# 教育部「5G行動寬頻人才培育跨校教學聯盟計畫」
# 5G行動網路協定與核網技術聯盟中心

課程: 5G系統層模擬技術

第一週：3GPP LTE及5G New Radio Access Network簡介與標準制定過程



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# Outline

- 技術介紹
  - 1G
  - 2G
  - 3G
  - LTE/4G
  - 5G
- 參考來源



# 技術介紹

- Mobile communications has become an everyday commodity.
- Mobile communication technologies are often divided into generations :
  - 1G is the analog mobile radio systems of the 1980s.
  - 2G is the first digital mobile systems.
  - 3G is the first mobile systems handling broadband data.
  - LTE is often called 4G, but many also claim that LTE release 10 ( LTE-Advanced) is the true 4G.
  - 5G is a generation currently under development. It denotes the next major phase of mobile telecommunications standards.

# 1G

- 1G international were started in the early 1980s.
  - The best-known ones are NMT (Nordic Mobile Telephony) that was started up in the Nordic countries, AMPS (Advanced Mobile Phone System) in the USA, TACS (Total Access Communication System) in Europe, and J-TACS in Japan.
  - The analog first-generation cellular systems supported plain old telephony services (POTS).



# 2G

- 2G systems were started in mid-1980s.
  - GSM (Global System for Mobile communications, TDMA) in Europe, IS-136 (TDMA) and IS-95 (CDMA) in US and Japanese PDC (Personal Digital Cellular, TDMA) in Japan.
  - The primary data services introduced in 2G were text messaging (Short Message Services, SMS) and circuit-switched data services enabling e-mail and other data applications, initially at a modest peak data rate of 9.6 kbit/s.

# 3G(1/2)

- 3G is named IMT-2000 in ITU (International Telecommunication Union).
- Wideband CDMA
  - The Wideband CDMA proposals from Europe and Japan were merged and came out as part Universal Mobile Telecommunication Services (UMTS), which was the European name for 3G.



# 3G(2/2)

- Third Generation Partnership Project (3GPP) was formed 1998 by standards-developing organizations from all regions of the world to standardize WCDMA.
- The present organizational partners of 3GPP are ARIB (Association of Radio Industries and Businesses, Japan), CCSA (China Communications Standards Association, China), ETSI (European Telecommunications Standards Institute, Europe), ATIS (Alliance for Telecommunications Industry Solutions, USA), TTA (Telecommunications Technology Association, South Korea), and TTC (Telecommunications Technology Committee, Japan).



# 4G

- 4G is named IMT-Advanced in ITU.
  - The first-release Long Term Evolution standard has been commercially deployed in Oslo, Norway, and Stockholm, Sweden since 2009.
  - 4G provides, in addition to the usual voice and other services of 3G, mobile broadband Internet access, for example to laptops with wireless modems, to smartphones, and to other mobile devices.

# 5G NR(New Radio)(1/3)

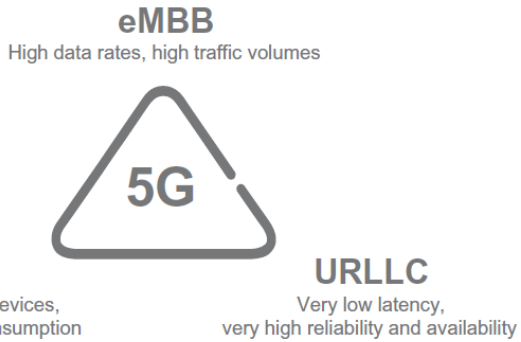
- IMT-2020 is a temporary name for 5G within ITU.
  - The 5G network is a key enabler for a fully mobile and connected information society in which information can be accessed by humans and machines anytime and anywhere.
  - The access is characterized by highly diverse requirements on e.g. higher data-rates, lower latency, ultra-high reliability, higher connectivity density, and higher mobility range, while at the same time ensuring security, trust and privacy.



# 5G NR (2/3)

- Three distinctive classes of use cases:
  1. Enhanced mobile broadband (eMBB)
  2. Massive machine-type communication (mMTC)
  3. Ultra-reliable and low-latency communication (URLLC)

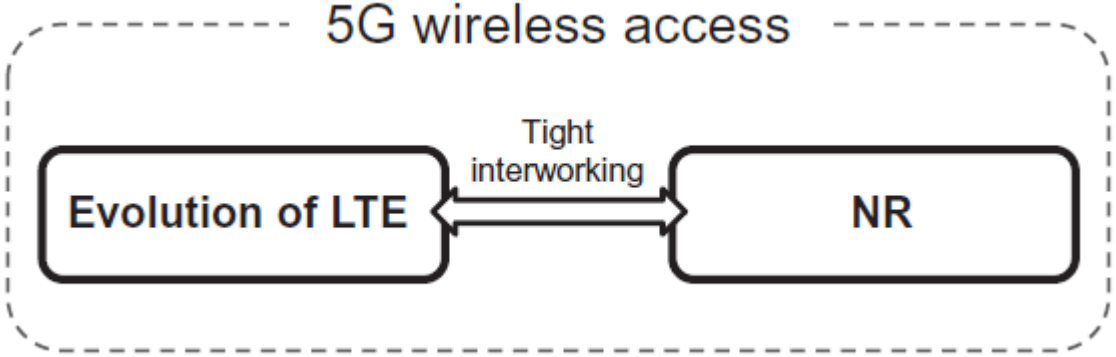
1. eMBB corresponds to a more or less straightforward evolution of the mobile-broadband services of today, enabling even larger data volumes and further enhanced user experience.
2. mMTC corresponds to services that are characterized by a massive number of devices, for example, remote sensors, actuators, and monitoring of various equipment.
3. URLLC type-of-services are envisioned to require very low latency and extremely high reliability. Examples hereof are traffic safety, automatic control, and factory automation.




[1] FIGURE 1.2 : High-level 5G use-case classification.

