 151 PB in 2023 to 227 PB in 2024, an increase of around 50%. This data traffic was generated from a device pool which now includes at least 50% 5G capable handsets (up from around 43% in 2023)[91] and represents around 21% of the total monthly mobile traffic, up from around 17% in 2023. 14% of this traffic is 5G SA traffic, around 3% of overall monthly mobile traffic in the UK. While 5G traffic has increased rapidly, 4G continues to carry most of the mobile data traffic, accounting for c.78% of total monthly data traffic (a decrease from 81% reported last year) (see Figure 3.5).[92]

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[87] Ofcom, Mobile Matters, 20 July 2023.
Mobile Matters 2024 : using crowdsourced data to assess people's experience of using mobile networks

[88] Traffic data rounded up to the nearest whole petabyte.

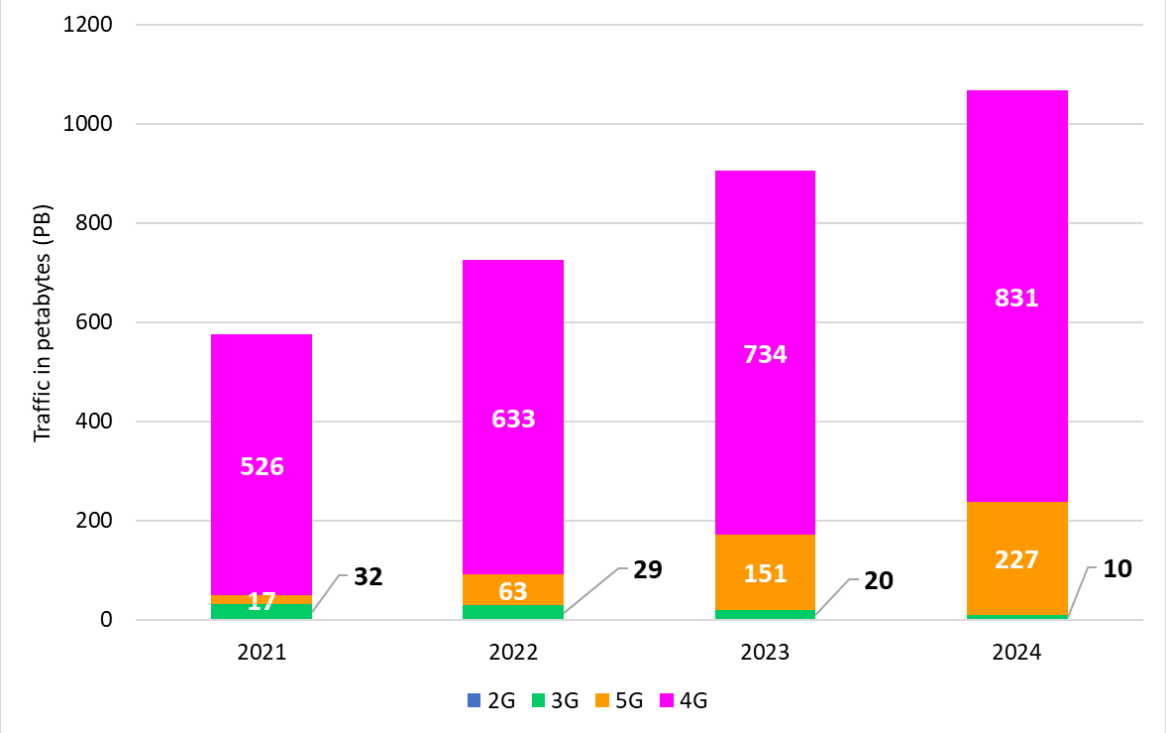
[89] The total traffic reported here is likely to be less than the actual traffic as one of the MNOs has underreported its traffic due to data issues on its performance reporting tool.

[90] The reported total monthly traffic includes all traffic across mobile networks, and therefore includes traffic generated by Fixed Wireless Access, where operators are offering domestic fixed broadband services over their wireless networks. All MNOs, except for one, offer FWA services with varying traffic splits, ranging from approximately 1% to 49%.

[91] Methodology for calculating total number of devices varies across MNO making this figure an approximation rather than an exact figure. Additionally, we note that not all 5G capable devices may be enabled with a 5G subscription.

[92] In comparison, only about 1% of data is now carried on 3G networks reflecting a long-term downward trend, with most voice traffic shifting to 4G/5G VoLTE and some to 2G networks.

Figure 3.5: Total monthly traffic by technology (2021-2024)



Source: Ofcom analysis of operator data (May 2021, May 2022, May 2023, July 2024)

Distribution of mobile traffic

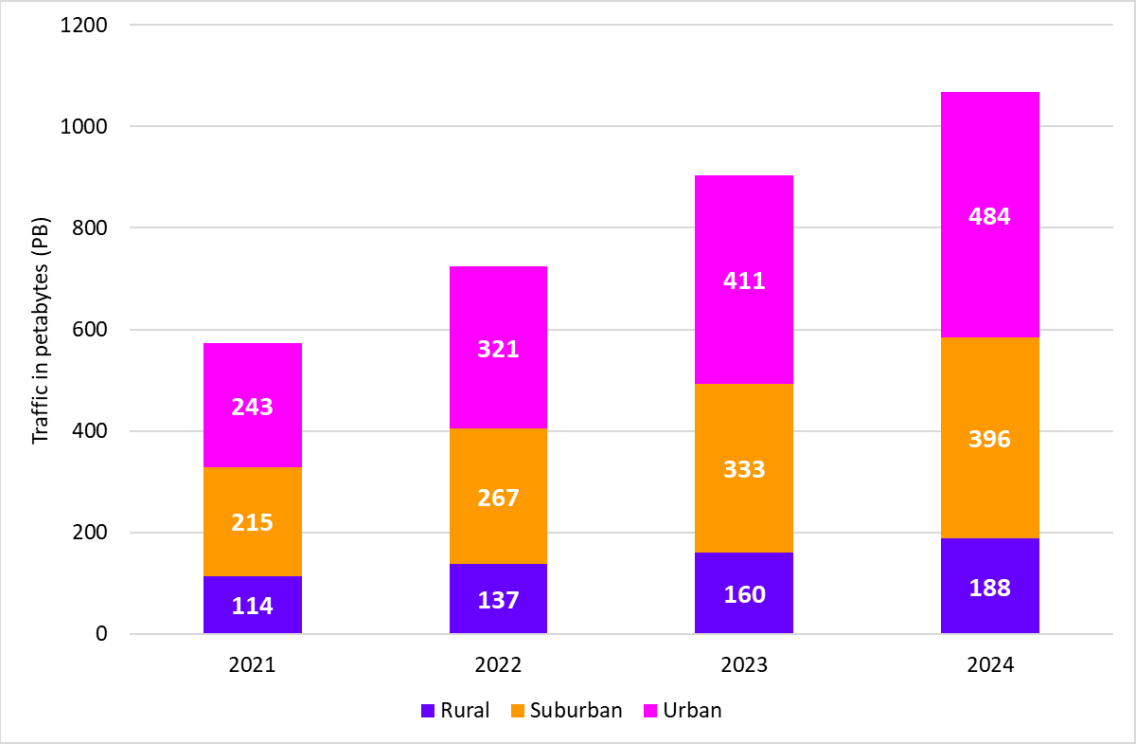
Data consumption continues to be divided between urban and rural areas as well as across the various nations of the UK in a way which largely mirrors population distribution, rather than any significant difference in data consumption of a typical user in rural areas or any specific UK nation when compared. Most of the monthly mobile data traffic (c.82%) is generated in urban and suburban areas (Figure 3.6).[93] [94]

Suburban areas experienced the highest monthly mobile traffic growth at 19%, slightly higher than the UK average of approximately 18%, but lower than the previous year's 25%, aligning with the broader traffic trends observed. Meanwhile, urban areas experienced a modest increase of around 18%, closely matching the UK average mobile growth. Rural areas also experienced growth with an increase of 17%, consistent with last year's increase of 17%.

[93] The rural population of England, Scotland and Wales is estimated to be between 17-20%, with the rural population in Northern Ireland somewhat higher. UK Government, Depopulation in rural areas, 09 September 2024. Scottish Government, Rural Scotland Key Facts 2021, 24 February 2021. Welsh Government, A Statistical Focus on Rural Wales, 2008. Northern Ireland Executive, Key Rural Issues, Northern Ireland 2023.

[94] The total mobile traffic, represented by the percentages in both rural and urban classifications as well as the nations' split, is slightly less than the total mobile traffic reported by MNOs. This is because not all sites could be spatially mapped onto the UK due to limitations in the ONS 2021 Census National Statistics Postcode Lookup (from August 2023) and Locale classification files, which we used to generate the classifications and geographical boundaries. However, this should not have a significant impact on figures reported as the number of sites affected is minimal.

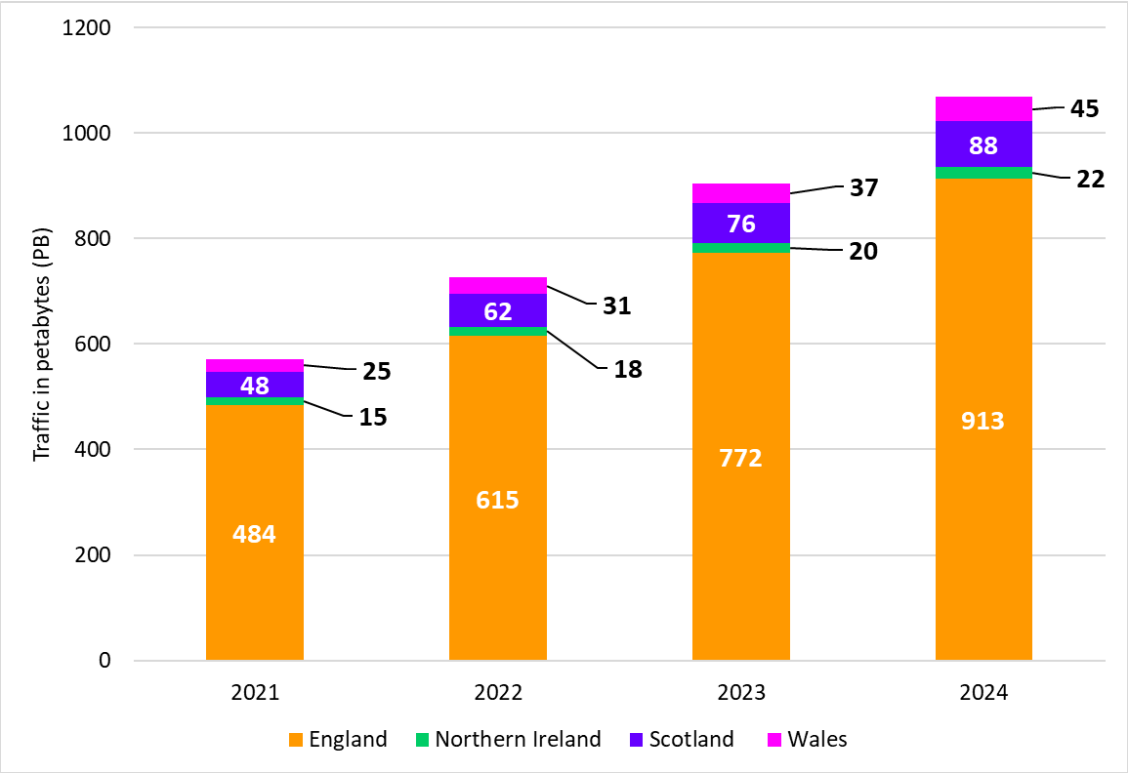
Figure 3:6: Total monthly mobile data traffic in rural, suburban and urban areas (2021-2024)



Source: Ofcom analysis of operator data (May 2021, May 2022, May 2023, July 2024)

Across nations, Wales had the highest monthly mobile traffic increase of c.20% since last year, slightly above the national average. Northern Ireland had the slowest increase at around 9%. England and Scotland also had notable increases of approximately 18% and 16%, respectively (see Figure 3.7). However, there has been a general decline in traffic growth across all nations compared to last year, aligning with the broader traffic trends observed.

Figure 3.7: Total monthly mobile data traffic trends by UK nations (2021-2024)



Source: Ofcom analysis of operator data (May 2021, May 2022, May 2023, July 2024)

Open RAN adoption

In December 2021, the UK Government confirmed an ambition for 35% of mobile traffic to be carried over open and interoperable systems (Open RAN)[95] by 2030, and in September 2023, in collaboration with the four major UK MNOs, reaffirmed this shared ambition for 35% of network traffic to take place over Open RAN.[96] [97]

Currently, Open RAN deployment remains limited, with just below 50 sites reported this year compared to around 40 sites reported last year. Similarly, mobile traffic carried over such architectures remains limited at around 24,600 GB, a decrease from 78,600 GB reported last year. We note, however, that we are still at an early stage in the commercialisation of Open RAN, and we will continue to monitor progress in the years ahead.

[95] Open Radio Access Network (Open RAN) is a network infrastructure that enables greater choice and flexibility in telecoms supply chains. It is considered to be one option that could allow the supply chain to be disaggregated with the use of "open" and "interoperable" off-the-shelf hardware, vendor-neutral protocols, and software-defined technology – Ofcom's article, What is Open RAN and why does it matter? provides further information on Open RAN.

[96] Minister for Media, Data and Digital Infrastructure, Telecoms Diversification: Update Against Taskforce Recommendations, 8 December 2021.

[97] UK and Mobile Network Operators' memorandum of understanding on Radio Access Network (RAN) solutions and Open RAN principles - GOV.UK

MNO private networks and IoT

Mobile services are not limited to public use; they also play a valuable role in supporting business connectivity and enabling device-to-device services. In today's digital environment, many businesses and public sector organisations depend on wireless broadband services to deliver their products and services effectively. Consequently, both MNO and non-MNO entities are leveraging the capabilities of 5G technology (in addition to other technologies) to provide customised connectivity solutions across a wide range of industries.

5G and private mobile networks

Emerging opportunities for private mobile networks, driven by 5G capabilities and its potential for ultra-low latency, are increasingly being leveraged by organisations seeking secure, high-capacity connectivity solutions, tailored to specific industry needs, such as real-time analytics, automation, and IoT applications. These networks are playing an increasingly important role in the digital transformation of many sectors of the economy, spanning from the enhancement of operations in ports to elevating user experiences in sports, media, and events. With a diverse range of providers, encompassing both MNOs and non-MNO entities and the opportunity for a broader set of players to emerge, this remains an active and developing area.

Whilst MNOs remain engaged in this space, the number of fully operational commercial private mobile networks run by UK MNOs remain limited. As of July 2024, less than 30 fully operational commercial private mobile networks were reported by MNOs, an increase of 11 compared to 2023. These networks utilise 4G, 5G, or a combination of both technologies primarily operating within 3400-4200 MHz and 2600 MHz bands. Of the reported private mobile networks, just over ten operate on 5G SA, with one of these private mobile networks delivered as a slice of the commercially deployed 5G SA network.[98]

Non-MNO players, including network equipment vendors, systems integrators, and specialist providers, continue to play a part in delivering private mobile networks across UK. Some of these players are accessing spectrum for their networks using our Shared Access licences (which also support a variety of other applications, including Fixed Wireless Access).[99] As set out in 2023, we consider that many Shared Access licences support private mobile network solutions. The number of Shared Access licences issued by Ofcom is just below 1,000, a decline from over 1,500 licences reported last year that is largely attributable to the return of a number of 'legacy' 1800 MHz licences that predated our Shared Access regime.[100] The majority of current licences fall within the 3800-4200 MHz band (c.57%), with an increase of around 60 additional licences this year, indicating an increase in the use of 5G-based solutions. Of these 3800-4200 MHz band licences, 63% are for medium power, with the remainder

[98] Network slicing is a feature of 5G SA networks. It allows an MNO to create multiple virtual networks (slices) on top of its common shared physical infrastructure. The virtual networks are then customised to operate with specific quality of service and meet the specific needs of applications, services, devices, customers or operators.
[99] Authorisations are provided either for single base stations at a medium power level, or multiple lower power base stations authorised within a 50m radius. Ofcom remains committed to enhancing this framework to support further sharing and improve the application experience for users. Statement and further consultation: Supporting increased use of shared spectrum
[100] Shared Access licences are available in parts of the 1800 MHz and 2.3 GHz bands, as well as 3.8-4.2 GHz and 26 GHz. Since 2023, BT EE has returned a large number of licences associated with its BT One Phone product, which predated the Shared Access regime.

being low power licences. These licences are distributed across the UK, with 86% in England, 8% in Wales, 5% in Scotland, and 1% in Northern Ireland.[101]

Internet of Things

The Internet of Things (IoT) refers to a network of devices and sensors which are capable of collecting and sharing data with people or with other devices, and taking action based on this information. These devices range from personal gadgets to industrial sensors and operate across various sectors, including healthcare, energy, manufacturing, and transport. In the UK, IoT connectivity is delivered by both MNOs and other non-MNO players, often operating in a specific local area. These providers utilise a range of frequencies, primarily within the lower and mid-band ranges that are either licence-exempt or authorised for use by MNOs.[102]

We have reported on both MNO and non-MNO IoT connectivity in previous years. This year, we are reporting on MNO IoT connectivity. We previously reported on estimations of IoT connections and data traffic based on data from a limited number of IoT providers in the UK. However, that reporting did not include a comprehensive set of stakeholders to provide a complete range of available IoT connectivity offerings. We plan to engage with the IoT stakeholder community to understand how development of our information gathering in this area would be helpful in providing a wider view of this offering in future reports.

IoT connectivity available from MNOs

UK MNOs continue to deliver IoT connectivity using their existing 2G, 3G, 4G, and 5G networks, as well as Low Power Wide Area Networks (LPWANs)[103] including NB-IoT[104] and LTE-M,[105] supporting a wide range of applications including asset tracking, utility metering, travel and transport, environmental monitoring, energy management solutions for smart buildings, car telemetry, and video surveillance.

The number of active IoT connections on MNO networks increased by 6.5%, reaching just above 26.5 million, though this marks a slowdown from the previous increase in 2023 of 31%. While these connections typically generate much lower data volumes than consumer handsets, MNO IoT traffic volumes continue to rise, increasing by 11% to 1.96 PB per month (a decline from the 17% growth reported last year). However, these volumes still represent less than 1% of overall data traffic.

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[101] The aggregated number of shared access licences, represented by the percentages across nations is slightly less than the total shared access licences. This is because not all shared access licences could be spatially mapped onto the UK due to limitations in the ONS 2021 Census National Statistics Postcode Lookup (from August 2023) and Locale classification files, which we used to generate the classifications and geographical boundaries. However, this should not have a significant impact on figures reported as the number of sites affected is minimal.

[102] Frequencies used by IoT services typically range from around 700MHz to 3800MHz.

[103] Low-power wide-area networks (LPWANs) are designed for IoT applications and services which have low data rates, long battery lives and, if required, can operate in remote and hard-to-reach locations. Furthermore, their extended range makes them better suited for in-building applications such as smart meters and smart car parks which may be located underground or in basements.

[104] Narrowband IoT (NB IoT) is a wide-area solution that supports massive deployment of IoT devices and is also optimised for a very long battery life. NB-IoT networks can be deployed in mobile bands and integrated on existing mobile base stations.

[105] Long Term Evolution for Machines (LTE-M) is a complementary technology to NB-IoT with the added capability of supporting IoT applications with higher data rates and lower latency requirements. It can also be deployed in mobile bands and integrated on existing mobile base stations.

IoT has the potential to play a growing role across a range of services

The increase in IoT devices and traffic suggests that businesses are increasingly leveraging IoT capabilities to enhance efficiency and innovation.

The ongoing phase-out of legacy 2G, 3G, and PSTN networks has implications for a range of sectors which include domestic and business customers, with the potential for IoT to play a crucial role in providing sustainable alternatives for essential services like security systems, telecare, and utility monitoring. Beyond these immediate applications, IoT's versatility supports a broad range of future innovations, driving improvements in service delivery across numerous sectors.

