Evolution from LTE to 5G

July 2017 Update

This report is the latest update in a series of studies published by GSA tracking the development of mobile technology markets worldwide. Previous editions of the reports were entitled “Evolution to LTE”. However, in recognition of the fact that many operators are now deploying enhancements to their LTE networks and working towards the future deployment of 5G networks, we have adjusted the title to reflect their new focus. We will of course continue to track LTE deployments in markets where that has yet to occur.

We summarize network trials, deployments, and the availability of services across a variety of technology innovations and spectrum bands. GSA welcomes additions to the database of information being maintained by GSA. The database also contains information about spectrum bands and bandwidth used, where available. If you have additional information please contact info@gsacom.com

We make no guarantees that the information is complete, but reasonable efforts have been made to be comprehensive and accurate. The next update of this report will be in October 2017.
Introduction

LTE is a global success, connecting over 1 in 4 mobile users worldwide and is the fastest developing mobile system technology ever. LTE is specified by 3GPP as a single global standard for paired and unpaired spectrum users. The vast majority of the standard is the same for FDD and TDD.

GSA's Evolution from LTE to 5G reports provides an independent in-depth status view and analysis of the global 4G/LTE, LTE-Advanced, LTE-Advanced Pro and 5G markets, supported by facts, and confirms the trends. Information is obtained, analysed and verified by GSA. This report is quarterly and referenced by industry across the whole ecosystem.

Key market facts

By the end of June 2017 GSA reports there were:

• **782** operators investing in LTE in 200 countries

• **601** commercially launched LTE or LTE-Advanced networks in **192** countries, including **98** LTE-TDD (TD-LTE) launched in **56** countries

• **109** commercial VoLTE networks in **57** countries, and **170** operators investing in VoLTE in **75** countries

• **197** launched networks are LTE-Advanced, in **96** countries

• GSA forecasts c. **652** commercially launched LTE networks by end-2017

• **6** NB-IoT and **2** LTE-M/Cat-M1 networks are commercially launched, with **55** NB-IoT and **16** LTE-M/Cat-M1 networks planned or being trialled

• **22** operators, at least, have now made public commitments to deployment of pre-standards '5G' or standards-based 5G networks in **16** countries.

LTE deployments

The drive towards LTE, LTE-Advanced, LTE-Advanced Pro and increasingly 5G for operators is more capacity, enhanced performance and improved efficiencies to lower delivery cost. Compared with 3G, LTE offers a big step in the user experience, enhancing demanding apps such as interactive TV, video blogging, advanced gaming, and professional services.

782 operators investing in LTE in 200 countries

Deployment of LTE-Advanced technologies – and particularly carrier aggregation – takes performance to a new level, and is a major current focus of the industry. Interest in LTE-Advanced Pro is high too, bringing with it new, globally standardised LPWA solutions: LTE Cat-M1 (LTE-M, eMTC) and Cat-NB1 (NB-IoT) with new business opportunities. And whilst LTE-Advanced and LTE-Advanced Pro solutions have yet to be deployed by many operators, vendors and network operators are already looking towards 5G, and its potential to meet future capacity, connectivity and service requirements.

LTE is a full IP network and harmonizes with other radio access technologies and is the natural evolution choice for GSM/HSPA, CDMA and WiMAX operators, enabling a single unifying global standard supporting TDD & FDD modes.
Spectrum for LTE deployments

Pressure for spectrum is high and operators should deploy the most efficient technologies using paired spectrum where available. LTE can be deployed in existing 2G or 3G bands and/or new bands e.g. 2.6 GHz or digital dividend spectrum (700/800 MHz) for more geographical coverage and improved in-building performance. 2.6 GHz is the capacity band in most regions. 1800 MHz (band 3) is the mainstream choice for LTE in the majority of regions. 700 MHz (bands 12, 13, 14 and 17) and 800 MHz (band 20 and regional variations) are firmly established as the main LTE bands for extended coverage and deepest building penetration.

