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The Master Plan of Taiwan's 5G Research Program

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Taiwan Dominates ICT Box Making

NB

WW No.1
TW/WW Market Share
89.60%

Mother Board

WW No.1
TW/WW Market Share
80.80%

LCD Monitor

WW No.1
TW/WW Market Share
65.70%

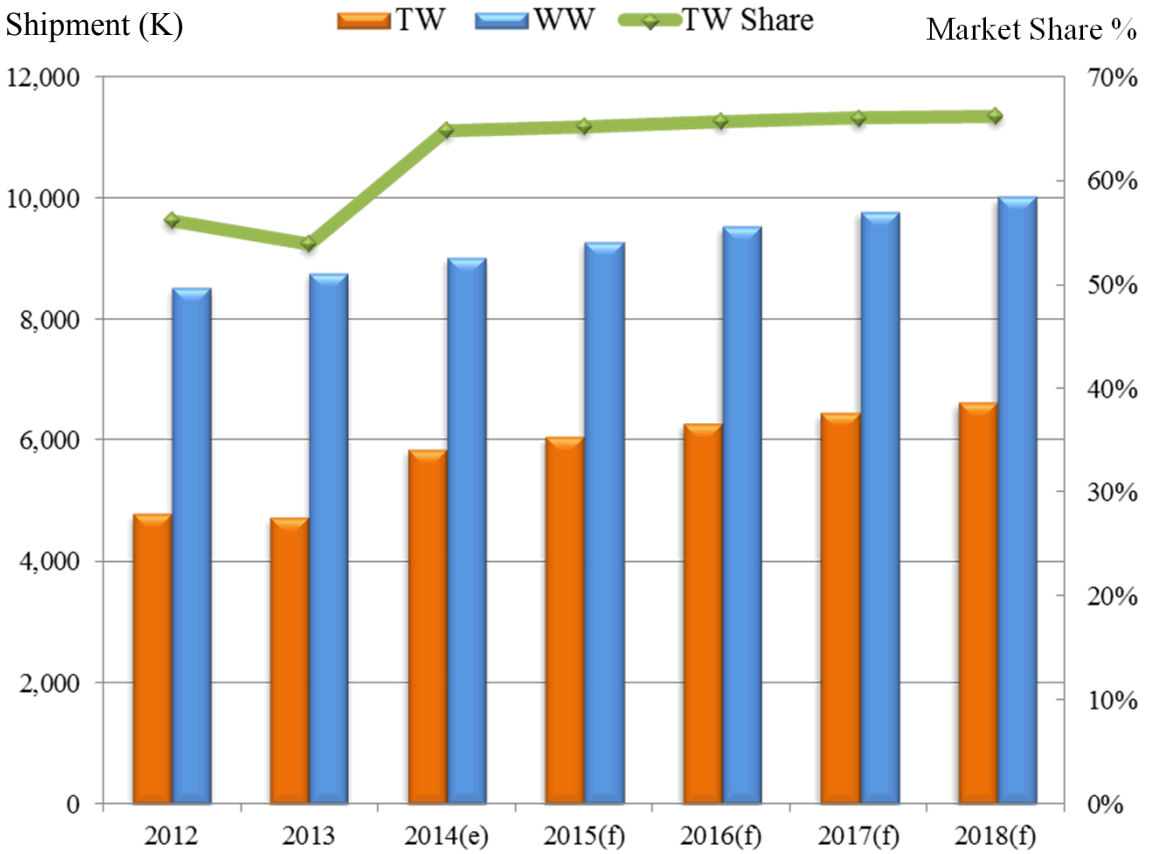
Server

WW No.1
TW/WW Market Share
53.90%

Tablet device

WW No.1
TW/WW Market Share
47.90%

Taiwanese server vendor's shipments and global market share (2012-2018)



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Major Taiwanese Players in ICT Space

Digital Content (Audio and Video)

Jay Chou
2nd most influential person in the world in 2011

Ang Lee
Won two Oscars for “Best Director” for "Brokeback Mountain" and "Life of Pi"

Industrial Design

2012 Geneva International Invention Exhibition, winning rate 97.6%, the top in the world

2012 Germany's IF Design Award, won three gold medals in

ICT Brand

Asus
World's 3rd in tablet PCs in 2013 Q1

Acer
World's 3rd in NBs in 2013 Q1

HTC
World's 4th in smart phones in 2012

D-Link
4th in global market share retailing WLAN Routers in 2012

Major customers of Taiwan's OEM

- Hon Hai
- Quanta
- Wistron
- Inventec
- Compal

Server	Notebook	Smart Handheld	Other types of consumer electronics
HP, IBM, Dell, Facebook, Google, Amazon…	HP, Lenovo, Apple, Dell, Acer, Toshiba, Asus…	Apple, Nokia, Sony, Motorola Mobility, RIM, Amazon, Asus, Lenovo, Xiaomi…	HP, Microsoft, Sony, Apple, Barnes & Noble, Toshiba, LG…