Network infrastructure is gradually being provided by an evolving set of players

MNO infrastructure underpins most of the coverage we report here. However, a variety of third-party players, from neutral host providers to satellite operators, are increasingly contributing to the provision of infrastructure[106] that supports both public and private networks. These players offer a range of services, from passive infrastructure[107] to comprehensive active infrastructure[108] tailored for specific environments such as office buildings, stadiums, and underground train stations. Some models even combine both approaches.

A neutral host provider in mobile communications is a third-party company that builds and manages network infrastructure, such as 5G towers and small cells, which it leases to one or multiple MNOs. This infrastructure approach can reduce costs, enhance efficiency, and improve network coverage, especially in areas where individual deployments would be expensive. For the year 2024, MNOs reported over 17,900 deployments on neutral host infrastructure, with around 89% of these deployments being sites for macrocells.[109] Indoor deployment continues to make up a small proportion, around 5%, of MNO reported neutral host deployments.[110]

We previously reported on estimations of mobile sites provided by neutral hosts and level of sharing, based on number of public networks hosted on the sites using data from some neutral host providers in the UK. However, this did not include a comprehensive set of stakeholders to provide a complete range of neutral host infrastructure offerings. We are therefore considering further development to our information gathering in this area by engaging further with the NH stakeholder community to provide a clearer view of this offering in future reports.

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[106] This includes, but is not limited to, remote rural lattice masts, urban rooftop sites, satellite constellations and street furniture with small cells to indoor coverage solutions and indicates a potential for this diversity of provision to grow in the future.

[107] Third party providers offer only the physical infrastructure required for network deployment, such as towers, antennas, and cables but do not manage the active components like radio equipment or the spectrum.

[108] Third party providers offer both the physical elements (passive infrastructure) like towers, antennas, etc., as well as the electronic components or elements of the network necessary for signal transmission and reception (i.e., active layer). For example, radio equipment.

[109] Note that we use unique eastings and northings to count individual MNO neutral host deployments. These deployments do not necessarily equate to a total of individual sites across all MNOs. For example, two or more MNOs may be hosted on the same site.

[110] Most of the deployments reported here support one operator with tower structures from MNOs, enabling MNOs to transition capital expenditure to operating costs. The neutral host providers could subsequently lease access to the infrastructure to numerous tenants.

Expenditure on mobile telecoms infrastructure

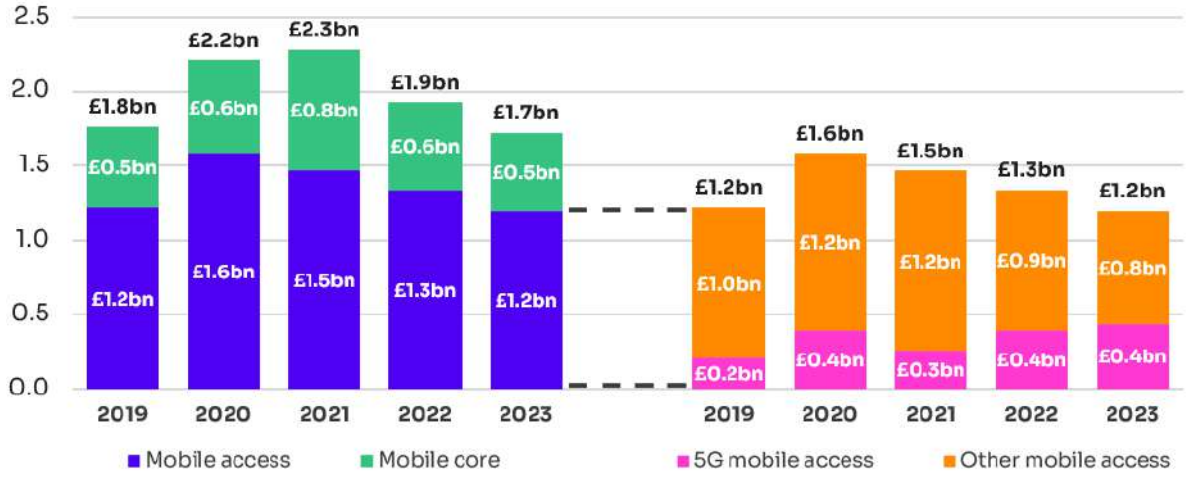
Estimated expenditure on mobile telecoms network infrastructure fell to £1.7bn in 2023

We estimate that mobile network operators (MNOs) invested £1.7bn in UK mobile network infrastructure in 2023, a £0.2bn (11%) year-on-year decline in real terms. In addition to this investment, £0.6bn was invested in infrastructure used to provide both fixed and mobile telecoms services.

Of the estimated mobile investment total, £1.2bn (69% of the total) was investment in mobile access network infrastructure (including site acquisition, equipment, and electronics). This represented a real-term fall of £0.1bn (11%) year-on-year. The remaining £0.5bn was spent on mobile core and backhaul networks, a £0.1bn (11%) fall compared to 2022.

All four UK MNOs continued to deploy 5G network infrastructure in 2023, when investment in 5G access networks totalled around £440m. This represented a £43m (11%) real-term increase compared to 2022. For the first time, we also collected information relating to investment in 5G core and backhaul networks (that are used to support standalone 5G mobile services) which totalled over £60m during the year.

Figure 3.8: Estimated mobile telecoms network capital expenditure: 2019 to 2023



Source: Ofcom analysis of operator data
Note: Adjusted for CPI (2023 prices)

4. Network security and resilience

Introduction

In December 2022, we published our procedural guidance on the exercise of Ofcom's functions to ensure compliance with the security duties in the Communications Act 2003 (the Act). This included our plans for a compliance monitoring programme and guidance on what security compromises are reportable to us and when they should be reported. We plan to consult on revising this next year, in particular to reflect our new resilience guidance and to update and further clarify our expectations on security compromise reporting.

In this section, we provide an update on our compliance monitoring programme, including our findings from our first information request, security compromises reported to us, and our work on monitoring compliance with high-risk vendor requirements. We note the importance of this work, given the increased number of actors and capabilities posing a threat to telecoms infrastructure.

We also report on our work on network resilience. We provide the latest summary of trends from the incident reports we receive from providers. In addition, we provide an update on our work on power back-up for mobile radio access networks.

Highlights

- **We are monitoring industry compliance with the telecoms security framework.** From our first information request, we are seeing significant investment by the providers to align their internal processes with their new legal obligations and providers appear to be making good progress on some of the initial measures.
- **Providers have ongoing obligations to report certain security compromises to us, which includes reporting both resilience and cyber-related incidents.** We are reviewing how our cyber compromise reporting guidance has been working in practice.
- **We have submitted three reports so far to the Secretary of State in October 2023, January 2024 and March 2024 based on the information gathered from relevant providers about high-risk vendors.** This follows the responsibility we were given to assist Government in its compliance assessment with the new restrictions on certain providers' use of Huawei products.
- **We have published significantly updated Resilience Guidance for Communications Providers.** This sets out the measures we expect providers to take to keep their networks and services running reliably.
- **The total number of significant resilience incidents reported to us has increased**. We received 1,523 submissions this reporting year, compared to 1,209 last year. In terms of lost customer hours, network change activities again caused the most serious cases, while hardware faults accounted for under a third of total lost hours.
- **There are resilience risks associated with legacy technologies and extreme weather events.** For example, this year saw a 45% rise in the number of PSTN incidents reported to us, although there was a 55% decrease in the number of PSTN service hours lost. On extreme weather incidents, the number of outages fell during the 2023/24 storm season, but certain events such as Storms Isha and Jocelyn caused significant impacts.

Network security

An update on our Telecommunications (Security) Act monitoring programme

As outlined in last year's report, a new security framework came into force in 2022placing new obligations on providers and giving Ofcom powers to monitor and enforce compliance.[111] The evidence we have gathered as part of our monitoring programme indicates that regulated providers are investing significantly in new programmes of work to align their internal processes with their new legal obligations, by reference to the recommended measures in the Telecommunications Security Code of Practice (the 'Code').

Our monitoring programme primarily focuses on the largest national-scale (Tier 1) public telecoms providers and to a lesser extent the medium-sized (Tier 2) providers.[112] We are in the early stages of our monitoring programme with deadlines in the Code spanning from 2024 to 2028 and the programme will continue to evolve as new threats emerge. We note the importance of this work, given the increased number of actors and capability posing a threat to telecoms infrastructure.

As set out in our procedural guidance, we are issuing statutory information requests approximately every nine months, with providers having six months to respond.

Our first round of statutory information requests sent in June 2023 focused on understanding the networks, services and assets in scope of the new framework, and some of the initial measures taken by the providers in response to a subset of measures set out in the Code. These requests asked all providers standardised questions in order to understand what they are doing in relation to each of these measures. Some questions included in our first statutory request were around:

- how providers keep records and test their externally facing systems,[113]
- ensuring default passwords are changed on equipment during installation,
- and understanding the signalling entering and leaving their networks and how malicious signalling could impact the equipment and data in their networks.

Due to the complexity of the networks and services some of the providers operate, we will often not have a complete picture of how they are adhering to each measure from their responses to each information request. We will continue to ask follow-up questions on areas where we want more detail, where answers are not clear, or we want to check on progress.

In general, our monitoring work to date suggests providers have good or improving governance practices with established policies, standards and processes in place, with significant investments underway to improve their security in line with the measures set out in the Code. Providers appear to be making good progress on initial measures, which focus on having security boundaries between the exposed edge and critical functions, ensuring privileged access is regularly reviewed and logged, and changing default passwords when setting up devices or services respectively.

[111] The relevant provisions of the Telecommunications (Security) Act 2021 ('the Security Act') and The Electronic Communications (Security Measures) Regulations 2022 (the 'Regulations') came into force in October 2022.
[112] Tier 1 and 2 providers are those that have a relevant turnover of greater than £1bn and £50m respectively.
[113] Any system or service with an externally-facing interface. An externally-facing interface is defined as any system interface that is accessible to people or systems outside of the provider's direct control.

We will be following up on several areas, including some of the signalling measures on how providers understand and monitor the signalling entering and leaving their networks, their processes in place for third party management, and asset management (including legacy and end of life equipment).

As part of the process set out in our procedural guidance and the Code regarding provider tiering, we have been through the first reporting cycle.[114] We sent the second round of our monitoring requests in June 2024 and responses are due in early 2025. In next year's Connected Nations report, we expect to share an overview of our findings from the second information request, and any additional information from our follow-up questions.

We have also onboarded new providers who have moved subsequently into Tier 2 and are starting our monitoring programme with them.

Finally, we would like to note that the National Cyber Security Centre (NCSC) is working on additional security advice to industry, some of which relates to topics covered by the Code. We have engaged with NCSC to support an international standard made available through the European Telecommunications Standards Institute (ETSI), which will support vendors in delivering suitable products to our regulated providers.[115]

Cyber security compromises reported to us

Providers have an ongoing obligation to report security compromises that meet certain criteria to us. Reporting of resilience-related incidents was a feature of the previous regime, and as such, our guidance and the processes followed by the providers are well-defined and embedded. In contrast, our guidance on cyber security compromise reporting is new and we expect to refine this over time. To help us understand how it is working so far, we engaged with the larger providers to understand how they handle cyber security compromises internally and the decision making involved on whether a cyber security compromise is reportable to us.

We are considering updating our procedural guidance to further clarify our expectations on security compromise reporting, particularly on the legal duty to report pre-positioning attacks. These are where an attacker gains initial access to the network or service in preparation to carry out a subsequent attack that would have a significant effect on the operation of the network or service.

Providers are required to report security compromises that are an indicator of pre-positioning as defined above or anything that has a significant effect on the operation of the network or service.

To date, while we have had very few incidents reported to us, those that have been reported have given various causes for those incidents, including Distributed Denial of Service (DDoS), ransomware, phishing and exploitation of vulnerabilities. We are aware that only a small number of overall cyber security incidents will meet the criteria under s105K of the Act[116] and therefore become reportable, while providers are likely to deal with a large number of less impactful cyber security compromises.

As part of our incident triage process, we sometimes ask follow-up questions on areas where we want more detail or to check on the provider's progress if they have mentioned any programmes of work in response to the incident, such as a root cause analysis. If there are concerns about a potential breach,

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[114] Telecommunications Security Code of Practice - the tiering system (page 7), Ofcom's procedural guidance - compliance monitoring based on tiering (page 10).

[115] ETSI TS 103 994-1

[116] A provider must report (a) any security compromise that has a significant effect on the operation of the network or service; (b) any security compromise within section 105A(2)(b) that puts any person in a position to be able to bring about a further security compromise that would have a significant effect on the operation of the network or service.

we will work with our enforcement team and discuss the best way forward including the option to open an investigation.

Outside their reporting duties, we see some examples of providers sharing findings from their cyber threat intelligence work with us, which suggests an encouraging degree of security maturity is developing in the sector.

We are continuing to follow the High-Risk Vendor monitoring direction issued by the DSIT Secretary of State

In October 2022, the DSIT Secretary of State placed restrictions on certain providers regarding the use of Huawei products within their networks and services, which provided for providers to comply with certain restrictions by various due dates.[117] In June 2023, DSIT issued a monitoring direction that requires us to collect information on whether providers are complying with the restrictions. We have published a redacted version of the direction on our website.

As required under the Direction, we have provided the Secretary of State with reports in each of October 2023, January 2024, and March 2024 setting out information on levels of compliance. The due dates for further restrictions are in 2025 and 2027 and we expect to follow the same process for each of these.

Global Titles and mobile network security

As discussed in our update above on our monitoring programme, signalling is an essential part of the networks and services providers offer and is an area we will be following up on. As part of our wider work, we became aware of mobile network security concerns arising from the leasing of Global Titles (GTs). GTs are created from UK mobile numbers, which Ofcom allocates, and enable access to the global mobile signalling network. GTs normally underpin the provision of legitimate mobile services, but there is evidence that GTs are sometimes being misused, for example to illicitly locate and track people using their mobile phones on other networks.

In July 2024, we consulted on proposals designed to tackle malicious signalling originating from UK GTs, including proposing a ban on the leasing of GTs to third parties by operators that hold UK mobile numbers.[118] We are currently considering responses to the consultation, and we are aiming to publish our final decisions on new rules in a Statement in Q4 2024/25.

SMS Blasters

We are also acutely aware of the telecoms fraud and spectrum impacts relating to the use of "SMS Blasters"[119] within the UK. Successful interventions have taken place by the Police,[120] and we continue to work with NCSC and other partners to ensure this new threat can be managed effectively.

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[117] The Secretary of State may give a 'designated vendor direction' to a public communications provider if they consider that the direction is necessary in the interests of national security and proportionate (s.105Z1 of the Communications Act 2003).

[118] Ofcom, Global Titles and Mobile Network Security – proposals to address misuse of Global Titles, 22 July 2024.

[119] An illegitimate telephone mast that bypasses mobile phone networks' systems in place to block suspicious text messages and is used to send smishing messages, posing as banks and other official organisations, to members of the public.

[120] City of London Police, Two people arrested in connection with investigation into homemade mobile antenna used to send thousands of smishing text messages to the public | City of London Police, 7 June 2024.

Network resilience

Updated Resilience Guidance for Communications Providers

Following our public consultation from 8 December 2023 to 1 March 2024,[121] we published the updated Network and Service Resilience Guidance for Communications Providers[122] and the associated statement[123] on 6 September 2024.

As more and more people rely on the internet to stay connected both at home and work, having resilient telecoms networks is vital to both consumers and businesses across the UK. Communications providers have a legal obligation to identify, prepare for and reduce the risk of anything that compromises the availability, performance or functionality of their network or service.

We have significantly updated our resilience guidance for communications providers, which sets out the measures we expect them to take to keep their networks and services running reliably. The updated guidance describes a range of practices in the architecture, design, and operational models that underpin robust and resilient telecommunications networks and services, as well as more specific measures that we expect communications providers to consider. These are designed to help achieve our aim of ensuring an appropriate level of resilience for services across the UK.

The measures include:

- making sure networks are designed to avoid or reduce single points of failure;
- making sure key infrastructure points have automatic failover functionality built-in, so that traffic is immediately diverted to another device or site when equipment fails; and
- setting out the processes, tools, and training that should be considered to support the requirements on resilience.

We will use the guidance as a practical reference both:

- in information gathering and monitoring of network and service resilience when engaging with communications providers and the wider industry; and
- as a starting point for considering compliance as part of any enforcement activities in relation to resilience issues.

We continue to receive reports of 'resilience incidents' from communications providers

As in previous years, we continue to receive reports from communications providers throughout the year about resilience incidents that had a significant impact on their networks and services. Our procedural guidance for providers explains the types and sizes of incidents we expect them to report to us in order for them to comply with their regulatory obligations.

The total number of reported incidents has increased over the last year

We received a total of 1,523 reports of resilience incidents from providers during this reporting year (September 2023 - August 2024), which covers both fixed and mobile incidents. This is 26% higher than the 1,209 reports received in 2023.

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[121] Ofcom, Resilience guidance consultation and Call for Input on mobile RAN power back up, 8 December 2023.
[122] Ofcom Statement: Network and Service Resilience Guidance, 8 December 2023.
[123] Ofcom Statement: Network and Service Resilience Guidance, 8 December 2023.[124] Lost Customer Hours is a metric calculated using the impact of an incident and its duration.

Fixed network incident reports increased substantially from 600 in 2023 to 910 in 2024. The volume of fixed incidents, particularly relating to PSTN voice, has grown over the years due to the equipment being beyond its intended lifespan and the reduction of qualified personnel within industry with experience of these legacy technologies. This year has seen a 45% increase in the number of PSTN incidents reported to us, although a 55% decrease in the amount of service hours being lost for customers (the ongoing migration of customers from PSTN to Digital Voice services means that fewer customers are impacted by service loss when the incidents occur).[124]

Meanwhile, mobile network resilience incidents reported to us increased from 609 in 2023 to 696 in 2024.

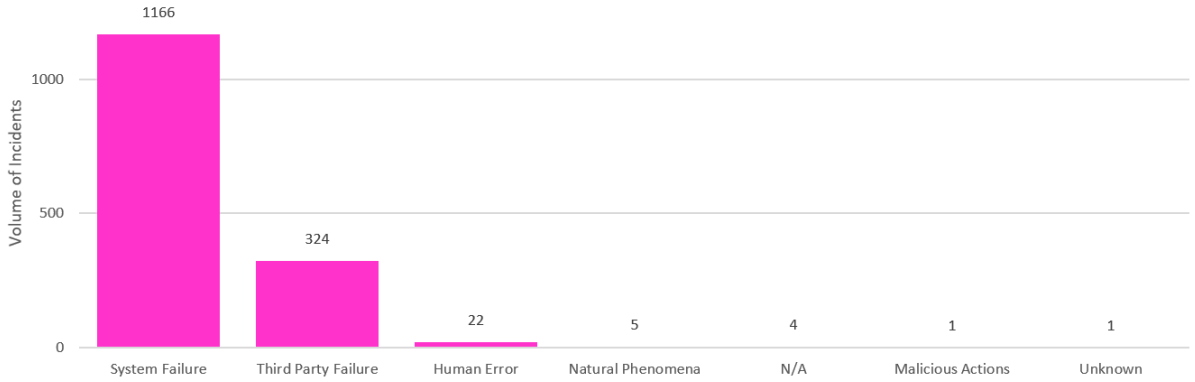
Figure 4.1: Volume of incidents reported to Ofcom each month

Source: Ofcom analysis of provider data (September 2023 - August 2024).

From the incidents that were reported to us over the period, we have seen that outages above the reporting thresholds[125] impacted a total of 24m customers and resulted in approximately 235m customer hours of service lost. This compares to last year when 17.5 million customers were impacted, and approximately 107 million customer hours of service were lost.[126] The large variation between the years is not uncommon and can be impacted by a small number of significant incidents rather than any one specific trend.

[124] Lost Customer Hours is a metric calculated using the impact of an incident and its duration.
[125] Annex 1 - General statement of policy under section 105Y of the Communications Act 2003
[126] Due to an established set of Causes and Threats we use ENISA categorisations. About ENISA - The European Union Agency for Cybersecurity — ENISA (europa.eu).

