CLEARED
For Open Publication
Mar 01, 2023
Department of Defense
OFFICE OF PREPUBLICATION AND SECURITY REVIEW

5G Core Operate Through Quarterly Update (Q1-2023)

Summary

This report summarizes information on vulnerabilities associated with the 5G network that potentially could be employed or leveraged by an untrusted network operator. The report is in support of the Under Secretary of Defense for Research and Engineering (OUSD R&E) 5G Operate Through Program. The information in this report is based on open-source material published or made available between 1 September and 30 November 2022.

5G Network Vulnerabilities for Operate Through

The vulnerabilities in this section were obtained from the National Institute of Standards and Technology (NIST) National Vulnerability Database (NVD) for this reporting period. Vulnerabilities that are of direct interest for the Operate Through program, as well as 5G-related vulnerabilities of potential general interest, are included.

Vulnerabilities Listed in NIST NVD

NIST CVE-2022-38788: A vulnerability was discovered in Nokia FastMile 5G Receiver

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-38788

An issue was discovered in Nokia FastMile 5G Receiver 5G14-B 1.2104.00.0281. Bluetooth on the Nokia outdoor unit (ODU) uses outdated pairing mechanisms, allowing an attacker to passively intercept a paring handshake and (after offline cracking) retrieve the personal identification number (PIN) and long-term key (LTK).

NIST CVE-2022-39063: Open 5GS, UPF PFCP Session Establishment Request Denial-of-service vulnerability

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-39063

When Open5GS User Plane Function (UPF) receives a Packet Forwarding Control Protocol (PFCP) Session Establishment Request, it stores related values for building the PFCP Session Establishment Response. Once UPF receives a request, it gets the f_teid_len from the incoming message and then uses it to copy data from incoming message to struct f_teid without checking the maximum length. If the pdi.local_f_teid.len exceeds the maximum length of the struct of f_teid, the memcpy() overwrites the fields (e.g., f_teid_len) after f_teid in the pdr struct. After parsing the request, the UPF starts to build a response. The f_teid_len with its overwritten value is used as a length for memcpy(). A segmentation fault occurs, as a result of a memcpy(), if this overwritten value is large enough.

Idaho National Laboratory

Contents:

Pg. 1–3
Summary
Vulnerabilities for Operate Through
NIST NVD Listed Vulnerabilities

Pg. 3–5
Literature Review

Pg. 6–7
Active Foreign Commercial 5G Standalone Networks

Pg. 7–8
Literature Review of Other Pertinent 5G-Related Items of Interest

Pg. 8
Projected Growth of 5G Global Connections

Pg. 9–15
Sources

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

22-50105_056

NIST CVE-2022-3299: A vulnerability in the library of Open5GS up to 2.4.10 was found that can lead to DoS

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-3299

A vulnerability has been found in Open5GS up to 2.4.10 and has been declared problematic. An unknown functionality in the library lib/sbi/client.c of the component Access and Mobility Management Function (AMF) is affected by this vulnerability. The manipulation leads to Denial of Service (DoS), and the attack can be launched remotely. The name of the patch is 724fa568435dae45ef0c3a48b2aabde052afae88. It is recommended to apply a patch to fix this issue. The identifier VDB-209545 was assigned to this vulnerability.

NIST CVE-2022-3354: Open 5GS, DoS vulnerability in the library of the UDP Packet Handler

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-3354

A vulnerability has been found in Open5GS up to 2.4.10 and classified as problematic. This vulnerability affects unknown code in the library lib/core/ogs-tlv-msg.c of the component User Datagram Protocol (UDP) Packet Handler. The manipulation leads to DoS. The exploit has been disclosed to the public. It is recommended to apply a patch to fix this issue. VDB-209686 is the identifier assigned to this vulnerability.

NIST CVE-2022-40890: Open 5GS, AMF vulnerability in Open5GS 2.4.10 and can lead to DoS

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-40890

A vulnerability in /src/amf/amf-context.c in Open5GS 2.4.10 and earlier leads to AMF DoS.

NIST CVE-2022-43677: In free5GC 3.2.1, a malformed NGAP message can crash the AMF and NGAP decoders

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-43677

In free5GC 3.2.1, a malformed next-generation (NG) Application Protocol (NGAP) message can crash the AMF and NGAP decoders via an index-out-of-range panic in aper.GetBitString.

NIST CVE-2022-38870: Free5gc v3.2.1 is vulnerable to information disclosure

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-38870

Free5gc webconsole comes with a default username: Admin. Using this username as a token header without any password or authentication makes it possible to leak the following information: Registered User Equipment (UEs) (plmnID,ueId); Subscriber information; (AccessType, CmState, Guti, Mcc, Mnc, Dnn, PduSessionId, Sd, SmContextRef, Sst, Supi, Tac); Tenant; and User.

