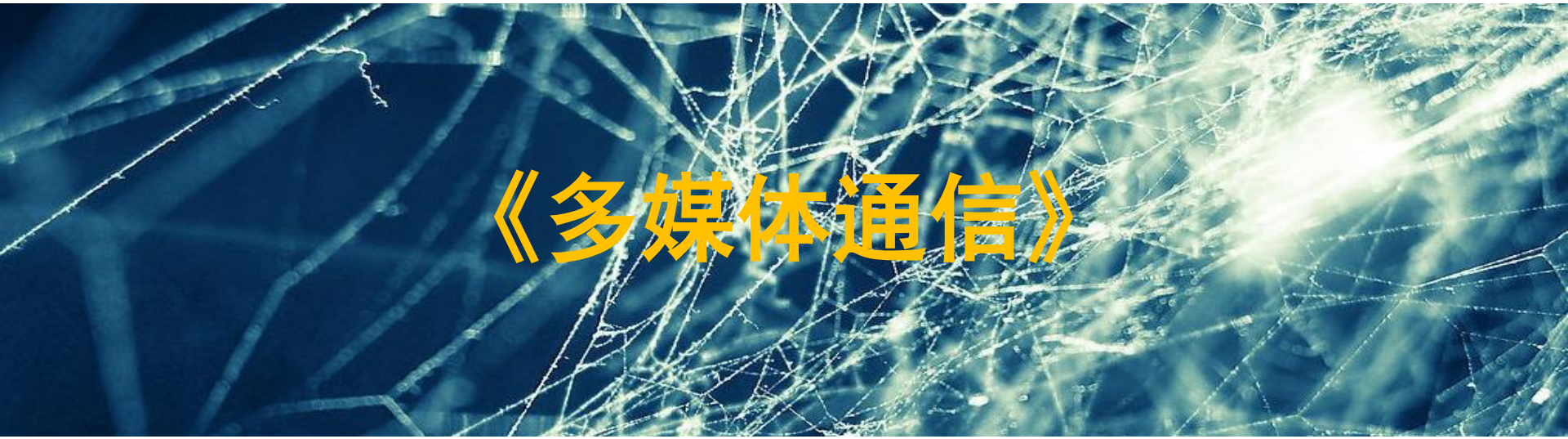

《多媒体通信》

移动通信网的现状与趋势

2019年11月10日

文献阅读报告（含PPT）提交：jjtmx@mail.ustc.edu.cn，11月30日24:00前

实验报告提交：jjtmx@mail.ustc.edu.cn，考试前

专题内容：移动通信网的现状与趋势

- 移动通信网的演进
  - 3GPP: The 3rd Generation Partnership Project
  - 商用PLMN (Public Land Mobile Network)演进
  - 3GPP网络架构演进
- 4.5G (LTE-Advanced Pro)
  - LTE-WLAN Inter-working
  - LTE-WLAN Aggregation
  - LTE对物联网的支持
- 展望5G
  - 5G标准化组织
  - 5G解决什么问题?
  - 5G用什么技术?
  - 5G现状
  - 关于5G与未来网络的思考

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The 3rd Generation Partnership Project (3GPP)
3GPP工作组,1998年底成立

A GLOBAL INITIATIVE

The project covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities - including work on codecs, security, quality of service - and thus provides complete system specifications.

Project Co-ordination Group (PCG)		
TSG RAN Radio Access Network	**TSG SA** Service & Systems Aspects	**TSG CT** Core Network & Terminals
RAN WG1 Radio Layer 1 spec	SA WG1 Services	CT WG1 MM/CC/SM (lu)
RAN WG2 Radio Layer 2 spec Radio Layer 3 RR spec	SA WG2 Architecture	CT WG3 Interworking with external networks
RAN WG3 lub spec, lur spec, lu spec UTRAN O&M requirements	SA WG3 Security	CT WG4 MAP/GTP/BCH/SS
RAN WG4 Radio Performance Protocol aspects	SA WG4 Codec	CT WG6 Smart Card Application Aspects
RAN WG5 Mobile Terminal Conformance Testing	SA WG5 Telecom Management	
RAN WG6 Legacy RAN radio and protocol	SA WG6 Mission-critical applications	

TSG: Technical Specification Groups
WG: Working Group

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http://www.3gpp.org/specifications-groups/specifications-groups retrieved:20171027

3GPP标准的编号

- TSG RAN：Radio Access network
  - TSG RAN：负责3GPP无线接入网技术规范
- TSG SA：Service & System Aspects
  - TSG SA：负责3GPP业务与系统方面的技术规范
- TSG CT：Core Network & Terminals
  - TSG CT：负责3GPP核心网及终端方面的技术规范

- TR : Technical Report 研究报告
- TS: Technical Specification 技术规范
  - SI (Study Item)输出研究报告 (TR)
  - WI (Work Item)输出技术规范 (TS)
  - 一个重要的课题通常会先经过SI研究阶段，然后再进入WI阶段的标准化制定工作。也有些WI会withdraw
  - TR和TS均采用5位编号，即TRxx.yyy TSxx.yyy

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3GPP Organizational Partners

- 欧洲电讯通讯标准化机构(European Telecommunications Standards Institute, ETSI)
- 北美的电讯通讯产业解决方案联盟(Alliance for Telecommunications Industry Solutions, ATIS)
- 日本的电波产业会(Association of Radio Industries and Businesses, ARIB)和情报通讯技术委员会(Telecommunication Technology Committee, TTC)
- 韩国情报通讯技术协会(Telecommunications Technology Association, TTA)
- 中国通讯标准化协会(China Communications Standards Association, CCSA) 1999年加入
- 印度电信标准化发展协会(Telecommunications Standards Development Society of India, TSDSI) 2015年加入

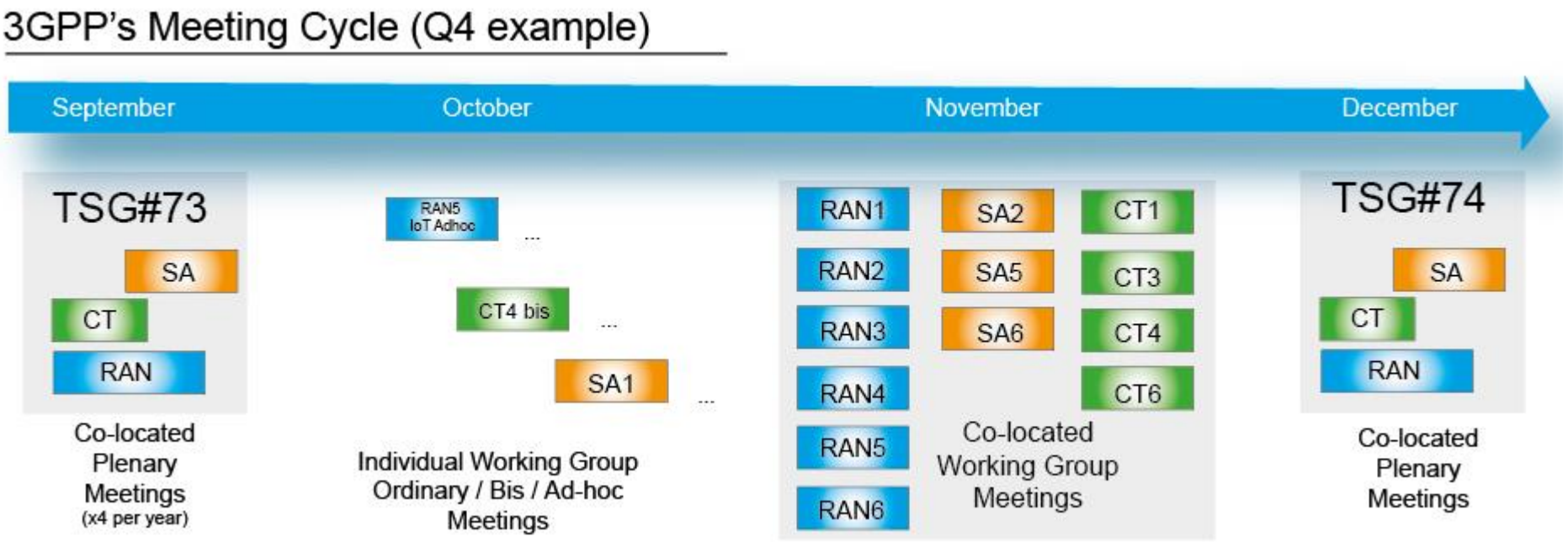
The seven 3GPP Organizational Partners determine the general policy and strategy of 3GPP and perform the following tasks:

- Approval and maintenance of the 3GPP scope;
- Maintenance of the Partnership Project Description;
- Taking decisions on the creation or cessation of Technical Specification Groups, and approving their scope and terms of reference;
- Approval of Organizational Partner funding requirements;
- Allocation of human and financial resources provided by the Organizational Partners to the Project Co-ordination Group;
- Acting as a body of appeal on procedural matters referred to them.

http://www.3gpp.org/about-3gpp/partners Retrieved:20161028

3GPP标准的产生

3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level. The three Technical Specification Groups (TSG) in 3GPP are: Radio Access Networks (RAN), Services & Systems Aspects (SA), Core Network & Terminals (CT) .
The Working Groups, within the TSGs, meet regularly and come together for their quarterly TSG Plenary meeting, where their work is presented for information, discussion and approval.



小结：3GPP

- The 3rd Generation Partnership Project (3GPP), 1998
- TSG: Technical Specification Groups
  - TSG RAN：Radio Access network
  - TSG SA：Service & System Aspects
  - TSG CT：Core Network & Terminals
- 3GPP Organizational Partners
  - ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC
- 3GPP Market Representation Partners
- WG: Working Group
  - TR : Technical Report
  - TS: Technical Specification
  - 3GPP's Meeting Cycle (Q4 example)

专题内容：移动通信网的现状与趋势

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  - 5G用什么技术?
  - 5G现状
  - 关于5G与未来网络的思考

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3GPP标准的演进
3GPP Release

Name	Status	Start date	End date	Closure date
Release 17	**Open**		2021-09-17 (SP-93)	
Release 16	**Open**	2017-03-22	2020-06-19 (SP-88)	
Release 15	Frozen	2016-06-01	2019-06-07 (SP-84)	
Release 14	Frozen	2014-09-17	2017-06-09 (SP-76)	
Release 13	Frozen	2012-09-30	2016-03-11 (SP-71)	
Release 12	Frozen	2011-06-26	2015-03-13 (SP-67)	
Release 11	Frozen	2010-01-22	2013-03-06 (SP-59)	
Release 10	Frozen	2009-01-20	2011-06-08 (SP-52)	
Release 9	Frozen	2008-03-06	2010-03-25 (SP-47)	
Release 8	Frozen	2006-01-23	2009-03-12 (SP-43)	
Release 7	Closed	2003-10-06	2008-03-13 (SP-39)	2014-09-17 (SP-65)
Release 6	Closed	2000-03-28	2005-09-28 (SP-29)	2014-09-17 (SP-65)
Release 5	Closed	2000-05-01	2002-09-12 (SP-17)	2014-09-17 (SP-65)
Release 4	Closed	1998-08-01	2001-06-21 (SP-12)	2014-09-17 (SP-65)
Release 1999	Closed	1996-11-01	1999-12-17 (SP-06)	2008-06-05 (SP-40)

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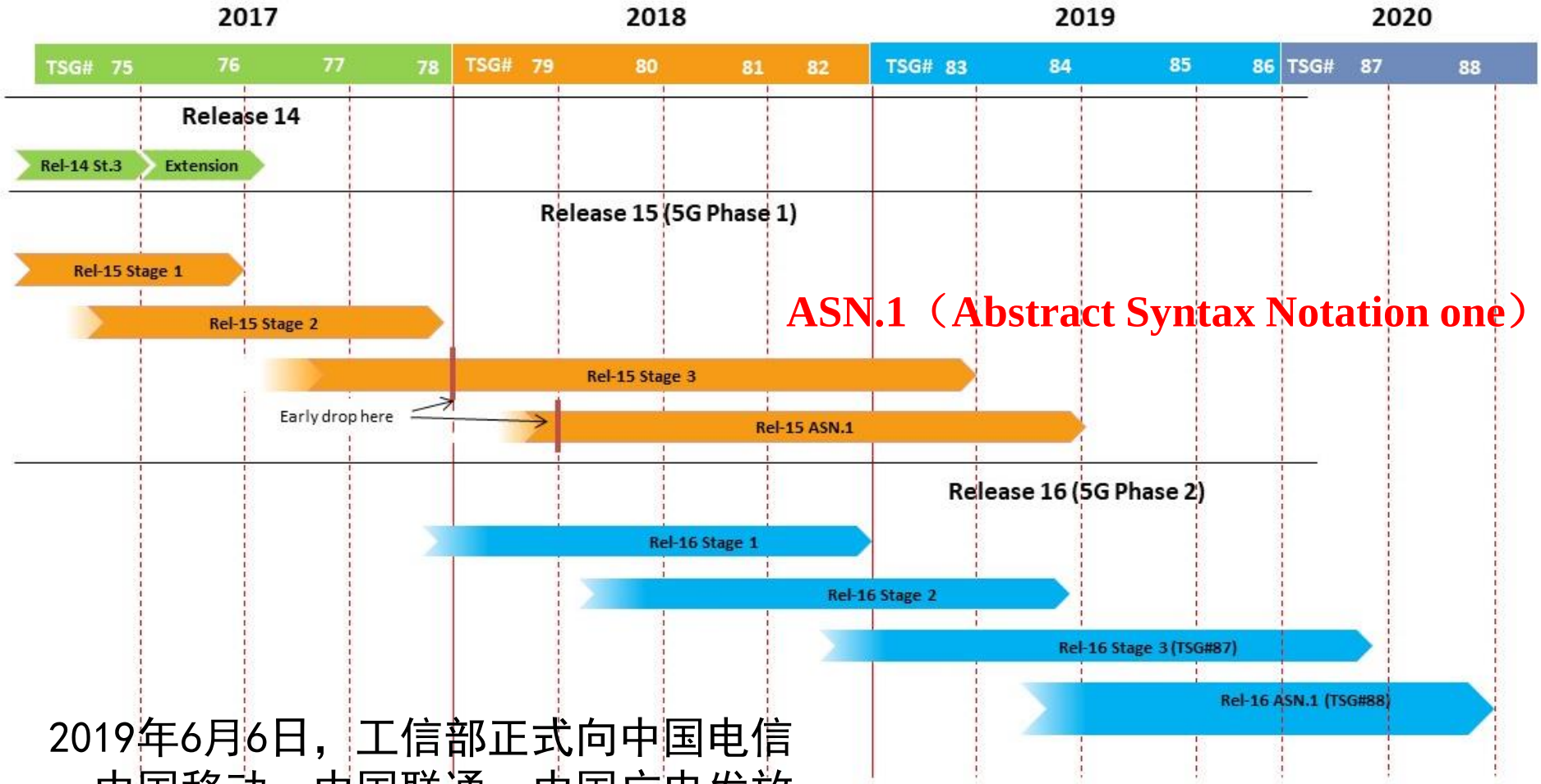
3GPP Ongoing Releases



ASN.1（Abstract Syntax Notation one）

2019年6月6日，工信部正式向中国电信、中国移动、中国联通、中国广电发放5G商用牌照，中国进入5G商用元年。

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3GPP标准的演进
Generations of Mobile Systems

Generation	Major Systems Milestones
1G	Analogue technology, from the 1980s onwards.
2G	First digital systems, deployed in the 1990s introducing voice, SMS and data services, including GSM/GPRS & EDGE, CDMAOne, PDC, iDEN, IS-136 or D-AMPS.
3G	The 3G system is based on evolved GSM. This has allowed for the maintenance and development of GSM, with the evolution of General Packet Radio Service (GPRS) and Enhanced Data rates for GSM Evolution (EDGE), as well as further developments with the Universal Mobile Telecommunications System (UMTS) and High Speed Packet data Access (HSPA). 3G brought a global vision to the evolution of mobile networks, with the creation of the ITU's family of IMT-2000 systems which included EDGE, CDMA2000 1X/EVDO and UMTS-HSPA+ radio access technologies.
3G/4G	**LTE(From Release 8)** has been the basis for all new mobile systems. **LTE-Advanced (From Release 10) is the first true 4G technology** to be specified by 3GPP. **LTE-Advanced Pro (Release 13)** is set to be used by other sectors, beyond telecoms, including Critical Communications (blue light services & other Mission Critical systems), the machine-to-machine or Internet of Things (IoT) sector, Transport (Rail, ITS, etc), Education and many other areas. LTE-Advanced Pro is 3GPP's stepping **stone to 5G** systems.

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http://www.3gpp.org/about-3gpp/about-3gpp Retrieved: 20171028

不同代的移动通信网

Cellular network standards		
List of mobile phone generations		
0G (radio telephones)		MTS · MTA - MTB - MTC - MTD · IMTS · AMTS · OLT · Autoradiopuhelin · B-Netz · Altai · AMR
1G (1985)	AMPS family	AMPS (TIA/EIA/IS-3, ANSI/TIA/EIA-553) · N-AMPS (TIA/EIA/IS-91) · TACS · ETACS
	Other	NMT · C-450 · Hicap · Mobitex · DataTAC
2G (1992)	GSM/3GPP family	GSM · CSD · HSCSD
	3GPP2 family	cdmaOne (TIA/EIA/IS-95 and ANSI-J-STD 008)
	AMPS family	D-AMPS (IS-54 and IS-136)
	Other	CDPD · iDEN · PDC · PHS
2G transitional (2.5G, 2.75G)	GSM/3GPP family	GPRS · EDGE/EGPRS (UWC-136/136HS/TDMA-EDGE)
	3GPP2 family	CDMA2000 1X (TIA/EIA/IS-2000) · CDMA2000 1X Advanced
	Other	WiDEN · DECT
3G (2003)	3GPP family	UMTS (UTRA-FDD / W-CDMA · UTRA-TDD LCR / TD-SCDMA · UTRA-TDD HCR / TD-CDMA)
	3GPP2 family	CDMA2000 1xEV-DO Release 0 (TIA/IS-856)
3G transitional (3.5G, 3.75G, 3.9G)	3GPP family	HSPA (HSDPA · HSUPA) · HSPA+ · LTE (E-UTRA)
	3GPP2 family	CDMA2000 1xEV-DO Revision A (TIA/EIA/IS-856-A) · EV-DO Revision B (TIA/EIA/IS-856-B) · EV-DO Revision C
	IEEE family	Mobile WiMAX (IEEE 802.16e) · Flash-OFDM · iBurst (IEEE 802.20)
4G (2013) (IMT Advanced)	3GPP family	LTE Advanced (E-UTRA) · LTE Advanced Pro (4.5G Pro/pre-5G/4.9G)
	IEEE family	WiMAX (IEEE 802.16m) (WiMax 2.1 (LTE-TDD))
5G (2020) (IMT-2020) (Under development)	LTE	
	5G-NR	

2.5G

2.75G

3.5G

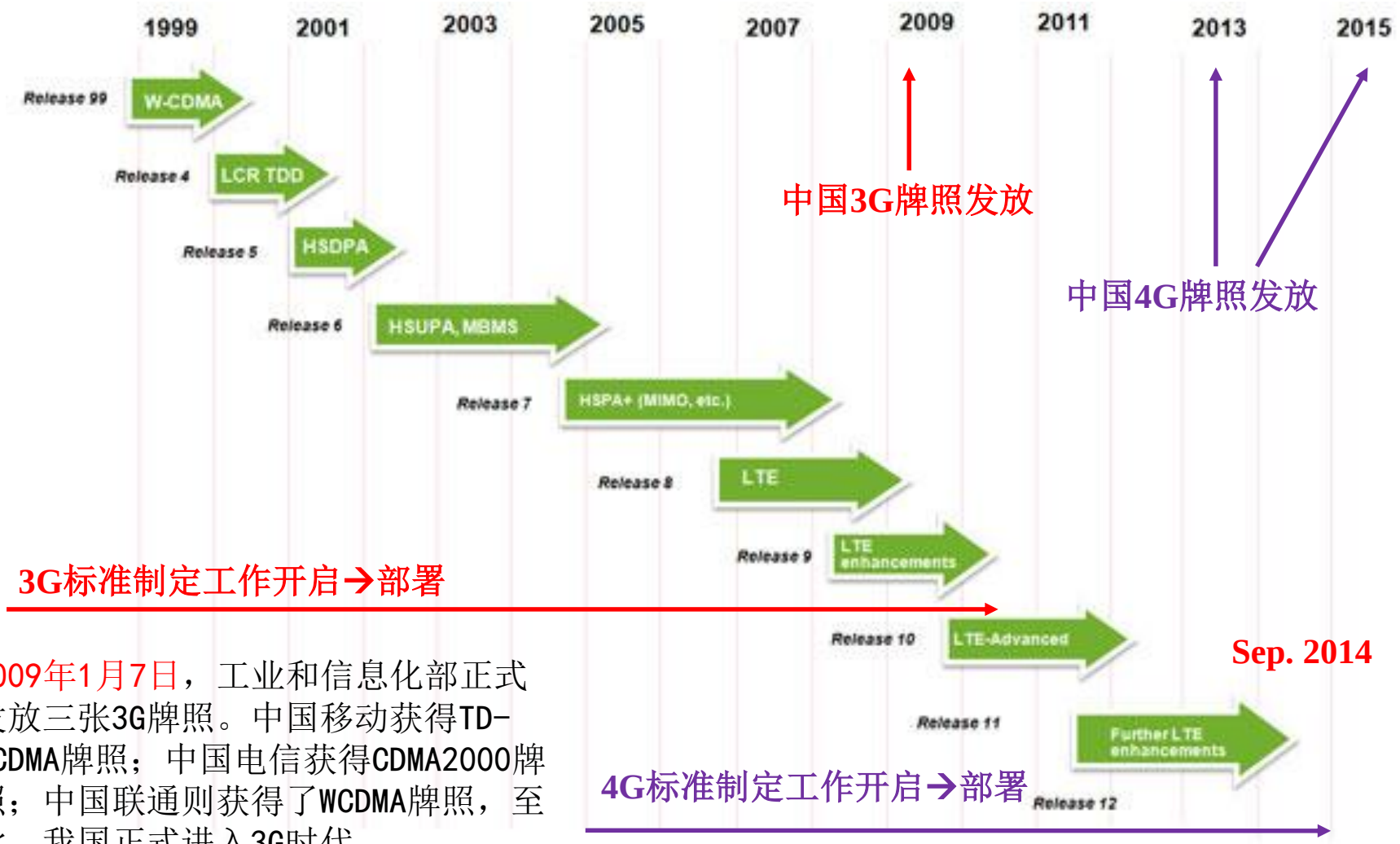
3.75G

3.9G

https://en.wikipedia.org/wiki/GSM Retrieved:20171028

3GPP标准的演进
中国的3G和4G

2013年12月4日工信部的公告三家运营商将同步获得首批4G牌照，为TD-LTE制式。
2015年2月27日工信部宣布向中国电信和中国联通发放FDD-LTE牌照，中国移动并未拿到FDD牌照。



2009年1月7日，工业和信息化部正式发放三张3G牌照。中国移动获得TD-SCDMA牌照；中国电信获得CDMA2000牌照；中国联通则获得了WCDMA牌照，至此，我国正式进入3G时代。

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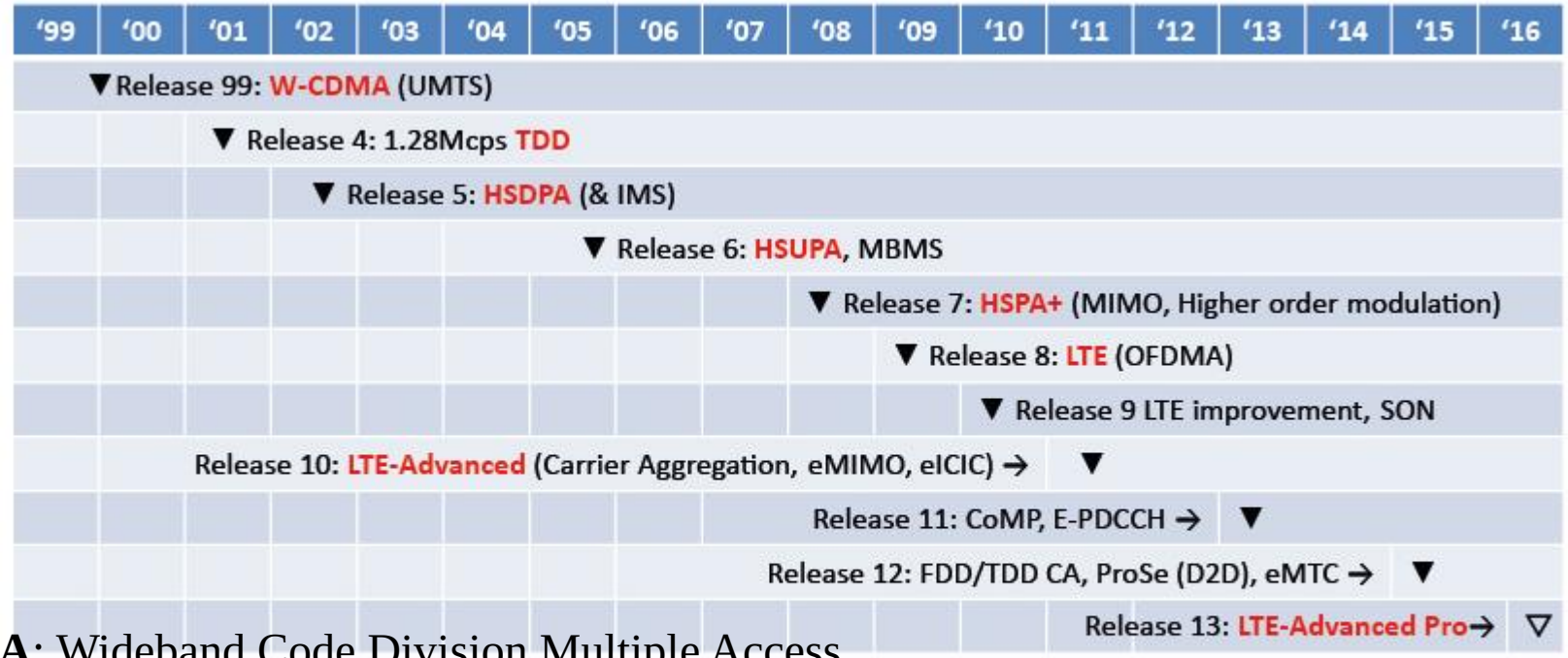
http://www.3gpp.org/about-3gpp/about-3gpp Retrieved: 20171028

3GPP标准的演进：Formal name & Release Radio Access Milestones



- Expanding Carrier Aggregation
- Narrowband IoT
- Elevation Beamforming/Full-Dimension (FD) MIMO for LTE
- LAA

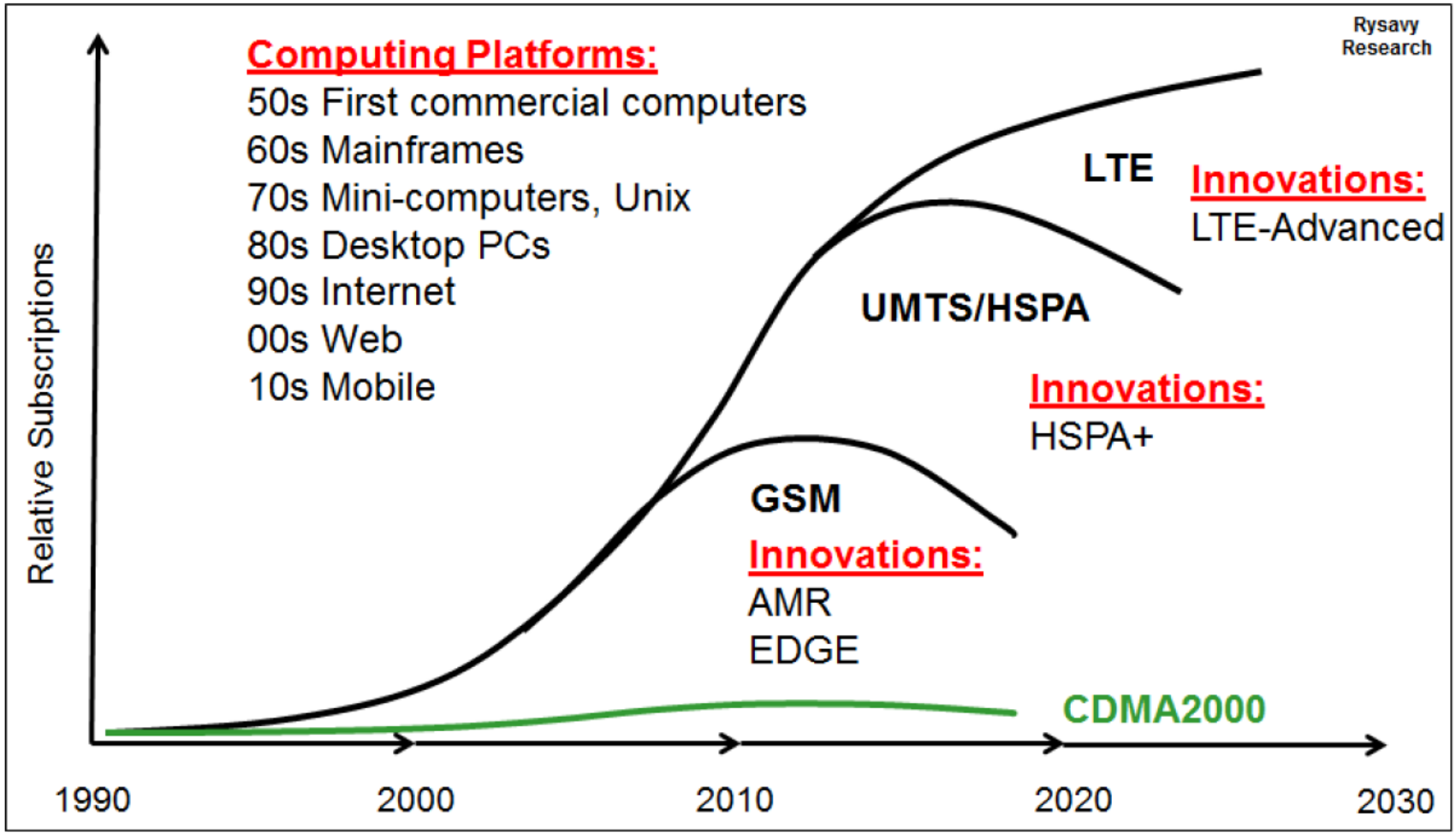
WCDMA: Wideband Code Division Multiple Access
TDD: Time Division Duplexing
HSPA+: High-Speed Packet Access+
HSDPA: High Speed Downlink Packet Access
HSUPA: High Speed Uplink Packet Access
LTE: Long Term Evolution
LTE-Advanced: enhancement of LTE
LTE-Advanced Pro: the next evolution of LTE

{ynh,cxh}@u

http://www.3gpp.org/about-3gpp/about-3gpp Retrieved:20171028

移动通信发展趋势
1G/2G/3G/4G技术更新的周期

Figure 15: Relative Adoption of Technologies[42]