# 5G (3/3)

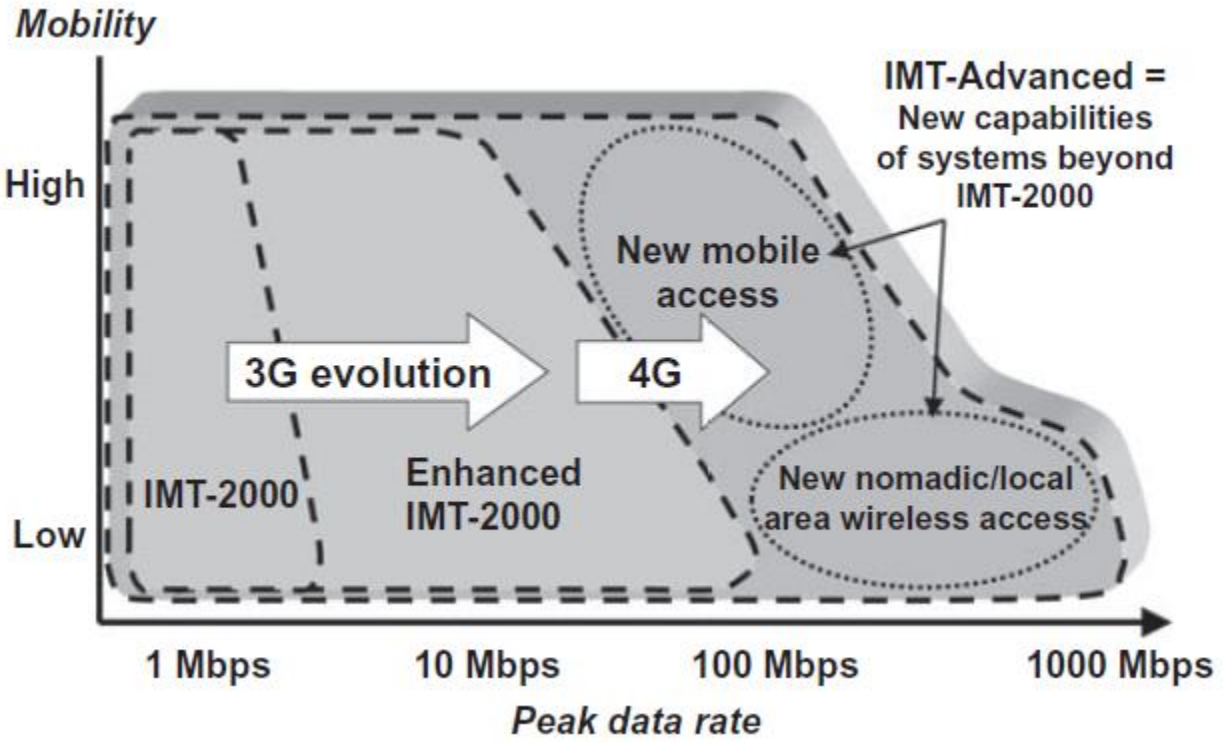
- The evolution of LTE will be able to support a wide range of the use cases envisioned for 5G.
  - The evolution of LTE should thus be seen as an important part of the overall 5G radio-access solution
- NR reuses many of the structures and features of LTE.
- Being a new radio-access technology means that NR, unlike the LTE evolution, is not restricted by a need to retain backwards compatibility.
- The requirements on NR are also broader than what was the case for LTE, motivating a partly different set of technical solutions.




[1] FIGURE 1.3 : Evolution of LTE and NR jointly providing the overall 5G radio-access solution.

# ITU Activities(1/4)

- IMT-2000 (3G) and IMT-Advanced (4G)
  - High-level requirements of 4G.



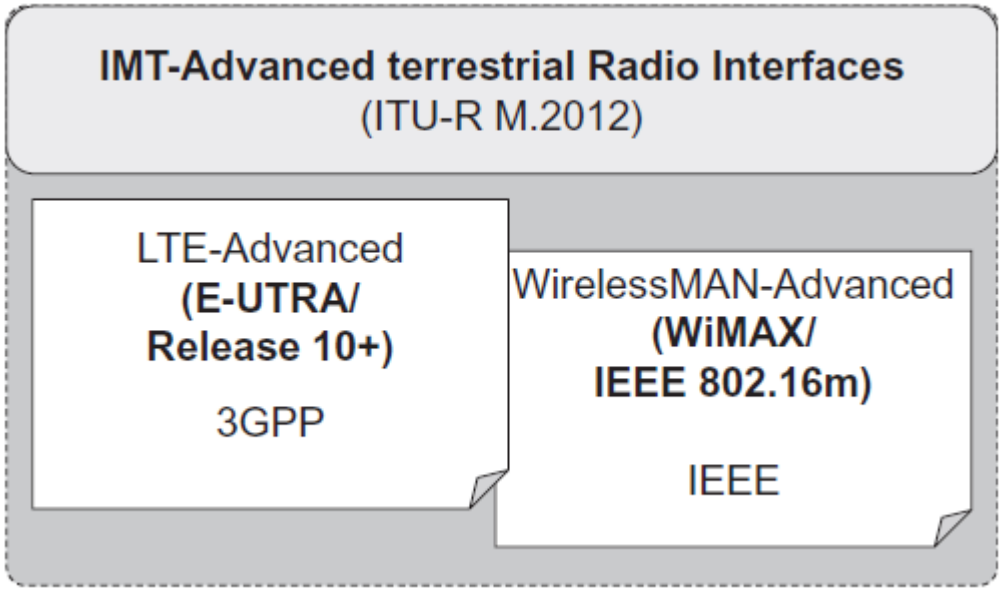

ITU: International Telecommunication Union
IMT: International Mobile Telecommunications



[1] FIGURE 2.2 : Illustration of capabilities of IMT-2000 and IMT-Advanced, based on the framework described in ITU-R Recommendation M.1645

# ITU Activities(2/4)

- Systems of 4G




[1] FIGURE 2.3 : Radio Interface Technologies IMT-Advanced

# ITU Activities(3/4)

- Drivers for LTE
  - Data rate
    - Many services with lower data rates such as voice services are important and still occupy a large part of a mobile network's overall capacity, but it is the higher data rate services that drive the design of the radio interface. The ever increasing demand for higher data rates for web browsing, streaming and file transfer pushes the peak data rates for mobile systems from kbit/s for 2G, to Mbit/s for 3G and getting close to Gbit/s for 4G.



# ITU Activities(4/4)

- Delay
  - Interactive services such as real-time gaming, but also web browsing and interactive file transfer, have requirements for very low delay. The delay for a packet sent from a server to a client and back is called latency.
- Capacity
  - From the mobile system operator's point of view, it is not only the peak data rates provided to the end-user that are of importance, but also the total data rate that can be provided on average from each deployed base station site and per hertz of licensed spectrum. This measure of capacity is called spectral efficiency.