Semiconductor OEM

TSMC
1st in global market share in 2012

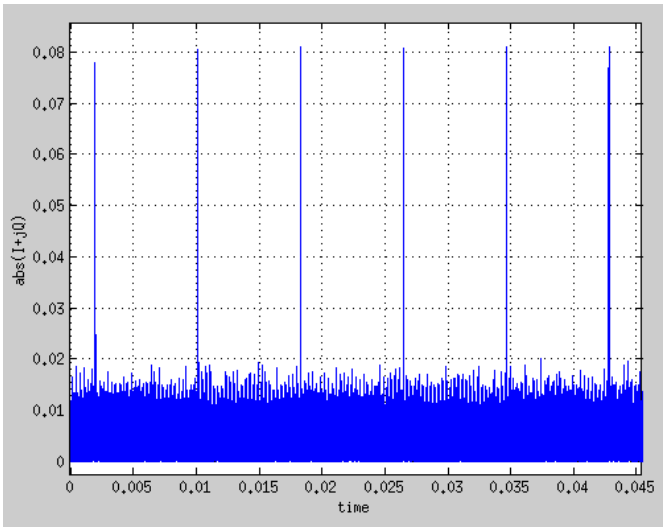
UMC
3rd in global market share in 2012

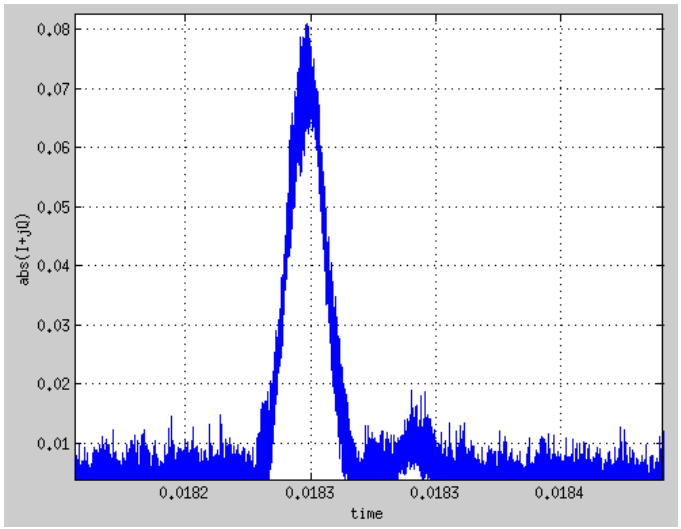
Mobile phone chip

MediaTek
3rd in global market share in 2012

Channel Measurement @ 11GHZ

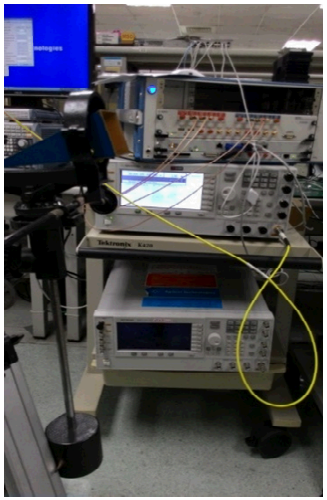
- 11GHz channel sounding instrument
- 11 GHz LOS channel measurement @ 97m
- Analysis of 11 GHz measured raw data
  - Frequency offset between PGA & PXA + SME06: 8.756 KHz