小结：移动通信系统的演进

- Generations of Mobile Systems
  - LTE-Advanced (From Release 10) is the first true 4G technology
  - 2009年1月7日，工信部发放三张3G牌照
  - 2013年12月4日，工信部发放首批4G牌照（TD-LTE制式）
  - 2015年2月27日，工信部向中国电信和中国联通发放FDD-LTE牌照，中国移动并未拿到FDD牌照
  - 2019年6月6日，工信部正式向中国电信、中国移动、中国联通、中国广电发放5G商用牌照
- Radio Access Milestones
  - **WCDMA**: Wideband Code Division Multiple Access
  - **TDD**: Time Division Duplexing
  - **HSPA+**: High-Speed Packet Access+
  - **HSDPA**: High Speed Downlink Packet Access
  - **HSUPA**: High Speed Uplink Packet Access
  - **LTE**: Long Term Evolution
  - **LTE-Advanced**: enhancement of LTE
  - **LTE-Advanced Pro**: the next evolution of LTE

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核心网、骨干网、支撑网、接入网

- 从业务角度划分：业务网：核心网+接入网。
- 从传输角度划分：通信网：骨干网+接入网。
- 核心网（Core Network）：业务层的角度划分，将接入网与其他接入网连接在一起的网络。
- 骨干网（backbone network）：城市之间的连接网络。
- 接入网（Access Network ）：指骨干网络到用户终端之间的所有设备。
  - 有线接入网技术：ADSL、Cable Modem、以太网接入、光纤接入
  - 宽带无线接入网技术：卫星通信接入、微波接入（MMDS, LMDS）、

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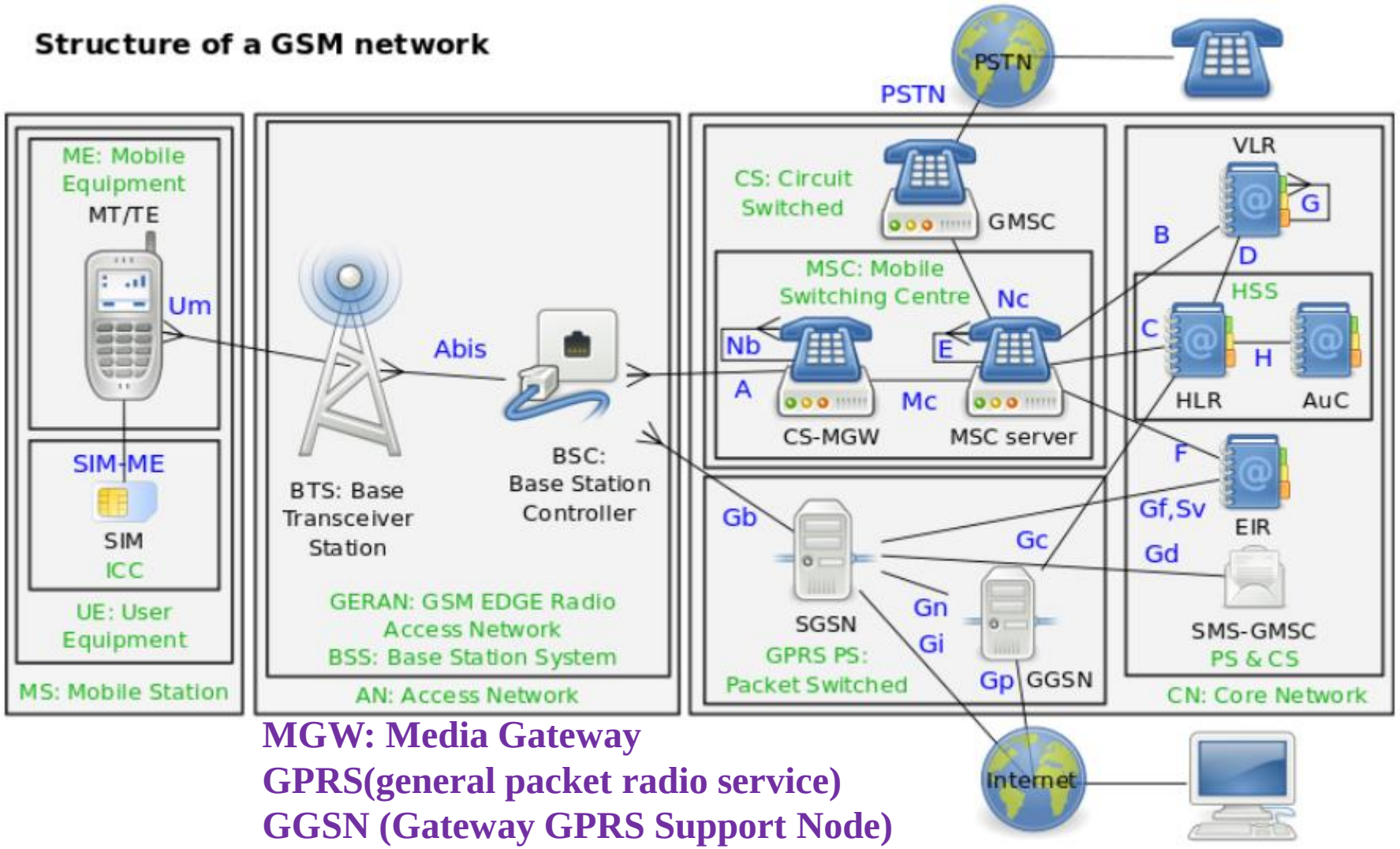
3GPP演进蓝图：网络架构

http://en.wikipedia.org/wiki/Gsm

2G

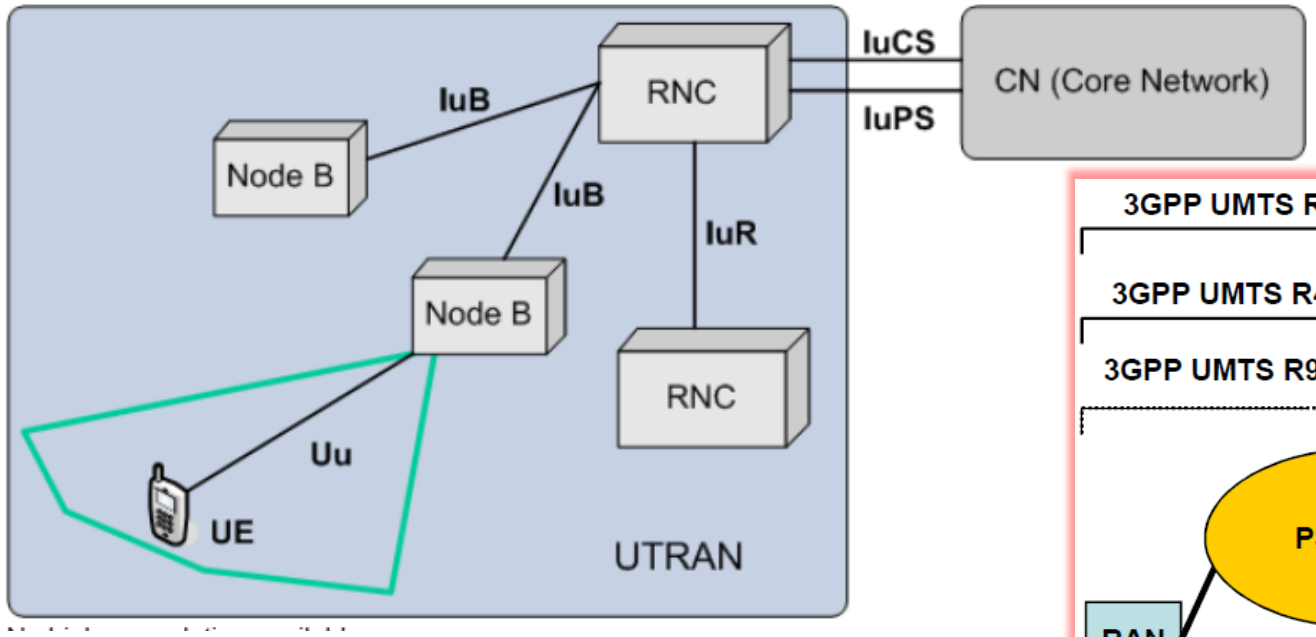
BTS: Base Tranceiver Stations
BSC: Base Station Controller

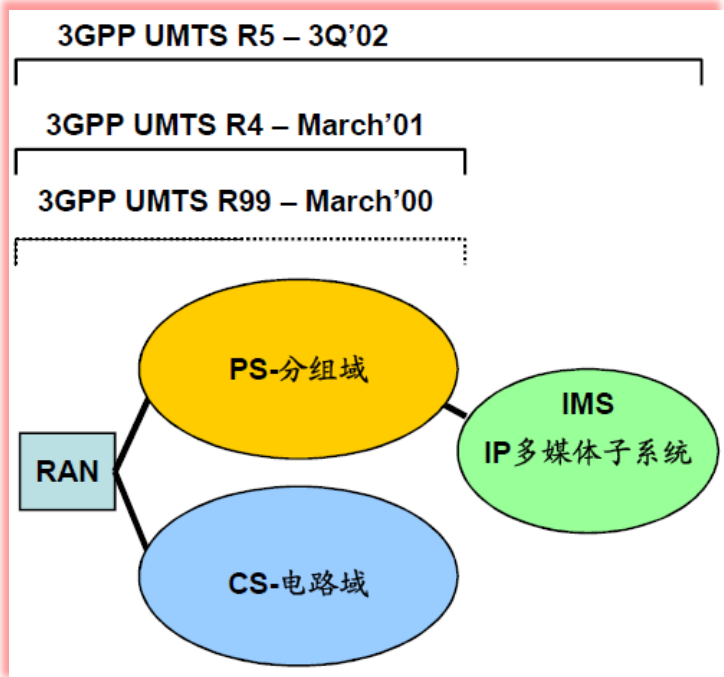
MSS: Mobile Switching Server
VLR: Visitor Location Register
HLR: Home Location Register



MGW: Media Gateway
GPRS(general packet radio service)
GGSN (Gateway GPRS Support Node)
SGSN(serving GPRS support node)

3GPP演进蓝图：网络架构
3G





RNC (Radio Network Controllers)

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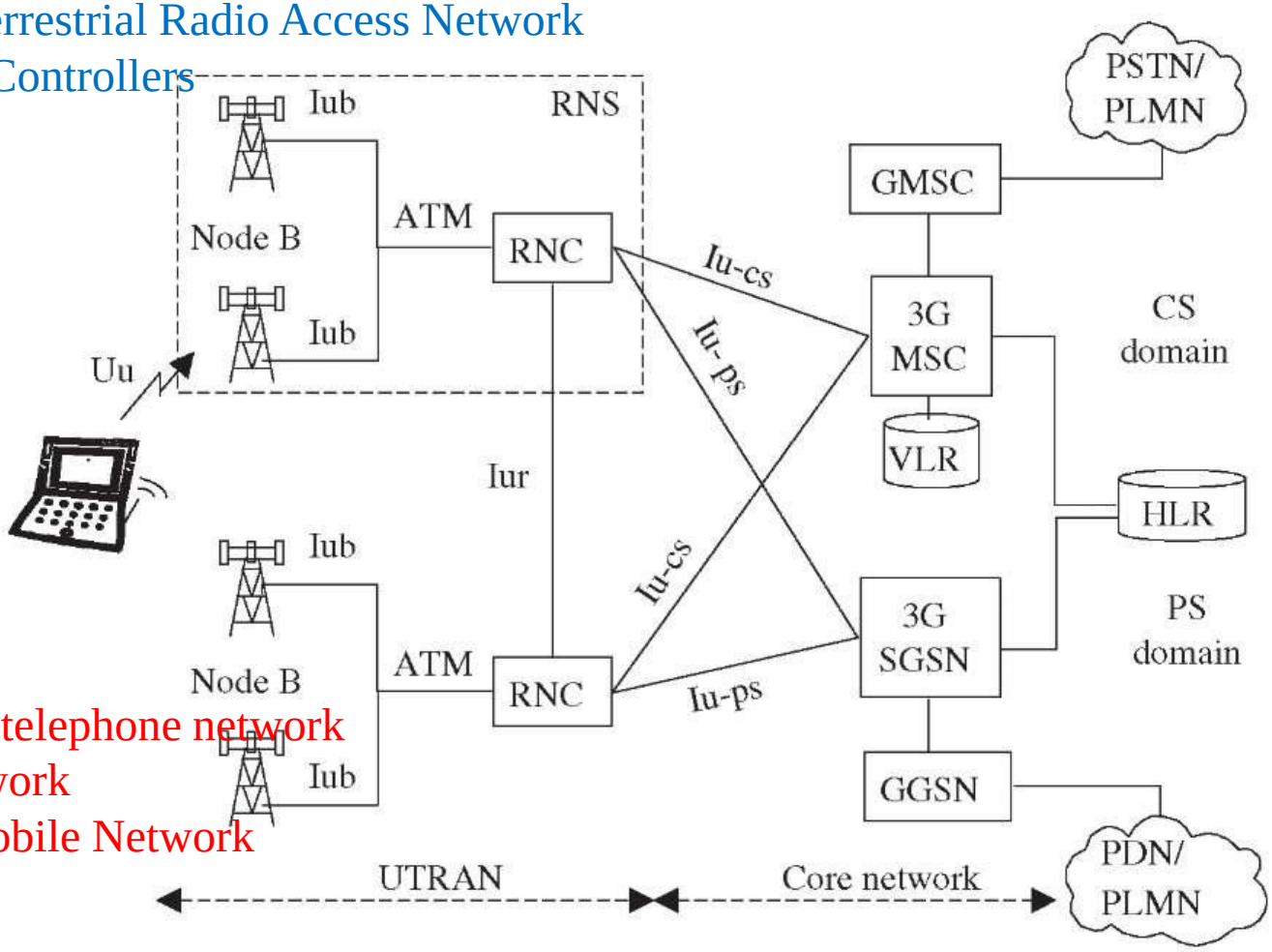
http://en.wikipedia.org/wiki/UTRAN

3GPP演进蓝图：网络架构
3G

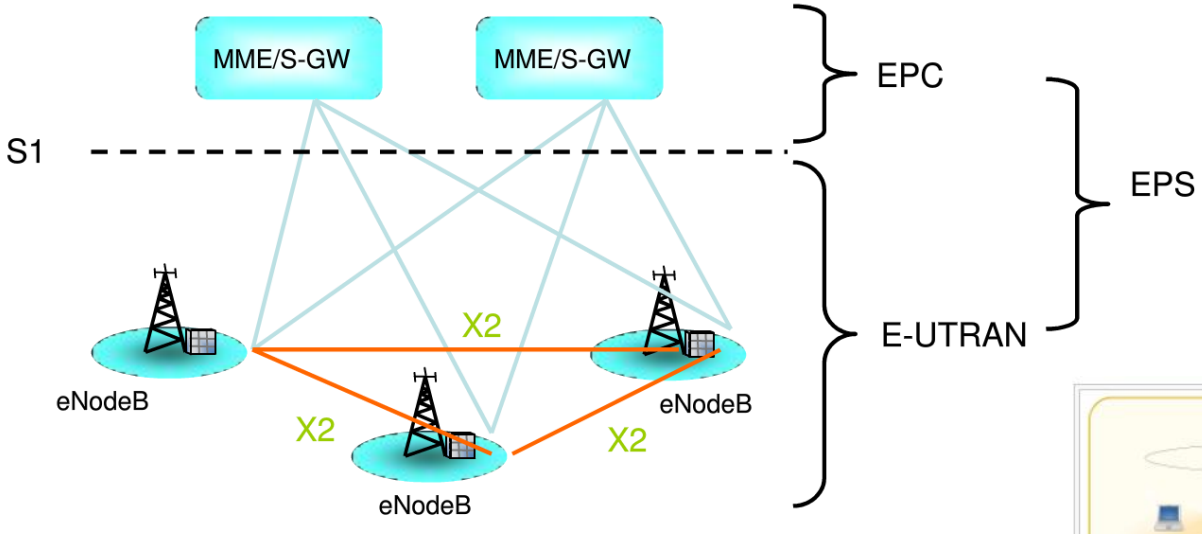
MSC: Mobile Switching Center
VLR: Visitor Location Register
HLR: Home Location Register

GGSN: Gateway GPRS Support Node
SGSN: serving GPRS support node
UTRAN: Universal Terrestrial Radio Access Network
RNC:Radio Network Controllers

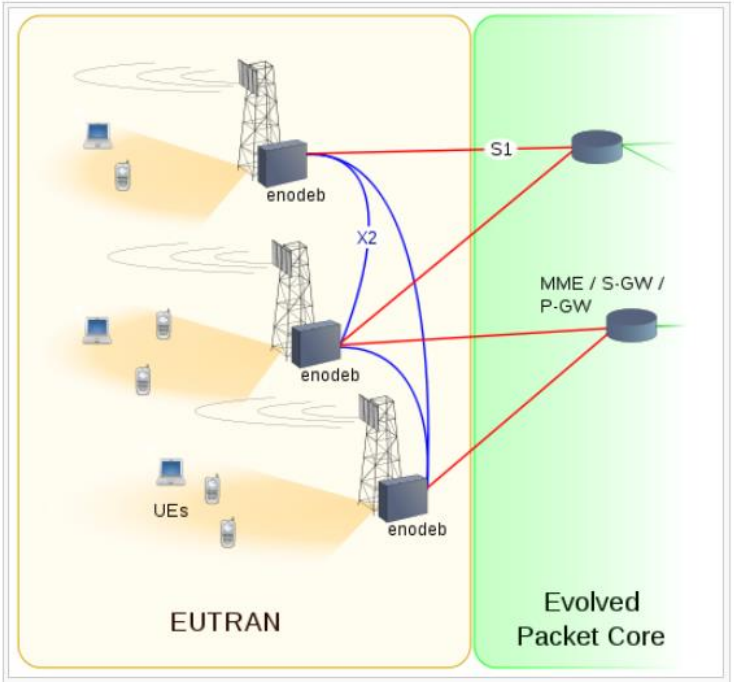


PSTN: Public switched telephone network
PDN: Packet Data Network
PLMN: Public Land Mobile Network

3GPP演进蓝图：网络架构
4G LTE系统架构



4G中接入网结构进一步简化，核心网扁平化



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http://en.wikipedia.org/wiki/E-UTRAN

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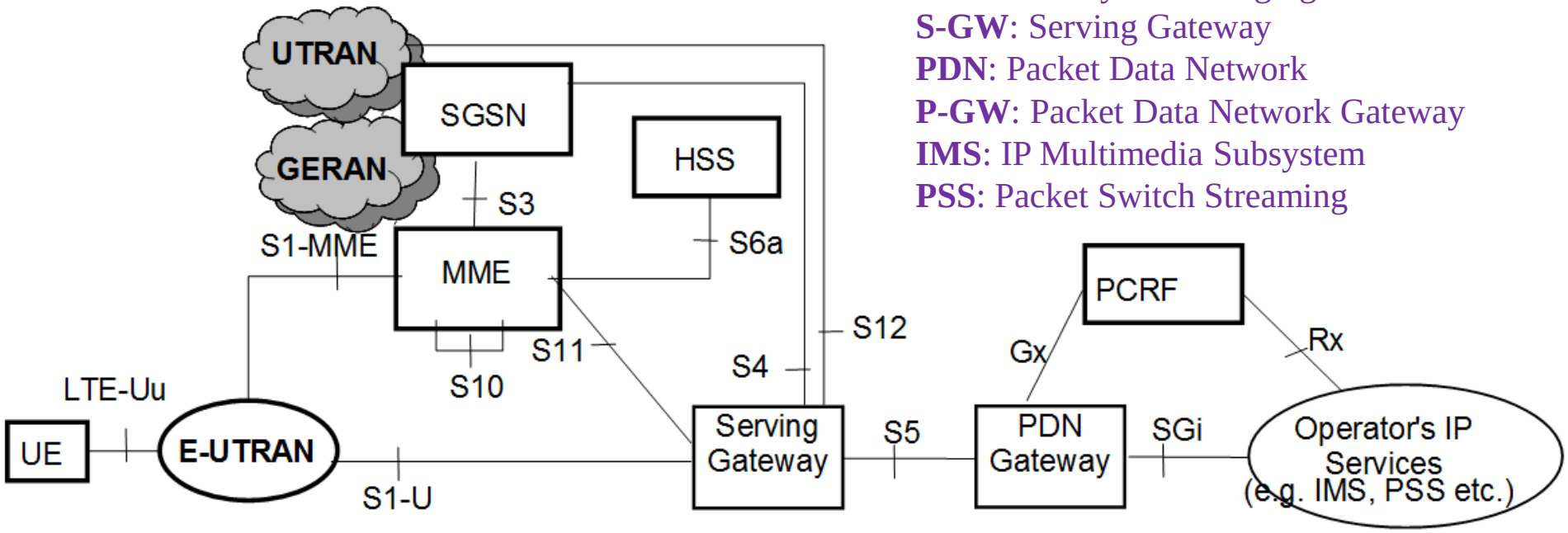
3GPP演进蓝图：4G网络架构
Non-roaming architecture for 3GPP accesses

UTRAN: Universal Terrestrial Radio Access Network
E-UTRAN: Evolved Universal Terrestrial Radio Access Network
GERAN: GSM EDGE Radio Access Network

PCRF: Policy and Charging Rules Function
S-GW: Serving Gateway
PDN: Packet Data Network
P-GW: Packet Data Network Gateway
IMS: IP Multimedia Subsystem
PSS: Packet Switch Streaming



MME: Mobility Management Entity
SGSN: serving GPRS support node
HSS: Home Subscriber Server

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3GPP演进蓝图：4G网络架构
Roaming architecture for 3GPP accesses

UTRAN: Universal Terrestrial Radio Access Network
GERAN: GSM EDGE Radio Access Network
E-UTRAN: Evolved Universal Terrestrial Radio Access Network
PLMN: Public Land Mobile Network

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SGSN: serving GPRS support node
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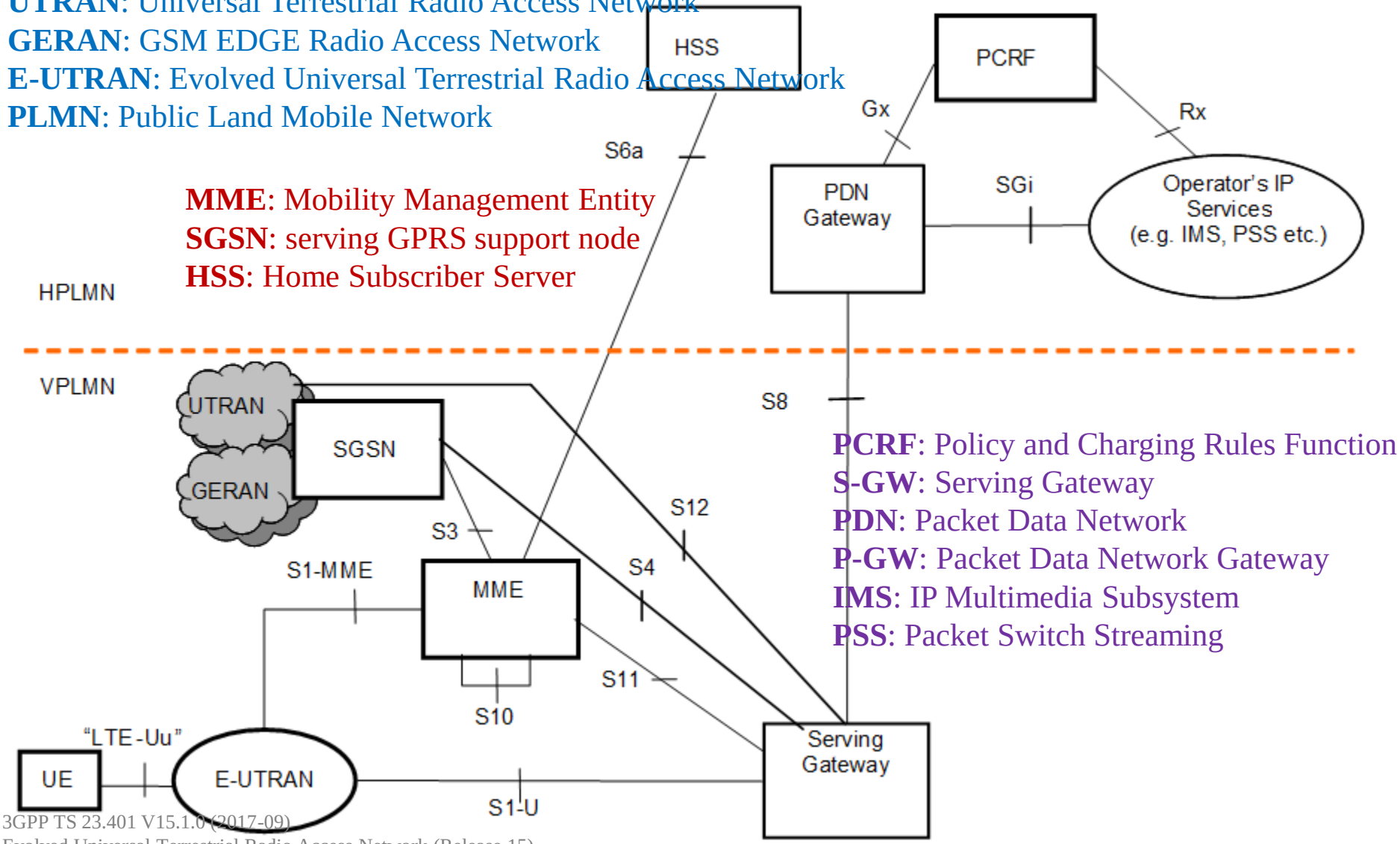
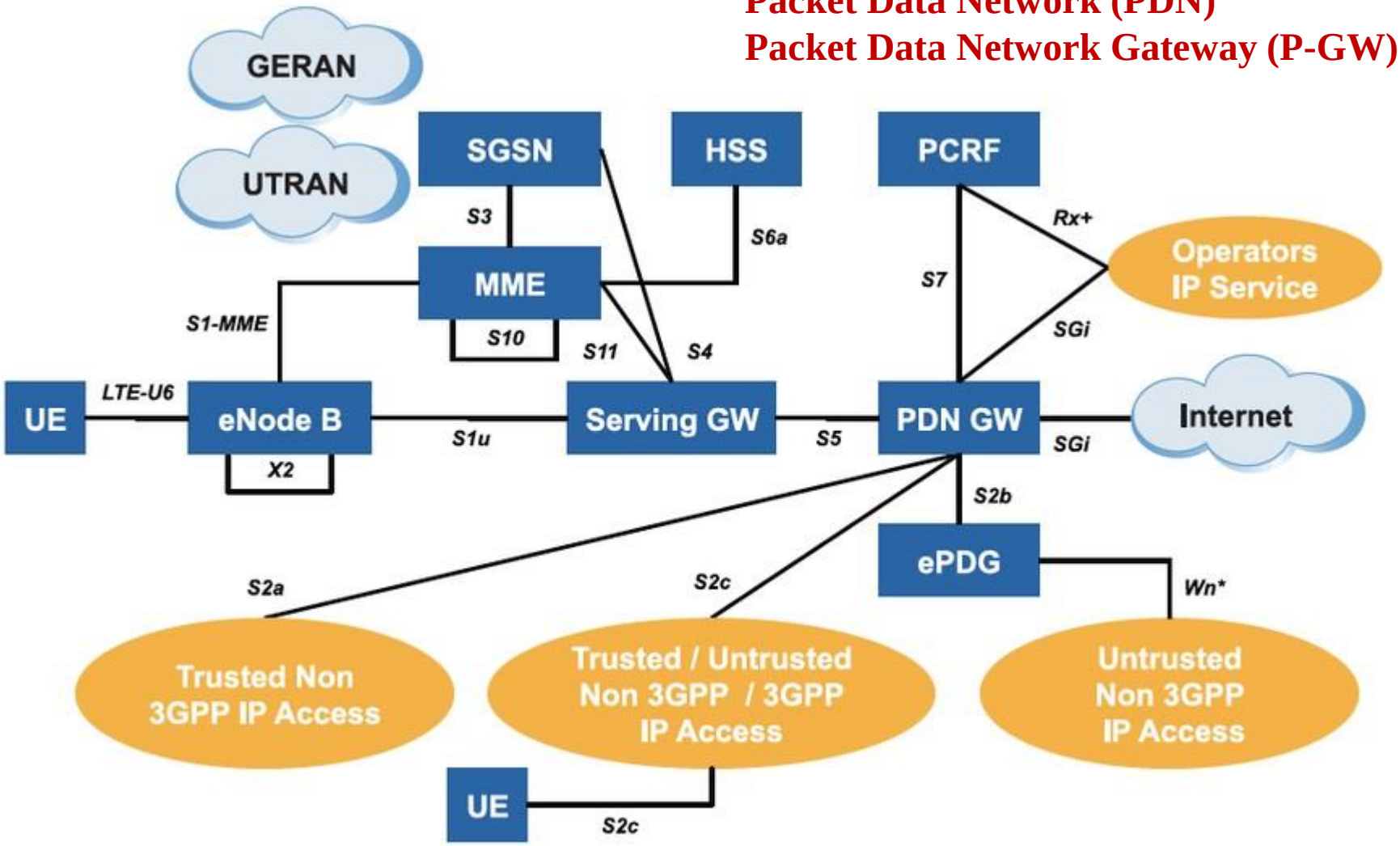


PCRF: Policy and Charging Rules Function
S-GW: Serving Gateway
PDN: Packet Data Network
P-GW: Packet Data Network Gateway
IMS: IP Multimedia Subsystem
PSS: Packet Switch Streaming

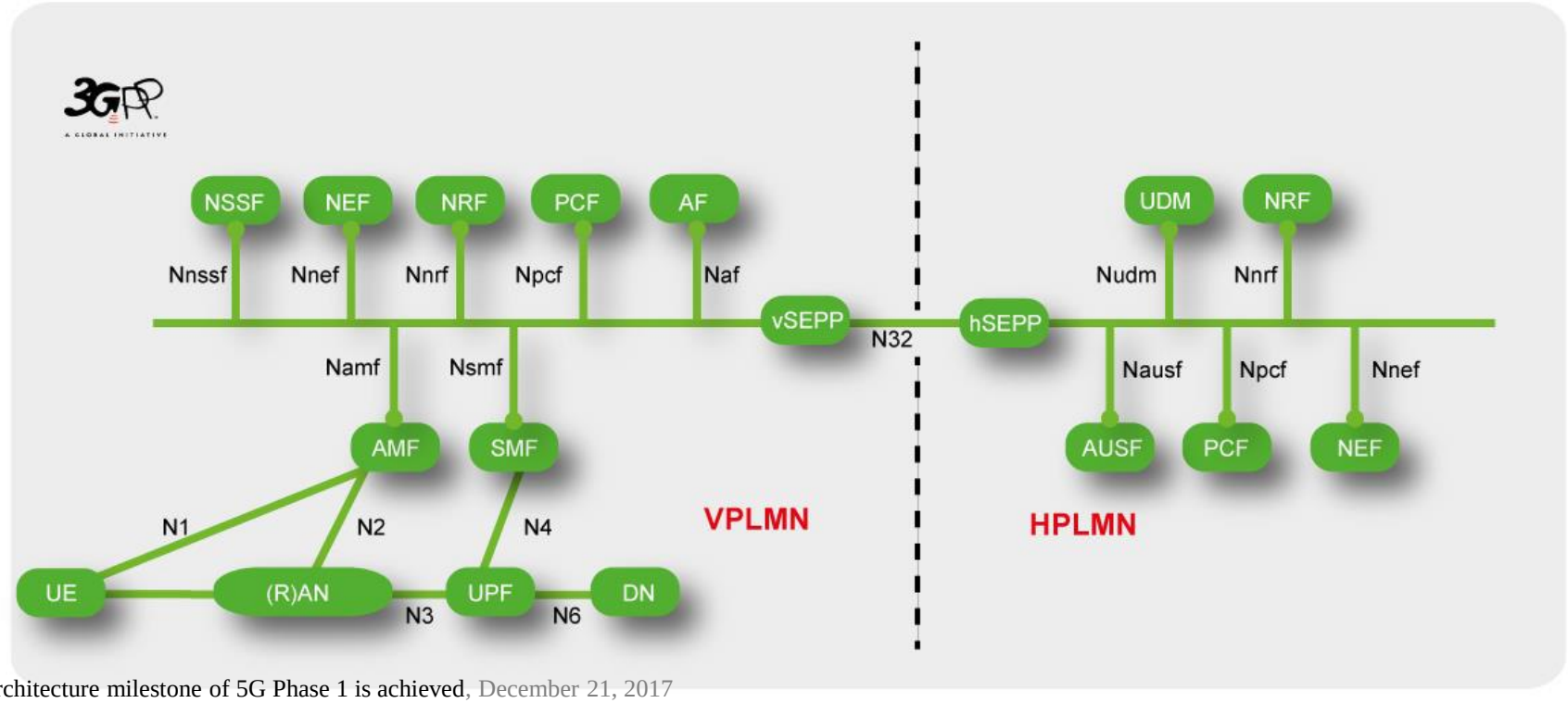
3GPP演进蓝图：4G网络架构
Non 3GPP IP Access

Mobility Management Entity (MME)
Serving Gateway (S-GW)
Packet Data Network (PDN)
Packet Data Network Gateway (P-GW)



