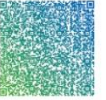




上海无线通信研究中心
SHANGHAI RESEARCH CENTER FOR WIRELESS COMMUNICATIONS



Open 5G Platform

Dr. Yang Yang

Shanghai Research Center for Wireless Communications
Key Lab of Wireless Sensor Network and Communication
SIMIT, Chinese Academy of Sciences

www.wico.sh

上海市浦东新区海科路100号8号楼4楼, 201210
电话: 021-60213003 传真: 021-60213000

4/F, Building 8, 100 Haik Rd, Pudong, Shanghai 201210, China
Tel: +86-21-60213003 Fax: +86-21-60213000

R&D Projects on 5G (as PI)



- **TT5G: Transmission Technologies for 5G** (61461136003), **National Natural Science Foundation of China (NSFC)** Key International R&D Collaboration Program (China-Finland), 2015-2017.
- **Testing and Evaluation Technologies for 5G Mobile Communications Technologies** (2014AA01A707), **Ministry of Science and Technology (MOST)** 863 Hi-Tech Program, 2014-2016.
- **Safety-Oriented Wireless Sensor Networks Technologies for the South-to-North Water Diversion Project of China** (2014ZX03005001), **National Science and Technology Major Projects** “New Generation Mobile Wireless Broadband Communication Networks”, 2014-2015.
- **Future Broadband Wireless Access Technologies** (2010DFB10410), **Ministry of Science and Technology (MOST)** Key International S&T Collaboration Program (China-Finland), 2010-2012.
- **UK-China Science Bridges: R&D on (B)4G Wireless Mobile Communications** (EP/G042713/1), **Research Councils UK (RCUK)** and **The Engineering and Physical Sciences Research Council (EPSRC)**, 2009-2012.

International Collaboration Partners



Sino-Sweden



Sino-Finland

Sino-UK

Honor:
International S&T
Collaboration Base,
Ministry of Science
and Technology, China

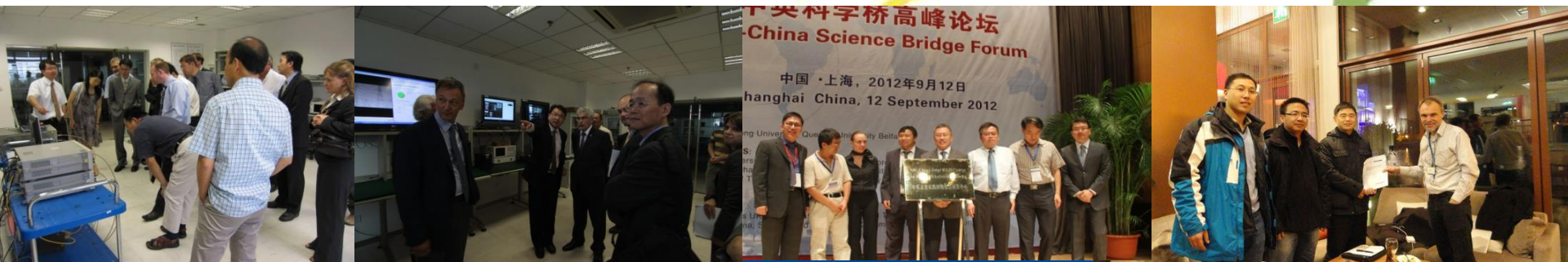


Sino-Canada

Sino-Australia



Brazil

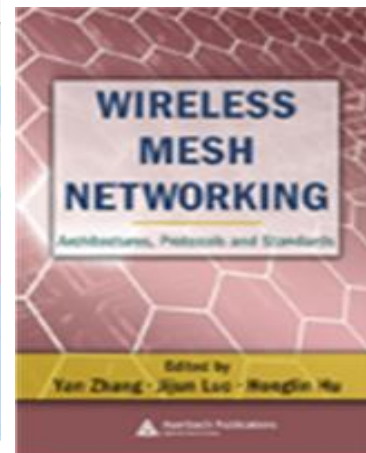
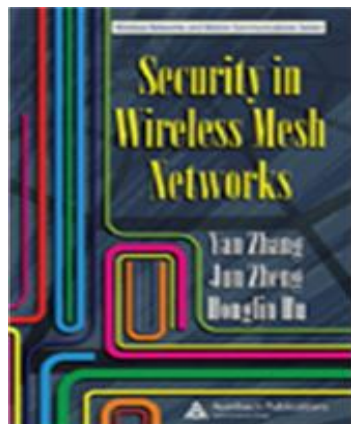
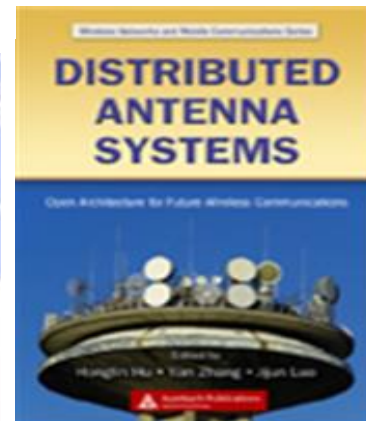
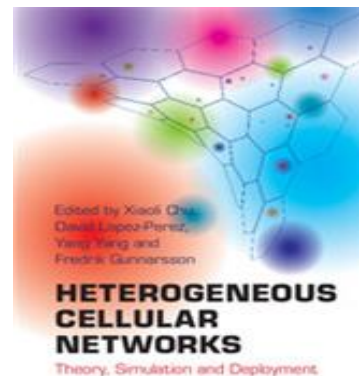


上海无线通信研究中心

SHANGHAI RESEARCH CENTER FOR WIRELESS COMMUNICATIONS

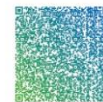
Research Outcomes (2011-2015)

- Patents/Copyrights: **270+**
- Technical Books: **2**
- Standard Proposals: **27**
- Research Papers: **300+**





上海无线通信研究中心
SHANGHAI RESEARCH CENTER FOR WIRELESS COMMUNICATIONS



5G: a Game Changer

www.wico.sh

上海市浦东新区海科路100号8号楼4楼, 201210
电话: 021-60213003 传真: 021-60213000

4/F, Building 8, 100 Haik Rd, Pudong, Shanghai 201210, China
Tel: +86-21-60213003 Fax: +86-21-60213000

TIP, February 22, 2016



- The Telecom Infra Project (TIP) is an engineering-focused initiative driven by operators, infrastructure providers, system integrators and other technology companies that aim to reimagine the traditional approach to building and deploying telecom network infrastructure.
- Focus areas: access, backhaul, and core and management.
- **Open and collaboration!**

Members (growing)

AMN	ACACIA	IP access
ADVA	Amarisoft	Juniper
ASOCS	Aricent	LEMKO
AW2S	Athonet	Lumentum
Axiata	BaiCells	MTN
Bandwidth	BlueStream	Nexius
Broadcom	Coriant	Nokia
EE	T-Mobile	Quortus
Equinix	Facebook	Radisys
Globe	Harman	Horizon
HCL	SK Telecom	iDirect
SS7	Starsolutions	Sysmocom
Intel	Indosat	Telefonica

FCC, July 14, 2016



- U.S. leadership in 5G is a national priority.
- There are others around the world who are saying, “No, we want to figure out what the standards are and then figure out how to do the spectrum.” We think that’s backwards.