NIST CVE-2022-43222: In open5gs v2.4.11 a component memory leak leads to a DoS vulnerability

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-43222

Open5gs v2.4.11 contains a memory leak in the component src/smf/pfcp-path.c. This vulnerability allows attackers to cause a DoS via a crafted PFCP packet.

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

NIST CVE-2022-43223: Malformated UE initial message crashes AMF causing DoS

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-43223

Open5gs v2.4.11 contains a memory leak in the component ngap-handler.c. This vulnerability allows attackers to cause a DoS via a crafted UE attachment.

NIST CVE-2022-38871: In Free5gc v3.0.5, the AMF breaks due to malformed NAS messages

CVSS Severity V3.1: Medium; V2.0 (Not available)

https://nvd.nist.gov/vuln/detail/CVE-2022-38871

In Free5gc v3.0.5, while sending malformed Non-access Stratum (NAS) messages (basic security features and fuzzing), the AMF breaks down.

Literature Review of 5G Vulnerabilities for Operate Through

The following section summarizes open-source literature focused on 5G-related vulnerabilities that either directly pertain to 5G Operate Through or are of potential general interest.

Over The Air Baseband Exploit: Gaining Remote Code Execution on 5G Smartphones

2021

https://keenlab.tencent.com/zh/whitepapers/us-21-Over-The-Air-Baseband-Exploit-Gaining-Remote-Code-Execution-on-5G-Smartphones-wp.pdf; https://i.blackhat.com/USA21/Wednesday-Handouts/us-21-Over-The-Air-Baseband-Exploit-Gaining-Remote-Code-Execution-On-5G-Smartphones.pdf

Assessment: The authors of this paper demonstrate how they can successfully compromise a 5G modem, commonly known as baseband, which oversees modulating the signal and implementing the radio protocols. A 5G (NR) modem is processing untrusted data from a radio network and is a target for a remote attacker who can force the modem to execute a full remote code. The authors demonstrate the code execution on a 5G NR radio by exploiting the vulnerabilities in the SIP protocol. This work is very relevant to OUSD Operate Through.

Abstract: In recent years we have seen the widespread adoption of 5G Cellular Networks, for consumer devices, IoT, and critical infrastructure. The estimate of the number of devices connected to a 5G network varies, but statistics show that vast numbers are present in the market. To join a 5G network, these devices must be equipped with a 5G modem that modulates the signal and implements the radio protocols; this component is also commonly referred to as baseband. It is of enormous importance to secure these components, since they process untrusted data from a radio network, making them particularly attractive for a remote attacker. In the authors' previous work, they examined the security modem for previous generation networks (such as 2G, 3G, and 4G) and achieved full remote code execution over the air. In this paper they explore what changed on 5G networks, what improved in terms of security, and what did not. They demonstrate that it is still possible to fully compromise, over the air, a 5G modem and gain remote code execution on a new 5G smartphone.

Towards secure intra-vehicle communications in 5G advanced and beyond: Vulnerabilities, attacks and countermeasures

14 November2022

https://www.sciencedirect.com/science/article/abs/pii/S221420962200095X

Assessment: Intra-vehicle communication is fundamental for the success of Vehicle-To-Vehicle, Vehicle-to-Infrastructure, V2X, and V2P communications. This article presents a comprehensive survey of architecture, performance, and security challenges that are necessary to understand when designing resilient intra-vehicle communication systems. This article is relevant to OUSD Operate Through.

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

Abstract: The Intelligent Connected Vehicle (ICV), the product of the deep integration of automobile, electronics, information, and artificial intelligence in the era of 5G advanced and beyond, has become the main pursuit of the automotive industry. To improve ICV security, traditional methods such as in-vehicle gateway firewall, encryption, and authentication are potential choices to protect the communications between vehicles and the outside world. Traditional methods, however, cannot be directly applied to ICV due to the extremely limited computing and storage resources of intra-vehicle communications and the high real-time requirements of the packets transmitted in the vehicle. Therefore, there is an urgent need for lightweight and real-time solutions for intra-vehicle communication security. In addition, no matter where an attack is launched, the attacker must control the corresponding Electronic Control Unit (ECU) through intra-vehicle communication to control the ICV's behavior. Therefore, intra-vehicle communications can be regarded as the last line of defense for ICV security. The authors conducted a comprehensive and new technical investigation about the security issues of intra-vehicle communications based on new work on vulnerabilities, attacks, and countermeasures. They also investigated the activities and contributions of standardization organizations and highlighted the new challenges for intra-vehicle communication security. Finally, they presented some discussions on next-generation intra-vehicle communication technologies and new solutions.