3GPP演进蓝图：5G系统架构
Service Based Architecture

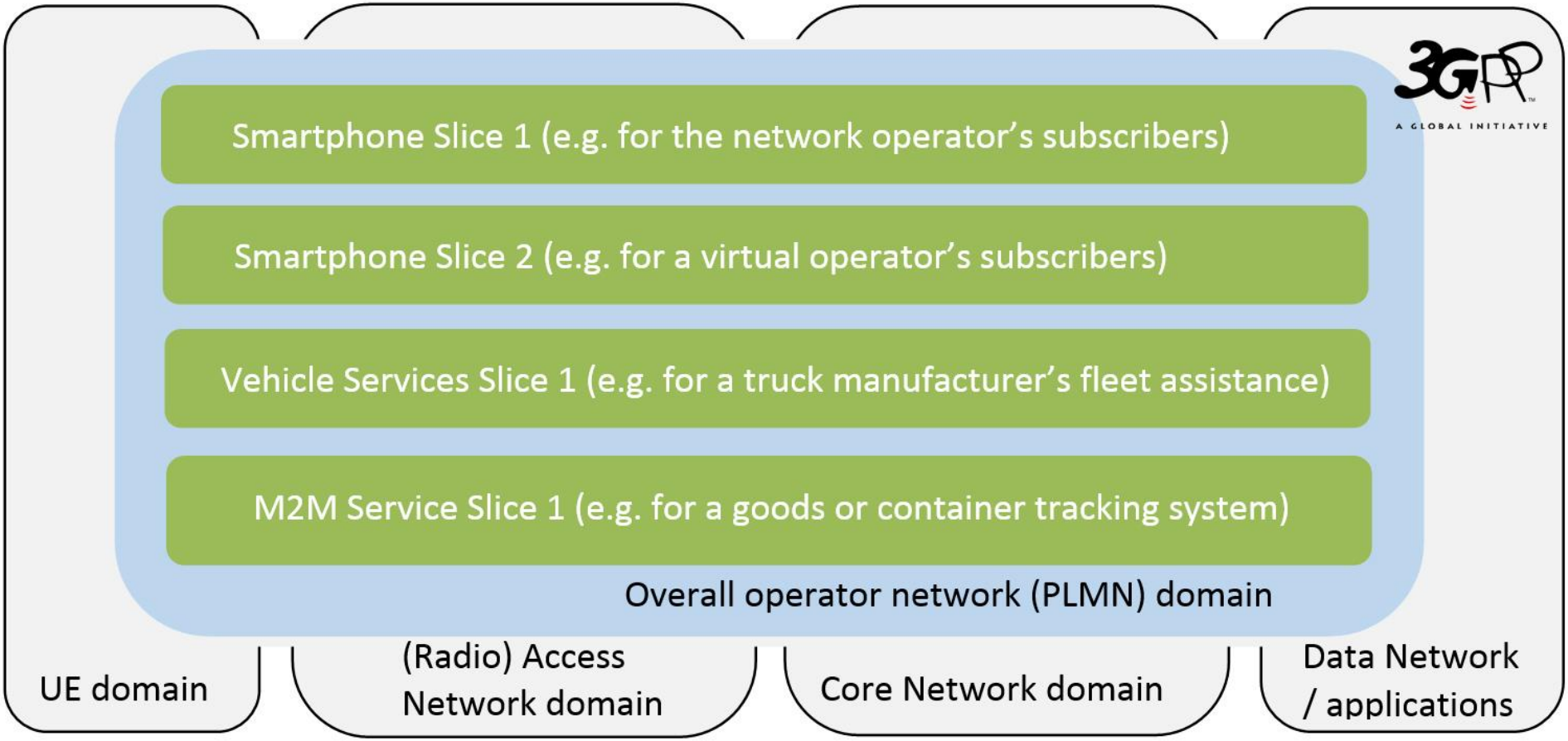
The roaming UE interfaces the Data Network (DN) in the visited network (VPLMN) and the home network (HPLMN) enables it with subscription information (UDM), subscriber authentication (AUSF) and UE specific policies (PCF). Network slice selection (NSSF), network access control and mobility management (AMF), data service management (SMF) and application functions (AF) are provided by the VPLMN. The user plane (UPF) is managed following a model of control and user plane separation similar to what was already introduced in the latest 3GPP 4G release. Security proxies (SEPP) protect the interactions between PLMNs.



System architecture milestone of 5G Phase 1 is achieved, December 21, 2017
https://www.3gpp.org/NEWS-EVENTS/3GPP-NEWS/1930-SYS_ARCHITECTURE Retrieved:20191110

3GPP演进蓝图：5G系统架构
Network Slicing

A distinct key feature of the 5G system architecture is network slicing.



System architecture milestone of 5G Phase 1 is achieved, December 21, 2017
https://www.3gpp.org/NEWS-EVENTS/3GPP-NEWS/1930-SYS_ARCHITECTURE Retrieved:20191110

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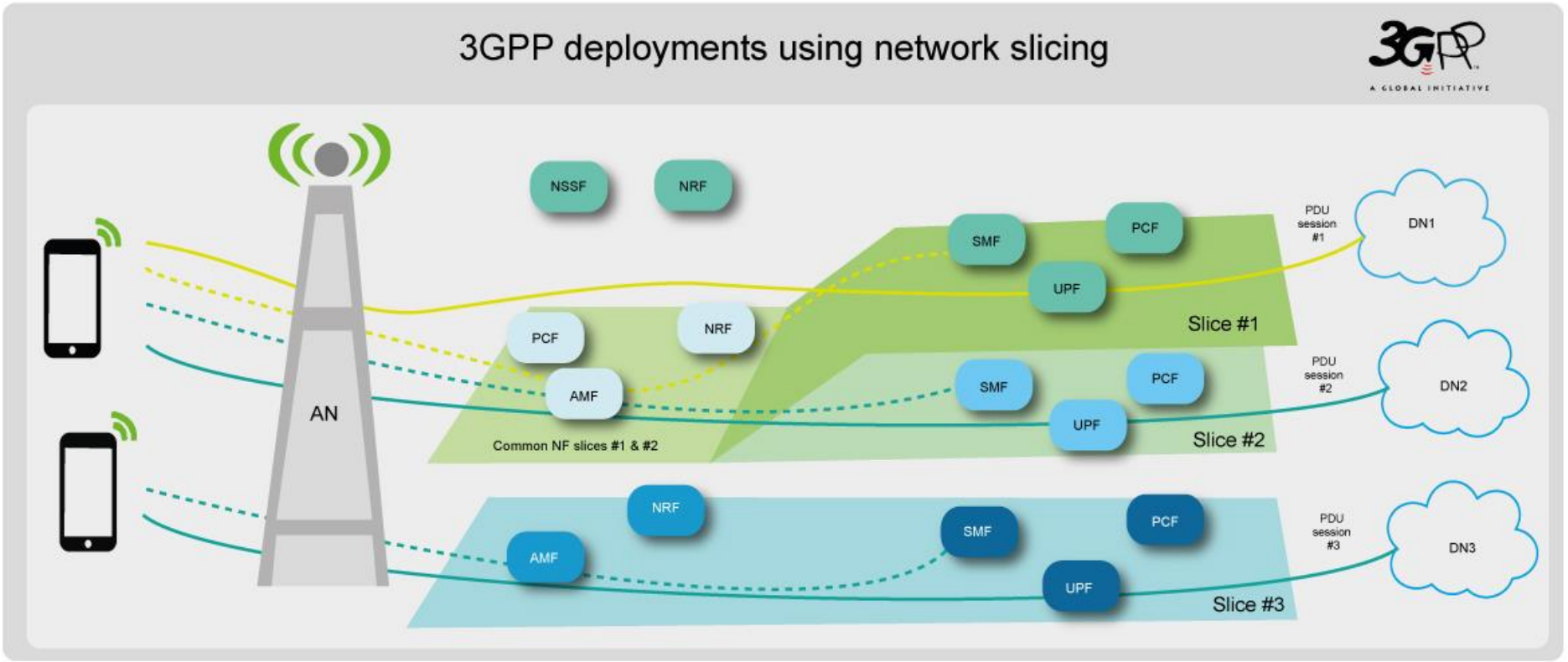
3GPP演进蓝图：5G系统架构
Deployment with Network Slicing

- **slice #3 is a straightforward deployment where all network functions serve a single network slice only.**
- **a UE receives service from multiple network slices, #1 and #2.**



System architecture milestone of 5G Phase 1 is achieved, December 21, 2017
https://www.3gpp.org/NEWS-EVENTS/3GPP-NEWS/1930-SYS_ARCHITECTURE Retrieved:20191110

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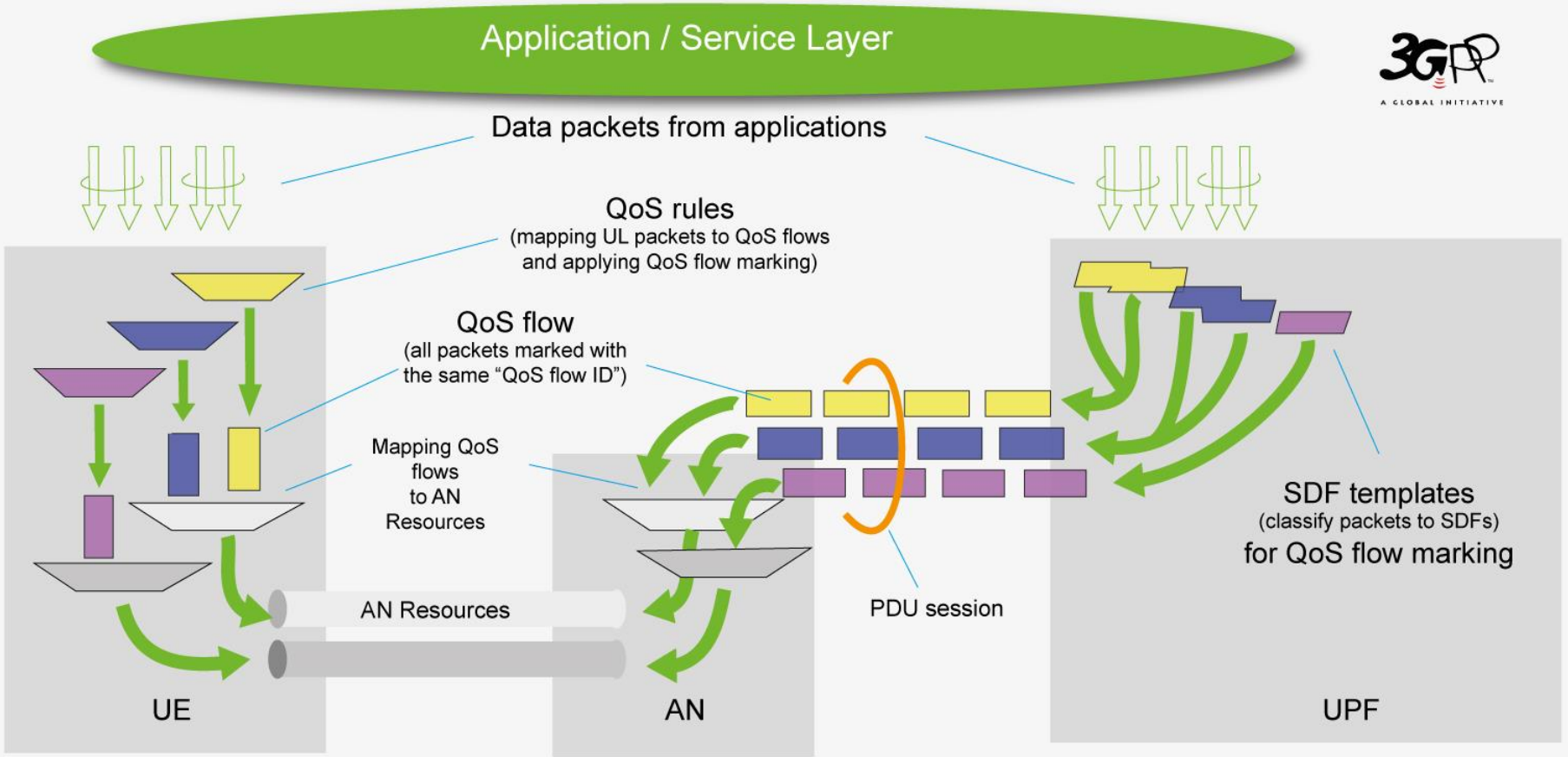
3GPP演进蓝图：5G系统架构
Application support



user plane (UPF)

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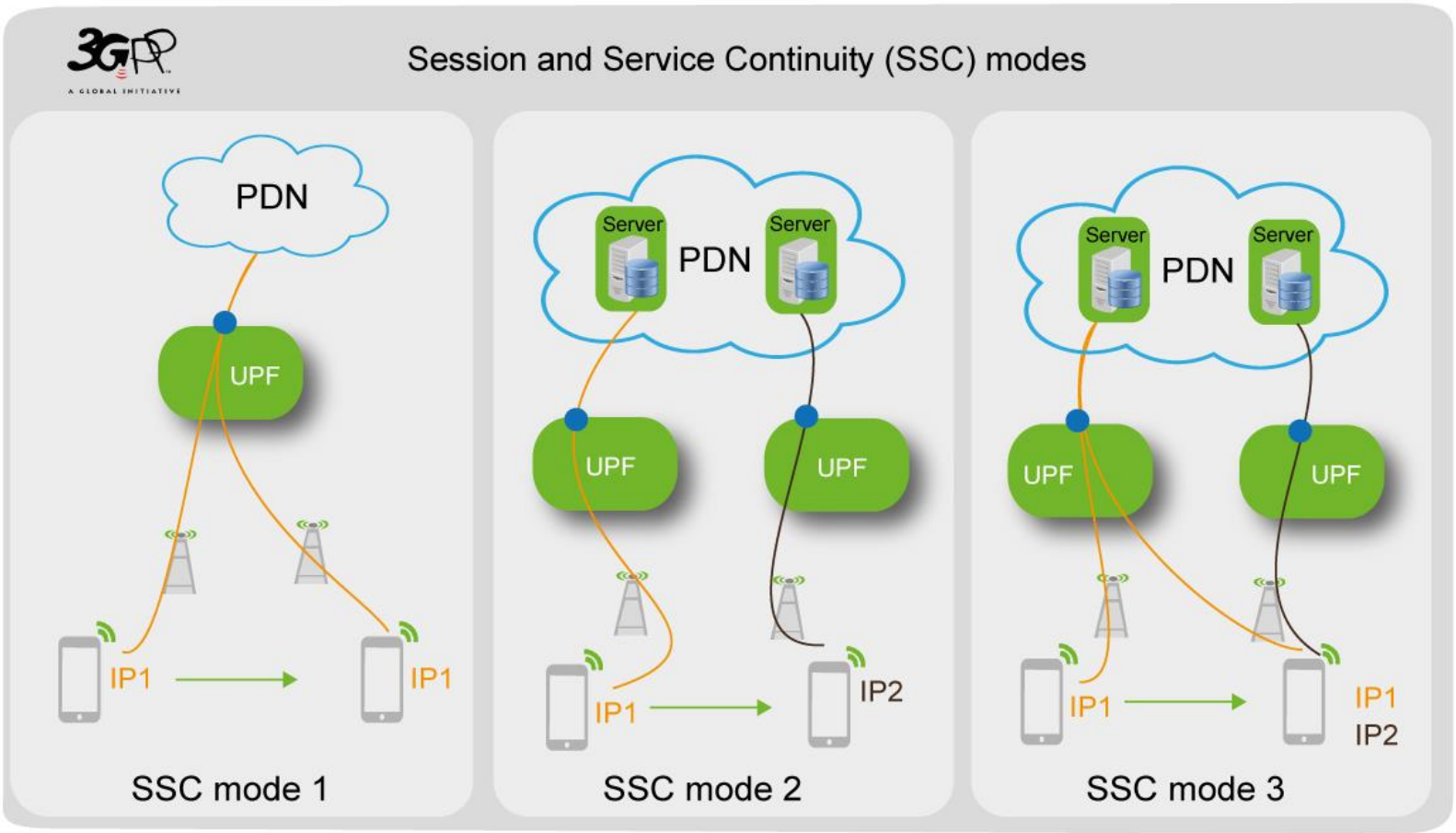
System architecture milestone of 5G Phase 1 is achieved, December 21, 2017
https://www.3gpp.org/NEWS-EVENTS/3GPP-NEWS/1930-SYS_ARCHITECTURE Retrieved:20191110

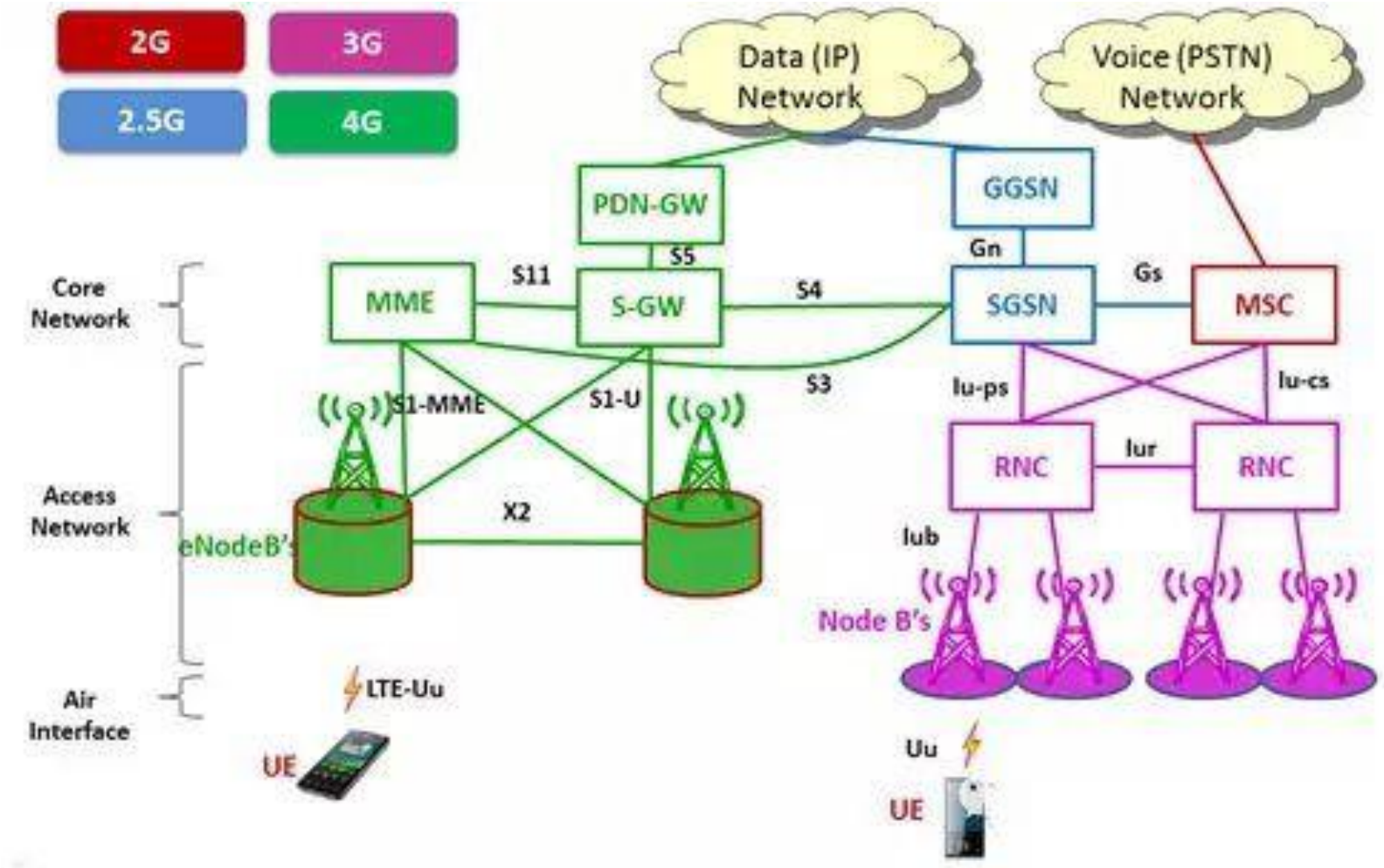
3GPP演进蓝图：5G系统架构
Session and Service Continuity (SSC) modes

The new modes allow for relocating the IP anchor. There are two options, make-before-break (SSC mode 3) and break-before-make (SSC mode 2).



System architecture milestone of 5G Phase 1 is achieved, December 21, 2017
https://www.3gpp.org/NEWS-EVENTS/3GPP-NEWS/1930-SYS_ARCHITECTURE Retrieved:20191110

3GPP演进蓝图：核心网2G/3G/4G并存



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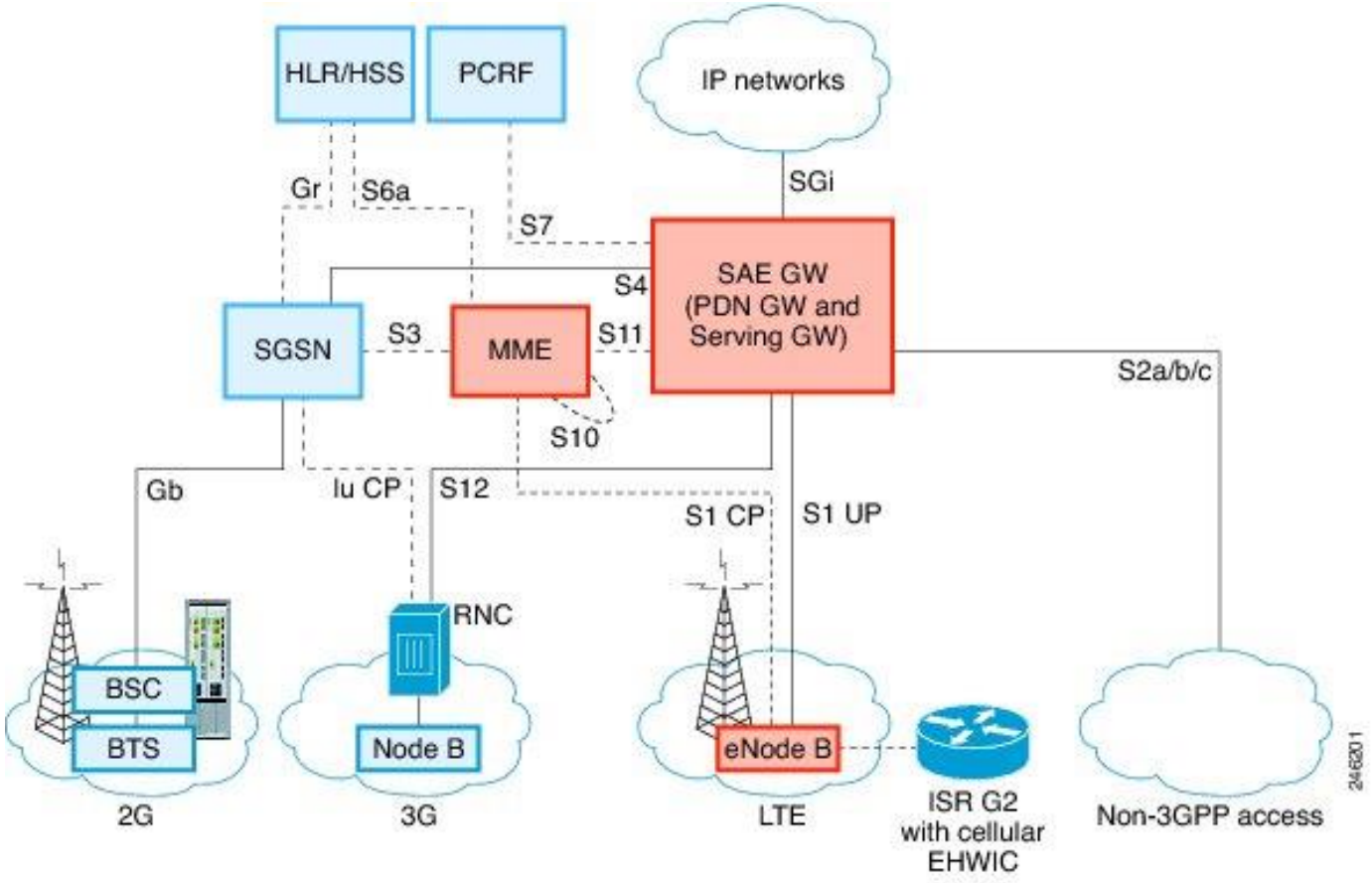
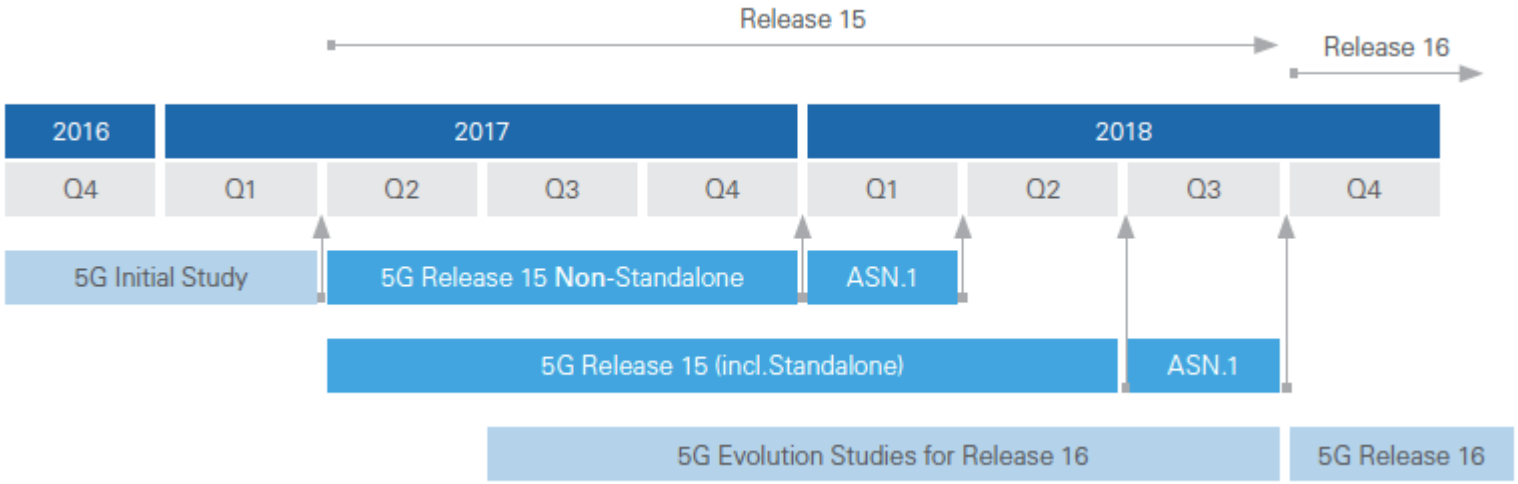
3GPP演进蓝图：网络架构
2G/3G/4G/Non-3GPP长期共存

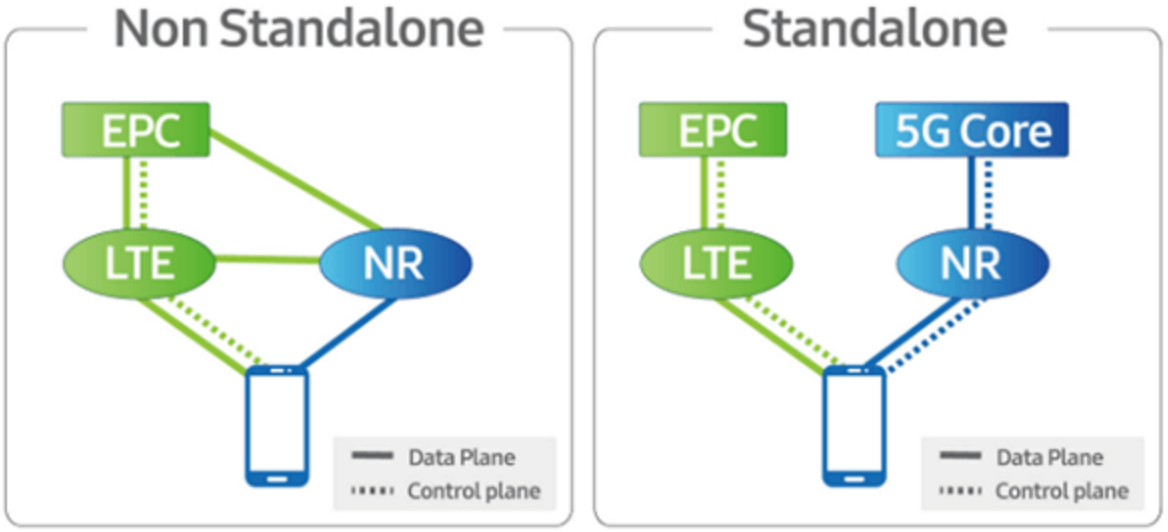
S-GW: Serving Gateway
P-GW: Packet Data Network Gateway
MME: Mobility Management Entity
SGSN: serving GPRS support node

HLR: Home Location Register
PCRF: Policy and Charging Rules Function
HSS: Home Subscriber Server



3GPP演进蓝图：网络架构
4G/5G长期共存





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小结：系统架构的演进

- **GSM**
  - BTS(Base Tranceiver Station)
  - BSS(Base station Controller)
  - **GPRS(general packet radio service)**
  - **GGSN (Gateway GPRS Support Node)**
  - **SGSN(serving GPRS support node)**
- **3G**
  - Node B
  - RNC (Radio Network Controllers)
  - **CS(Circuit Switched Domain)**
  - **PS(Packet Switched Domain)**
  - **IMS(IP Multimedia Subsystem)**
- **4G**
  - eNodeB
  - MME (Mobility Management Entity)
  - **EPC(Evoled Packet Core)**
- **5G**
  - **Service Based Architecture**
  - **Network Slicing**
  - **Application support**
- **2G/3G/4G/5G/Non-3GPP长期共存**