Figure 4.2: Volumes of incidents by root cause of incident

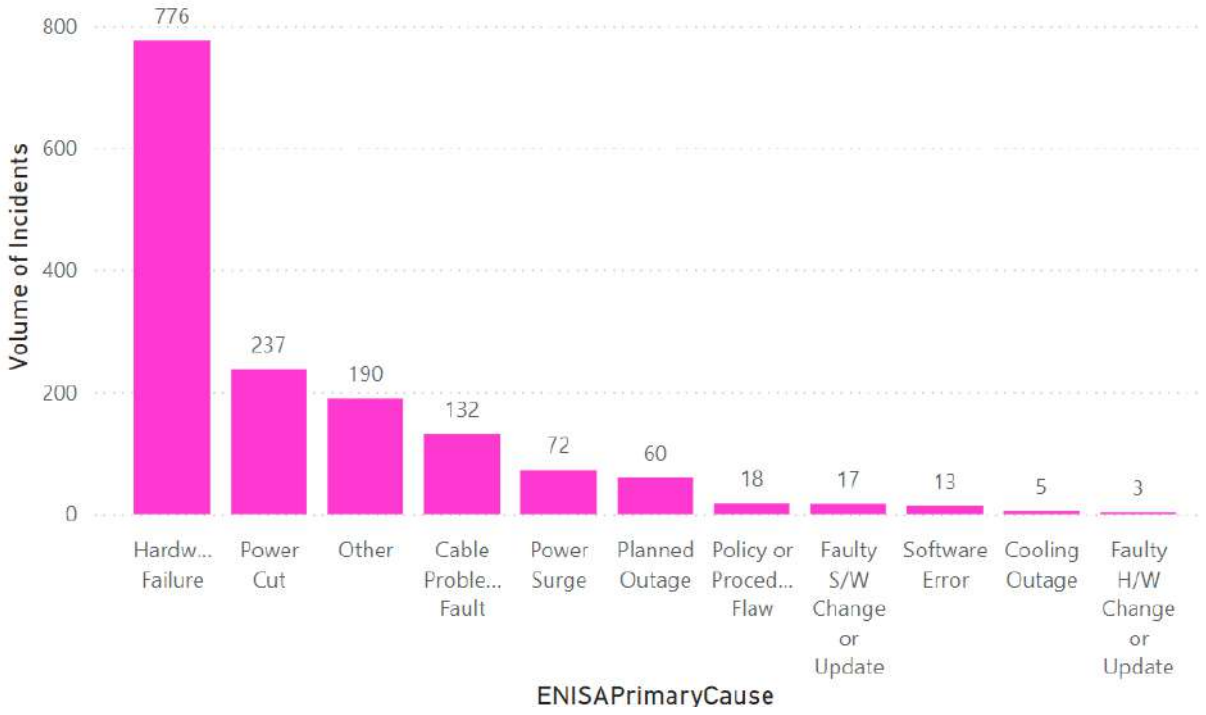


Source: Ofcom analysis of provider data (September 2023 - August 2024).

The most prevalent root cause for the majority of reported failures was system failures. This root cause category includes primary causes such as hardware failures, design errors, and faulty changes (Figure 4.2).

Failing equipment still generates the highest volumes of reported incidents

Figure 4.3: Volumes of incidents reported by primary cause of incident



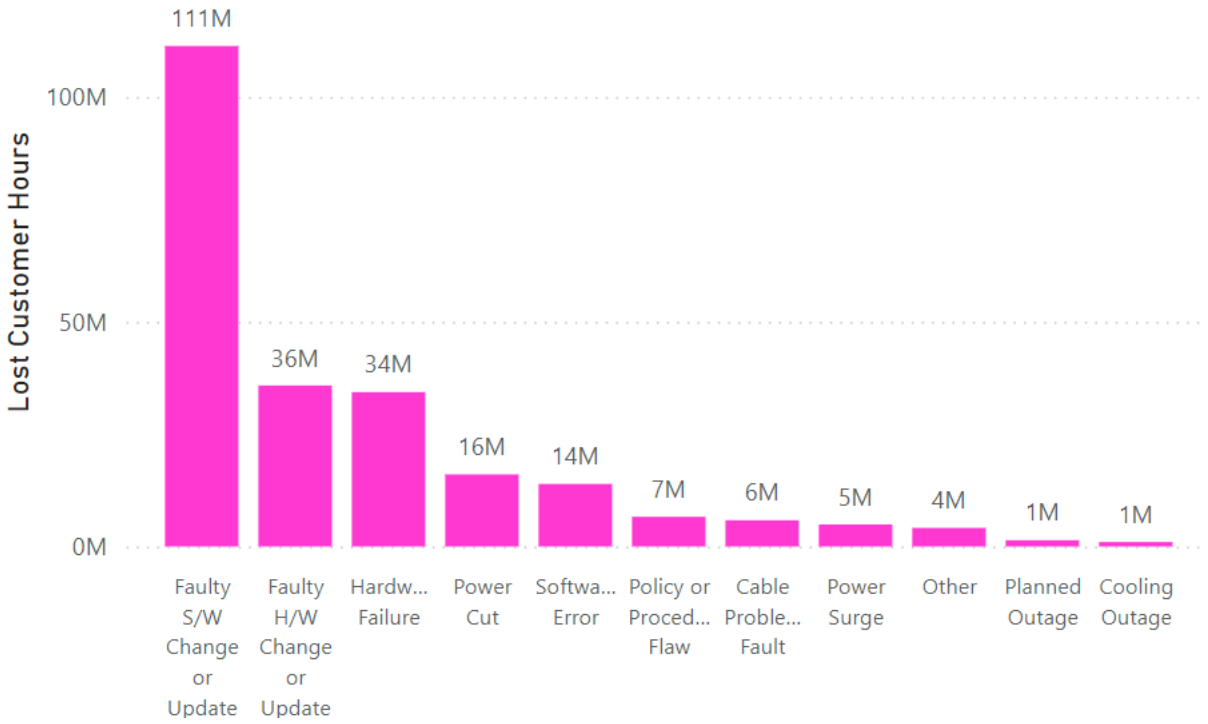
Source: Ofcom analysis of provider data (September 2023 - August 2024)

The root causes used to categorise incidents in Figure 4.2 are quite broad. By looking deeper into the primary causes, we can gain further insight into the specific factors that are driving customers to lose service (see Figure 4.3 and Figure 4.4).

As in previous years, hardware failures are the largest volume (776) of reported incidents when categorised by primary cause, exceeding over half of the total number of reports received. However, the hardware failure incidents generated under a third of the total lost customer hours reported to us this year (30%).

This year we received 237 reports related to power cuts, leading to 16 million user hours being lost. There were a further 72 power surge incidents reported, resulting in 4.9 million user hours being lost. This means that power incidents reported to us generated 20% of the total volume of incidents reported but fewer than 9% of the reported total user hours lost. 57% of these hours lost impacted mobile base stations or the associated backhaul transmission systems.

Figure 4.4 : Volume of lost customer hours by primary cause



Source: Ofcom analysis of provider data (September 2023 - August 2024)

Changes to networks are driving the highest impact incidents

As last year, 20 resilience incidents were reported to us this year with impacts exceeding 1 million user hours of lost service.

This represented 83% of user hours lost across all incident reports. Of these, the five largest outages were all related to change activities and represented 62% of user hours lost across all incident reports.[127] The top five were related to a "Faulty Software (S/W) Change or Update" or "Faulty Hardware (H/W) Change or Update."

CrowdStrike Outage

On 19 July 2024, American cybersecurity company CrowdStrike distributed a faulty update to its 'Falcon Sensor security software' that caused an IT outage.[128] As widely reported in the press this impacted an estimated 8.5 million Microsoft Windows computers globally.[129]

[127] 'Change activities' are where a communication provides makes planned modifications to a network or service. This could be for example updating software or hardware, adding a new feature, fixing a bug etc.
[128] CrowdStrike, Remediation and Guidance Hub: Channel File 291 Incident, 6 August 2024. Falcon Content update.
[129] BBC News, CrowdStrike IT outage affected 8.5 million Windows devices, Microsoft says - BBC News, 20 July 2024.

We had limited reports of incidents due to there not being a significant impact on communication providers networks and services. Based on the feedback we did receive from communication providers, this was at least partly due to the use of Microsoft Windows computers being of lower prevalence within communication providers networks.

999 emergency call handling service enforcement action and investigations

On Sunday 25 June 2023, BT, which manages the Emergency Call Handling Services (ECHS) system, experienced a disruption to the service. During the incident, nearly 14,000 call attempts – from 12,392 different callers – were unsuccessful.

The incident also caused disruption to text relay calls, which meant people with hearing and speech difficulties were unable to make any calls, including to friends, family, businesses and services. This left deaf and speech-impaired users at increased risk of harm. Following the incident, on 28 June 2023, we opened an investigation into BT's compliance with its security duties under the Act and various General Conditions.[130]

Our investigation found that BT had breached security duties imposed under section 105A of the Act and Regulation 9 of the Electronic Communications (Security Measures) Regulations 2022, as it did not adequately prepare for the occurrence of an outage of the ECHS. Specifically, we found BT did not take sufficient measures:

- to ensure that it had clearly defined and tested means and procedures in place for identifying, assessing and addressing the occurrence of security compromises; and
- to prepare for the occurrence of security compromises by having in place an appropriate backup system capable of adequately limiting the adverse effects of the security compromise and enabling BT to recover.

As a result of BT's failures, Ofcom decided to fine the company £17,500,000.[131]

Ofcom have also opened two further investigations related to provision of 999 services in the past year:

- We have opened an investigation following Vonage's notification of an incident which resulted in disruption for its business customers to emergency call services between 23 October 2023 and 3 November 2023.[132]
- We are investigating whether Gigaclear Limited (Gigaclear) failed to provide accurate and reliable caller location information to emergency organisations between January 2022 and March 2024.[133]

[130] Ofcom, Ofcom Investigation into BT following 999 emergency call service outage on 25 June 2023, 13 July 2023.
[131] Ofcom, BT fined £17.5ml for 999 call handling failures, 22 July 2024.
[132] Ofcom, Investigation into Vonage's compliance with emergency calls access rules, 19 March 2024.
[133] Ofcom, Investigation into Gigaclear Limited's compliance with General Conditions A3.5 and A3.6(a), 11 October 2024.

Extreme weather events and preparedness

This year there have been a number of named storms including Isha and Jocelyn in January 2024.[134] [135] Whilst these have not been as acute and widespread as storms in previous years, there was still a significant impact on the availability of telecoms services to customers.[136]

It is crucial to continue the work with Government, industry, other regulators, and relevant bodies to understand necessary adaptations and transformations, as the frequency and severity of storms are likely to increase.[137] This is especially important in a world where our dependence on communications is only going to grow ever greater.[138]

We are working with the Electronic Communications Resilience & Response Group (EC-RRG) to investigate potential options to improve the Ofcom incident reporting mechanisms for severe weather events.

Update on Power Backup for Mobile Radio Access Networks

Mobile networks are dependent on electrical power, and power outages can cause service disruption for mobile customers. In this year's reporting window (September 2023 to August 2024), the impact of power issues on mobile radio access networks was 12 million customer hours lost.

Mains power disconnections can impact mobile access networks. In severe cases, this can lead to outages affecting many mobile cell sites in an area at the same time, for several hours in some cases. This means that, unless overlapping coverage is available from mobile cell sites that are unaffected by a mains power outage, or the mobile mast has power back-up to provide power, customers on the relevant networks will be unable to use their phones for voice and data services until the power is restored.

As our reliance on mobile services grows, there has been an increasing focus and dependence on the resilience of mobile access networks. This year, we asked the four MNOs for an update on their power resilience capabilities at their mast sites. While the overall situation across the UK is broadly similar to that which we reported last year, some MNOs have increased the number of sites for which power backup is available. This new data suggests that around 20% of all mobile radio sites (i.e. across all MNOs) have some power back-up to maintain functionality at the RAN for more than 15mins, with around 5% of sites able to withstand a six-hour power loss (excluding battery back-up for transmission traffic).

Next Steps

Alongside the consultation on the revised Resilience Guidance covered earlier in this chapter, we published a call for input (CFI) on power backup for mobile radio access networks (RAN).[139] Our aim was to prompt a discussion about what power backup MNOs can and should provide for their networks and

[134] Met Office, UK storm season, 2023/24.
[135] Shortly before the publication of this report there have been further named storms, including Storm Bert, at the beginning of the UK storm season, 2024/25. We are still assessing the impact on the availability of telecoms services to customers and will update in our Connected Nations 2025 report.
[136] See for example, Fibrus: Storm-damaged broadband repairs may take a week - BBC News, 24 January 2024.
[137] Government resilience: extreme weather - NAO report
[138] Digital development strategy 2024 to 2030 - GOV.UK, 18 March 2024.
[139] Ofcom Statement: Network and Service Resilience Guidance, 8 December 2023. Consultation on resilience guidance and mobile RAN power back-up responses.

services. We have published the responses to this CFI so interested parties can consider the views shared by respondents.

While the feedback showed strong interest in mobile resilience, some highlighted the need for a broader approach to power backup beyond the telecoms sector.[140] Additionally, responses offered valuable insights into potential harms from power outages, such as the effect on emergency services and communication difficulties, particularly in rural areas where communities could be more vulnerable to the impacts of outages.

We are analysing the information gathered to determine if additional resilience measures are needed for the mobile RAN. This analysis will consider a range of solutions, rather than a one-size-fits-all approach, and we plan to work with the UK Government and industry to identify the most suitable way forward.

[140] Ofcom, Statement: Network and Service Resilience Guidance, 8 December 2023. Consultation on resilience guidance and mobile RAN power back-up responses.

05.

MENINGKATKAN KETAHANAN PANGAN MELALUI TRANSFORMASI DIGITAL DENGAN IPV6 DAN JARINGAN 5.5G - Intan Rahayu, S.Si, MT, LA.27001, CCISO, CIPP/E (Kementerian Pertanian Republik Indonesia)

Kementerian Pertanian
Republik Indonesia

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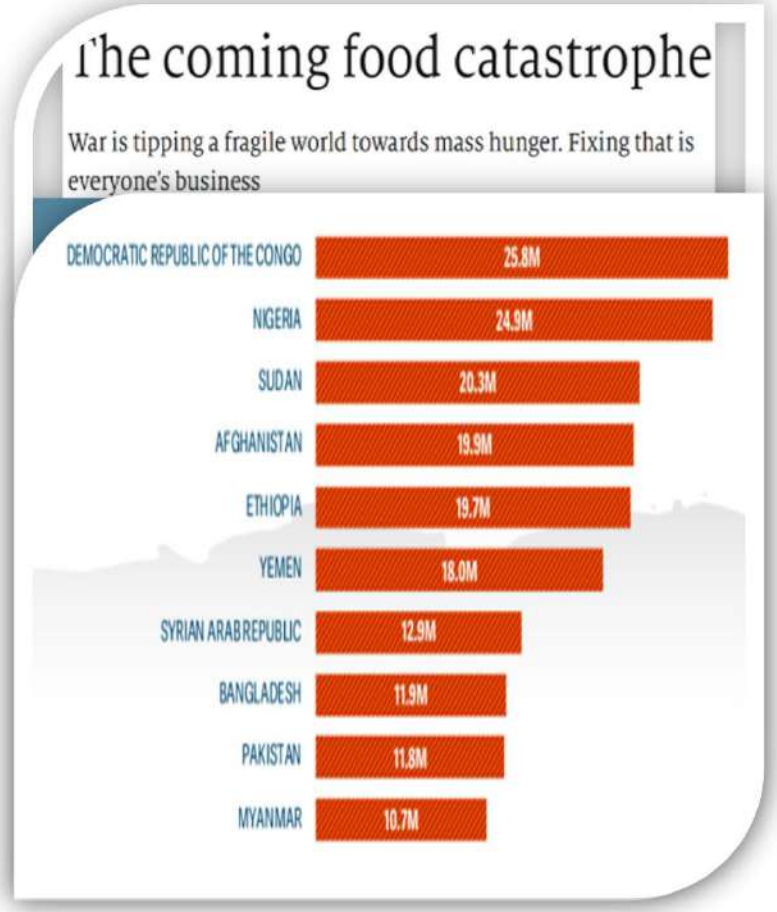
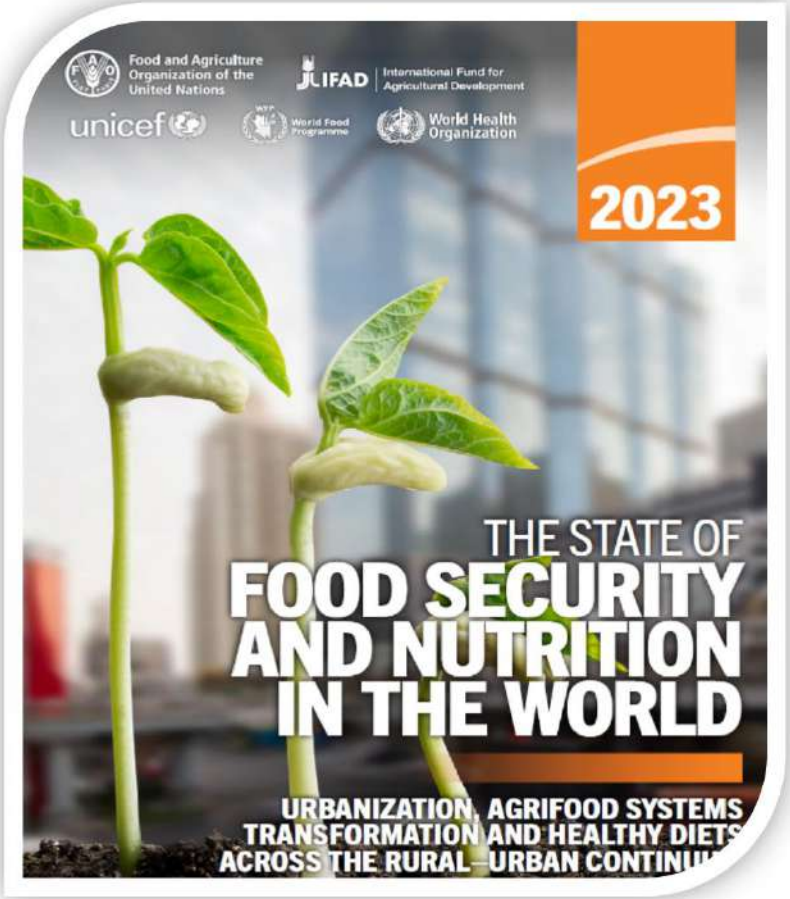


58 negara kelaparan serius

Sumber: FAO (2023)



725 juta penduduk dunia kekurangan gizi (55% di Asia dan 38% di Afrika)

Sumber: FAO (2023)

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Sumber: Kemendagri, Kemenkes (2023)

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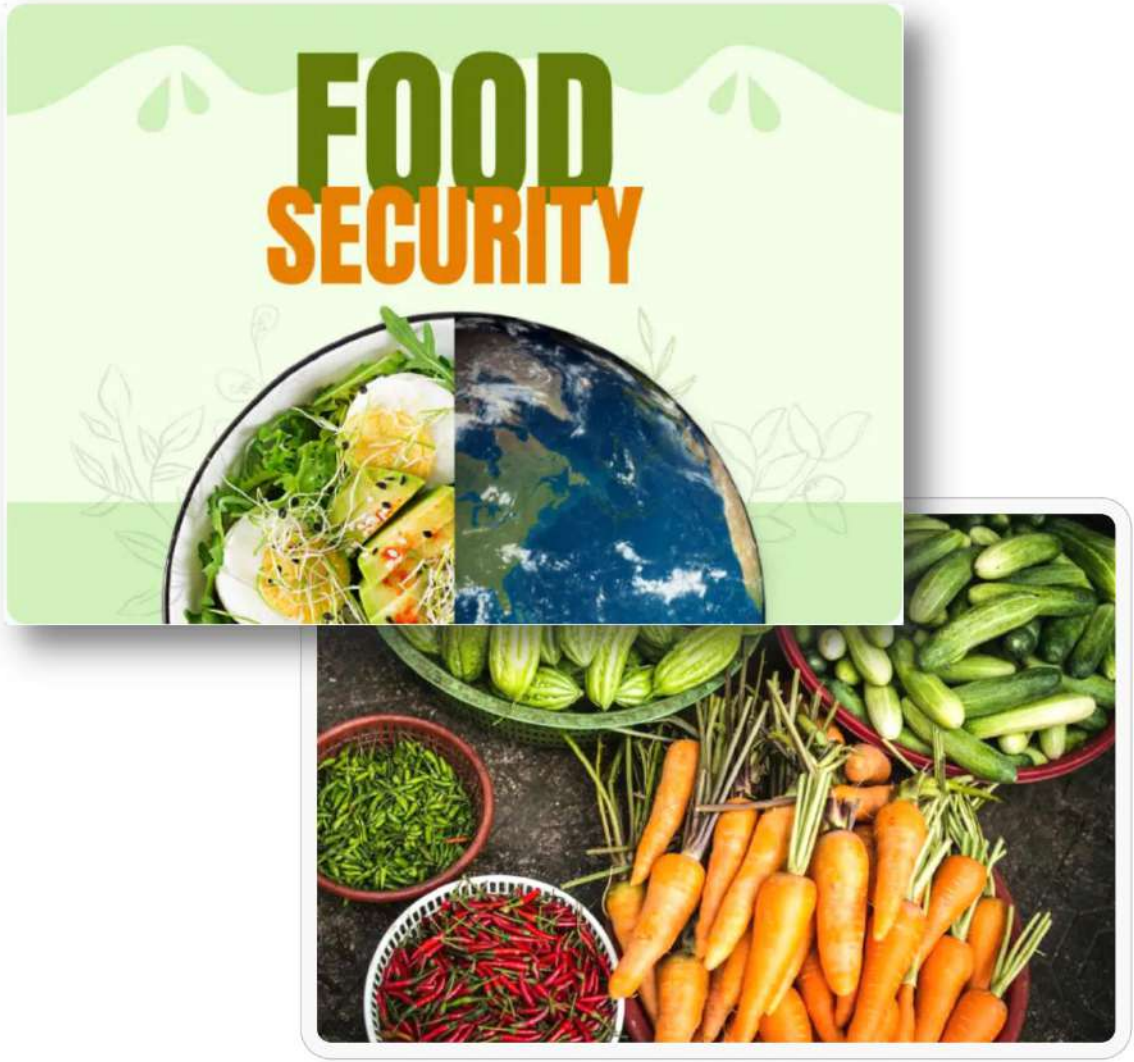

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1. Perubahan Iklim

Kekeringan/Kebajiran → gagal panen.