280 operators have launched LTE1800 systems in 119 countries

Adoption of the APT700 MHz band plan for LTE network deployments in markets across the APAC and Latin America regions and in Europe represents a major opportunity for near-global spectrum harmonization, paving the way for ensuring the greatest economies of scale for devices and capacity for mobile broadband services, and for roaming. The FDD plan configuration (band 28) has attracted unanimous support. Meanwhile the global success of mobile broadband enabled by LTE has led to additional frequency bands being allocated and standardised. In some regions 450 MHz spectrum is attracting interest for rural coverage and M2M service applications. LTE450 is launched in several markets.

Evolutions of LTE standards now completed enable the possibility to extend the benefits of LTE-Advanced to unlicensed spectrum. There are several options for deploying LTE in unlicensed spectrum. The GSA report “LTE in Unlicensed Spectrum” gives details of market progress in the use of LAA and eLAA, LTE-U, LWA and LWIP, and also discusses other approaches such as MulteFire and CBRS. Momentum is building behind LAA, and LTE-U has been launched in the USA.

LTE technology evolution

LTE radio network products incorporate several features to simplify building and management of next-generation networks. Plug-and-play, self-configuration and self-optimization simplify and reduce network roll-out and management cost. LTE is being deployed alongside simplified, IP-based core and transport networks that are easier to build, maintain and introduce services on. The 3GPP core network has also undergone System Architecture Evolution, optimized for packet mode and the IP-Multimedia Subsystem (IMS) to support all access technologies, including fixed access. This allows:

- Improvements in latency, capacity, and throughput
- Simplification of the core network, and optimization for IP traffic, services, and growth
- Simplified support and handover to non-3GPP access technologies

The resulting evolved packet system comprises the core network, evolved packet core (EPC) and radio network. The whole system is often called LTE.

Deployment of LTE-Advanced is the key trend globally. Carrier aggregation was the first feature to be commercialized, facilitating higher data throughput rates in both directions, more efficient use of spectrum assets for network operators, and an enhanced user experience of mobile broadband.
LTE-Advanced Pro (Release 13 and later) features enable the era of Gigabit LTE for enhanced mobile broadband service (though devices meeting UE Cat-16 are still some way from commercialisation). It also opens new markets: importantly it delivers new globally standardised solutions LTE-M/Cat-M1 and NB-IoT/Cat-NB1 for the vast IoT Low Power Wide Area (LPWA) market. These narrowband solutions complement existing LTE Cat-1 IoT technology. LTE-Advanced Pro also meets the needs of the mission and business critical push-to-talk sectors e.g. emergency services, public safety and railway communications.

Most LTE-Advanced systems today support Category-6 (300 Mbit/s downlink) user devices. The ecosystems of networks and devices for Category-9 (450 Mbit/s) and higher are rapidly developing and 256QAM, high-order MIMO, more carrier aggregation and LTE-Advanced Pro features are supporting this move. The introduction of HD voice services for LTE users enabled by VoLTE is entering the mainstream. The market for ViLTE (video over LTE) is developing. Commercialization of LTE Broadcast, enabled by eMBMS technology, is set to develop further in 2017.

**LTE global status**

Previous versions of this report have provided a full list of LTE deployments. This is still available as a separate document. This report summarizes the overall status of the market and covers recent developments.

The start of 2017 saw the continued introduction of LTE to new markets and regions around the world. Although already widely deployed, it is still being introduced and several countries announced LTE services. By early July 2017 there were 601 LTE networks in service worldwide.

2017 has seen LTE/4G services introduced by operators in 21 regions/countries including Afghanistan, Antarctica, Barbados, Bermuda, Botswana, Congo, Cook Islands, Guyana,
Libya, Madagascar, Nepal, Northern Mariana Islands, Myanmar, Pakistan, Samoa, Somalia, South Africa, Sudan, Tahiti, Trinidad & Tobago and Vietnam. Future launches can be expected too. By the end of 2017 GSA forecasts 652 LTE networks will be in service. In the last quarter spectrum awards for additional services, trials or deployment plans have come to light in several countries including Afghanistan, Bangladesh, Kenya, Nepal, Nigeria, and Pakistan. In total, 782 operators worldwide have either announced trials of, or made commitments to deploy, or have deployed LTE; and a further 27 have been involved in pre-commitment trials.

A significant trend is the discontinuation of 2G networks, which are being switched off so that spectrum can be re-farmed for LTE services.

**VoLTE global status**

170 operators are investing in VoLTE in 75 countries including 109 operators with commercially launched VoLTE-HD voice service in 57 countries.