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小结：3GPP Release演进

- Release 99: 进入3G
- Release 5: IMS、HSDPA
- Release 6: HSUPA、MBMS
- Release 7: HSPA+
- Release 8: 进入4G?, LTE
- Release 9: MIMO、Dual-Cell HSDPA
- Release 10: Dual-Cell HSUPA
- Release 11: Hetnet、CoMP
- Release 12: 原定2014年冻结，实际2015.03冻结
  - MIMO, small cells, femtocells, M2M, Proximity Services (ProSe), SON, Heterogeneous Network (HetNet) mobility, Multimedia Broadcast/Multicast Services (MBMS), Local Internet Protocol Traffic Offload/Selected Internet Protocol Traffic Offload (LIPTO/SIPTO), Enhanced International Mobile Telecommunications Advanced (eIMTA) and Frequency Division Duplex-Time Division Duplex Carrier Aggregation (FDD-TDD CA).
- Release 13: 2016.03冻结
  - LTE in unlicensed spectrum, Carrier Aggregation enhancements, LTE enhancements for Machine-Type Communications (MTC), Enhancements for D2D, Elevation Beamforming / Full-Dimension MIMO, Enhanced multi-user transmission techniques, Indoor positioning, Single-cell Point-to-Multipoint (SC-PTM)
- Release 14: 2017-06-09冻结
- Release 15: 2019-06-07冻结，进入5G

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专题内容：移动通信网的现状与趋势

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  - 商用PLMN (Public Land Mobile Network)演进
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- 展望5G
  - 5G标准化组织
  - 5G解决什么问题?
  - 5G用什么技术?
  - 5G现状
  - 关于5G与未来网络的思考

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4.5G (LTE-Advanced Pro)

3GPP在2015年10月22日的PCG(Project Coordination Group,项目合作组)第35次会议上正式确定将LTE新标准命名为LTE-Advanced Pro。这是4.5G在标准上的正式命名。LTE-Advanced Pro包括正在进行标准化的LTE Release 13及后续版本的内容,主要特性有LAA(Licensed-Assisted Access)、3D/FD-MIMO(FD, Full Dimension)、NB-IoT(Narrow Band Internet of Things)、Massive Carrier Aggregation、Latency Reduction、Downlink Multiuser Superposition Transmission和SC-PTM(Single Cell-Point to Multi-point)等。

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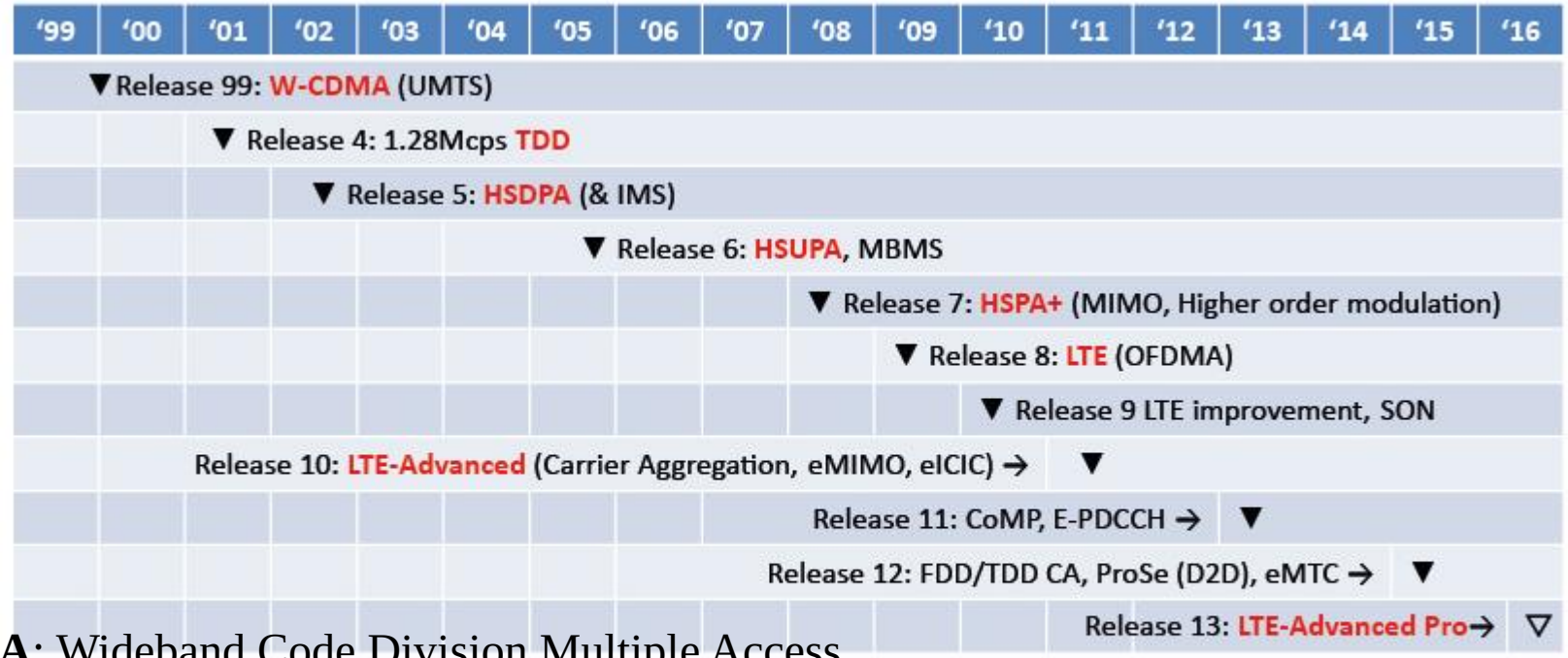
http://www.huawei.com/minisite/4-5g/cn/

3GPP标准的演进：Formal name & Release Radio Access Milestones

Review



- Expanding Carrier Aggregation
- Narrowband IoT
- Elevation Beamforming/Full-Dimension (FD) MIMO for LTE
- LAA

WCDMA: Wideband Code Division Multiple Access
TDD: Time Division Duplexing
HSPA+: High-Speed Packet Access+
HSDPA: High Speed Downlink Packet Access
HSUPA: High Speed Uplink Packet Access
LTE: Long Term Evolution
LTE-Advanced: enhancement of LTE
LTE-Advanced Pro: the next evolution of LTE

http://www.3gpp.org/about-3gpp/about-3gpp Retrieved:20171028

4.5G(Release 12/13)

- 简单的互联
- LTE与WLAN融合
  - LTE WLAN interworking（数据分流）
  - LTE WLAN aggregation（数据聚合）
    - LWA: LTE-WLAN Aggregation
    - LWIP: LTE WLAN Radio Level Integration with IPsec Tunnel
- LTE对物联网的支持
  - Low Power Wide Area Network(LPWAN)
  - IoT in 3GPP Release 13
    - EC-GSM-IoT(Extended Coverage-GSM)
    - eMTC(LTE-M, Low-Cost MTC)
    - NB-IOT

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  - 5G现状
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RAN LTE-WLAN Inter-working
3GPP定义了6 种LTE与WLAN融合的场景

- *3GPP system based Access Control*: The user faces control procedures (authentication and authorization) similar for WLAN as within the 3GPP domain.
- *3GPP system based Access Charging*: This capability enables that the 3GPP charging mechanism can be reused for WLAN.
- *Access to 3GPP system PS based services from WLAN*: The user is offered access to the same PS based services over WLAN as may be accessed via the 3GPP system.
- *Service continuity*: services will survive the process of change of access network technology between WLAN and a 3GPP system.
- *Seamless service continuity*: to provide seamless service continuity between the access technologies by minimizing aspects such as data loss and break time during the switch between access technologies.
- *Access to 3GPP system CS based Services with seamless mobility*: to allow the operator to grant access to 3GPP system CS based services through the WLAN.

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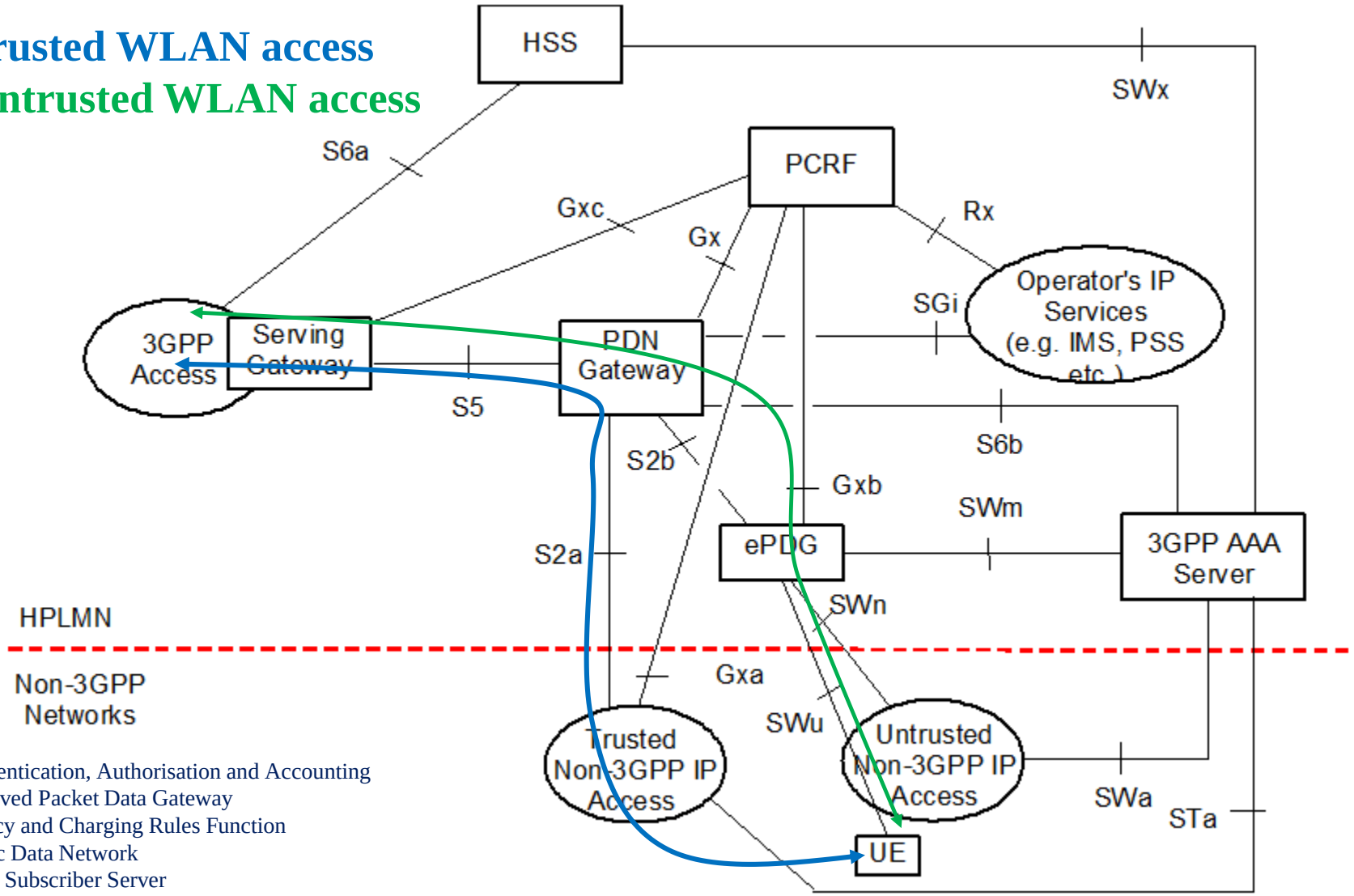
3GPP TR 22.934, Feasibility study on 3GPP system to Wireless Local Area Network (WLAN) interworking (Release 13)

RAN LTE-WLAN Inter-working示例

Non-Roaming Architecture within EPS using S5, S2a, S2b

S2a: Trusted WLAN access

S2b: Untrusted WLAN access



AAA: Authentication, Authorisation and Accounting
ePDG: Evolved Packet Data Gateway
PCRF: Policy and Charging Rules Function
PDN: Public Data Network
HSS: Home Subscriber Server

3GPP TS 23.402, Architecture enhancements for non-3GPP accesses (Release 13)

小结：RAN LTE-WLAN Inter-working

- Rel-8阶段起步
  - ePDG: Evolved Packet Data Gateway
  - S2a 针对授信的WLAN 接入
  - S2b 针对非授信的WLAN 接入
  - S2c 则可以兼容授信和非授信的WLAN 接入
- Rel-9: MAPIM
  - MAPCON: mutiple access PDN connetion
  - IFOM: IP flow mobility
- Rel-10:
  - Access network discovery and selection function (ANDSF)
- Rel-11：SaMOG
  - TWAG/TWAP

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  - 5G现状
  - 关于5G与未来网络的思考

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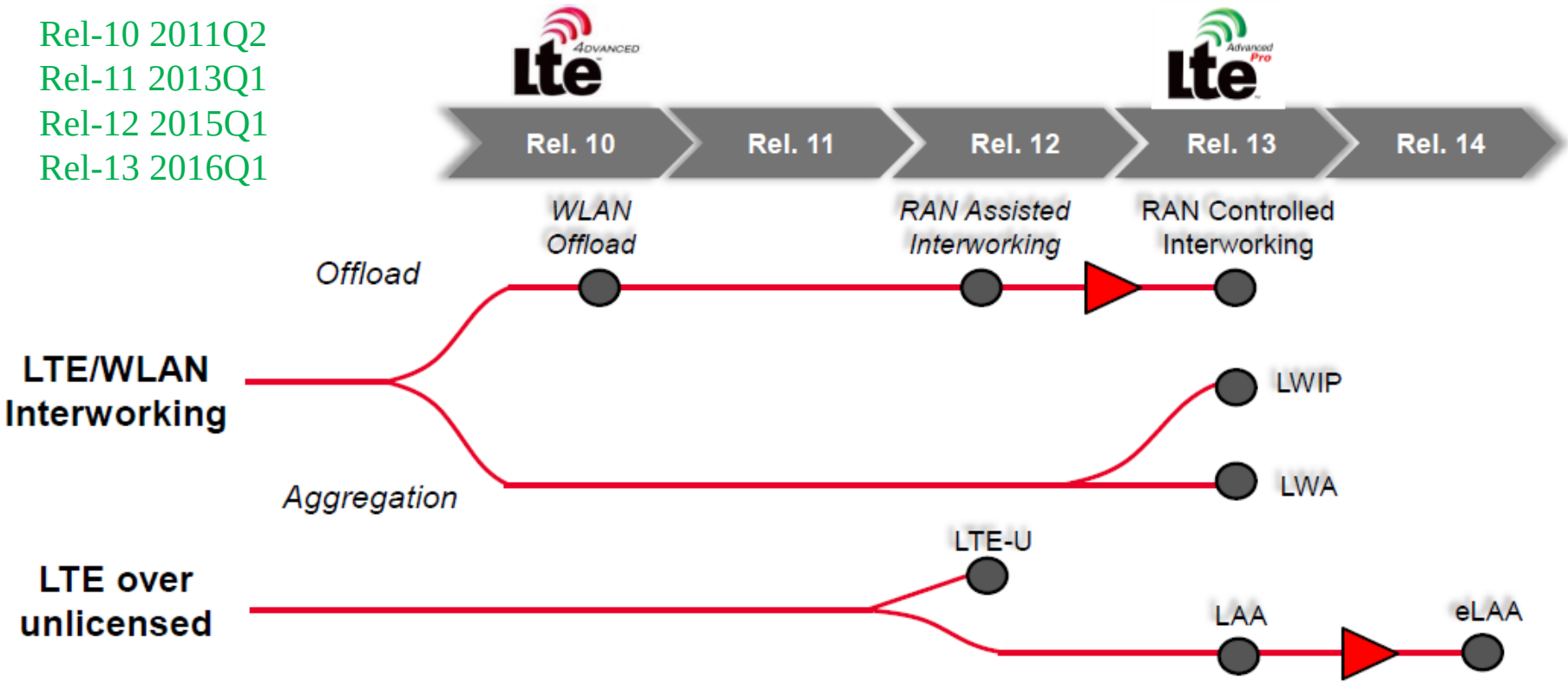
3GPP LTE/WLAN融合方案的进展

Rel-10 2011Q2
Rel-11 2013Q1
Rel-12 2015Q1
Rel-13 2016Q1



LWA (LTE-WLAN Aggregation)
LWIP (LTE WLAN Radio Level Integration with IPsec Tunnel)
LTE-U (LTE-Unlicensed)
LAA (Licensed Assisted Access)

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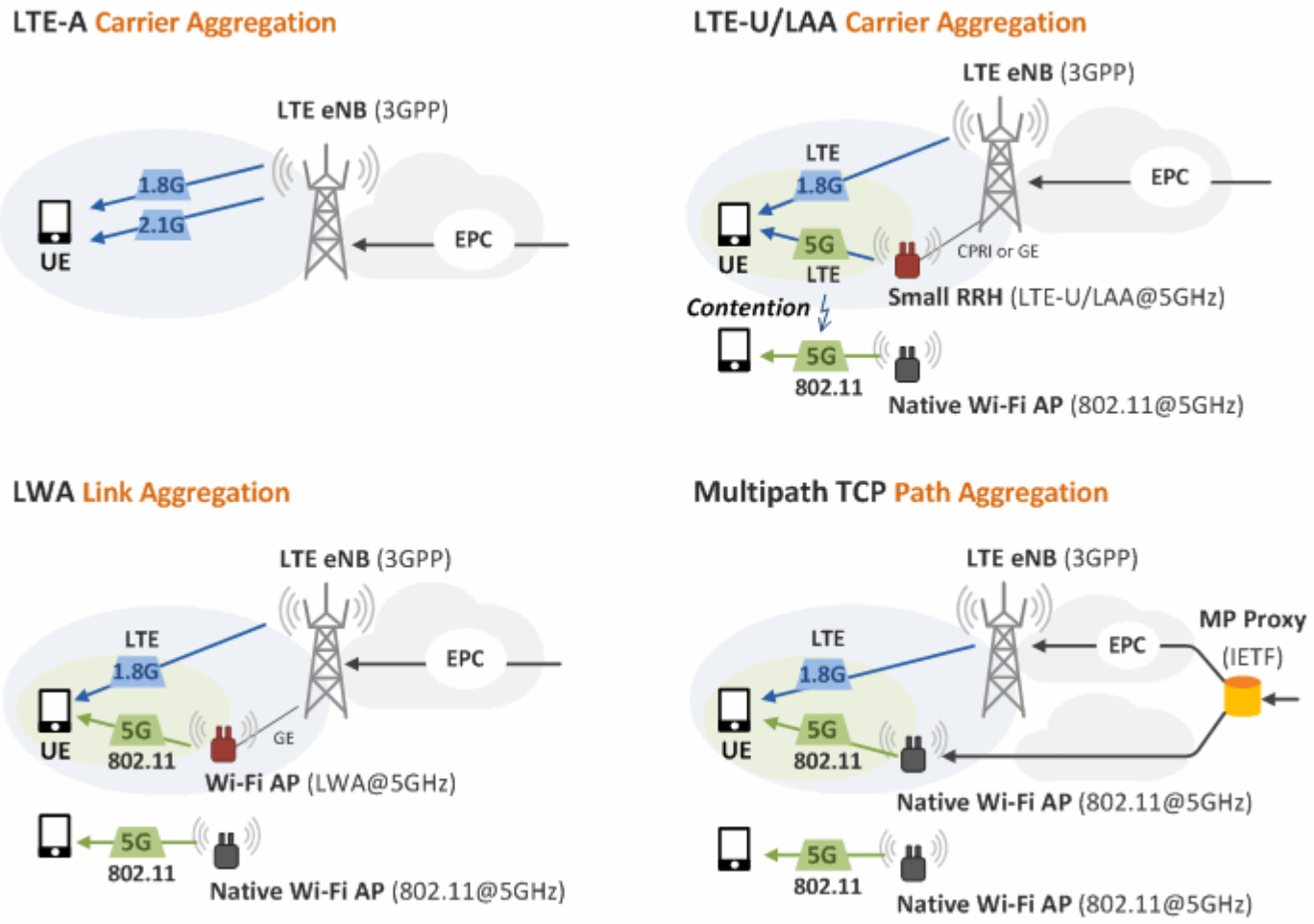
LTE与WLAN融合的可能方式

链路层



传输层

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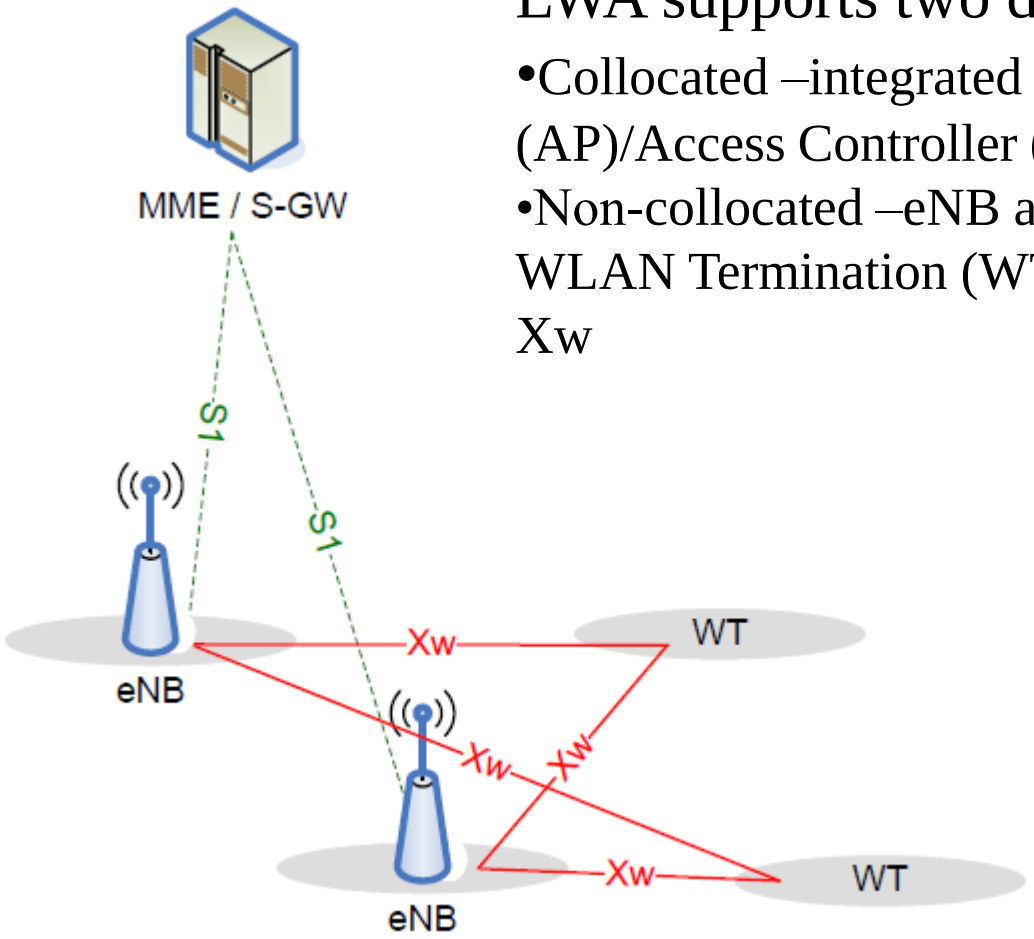
LWA: Network Architecture
LWA (LTE-WLAN Aggregation)



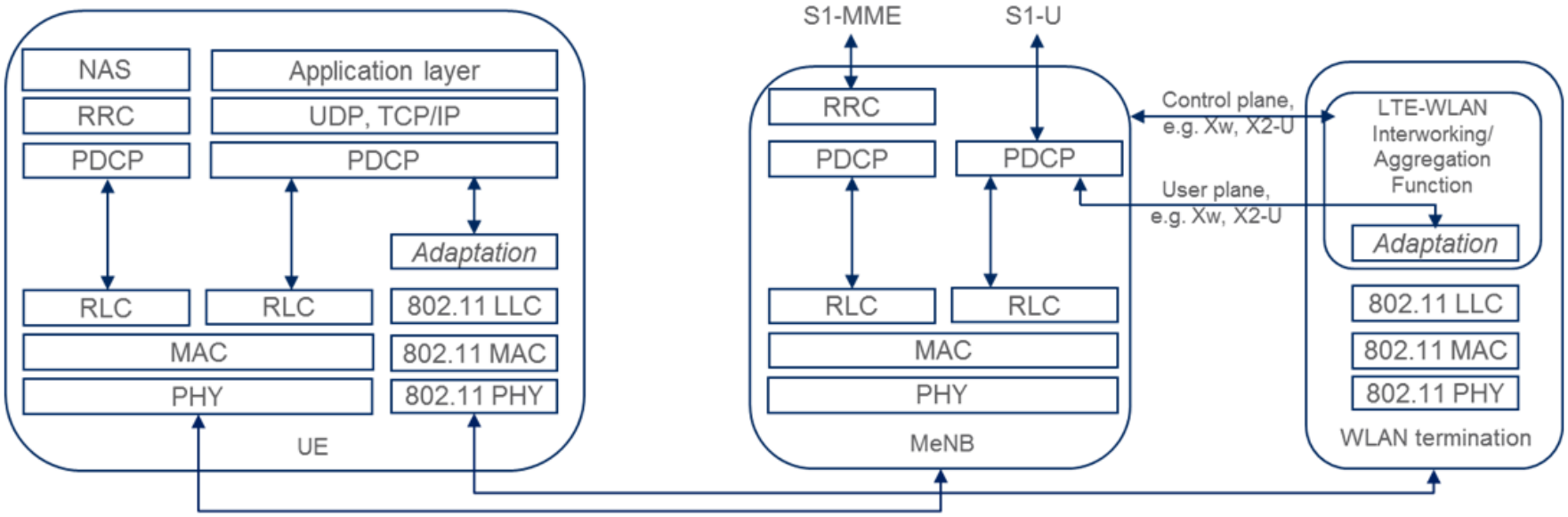
LWA supports two deployment scenarios:

- Collocated –integrated eNB and WLAN Access Point (AP)/Access Controller (AC)
- Non-collocated –eNB and WLAN AP/AC connected via WLAN Termination (WT) using standardized interface Xw

LWA: Data Plane
LWA: Control Plane

- In Release-13, LWA supports aggregation in downlink only, while uplink transmission is always on LTE
- PDCP PDUs sent via WLAN are encapsulated in LWA Adaptation Protocol (LWAAP) which carries bearer identity
- LWA activation and deactivation are controlled by eNB
- eNBconfigures WLAN mobility set for UE

在PDCP子层融合



Licensed-Assisted Access

LTE-WLAN aggregation, introduced in Release 13, is another area where protocols will be enhanced in Release 14. Release 13 supports LTE-WLAN aggregation for the DL. Release 14 will allow aggregation for the **UL** as well. Additional information collection and feedback (e.g., better estimation of available WLAN capacity) as well as automatic neighbor relation procedures are to be introduced to improve performance.

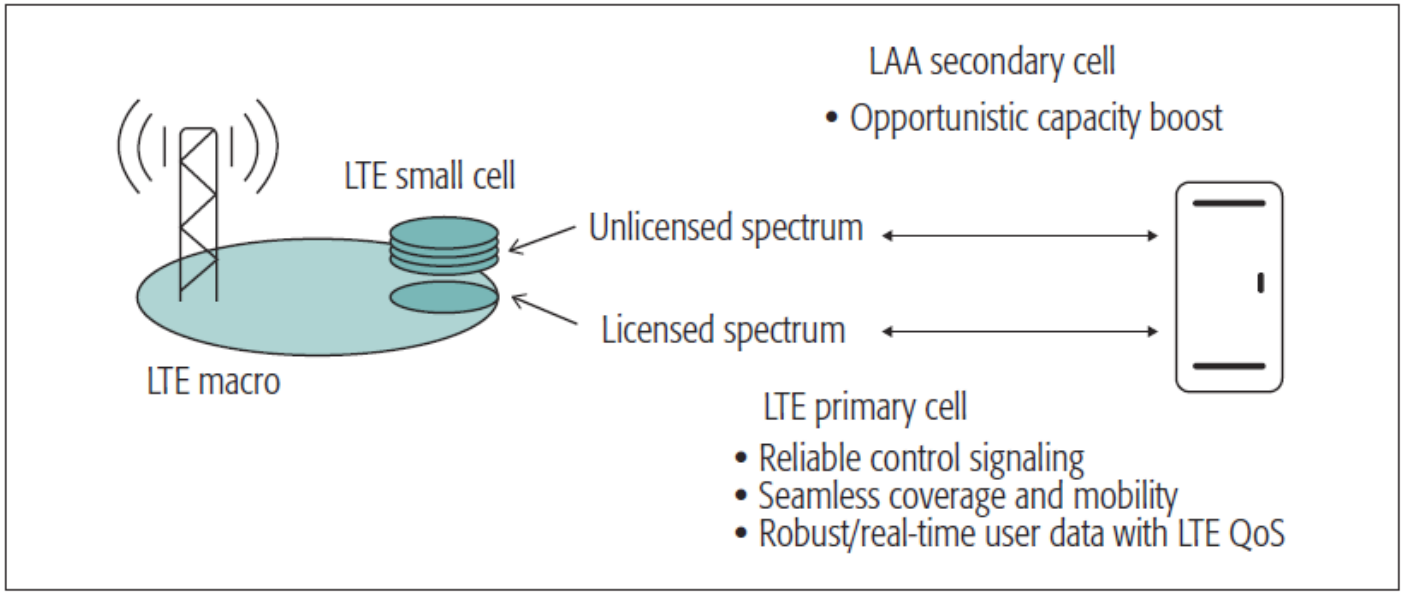


Figure 2. LAA enabling transmissions on secondary cell(s) operated in unlicensed spectrum controlled from a primary cell operating in licensed spectrum using carrier aggregation.