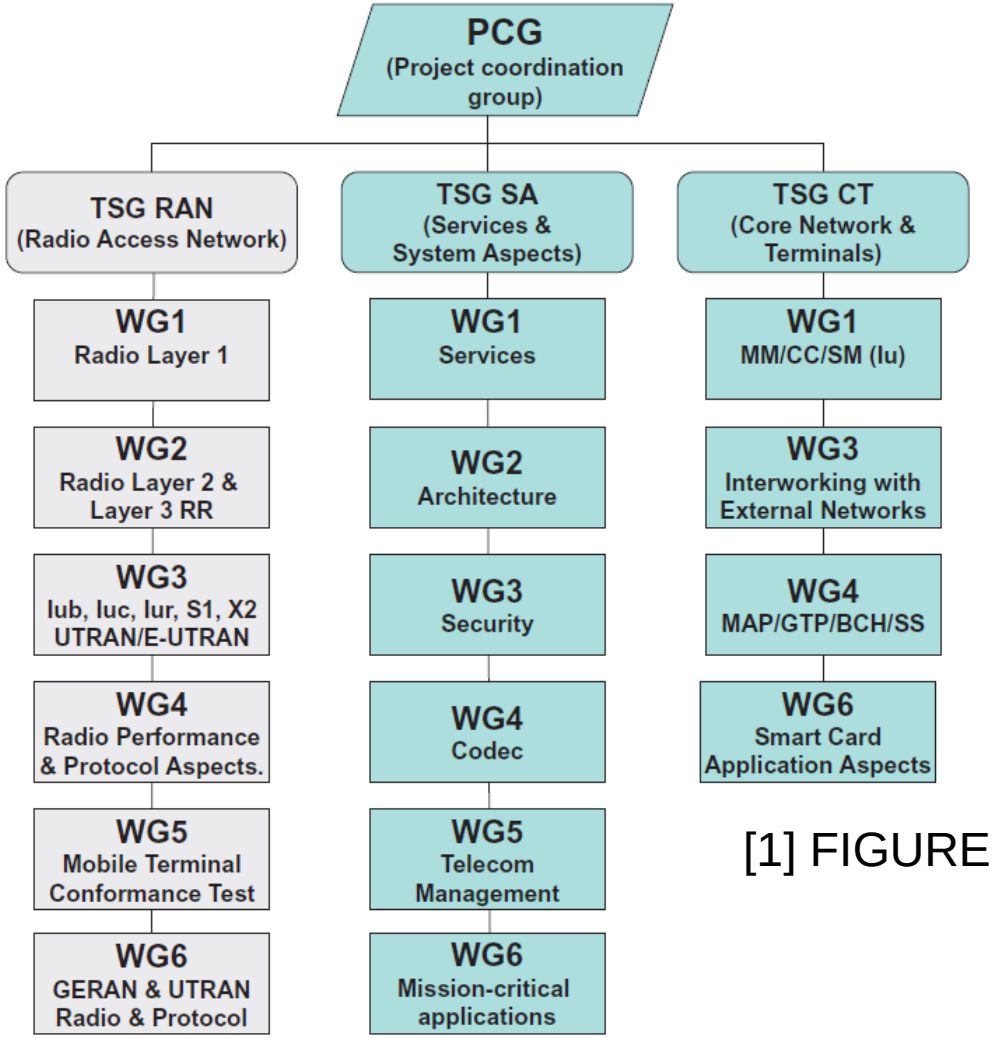
# 3GPP(1/2)

- The Third-Generation Partnership Project (3GPP) is the standards-developing body that specifies the LTE/LTE-Advanced, as well as 3G UTRA and 2G GSM systems.
- 3GPP is a partnership project formed by the standards bodies ETSI, ARIB, TTC, TTA, CCSA, and ATIS.
  - http://www.3gpp.org/



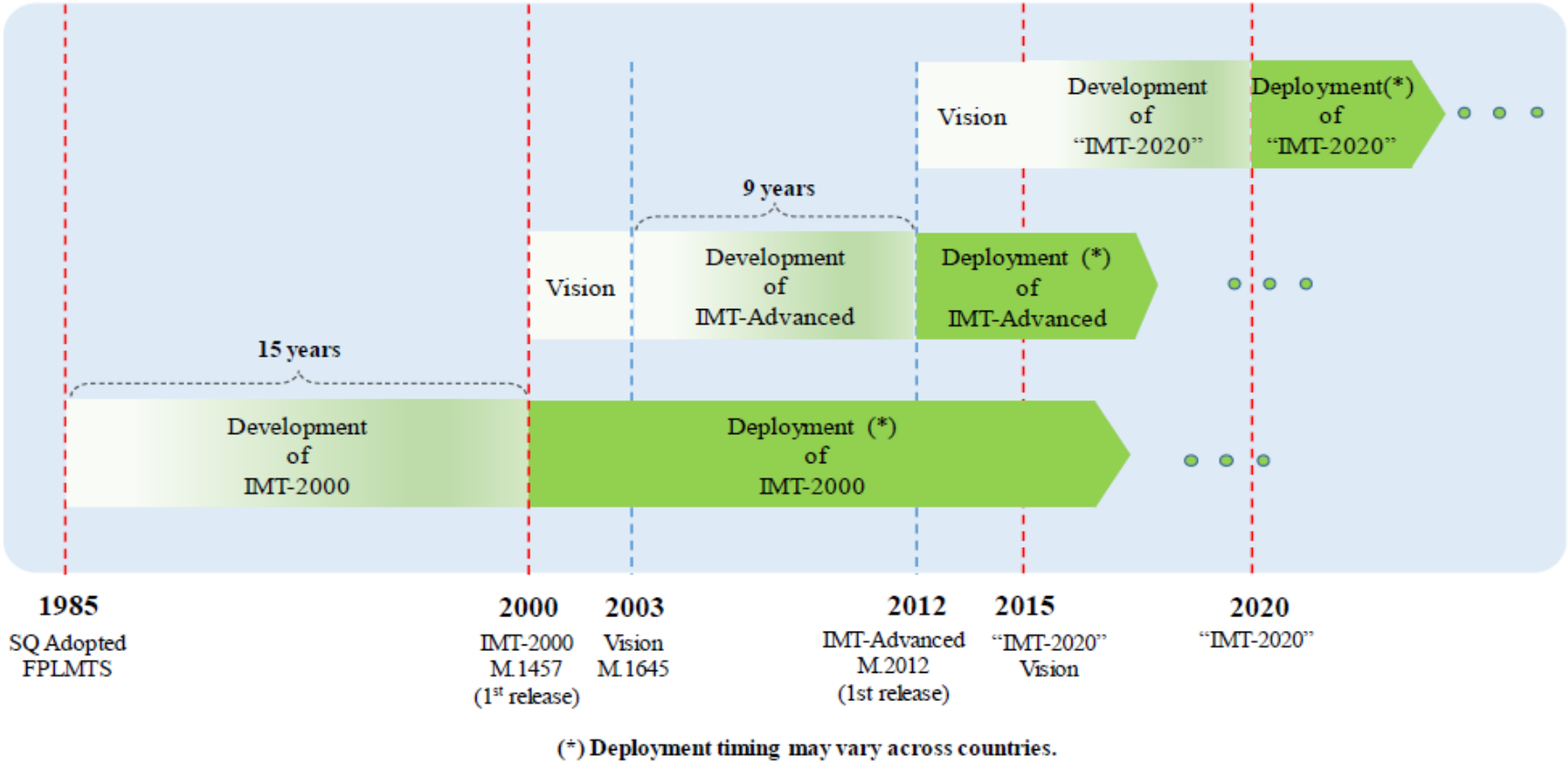
# 3GPP(2/2)