7. Alih Fungsi Lahan

Laju ± 100 rb ha/tahun

2. Kondisi Perekonomian Global

- nilai tukar rupiah lemah
- biaya produksi jadi mahal
- pelemahan ekspor

6. Aspek Distribusi

Indonesia sebagai negara kepulauan.

3. Gejolak Harga Pangan Global

Harga pangan mahal

5. Peningkatan Jumlah Penduduk

melebihi kapasitas lahan yang tersedia

4. Bencana Alam

Gagal Panen

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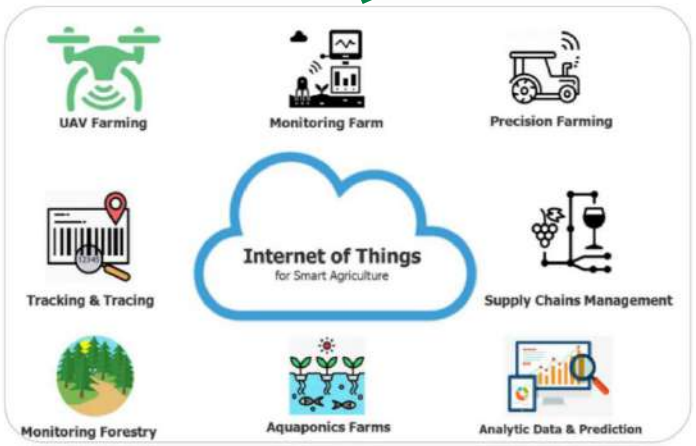

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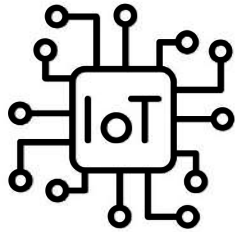

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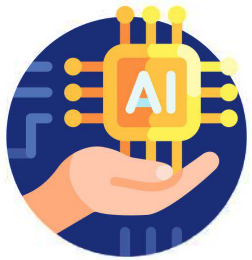
AI membantu memprediksi perubahan cuaca dan serangan hama lebih dini melalui data set yang tersedia dan laporan yang masuk ke dalam datawarehouse



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Dengan analisis data, distribusi dan produksi dapat dirancang untuk mengurangi surplus yang berakhir sebagai limbah

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Soil Health

Weather Monitoring

Crop Management

Drone Monitoring

Smart Irrigation

Pest Management

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Precision Livestock Management (PLM)

Animal Identification

Automated Weighing System

Animal Welfare Monitoring

Disease Detection System

Automated Feeding System

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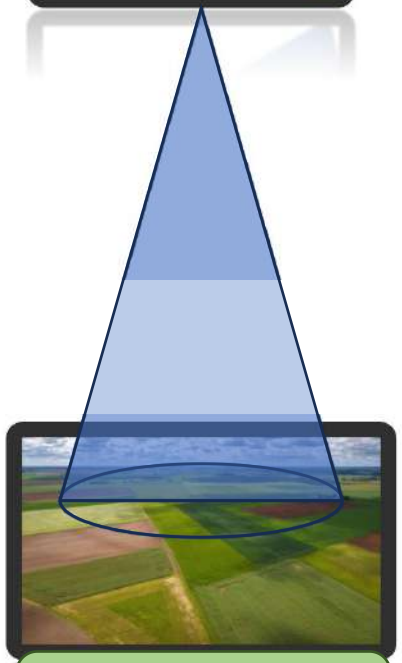
Autonom Harvester

Autonomous Agricultural Vehicle

Remote

Autonom Drone Sprayer

Autonom Tractor



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BLOK IP
IPv6 menyediakan ruang alamat IP yang jauh lebih besar dibandingkan IPv4, memungkinkan miliaran perangkat IoT untuk terhubung

REALTIME DATA STREAMING
Dapat mengirimkan data langsung dari sensor atau drone tanpa jeda waktu

LEBIH EFISIEN
Protokol ini juga lebih efisien dalam routing dan transfer data

dk (G(0(F8F(a

KONEKTIVITAS
dapat mendukung konektivitas hingga 100 miliar perangkat

SECURITY
IPv 6 sudah dibekali dengan enkripsi dalam membuat proses pertukaran data yang lebih aman. Selain itu, lebih siap dalam menangkal serangan dari Address Resolution Protocol yang dapat mengalihkan traffiic dan juga memanipulasinya

LATENSI
5.5G memiliki latensi serendah 4 ms

kj oW nc(oWmSkSi (oWei j gj ac(dkr G(0(F8F(a(kSVS(nWeoj m(kSi aSi

SMART FARMING

- Penggunaan teknologi drone dan IPv 6 utk mengidentifikasi kebutuhan nutrisi dari tanaman
- Sistem irigasi Otomatis dapat dilakukan berdasarkan data-data yang dikirimkan melalui sensor

1

SUPPLY CHAIN MANAGEMENT

- Pelacakan produk pangan dapat dilakukan dengan memanfaatkan sensor IOT dari ladang hingga ke konsumen
- Prediksi pasar dapat dilakukan dengan mempelajari dan mengumpulkan data trend demand produk pangan dari masyarakat

2

RECOMMENDATION SYSTEM

- Rekomendasi tanaman apa yang cocok dengan kondisi lahan pada suatu Lokasi.
- Rekomendasi waktu pemupukan dan waktu penyiraman untuk mendapatkan hasil yang optimal pada suatu tanaman

3

EARLY WARNING SYSTEM

Notifikasi informasi dapat langsung dikirimkan ke petani apabila terjadi serangan penyakit maupun informasi cuaca ekstrim seperti banjir, badai dan kekeringan

4

VWUaWHJL h(npkkj mo(nunoWh

Pemangku kebijakan dapat membuat Keputusan yang lebih akurat dan akuntabel berdasarkan data-data yang dikirimkan dari lapangan secara realtime dan diolah menjadi sebuah informasi rekomendasi

5


KEMENTERIAN PERTANIAN R.I.

06.

5G related policy considering MVNOs - ITUPublications

ITUPublications

International Telecommunication Union
Standardization Sector

ITU-T Technical Report

(07/2024)

DSTR-STUDY_IMT2020MVNOs

5G related policy considering MVNOs

Technical Report ITU-T DSTR-STUDY_IMT2020MVNOs

5G related policy considering MVNOs

Summary

This Technical Report seeks to study the various economic and policy aspects related to IMT2020 technologies taking into consideration mobile virtual network operators (MVNOs). In addition, it presents an overview of 5G deployment and MVNOs, a detailed review of MVNO conceptual models as well as drivers and barriers to MVNO rollout. The report also presents various case studies from Member States in order to inform best practices.

Keywords

5G, MVNOs.

Note

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

Change Log

This document contains Version 1 of the ITU-T Technical Report DSTR-STUDY_IMT2020MVNOs on "5G related policy considering MVNOs" approved at the ITU-T Study Group 3 meeting held in Geneva, 9-18 July 2024.

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Technical Report ITU-T DSTR-STUDY_IMT2020MVNOs

5G related policy considering MVNOs

1 Scope

The transition from 4G to 5G services will transform the way in which telecommunications/information and communication technology (ICT) ecosystems function worldwide, as 5G transformative potential is reshaping existing business models across the length and breadth of every sector. To fully harness the enormous potential shown by 5G, stakeholders must proactively realign existing practices to ensure that the benefits of 5G are availed of without extensive complexities and disruption. At policy and regulatory level, the basic necessities required for 5G wireless networks such as guaranteed availability of spectrum and provision of support infrastructure have to be provided in a fair, responsible and seamless manner. The progressive development of 5G wireless technologies offers a unique opportunity to drastically broaden the boundaries and adaptability of wireless networks, which in turn will have significant ramifications on broadband competitiveness, efficiency, and development. 5G is set to transform the business models of both mobile network operators (MNOs) and mobile virtual network operators (MVNOs). Policy makers have a critical role to play in order to create an enabling environment that allows the full potential of emerging technologies and future networks. By addressing the key issues mentioned above, governments can pave the way for a successful 5G transition, driving economic growth, innovation, and social progress.

2 References

[ITU-T Y.3100] Recommendation ITU-T Y.3100 (2017), *Terms and definitions for IMT-2020 network.*

[ITU-T Y.3103] Recommendation ITU-T Y.3103 (2018), *Business role-based models in IMT-2020.*

3 Definitions

3.1 Terms defined elsewhere

This Technical Report uses the following term defined elsewhere:

3.1.1 network slice [ITU-T Y.3100]: A logical network that provides specific network capabilities and network characteristics.

3.2 Terms defined in this Technical Report

This Technical Report defines the following term:

3.2.1 mobile virtual network operator (MVNO): A wireless communication services provider that does not own the wireless network infrastructure over which it provides services to its customers.

4 Abbreviations and acronyms

This Technical Report uses the following abbreviations and acronyms:

3GPP 3rd Generation Partnership Project

5GC Core network for IMT-2020, known as "5G Core network"

API Application Programming Interface

ASP	Applications Service Provider
BSS/OSS	Business Support System/Operation Support System
BTS	Base Transceiver System
BSC	Base Station Controller
CERRE	Centre on Regulation in Europe
CSP	Contents Services Provider
DECT	Digital Enhanced Cordless Telecommunications
DSLAM	Digital Subscriber Line Access Multiplexer
EMB	Enhanced Mobile Broadband
en-gNodeB	NR wireless base station connected to EPC and eNodeB with certain RP
eNodeB	E-UTRA Wireless base station
EPC	Core network for IMT-Advanced, known as "Evolved Packet Core"
E-UTRA	Evolved Universal Terrestrial Radio Access
gNodeB	NR wireless base station
GMSC	Gateway Mobile Switching Centre
HSS	Home Subscriber Server
IoT	Internet of Things
IP	Internet Protocol
LAN	Local Area Network
LTE	Long Term Evolution
MIC	Ministry of Internal affairs and Communications
mMTC	massive Machine Type Communications
MNO	Mobile Network Operator
MSC	Mobile Switching Centre
MVNE	Mobile Virtual Network Enabler
MVNO	Mobile Virtual Network Operator
ng eNodeB	E-UTRA wireless base station connected to 5GC and gNodeB with certain RP
NFP	Network Facilities Provider
NR	New Radio
NRA	National Regulatory Authority
NSA	3GPP 5G-SRIT, known as "Non-Standalone"
NSO	Network Service Operator
PGW	Packet Gateway
PSTN	Public Switch Telephone Network
RIT	Radio Interface Technology
RP	Reference Point
RSU	Remote Switching Unit

QoS	Quality of Service
SA	3GPP 5G-RIT, 5Gi and DECT 5G-SRIT, known as "Standalone"
SLA	Service Level Agreement
SRIT	Set of Radio Interface Technology
SSA	Secondary Switching Area
TAX	Trunk Automatic Exchange
TRAI	Telecom Regulatory Authority of India
TSP	Telecom Service Provider
UE	User Equipment
UL	Unified License
URLLC	Ultra Reliable and Low Latency Communications
VAS	Value Added Services
VoIP	Voice over Internet Protocol
VMNO	Virtual Mobile Network Operator
VNO	Virtual Network Operator

5 Overview of mobile virtual network operators (MVNOs)

The definition of mobile virtual network operator (MVNO) is widely accepted as a licensed mobile telecommunications operator without radio spectrum licenses and radio facilities (i.e., base stations) of its own that piggybacks on a host mobile network operator (MNO) with those radio resources. MVNO businesses can be broken down into several categories. Figure 1 shows the typical classification of MVNO businesses.

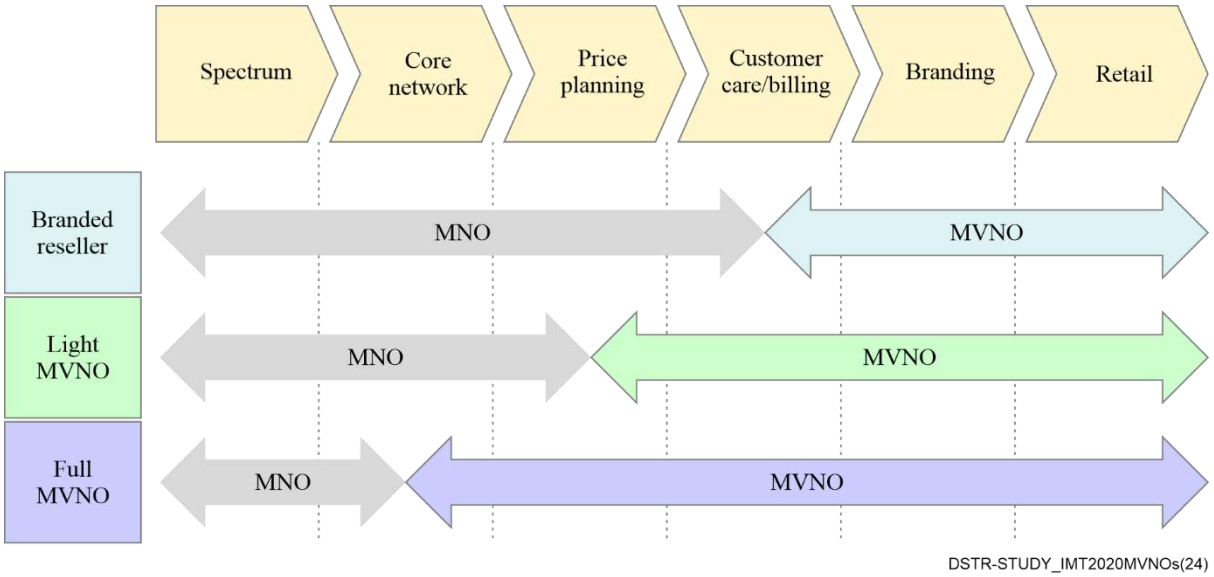


Figure 1 – The typical classification of MVNOs

MVNOs have been seen in many countries since approximately 2000. In those countries, MVNOs continue to play their anticipated role as not only providers of a variety of diversified mobile services for niche markets but also as actors for healthy competition in entire mobile markets, which have been fundamentally liable to oligopoly from finite resources of spectrum. Furthermore, they also fulfil

an innovator role because of their tendency to be relatively independent from geographical boundaries, physical networks, and existing mobile market structures.

This definition and these anticipated roles of MVNOs have not been, and will not be, affected by the evolution of mobile technology. However, the progress of network virtualization and network softwarization towards 5G will urge MVNOs to change their current ways of doing business and how they piggyback on their host MNOs. The social acceptance of Internet of things (IoT) applications will require the deep engagement of various MVNOs with a high degree of flexibility. Therefore, to formulate appropriate policies, some of which are illustrated in clause 8, that are adapted to each domestic mobile market, regulators need to recognize what happens now in relation to MVNOs and the progress of network virtualization/softwarization.

6 5G deployment and MVNOs

It is often said that there are two steps towards 5G, "non-standalone" (NSA) as an earlier deployment and "standalone" (SA) as later one. NSA is now ready to be deployed, and indeed NSA has already been deployed by mobile network operators (MNOs) in many countries, and is applicable by many MVNOs in those countries.

6.1 MVNOs in 5G NSA

In 5G NSA architecture, 5G deployment will be very limited, both in terms of its radio facilities and core networks. All 5G radio facilities (en-gNodeB) will be hosted by evolved packet core (EPC) with minimal software upgrades.

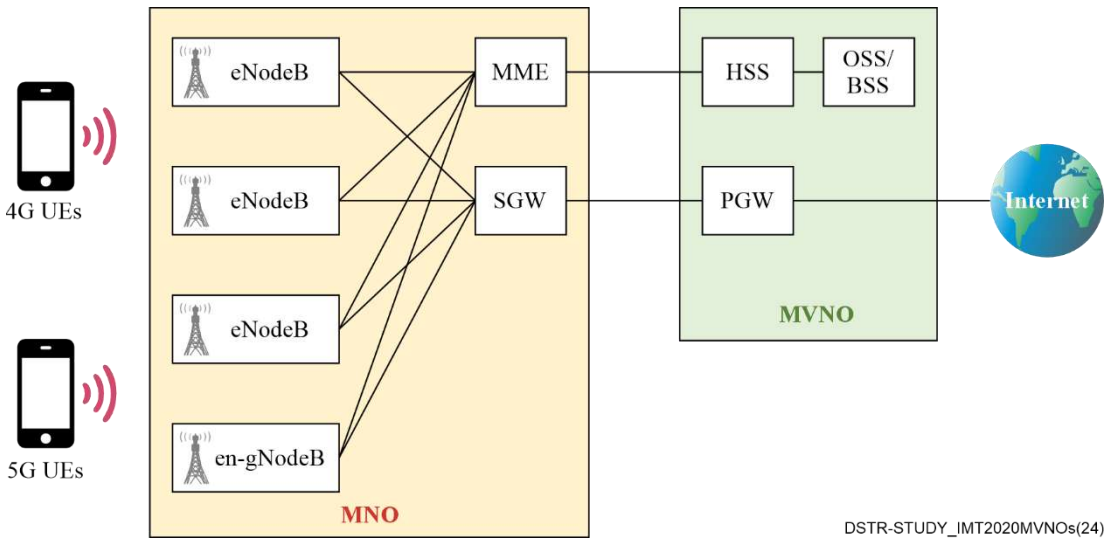


Figure 2 – Anticipated interconnection model of MVNOs in 5G NSA

Figure 2 shows how an MVNO can be hosted by an MNO in 5G NSA, in a manner quite similar to that with 4G or earlier technologies. Some EPC nodes like the packet gateway (PGW) or home subscriber server (HSS) might be operated by the MVNO itself under a commercial agreement with the host MNO as necessary to ensure the flexibility of services. In such cases, physical interconnections divide a core network into two parts.