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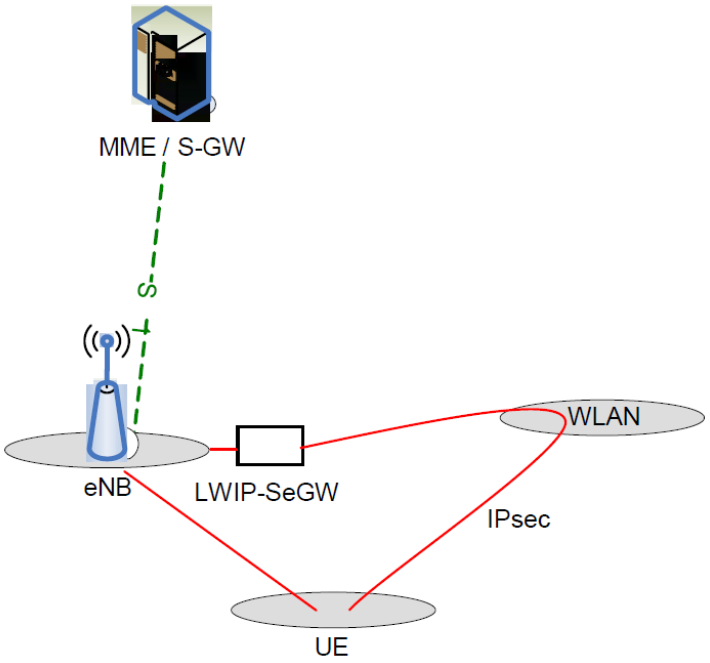
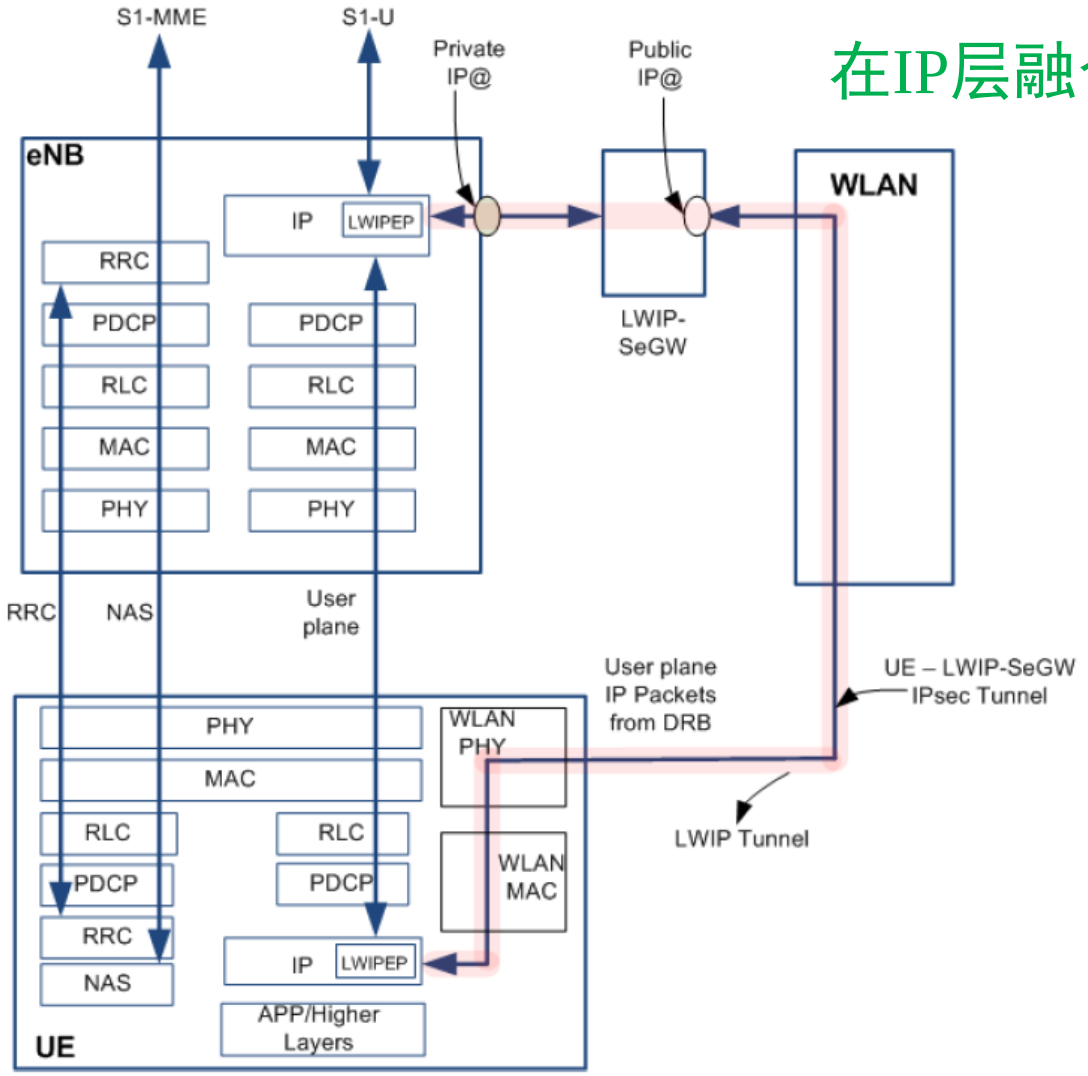
Hoymann, C., et al. (2016). "LTE release 14 outlook." IEEE Communications Magazine 54(6): 44-49.

LWIP
(LTE WLAN Radio Level Integration with IPsec Tunnel)

- UE uses WLAN via IPsec tunnel between eNB and UE
- WLAN is hidden from CN
- LWIP is controlled by eNB, based on UE measurement reporting
- For security reasons IPsec tunnel is terminated in LWIP-SeGWin eNB
- IPsec tunnel is transparent to WLAN infrastructure
- Single IPSec tunnel per UE for UL and DL data



LWIP: Data Plane



- Uplink and downlink data supported over WLAN
- Multiple bearers can be offloaded via IPSec
- In uplink, PDCP SDUs are encapsulated in Generic Routing Encapsulation (GRE) protocol
- No re-ordering support: eNB in DL and UE in UL are not expected to send packets on a data radio bearer via LTE and WLAN simultaneously

小结：LTE与WLAN融合

Unified Network (LTE – WLAN) ⟷ | Single RAT (LTE) ⟷

	RALWI	RCLWI	LWA	LWIP	LTE-U	LAA
Complete name	RAN Asissted LTE-WLAN Interworking	RAN Controlled LTE-WLAN Interworking	LTE WLAN Aggregation	LTE WLAN Integration with IP Tunneling	LTE Unlicensed	License Assisted Access
3GPP Release	12	13	13	13	12*	13
Infrastructure	EPC + legacy WLAN	EPC + legacy WLAN	EPC + WLAN	EPC + legacy WLAN	EPC	EPC
WLAN relation	Offload	Offload	Aggregation	Aggregation	co-existence	co-existence
Co-existence	CSMA	CSMA	CSMA	CSMA	CSAT	LBT
Aggregation layer	IP	IP	PDCP	IP	MAC	MAC
DL and/or UL	DL and UL	DL and UL	DL only	DL (and UL)	DL only	DL only

⟷ LTE-WLAN Offload | ⟷ LTE-WLAN Aggregation | ⟷ LTE Carrier Aggregation

LAA(Release 14): Licensed-Assisted Access

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低功耗广域网络
Low Power Wide Area Network(LPWAN)

LPWAN是为物联网应用中的M2M通信场景优化的，由电池供电的，低速率、超低功耗、低占空比的，以星型网络覆盖的，支持单节点最大覆盖可达100公里的蜂窝汇聚网关的远程无线网络通讯技术。LPWAN尚未形成统一的标准，Sigfox, LoRa, Telensa, PTC等都是比较典型的LPWAN技术。

- Traffic information
- eCall

Vehicle telematics

- Irrigation control
- Environment sensing
- Animal tracking

Agriculture

- Motorcycles, bicycles
- Cars
- Truck trailers
- Shipping containers
- Kids, pets
- Insurance – valuable assets
- Find my stuff

Tracking

- Smart grids

Energy/Smart grid

- Electric
- Water
- Gas
- Heat
- Infrastructure & production

Smart metering

- Earthquake sensors
- Avalanche and flooding
- Heating and AC
- Equipment status
- Forest fires
- Air pollution

Environment & Industrial

- Traffic sensors & control
- Street lighting
- Infrastructure monitoring
- Trash and waste containers
- Public events – location services
- Advertising displays
- ATM's, vending machines
- Smart parking

Smart city

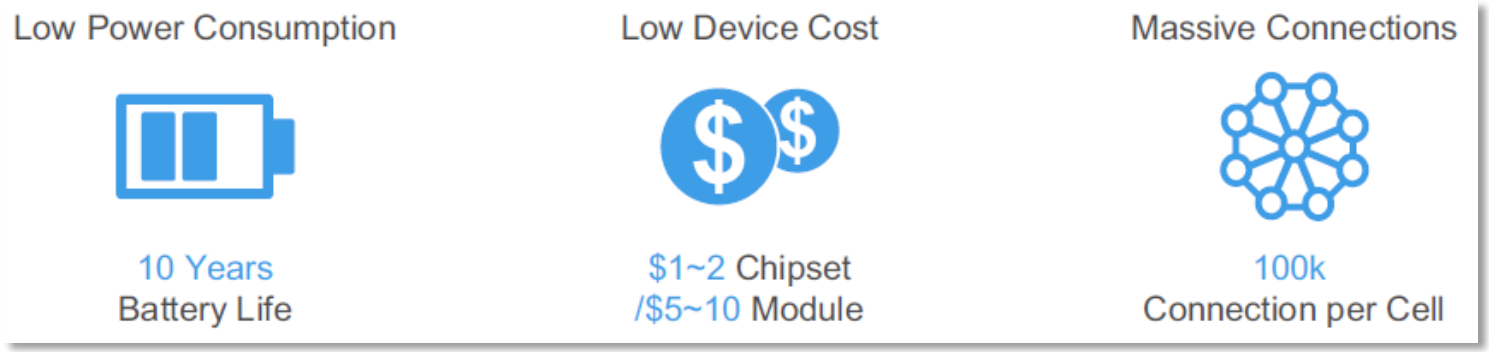
- Smoke detectors
- Security systems
- Smart appliances
- Smart heat
- Control/monitoring
- Video surveillance

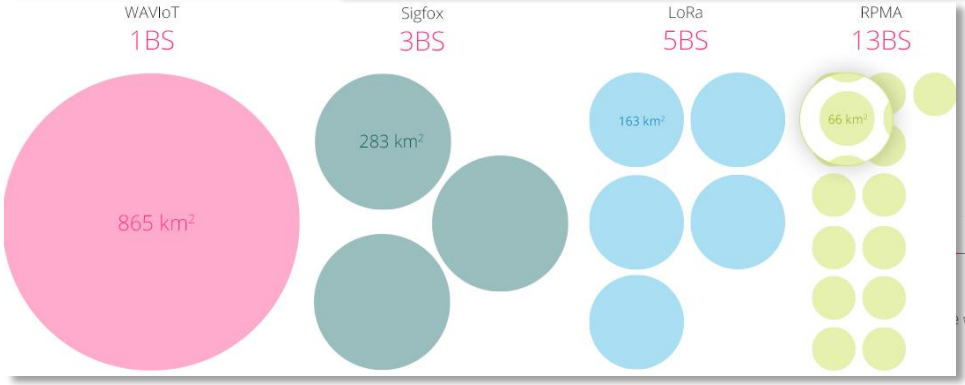
Secure/Smart home

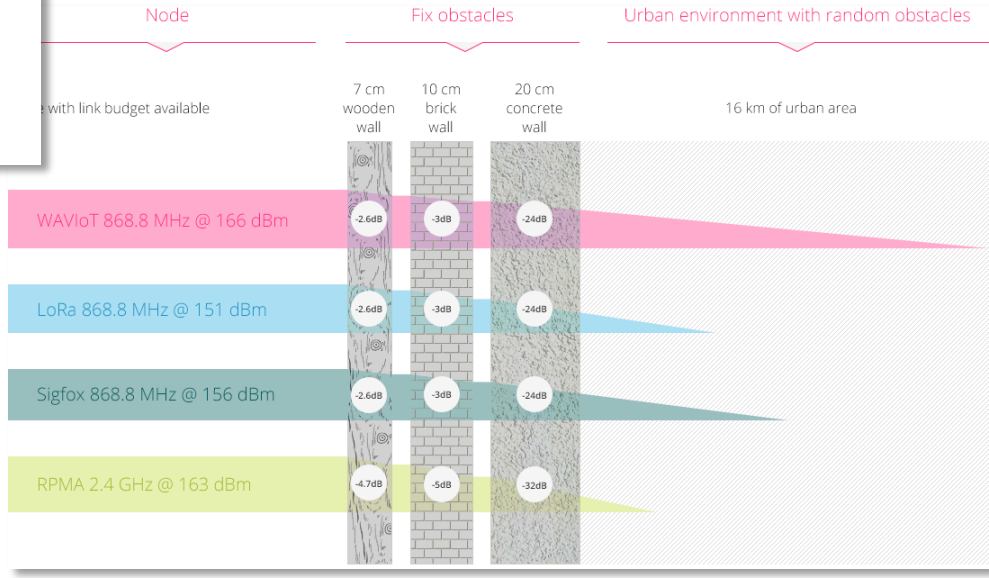
- Medical wearable's

mHealth

LPWAN的特点


Low Power Consumption
10 Years
Battery Life
Low Device Cost
$1~2 Chipset
/$5~10 Module
Massive Connections
100k
Connection per Cell


WAVIoT
1BS
865 km²
Sigfox
3BS
283 km²
LoRa
5BS
163 km²
RPMA
13BS
66 km²


Node
Fix obstacles
Urban environment with random obstacles
with link budget available
7 cm wooden wall
10 cm brick wall
20 cm concrete wall
16 km of urban area
WAVIoT 868.8 MHz @ 166 dBm
LoRa 868.8 MHz @ 151 dBm
Sigfox 868.8 MHz @ 156 dBm
RPMA 2.4 GHz @ 163 dBm
-2.6dB
-3dB
-24dB
-4.7dB
-5dB
-32dB

有哪些可用的LPWAN技术？

- **LoRaWAN**
- **3GPP LTE-MTC (release 12)→ LTE-eMTC (release 13)**
- DASH7
- RPMA(ingenu)
- WAViot
- Telensa
- Nwave
- Sigfox
- Weightless
- ……

Low Power Wide Area Networks: A Survey
https://arxiv.org/pdf/1606.07360.pdf
http://cms.edn.com/ContentEETimes/Documents/EDN/LP%20WAN%20Comparison%20Table%20final.pdf

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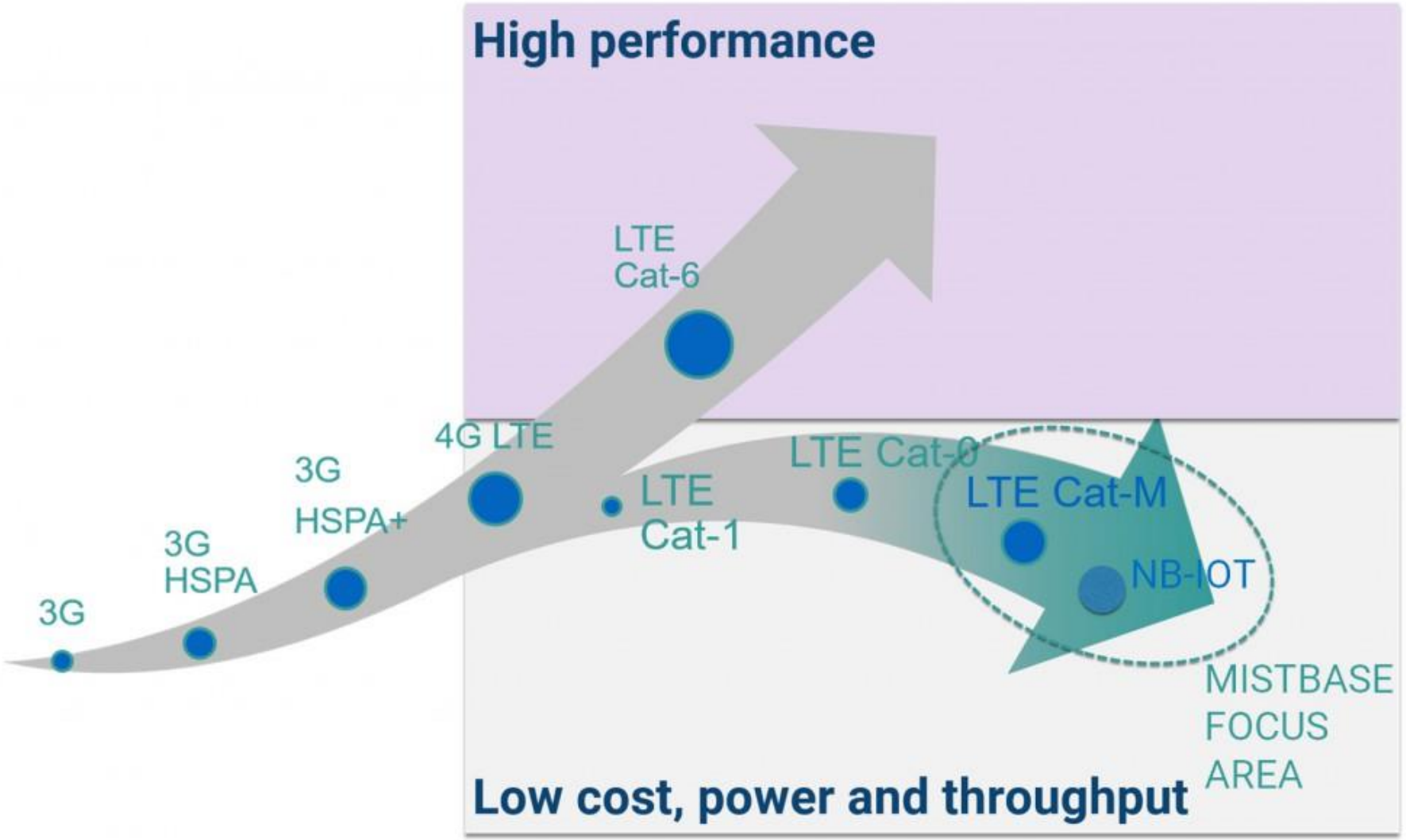
部分LPWAN的技术参数概览

Technology	WAVIoT NB-Fi	Link Labs LoRa	Sigfox UNB	Ingenu RPMA	Nwave Weightless	LTE-M
Frequency	868.8 MHz	868.8 MHz	868.8 MHz	2.4 GHz	868.8 MHz	1.8 - 2.7GHz
Max urban range with 99% reliability, m.	16 600	7 200	9 500	4 600	4 100	640
Maximum link budget, dBm	166	151	156	163	147	147
Node bandwidth	100 Hz	125 kHz	100 Hz	1 MHz	200 Hz	192 kHz
Spectrum efficiency	High	Very Low	Low	Medium	Low	High
Gateway mode	Full Duplex	Half Duplex	Half Duplex	Half Duplex	Uplink Only	Full Duplex
Nodes per gateway	1 350 000	40 000	50 000	500 000+	50 000	20 000
Scalability	High	Very Low	Low	High	Low	High
Simultaneous demodulation capacity	120 000	8	25	4 000	25	64
Security	XTEA 256 bit	32 bit	16 bit	AES 128 bit	No	128 - 256 bit
Minimum node cost, USD	$1.99	$29.00	$1.99	$5.00	$19.00	$5.00
Battery lifetime	10 years	10 years	10 years	10 years	10 years	5 years
Sector antennas	Yes	No	No	No	No	Yes
Commercial Deployment	100+	100+	100+	30	10	N/A until 2020
First commercial project	2011	2014	2010	2010	2013	2020

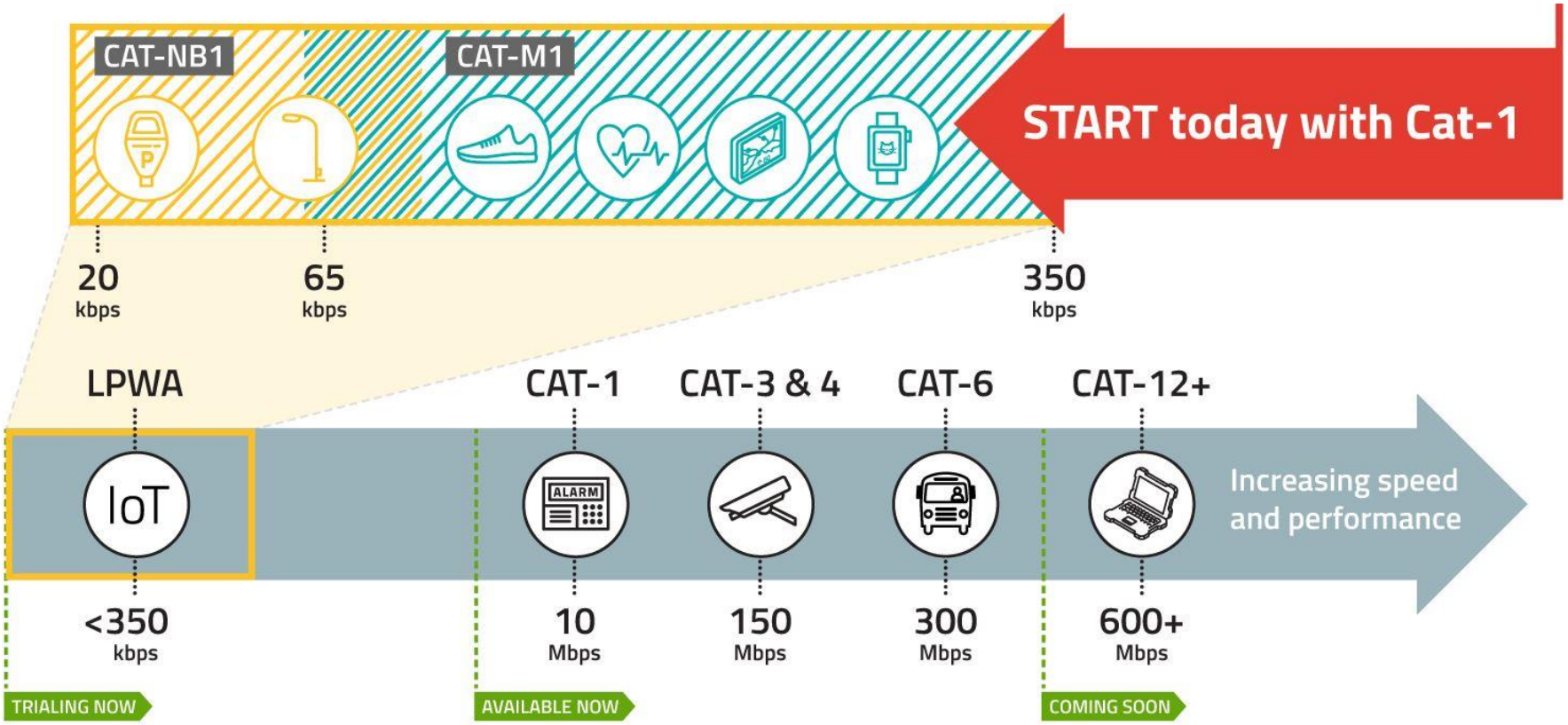
部分LPWAN的技术参数概览

	Wi-SUN	SIGFOX	LoRa	EC-GSM	CAT-M1	CAT-NB1
Available	Y	Y (EU,NA)	Y	Y	2017	2017->
Deployment	Private	SIGFOX	Private/MO	Mobile operator/software upgrade		
Specification	802.15.4	ETSI LTN (exp. YE'17)	LoRaWAN	3GPP	3GPP	3GPP (exp. YE'16)
TX up (dBm)	>=-3	14	14	23/33	20/23	23
Bandwidth up	200–400–600 KHz	100/600 Hz (EU/NA)	125–500 KHz	200 KHz	1.08 MHz	200 KHz
Modulation	FSK	DBPSK up GFSK down	Chirp spread spectrum	GMSK	π/2 BPSK π/4 QPSK	QPSK QAM
Data rate up	50 Kb/s to 300 Kb/s	100 bps (EU) 600 bps (NA)	0.3 kb/s to 50 kb/s	70 kb/s	375 Kb/s	65 kb/s
Band	Unlicensed, sub-GHz IMS band (433 MHz and 868 MHz in EU, 928 MHz in NA)			2G	LTE	2G and LTE

3GPP逐步向2个方向发展



3GPP在2个方向的演进



CAT-?　　←移动终端的类型

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User Equipment (UE) categories

Note: Maximum datarates shown are for 20 MHz of channel bandwidth. Category 6 and above include datarates from combining multiple 20 MHz channels. Maximum datarates will be lower if less bandwidth is utilized.

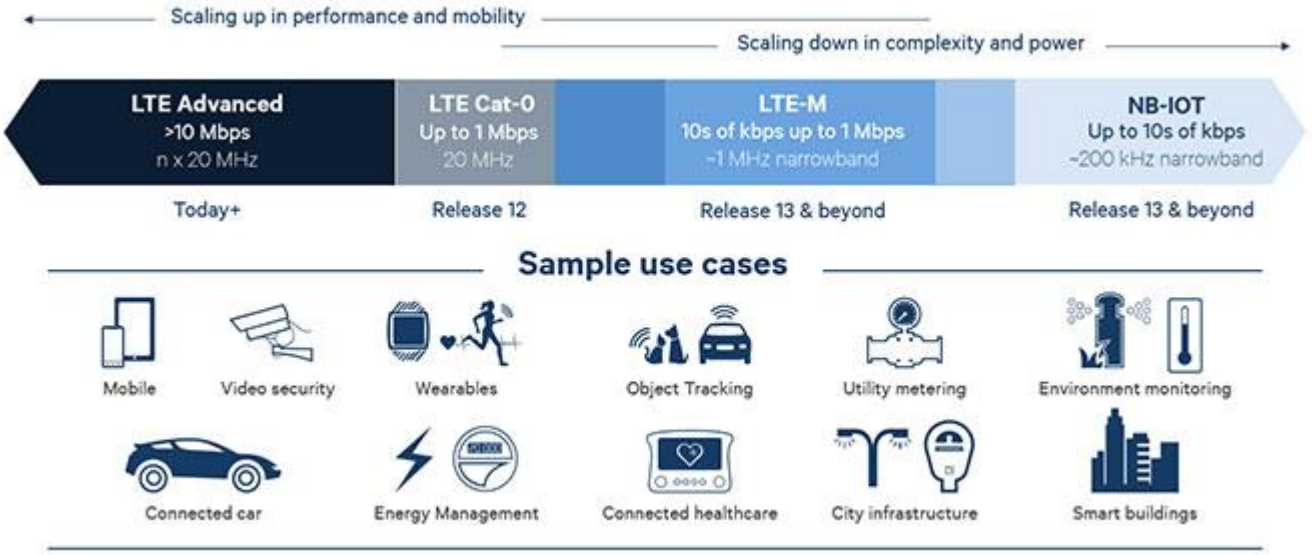
Note: The 3.0 Gbit/s / 1.5 Gbit/s data rate specified as Category 8 is near the peak aggregate data rate for a base station sector. A more realistic maximum data rate for a single user is 1.2 Gbit/s (downlink) and 600 Mbit/s (uplink). Nokia Siemens Networks has demonstrated downlink speeds of 1.4 Gbit/s using 100 MHz of aggregated spectrum.

User equipment Category	Max. L1 datarate Downlink (Mbit/s)	Max. number of DL MIMO layers	Max. L1 datarate Uplink (Mbit/s)	3GPP Release
NB1	0.68	1	1.0	Rel 13
M1	1.0	1	1.0	
0	1.0	1	1.0	Rel 12
1	10.3	1	5.2	Rel 8
2	51.0	2	25.5	
3	102.0	2	51.0	
4	150.8	2	51.0	
5	299.6	4	75.4	
6	301.5	2 or 4	51.0	Rel 10
7	301.5	2 or 4	102.0	
8	2,998.6	8	1,497.8	
9	452.2	2 or 4	51.0	Rel 11
10	452.2	2 or 4	102.0	
11	603.0	2 or 4	51.0	
12	603.0	2 or 4	102.0	
13	391.7	2 or 4	150.8	Rel 12
14	3,917	8	9,585	
15	750	2 or 4	226	
16	979	2 or 4	n/a	
17	25,065	8	n/a	Rel 13
18	1174	2 or 4 or 8	n/a	
19	1566	2 or 4 or 8	n/a	

3GPP TS 36.306 V14.4.0 (2017-09)
User Equipment (UE) radio access capabilities (Release 14)
https://en.wikipedia.org/wiki/E-UTRA#User_Equipment_.28UE.29_categories

3GPP LTE-MTC → LTE-eMTC

	LTE Rel-8 Cat-1	LTE Rel-12 Cat-0	LTE Rel-13 Cat-M1	NB-IoT Rel-13
DL peak rate	10 Mbps	1 Mbps	1 Mbps	~0.2 Mbps
UL peak rate	5 Mbps	1 Mbps	1 Mbps	~0.2 Mbps
Duplex mode	Full	Half or full	Half or full	Half
UE bandwidth	20 MHz	20 MHz	1.4 MHz	0.18 MHz
Maximum transmit power	23 dBm	23 dBm	20 or 23 dBm	23 dBm
Relative modem complexity	100%	50%	20-25%	10%
Note: peak data rates refer to full duplex operation for Cat-0 and Cat-M1				



3GPP LTE-MTC → LTE-eMTC

	LTE Cat 1	LTE Cat 0	LTE Cat M1 (eMTC)	LTE Cat NB1 (NB-IoT)
3GPP Release	Release 8	Release 12	Release 13	Release 13
Downlink Peak Rate	10 Mbps	1 Mbps	1 Mbps	250 kbps
Uplink Peak Rate	5 Mbps	1 Mbps	1 Mbps	250 kbps (multi-tone) 20 kbps (single-tone)
Number of Antennas	2	1	1	1
Duplex Mode	Full Duplex	Full or Half Duplex	Full or Half Duplex	Half Duplex
Device Receive Bandwidth	1.08 - 18 MHz	1.08 - 18 MHz	1.08 MHz	180 kHz
Receiver Chains	2 (MIMO)	1 (SISO)	1 (SISO)	1 (SISO)
Device Transmit Power	23 dBm	23 dBm	20 / 23 dBm	20 / 23 dBm

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https://en.wikipedia.org/wiki/NarrowBand_IOT

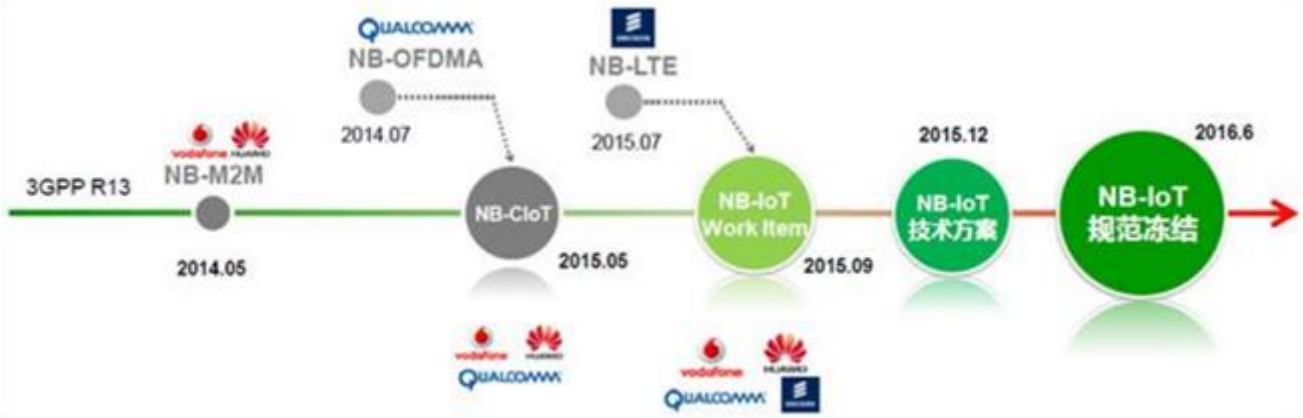
IoT in 3GPP Release 13

- EC-GSM-IoT(Extended Coverage-GSM)
- eMTC(LTE-M, Low-Cost MTC)
- NB-IOT(Narrow Band Internet of Things)

	LoRa	GSM (Rel.8)	EC-GSM-IoT (Rel.13)	LTE (Rel.8)	eMTC (Rel.13)	NB-IoT (Rel.13)
LTE user equipment category	N/A	N/A	N/A	Cat.1	Cat.M1	Cat.NB1
Range Max. coupling loss	<15km 155dB	<35km 144dB	<35km 164dB	<100km 144dB	<100km 156dB	<35km 164dB
Spectrum	Unlicensed <1GHz	Licensed GSM bands	Licensed GSM bands	Licensed LTE bands In-band	Licensed LTE bands in-band	Licensed LTE in-band guard-band stand-alone
Bandwidth	<500kHz	200kHz	200kHz	LTE carrier bandwidth (1.4 – 20MHz)	1.08MHz (1.4MHz carrier bandwidth)	180kHz (200kHz carrier bandwidth)
Max. data rate*	<50kbps (DL/UL)	<500kbps (DL/UL)	<140kbps (DL/UL)	<10Mbps(DL) <5Mbps(UL)	<1Mbps (DL/UL)	< 170kbps (DL) < 250kbps (UL)

*Max data rates provided are instantaneous peak rates.