Tom Wheeler, FCC Chairman

Licensed			Unlicensed
27.5GHz-28.35GHz	37GHz-38.6GHz	38.6GHz-40GHz	64GHz-71GHz

Source: FCC

White House, July 15, 2016



- Advanced Wireless Research Initiative, USD 400 million, led by the NSF.
- **Deployment of four city-scale testing platforms for advanced wireless research.**
- (To) allow academics, entrepreneurs, and the wireless industry to test and develop advanced wireless technology ideas, some of which may translate into key future innovations for 5G and beyond.

Strong support from public and private sectors

NSF	DARPA
NIST	NTIA
AT&T	Carlson Wireless
HTC	CommScope
Intel	InterDigital
NI	Juniper Networks
Nokia	Keysight
Oracle	Qualcomm
Viavi	Samsung
Sprint	Shared Spectrum
Verizon	T-Mobile
ATIS	CTIA
TIA	Source: White House

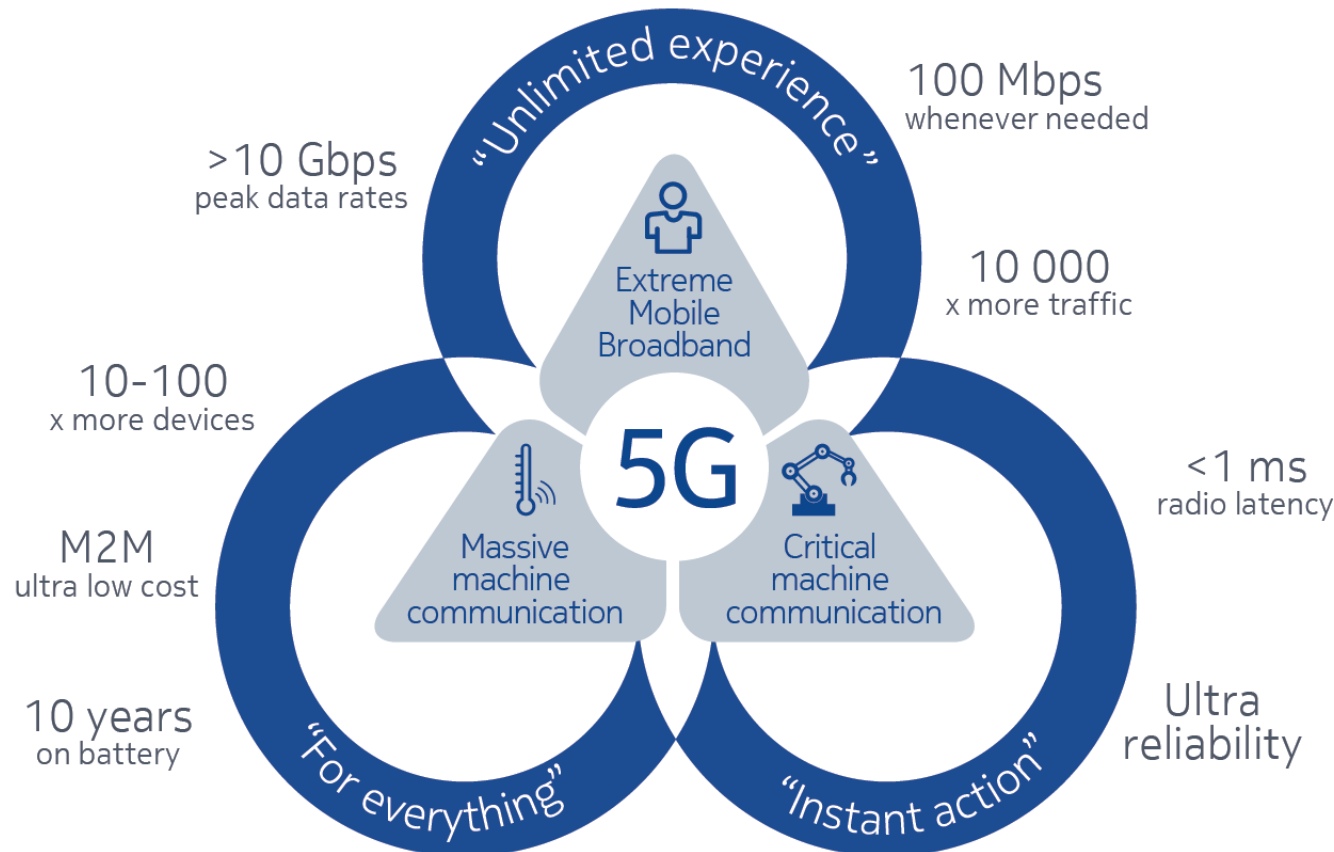
Outline

- **5G Vision:** a user-centric flat network
- **Approach:** software defined mobile network
- **Challenges:**
 - Real-time processing
 - Industry applications
 - Your participation

5G Technical Requirements



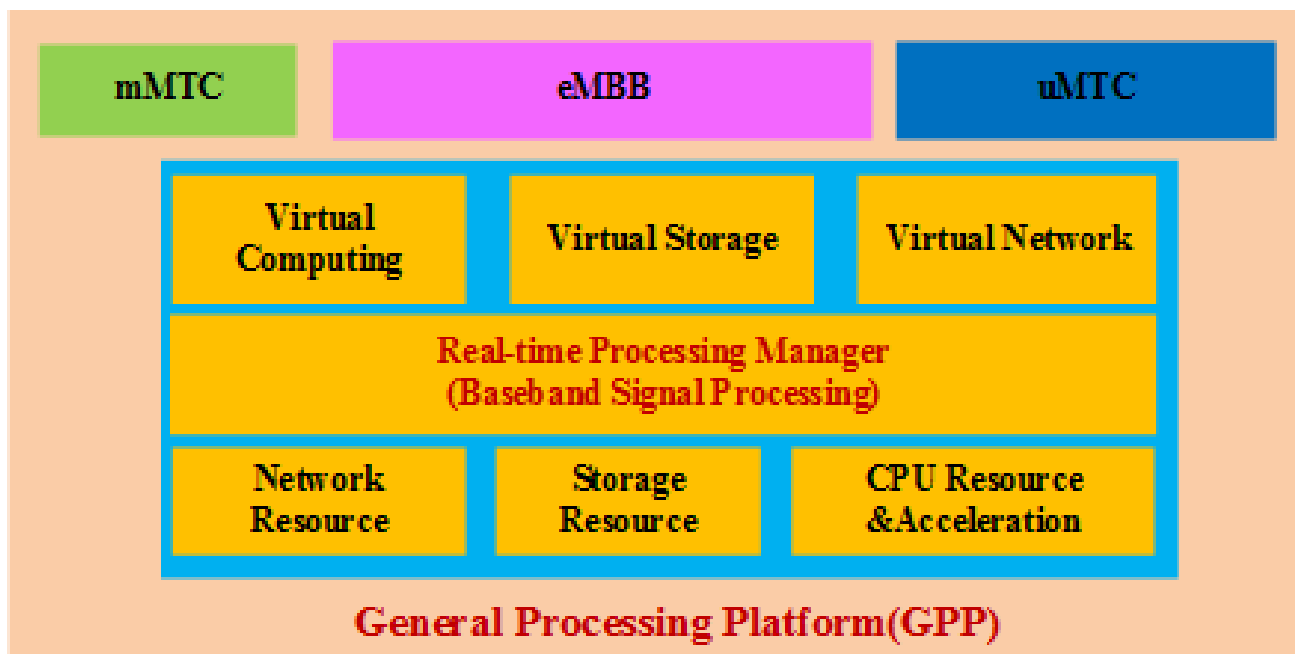
- Can **one** 5G network satisfy **all** diversified requirements?
- How to make 5G networks super flexible and adaptive?