- Project structure



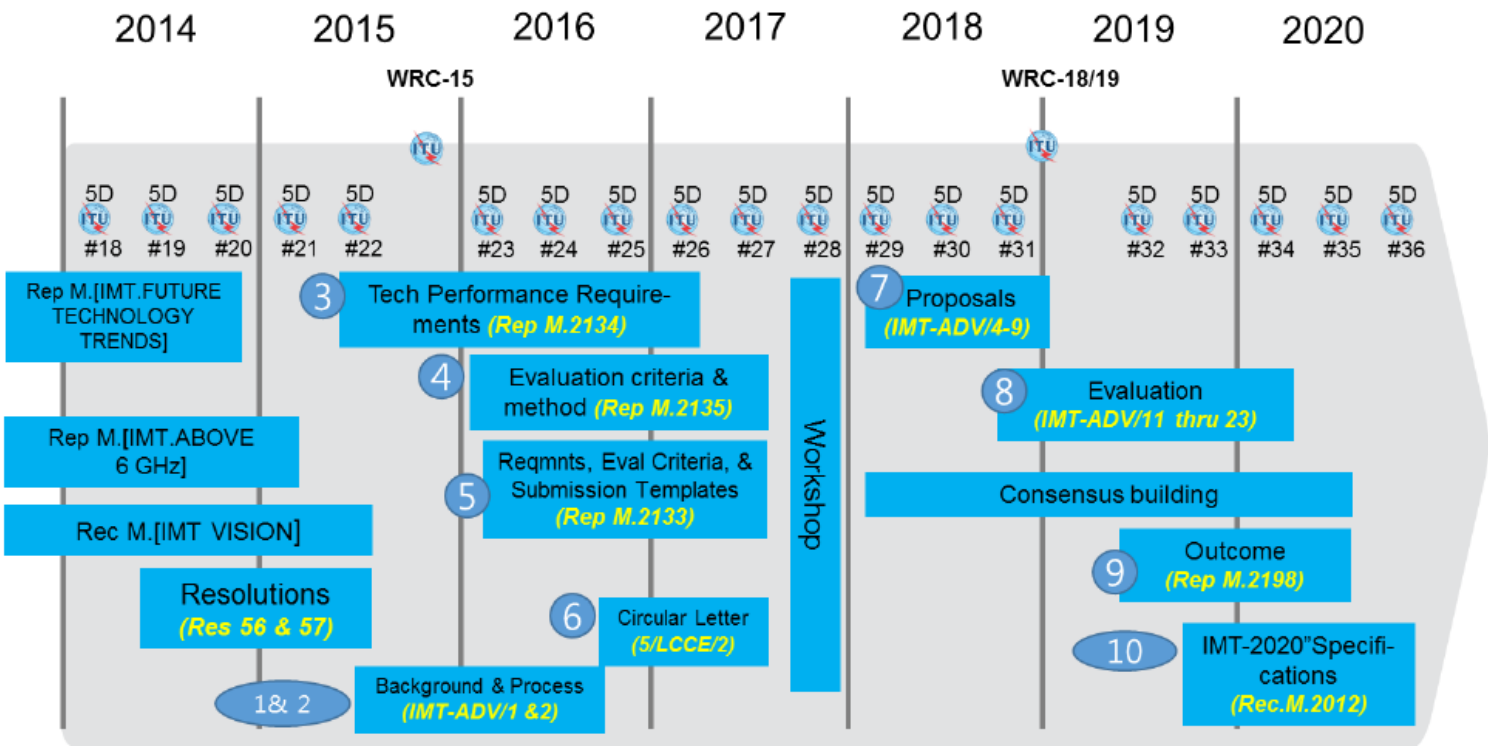

[1] FIGURE 2.9 : 3GPP organization.