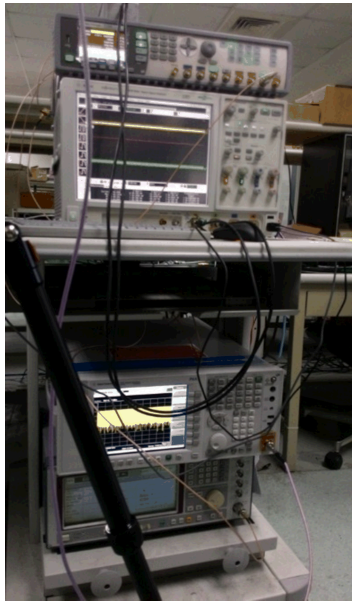


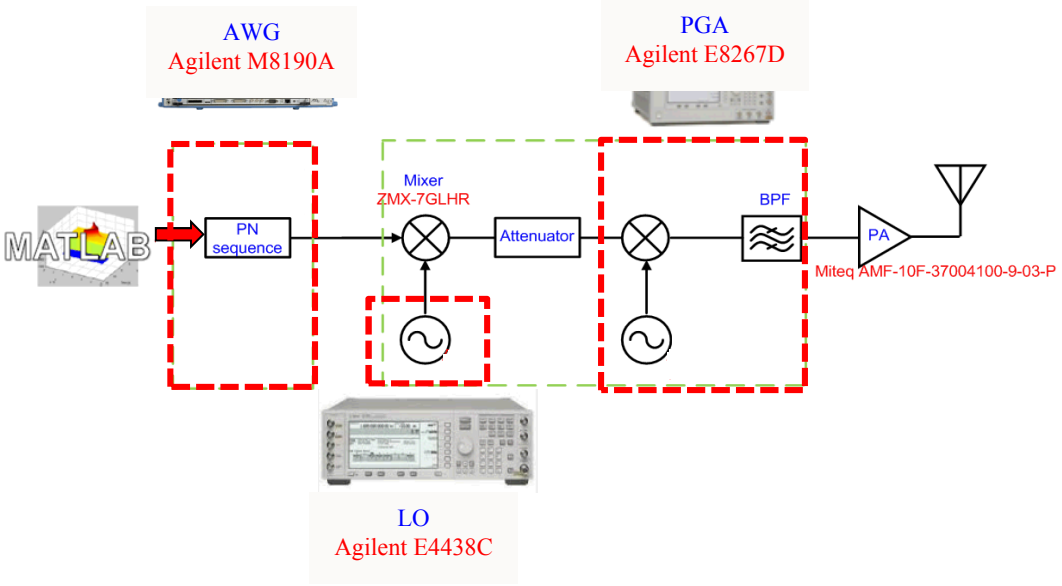
Channel Measurement @ 38GHZ

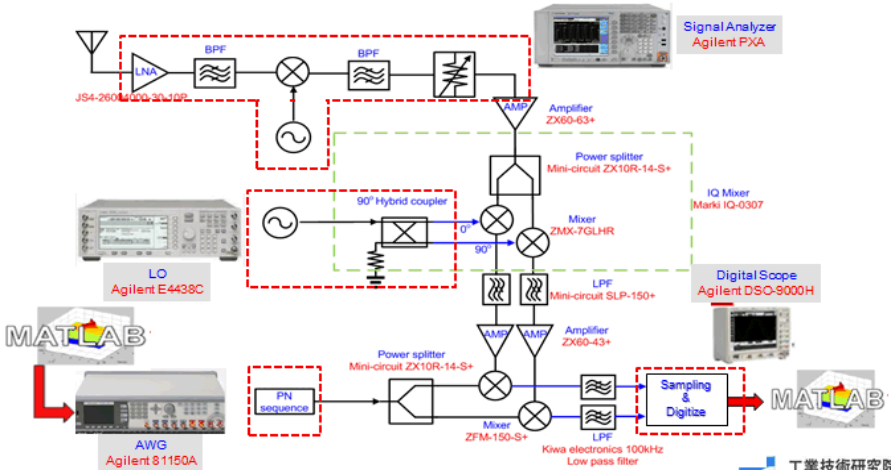
- 38GHz Tx for channel sounder



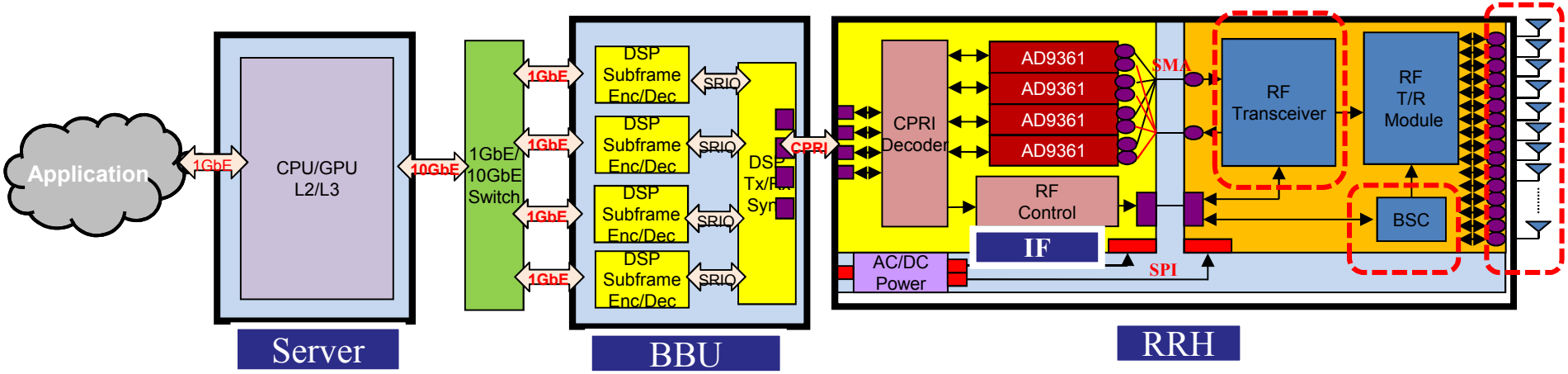
- 38GHz Rx for channel sounder

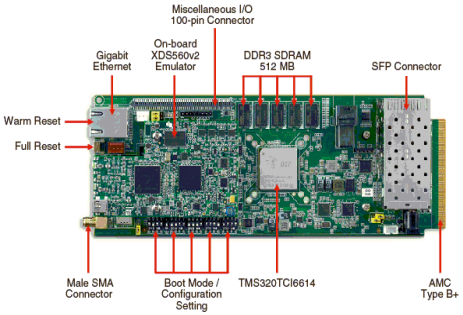


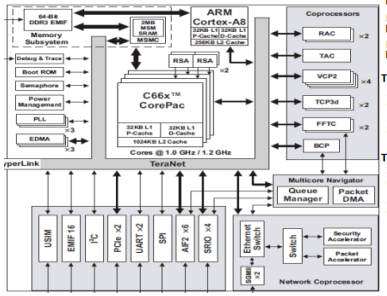




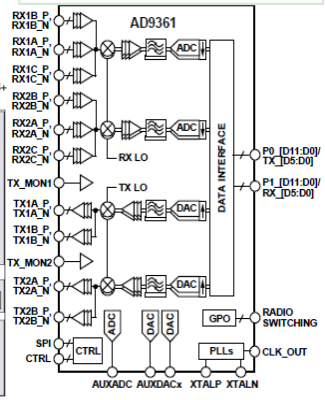