Source: Nokia

5G Vision: GPP-based Platform

- Software defined mobile network and resource/network function virtualization could meet different diversified 5G use cases and business models, i.e. eMBB, mMTC and uMTC.

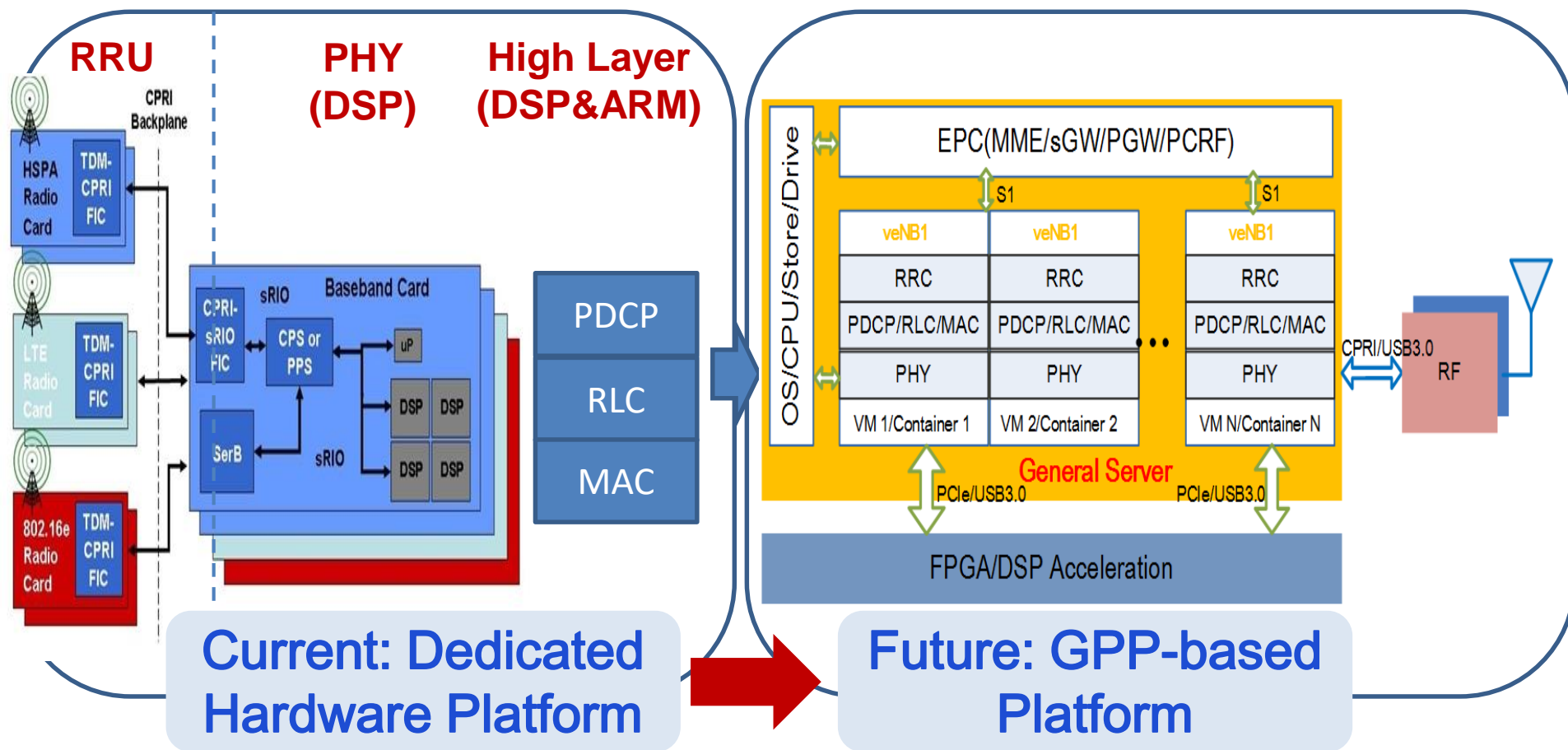


**Virtualized
Network Slices**



Motivation: Flexible and Adaptive

- To decouple software and hardware designs
- To realize flexible deployment of network functions