6.2 MVNOs in 5G SA

In contrast to 5G NSA, 5G SA does not require EPC, as all gNodeBs will be switched to a 5G core network (5GC), and likewise for upgraded 4G radio facilities (ng eNodeB). 5GC is expected to be built up as software-based functions on the computing resource platform, like cloud-based applications, using virtualization technology.

A logical network composing a 5GC, also known as a 'network slice' or simply a 'slice', can be distinguished to provide operators flexibility to create networks customized according to diverse requirements from the perspective of functionality, performance, isolation, etc. The customer's requirement for mobile service could be complicated, and well-placed in-between three representative services of 5G: enhanced mobile broadband (EMB), ultra reliable and low latency communications (URLLC), and massive machine type communications (mMTC). These dedicated flexibilities for the customers' requirements are important so that an MNO can configure a customized 5GC for a certain application/use-case to ensure the requirement of quality of service (QoS) from one end user equipment (UE) to the other end (application server). Figure 3 shows MVNOs in 5G SA.

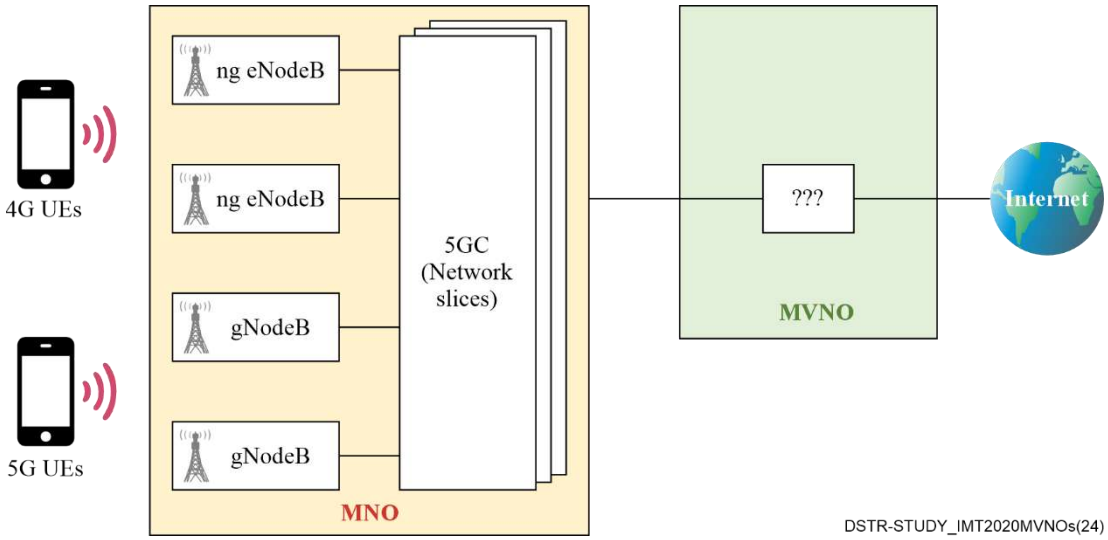


Figure 3 – MVNOs in 5G SA

From the MVNO point of view, these flexibilities are also imperative, as an MVNO can then offer various and innovative services dedicated to specific customers. However, current interconnection models of piggybacking could undermine an MVNO's flexibilities because cooperation between the MNO's part and the MVNO's part of the 5GC is essential for the end-to-end QoS guarantees that are requested by the customers.

Consequently, all MVNO stakeholders must forge different cooperation models between MVNOs and their host MNOs, or improve the current interconnection models thoroughly in order to allow MVNOs to ensure end-to-end QoS guarantees.

7 Conceptual models of MVNOs in 5G SA

7.1 Light "VMNO"[1]

The Centre on Regulation in Europe (CERRE), the European regulatory think tank, argues in its White Paper published in September 2019[2] that full MVNOs ("so-called deep-MVNOs typically own a part of the signalling and routing control infrastructure" in the original document. There is no internationally united definition of "full MVNO" yet.) may no longer be possible in the fully virtualized infrastructure of 5G. As an alternative, CERRE calls for the introduction of a new conceptual operator model called the virtual mobile network operator (VMNO), under which VMNOs are granted access to the application programming interfaces (APIs) provided by the host MNO to

[1] Here and below – the abbreviation of VMNO is introduced only for the purpose of describing the conceptual title from certain companies or to substitute for the traditionally used abbreviation of MVNO.

[2] https://cerre.eu/publications/euambitions-digital/

enable them to manage their own slice with the same level of flexibility as that of the host MNO. This would enable VMNOs to offer adequate QoS levels for dedicated applications that provide high-value mobile solutions for particular industries or across industries (verticals).

Figure 4 shows the anticipated structure of VMNOs (for the sake of expediency, these are called "light VMNOs" in the figure and in this Report) and host MNOs.

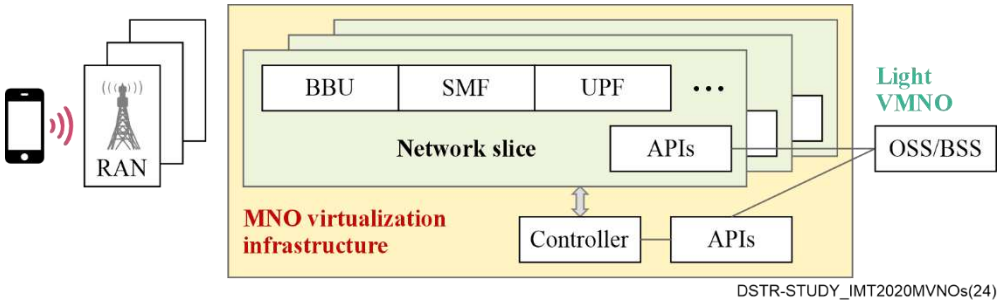


Figure 4 – Anticipated light VMNO structure

This structure allows light VMNOs to manage their virtualized core network on the host MNO's virtualization infrastructure through APIs. At least two sets of APIs will be required, one for managing core network functions on an individual slice and one for managing slices themselves, including the ability to create new slices, delete unused slices, etc. In this sense, the light VMNO is expected to play the role of not only network slice provider but also network slice management and orchestration provider both defined in [ITU-T Y.3103].

7.2 Full VMNO

The Telecom Services Association, one of four Japanese telecommunications industry associations, called for the addition of another type of virtual telecommunications operator on 5G SA called full VMNO, with reference to the light VMNO concept originated by CERRE.

The base technology for the full VMNO concept is spectrum sharing. Even so, full VMNOs could also be enabled from the progress of virtualization. Figure 5 illustrates the structure of a full VMNO.

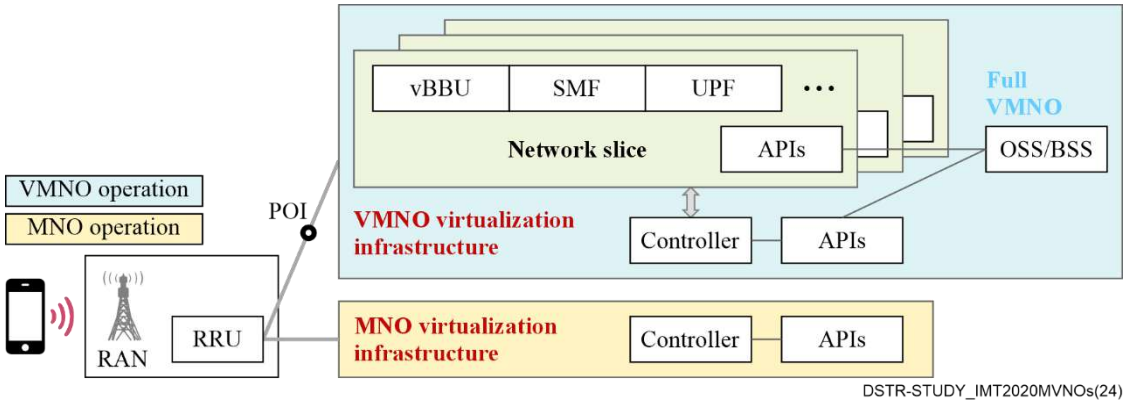


Figure 5 – Anticipated full VMNO structure

The difference between a light VMNO and the full VMNO concept proposed by the Telecom Services Association lies in ownership of the virtualization infrastructure. Light VMNO fully depends on the host MNO's infrastructure, while full VMNO is independent of the MNO's infrastructure except for the radio part. This would give full VMNOs an opportunity to cooperate commercially with other wireless network operators with technical and operational independence from their host MNO. Having this independence is a benefit of full MVNOs in the current generation.

7.3 Evolved interconnection model

Full MVNO in the current generation is technically based on the standardization of international roaming. Figure 6 shows current logical interconnections between home and visited operators in a current LTE roaming scenario, and full MVNO architecture in the current long term evolution (LTE) generation in comparison.

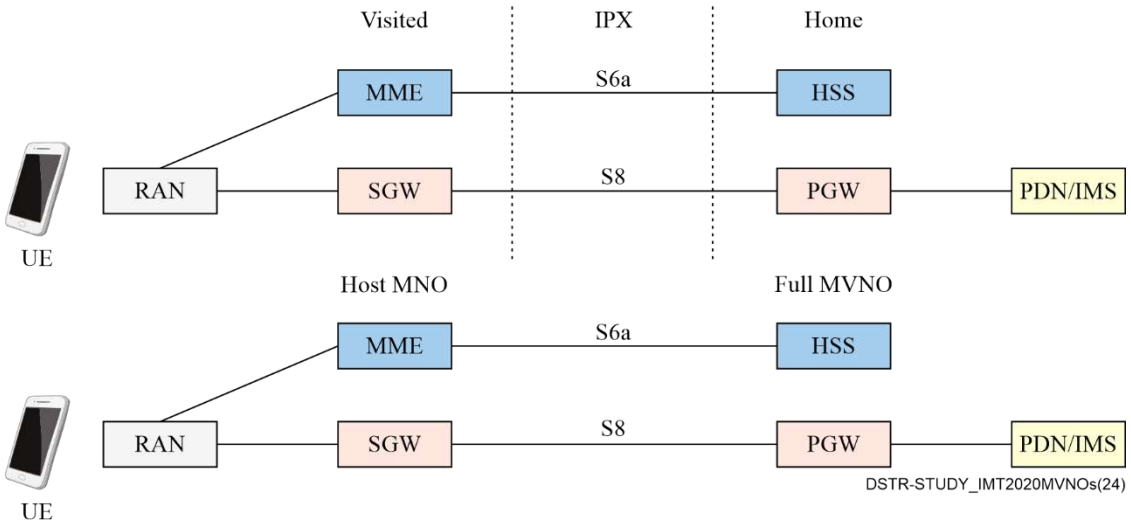


Figure 6 – International roaming and full MVNO piggybacking in 4G LTE

It is intuitive then to utilize 5G SA international roaming architectures as the technological basis of MVNOs in 5G SA. Figure 7 shows the network diagram of 5G SA roaming under study.

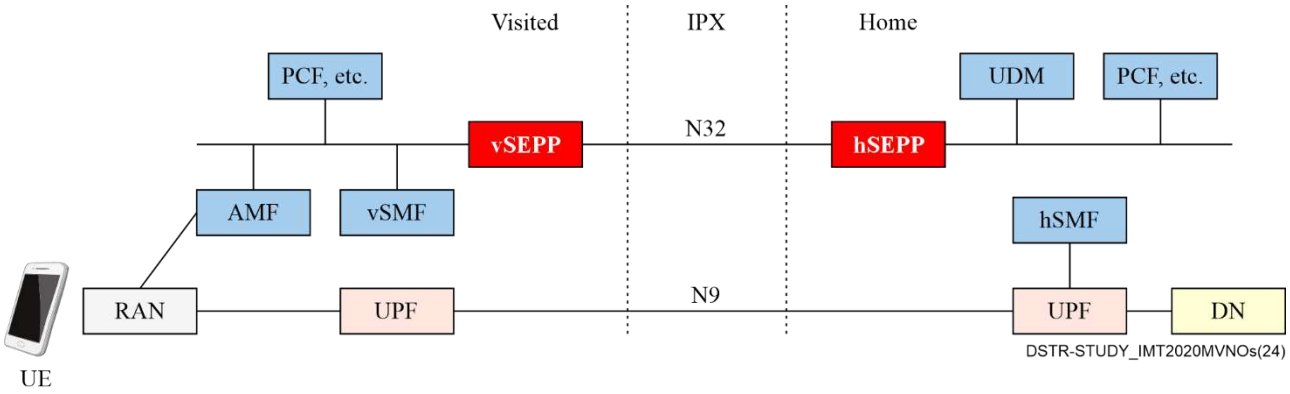


Figure 7 – International roaming architecture in 5G SA

There is as yet no commercialized use-case of 5G SA international roaming, so an MVNO and their host MNO should carefully observe the progress of the standardization work and its commercial deployments, so that they can utilize it as their own piggybacking measure. In addition, it is necessary to realize that managing/coordinating slices between both sides is out of scope of 5G SA international roaming so far. So, an MVNO based on this model should prudently negotiate with their host MNO how to operate slices across both networks if they wish to offer advanced and unprecedented mobile connectivity services with slice, for their customers' requirements from the perspective of functionality, performance, isolation, etc.

8 Policy, regulatory and economic aspects of MVNOs

The concept of MVNOs is to bring in optimization of telecom resources used, innovative business models at service delivery layer, and provision of value addition and differentiation in collaboration with MNOs.

8.1 Drivers and enablers of MVNOs

MVNOs ideally provide an alternative to additional MNOs which comes with a lot of regulatory issues including the headache of spectrum scarcity. MVNO regulation is relatively simple compared to regulating a whole new MNO as they, to a large extent, rely on market forces – unlike the regulation of alternative MNOs, which is complex and driven primarily by the scarcity of spectrum, the substantial capital-intensive costs involved, and the fundamental impact that telecommunications have on the economic and social fabric of any market.

The emergence of the MVNO model in a market is driven by a number of factors:

a) Mature consumer market that is highly segmented, creating opportunities in niche/segmented markets that require unique and integrated offerings.

b) A strategic decision by an MNO looking to extend its existing operations and target niche or underserved segments through a second or perhaps multiple brands.

c) Competitive pressure to continue to invest in improving the network leaving little room to concentrate on marketing and distribution channels.

d) Slowing growth of subscriptions thus making wholesale a more attractive revenue source to the mobile operators than the retail headache.

e) Emerging innovative products fuelled by integration of voice and data products such as video, music, and gaming making mobile a viable and numerous media content channel.

f) Market opportunities for customer acquisition by non-mobile companies e.g., banks based on their existing core competencies such as content, brand extensions or efficient distribution channels.

g) Mobile operators often find it difficult to succeed in all customer segments. MVNOs are a way to implement a more specific marketing mix, whether alone or with partners. They can also help attack specific, targeted segments given that MVNOs have a thorough knowledge of their market segment, allowing them to cater to that segment in a far more personal, relevant way than large-scale MNOs can.

h) Many mobile operators have capacity, product and segment needs. An MVNO strategy can generate economies of scale for better network utilization, including utilizing multiple networks provided by multiple MNOs for the sake of maximalising spectrum efficiency and network redundancy, especially in the case of full MVNO.

i) High churn from MNOs as MVNOs propositions may be more attractive to existing MNO customers leading to mass migration.

j) MVNOs can effectively target the IoT market by offering specialized connectivity solutions tailored to the unique requirements of various devices and applications.

The optimal timing for introduction of MVNOs in many markets depends primarily on the level of market saturation, as measured by mobile penetration, and the level of market concentration, as measured by the distribution of existing players' market share. However, in addition to the driving factors highlighted above, national regulatory authorities (NRAs) can take specific steps to create an enabling environment for the sustainable deployment of various MVNO models.

Typically, MVNOs may be considered as a type of active infrastructure sharing which may or may not require the shared use of radio frequency spectrum. Regulatory frameworks focused on promoting equitable and non-discriminatory access can therefore create favourable conditions for the roll out of

MVNOs. However, in the face of increasing 5G deployment and adoption, there is a need to review traditional policy and regulatory frameworks to incorporate the new dimensions of access and infrastructure sharing in a 5G era while ensuring guaranteed availability of spectrum and shared infrastructure in a fair and responsible manner. Specifically, the following enablers can be beneficial for forward-looking frameworks to facilitate MVNO rollout:

– **Non-discriminatory access to network infrastructure:** Regulatory frameworks that mandate MNOs to provide fair and non-discriminatory access to their network infrastructure ensure that MVNOs can utilize existing infrastructure without facing barriers imposed by incumbent operators, thereby fostering competition and service diversity.

– **Spectrum sharing policies:** Clear policies and guidelines for spectrum sharing that allow MVNOs to access necessary radio frequencies, either through leasing arrangements or dynamic spectrum access models would ensure that spectrum is used efficiently and that smaller players have the opportunity to enter the market and innovate.

– **Simplified licensing procedures:** A streamlined licensing process for MVNOs would reduce administrative burdens and accelerate market entry. This could include the introduction of unified or light licensing regimes that are more adaptable to different MVNO models and business models, thus encouraging more entrants into the market.

– **Support for network slicing:** Enabling MVNOs to leverage network slicing capabilities of 5G networks, would allow them to offer customized and differentiated services over shared physical infrastructure. Regulatory support for network slicing can therefore promote innovation and tailored service offerings, meeting diverse consumer and enterprise needs.

– **Incentives for infrastructure sharing:** Providing incentives for MNOs and other infrastructure owners to engage in active infrastructure sharing with MVNOs would make it economically attractive for MNOs to share their network resources, thereby lowering the entry barriers for MVNOs. This can include financial incentives, tax benefits, or regulatory forbearance.

8.2 Factors that inhibit MVNOs rollout

Factors that inhibit MVNOs rollout include:

a) Intense market competition and saturation, where established MNOs often dominate, making it difficult for MVNOs to carve out a niche and attract customers.

b) MVNOs are sometimes at a disadvantage due to their dependency on MNOs for network access and infrastructure. MVNOs depend on the agreements with MNOs and this reliance can create vulnerabilities and limit the MVNOs' ability to control service quality and pricing. Moreover, MNOs control the physical infrastructure, giving them significant leverage in negotiations.

c) The host MNOs may consider MVNOs as threat which can cannibalize the MNO's current offerings. MVNO will bring in more competition which could further lower the average revenue generated per user (ARPU).

d) The MVNO model is highly dependent on value added services (VAS) for earning profitable revenue, which in turn depends on 3G, 4G and 5G network availability.

e) Slowing penetration growth for MNOs as MVNOs become aggressive marketers and the new frontier for growth leaving MNOs stagnant and probably concentrating on infrastructure.

f) Increasing customer acquisition costs as competition become difficult and aggressive marketing becomes the only way. Distribution channels have to be close to customers hence increased cost.

g) MVNO can trigger price wars and undermine profitability of all players and driving the mobile market towards lower ARPU.

h) Though MVNO can increase MNOs network utilization, it can also cause serious network congestion problems which leads to reductions in service quality.

i) Lack of brand recognition: MVNOs may have difficulty building brand recognition and customer loyalty compared to larger, well-established MNOs.

j) Lack of an enabling licensing framework in some jurisdictions.

k) Lack of technology know-how and other requisite skills by the MVNOs.

The IMT-2020 networks with its unique features such as network slicing, optimization for specific service level agreements (SLA) and QoS can offer a huge landscape for MVNOs. The role of MVNOs in the 5G deployment scenario has to be explored and the experiences of some countries in this subject can serve as a guide for other countries to plan the policies and regulations concerning MVNOs.

9 Regional case studies

9.1 Japan

During the public consultation held by the Ministry of Internal affairs and Communications (MIC) in September 2019 to consider how to ensure adequate MVNO access to MNO networks in 5G, Telecom Services Association posed two concepts of VMNO simultaneously.