NB-IoT (Narrow Band Internet of Things)



NB-IoT具有广覆盖、低功耗、支持海量连接的特点， NB-IoT由沃达丰、华为主导的NB-M2M，高通主导的NB-OFDM，爱立信主导的NB-LTE融合而成。2016年6月16日，NB-IoT技术协议获得了3GPP无线接入网（RAN）技术规范组会议通过，宣告NB-IoT标准形成。2016年9月，将进行NB-IoT性能标准制定，12月完成一致性测试后，NB-IoT将进入商用阶段。

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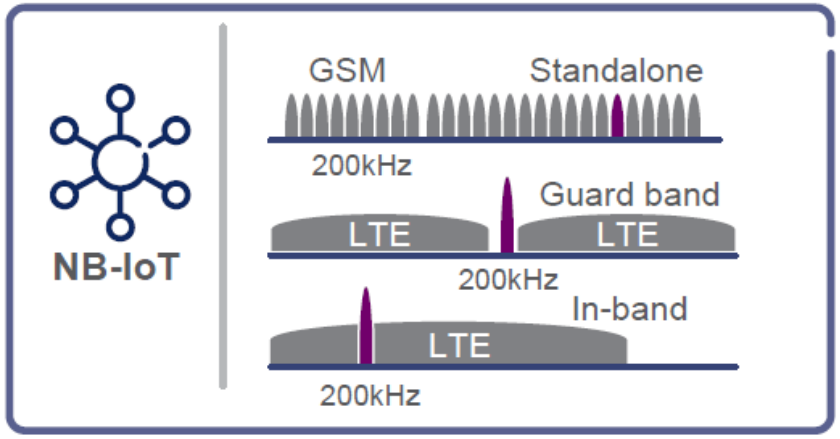
NB-IoT技术参数概览



- 独立部署（Stand-alone）
- 保护带部署（Guard-band）
- 带内部署（Inband）

- 下行采用OFDMA，12个子载波，子载波间隔15kHz。
- 上行采用SC-FDMA，Single-tone：3.75kHz/15kHz，Multi-tone：15kHz。
- 仅支持半双工，具有单独的同步信号。

NB-IoT reuses the LTE design extensively, including the numerologies, downlink orthogonal frequency-division multiple-access (OFDMA), uplink single-carrier frequency-division multiple-access (SC-FDMA), channel coding, rate matching, interleaving, etc.

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小结：LTE对物联网的支持

- LPWAN: Low Power Wide Area Network
  - LoRaWAN
  - 3GPP LTE-MTC (release 12)
  - 3GPP LTE-eMTC (release 13)
- IoT in 3GPP Release 13
  - EC-GSM-IoT(Extended Coverage-GSM)
  - eMTC(LTE-M, Low-Cost MTC)
  - NB-IOT: Narrow Band Internet of Things

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  - 5G标准化组织
  - 5G解决什么问题?
  - 5G用什么技术?
  - 5G现状
  - 关于5G与未来网络的思考

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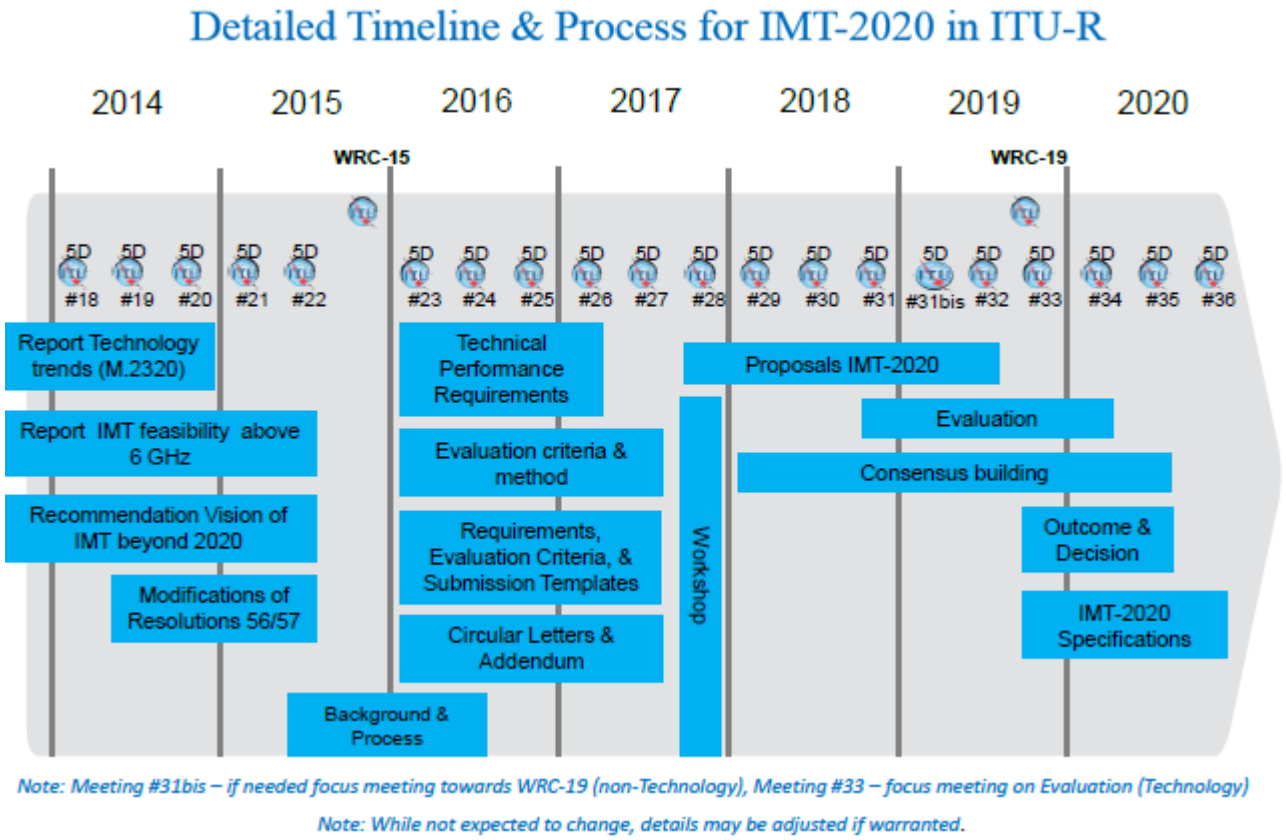
IMT-2020与5G

In early 2012, ITU-R embarked on a programme to develop "IMT for 2020 and beyond", setting the stage for 5G research activities that are emerging around the world.

In September 2015, ITU-R has finalized its "Vision" of the 5G mobile broadband connected society. This view of the horizon for the future of mobile technology will be instrumental in setting the agenda for the World Radiocommunication Conference 2019, where deliberations on additional spectrum are taking place in support of the future growth of IMT.



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http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx Retrieve: 20171028

7th Framework Programme之5G

- 欧盟科技框架计划（Framework Programme，简称FP）
  - 从1984年的FP1开始，2007年1月1日启动第七个科技框架计划（2007-2013），预算为505.21亿欧元。FP7在5G技术开发累积投资6亿欧元。
- FP7推出八个项目探索5G技术选择方案
  - **METIS**: Mobile and Wireless Communications Enablers for the Twenty-twenty (2020) Information Society
  - **5GNOW**: 5th Generation Non-Orthogonal Waveforms for Asynchronous Signalling
  - **iJOIN**: Interworking and JOINt Design of an Open Access and Backhaul Network Architecture for Small Cells based on Cloud Networks.
  - TROPIC: Distributed computing, storage and radio resource allocation over cooperative femtocells
  - **MCN**: Mobile Cloud Networking
  - **COMBO**: COnvergence of fixed and Mobile BrOadband access/aggregation networks
  - **MOTO**: Evolving mobile internet with innovative terminal-to-terminal offloading technologies
  - **PHYLAWS**: PHYsical LAyer Wireless Security

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8th Framework Programme之5G Horizon 2020

- Horizon 2020 is the current EU framework programme for research and innovation. With a budget of €75 billion, Horizon 2020 will run over seven years from 2014 – 2020.
  - 5G PPP由政府出资管理项目吸引民间企业和组织参加，计划在2014-2020年期间投资7亿欧元，拉动5-10倍企业投资。5G PPP计划发展800个成员，包括ICT的各个领域：无线/光通讯、物联网、IT(虚拟化、SDN、云计算、大数据)、软件、安全、终端和智能卡等。

5G PPP
The 5G Infrastructure Public Private Partnership

EURO 5G

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5G标准化组织
民间组织→政府民间合作组织

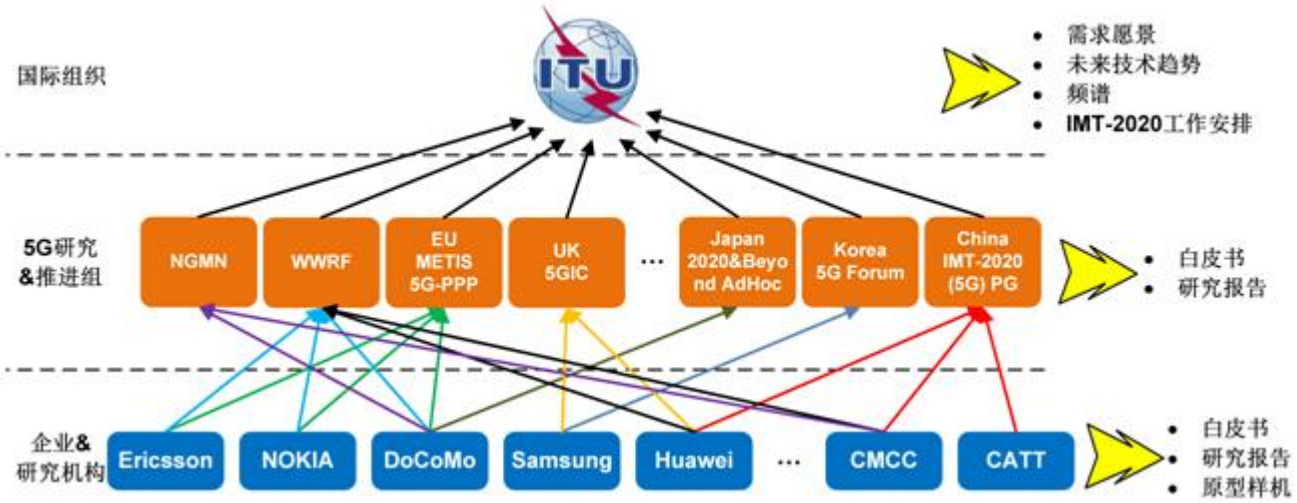
◆3GPP(3rd Generation Partnership Project）是一个成立于1998年12月的标准化组织。成员包括欧洲的ETSI、日本的ARIB和TTC、中国的CCSA、韩国的TTA、北美洲的ATIS、印度的TSDSI 。目标是在ITU的IMT-2000计划范围内制订和实现全球性的第三代移动通信系统规范。其标准演进是以GSM为基础的移动通信框架中进行的，实现了从2G（GSM）到3G（WCDMA）到3.9G（LTE）到4G（LTE-Advanced），正在朝IMT-2020演进。

◆5G是**ICT融合**的产物，5G已经不仅指蜂窝移动通信的第五代而是泛指“移动宽带”的基础设施。它是传统移动通信与云计算/大数据、SDH/NFV以及未来网络等融合的产物。面对5G挑战3GPP的局限性开始显现出来。这表现在两方面，一方面是单纯依靠电信业（CT）的力量不足以满足5G发展的需求，必须ICT融合与IT业合作，而这一合作也就是ICT融合的过程。另外一方面是：3GPP是多国通信标准化组织合作的民间组织，为保证5G快速发展的需求，有政府参与支持的政府民间合作机制更有力于5G的发展。

◆为此，欧盟为维持其在移动通信方面的领先优势（欧洲ETSI是3GPP的主导）率先在其Horizon 2020计划中成立了5G PPP（Public-Private Partnership）(5G政府民间合作计划)。

5G标准化组织
国际、国家、地区、联盟…

中国：IMT-2020 (5G) Promotion Group
欧洲：5G PPP（Public-Private Partnership）
韩国：5G Forum
美国：5G Americas
日本：5G MF
运营商的论坛：NGMN



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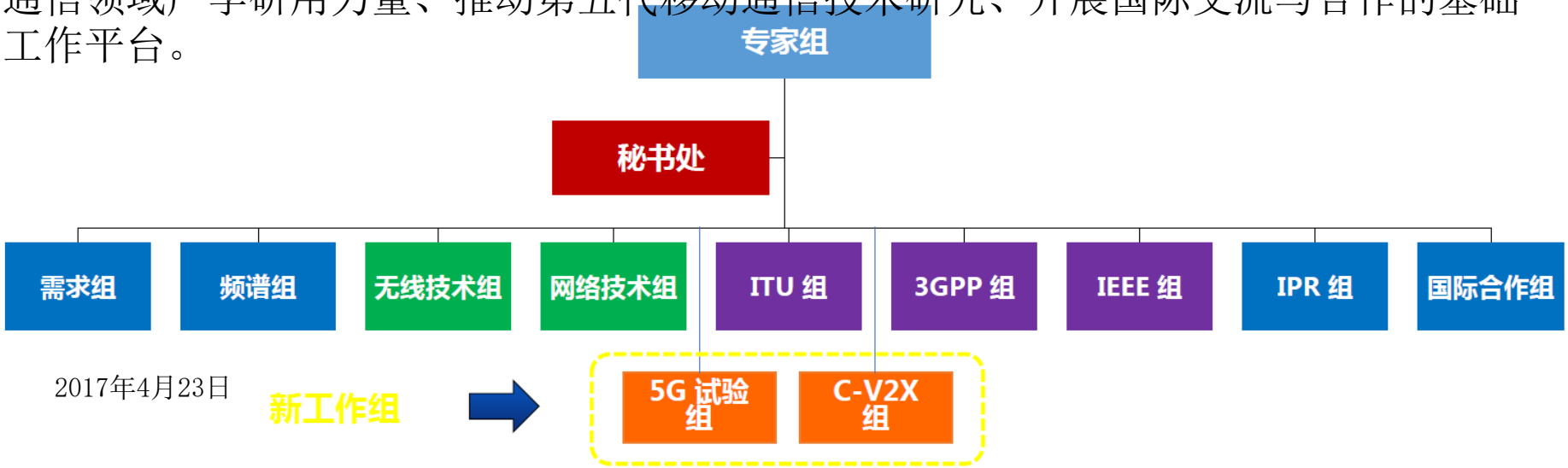
5G标准化组织
IMT-2020 (5G) Promotion Group

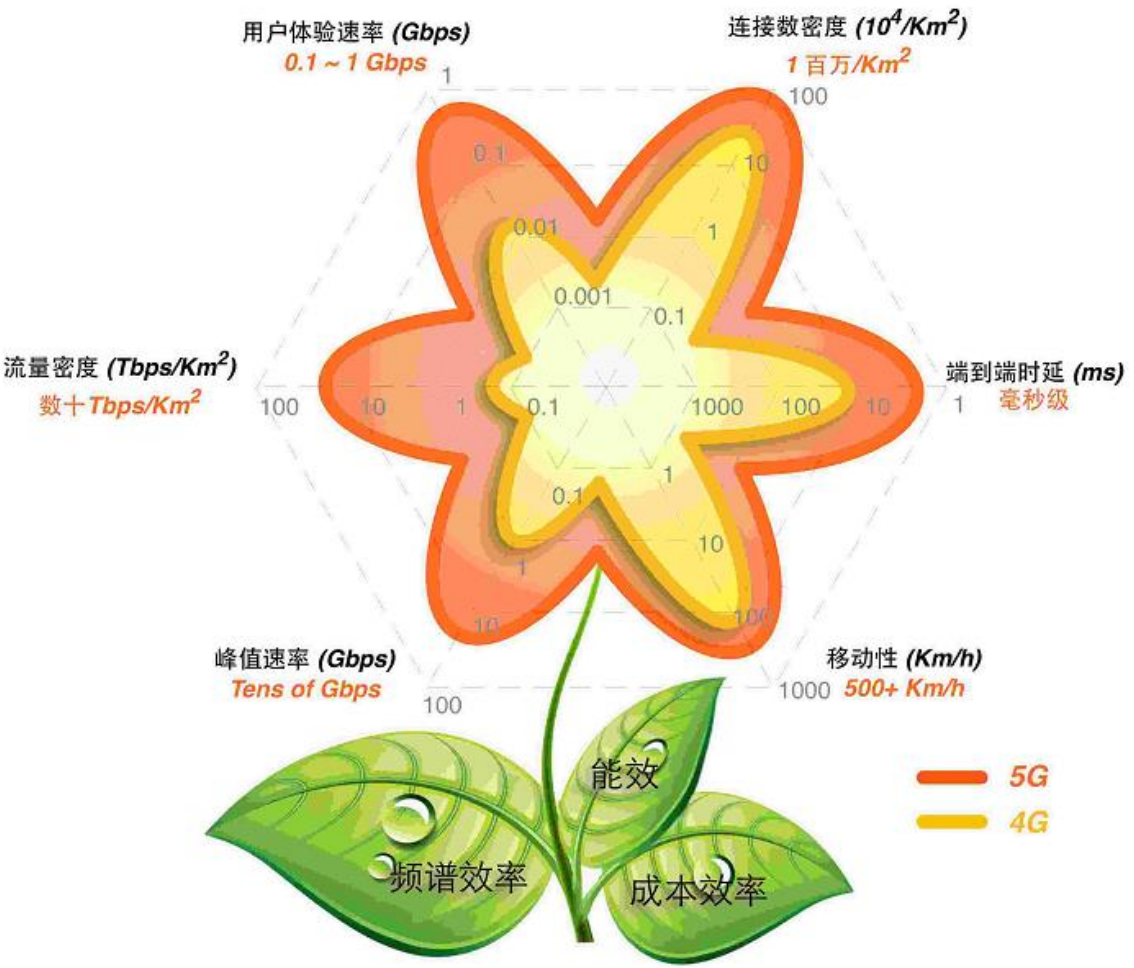
http://www.imt-2020.cn/zh

IMT-2020(5G)推进组于2013年2月由我国工业和信息化部、国家发展和改革委员会、科学技术部联合推动成立，组织架构基于原IMT-Advanced推进组，是聚合移动通信领域产学研用力量、推动第五代移动通信技术研究、开展国际交流与合作的基础工作平台。



IMT-2020(5G)推进组
5G的关键能力

5G需要具备比4G更高的性能，支持0.1~1Gbps的用户体验速率，每平方公里一百万的连接数密度，毫秒级的端到端时延，每平方公里数十Tbps的流量密度，每小时500Km以上的移动性和数十Gbps的峰值速率。其中，用户体验速率、连接数密度和时延为5G最基本的三个性能指标。同时，5G还需要大幅提高网络部署和运营的效率，相比4G，频谱效率提升5~15倍，能效和成本效率提升百倍以上。



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  - 5G现状
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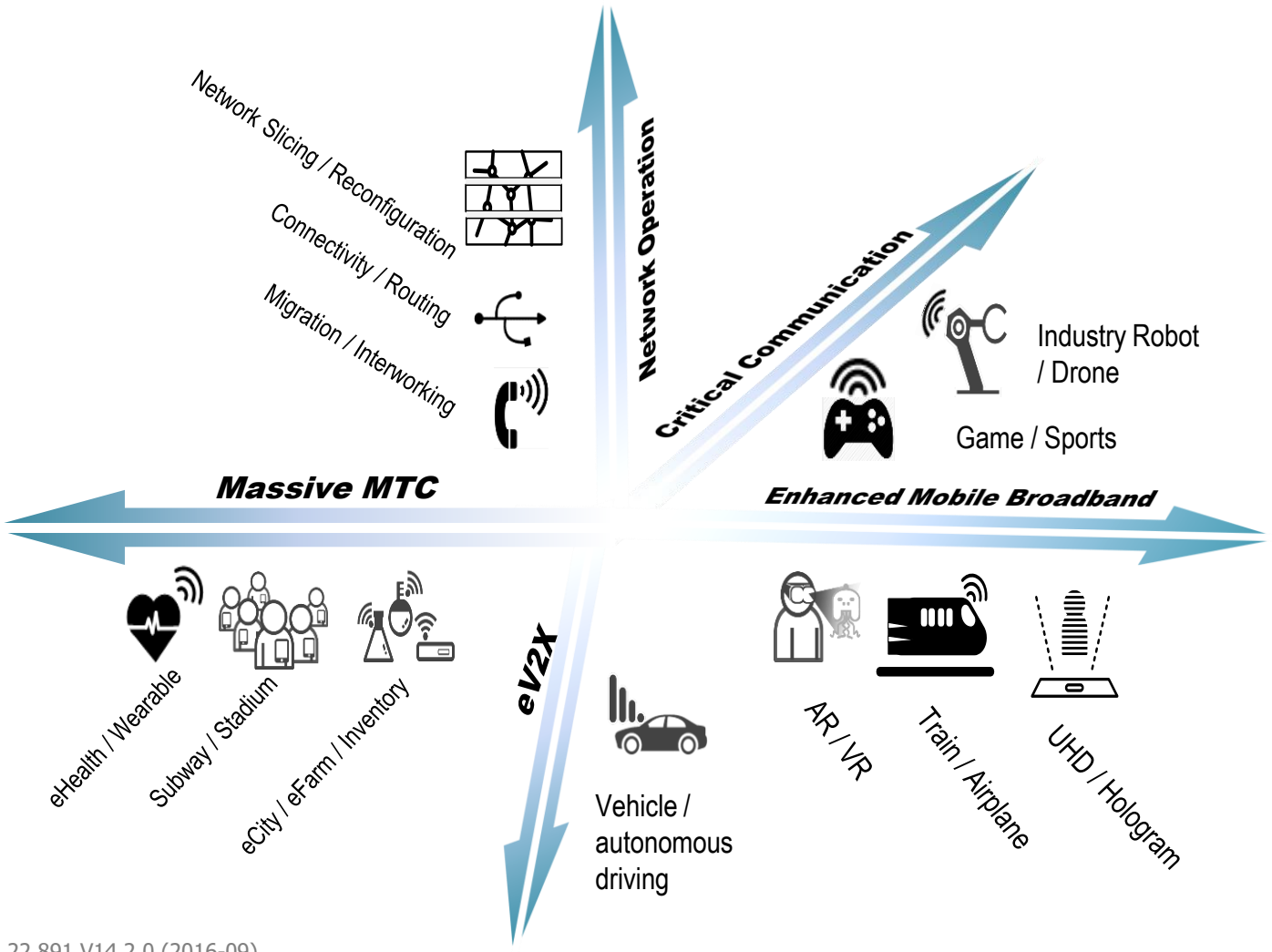
5G的应用场景？
Release 14 预期的5类场景



3GPP TR 22.891 V14.2.0 (2016-09)
Technical Specification Group Services and System Aspects;
Feasibility Study on New Services and Markets Technology Enablers;

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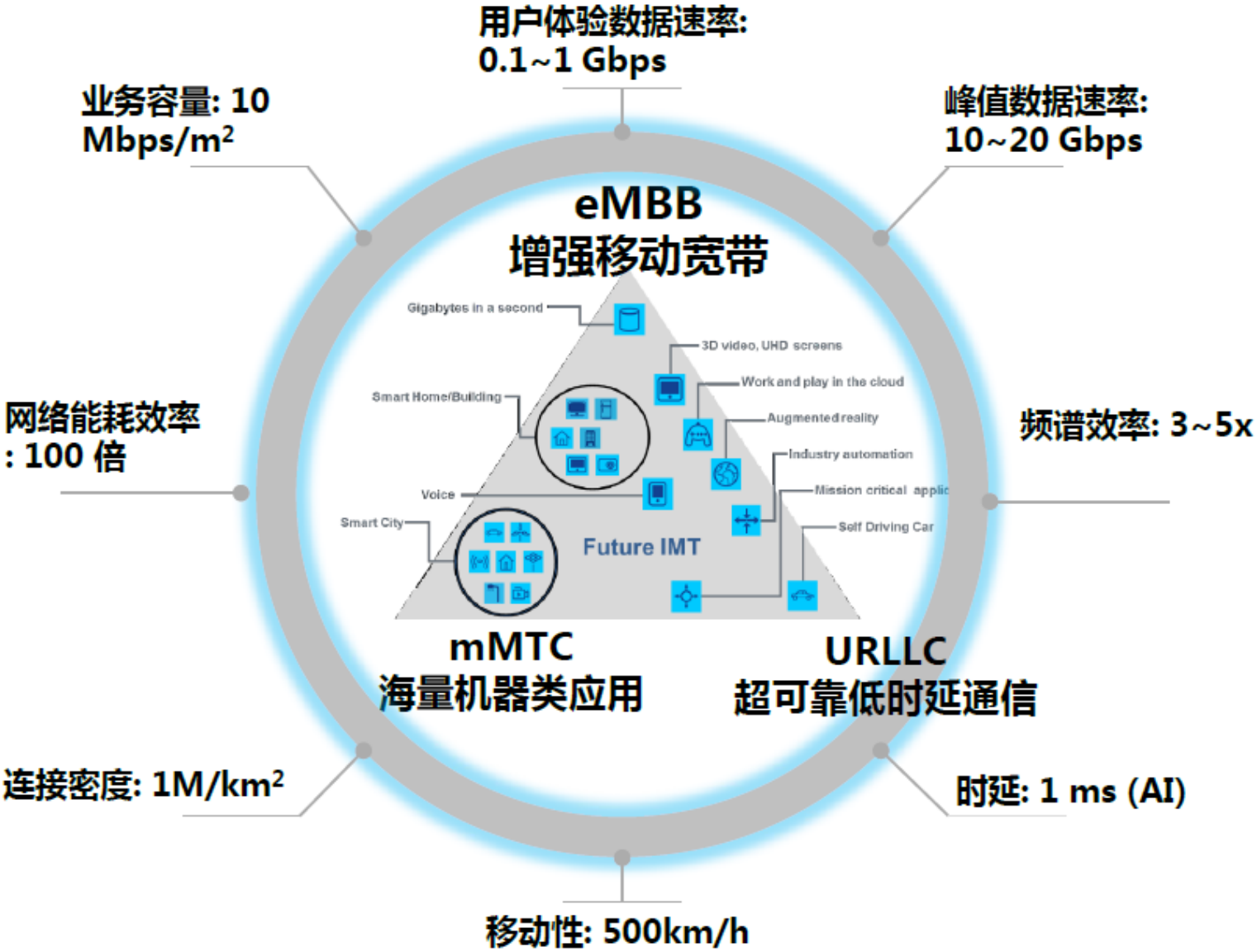
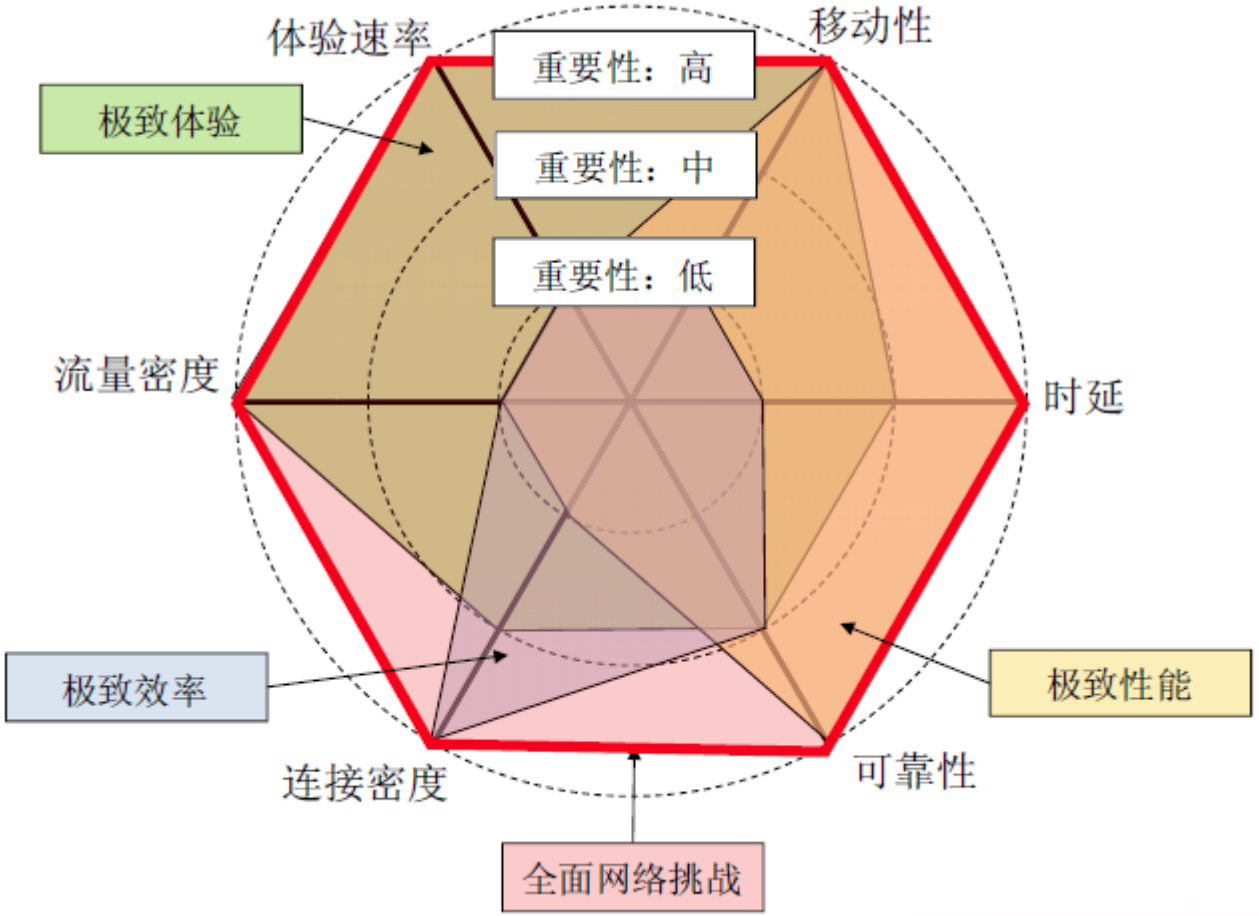
5G的应用场景？
三大类场景、KPI