5G Managed Security Survey

15 November 2022

https://onestore.nokia.com/asset/212741?_ga=2.218954462.611512529.1668533812-1895305122.1668533812

Assessment: While not specific to the Operate Through scenario, this report is one of the first to provide specific insights into vulnerabilities of operational 5G networks and a global cross-section of their associated operators. Because many victims are reluctant to reveal they were the subject of cyber-attacks, it is not surprising that there are far more attacks occurring than are reflected in open-source literature.

Abstract: Nokia commissioned GlobalData to conduct research into the current and future 5G security landscape and the managed security services market. Surveys were conducted of 50 communications service providers spread equally among Asia-Pacific, Latin America, North America, Europe, and the Middle East/North Africa. Among the key findings were that most respondents suffered at least one breach in the last year, and a third reported eight or more breaches in a single category. Further, 74% of the respondents reported at least one attack that resulted in service unavailability to at least 5% of their customer base, with 40% of respondents suffering at least four such attacks. Finally, 56% indicated they needed to substantially improve their capabilities against telecom-specific attacks, such as illegal call redirection, interception, messaging attacks, etc.

Open RAN – Not Solving the "5G China Challenge"

15 November 2022

https://chinaobservers.eu/open-ran-not-solving-the-5g-china-challenge/

Assessment: Open Radio Access Network (RAN) alliance is an operator-led alliance that supports splitting of RAN functionality from a centralized entity entirely running inside a base station into multiple entities such as Control Units (CU), Data Units (DU), and Radio Units (RU). Third Generation Partnership Project (3GPP) standards have been extended to allow such a split, and as a result, RAN now has become cloud-based, software-defined networking (SDN) controlled, software-based, and, hence, much more diversified. But this diversification does not reduce the security risks. The article raises an important point that Open RAN can be a security risk because a significantly large number of its developers and members are China-based entities.

Abstract: The high market share of Chinese technology giant Huawei in 5G infrastructure has made observers hope that a technological disaggregation of 5G's RAN could solve geopolitical challenges

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

posed by China. While technologically promising, this approach, known as Open RAN, neither reduces reliance on China nor necessarily offers a higher degree of network security.

Securing the 5G Network on AWS with Palo Alto Networks

26 November 2022

https://aws.amazon.com/blogs/apn/securing-the-5g-network-on-aws-with-palo-alto-networks/

Assessment: This is an excellent article that discusses how Palo Alto's 5G security solutions protect AWS cloud-hosted 5G networks via Zero Trust.

Abstract: When building 5G networks on Amazon Web Services (AWS), Zero Trust security design principles must be applied throughout the architecture when building 5G networks on AWS, on top of the infrastructure layer security AWS already provides. The core principle of this is "never trust, always verify, and verify continuously" for building complete solutions for 5G networks. In this article, the authors discuss how to implement a 5G end-to-end security model based on Zero Trust using Palo Alto Networks' 5G-native security solution for highly distributed and cloud-native 5G networks, with containerized 5G security and real-time threat correlation among 5G users, device identifiers, and a 5G network slice.

Security Threats to Voice Services in 5G Standalone Networks

4 September 2022

https://www.hindawi.com/journals/scn/2022/7395128/

Assessment: This paper presents security vulnerabilities that arise in 5G cellular systems when a 5G New Radio (NR) voice call is routed over Evolved Packet Core (EPS), i.e., 4G systems, due to lack of 5G NR resources end-to-end, which happens frequently in today's networks. The authors identified a few vulnerabilities in EPS protocols that can lead to DoS and other attacks when 5G NR calls are carried over 4G networks.

Abstract: With the rapid development of 5G Standalone (SA) networks, subscribers are increasingly motivated to make calls through 5G. To support voice services critical to mobile users, 5G SA networks adopt two solutions: VoNR (Voice Over New Radio) and EPS (Evolved Packet System) fallback. At this stage, 5G SA networks provide voice services through EPS fallback, which leverages 4G networks to support voice calls for 5G users. This switch between cellular network systems may expose vulnerabilities to adversaries. However, there is a lack of security research on voice services in the 5G SA network. In this paper, the authors analyze the security of EPS fallback and its closely related IP Multimedia Subsystem (IMS) from the perspective of the protocol and the practices of the carriers. The authors uncovered two protocol design vulnerabilities and two implementation flaws and exploited them to design three attacks: voice DoS, voice monitoring, and SMS spoofing and interception. The authors validated these vulnerabilities and attacks using software-defined radio (SDR) tools and a set of open-source software in three mobile carriers. Their analysis revealed that the problems stem from both specifications and carrier networks. Finally, they proposed several potential countermeasures to defend against these attacks.