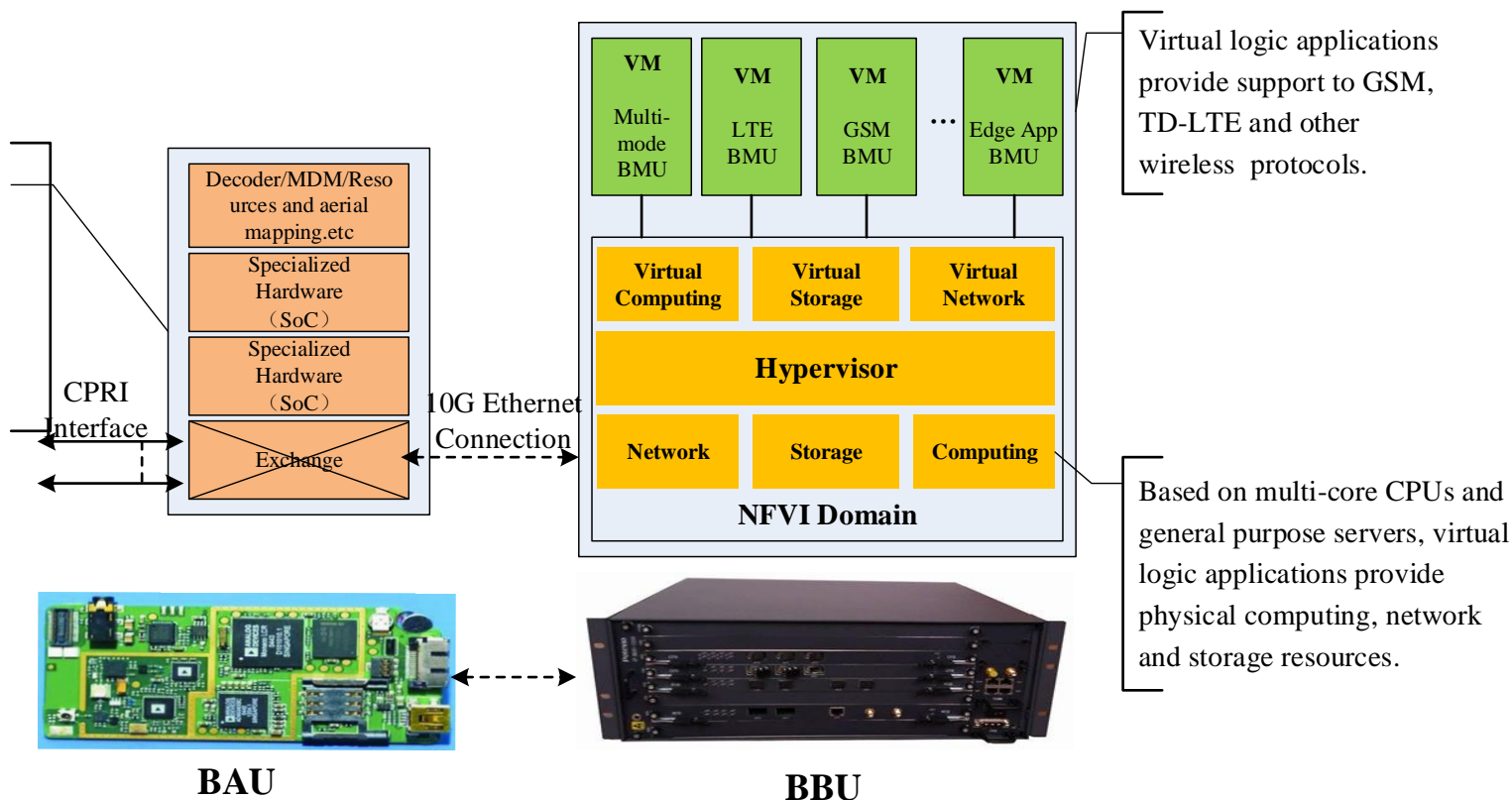
Outline

- 5G Vision: a user-centric flat network
- **Approach:** software defined mobile network
- Challenges:
 - Real-time processing
 - Industry applications
 - Your participation

Software Defined RAN



Making up the weakness of general processor, providing standard function of CODEC, MDM, resource mapping, FFT/IFFT/DFT and etc.



Dedicated accelerations
with FPGA and DSP

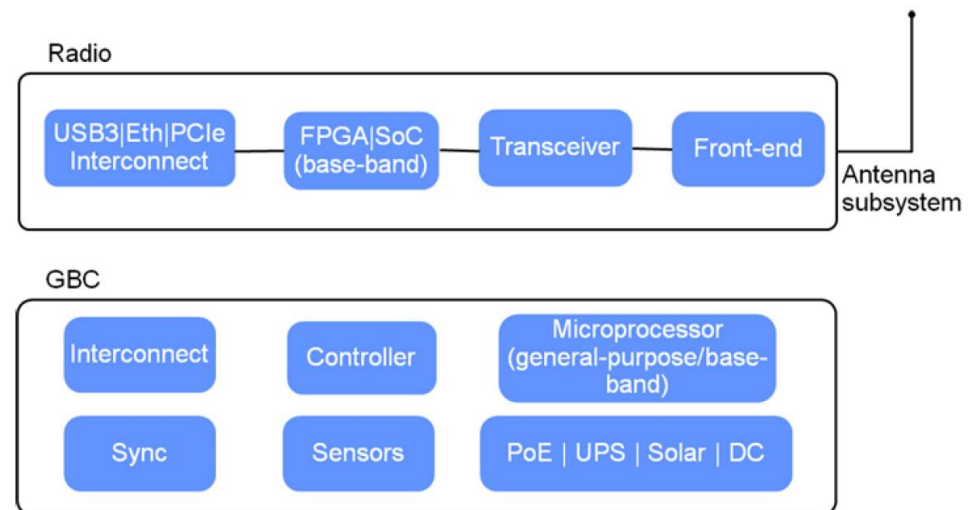
Virtualization of
baseband resources

Source:
Alcatel-Lucent
Shanghai Bell

Facebook OpenCellular: an Open Source Wireless Access Platform



- **Radio:** Radio with integrated front-end, which is based on SDR/SoC and supports network-in-a-box or access point.
- **GBC:** General Baseband Computing
- **Function:** SMS messages, voice calls, basic data connectivity using 2G implementation.



Source: Facebook

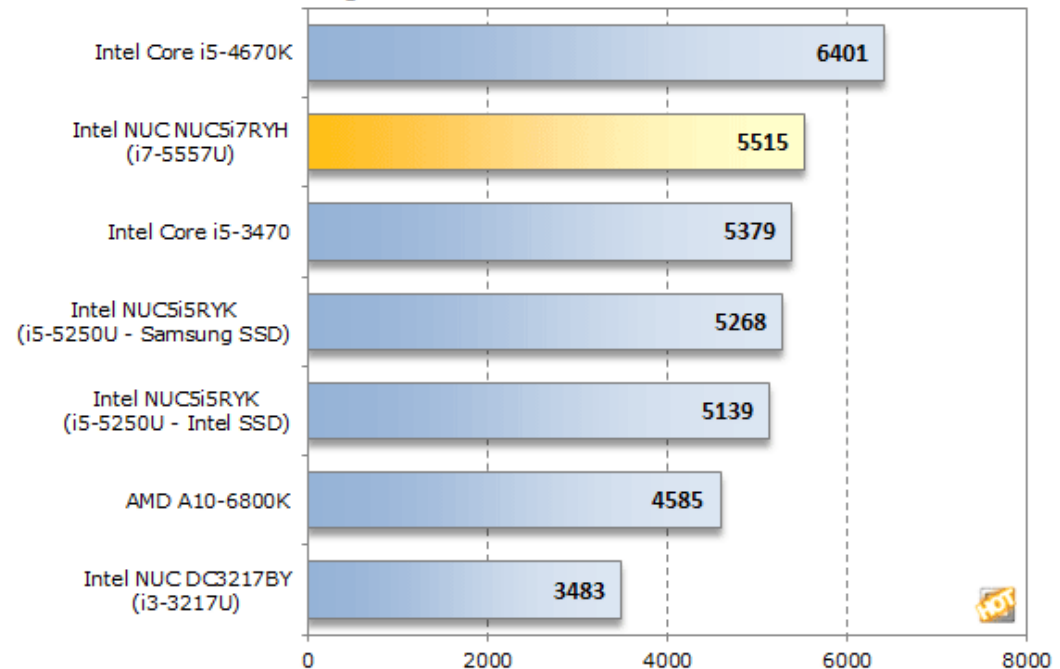
it is a just mini PC



Intel NUC 5i7RYH
Core i7-5557U
3.1 GHz-3.4 GHz
Dual-core
4 MB cache
Price: < 600 USD