Operators introducing VoLTE services in the second quarter of 2017 were Sunrise (Switzerland), TeliaSonera (Sweden), 3 (Sweden), and U Mobile (Malaysia). Deployments, trials and plans for launch were announced by Jazz (Pakistan), Smart (Philippines) and Digi Mobile (Romania).

VoLTE and ViLTE roaming services were launched in April 2017 by CSL in Hong Kong and CTM in Macau.

**LTE TDD (TD-LTE) global status**

LTE is an open standard developed by 3GPP. The advanced technological performance of LTE came with in-built flexibility to operate in either paired (FDD, or Frequency Division Duplexing, mode) or unpaired (TDD, or Time Division Duplexing mode) spectrum and various channel bandwidths – all with a single technology. Companies from around the globe contributed to the LTE standard and its evolution.
The emphasis was always to leverage synergies between the two duplex modes to the largest extent possible. This allows operators to best utilize their current network assets, spectrum allocations and various bandwidth needs, while securing support, choice and economies of scale from the global vendor ecosystem, and limit potential market fragmentation.

The result is major commonality of the LTE specifications for the FDD and TDD modes - in fact the vast majority of the LTE standard is identical for both modes - and the huge global success of LTE.

**Figure 3: Number of commercial networks using TDD bands 38-43**

![Pie chart showing distribution of TDD bands](image)

Most LTE deployments use paired spectrum (FDD). The LTE TDD mode is complementary and the perfect choice for providing high-speed mobile broadband access in unpaired spectrum. Many operators have deployed both FDD and TDD modes in their networks. LTE TDD also provides a future-proof evolutionary path for TD-SCDMA, another 3GPP standard. LTE TDD is an integral part of the 3GPP standard, implementing a maximum of commonalities with LTE FDD and offering comparable performance and similar high spectral efficiency.

**98 LTE-TDD (TD-LTE) systems are commercially launched in 56 countries.**

Launch was announced in the last quarter for Vodafone Spain. 32 operators have deployed converged FDD & TDD networks. Usage of the technology will continue to grow. APT Taiwan and DTAC Thailand have revealed plans to deploy TDD systems, and TDD spectrum is being used for testing future technology - for instance Vodafone and Sri Lanka Telecom revealed trials of 5G technologies (Massive MIMO and carrier aggregation respectively) using TDD bands in the last quarter.

Figure 3 shows the different spectrum bands in use in the 98 commercially launched networks. Band 40 is the most popular TDD band. Eight networks are using multiple TDD bands.

**LTE-Advanced global status**

As of 31 March 2017, there were 197 commercially launched LTE-Advanced networks in 96 countries. Recent launches of LTE-Advanced networks are those by Rain (a fixed wireless network operator in South Africa), Dialog Axiata (Sri Lanka), and Kcell (Kazakhstan). MPT (Myanmar) launched a 150 Mbit/s-capable network using 4x4 MIMO, but without features making it LTE-Advanced.

Expansions of existing LTE-Advanced networks have been announced by at least eight operators in the last quarter. Many operators are increasing the speeds of their LTE-Advanced networks using different carrier aggregation combinations, and are extending the coverage of LTE-Advanced to more cities. Among the most interesting developments are:

- Bell Canada's peak speed of 750 Mbit/s using four-channel CA and 256QAM modulation; it says average real-world speeds are expected to be 22-174 Mbit/s.
• Claro Brazil’s Brasilia network that it says can achieve an average speed of 250 Mbit/s using 4x4 MIMO, 256QAM, and carrier aggregation in 700 MHz spectrum.

• EE (UK), which claims speeds of 429 Mbit/s in its network. It is rolling out more sites across the UK during 2017. EE is using 30 MHz of 1800 MHz spectrum and 35 MHz of 2.6 GHz spectrum, with 4X4 MIMO and 256QAM.

• Spark in New Zealand has introduced LTE-Advanced to Queenstown and plans to roll-out to 10 more towns by summer 2018.