The MNOs that participated in the consultation made the following statements:

– Prior to the negotiations between MNOs and MVNOs, MNOs would like to clarify the MVNOs' request related to their services to be realized and practical architecture for connection by means of the open 5G SA functions. Further, it is appropriate in principle to entrust business-based discussion to related operators firstly so that various players are able to create new value flexibly using their ingenuity and inventiveness, which is from the perspective of cultivating innovation and bolstering international competitiveness, including that of domestic vendors and the creation of innovation. Related parties should not have discussions anticipating unspecified future technologies.

– When considering the openness of MNO networks, examination of regulations should be executed if necessary, based on the contents of the MVNO guideline that respects the consensus building from the subject discussion between related operators while looking at the progress of technical standardization and related technical consideration by each MNO, and, as for the basic framework of unbundling, taking into account of the second class operators' infrastructure investment and incentive to innovation.

– In terms of full VMNOs, careful discussion is required because there are various concerns about serious risks – e.g., unplanned network interruptions, loss of service quality and security risks, due to lack of network management integrity, including capacity planning for the radio facilities, network admission controls based on SLAs, etc., if the core network is out of the MNO's control.

On the concept of both full VMNOs and light VMNOs for virtual telecommunications operators on 5G SA, the necessity of further consideration is recognized as stated in the report of the consultation published in February 2020 to ensure fair competition among MNOs and MVNOs to enable MVNOs to develop high-value services in accordance with 5G features.

Further discussion took place between the Telecom Services Association and three major MNOs (NTT DOCOMO, KDDI and SoftBank) from March to May 2021. The conclusion of this discussion contained a total of five possible models, including two concepts of VMNO, one wholesale model with a minimum flexibility, and two evolved interconnection models (one is based on the technical standardization for international roaming, the details are shown in clause 7.3).

In response to this conclusion, MIC urged both MVNOs and MNOs to discuss individually in accordance with their commercial MVNO agreements, to deepen their mutual understanding, to

remedy asymmetry of information across both sides, and to seek a way forward on how MVNOs can launch their 5G SA services with the least delay from MNO's 5G SA launch.

9.2 India

The Government of India has issued guidelines[3] for granting of a unified license for virtual network operators. After considering the recommendations of the Telecom Regulatory Authority of India (TRAI) on VNOs, the Indian Government has decided to grant a unified license (UL) VNO. The basic features of UL (VNO) are as follows:

i) VNOs are treated as extensions of network service operator (NSOs) of telecom service providers (TSPs) and they would not be allowed to install equipment interconnecting with the network of other NSOs.

ii) Applicants can apply for a UL (VNO) along with VNO authorization for any one or more of services listed below:

- Unified license VNO (all services)
- Access service (service area-wise)
- Internet service (Category-A with all India jurisdiction)
- Internet service (Category-B with jurisdiction in a service area)
- Internet service (Category-C with jurisdiction in a secondary switching area (SSA))
- National long distance (NLD) service
- International long distance (ILD) service
- Global mobile personal communication by satellite (GMPCS) service
- Public mobile radio trunking service (PMRTS) service
- Very small aperture terminal (VSAT) closed user group (CUG) service
- INSAT MSS-reporting (MSS-R) service
- Resale of international private leased circuit (IPLC) service
- Machine to machine (M2M) (Category-A with all India jurisdiction)
- Machine to machine (M2M) (Category-B with jurisdiction in a service-area)
- Machine to machine (M2M) (Category-C with jurisdiction in an SSA/district area).

Some of the notable guidelines are:

1. VNOs that enter the network would do so based on arriving at a mutual agreement between an NSO and a VNO.
2. The terms and conditions of sharing of infrastructure between the NSO and VNO shall be on the basis of mutually accepted terms and conditions between the NSO and the VNO.
3. VNOs shall be permitted to set up their own network equipment viz. base transceiver system (BTS), base station controller (BSC), mobile switching centre (MSC), remote switching unit (RSU), digital subscriber line access multiplexer (DSLAM), local area network (LAN) switches). VNOs shall not be allowed to own/ install equipment of core infrastructure, i.e., gateway mobile switching centre (GMSC), soft switches and trunk automatic exchange (TAX) or equivalent. Therefore, they are not allowed to own/install equipment which are required for interconnection with other NSO(s), viz. GMSCs, soft-switches and TAX. Soft switch is an application programme interface (API) that is used to bridge a traditional public switch telephone network (PSTN) and voice over Internet protocol (VoIP) by linking PSTN

[3] 17th January, 2022/ No. 20-577/2016 AS-I (Vol-III).

to Internet protocol (IP) networks and managing traffic that controls a mixture of voice, fax, data and video. Soft switch is a software-based switching platform based on open systems.

4. VNOs shall also be allowed to create their own service delivery platforms in respect of customer service, billing and VAS.
5. An operator who wishes to provide telecom services to its customers utilizing the underlying network and/or access spectrum of an existing NSO will have to obtain UL (VNO) license.
6. There shall be no restriction on the number of VNOs parented by an NSO.
7. VNOs will be allowed to have agreements with more than one NSO for all services other than access services and such services which need numbering and unique identity of the customers.
8. An NSO shall allocate a numbering range to their VNO(s) from the numbering range allocated to it by the licensor. VNOs shall also utilise the LRN and network codes of the parent NSO for the purpose of routing of calls.
9. There would not be any mandate to an NSO for providing time bound access to its VNO; rather, it shall be left to the mutual agreement between NSO and VNO. However, the Department of Telecommunications/TRAI shall have the right to intervene in the matter as and when required to protect the interest of consumers and the telecom sector.
10. Charging and accounting functions (CAF) verification and number activation shall be the responsibility of a VNO.
11. A VNO shall bear the penalty on account of failure of subscriber verification norms (for its own customers). Other penalties which are beyond the scope of the VNO viz. roll out obligations, core network issues, etc. shall be borne by the NSO as per existing norms defined for them.
12. No spectrum shall be assigned to the VNOs.

9.3 Kenya

9.3.1 MVNO and unified licensing framework

In 2008, the regulator adopted a unified licensing framework (ULF) which sought to address challenges associated with a technology specific licensing regime arising from the technological advancements that led to convergence.

This framework collapsed all the technology specific licenses into three categories with regards to MVNO as follows:

1. Network facilities provider (NFP) – that owns and operates any form of communications infrastructure (based on satellite, terrestrial, mobile or fixed);
2. Applications service provider (ASP) – that provides all forms of services to end users using the network services of a facilities provider. The services are all communication services except services that are content in nature. Resources applicable to this license are numbering resources both for customers and for network nodes; and
3. Contents services provider (CSP) – to provide content related services to end users who are customers of the application service providers. Content service providers use the infrastructure of network facilities providers and the systems of the application service providers to reach their customers. The services offered by content service providers are of information, entertainment, education, health, social, etc., nature that can either be text, voice, video clips delivered to a customer's mobile device on request or as subscribed to by the customer. With these three categories, the existing MNOs were therefore issued with NFP-T1 license to cover the entire infrastructure related component while all other services including subscription of customers are covered under the ASP license.

Upon the adoption of ULF in 2008, the regulator took a position that MVNOs fall under the ASP license since they do not require access spectrum but must register customers. This has remained the position of the regulator with regards to MVNOs and indeed informed a few interested parties that the "issues on the introduction of MVNOs relate to network capacity, interconnection, co-location, and infrastructure sharing among others and that there is a strong link between the viability of this business with the availability of extra/unutilized capacity within the networks of the existing cellular mobile operators and indeed the operators' willingness to make the same available for use by the said MVNOs".

The regulator has further maintained that potential MVNO's wishing to provide the said MVNO services should first approach the existing MNOs with a view to determining whether they have extra network capacity which they are willing to make available for use by an MVNO. Once this has been established the MVNOs would approach the regulator for further consideration on the licensing of the operation.

9.3.2 MVNO models

There are four permitted business models of MVNOs in Kenya and the characteristics of each of these business models and the corresponding licensing requirements are discussed below:

9.3.2.1 Full MVNO

A full MVNO is one that owns or provides network facilities and network services such as mobile switching centres, home location registers ("HLR"), authentication centres and cellular mobile services. Full MVNOs are able to secure their own numbering ranges, offer their own SIM cards and have full flexibility on the design of the services and tariff structures. A key feature that distinguishes a full MVNO from other business models is its ability to operate independently of the MNOs.

A full MVNO may require a network facility provider-Tier 2 (NFP T2) licence in addition to the application service provider (ASP) license in order to build full core infrastructure including the interconnecting backbone infrastructure. Where the full MVNO does not obtain the NFP-T2 license, the MVNO will lease backbone infrastructure from the licensed NFP-T2 operators.

It therefore follows that existing NFP-T2 operators can provide full MVNO services if they establish the relevant core network elements necessary for the provision of cellular mobile services.

9.3.2.2 Enhanced MVNO service providers

Enhanced service providers are those who do not own or provide network facilities but have the ability to secure their own numbering range, operate their own HLR and offer their own SIM cards with their own mobile network code. They are dependent on MNOs for network facilities, as well access to the radio network. These service providers are still able to maintain some independence from MNOs as they are able to differentiate their products.

Enhanced service providers require an ASP licence to provide cellular mobile services and related application services to end users.

9.3.2.3 Enhanced reseller

Enhanced resellers are primarily distributors who resell services provided by MNOs. As with enhanced service providers, enhanced resellers rely on MNOs for access to the radio network and network facilities. The key feature that distinguishes enhanced resellers from enhanced service providers is that enhanced resellers do not have their own SIM cards. While they may still be able to offer their own branded packages, they will not be able to distinguish their services by their MNC. Enhanced resellers are likely to carry out customer care and billing in-house.

Enhanced resellers require an ASP licence to provide cellular mobile services and related application services to end users.

9.3.2.4 Resellers

Resellers merely resell subscriptions to end users. In most cases, resellers are completely dependent on MNOs for every aspect of service provision, billing and customer care. However, end users will not be able to make a distinction between resellers, other forms of MVNOs and MNOs as resellers have a direct relationship with end users. MVNOs that operate as resellers are likely to require an ASP licence.

9.3.3 Mobile virtual network enablers (MVNE)

Mobile virtual network enablers (MVNE), typically known as **network enablers**, are another party provider focused on the provision of infrastructure that facilitates the launch of MVNO operations. An MVNE can be positioned between a host MNO and an MVNO venture to provide services ranging from value added services and back-office processes to offer definition. MVNEs reduce the entry barriers for MVNO ventures, given that an MVNE aggregates the demand of small players to negotiate better terms and conditions with host MNOs. They pass on some of these benefits to their MVNO partners.

An MVNE in Kenya will be required to obtain both NFP-T2 and ASP licenses to provide cellular mobile services and related application services to end users.

9.3.4 Principles for licensing an MVNO

a) The requirements for an MVNO license are similar to those of ASPs except that there will be an additional requirement that they provide a commitment letter and contract to show that the proposed MNO has accepted to host the proposed MVNO. This will continue to be a requirement until such a time that the regulator will have put in place a regulatory framework that obligates MNOs to take on board MVNOs as and when they come.

b) The existing service provider will also be allowed to provide MVNO services upon submission of the commitment letter and contract as above and upon approval by the regulator.

c) The model chosen by an MVNO will largely depend on the agreement signed with the host MNO and the regulator has no restriction on the model adopted by an ASP except that an MVNE or full MVNO that intends to build interconnecting infrastructure is required to be in possession of ASP and NFP-T2 licenses.

d) MVNO will is authorised to provide services in accordance with ASP licence term 5.2 which states that "*the Licensee is authorized to provide the licensed services provided that the Licensee has filed the details of the particular service to be provided and obtained approval from the Authority*".

e) The application fees, initial fees and annual fees are similar to those of the ASP license.

In Kenya, the growth of subscribers is up to around 66.7 million as at December 2023, see Figure 8. The telecoms market has a high market concentration with HHI above 5000. These indicators could be considered as an incentive for MVNO markets.

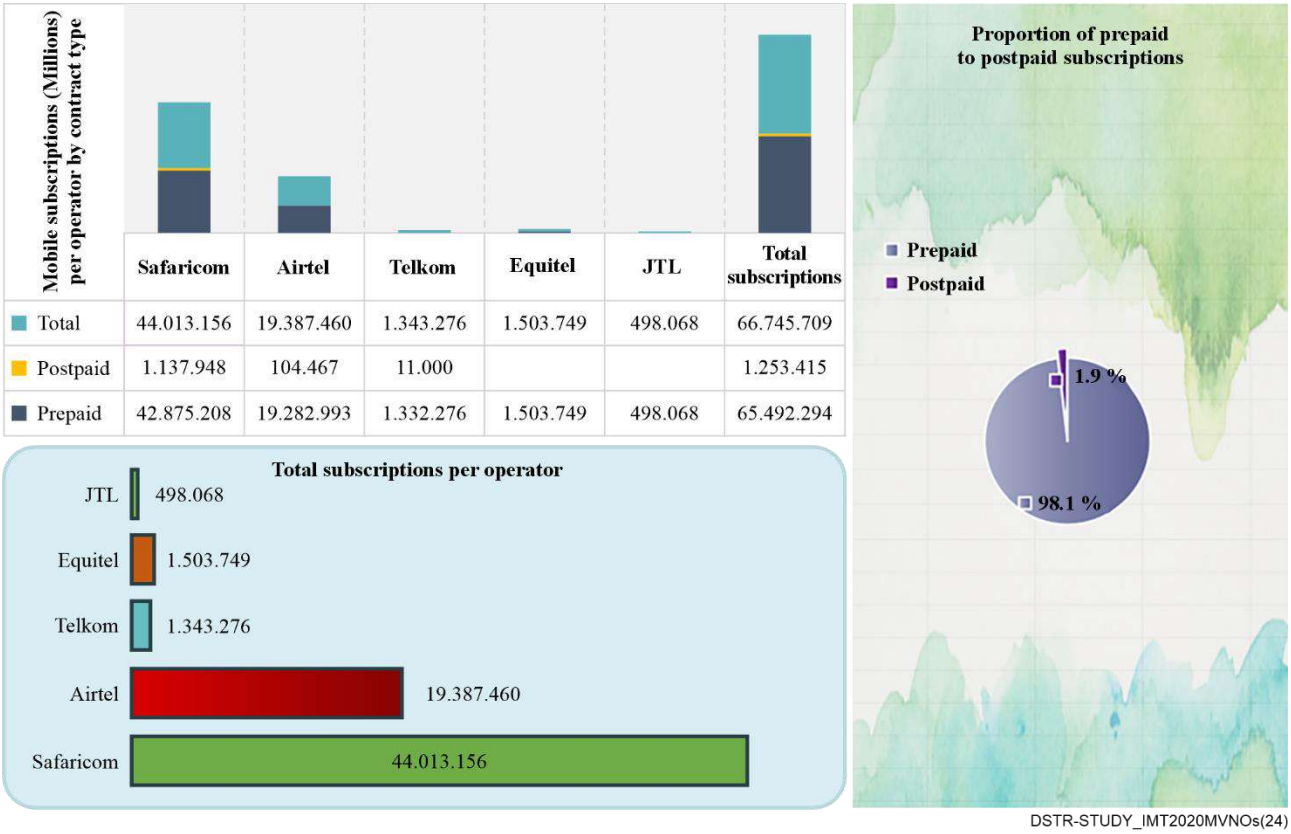


Figure 8 – Kenya telecoms market (Source: Communications Authority of Kenya)

From our analysis, 2 out of 4 MNOs (Telkom Kenya Limited, and Jamii Telecommunication Limited) operate below capacity, therefore there is an opportunity for MVNOs to enter into agreements that enable them to access excess capacity.

Since 2014 the regulator has licenced 10 MVNOs. Equitel is the most active MVNO with slightly over a million subscribers and a market share of 2.2 percent of the total market.

9.4 Zimbabwe

Zimbabwe adopted a Converged Licensing Framework in 2021 through the promulgation of the Postal and Telecommunications (licensing, registration and certification) Regulations of 2021. The framework ushered in service and technology neutrality, which is critical for 5G development. The framework also ushered in mobile virtual network operators (MVNOs) as a license category under the Application Services License category. The framework provides for the following four MVNO operating models:

a) **Light MVNO**: Under this operating model, an MVNO has ownership of the client and the intelligent network platform and even partial ownership of the VAS platform, ownership of the radio access network and part of the core network remains with the host MNO.

b) **Full MVNO**: Under this operating model, an MVNO operates like an MNO in virtually all ways except that the MVNO has no ownership of the radio access network. At this end of the spectrum, the full MVNO gets the benefits associated with ownership of the core network infrastructure. This allows the full MVNO to provide additional differentiated services from MNOs as well as achieve a higher degree of independence from the host MNO as the MVNO has full control of other aspects such as interconnection with other operators.

c) **MVNE**: The mobile virtual network enabler (MVNE) acts as the middleman between MVNOs and host MNOs by providing the infrastructure platform required by MVNOs. As

the MVNE can host several MVNOs, the MVNE can negotiate better wholesale agreements with the host MNOs.

d) **Branded reseller**: Under this operating model, an MVNO offers its own value-added services (VAS) to its customers. The branded reseller model allows the MVNO to enjoy the benefits of operating under its own brand. The branded reseller is responsible for the costs of branding, sales, and distribution and enters into a revenue sharing agreement with the host MNO.

Two mobile virtual network operators have been licensed to date. As with the MNOs, all categories of MVNO are subject to the following regulatory policies amongst others:

– Tariff regulation.

– Competition policy.

– Consumer protection.

– Provision of universal access and service.

Economic and policy regulation is currently targeted at creating an enabling environment for these new players as well as promoting access to essential resources, transparency, innovation and accountability.

9.5 Brazil

In 2010, through the Anatel Resolution n. 550, the bases for exploring the mobile virtual network operator (MVNO) in Brazil were approved. The exploitation of the mobile service through a virtual network can occur in two different ways: Authorization and Accreditation. Both modalities require confirmation from Anatel.

In the Authorization modality, the unique difference of the MVNO provider to an MNO provider is the ownership of radio frequencies. The MVNO provides service is through network sharing with MNOs. In this modality, the MVNO provider is directly responsible to Anatel for regulatory obligations relating to numbering resources, service plan registration, interconnection and consumers.

In the Accreditation modality, the interested party (accredited) has to sign a private contract with an MNO provider or with an MVNO provider in the authorization modality, which must be approved by Anatel. The business model covered by the accreditation modality is established by the company authorized to provide the mobile service and the accredited person does not need to be qualified by Anatel. The company that holds the authorization to provide the mobile service is responsible for regulatory obligations relating to numbering resources, service plan registration, interconnection and consumers.

In both forms, Authorization and Accreditation, a contractual relationship can be maintained with more than one company. The option to develop multiple contracts without the impediments of exclusivity clauses, allows the MVNO operator to adapt the allocation of its resources and the needs of its customers. Furthermore, by opting for an arrangement with multiple networks, the MVNO would be able to mitigate risks associated with dependence on a single source provider.

10 Conclusion

In conclusion, 5G/IMT-2020 represents more than just another step in the evolution of wireless technologies. It will serve as the catalyst for development in the mobile market, not only of MNOs but also of MVNOs. Although the advent of MVNOs in the beginning of the 2000s was spontaneous, it would be beneficial to consider technological standards and telecommunication policies under the presence of two types of operators – MNOs and MVNOs – in this transient period from 4G to 5G and beyond.

This Technical Report highlights the various economic and policy aspects related to IMT-2020 technologies taking into consideration MVNOs. It also reviews the drivers and barriers to MVNOs rollout, various MVNO conceptual models as well as the policies implemented in some Member States as detailed in the case studies. It is essential that an enabling environment is nurtured to promote effective competition, innovation and investment in emerging technologies and markets. Thus, this Technical Report is expected to be of good help and use for promoting MNOs and MVNOs to enhance digital transformation.

07.