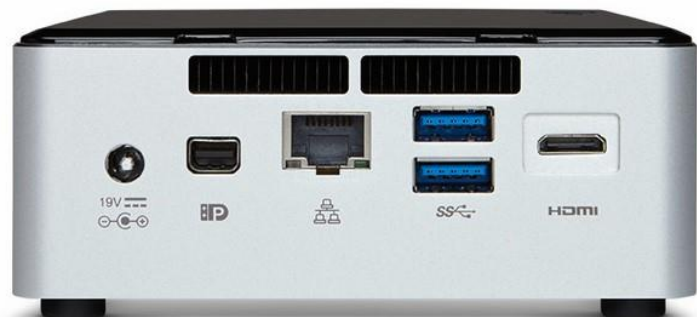


Futuremark PCMark 7
Overall PCMark Score
Intel NUC5i7RYH - Core i7-5557U
Higher Scores = Better Performance



Source: Internet

You think it is a just mini PC

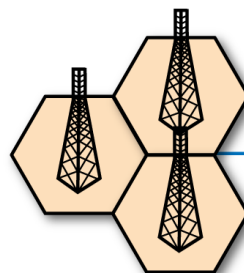


eNodeB

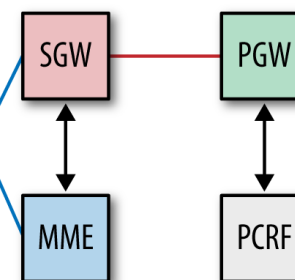
EPC



Radio Access Network (RAN)



Core Network (EPC)



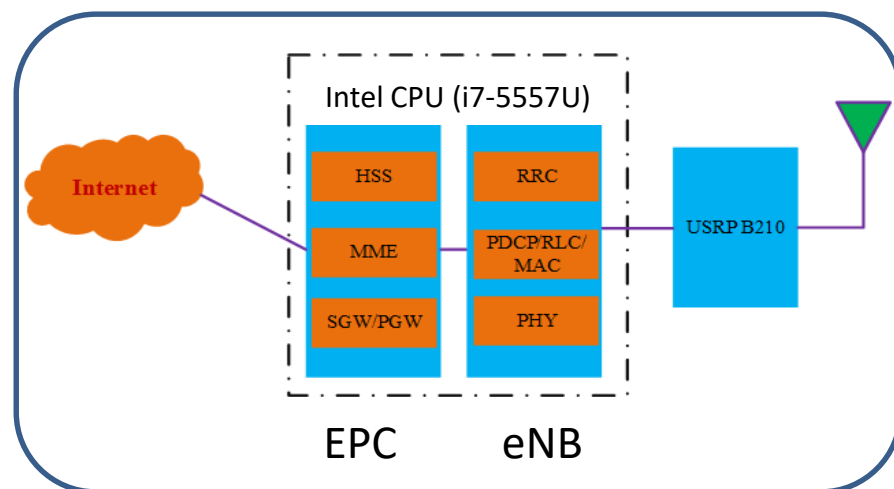
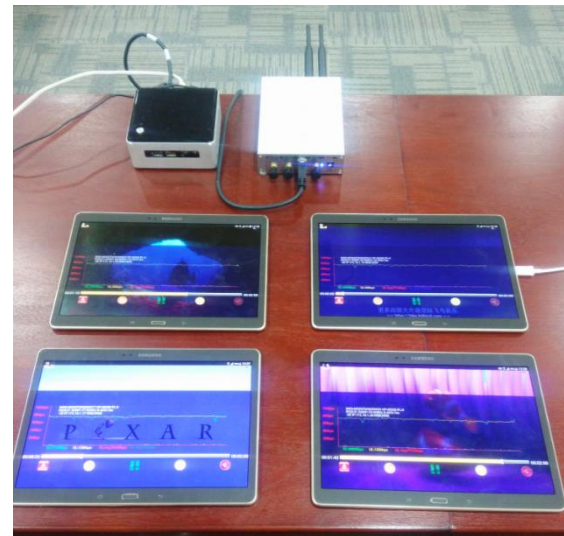
External Network