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

Active Foreign Commercial 5G Standalone Networks

Lists foreign network operators that claim to have launched 5G SA commercial mobile services as of 30 November 2022.[a]

Table 2. Foreign 5GSA Commercial Networks

Country	Operator	5G SA Launch	Remarks
Australia	Telstra[1] Optus[2] TPG Telecom[3]	May 2020 November 2021 November 2021	Telstra claimed to be the first Australian provider to enable 5G SA services to its customers. Telstra's spectrum operates in Low (700-900 MHz), Mid (1800-3600 MHz), and High (26-28 GHz) bands.[4] Optus is providing 5G SA services in the 3500 MHz, 2300 MHz, and 2100 MHz spectrum bands; TPG's standalone core network runs on TPG's 700 MHz spectrum holdings. Note that TPG now incorporates Vodafone Australia.[5]
Bahrain	STC Bahrain	May 2022	STC Bahrain launched the country's first 5G SA network using Huawei equipment. The network supports enhanced mobile broadband (eMBB), ultra-reliable low latency communications (URLLC) and Massive Machine-Type Communications (mMTC) services.[6]
Brazil	TIM Brasil Claro Brasil Vivo	July 2022 July 2022 July 2022	All three of Brazil's wireless providers activated 5G SA commercial services in July 2022 in the capital of Brasilia in the 3500 MHz band (TIM soft-launched its 5G SA services in April to select users).[7,8] 5G services in the 26 GHz band, primarily aimed at hotspot coverage for industrial applications or point to point solutions, are also planned.[9]
Canada	Rogers Communications[10]	March 2022	Rogers' 5G SA network is Canada's first. The company's 5G services operate in the 600, 1700, and 2500 MHz bands.[11] The company expanded its spectrum to the 3500 MHz band in June 2022.[12]
China	China Mobile[13] China Telecom China Unicom	November 2020[14] November 2020[15] November 2020	As of early 2021, these three operators had deployed over 700,000 5G SA base stations; China Mobile commissioned 5G SA services in all prefectures and cities across China; and China Telecom and China Unicom jointly built the world's largest shared 5G SA network covering 300 cities.
Finland	Telia Company[16]	November 2021	Telia was the first commercially available 5G SA network in the Nordic and Baltic regions. The company offers 5G services in the 700 and 3500 MHz and has also acquired spectrum in the 26 GHz band. The company is working on rolling out 5G services to all of its markets across the Nordic and Baltic countries.[17]
Germany	Deutsche Telekom[18] Vodafone[19]	April 2022 March 2022	As of early 2022, Deutsche Telekom's network had 5,000 antennas operating in the 3600 MHz spectrum, providing coverage to over 200 urban centers and cities. Vodafone had over 4,000 antennas supporting 5G SA services, operating in the 3600, 1800, and 700 MHz spectra and is projected to reach nationwide coverage by 2025.
Italy	Linkem[20]	October 2021	Linkem's 5G SA network is Italy's first and operates in the 3500 MHz band.
Japan	SoftBank Corp.[21] NTT Docomo[22]	October 2021 August 2022	Supporting SoftBank Air Terminals, SoftBank provides coverage in the 3.9-4.0 GHz and 29.1-29.5 GHz ranges.[23] NTT Docomo launched the world's first commercial 5G SA network allowing smartphones to simultaneously utilize both mid-band (sub-6 GHz) and mmWave frequencies, providing 5G NR Dual Connectivity (NR-DC) to users.
Kuwait	STC Kuwait[24]	May 2021	STC's 5G services were launched in the 3500 Mhz band and the company expanded its services into the 2100 MHz band, as well.[25]

[a] This list does not include commercial 5GSA fixed wireless or private networks, or operators engaged in testing or trials.

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

Country	Operator	5G SA Launch	Remarks
Philippines	Smart Communications[26]	October 2021	Smart launched the first 5G SA network in the Philippines in Makati City. Based on available information, the company's 5G services appear to mainly be in the 700 and 3500 MHz bands, although 5G carrier aggregation tests have also been carried out using the 2600 and 3500 MHz bands.[27]
Saudi Arabia	Zain KSA[28] STC Saudi Arabia[29,30]	February 2022 August 2021	At launch, Zain's network comprised 5,000 towers and covered 51 cities. The provider operates 5G in the 2600 and 3500 MHz bands.[31] STC's 5GC supports both 5GNSA and 5G SA services.
Singapore	M1 Limited[32] StarHub Mobile[33] Singtel[34]	July 2021 July 2021 September 2021	M1 and StarHub Mobile engaged in a joint venture to build their 5G SA network; both the M1/StarHub and the Singtel networks were commissioned in the 3500 MHz spectrum.
South Africa	Rain[35]	July 2020	South Africa's Rain launched the first 5G SA network in Africa in partnership with Huawei. Rain secured bandwidth in the 700 MHz and 2600 MHz bands,[36] although it applied for spectrum in the 800 and 3500 MHz bands, as well.[37]
South Korea	KT[38]	July 2021	KT is the first provider in South Korea to launch 5G SA services. In 2018, KT secured 5G spectrum in the 3500-3600 MHz and 26.5-27.3 GHz bands.[39]
Spain	Vodafone[40]	December 2021	Vodafone's initial 5G SA commercial rollout in Spain was for the businesses in the Almeria Science and Technology Park.
Taiwan	Taiwan Mobile Co.[41]	October 2021	Taiwan Mobile 5G services operate in the 700 MHz and 700 MHz + 3500 MHz/28 GHz (low+high) bands. The company also operates 4G/5G EUTRA-NR EN-DC in the 700 MHz, 1800 MHz, 2100 MHz, 3500 MHz, and 28 GHz bands.[42]
Thailand	AIS[43]	July 2020	AIS launched 5G SA services in July 2020,[44] and by August 5G SA had reportedly extended services to all 77 provinces in the country.[45] AIS 5G operates in the 700 MHz, 2600 MHz, and 26 GHz bands.[46]