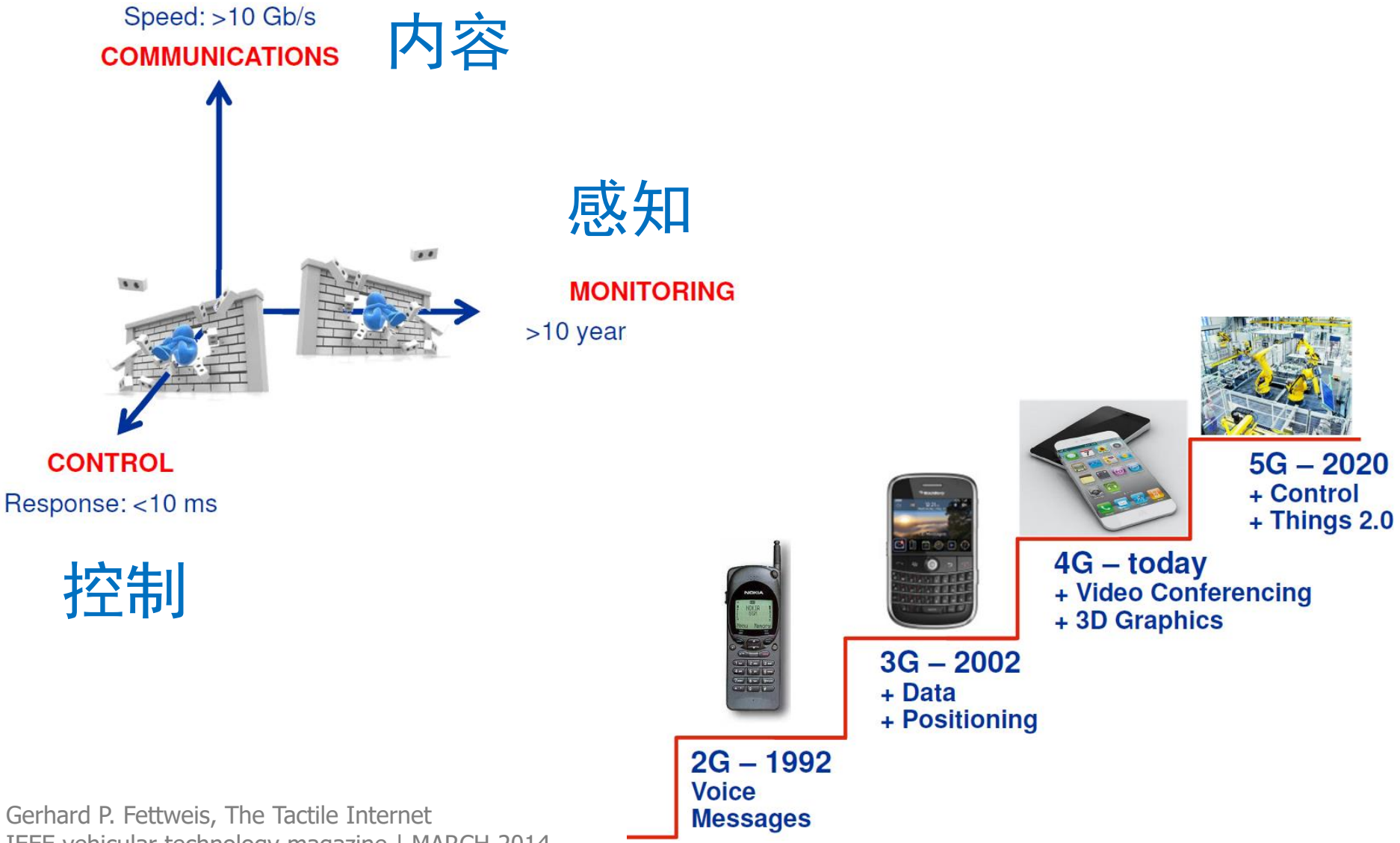


中国5G推进组

- 极致性能指标带来全面挑战
- 多网融合成5G架构优先选择
- 网络与业务融合



小结：5G解决什么问题?
Communications Monitoring Control



Gerhard P. Fettweis, The Tactile Internet
IEEE vehicular technology magazine | MARCH 2014

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  - 5G现状
  - 关于5G与未来网络的思考

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5G用什么技术? 架构和服务
Spatial Densification

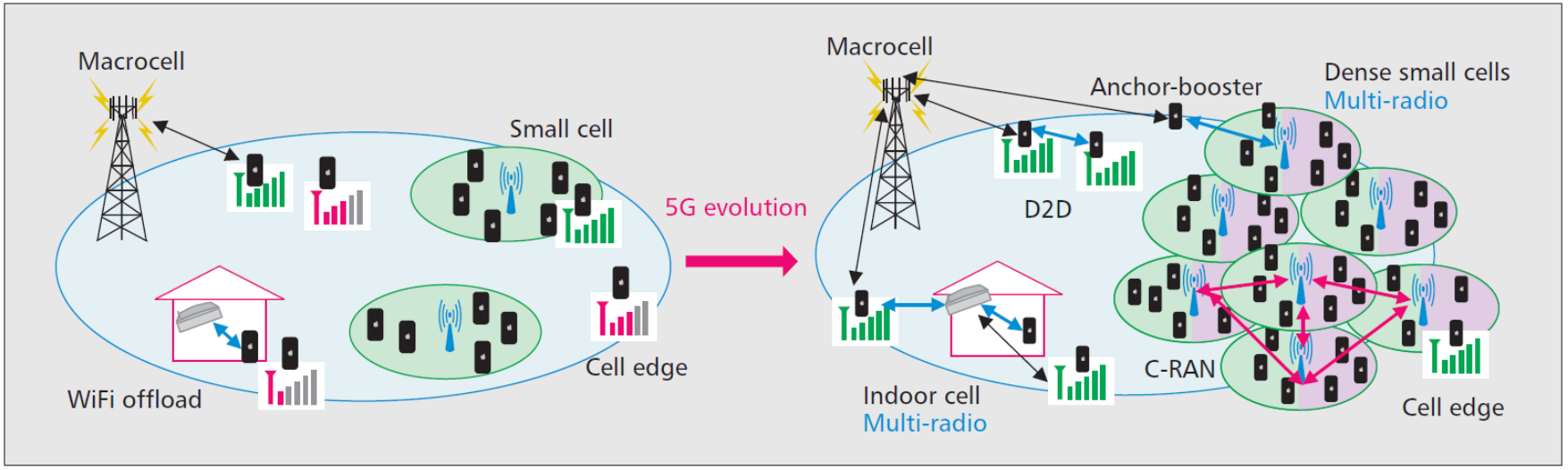

Figure 1. *The evolution of HetNet architecture.*

Heterogeneous Networks: Macrocells, Picocells, Relay
Neighborhood Small Cells (NSC)
Device-to-device (D2D) communication

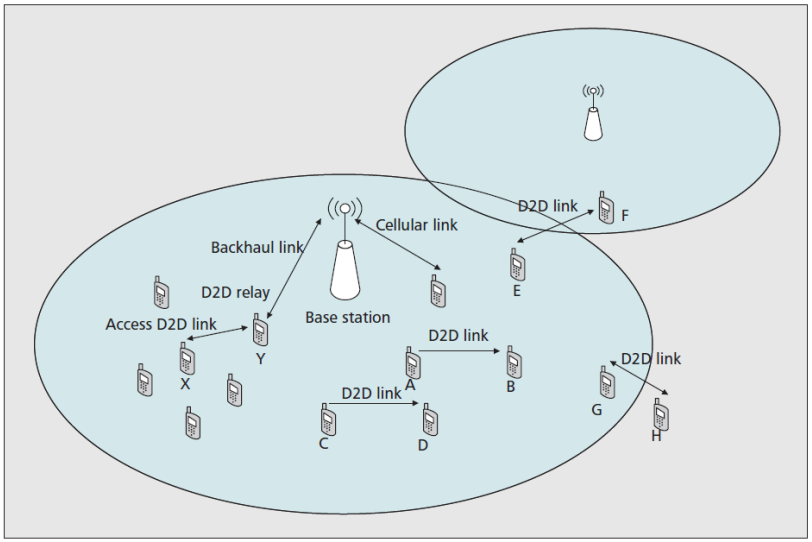

Figure 5. *Illustration of D2D-based proximal communication and multihop (relay) service.*

5G用什么技术? 架构和服务
Multimedia Broadcast and Multicast Services

- eMBMS uses the MBMS single frequency network (MBSFN) transmission mode, where all cells in an area transmit the broadcast signal synchronously.
- Interference does not occur from any cell in the area where the signal arrives with a delay shorter than the cyclic prefix (CP). The CP available today for eMBMS is 16.7 ms, but this is not large enough to offer higher spectral efficiency of 2 b/s/Hz in relevant deployment scenarios such as the lower 700 and 800 MHz frequency bands and rural scenarios with smaller indoor losses or outdoor rooftop antennas for TV reception. This motivates the introduction of a longer CP, up to about 200 ms. In order to keep the relative overhead of the CP constant, the OFDM symbol length and thereby the number of subcarriers need to be increased proportionally.

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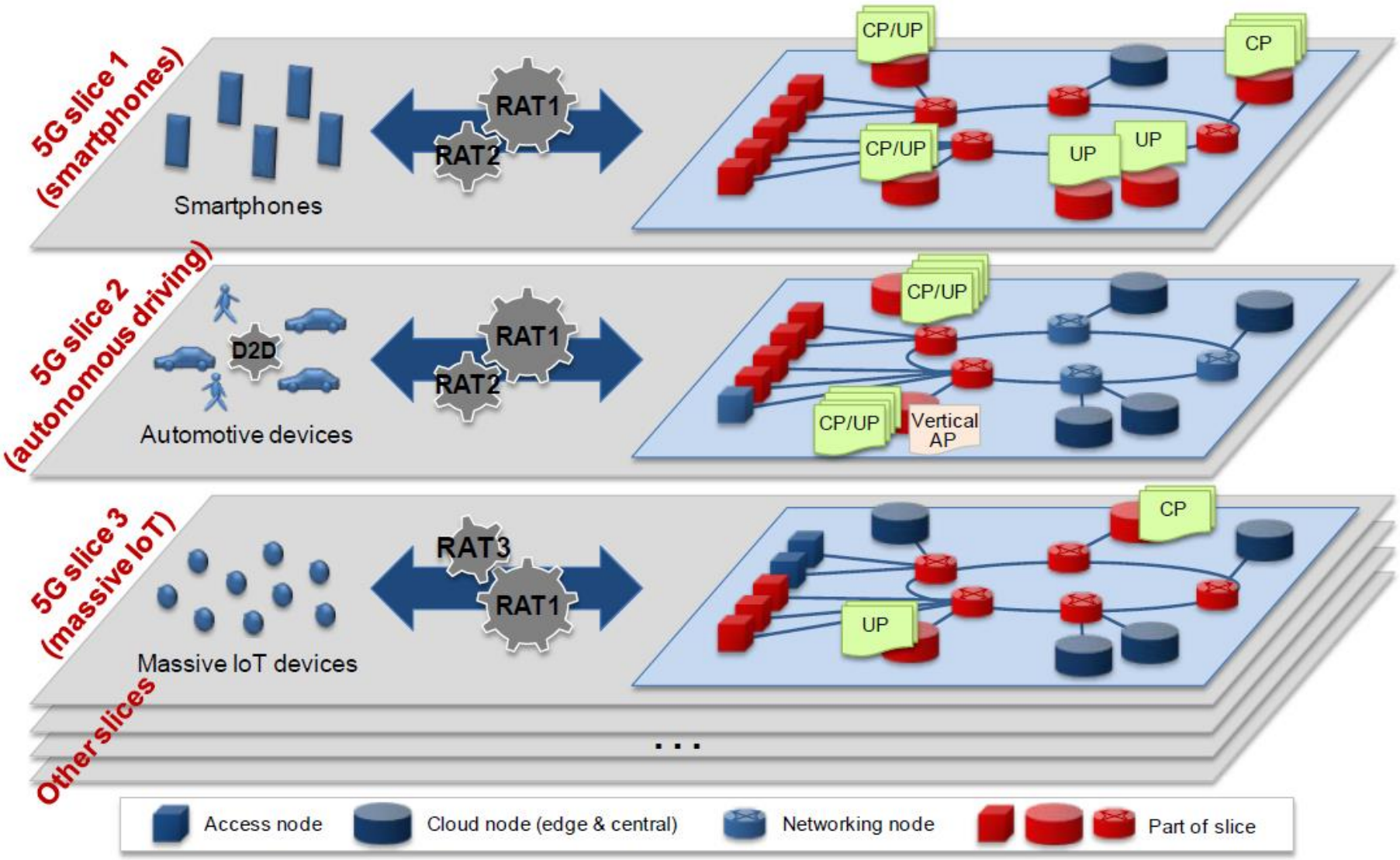
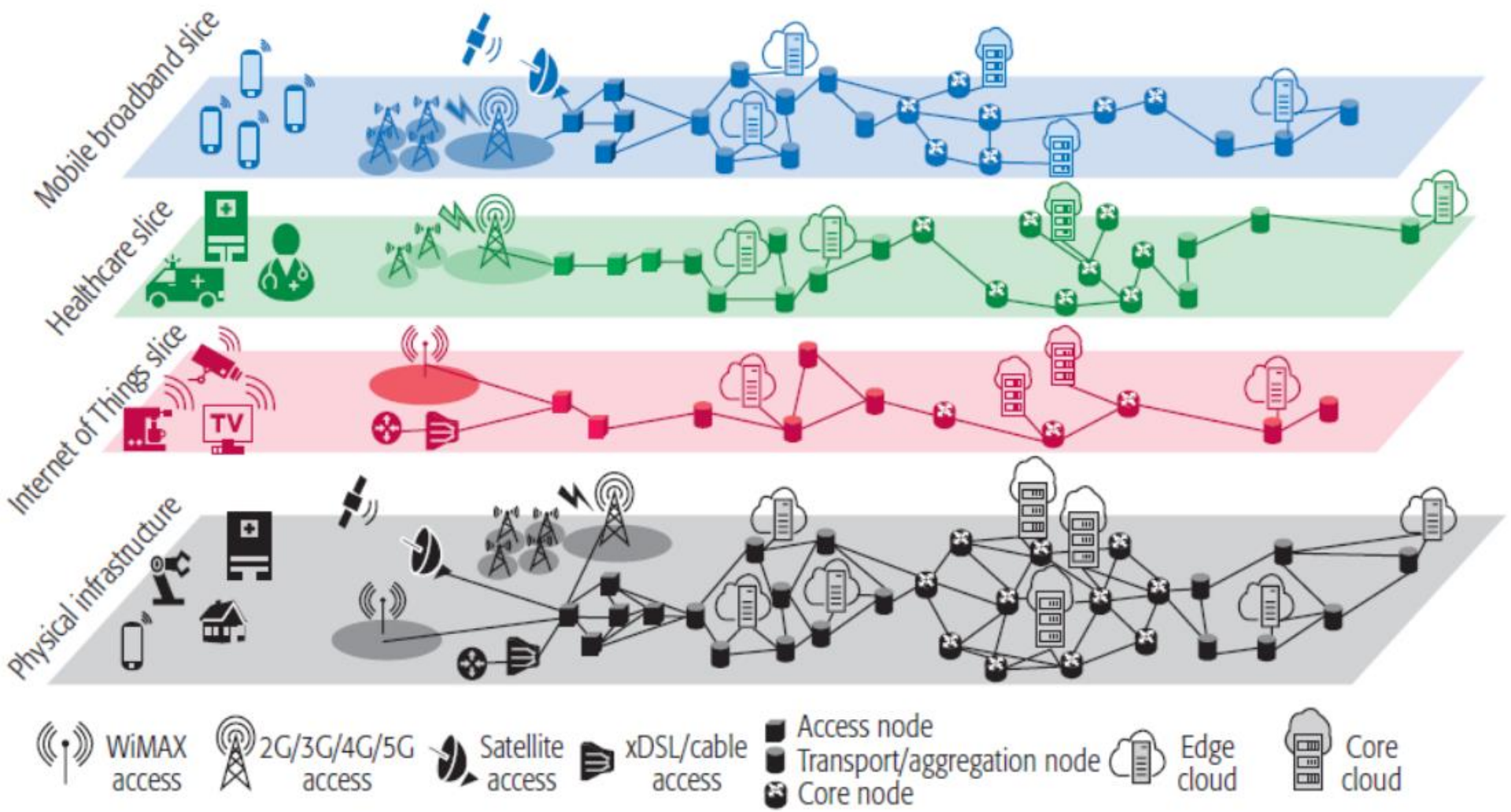
Hoymann, C., et al. (2016). "LTE release 14 outlook." IEEE Communications Magazine 54(6): 44-49.

5G用什么技术?架构和服务
Network Slicing



5G用什么技术?架构和服务
Network Slicing: 物理网络vs.虚拟网络



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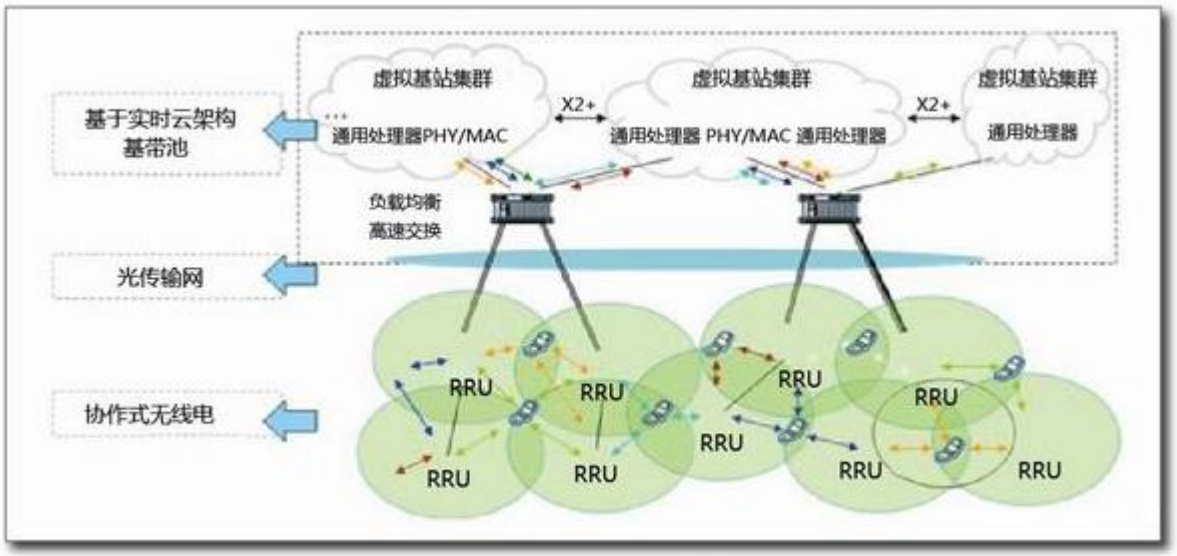
Network Slicing for 5G with SDN/NFV: Concepts, Architectures, and Challenges
IEEE Communications Magazine • May 2017

5G用什么技术?架构和服务
Cloud RAN

◆Cloud RAN (C-RAN), creates a super base station with distributed antennas supporting multiple RAN protocols and dynamically adapting its signal processing resources based on the varying traffic load within its geographical coverage.

C-RAN simplifies implementation of LTE-A features such as coordinated multipoint (CoMP) and enhanced intercell interference coordination (eICIC) by centralizing baseband processing.



http://www.c-ran.com

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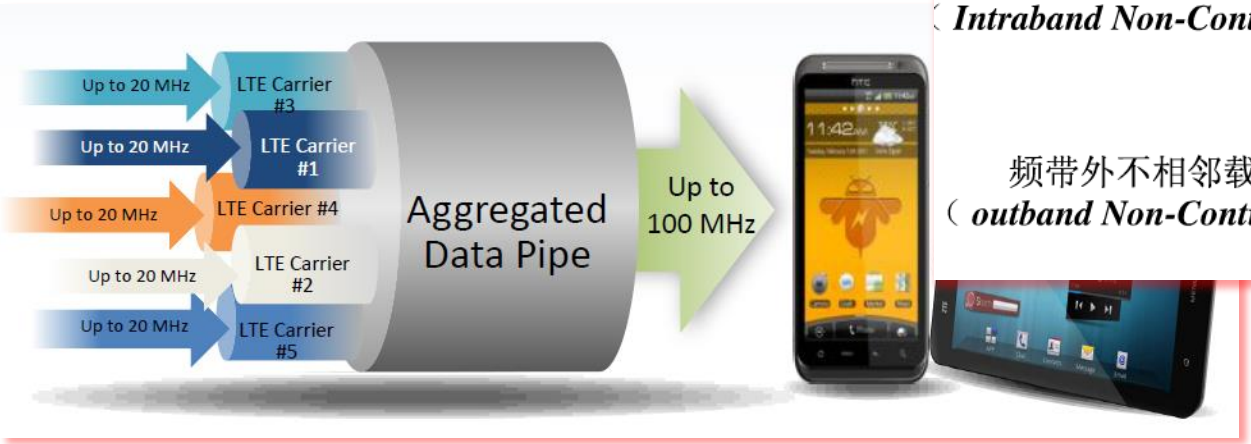
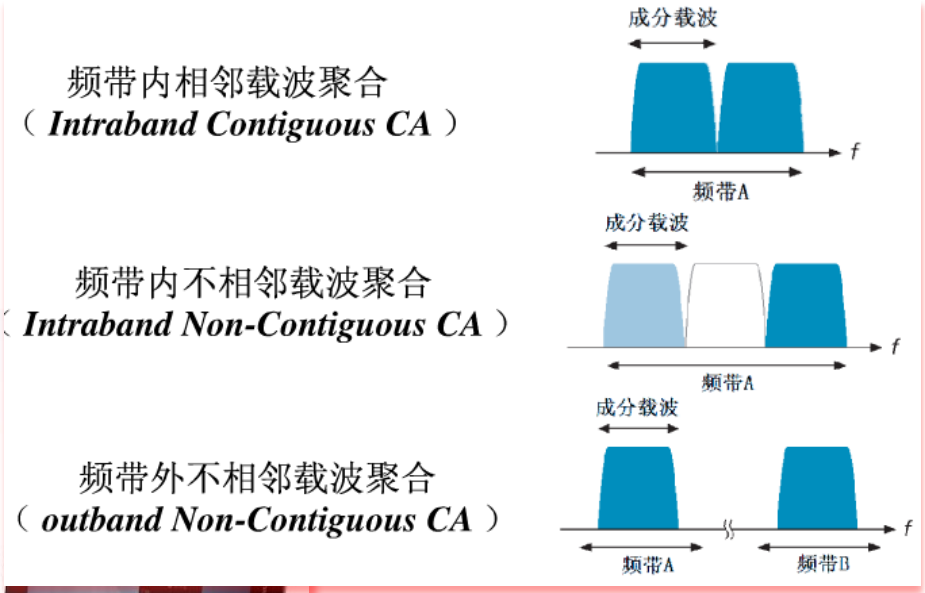
5G用什么技术? PHY
从LTE R10开始的Spectral Aggregation

- Spectrum Availability and Multiband Operation
- Cognitive Radio Network
  - exploration of TV white spaces in the United States





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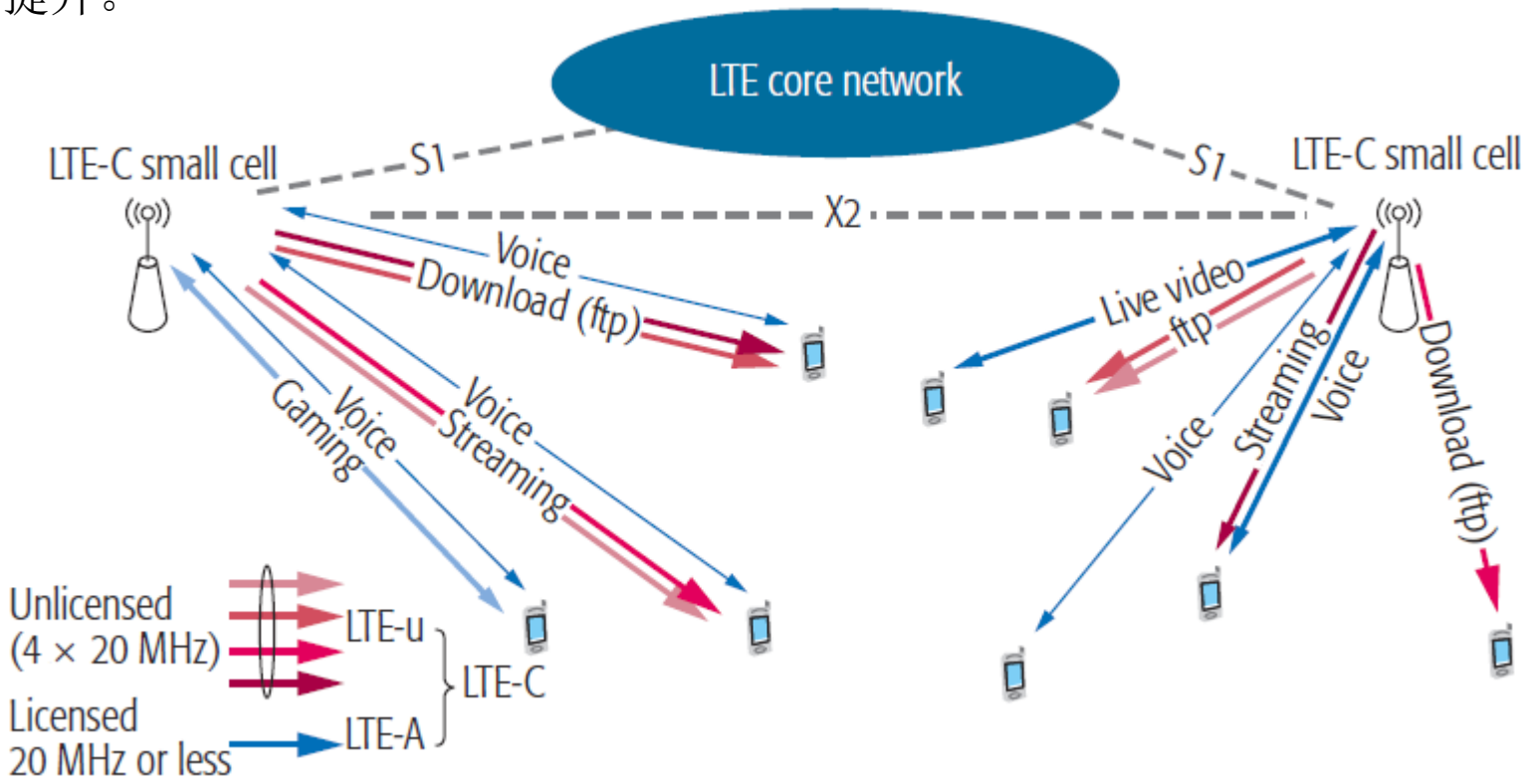
5G用什么技术? PHY
LTE-U (LTE-Unlicensed)

LTE-U (LTE-Unlicensed) 主要是解决当前网络速率、容量跟用户设备对需求的矛盾。提高容量具体方案就是用LTE-A 的载波聚合方案，载波聚合的需求就是频谱，而授权的频谱不够用怎么办，那就用未授权的。所以在R13中提出了LTE-U，即使用授权的频谱作为主载波，使用非授权的5G频谱做为辅载波，达到载波聚合的效果，从而实现速率和容量的提升。



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Cellular Communications on License-Exempt Spectrum, Bingying Ren, Mao Wang, Jingjing Zhang, Wenjie Yang, Jun Zou, Min Hua, and Xiaohu You
IEEE Communications Magazine • May 2016

5G用什么技术? PHY
New Waveform to Support Sporadic Traffic

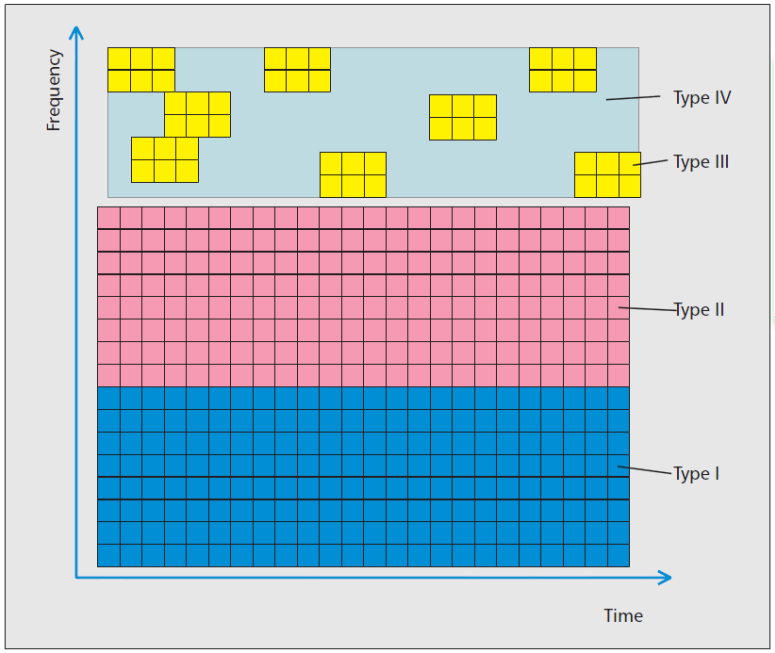

Figure 2. *The 5G vision of a unified frame for different types of traffic.*

OFDM	Orthogonal Frequency Division Multiplexing
BFDM	Biorthogonal Frequency Division Multiplexing
FBMC	Filter Banks Multicarrier
UFMC	Universal Filtered Multicarrier
GFDM	Generalized Frequency Division Multiplexing

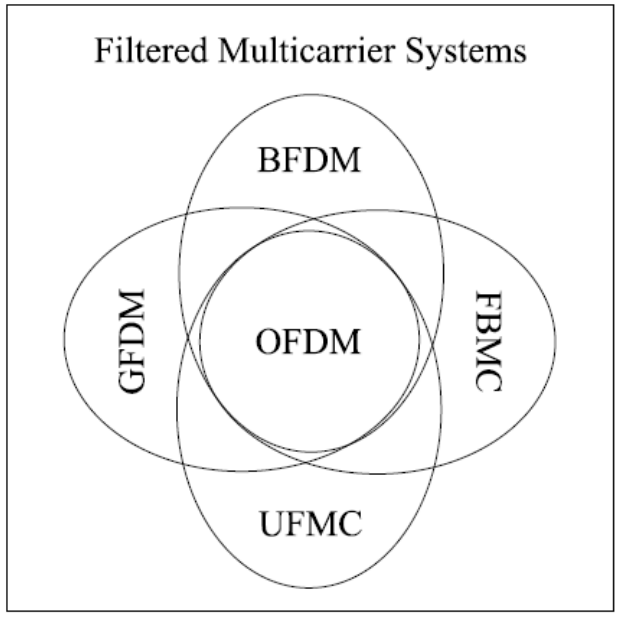

Figure 2. The 5G vision of a unified frame for different types of traffic. Types I and II represent high rate data for video with possible non-orthogonal advanced receiver processing for cell edge or CoMP users for the second type.
Type I possibly also carries real-time traffic. Types III and IV is sporadic asynchronous MTC traffic, possibly containing an energy-efficient spreading element, for example, for sensors in the case of Type IV, as schematically indicated by the green shade.

5G用什么技术? PHY Latency Reduction

In the UL, the medium access is based on **scheduling requests (SRs)** that are sent by the terminal to request resources if data needs to be sent. This introduces delay since the terminal must wait for an SR opportunity as well as the extra round-trip time needed to grant the transmission.

By instead configuring a terminal with a periodic UL grant (e.g., with a 1 ms periodicity), referred to as a **Fast UL grant** [5], the terminal is allowed to transmit without the SR related delay.

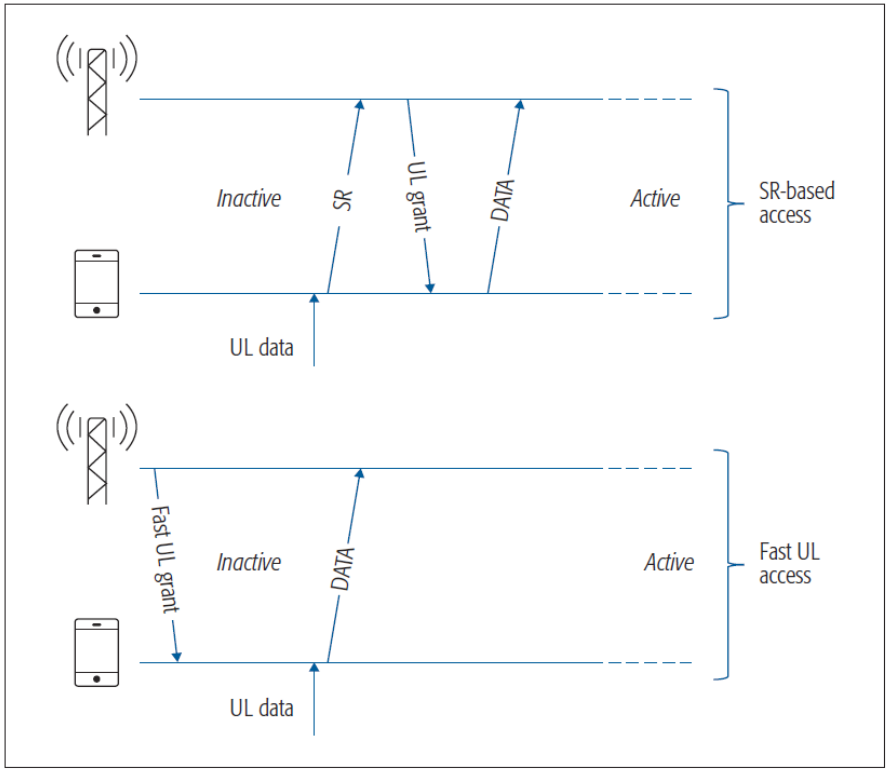

Figure 1. Conventional scheduling-request-based access (top) and access with a Fast UL grant (bottom).