# Timeline for IMT Development and Deployment

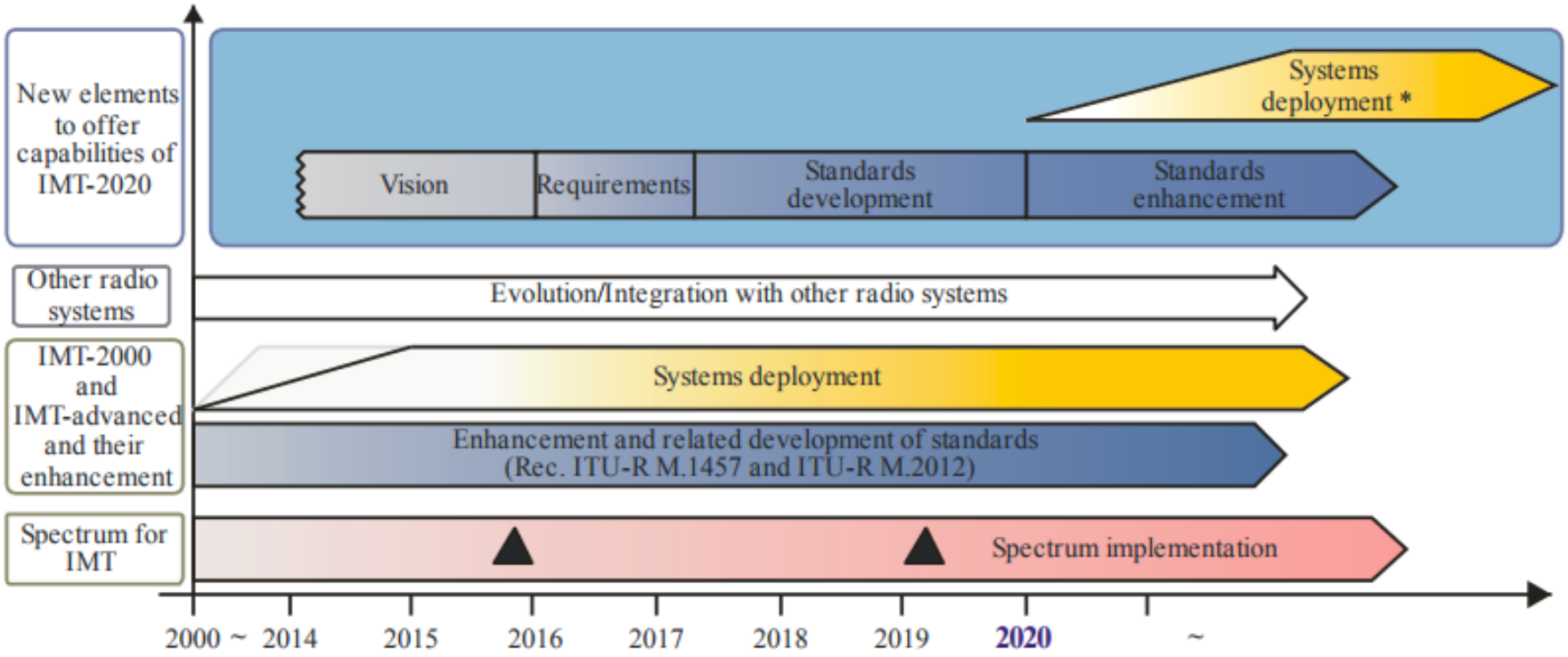



IMT-2000: 3G
IMT-Advanced: 4G
IMT-2020: 5G

# Timeline and Process for IMT-2020 in ITU



# ITU-R IMT Phases and Timelines



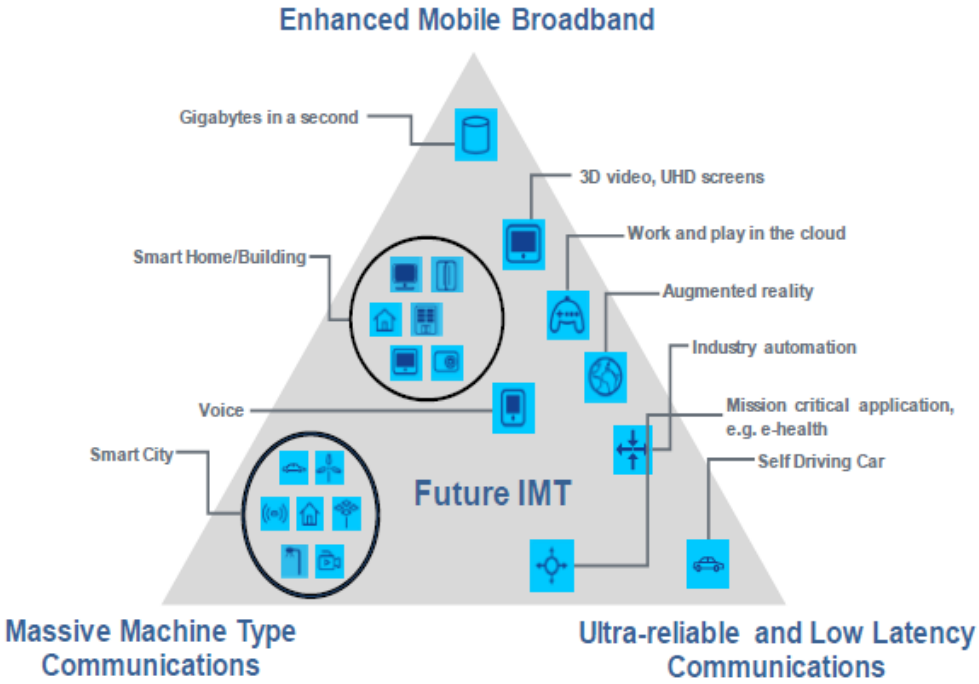

The sloped dotted lines in systems deployment indicate that the exact starting point cannot yet befixed.

▲ : Possible spectrum identification at WRC-15 and WRC-19

* : Systems to satisfy the technical performance requirements of IMT-2020 could be developed beforyear 2020 in some countries.
: Possible deployment around the year 2020 in some countries (including trial systems)