Literature Review of Other Pertinent 5G-Related Items of Interest

Huawei and AICTO Hosted the 1st Africa 5G Summit

1 November 2022

https://www.huawei.com/en/news/2022/11/africa-5g-summit

Assessment: Having been largely shut out of most Western telecommunications markets over vulnerabilities in its equipment enabling Chinese government surveillance activities, Huawei has turned its attention to expanding its interests in Africa. Twelve countries in Africa have rolled out commercial 5G services thus far,[47] although South Africa is the only one thus far confirmed to have an operational 5G SA network. Proliferation of Huawei 5G equipment across Africa could have potential security implications for U.S. AFRICOM communications.

Abstract: The first Africa 5G Summit was held in Bangkok, Thailand, with the theme of "5G Lighting Up Digital Africa." The summit was hosted by Huawei and supported by the Tunisia based Arab ICT Organization (AICTO), which aims to build a communication platform between Africa and the world's 5G leading markets. ICT industry organizations, government regulators, and carriers were invited to gather in this summit to share experience and exchange viewpoints on key topics, such as "National 5G strategic planning, Carriers' 5G business practices and the strategy of 4G/5G collaborative network evolution," in order to support the steady growth of 5G and acceleration of unleashing the potential of a digital economy.

Benjamin Hou, President of Huawei Northern Africa Carrier Business, delivered the closing speech, in which he said, "as the third wave of global 5G market, Africa will open the 5G era in 2023. Huawei will

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

further increase its investment in Africa to support the steady development of 5G to facilitate digital transformation in the region. In Africa, for Africa, Huawei will continue to deepen cooperation with industry partners to support customers' business success in the 5G era."

Projected Growth of 5G Global Connections

Figure 1 illustrates the projected growth of 5G global connections[b] from 2021 through 2030 based on data from GSMA, divided by Combatant Command.[c]