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Hoymann, C., et al. (2016). "LTE release 14 outlook." IEEE Communications Magazine 54(6): 44-49.

5G用什么技术? PHY
NOMA: Non-Orthogonal Multiple Access

- Basic NOMA
  - with a SIC Receiver
- LDS-CDMA
  - Low-Density Spreading CDMA
- LDS-OFDM
  - Low-Density Spreading OFDM
- SCMA
  - Sparse Code Multiple Access
- MUSA
  - Multi-User Shared Access
- PDMA
  - Pattern-division multiple access

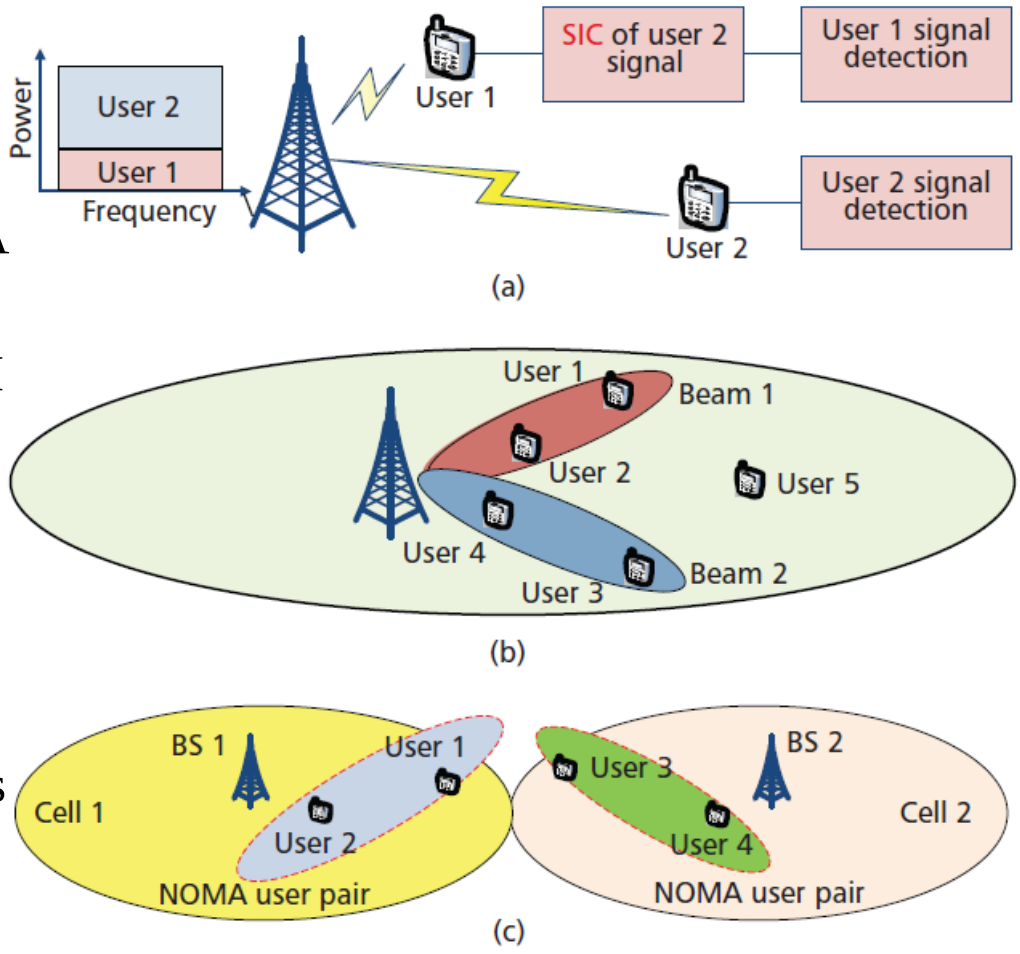
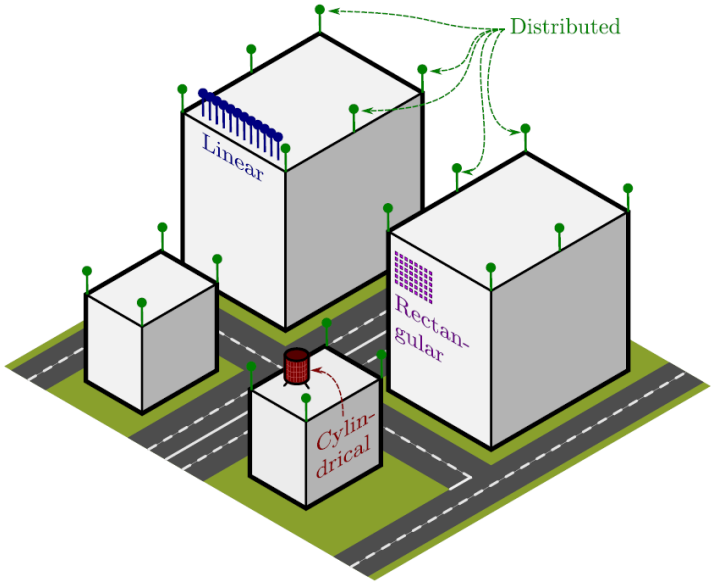
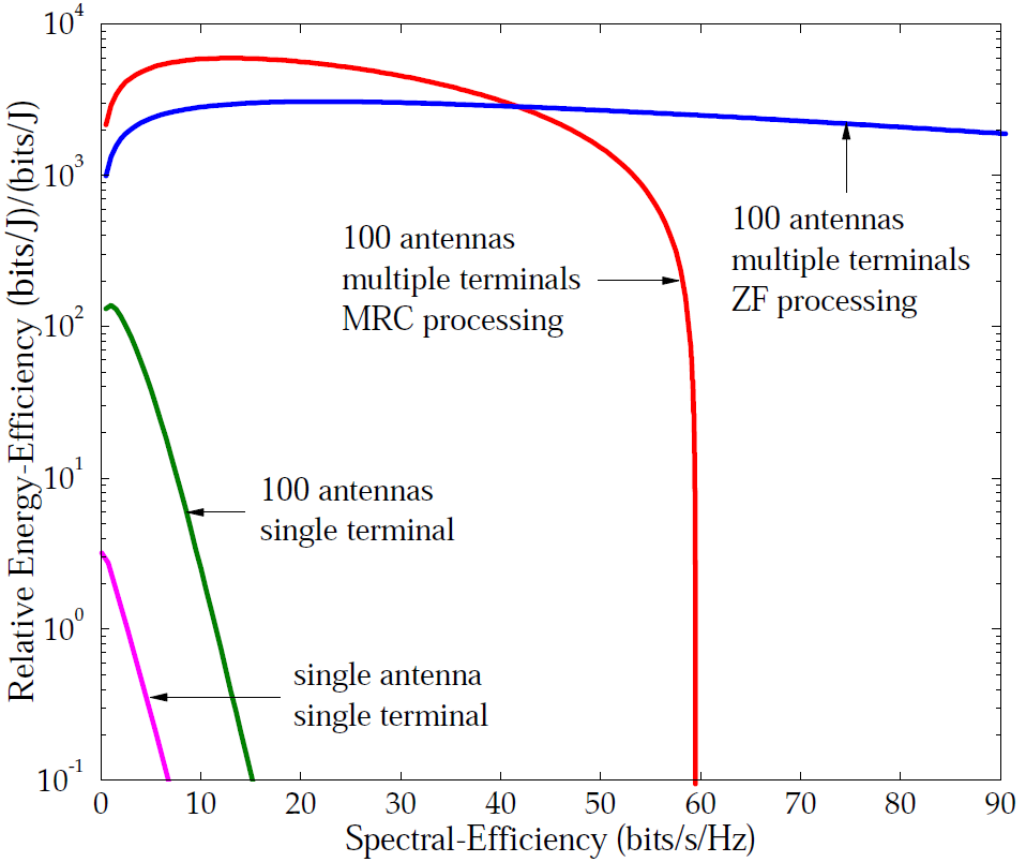


Figure 2. Illustration of NOMA via power domain multiplexing: a) basic NOMA with a SIC receiver; b) NOMA in MIMO systems; c) network NOMA.

5G用什么技术? PHY
Massive MIMO

◆Drastically higher capacity can be obtained by very large MIMO (VLM) arrays employed at the base station.





It is expected that VLM will be a core technology in next generation wireless systems.

http://www.commsys.isy.liu.se/~egl/vlm/vlm.html
http://arxiv.org/pdf/1304.6690v3.pdf

5G用什么技术? PHY
Massive Multi-Antenna Systems

The **closed loop** mode uses measurement channel state information reference signals (CSI-RS) per antenna and a precoder matrix codebook for terminal feedback (Fig. 4).
Open loop beamforming, where the beamforming direction is determined without explicit feedback from the terminal, has increased efficiency for large numbers of transmit antennas, since the CSI-RS are terminal-specific and beamformed (Fig. 5).

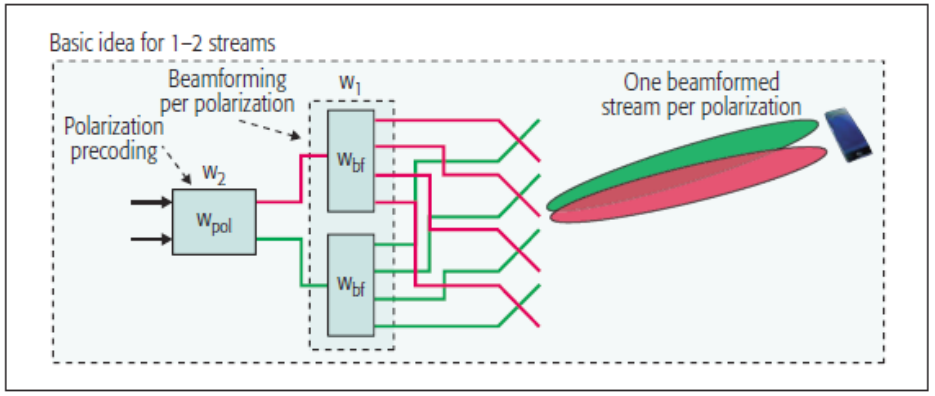


Figure 4. Closed loop MIMO where the terminal controls the precoders W1 and W2 for robust operation.

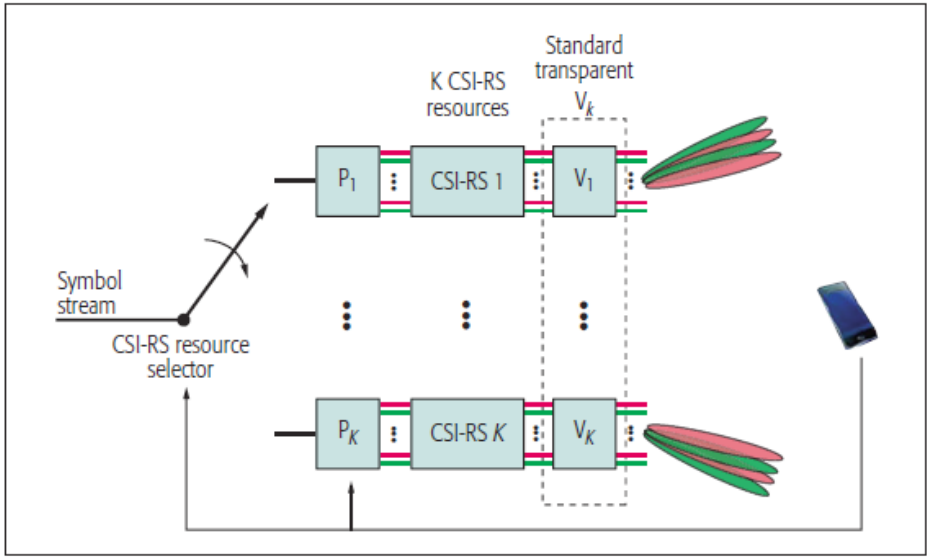
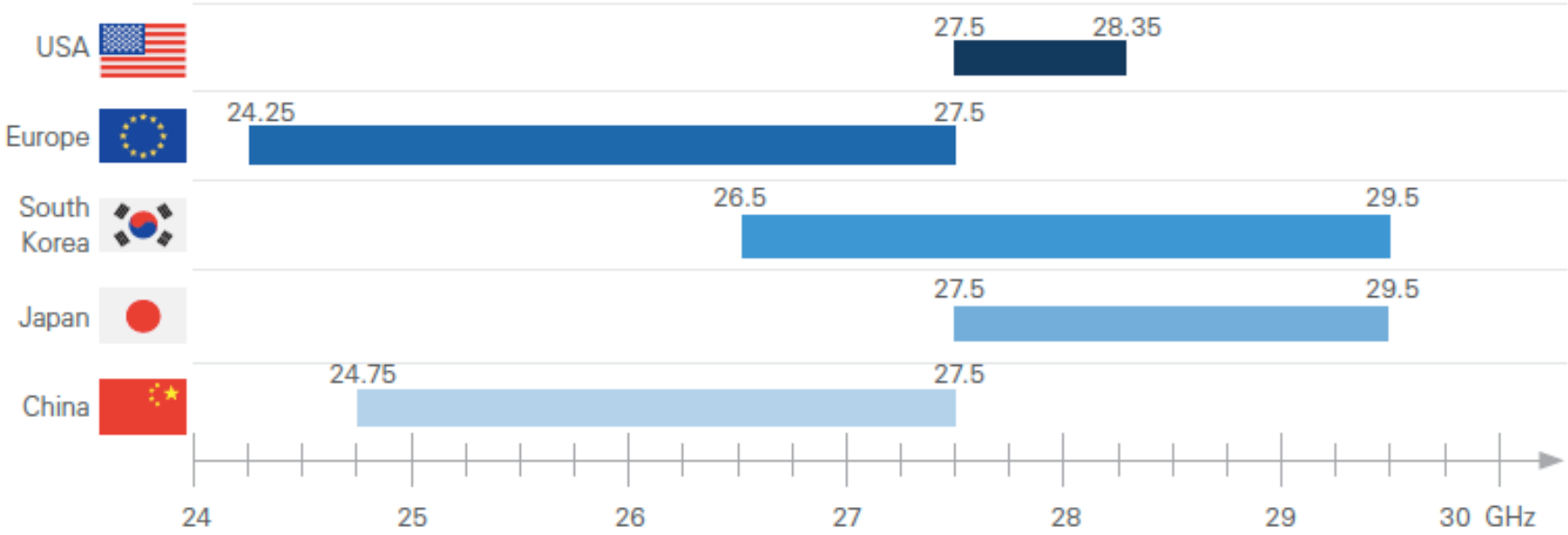


Figure 5. Open loop beamforming, where the terminal selects one out of K beams formed by the standard transparent precoders Vk, which are determined without explicit terminal feedback.

Hoymann, C., et al. (2016). "LTE release 14 outlook." IEEE Communications Magazine 54(6): 44-49.

5G用什么技术? PHY
mm-wave communications (3–300 GHz)

相比于现有移动通信网的频段，毫米波频段的可用带宽大（超过1GHz）
2012.12 IEEE 802.11ad，60GHz，3Gbps



3GPP Release 15 Overview
https://spectrum.ieee.org/telecom/wireless/3gpp-release-15-overview Retrieved: 20191110

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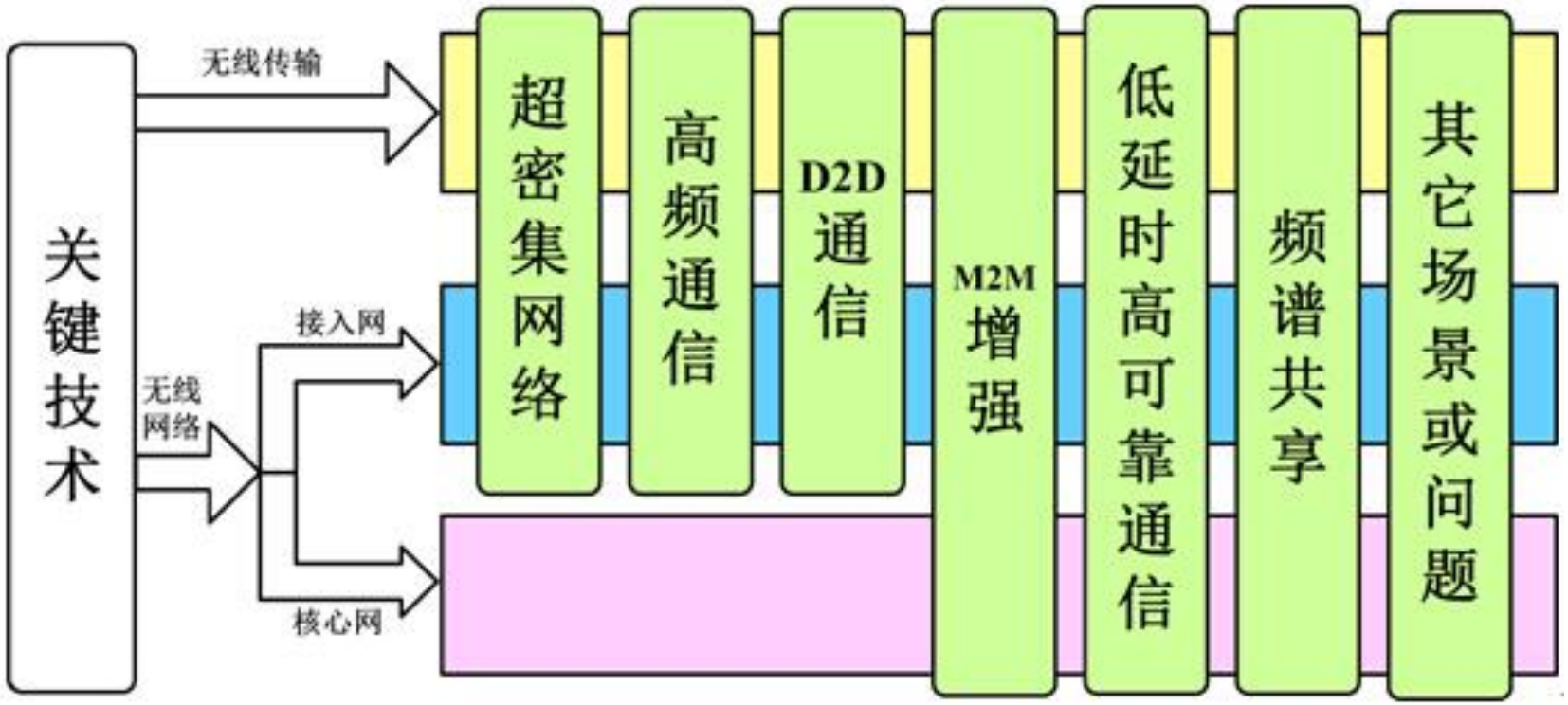
小结：5G的关键技术

- 核心网： SDN、NFV、Network Slicing…
- 接入网： Massive MIMO、mmWave、NOMA...



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专题内容：移动通信网的现状与趋势

- 移动通信网的演进
  - 3GPP: The 3rd Generation Partnership Project
  - 商用PLMN (Public Land Mobile Network)演进
  - 3GPP网络架构演进
- 4.5G (LTE-Advanced Pro)
  - LTE-WLAN Inter-working
  - LTE-WLAN Aggregation
  - LTE对物联网的支持
- 展望5G
  - 5G标准化组织
  - 5G解决什么问题?
  - 5G用什么技术?
  - 5G现状
  - 关于5G与未来网络的思考

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5G现状

2019年6月6日，工信部正式向中国电信、中国移动、中国联通、中国广电发放5G商用牌照。8月12日，中国电信决定9月率先在京放出5G专用号段的手机号码，且老用户升级5G无需换卡换号。2019年10月31日，三大运营商公布5G商用套餐，并于11月1日正式上线5G商用套餐。

已明确的关键指标

ITU has put forth some requirements for 5G that focus on fulfilling three KPIs:

- >**10 Gb/s** peak data rates for the enhanced mobile broadband (eMBB)
- >**1 M/km^2** connections for massive machine-type communications (MMTC)
- <**1 ms** latency for ultra-reliable low-latency communications (URLLC).

Metric	Requirement	Comments
Peak Data Rate	DL: **20 Gb/s** UL: 10 Gb/s	Single eMBB mobile in ideal scenarios assuming all resources utilized
Peak Spectral Efficiency	DL: **30 b/s/Hz** (assuming 8 streams) UL: 15 b/s/Hz (assuming 4 streams)	Single eMBB mobile in ideal scenarios assuming all resources utilized
User Experienced Data Rate	DL: 100 Mb/s UL: 50 Mb/s	5% CDF of the eMBB user throughput
Area Traffic Capacity	Indoor hotspot DL: 10 Mb/s/m^2	eMBB
User Plane Latency	eMBB: 4 ms URLLC: **1 ms**	Single user for small IP packets, for both DL and UL (eMBB and URLLC)
Control Plane Latency	20 ms (encouraged to consider **10 ms**)	Transition from Idle to Active (eMBB and URLLC)
Connection Density	1M devices per km^2	For mMTC
Reliability	99.9999% success prob.	32 L2 bytes within 1 ms at cell edge
Bandwidth	>100 MHz; up to **1 GHz in > 6 GHz**	Carrier aggregation allowed

3GPP Release 15 Overview
https://spectrum.ieee.org/telecom/wireless/3gpp-release-15-overview Retrieved: 20191110

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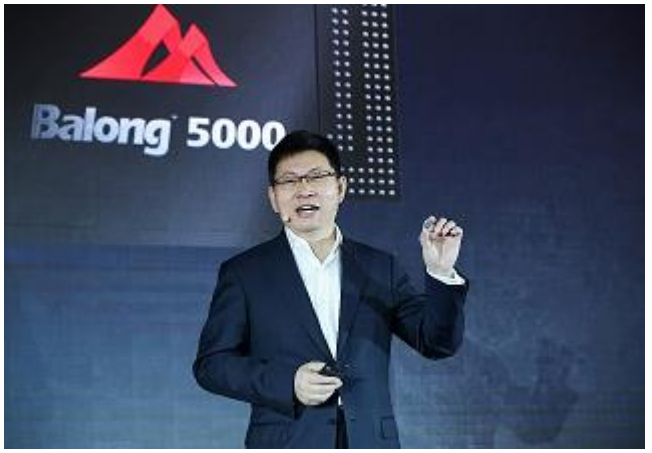
5G的通信芯片

◆2019年7月17日，在2019IMT-2020(5G)峰会上，IMT-2020(5G)推进组组长王志勤公布了5G终端芯片的测试进展。

- 面向SA/NSA两种制式的是华为海思的巴龙5000芯片和MTK的Helio M70芯片，其中华为完成了该款芯片从室内功能到外场性能上的全部网络测试，MTK只完成了室内测试，室外测试仍在进展中。
- 仅面向NSA设计的芯片，是高通X50芯片和紫光展锐的Ivy510新品，其中高通已完成了从室内到外场的全部测试，紫光展锐的相关测试正在开始阶段。
- 这些芯片在下行峰值基本处于1.3～1.5Gbps或1.5～1.8Gbps之间。

Balong 5000 is the first chipset to perform to industry benchmarks for peak 5G download speeds. At Sub-6 GHz (low-frequency bands, the main spectrum used for 5G), Balong 5000 can achieve download speeds up to 4.6 Gbps. On mmWave spectrum (high-frequency bands used as extended-spectrum for 5G), Balong 5000 can achieve download speeds up to 6.5 Gbps.



3GPP Rel-16: Ongoing RAN-SA Studies

Common 5G focus areas across Radio Access Network and System / Core Network

Focus Area	System Studies	RAN Studies
URLLC for 5G	Enhancement of URLLC support in 5G, Enhanced support of Vertical and LAN Services, Cyber-physical control applications in vertical domains	Physical layer enhancements for NR UR Low Latency Cases, NR-based access to unlicensed spectrum, NR Industrial Internet of Things
V2X for 5G	Architecture enhancements for 3GPP support of advanced V2X services	NR Vehicle-to-Everything (V2X)
Positioning	Enhancement to the 5GC Location Services, 5G positioning services	NR positioning support
UE Capabilities	Optimisations on UE radio capability signalling	Optimisations on UE radio capability signalling – NR/E-UTRA Aspects
5G Satellite Aspects	Architecture aspects for using satellite access in 5G, Integration of Satellite Access in 5G	Solutions for NR to support non-terrestrial networks (NTN)

Many other features have *impacts* across the system (both in RAN and non-RAN areas), however, these are mainly handled on one side or the other. They require alignment not significant coordination.

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6G

◆2019年11月3日，科技部会同发展改革委、教育部、工业和信息化部、中科院、自然科学基金委在北京组织召开6G技术研发工作启动会，相关部门领导和有关专家参加会议，会议宣布成立国家6G技术研发推进工作组和总体专家组。

- 日本国立通信技术研究机构与NTTDOCOMO、NEC公司等，已经组成了研究团队，从2018年开始，启动了6G技术的研发。2019年10月31日，日本通信运营商NTT、索尼、美国英特尔联合发布消息称，3方将在“6G”通信标准领域展开合作。
- 韩国三星电子已经开设一个新的研究中心，用于开发6G移动网络的核心技术。
- 近日，芬兰奥卢大学发布了全球首个6G白皮书《6G无线智能无处不在的关键驱动与研究挑战》。

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  - 5G用什么技术?
  - 5G现状
  - 关于5G与未来网络的思考

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思考：仍然在构筑“带围墙的花园”？

- 在互联网开始商业化以前，电信网络采用的是“面向连接，电路交换，集中控制”的架构，和“运营商为中心”的运营模式。1995年采用“无连接、分组交换、分布、自治”架构的互联网开始商业化并且大获成功，1998年电信业接受IP, 开始了IP化的进程。IP网取代话音网成为电信的基础网络。电信网接受了IP，并没有接受互联网“分布、自治、扁平”的架构，坚持发展IMS/NGN, 建设集中控制，可管可控的IP网-“带围墙的花园”。
- 从3GPP发布的R15的文件给出的5G架构看，5G仍然在构筑“带围墙的花园”。
  - 目前在ITU、IETF、ETSI和我国（重大科技专项3）都在进行在5G中采用ICN协议取代TCP/IP协议的研究，探讨各种演进过渡方法5G。另外一个可能是基于区块链技术发展发展分布式的用户管理系统。

思考：SDN与未来网络

- SDN所倡导的软件化和虚拟化，目前已经成为未来网络演进发展的重要趋势和特征，相关的技术和协议将被用来构成未来网络基础设施。
  - SDN可以在一个物理网络基础设施上产生多个虚拟网络在逻辑上彼此相互隔离，可编程运行不同的协议。但是这仅仅是问题的一个方面，作为后IP网需要有新的协议取代今天的TCP/IP。SDN提供的是实现未来网络的手段，而不是未来网络本身。他可以为后IP网络提供实验床。
  - 今天美国的Internet2和GENI都开始使用SDN为发展后IP网络研究发展提供实验环境。
- SDN采用的“集中控制，分散下发”的理念与传统电信网是类似的，但是与互联网的分布自治原则是背道而驰的，也不会为未来后IP网所接受。

思考：5G与未来互联网的融合

◆3G早期仍然是基于ATM的面向连接的系统（B-ISDN），随后面对接入互联网的强大需求继固网之后蜂窝移动通信也开始了IP化的进程。一方面是发展HSPA实现空口IP化，另外一方面是核心网的IP化和扁平化。扁平化的蜂窝移动通信网络成为一个扁平的IP专网，通过网关连接公共互联网。移动性管理和用户管理全部在蜂窝移动网上完成，公共互联网仍然保持固定互联网的原有形态，用户使用移动运营商提供的临时IP地址，不需要移动性管理。

◆通过网关隔离，蜂窝移动通信网络和公共互联网独立发展的格局造就了今天移动宽带的快速发展。目前蜂窝网和WLAN 使用不同的网关在不同地点连接公共互联网，而移动性管理和用户管理都在蜂窝网的核心网上，在WLAN上登陆的用户需要经过公共互联网回到蜂窝网的核心网上才能得到移动性和用户管理。

◆当前基于TCP / IP的互联网网络协议框架有一定局限性。通过DHCP和DNS等协议分配和管理IP地址是相对静态的，TCP假设存在同生的端到端路径的存在，这些在应用于移动终端无线接入的场景时都有问题……蜂窝网与互联网的标准也要融合，形成统一的移动互联网架构。

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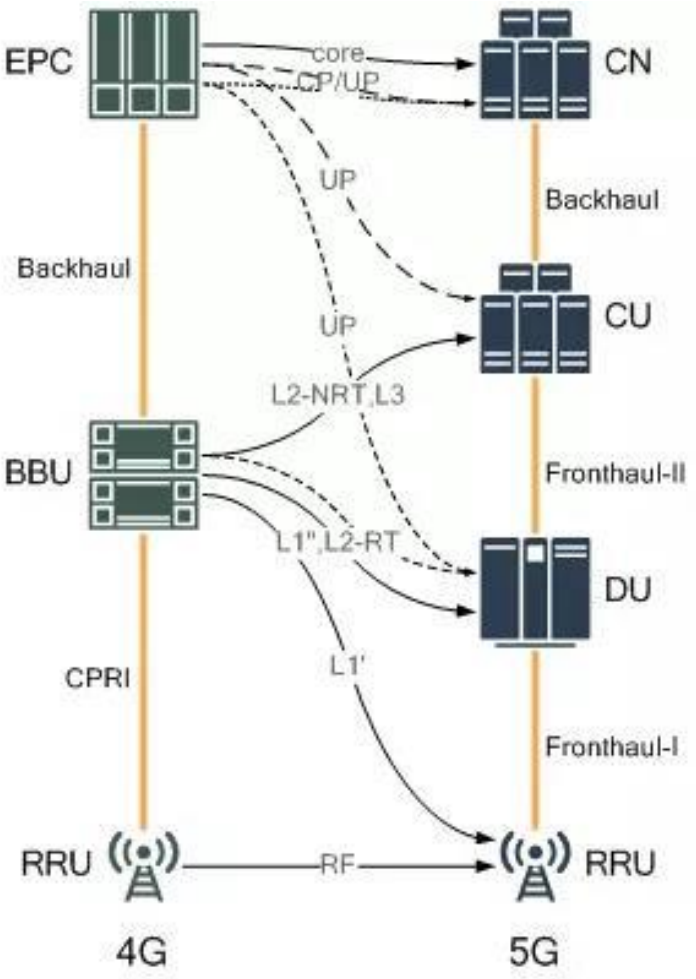
思考：天线技术成为最后的舞台？

接入网的基带处理单元BBU可能被重构为CU（Centralized Unit，集中式单元）和DU（Distributed Unit，分布式单元）两个功能实体。



小结：影响未来网络的思路

- IP化
- 扁平化
- 边缘计算
- 软件化
- 虚拟化

- 不带围墙的花园？
- 动态的用户地址？
- 取代TCP/IP？

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