5G SDR Development Platform



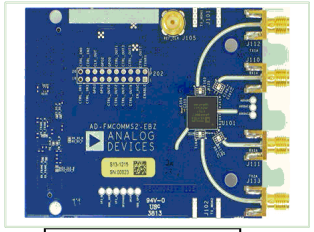


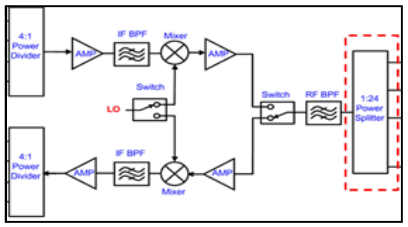


TMS320TCI6614

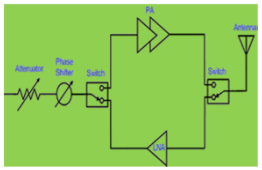


AD9361



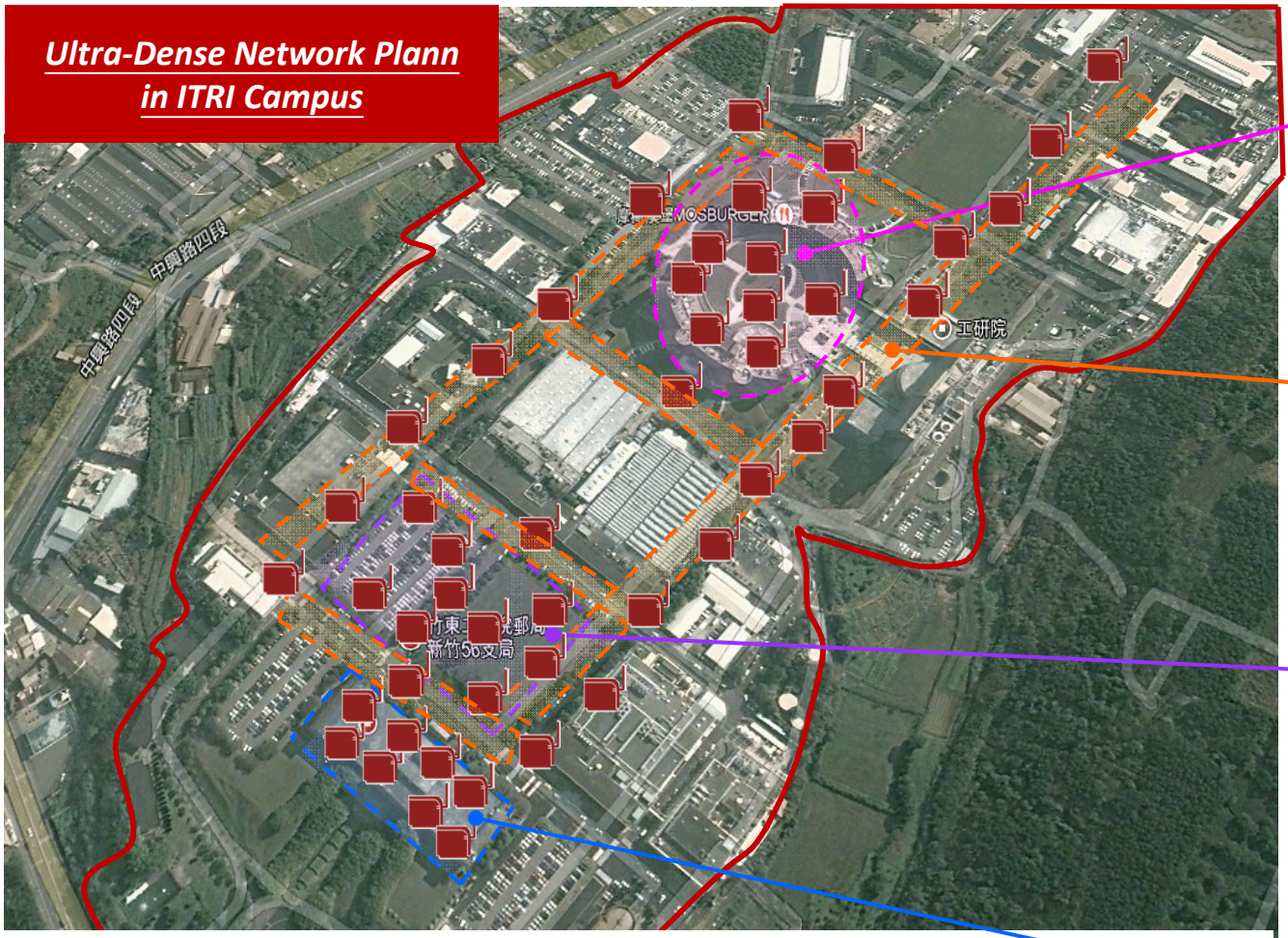


RF Transceiver



T/R module

Ultra Dense Network Test-bed



Hotspot:
- Convenience Store
- Fast Food Restaurant
- Food Court
- Post Office
- Bank

- **150 x 150 Square Meters**
- **First Floor and Underground Floor**
- **Peak Times: 3000 people**
- **Off-peak Times: 100 people**

Mobility:
- Bi-directional
- Speed Limit: 30Km/h

- **Max. 900 Meters Lane**

Outdoor:
- Softball Field
- Car Park

- **125 x 150 Square Meters**
- **Average 200 people**

Indoor:
- Office
- Meeting Room
- Lecture Hall
- Lobby
- **100 x 35 Square Meters**
- **3 Stories High**
- **Average 800 people**