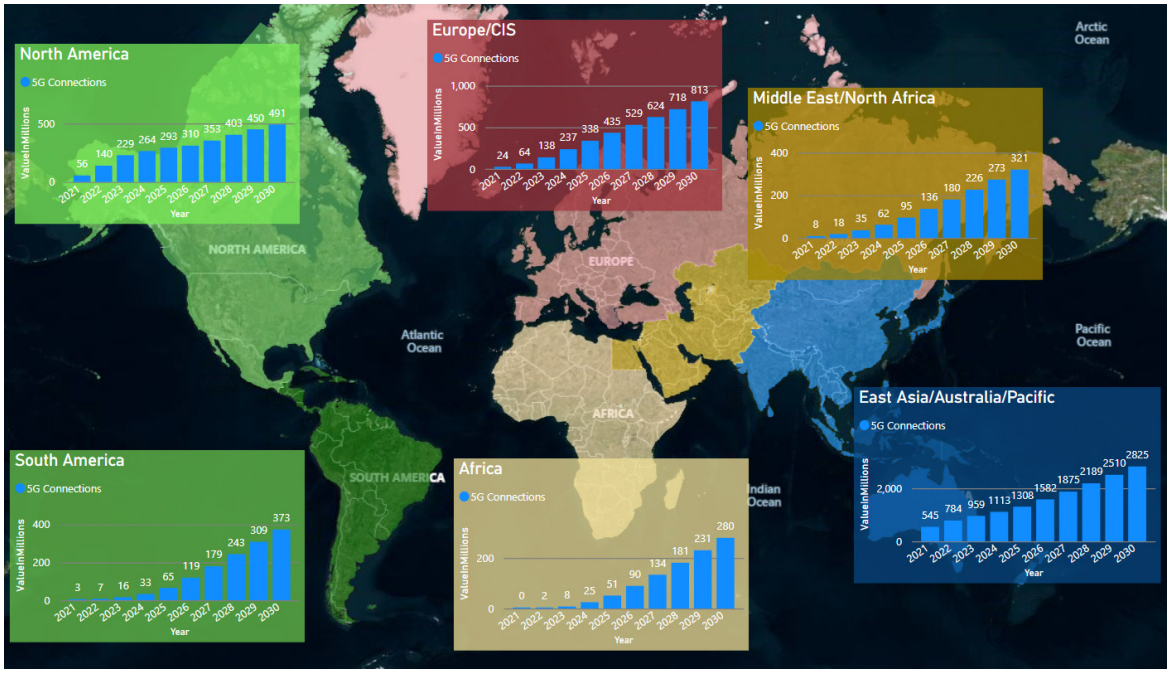

Figure 1: *Growth Projections for Global 5G Connections (GSMA)*

[b] Each connection is defined as being associated with a unique SIM. Note also that the statistics for connections include estimates for devices that use multiple SIMs.

[c] This graphic will be updated periodically to reflect any significant changes in trend projections.

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

Sources

[1] [Telstra | Nikos Katinakis "We're the first to enable standalone 5G in Australia" | https://exchange.telstra.com.au/were-the-first-to-enable-standalone-5g-in-australia/ | 1 May 2020 | Accessed on 16 October 2022 | The source is publicly available information and does not contain classification markings]

[2] [Optus | "Optus switches on Standalone 5G network for limited trial" | https://www.optus.com.au/about/media-centre/media-releases/2021/11/optus-switches-on-standalone-5g-network-for-limited-trial | 30 November 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[3] [CRN | Nico Arboleda | "TPG Telecom launches 5G standalone network" | https://www.crn.com.au/news/tpg-telecom-launches-5g-standalone-network-572694 | 16 November 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[4] [Telstra | "5G and EME" | https://telstra.com.au/consumer-advice/eme/5g-and-eme | Accessed on 16 October 2022 | The source is publicly available information and does not contain classification markings]

[5] [Telecoms.com | Jamie Davies | "Vodafone Australia finally completes merger with TPG" | https://telecoms.com/505494/vodafone-australia-finally-completes-merger-with-tpg/ | 13 July 2020 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[6] [IEEE Communications Society | Alan Weissberger | "STC launches first 5G standalone (SA) core network in Bahrain via Huawei" | https://techblog.comsoc.org/2022/05/23/stc-launches-first-5g-standalone-sa-core-network-in-bahrain/ | Accessed on 8 June 2022 | The source is publicly available information and does not contain classification markings]

[7] [TeleSemana.com | Andrea Catalano | "TIM Brasil implementó su red core 5GSA mientras la casa matriz está en zozobra" | https://www.telesemana.com/blog/2022/04/07/tim-brasil-implemento-su-red-core-5g-sa-mientras-la-casa-matriz-esta-en-zozobra/ | 7 April 2022 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[8] [COMMS Update | "Vivo, TIM, Claro all switch on 5G in Brasilia" | https://www.commsupdate.com/articles/2022/07/07/vivo-tim-claro-all-switch-on-5g-in-brasilia/ | 7 July 2022 | Accessed on 27 July 2022 | The source is publicly available information and does not contain classification markings]

[9] [TeleSemana.com | Andrea Catalano | "TIM Brasil define cómo desplegará sus redes a partir del espectro adquirido de 5G y anticipa parte de su estrategia commercial" | https://www.telesemana.com/blog/2021/12/09/tim-brasil-define-como-desplegara-sus-redes-a-partir-del-espectro-adquirido-de-5g-y-anticipa-parte-de-su-estrategia-comercial/ | 9 December 2021 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[10] [Ericsson | "Ericsson, Rogers launch Canada's first commercial 5G standalone network" | https://www.ericsson.com/en/press-releases/6/2022/3/ericsson-rogers-launch-canadas-first-commercial-5g-standalone-network | 28 March 2022 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[11] [Comms Update | "Rogers doubles 5G cities/towns to 130; launches Dynamic Spectrum Sharing" | https://www.commsupdate.com/articles/2020/10/14/rogers-doubles-5g-citiestowns-to-130-launches-dynamic-spectrum-sharing/ | 14 October 2020 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

[12] [T-Net | "Rogers to Launch Premium 3500 MHz 5G Spectrum in Nanaimo, a First in Canada" | https://www.bctechnology.com/news/2022/6/17/Rogers-to-Launch-Premium-3500-MHz-5G-Spectrum-in-Nanaimo-a-First-in-Canada.cfm | 17 June 2022 | Accessed on 27 July 2022 | The source is publicly available information and does not contain classification markings]