• Vodafone Spain has launched a commercial LTE-Advanced network in Madrid and Salamanca and claims download speeds of 700 Mbit/s. It plans to expand the network to Barcelona, Valencia, Malaga, Seville, Bilbao, Zaragoza and La Coruña. Its network uses 256QAM, 4x4 MIMO and carrier aggregation of at least 3 bands (from its 800/1800/2100 and 2600 MHz spectrum holdings).

New or expanded LTE-Advanced trials and plans have been announced by Telenor Bulgaria, A1 Slovenija, Vodacom South Africa, Vivacell Armenia and NBN (for fixed wireless services in Australia).

Some LTE-Advanced networks make use of features that are marketed as LTE-Advanced Pro, for instance, those making use of carrier aggregation of large numbers of channels, or carriers across TDD and FDD modes, LAA, massive MIMO, Mission-Critical Push-to-Talk, LTE Cat-NB1/NB-IoT or LTE-M/Cat-M1. Some networks are also promoted as “Gigabit LTE” if they make use of multiple LTE-Advanced networks to deliver very high downlink throughput.

Rather than reporting progress of LTE-Advanced Pro as a whole, we will track trials and deployments of specific features of 3GPP Releases 13 and 14. The GSA report “LTE in Unlicensed Spectrum” tracks progress of LAA/eLAA: by the end of June 2017, there were 15 operators in 12 countries trialling or deploying LAA. The number of NB-IoT and LTE-M networks are reported elsewhere in this document.

We also track reported fastest downlink speeds in commercially launched LTE-Advanced networks. There is a wide variation, as shown in Figure 4 on page 8.

197 commercial LTE-Advanced networks in 96 countries

This is unsurprising, as operators around the world have different amounts of spectrum (numbers of carriers and bandwidth of those carriers) that they can aggregate to increase maximum throughput. They also vary in terms of their deployment of additional features such as use of 256QAM modulation and 4x4 MIMO. Note also that some operators report theoretical downlink speeds; other report live-network tested speeds.

Carrier aggregation has been the dominant feature of LTE-Advanced networks. Varying numbers of carriers, and varying amounts of total bandwidth have been aggregated in trials and demos, but in commercial networks, the greatest number of carriers aggregated (where we have data) is five. Some trials and demos have aggregated up to 10 carriers.
Among commercial LTE-Advanced networks using CA for which we have data, the average amount of bandwidth aggregated is 40 MHz but some commercial networks are aggregating 60 MHz of bandwidth, for instance in Estonia, Sweden, Switzerland and the USA.

**LTE 1800 global status**

LTE network deployment in the 1800 MHz (band 3) is mainstream. The 1800 MHz band is now widely available throughout Europe, APAC, MEA, and regions of South America – and has emerged as a core band for LTE deployments.

**280 operators have commercially launched LTE1800**

There are systems in 119 countries/territories either as a single band or as part of a multi-band deployment. In the last quarter launches have been announced by several operators in Myanmar (MPT, Ooredoo and Telenor), as well as an operator in Nepal (NCell).

1800 MHz is the most widely used and prime band for LTE

Deployed globally, in 47% of LTE networks, and has greatly assisting international roaming for mobile broadband services. More LTE1800 deployments are in progress. 1800 MHz mobile licences have been awarded to 350+ operators in nearly 150 countries.

Recent licensing activities include the award of 1800 MHz spectrum to three Saudi Arabian operators (Mobily, STC, and Zain), and to Jazz in Pakistan. Meanwhile, Ukraine is preparing a tender for licences to operate in band 3, and both Costa Rica and India are looking again at selling portions of band 3 that remained unsold after previous auctions.

**APT700 global status**

Industry support for the APT700 band plan is strong. Whereas APT700 provides both FDD and TDD arrangements, it is the FDD plan that has gained global support from industry.
and regulators in markets addressing nearly 4 billion people. The FDD configuration is standardised by 3GPP (band 28) for a 2 x 45 MHz arrangement, with 10 MHz guard band between downlink and uplink. The APT700 FDD band plan (3GPP Band 28) uses 703-748 MHz for the uplink with 10 MHz guard band and 758-803 MHz for the downlink.

700 MHz is excellent for wide area coverage in regional and rural environments, and for in-building coverage, and is an important digital dividend arising from the shift by TV broadcasters to digital transmissions. Adoption of the APT700 FDD band plan by many countries has created a major opportunity for near global spectrum harmonization for LTE, ensuring the greatest economies of scale for user devices, capacity for mobile broadband, and roaming.