Source: Internet

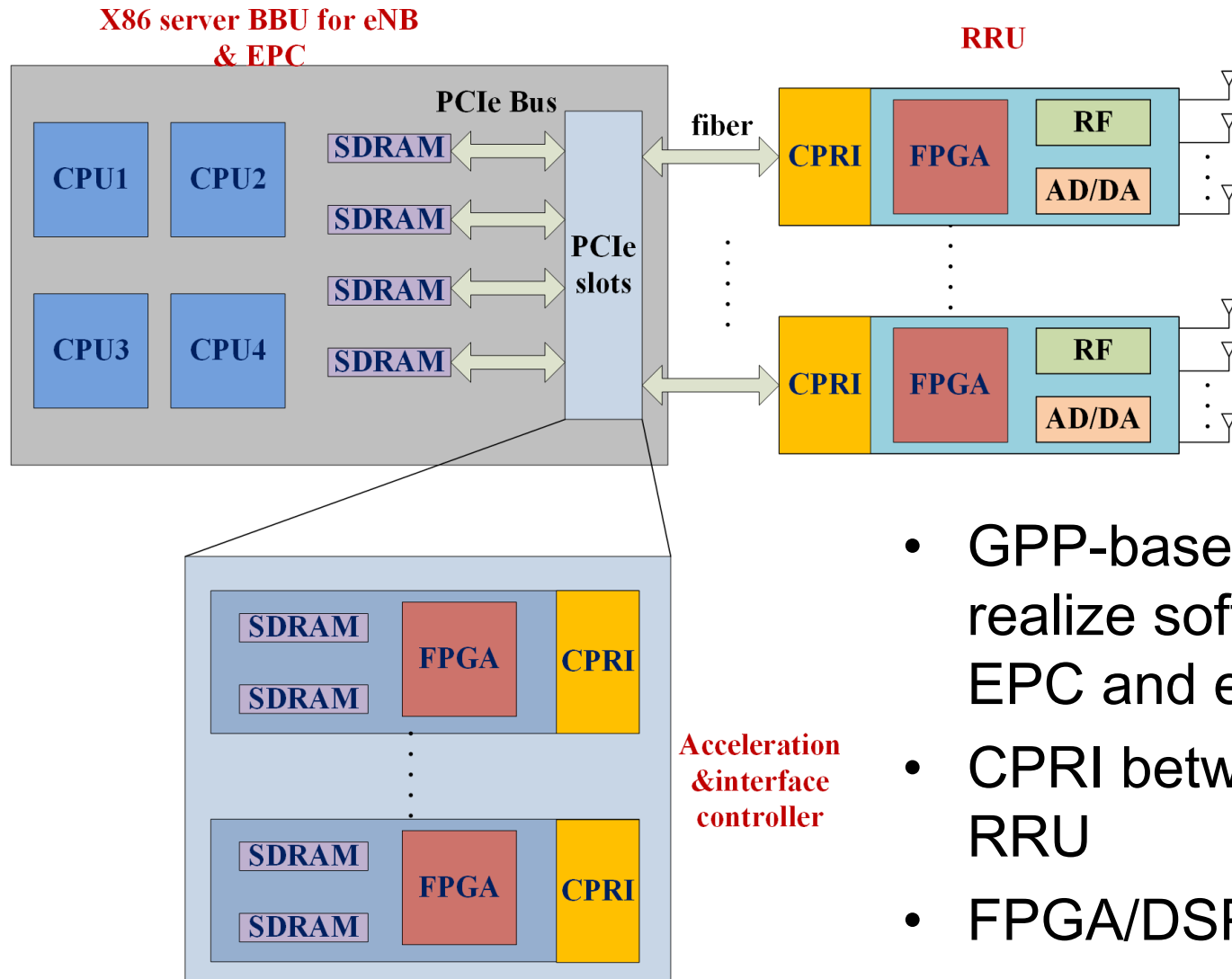
Software Defined Mobile Network



- Based on OAI open-source LTE platform
- Real-time software defined LTE network (including RAN and EPC) on a multi-core GPP-based platform
- FDD and TDD modes
- Support multiple commercial LTE mobile terminals for each eNB
- Support video streaming and web browsing traffic



Open 5G Platform Architecture



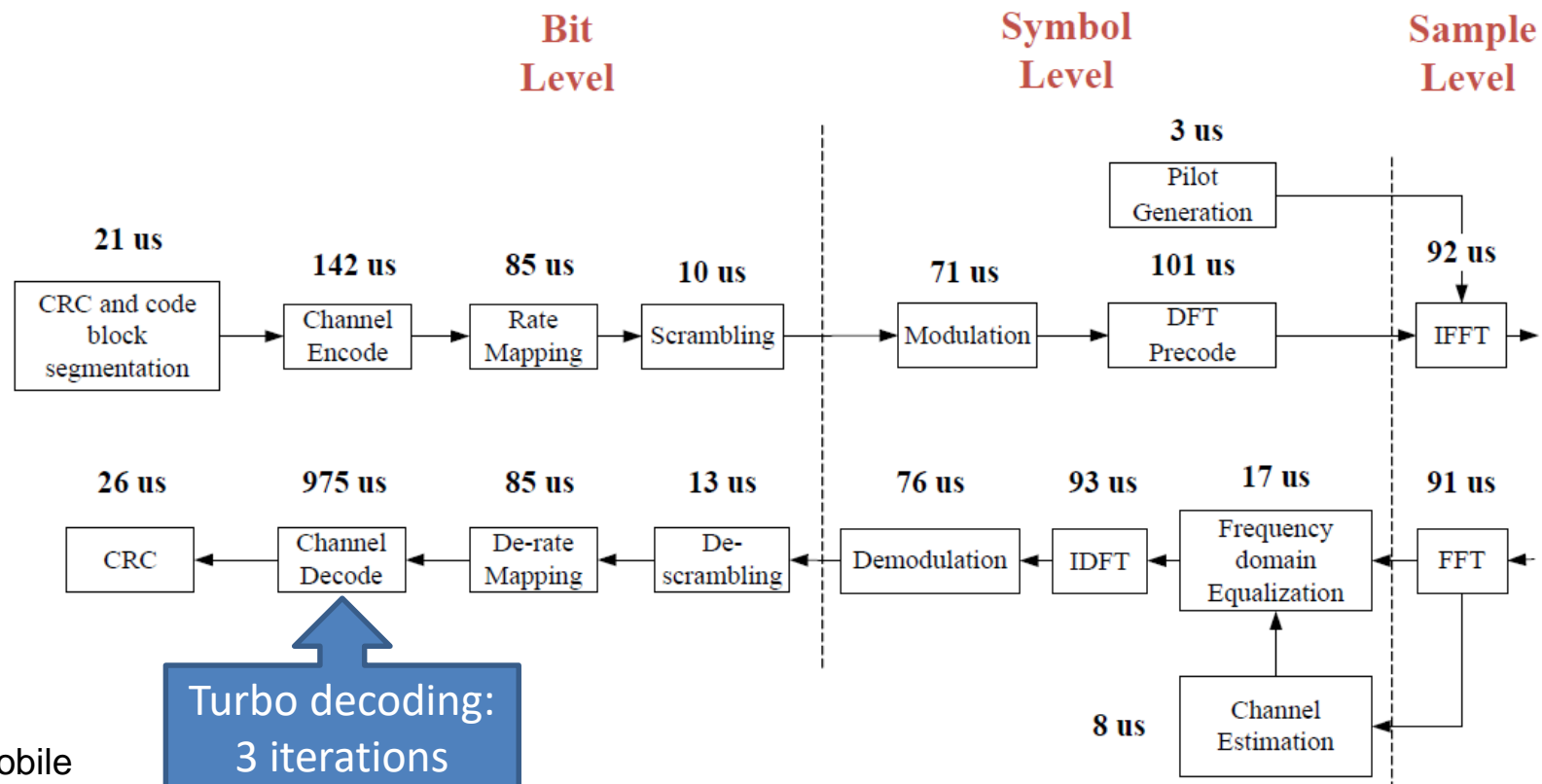
- GPP-based platform to realize software defined EPC and eNB BBU
- CPRI between BBU and RRU
- FPGA/DSP Acceleration

Outline

- 5G Vision: a user-centric flat network
- Approach: software defined mobile network
- **Challenges:**
 - Real-time processing
 - Industry applications
 - Your participation

Delay of baseband signal processing

- TD-LTE uplink and downlink on a GPP-based platform;
- Multi-core parallel computing achieves real-time requirements.