[13] [RCR Wireless News | Juan Pedro Tomás | "Chinese telcos expected to deploy 1 million 5GSA stations in 2021" | https://www.rcrwireless.com/20210205/business/chinese-telcos-expected-deploy-1-million-5g-sa-base-stations-this-year | 5 February 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[14] [China Mobile | "China Mobile Hong Kong Launches Hong Kong's First 5G Standalone Network" | https://eshop.hk.chinamobile.com/en/about_us/media_centre/NewsPDF/20201126pr.html | 30 November 2020 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[15] [IEEE ComSoc Blog | Alan Weissberger | "China Telecom launches 5G standalone cloud native network with Tianyi Cloud" | https://techblog.comsoc.org/2020/11/16/china-telecom-progressing-5g-standalone-network/ | 16 November 2020 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[16] [Telia Company | "Telia Company launches 5GSA core network in Finland – the first commercially available 5GSA network in the Nordic and Baltic region" | https://www.teliacompany.com/en/news/press-releases/2021/11/telia-company-launches-5g-sa-core-network-in-finland--the-first-commercially-available-5g-sa-network-in-the-nordic-and-baltic-region/ | 10 November 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[17] [Telia Company | "Telia's 5G network measures data speeds of 4 gigabit per second – almost a world record" | https://www.teliacompany.com/en/news/news-articles/2021/telias-5g-network-measures-data-speeds-of-4-gigabit-per-second--almost-a-world-record/ | 26 April 2021 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[18] [Fierce Wireless | Monica Alleven | "Deutsche Telekom touts 5GSA rollout in Germany" | https://www.fiercewireless.com/5g/deutsche-telekom-touts-5g-sa-rollout-germany | 5 April 2022 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[19] [RCR Wireless News | Juan Pedro Tomás | "Vodafone's 5GSA network already reaches 10 million people in Germany" | https://www.rcrwireless.com/20220315/carriers/vodafone-5g-sa-network-already-reaches-10-million-people-germany | 15 March 2022 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[20] [Comms Update | "FWA operator Linkem launches Italy's first 5GSA network" | https://www.commsupdate.com/articles/2021/10/01/fwa-operator-linkem-launches-italys-first-5g-sa-network/ | 1 October 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[21] [SoftBank | "SoftBank Corp. First Carrier in Japan to Provide 5G Standalone Commercial Services" | https://www.softbank.jp/en/corp/news/press/sbkk/2021/20211019_01/ | 19 October 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[22] [Qualcomm | "Qualcomm and NTT DOCOMO Unleash Next Generation 5G Speeds and Coverage Through World's First High-Speed 5G Standalone Service" | https://www.qualcomm.com/news/releases/2022/09/qualcomm-and-ntt-docomo-unleash-next-generation-5g-speeds-and-co | 7 September 2022 | Accessed on 16 October 2022 | The source is publicly available information and does not contain classification markings]

[23] [Comms Update | "SoftBank adds mmWave to 5G services" | https://www.commsupdate.com/articles/2021/03/22/softbank-adds-mmwave-to-5g-services/ | 22 March 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[24] [Developing Telecoms | Shailaja Pai | "STC Kuwait rolls out commercial 5G standalone infrastructure" | https://developingtelecoms.com/telecom-technology/wireless-networks/11104-stc-kuwait-rolls-out-commercial-5g-standalone-infrastructure.html | 10 May 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[25] [Comms Update | "STC Kuwait launches commercial 5G standalone infrastructure; boosts 2100MHz 5G coverage" | https://www.commsupdate.com/articles/2021/05/07/stc-kuwait-launches-commercial-5g-standalone-infrastructure-boosts-2100mhz-5g-coverage/ | 7 May 2021 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[26] [Developing Telecoms | Shailaja Pai | "Smart fires up first 5GSA network in Makati, Philippines" | https://developingtelecoms.com/telecom-business/operator-news/12024-smart-fires-up-first-5g-sa-network-in-makati-philippines.html | 5 October 2021 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[27] [Smart | "Smart gears up for leading high performance 5G Capacity and Coverage Features" | https://smart.com.ph/About/newsroom/press-releases/2020/12/23/smart-gears-up-for-leading-high-performance-5g-capacity-and-coverage-features | 23 December 2020 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[28] [Developing Telecoms | Shailaja Pai | "Zain launches Saudi Arabia's first 5G standalone network" | https://developingtelecoms.com/telecom-business/operator-news/12805-zain-launches-saudi-arabia-s-first-5g-standalone-network.html | 3 February 2022 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[29] [IEEE Communications Society | Alan Weissberger | "STC launches first 5G standalone (SA) core network in Bahrain via Huawei" | https://techblog.comsoc.org/2022/05/23/stc-launches-first-5g-standalone-sa-core-network-in-bahrain/ | Accessed on 8 June 2022 | The source is publicly available information and does not contain classification markings]