Over 50 countries and territories have allocated, committed to, or recommend APT700 FDD (band 28) for LTE system deployments:

- **LAC region**: Argentina, Brazil, Chile, Colombia, Costa Rica, Curaçao, Dominican Republic, Ecuador, Honduras, Mexico, Panama, Peru, Suriname, Venezuela
- **APAC/Oceania**: Afghanistan, Australia, Bangladesh, Bhutan, Brunei, Cambodia, Fiji, India, Indonesia, Japan, Laos, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Papua New Guinea, Philippines, Singapore, South Korea, St. Maarten, Taiwan, Thailand, Tokelau, Tonga, Vanuatu, Vietnam
- **MEA**: UAE confirmed adoption of the APT700 lower 2 x 30 MHz duplexer. This is also the preferred frequency arrangement for 700 MHz allocations in Europe and throughout ITU Region 1.
- **Africa**: Zimbabwe
- **Europe**: Compatibility with the APT700 band in Europe will be high. In December 2016 the EU adopted a Decision that Member states must reassign the 700 MHz

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band (694-790 MHz) to wireless broadband services under harmonised technical conditions by 30 June 2020 (if any are unable to do so they may decide, for duly justified reasons, to delay availability of the band by up to 2 years). Member states must also adopt and make public a national plan by 30 June 2018, describing how each will implement the decision. Licensing actions are committed, completed, underway or planned in many countries including Austria, Denmark, Finland, France, Germany, Iceland, Romania, Slovenia, and the UK.

APT700 Band 28 is already licensed to mobile operators in many countries, including: Argentina, Australia, Bhutan, Brazil, Chile, Ecuador, Fiji, Finland*, France*, Germany*, Japan, Mexico, Mongolia, New Zealand, Nigeria, Panama, Papua New Guinea, Peru, Panama, Philippines, Singapore, South Korea, Suriname, Taiwan, Tokelau and Vanuatu. Those marked * have compatibility with the lower duplexer arrangement of APT700 (703-733 / 758-788 MHz).

41 operators have now launched commercial services using APT700 band 28, or services in compatible European bands (CEPT 700). New launches in 2017 include three Finnish operators (DNA, Elisa and Sonera), Bluesky in Samoa, and Digicel and Flow in the British Virgin Islands. New deployments have also been announced in Mexico (where ALTÁN Redes will deploy a wholesale mobile network at 700 MHz for use by other mobile operators and service providers), in Chile, where Telefonica is deploying an NB-IoT network operating at 700 MHz that will be used to connect smart water meters, in China, where Shanghai Oriental Pearl Group is deploying a FDD-LTE network in the 700 MHz band for smart city applications, and in Australia where TPG Telecom is deploying a nationwide network.

Other activities in the last quarter have been the award of 700 MHz spectrum in Iceland, and Saudi Arabia; the Colombian Ministry
continued with its process of consultation with a view to awarding licenses to operate in the 700 MHz band; and PTS Sweden resumed its 700 MHz licence consultation process.

**LTE Broadcast / Multicast (eMBMS) global status**

LTE Broadcast (also called LTE Multicast) enabled by eMBMS technology substantially reduces the bandwidth needed to deliver multimedia content in one-to-many scenarios thus allowing operators to efficiently launch media services over LTE. It offers mobile-network operators a profitable business proposition through service differentiation, new revenue opportunities, and more efficient distribution of live and other digital media. LTE Broadcast enables multiple users to receive the same content simultaneously. LTE broadcast can deliver the same content to multiple users with the capability to support a virtually unlimited number of users simultaneously, thereby maintaining efficient use of spectrum and network investments. LTE Broadcast will open new business models for mobile network operators. Other reports on the GSA website examine the cases for eMBMS.

Numerous network operators have been testing eMBMS. In a select few cases, commercial services have already been launched. Additionally, TV broadcasters and content owners have engaged in LTE Broadcast trials e.g. BBC (UK), IRT (Institut für Rundfunktechnik, research institute of broadcasting companies in Austria, Germany and Switzerland, Bayerischer Rundfunk, and further research partners), TDF (France) and RAI (Italy).