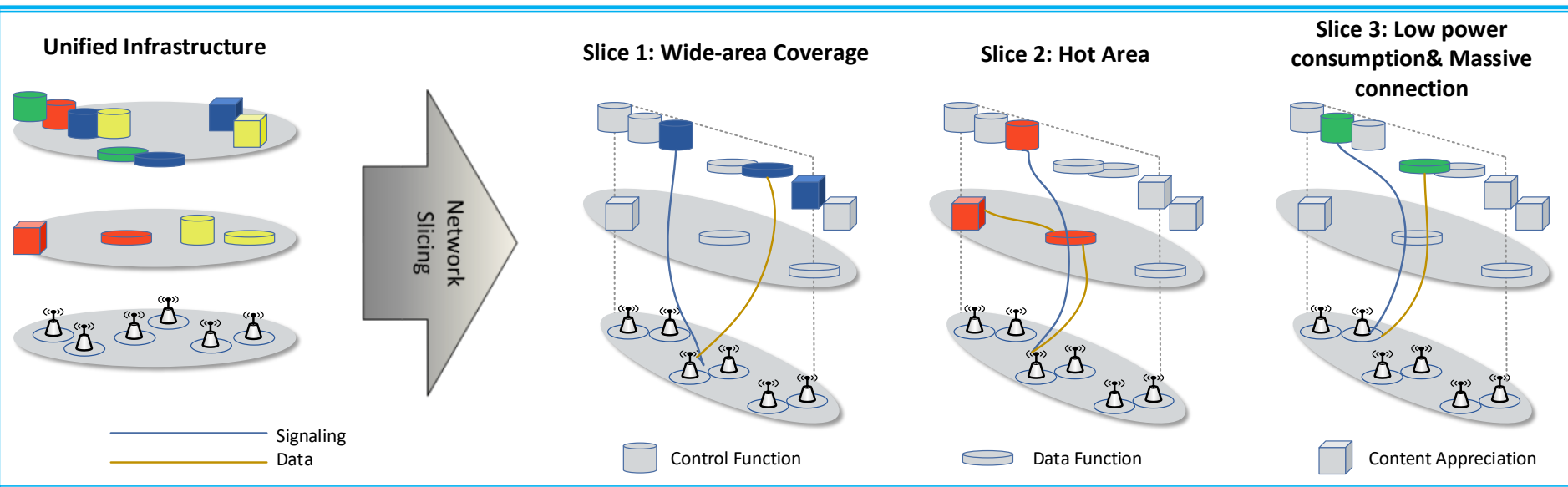


Delay of baseband signal processing

- **Our GPP-based platform:** IBM System x3400 M3 with 2.13GHz CPU, quad-core Intel Xeon E5606, 4G RAM, 256G HDD, Linux Debian 7 OS with the version 64 bits Ubuntu 14.04 DeskTop.
- **Turbo decoding** is the bottleneck for real-time processing.

Function \ Processing Time(μs) \ Rate (Mbps)	Rate (Mbps)			
	2.152	8.76	13.536	17.56
De-scrambling	7.96	21.93	33.38	43.26
De-modulation	7.89	13.72	15.94	17.84
De-interleaving	6.27	30.19	48.68	72.11
Turbo decoding	113.44	465.01	734.86	1047.61

Network Slicing for Various Use Cases



- **Open Source Software:** to build a collaborative community and ecosystem for innovations in EPC, eNB and terminals.
- **GPP-based Hardware:** to replace dedicated hardware (e.g. ASIC), thus enabling flexible and adaptive service creations and deployments for various use cases and business models.

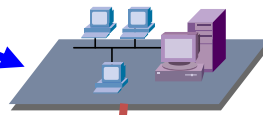
Customized Industry Applications



Data Analysis



Business Platform



Monitor Center



Open EPC

Network Management

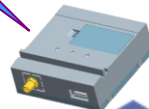
Open RAN

Soft Terminals



Video Surveillance

Environment Monitoring



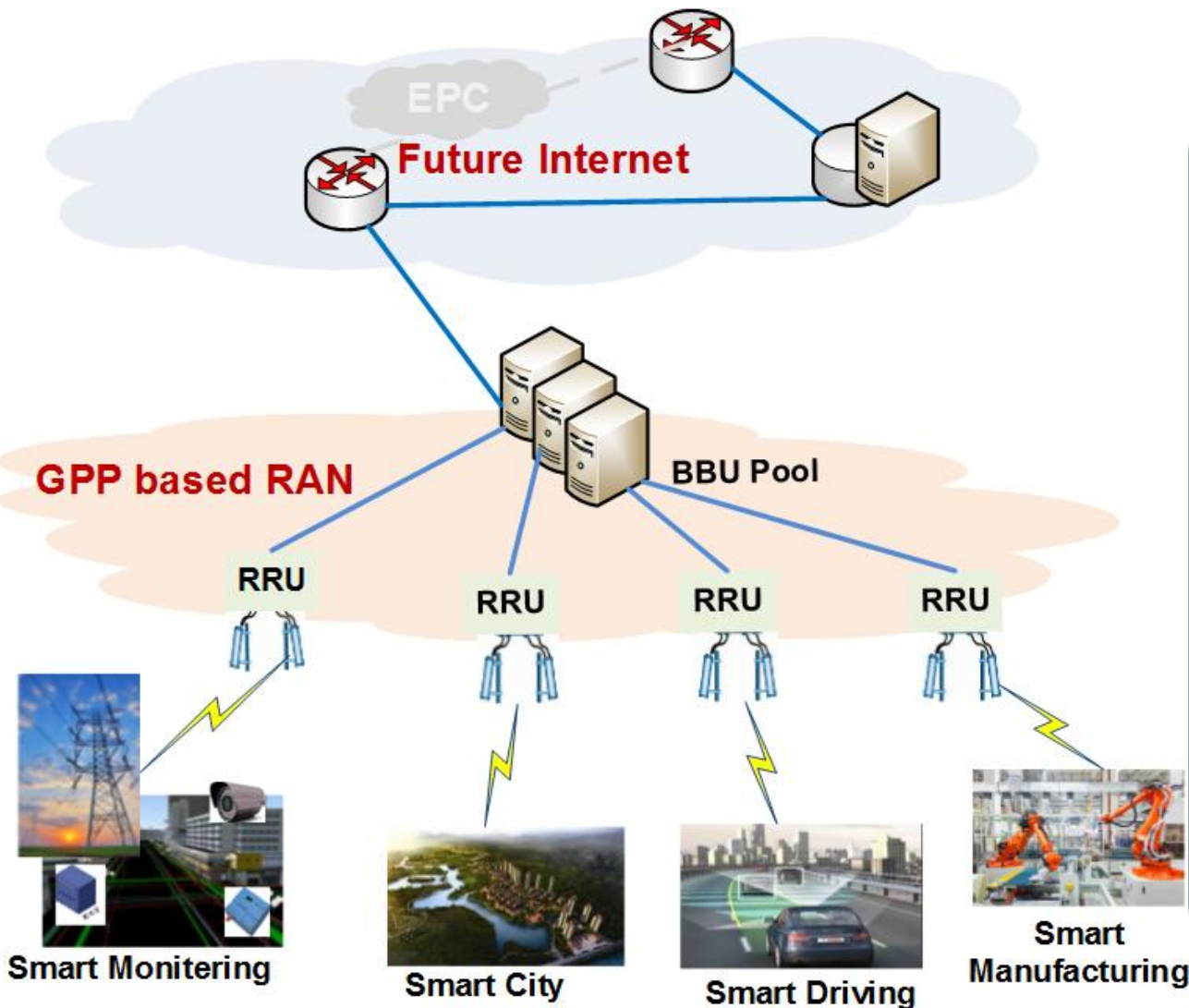
Soft Terminals

Smart Grid



- GPP-based 5G network supports **fast prototyping** of special industry requirements on soft terminals, open RAN and open EPC.
- **Quick deployment** of dedicated network slices for customized industry applications.