[30] [Developing Telecoms | STC and Ericsson Expand 5G Standalone in Saudi Arabia | https://developingtelecoms.com/telecom-technology/wireless-networks/11681-stc-and-ericsson-expand-5g-standalone-in-saudi-arabia.html | 11 August 2021 | Accessed on 8 June 2022 | The source is publicly available information and does not contain classification markings]

[31] [Comms Update | "Zain KSA rolls out 5G services" | https://www.commsupdate.com/articles/2019/06/27/zain-ksa-rolls-out-5g-services/ | 27 June 2019 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[32] [RCR Wireless News | Juan Pedro Tomás | "M1 launches 5G Standalone network in Singapore" | https://www.rcrwireless.com/20210728/business/m1-launches-5g-standalone-network-singapore | 28 July 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[33] [RCR Wireless News | Juan Pedro Tomás | "M1 launches 5G Standalone network in Singapore" | https://www.rcrwireless.com/20210728/business/m1-launches-5g-standalone-network-singapore | 28 July 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[34][Ericsson | "Singtel enters 5G standalone era powered by Ericsson" | https://www.ericsson.com/en/press-releases/2/2021/9/singtel-enters-5g-standalone-era-powered-by-ericsson | 22 September 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[35] [RCR Wireless News | Juan Pedro Tomás | "Rain launches standalone 5G network in South Africa" | https://www.rcrwireless.com/20200720/business/rain-launches-standalone-5g-network-south-africa | 20 July 2020 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[36] [Mobile World Live | Anne Morris | "South Africa completes first phase of delayed auction" | https://www.mobileworldlive.com/featured-content/top-three/south-africa-completes-first-phase-of-delayed-auction | 9 March 2022 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[37] [Rain | "Application Form for 700MHz, 800MHz, 2.6GHz and 3.5GHz Spectrum Award Process" | https://www.icasa.org.za/uploads/files/IMT-ITA-Application-15-01-2021-Final-Draft-Part-1.pdf | 28 December 2020 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[38] [ZDNet | Cho Mu-Hyun | "KT becomes first South Korean telco to launch 5G standalone service" | https://www.zdnet.com/article/kt-becomes-first-south-korean-telco-to-launch-5g-standalone-service/ | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[39] [Everything RF | "5G Frequency Spectrum in South Korea" | https://www.everythingrf.com/community/5g-frequency-spectrum-in-south-korea | 22 July 2020 Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[40] [5GWorldPro.com | "Vodafone Spain deploys 5G Standalone in Almeria" | https://www.5gworldpro.com/blog/2021/12/10/vodafone-spain-deploys-5g-standalone-in-almeria/ | 10 December 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[41] [Nokia | "Nokia deploys 5G standalone core network for Taiwan Mobile" | https://www.nokia.com/about-us/news/releases/2021/10/22/nokia-deploys-5g-standalone-core-network-for-taiwan-mobile/ | 22 October 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

[42] [Taiwan Mobile | "Taiwan Mobile's 5G Advantage" | https://english.taiwanmobile.com/product/5G_advantage.html | 2022 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[43] [The Fast Mode | Ray Sharma | "Thai Operator AIS, Samsung Launch 5G VoNR over 5GSA network" | https://www.thefastmode.com/services-and-innovations/21155-thai-operator-ais-samsung-launch-5g-vonr-over-5g-sa-network | December 2021 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[44] [AIS | "AIS 5G underlines leadership as first in the world to launch SA Teams up with Samsung to showcase Samsung Galaxy S21 Series 5G AIS 5GSA: most bandwidth for best speeds and lowest latency in Thailand" | https://investor.ais.co.th/news.html/id/2339032/group/newsroom_press | 11 June 2021 | Accessed on 13 April 2022 | The source is publicly available information and does not contain classification markings]

This newsletter is a product of the DoD OUSD 5G Initiative in partnership with Idaho National Laboratory

22-50105_04

[45] [Bangkok Post | "AIS 5G service reaches every province" | https://www.bangkokpost.com/business/1972579/ais-5g-service-reaches-every-province | 22 August 2020 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[46] [RCR Wireless News | Catherine Sbeglia Nin | "AIS launched 5G standalone services in July 2020" | https://www.rcrwireless.com/20210723/5g/ais-and-vivo-conduct-5g-standalone-network-tests-in-thailand | 23 July 2021 | Accessed on 28 April 2022 | The source is publicly available information and does not contain classification markings]

[47] [The Africa Report | Abdul Halim | "Tanzania becomes the latest African country to launch 5G" | https://www.theafricareport.com/241231/tanzania-becomes-the-latest-african-country-to-launch-5g/ | 15 September 2020 | Accessed on 14 November 2022 | The source is publicly available information and does not contain classification markings]