In June, ZTE signed a strategic partnership with Belgian operator Telenet covering 5G and IoT collaboration. LTE Broadcast is among the technology solutions being explored to deliver high capacity in the network.

The use of LTE for public safety services will have been boosted by an agreement in May 2017 by the Asia-Pacific Telecommunity Wireless Group (APT-AWG) to harmonise bands in 700-800 MHz spectrum for public safety applications.

**IoT global status**

The second quarter of 2017 saw momentum continue to build behind cellular IoT networks based on NB-IoT/Cat-NB1 and LTE-M/Cat-M1. Most activity involved NB-IoT/Cat-NB1. Some operators, though, are still undecided on which network technologies will underpin their IoT services. For instance EE in the UK is trialling LTE-M/Cat-M1 in BT’s labs, is planning to deploy NB-IoT/Cat-NB1 in the coming months, and has deployed LoRaWAN networks in Milton Keynes and London.

KDDI in Japan has stated that it will deploy an LPWA network in 2017-18, but has not yet decided between LTE-M/Cat-M1 and NB-IoT/Cat-NB1.

Activity worldwide is indicated in Figure 7. The latest numbers of commercially launched services and trials as of end-June 2017 is

- **6 commercial NB-IoT networks** (Telus Canada, T-Mobile Netherlands (nationwide since May 2017), Telia Norway, Vodafone Spain, Deutsche Telekom, and Vodacom South Africa).
• A further **55 networks in 37 countries** trialling, demonstrating or planning to deploy NB-IoT/Cat-NB1 (18 of them with a stated commitment to launch during 2017).

• **2 commercial LTE-M networks** (Verizon USA and AT&T USA).

• **16 other networks in 10 countries** trialling, demonstrating or planning to deploy LTE-M/Cat-M1 (7 of them with a stated commitment to launch during 2017).

There are two NB-IoT/Cat-NB1 networks planned by operators who are not operating LTE networks: Velcom in Belarus (using GSM 900 MHz spectrum), and Dish in the US (using its 700 MHz spectrum assets).

### 5G global status

Testing and trialling of new pre-standard 5G technologies is already well underway. In the first six months of 2017 we have identified at least 36 operators from 23 countries that have demonstrated 5G technologies, or announced 5G tests, or trials.

New 5G technology trials were announced during the second quarter of 2017 by Turkcell, Telekom Romania, Sri Lanka Telecom, Korea Telecom, Batelco, Celcom Axiata, Telus, Elisa, Swisscom and DNA. Nine other operators that had already begun trialling 5G technologies announced further trials during the quarter.

Operators continue to provide clarity about their intentions in terms of launch timetables for 5G, or at least pre-standards 5G. Recent announcements include:

• MTS now expects to have a 5G network in Moscow at 2018 Football World Cup; it had previously indicated 2020 as a target launch date

• SK Telecom plans to launch a pre-5G network by the end of 2017, and a 5G network by 2020

• Telefónica’s group CTO said at MWC Shanghai that the UK is likely to be the first market to receive 5G services from the operator, followed by Germany and Spain.

Figure 7: IoT network launches, trials, demos and plans by country
At least 22 operators have now made public commitments to deployment of 5G or pre-standards 5G networks in 16 countries, with the earliest launch dates currently planned by operators in Italy and the US though the earliest launches are necessarily limited in scope to either specific applications, or in limited geographic areas where they will function as extended commercial trials ahead of further development and roll-out.

Figure 8 shows the countries and current planned dates for the earliest 5G launches in those countries; note that some targets are after the currently planned date (2020) for finalisation of 5G standards. We have only included countries where operators have announced their plans, not countries where governments have made general statements of intent.

Note: Omissions and Errors Accepted.

Figure 8: Pre-standards and standards-based 5G network plans announced (earliest launch date per country)
About GSA

GSA (the Global mobile Suppliers Association) is a not-for-profit industry organisation representing companies across the worldwide mobile ecosystem engaged in the supply of infrastructure, semiconductors, test equipment, devices, applications and mobile support services.

GSA actively promotes the 3GPP technology road-map – 3G; 4G; 5G – and is a single source of information resource for industry reports and market intelligence. GSA Members drive the GSA agenda and define the communications and development strategy for the Association.

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