New Direction of Smart X Development: Human-Centric & Trusted Society - Prof. SuhonoHarsoSupangkat (ITB)

Opening Speech ICISS 2024

New Direction of Smart X Development: Human-Centric & Trusted Society

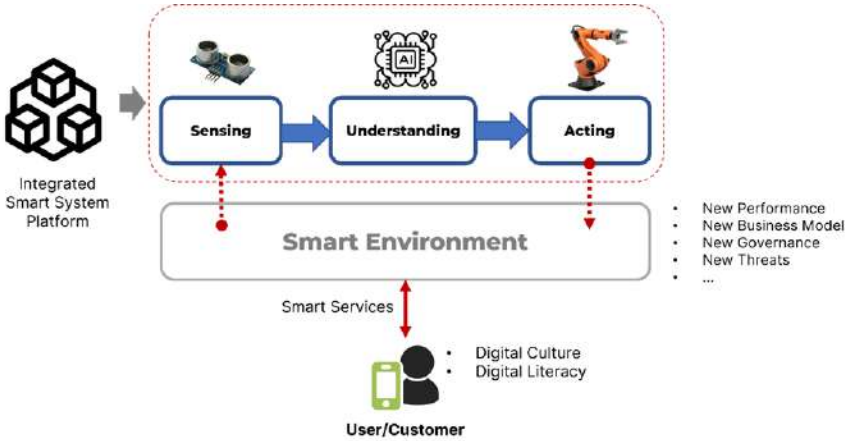
Prof. Suhono Harso Supangkat

Smart City and Community Innovation Center (SCCIC) ITB

Smart-X

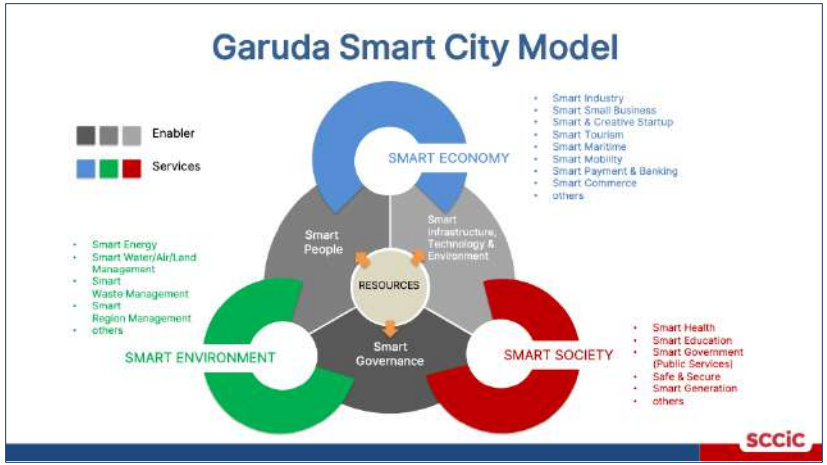
- The rapid **development** of **technology** encourages the **massive application** of technology in various environments, including the business, government, or daily human environments.
- Various environments have also changed to “smart”, such as smart cities, smart buildings, smart maritime, smart energy, and so on; which can also be referred to as **“Smart-X”**.

- In general, **“Smart-X”** always runs the process of "sensing-understanding-acting".



Smart City

Smart City is a city that is able to manage existing resources effectively and efficiently to provide quality services to its people by utilizing information and communication technology (ICT).



Some key points on the implementation of Smart City:

Effective and Efficient Governance

- City resources must be managed effectively and efficiently in order to improve public welfare.

Technology as an Enabler

- The implementation of technology, which is an important pillar in achieving the goal of a smart city, must continue to be revised and improved.

Human as a Center of Attention

- Technology is a tools, urban development must still place human as the main focus, both as developers and users.

Evaluation of Smart City Implementation in Indonesia

Smart Parking

Low usage, resistance of parking attendants, weak supervision and law enforcement

Bike Sharing

Limited supporting infrastructure such as safe and comfortable bicycle lanes, low public awareness

Public Transport

Lack of good integration between modes of transportation, resistance from users

Have the same problem: **Human**

Human-Centric: A Global Trend in Smart City Development

Xu, H., and Geng, X. (2019) – People-Centric Service Intelligence

Paradigm Shift

The paradigm shift of smart city development from a technology-centric model to a human-centric model will prioritize human needs and sustainable development practices.

This paradigm shift is in line with:

UN-Habitat Initiative

Initiatives that aim to ensure that technology is used to empower communities, increase social inclusion, and promote sustainability.


UN-HABITAT
FOR A BETTER URBAN FUTURE

FLAGSHIP PROGRAMME

People-Centered Smart Cities

Building People-Centered Smart Cities from the ground up

The world is rapidly urbanizing. In 2008, the important milestone of more than 50 percent of the world's population living in urban areas was reached, a figure that is estimated to rise to 70 percent by 2050. At the same time, the world is rapidly becoming more digital. Data, artificial intelligence, connectivity and the new digital economy are shaping the future of our societies.

Digital technologies have the potential to serve people, improve public services and working conditions. But persistent digital divides remain, and the digital revolution must be directed and governed in a democratic and inclusive way.

Today, while more than 50 percent of the world's population is online, there are still 3.6 billion people without affordable access to the internet. Among the world's 47 least developed countries, more than 80 per cent of the population is still offline. And the gender gap in connectivity continues to widen.

Only 2 per cent of women in Latin America and the Caribbean and in East Asia and the Pacific own a mobile phone with internet access. Worldwide, some 327 million fewer women than men have a smartphone and can access the mobile internet.

Women are also drastically under-represented in scientific education, information and communications technology jobs, and tech-related academic careers. **Connecting all the world's people by 2030 should be a shared priority, not only for sustainable development, but for gender equality.**

Digital technologies, depending on their use, can be a force that widens social gaps or reduces them. Considering the importance of this, the Secretary General has made one of his top five priorities for 2019 "reducing digital inequality, building digital capacity and ensuring that new technologies are a force for good" and is pursuing the implementation of the recommendation of the High-Level Panel on Digital Cooperation on capacity-building and on the need to maximize digital public goods.

The United Nations is the essential platform where all relevant actors, including governments, along with companies, technical experts and civil society – can come together to share policy expertise, and explore the possibility of a **Global Commitment on Digital Trust and Security.**

The UN Strategy on Sustainable Urban Development highlights digital transformation and new technologies as one of four frontier issues that require a special, coordinated response. The New Urban Agenda calls for the adoption of "a smart-city approach that makes use of opportunities from digitalization, clean energy and technologies".

The explosion in digital technologies is playing a major role in shaping cities – from the internet of things, to digital platforms for service delivery and 5G for autonomous mobility – and our challenge is to set a new direction that favours inclusive, resilient and sustainable use of technologies by local governments.

These technologies, if well governed, can contribute to sustainable development by reducing carbon emissions and facilitating the ecological transition, increasing access to affordable housing, enhancing participation in policy making for citizens, and ensuring access to inclusive services for communities.

Society 5.0

A concept that focuses on how technology can be used to create a more inclusive and sustainable society.

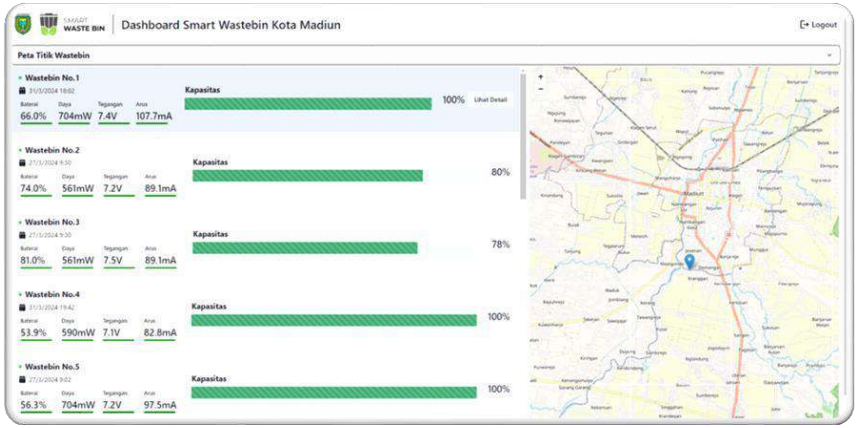
SCCIC Solution: Innovative Living Lab Model

The living lab involves community participation to co-create urban solutions, increasing relevance and effectiveness.

Some of the solutions developed by SCCIC ITB based on Living Lab:

- **Smart Waste Bin**
  Improve waste transportation efficiency through real-time monitoring of waste volume.
- **Road Anomaly Detection System**
  Detect congestion, accidents, and traffic disruptions and ensure the safety of road users.

SCCIC Smart Waste Bin



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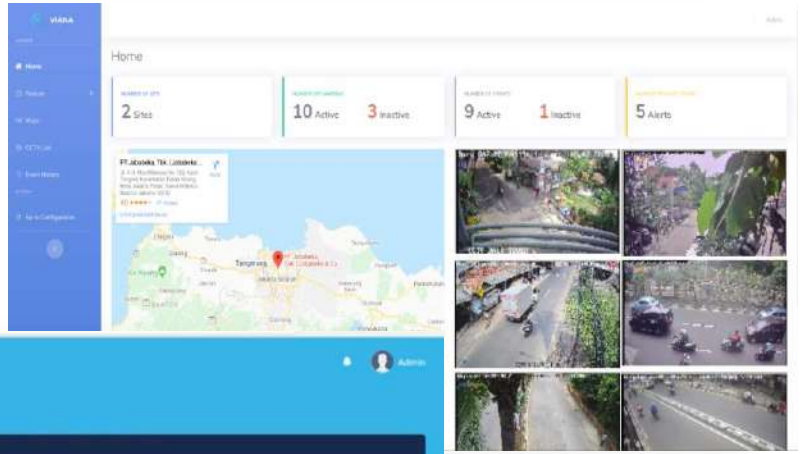
SCCIC Road Anomaly Detection System



Some Important Aspects of the Human-Centric and Sustainability Approach

- **Living Lab-Based Innovation Model**
  Active public involvement in the creation and management of urban solutions can ensure that the needs of the community are met and prioritized in a sustainable manner.
- **Eco-Friendly Technology**
  The use of environmentally friendly technology is essential to maintain ecological integrity while meeting the goals of sustainable urban development.
- **Accessibility of Inclusive Facilities**
  Ease of access to public facilities for all members of the community encourages equality and sustainable social cohesion.

Problems in Digital Interaction

Security of Digital Services

Distrust in security and privacy when using digital services

Misuse of Personal Data

Distrust of the management of personal data by companies and institutions

Disinformation and Fake News

Distrust of information and news circulating on social media and online platforms

Illegal Online Gambling and Loans

Distrust of online financial services due to fraud, non-transparent practices, and intimidation

Have the same problem: **Distrust**

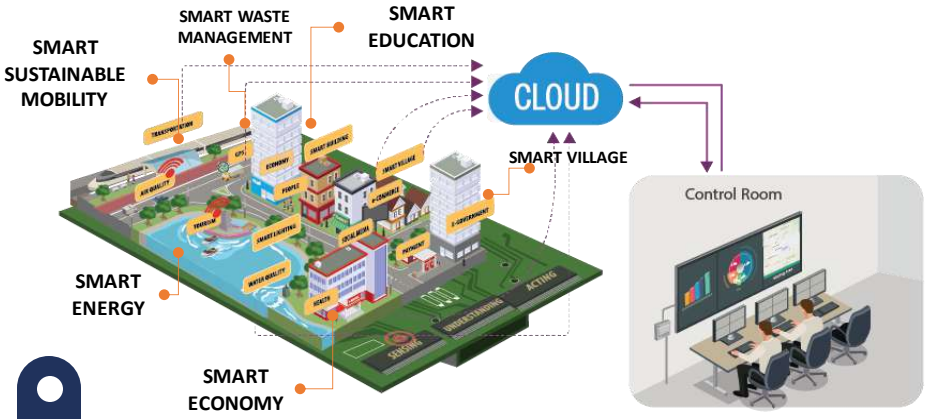
Trusted Society: Building Trust in Digital Interactions

Achievement of the vision of "Trusted Society", requires:

- Services that **focus on individuals** by **integrating** elements of a broader range of **social data**
- **Computing technology** innovations that enable **high-speed big data processing** with the use of simulation techniques that can **transform data** into **meaningful social value**
- Use of **trusted technology** that ensures absolute **data integrity** while **anticipating data exploitation** and **privacy conflicts**

Trusted Society is still part of a human-centric approach, which provides a structure that upholds sustainability values for **cities** and **planets**, and social well-being for **humans**

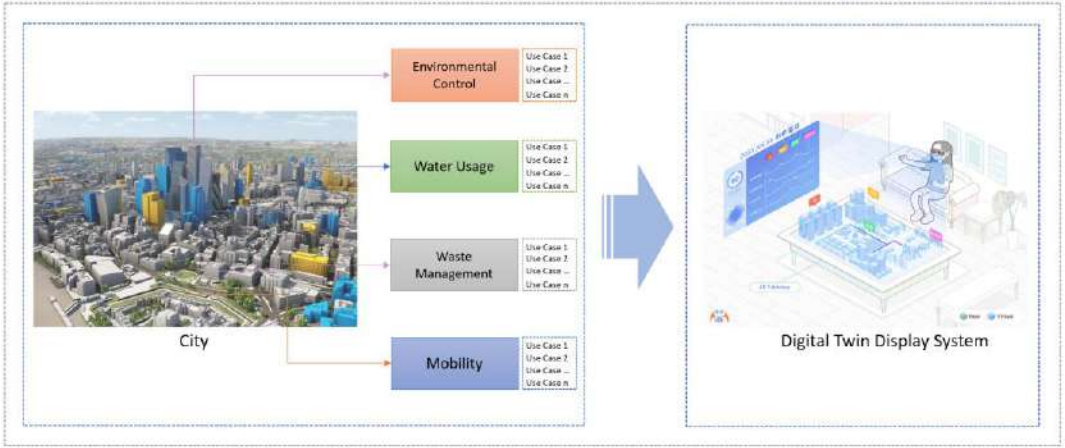
Fujitsu (2022) – Creating a Trusted Society - by listening to consumers
https://corporate-blog.global.fujitsu.com/fgb/2022-03-02/02/



SCCIC Solution: Cognitive City Platform

A cognitive city platform is a **technology infrastructure** that provides a suite of tools and services to **integrate, analyze, and manage data** from **multiple sources** in the context of a smart city.

The platform combines technologies such as **artificial intelligence**, **big data analytics**, and **cloud computing** to provide a deeper understanding of the city's needs and dynamics and provide responsive and adaptive solutions.



Digital Twin for Smart X

Digital Twin Technology, as **a virtual representation of physical systems**, plays a critical role in Smart X by **integrating real-time data** and **advanced analytics** to optimize performance, enhance human-centric considerations, and built trust in digital interactions.

It enables **proactive management** across smart environments, **improving efficiency**, and **user experience** while **ensuring security and transparency**.

Opportunities and Challenges of Technology in Smart-X Implementation (1)

Technology Opportunities	Description	Challenges
1. Artificial Intelligence (AI)	AI can be used to **automate** and **optimize** various **smart city services**, such as traffic management, environmental data analysis, and public services. AI enables faster and more accurate predictive analytics, pattern detection, and decision-making.	**Ethics:** AI can violate ethics if: • The model is **based** on **biased data** that then **results** in **discriminatory decisions** • Used in **critical decision-making** • Used to collect, analyze, and store **personal data without** the **consent** or **full understanding** of the individual • Used to **spread disinformation** or **propaganda**

Opportunities and Challenges of Technology in Smart-X Implementation (2)

Technology Opportunities	Description	Challenges
2. Internet of Things (IoT)	IoT allows **devices** and **city infrastructure** to **connect and communicate** with each other in real-time. This technology allows for traffic monitoring, energy management, environmental sensors, and more efficient and automated waste management.	• **Security**: IoT devices are vulnerable to cyberattacks and data theft. • **Interoperability**: Many IoT devices from different vendors are difficult to integrate.
3. Big Data Analytics	Big data analysis **helps** city governments **understand patterns and trends** from data generated by various systems in the city. This allows for **more informed decision-making based on data**, such as in transportation planning, public health, and environmental policy.	• **Data Privacy and Security**: Collection and analysis of data on a large scale can violate individual privacy. • **Data Quality**: Analysis is only as accurate as the data used, so low-quality data can produce false insights.

Opportunities and Challenges of Technology in Smart-X Implementation (3)

Technology Opportunities	Description	Challenges
4. Blockchain	Blockchain increases **transparency and security** in smart city **transactions**, such as digital identity management, electronic voting systems, and public asset tracking. This technology provides an immutable record, which helps to increase public trust.	• **Scalability**: Blockchain technology still faces challenges in terms of scalability, especially for applications that require fast transactions. • **Regulation and Law**: Lack of clear regulation and legal standards regarding the use of blockchain.
5. Cloud Computing	Cloud computing allows for the **storage and processing** of **large amounts of data** at a more **cost-efficient** rate. It supports smart city services such as real-time data analysis, digital public services, and decentralized infrastructure management.	• **Data Security**: Reliance on cloud service providers increases the risk of data leaks or cyberattacks. • **Migration Complexity**: Migrating systems to the cloud can be complex and require significant changes to existing IT architectures.

Opportunities and Challenges of Technology in Smart-X Implementation (4)

Technology Opportunities	Description	Challenges
6. 5G Technology	5G networks offer **ultra-high internet speeds** with **low latency**, which is **essential** for the **implementation** of **intelligent services** such as autonomous vehicles, augmented reality for urban navigation, and faster and more reliable communication between devices.	• **Infrastructure**: The development of adequate 5G infrastructure requires large investment and a long time. • **Security**: 5G technology could unlock more potential attack points in the network.
7. Digital Twin	Digital Twin Technology offers **a real-time virtual representations** of physical systems, enabling continuous monitoring and predictive analysis for **smarter resource management**. It **Enhances decision-making** and **operational efficiency** in smart cities, buildings, and other by simulating and optimizing various scenarios	• **Integration Complexity**: requires complex integration of diverse systems and IoT devices. • **Data Security and Privacy**: demands robust protection • **Scalability**: need high computational power and data storage.

08.

THE ROLES OF SATELLITE TECHNOLOGY AND IMPLEMENTATION OF 5G/6G FOR IMPROVING CONNECTIVITY - Sigit PW Jarot (MASTEL)

THE ROLES OF SATELLITE TECHNOLOGY AND IMPLEMENTATION OF 5G/6G FOR IMPROVING CONNECTIVITY

Sigit PW Jarot (sigit.jarot@gmail.com)
Head of National Telematics Infrastructure
Mastel (The Indonesian Telematics Society)

Digital Industry Association Leaders Summit (DIALS) and
Indonesia Internet Expo and Summit (IIXS) 2024
12-14 Agustus 2024

2024 Tahun Penting NTN

Pragmatism

- **Filling the gap.** 7% coverage gap. Satellite is the only feasible option.
- **Proof points.** Key for product and pricing strategy.

Satellite Economy

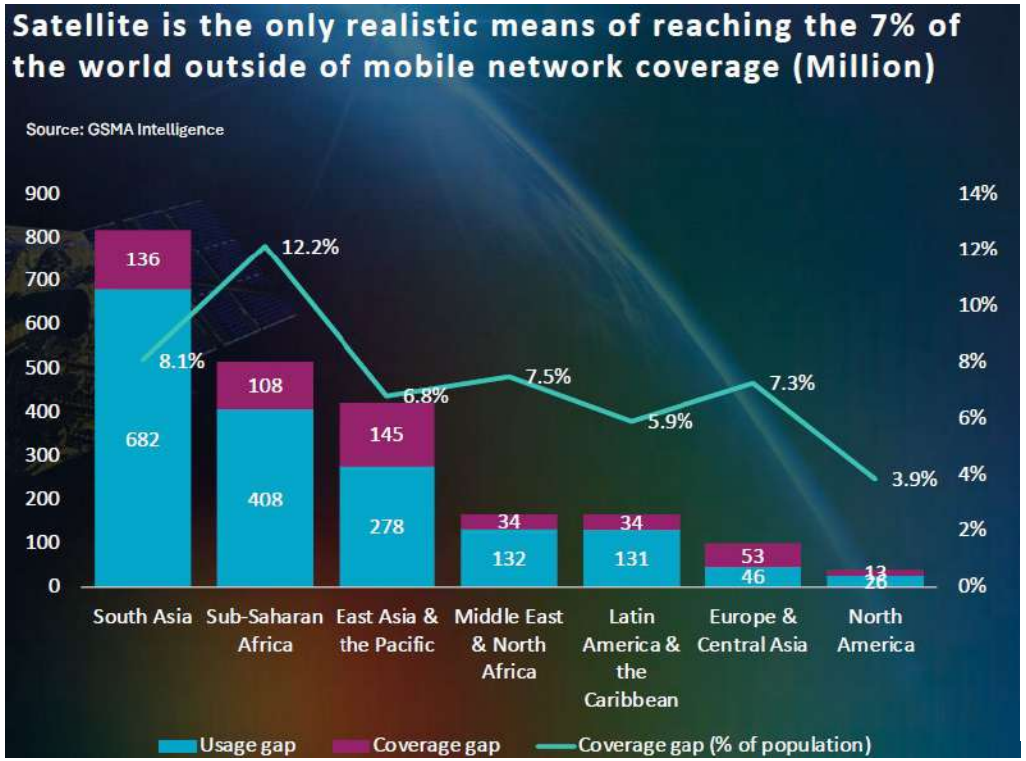
- **Consumers.** GSMA Intelligence $20–25 billion per year by 2035 (2/3 of the total satellite-enabled connectivity revenue).
- **B2B.** IIoT service, $10 billion per year by 2035 (almost 1/3 of the total).