# Usage Scenarios of IMT for 2020 and Beyond

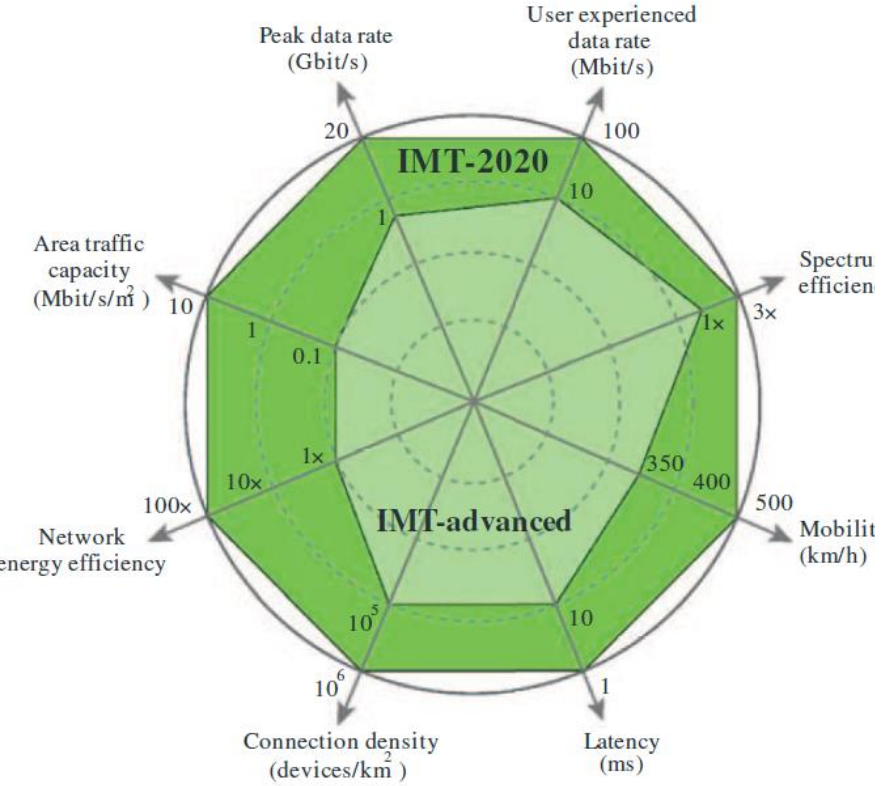
以人為出發點的使用情境，讓用戶可以有效連結到多媒體內容、服務和數據

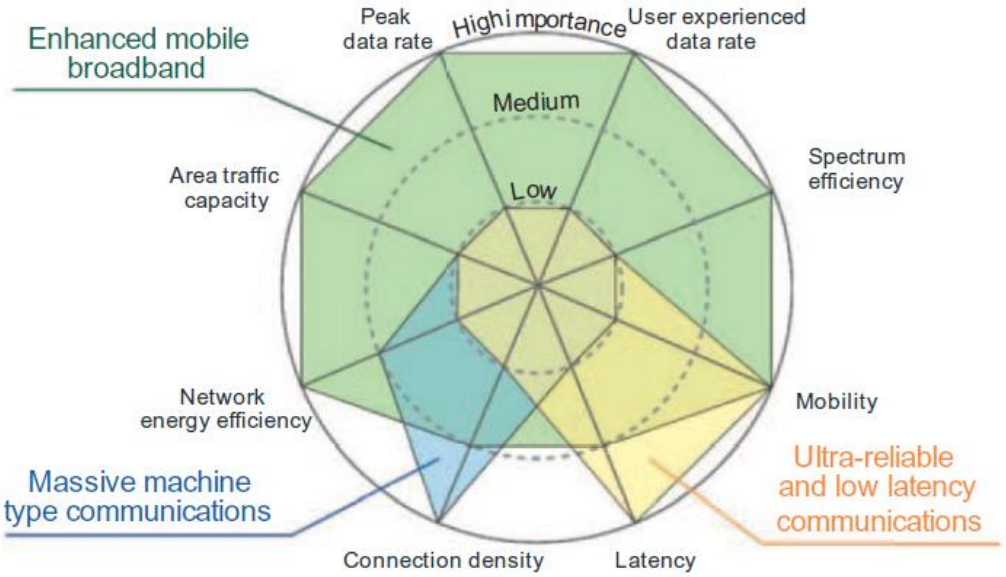



主要的訴求在於滿足大量連結的終端，而這些終端對於數據傳輸量的需求非常小，且終端必須是低成本、電池壽命長

不同個案對於網路需求有所不同，主要的需求指標與傳輸速率、延遲性、可靠度相關

# Key Capabilities of IMT-2020



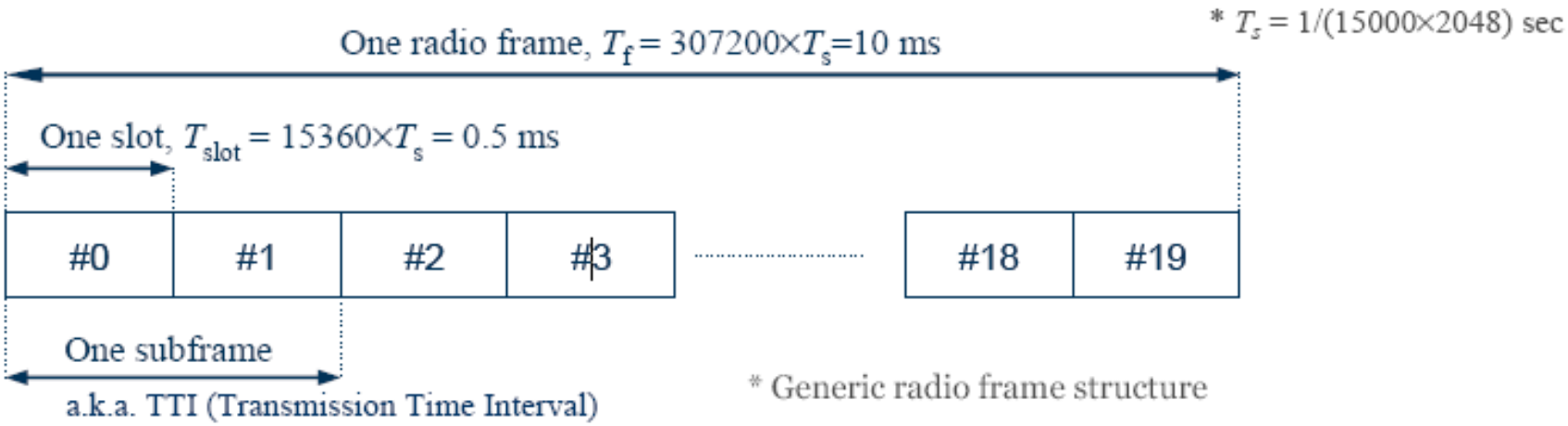

[1] FIGURE 2.6 : Key capabilities of IMT-2020 (左)
[1] FIGURE 2.7 : Relation between key capabilities and the three usage scenarios of ITU-R.(右)

# Introduction to LTE and LTE-A

- Key Features of LTE
  - Multiple access scheme
    - Downlink: Orthogonal Frequency Division Multiple Access (OFDMA)
    - Uplink: Single Carrier FDMA (SC-FDMA)
  - Adaptive modulation and coding
    - DL modulations: QPSK, 16QAM, and 64QAM
    - UL modulations: QPSK and 16QAM
  - Bandwidth scalability for efficient operation in differently sized allocated spectrum bands.
  - Multiple Antenna (MIMO) technology for enhanced data rate and performance.
  - Support for both FDD and TDD.
  - Channel dependent scheduling & link adaptation for enhanced performance.



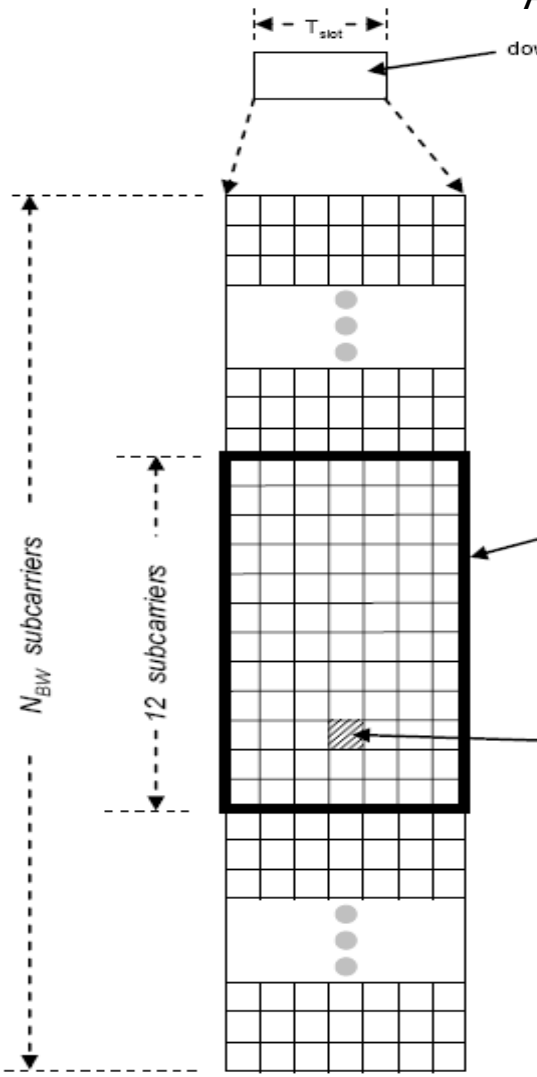
# LTE Frame Structure




- LTE frames are 10 ms in duration.
- They are divided into 10 subframes, each subframe being 1.0 ms long.
- Each subframe is further divided into two slots, each of 0.5 ms duration.
- Slots consist of either 6 or 7 OFDM symbols, depending on whether the normal or extended cyclic prefix is employed.