GPP-based 5G Network for IoT Applications



- GPP-based 5G network supports a variety of IoT applications
- Massive and low rate connections
- Low power consumption and depth coverage
- Low latency and high reliability

Heterogeneous Wireless Testbed



➤ LTE + 5G hierarchical network architecture

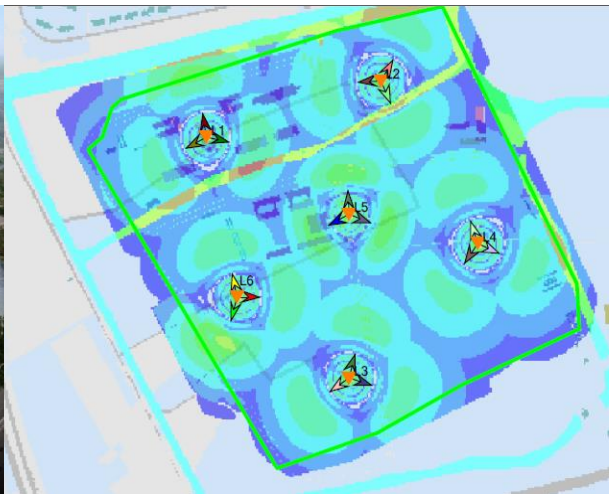
- 6 macro-cell base stations
- 10~20 micro-cell base stations
- 100+ small base stations
- Trial of GPP-based BSs

➤ 802.11ac high speed WLAN

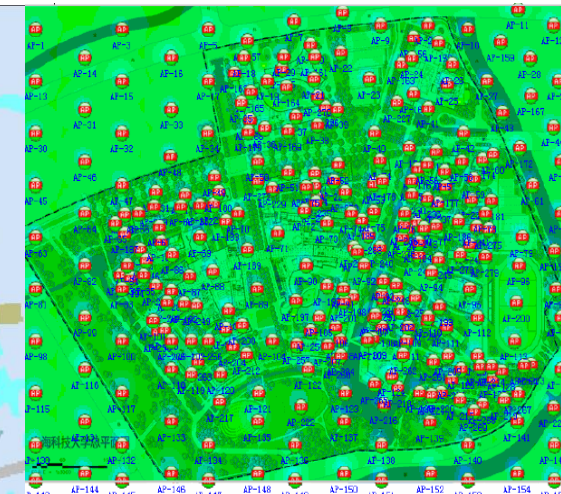
- 100~200 outdoor APs
- 1000~10000 indoor APs
- UDN, multi-carriers
- Trial of GPP-based APs



ShanghaiTech University

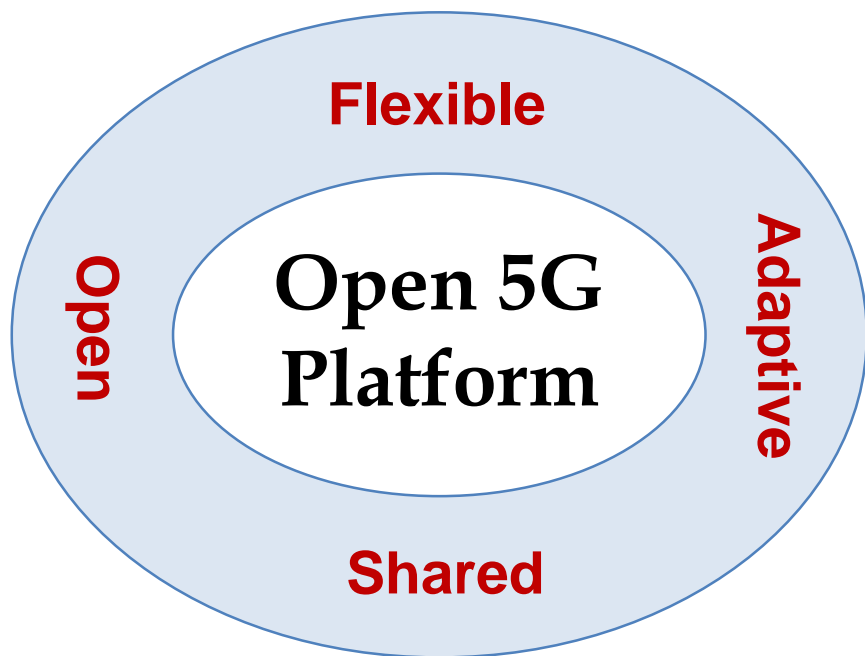


LTE+5G macro-cell BSs

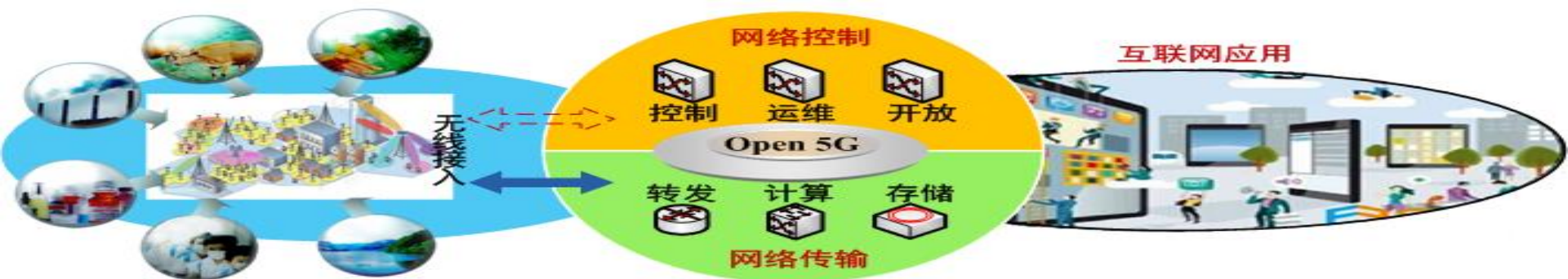


802.11ac outdoor APs

Conclusion: More Innovation and Impact



- **Professor:** evaluation of creative ideas
- **Student:** learning by doing
- **Industry:** fast prototyping and trials of new products
- **Application:** cross-domain customized services



Join us in this
OPEN world!



Many thanks to
Prof. Luciano Leonel Mendes
and Bianca Bandeira!

Dr. Yang Yang

Email: Yang.Yang@wico.sh