Laying foundation for long-term

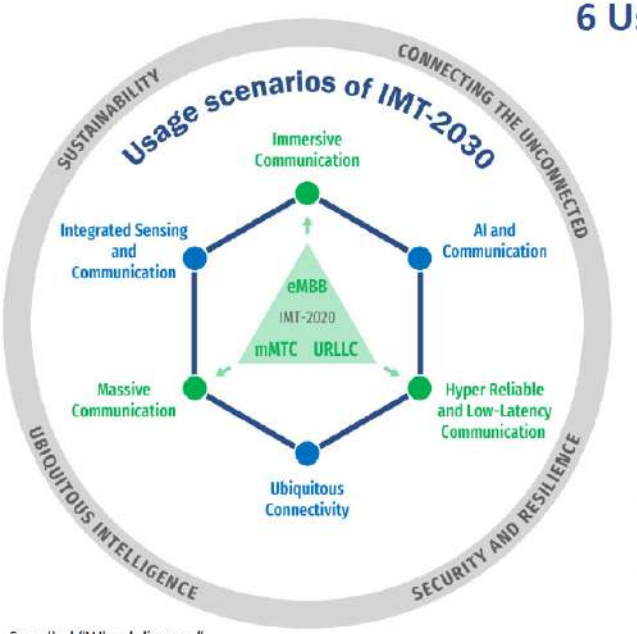
- **NTN standards.** 3GPP standards towards NTN as native 6G component.
- **Fragmentation.** Risks remain if prominent hold-outs continue to pursue proprietary models.
- **Devices.** D2D service to be a model to pursue.

Extending Coverage➔ Ubiquitous

- 7% world population outside mobile BB coverage
- > 80% land, 95% sea outside mobile coverage mobile
- 5G/6G not-only about high-speed, but also ubiquitous mobile network access.



Usage scenarios



So called "Wheel diagram"

6 Usage scenarios

Extension from IMT-2020 (5G)

- eMBB ➔ Immersive Communication
- mMTC ➔ Massive Communication
- URLLC ➔ HRLLC (Hyper Reliable & Low-Latency Communication)

New

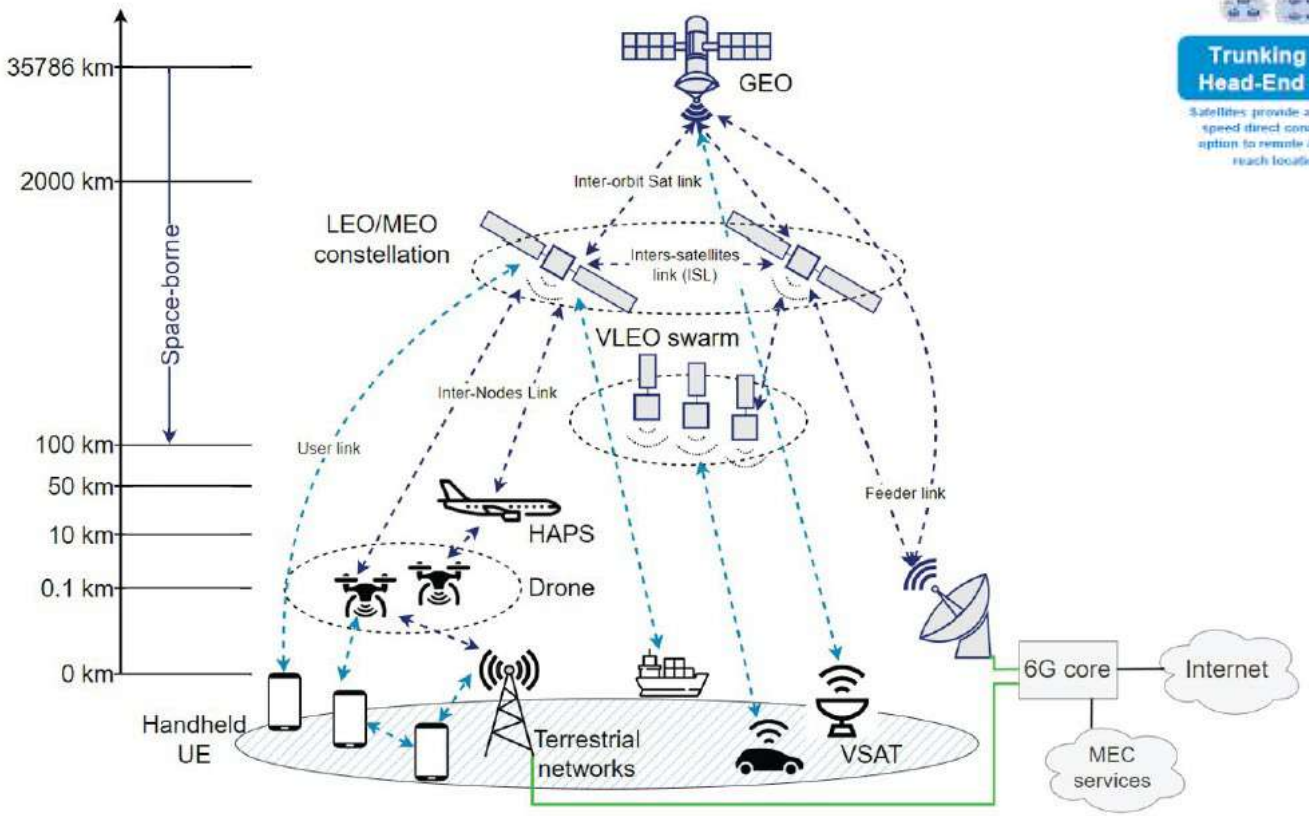
- Ubiquitous Connectivity
- AI and Communication
- Integrated Sensing and Communication

4 Overarching aspects:

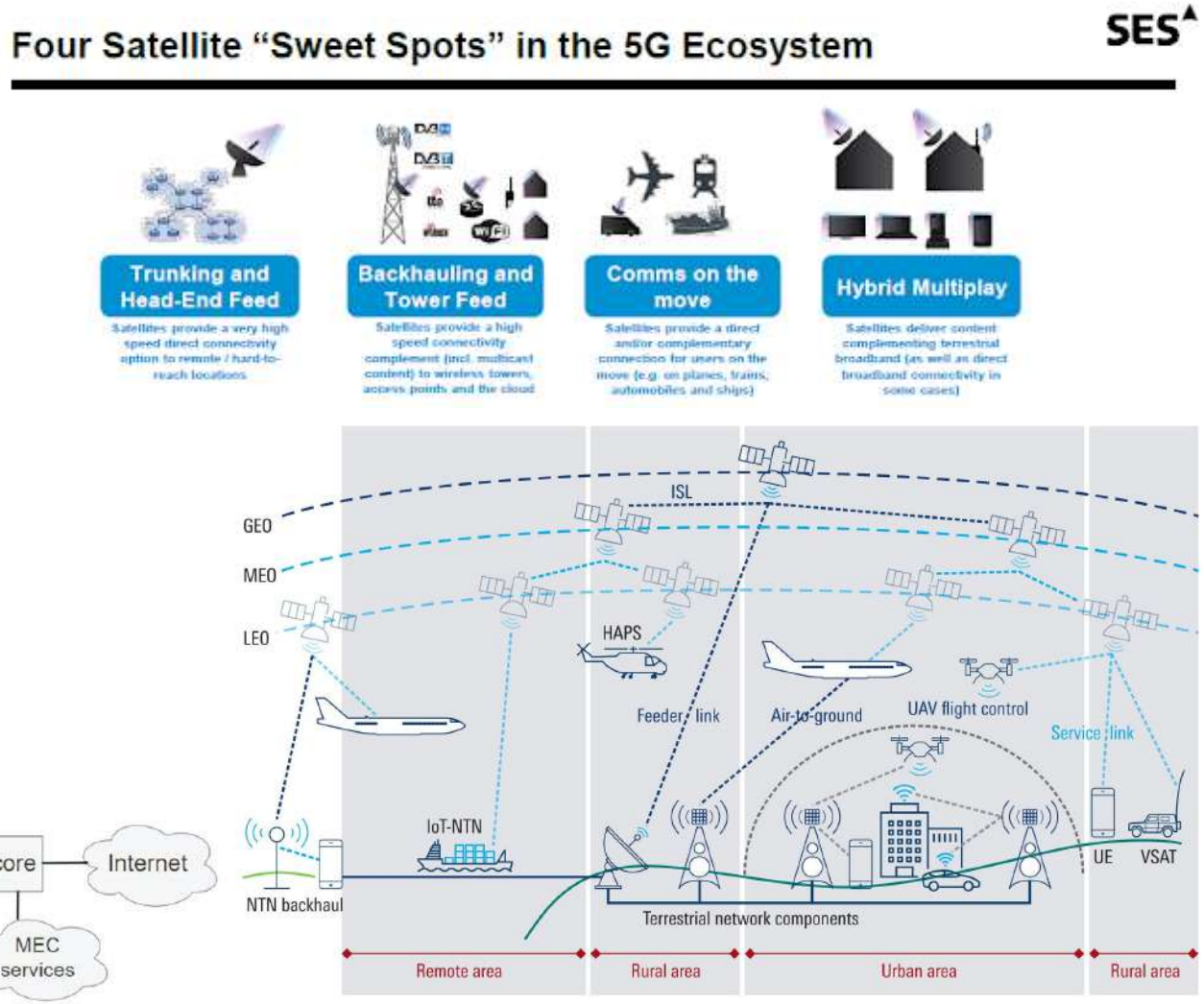
act as design principles commonly applicable to all usage scenarios

Sustainability, Connecting the unconnected, Ubiquitous intelligence, Security/resilience

NTN Multi-dimensional Architecture and Use-cases

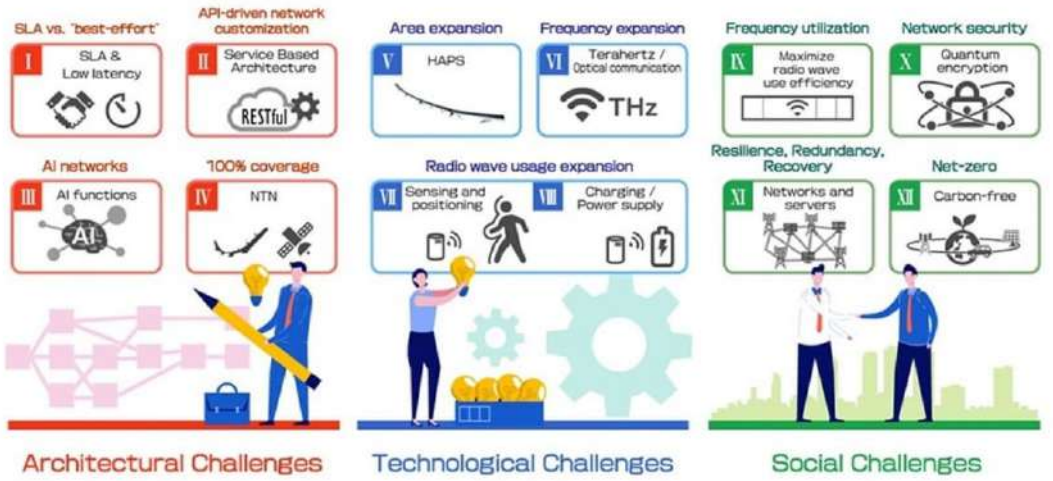


Source: NTT



Source: RS

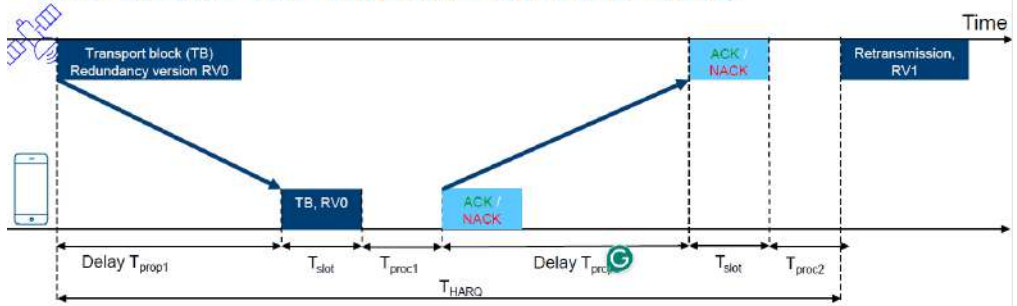
NTN Standards in 5G/6G



- **Rel-15, 16**
  - Study on using Satellite Access in 5G
  - Integration of Satellite Access in 5G
- **Rel 17**
  - Integration of satellite components in the 5G architecture
  - NB-IoT/eMTC support for Non-Terrestrial Networks
- **Rel 18**
  - Support of Satellite Backhauling in 5GS" and "5GC enhancement for satellite access phase 2
- **Rel 19**
  - Satellite access - Phase 3
  - Integration of satellite components in the 5G architecture Phase 3
- **Rel 20**
  - Satellite access - Phase 4
    - Emergency communications and mission-critical
    - IMS voice calls using GEO satellite access
    - Multi-orbit satellite access (LEO, MEO, GEO)
    - User notification that a mobile terminated communication failed when the UE was unreachable in satellite access

6G-SANDBOX is the first SNS Platform enabling open experimentation with these technologies

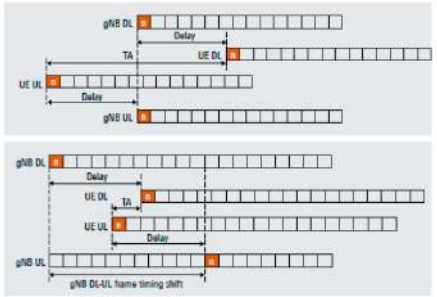
NTN: ROUND-TRIP-TIME ASPECTS AND HARQ



Constellation	T_{HARQ} max	#HARQ processes	UE side feasibility
Terrestrial	16 ms	16	Rel. 15
LEO	50 ms	50 theoretical 3GPP agrees to 32	HARQ extension
GEO	600 ms	600	For future study

Assumption: 15 kHz SCS and 1 ms slot duration (TR 38.811)

NON TERRESTRIAL NETWORK CHALLENGES

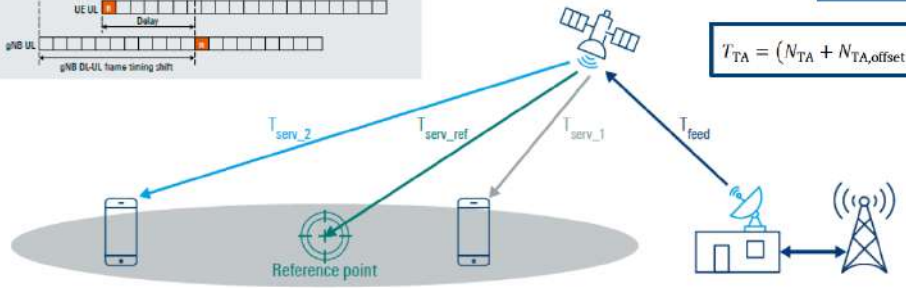


Idea to adjust large timing advance values:
⇒ large TX – RX offset in the UE

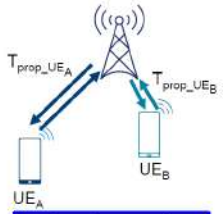
Idea to adjust shorter timing advance values:
⇒ large TX – RX offset in the gNB
⇒ possible SFN shift in gNB for UL/DL

Timing advance depends on UE and cell specific values + TA control

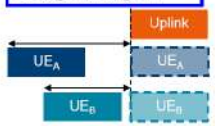
$$T_{TA} = (N_{TA} + N_{TA,offset} + N_{TA,adj}^{common} + N_{TA,adj}^{UE})T_c$$

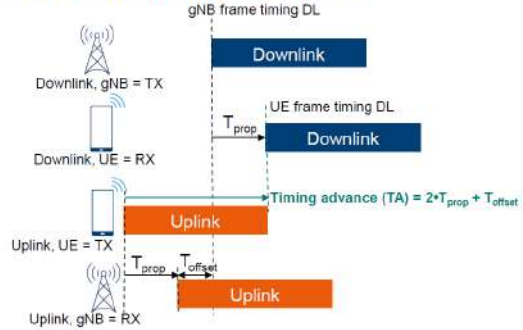


NON TERRESTRIAL NETWORK TIMING ADVANCE



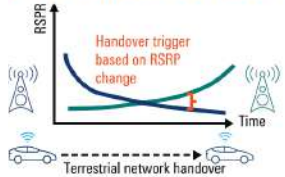
Timing advance aligns UL signals at gNB

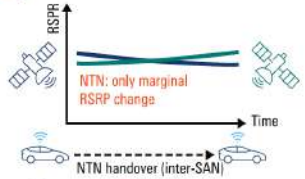


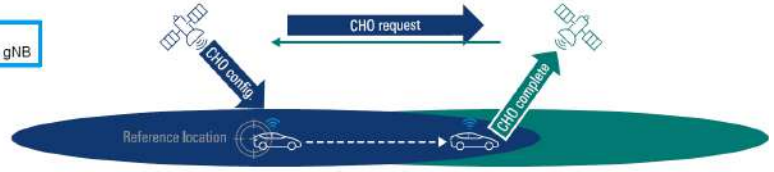


Timing advance with perspective UE and gNB.
T_{offset} can indicate an optional time difference between UL and DL frames at the gNB

NTN HANDOVER EXAMPLE (CHO)



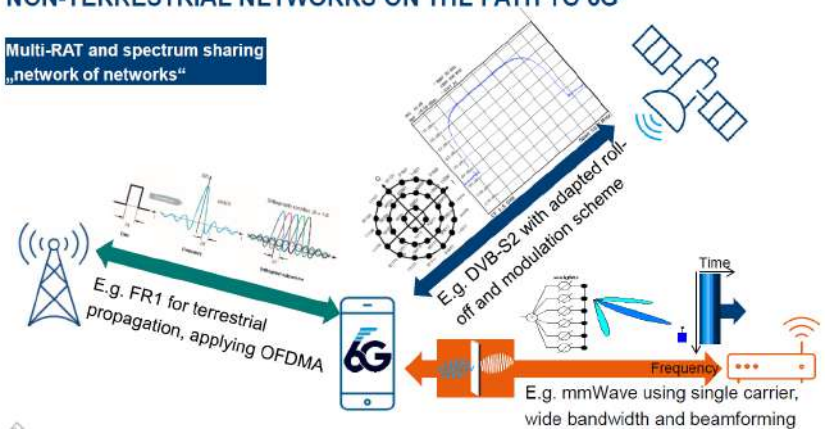




Conditional handover (CHO): network configures UE with triggering condition; e.g. distance between UE and reference location

NON-TERRESTRIAL NETWORKS ON THE PATH TO 6G

Multi-RAT and spectrum sharing „network of networks“



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