# Generic Frame Structure

Available Downlink Bandwidth is Divided into Physical Resource Blocks



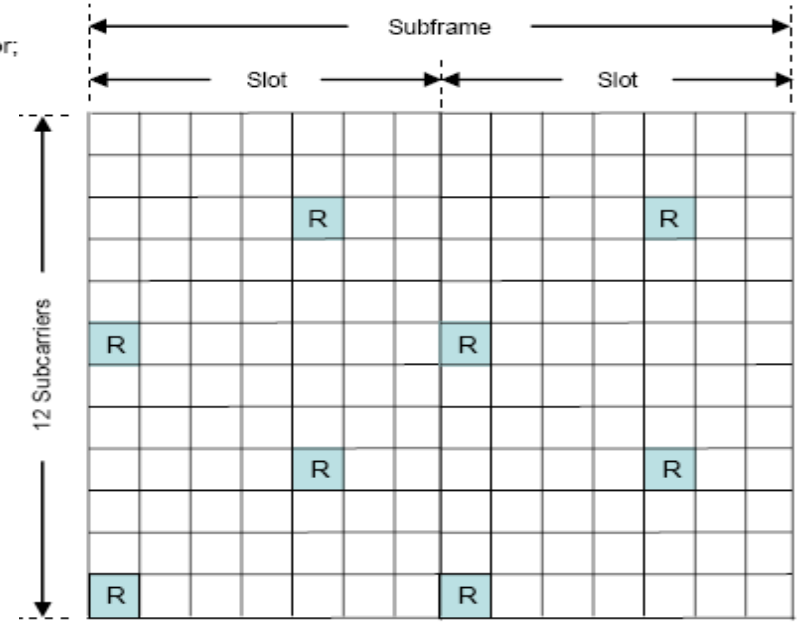

| Bandwidth (MHz) | 1.25 | 2.5 | 5.0 | 10.0 | 15.0 | 20.0 |
|---|---|---|---|---|---|---|
| Subcarrier bandwidth (kHz) | 15 | | | | | |
| Physical resource block (PRB) bandwidth (kHz) | 180 | | | | | |
| Number of available PRBs | 6 | 12 | 25 | 50 | 75 | 100 |

***Resource Block:***

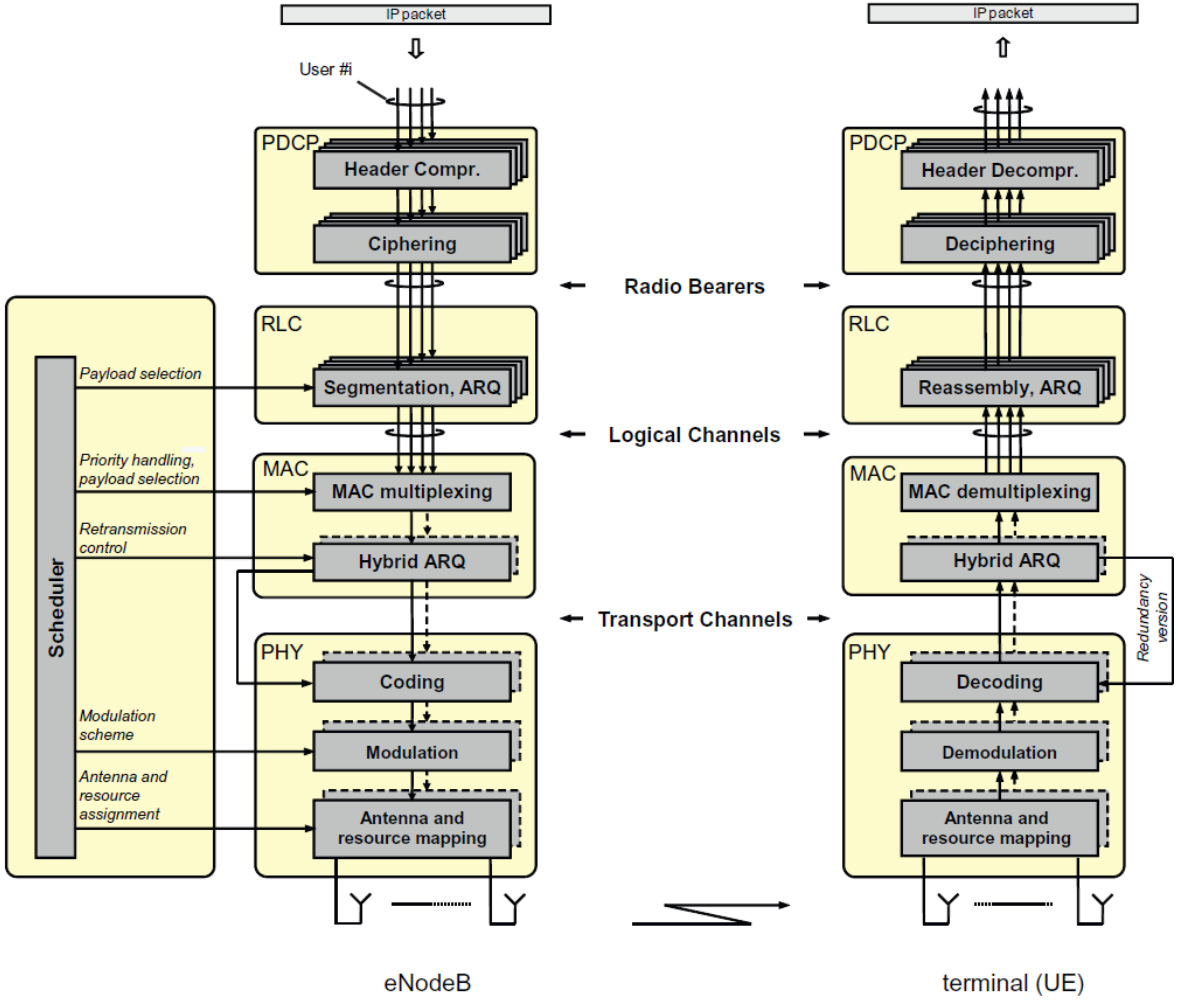
7 symbols X 12 subcarriers (short CP), or;

6 symbols X 12 subcarriers (long CP)

Resource Element



# LTE protocol architecture (DL)

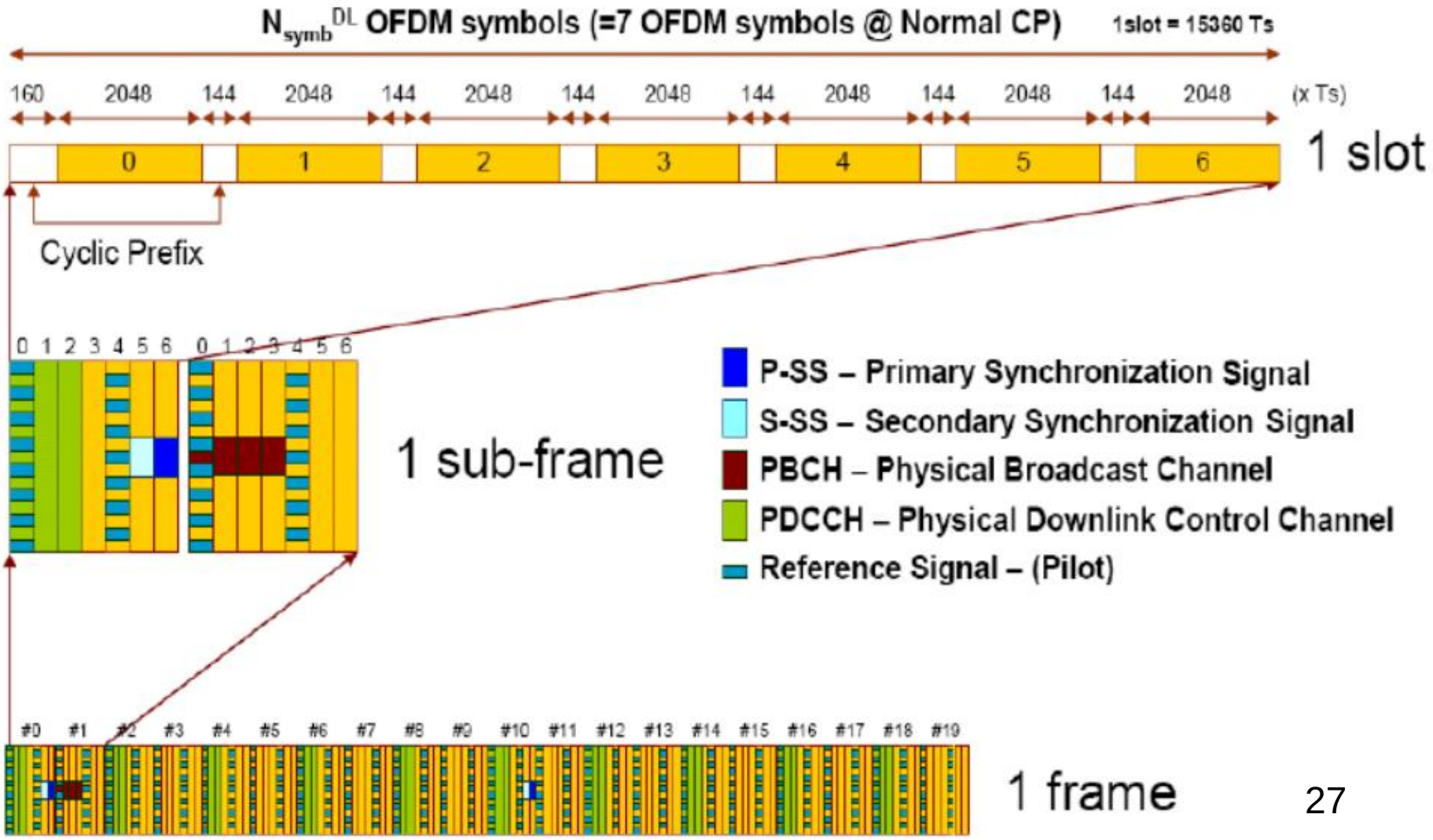




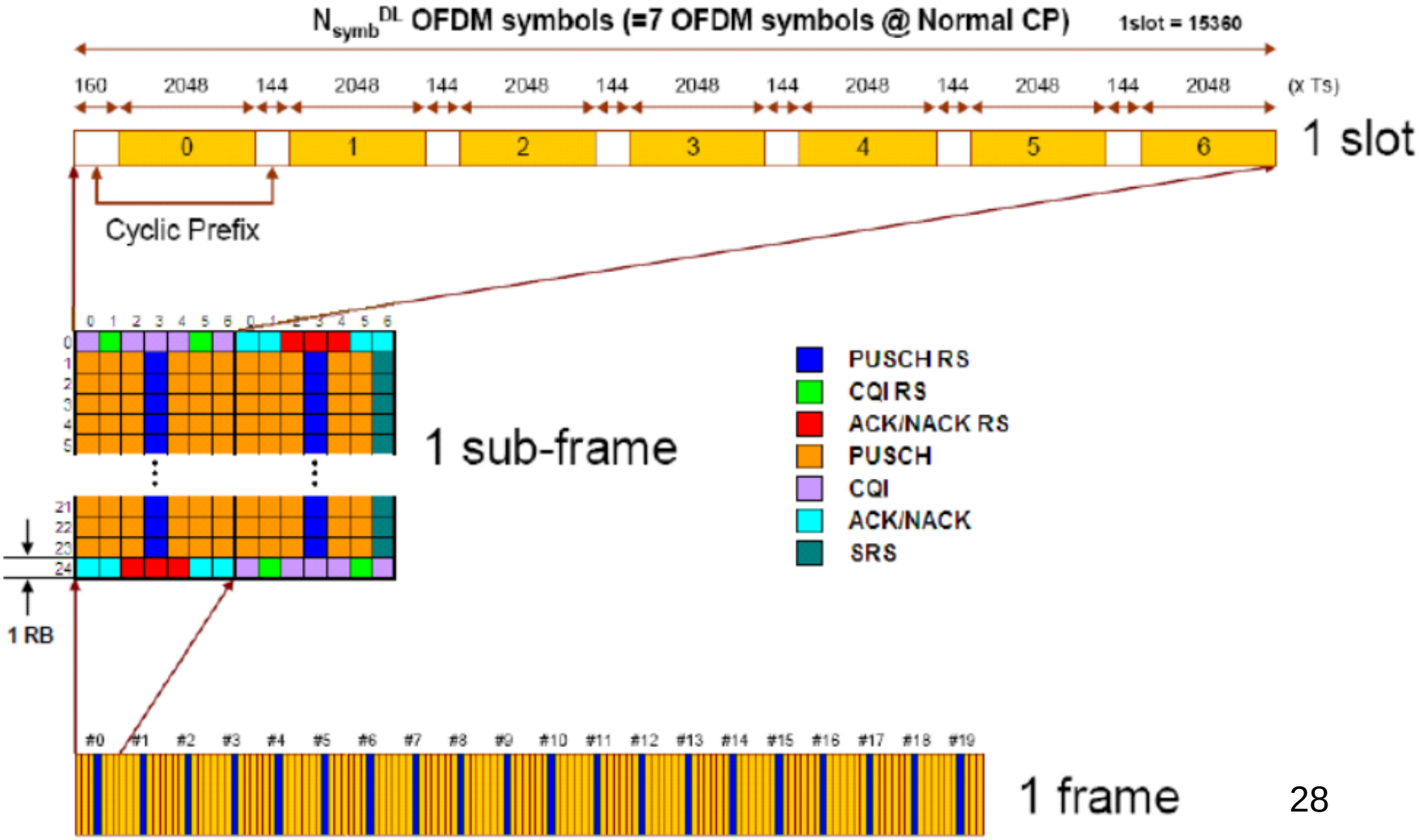

Erik Dahlman, Stefan Parkvall, and Johan Sköld , 4G LTE/LTE-Advanced for Mobile Broadband_2011

**FIGURE 8.4** LTE protocol architecture (downlink).

# DL Frame Structure Type 1



# DL Frame Structure Type 2



# 參考資料


[1] Erik Dahlman, Stefan Parkvall, and Johan Sköld, 5G NR: The Next Generation Wireless Access Technology,

[2] Erik Dahlman, Stefan Parkvall, and Johan Sköld, 4G LTE/LTE-Advanced for Mobile Broadband_2011

[3] 維基百科

- https://en.wikipedia.org/wiki/List_of_mobile_phone_generations
- https://en.wikipedia.org/wiki/4G

[4] 3GPP TR 25.814 V0.4.1 (2005-11), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Physical Layer Aspects for Evolved UTRA (Release 7)

[5] 106年3GPP國際標準最新動態分享會 (3)

- http://std-share.itri.org.tw/event/More?ClassID=1&id=977