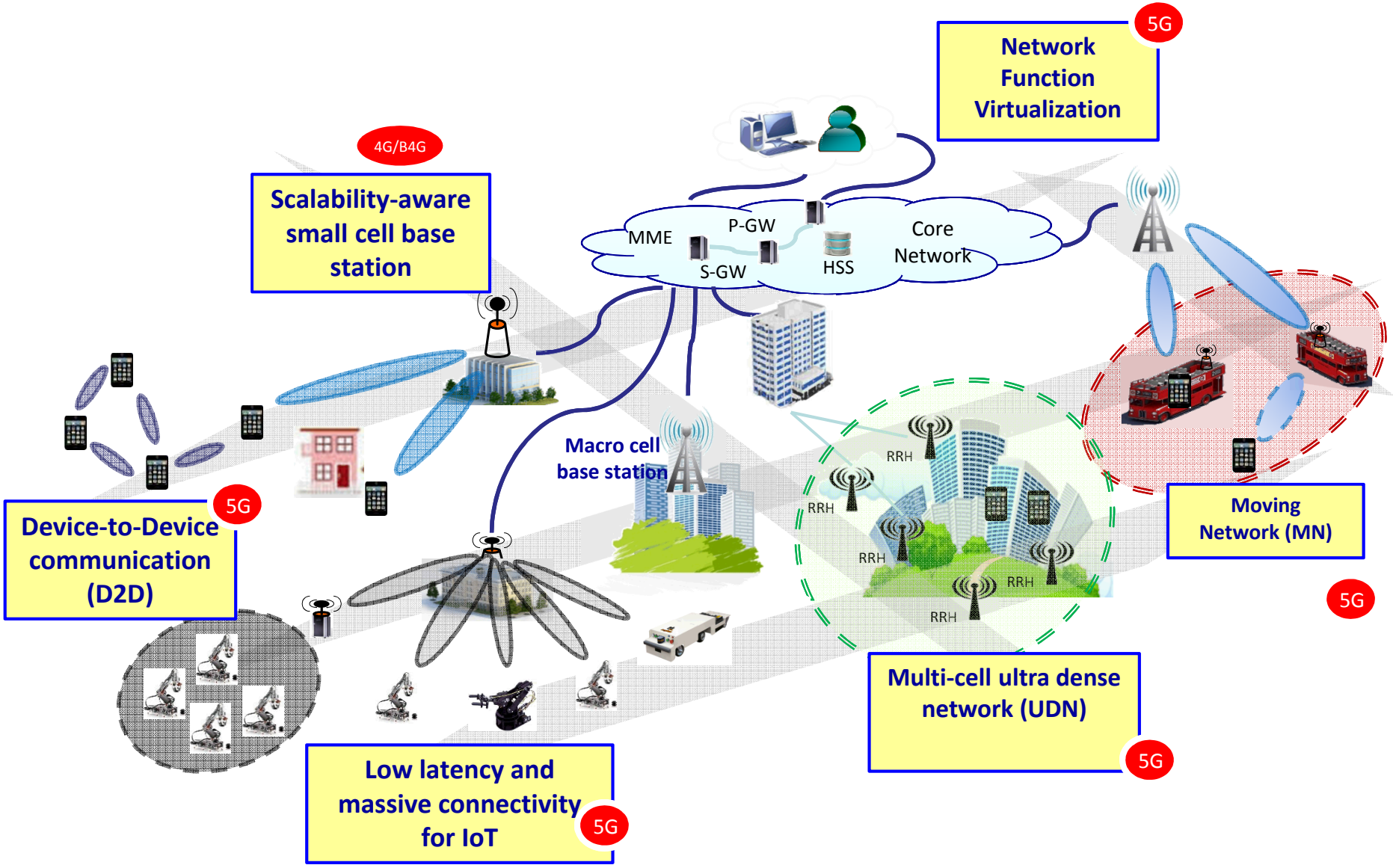
Technology Issues

- Interference Management, SON, Cross BS Coordination, Wireless Backhaul. ,,,

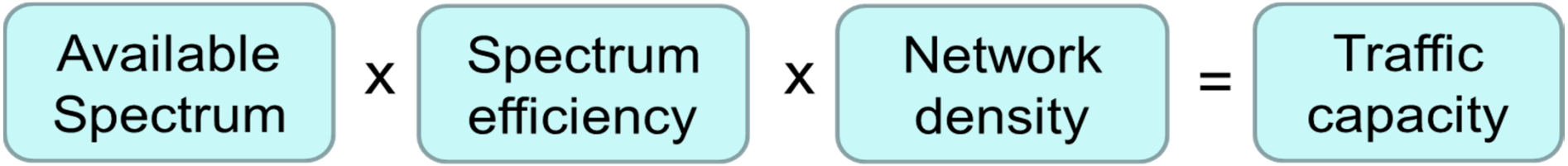
Goals of Taiwan's 5G Program

- Three phases:
  - Phase 1 (2015-2016): planning, team build-up and preparation
  - Phase 2 (2017-2020): Build-up of key enabling technologies
  - Phase 3 (2021-2024): Productization and commercialization
- By the end of 2020, Taiwan will
  - Contribute to up to 4% of the essential IPs in the 5G standard (3GPP R14 ~ R17),
  - Be one of the countries that deliver the first wave of end-to-end demonstration systems of the 5G standard,
    - Develop comprehensive integrated circuit technologies that implement the 5G standard for mobile devices and small cells, and
    - Develop complete protocol software stack that implements the 5G standard.

Use Cases in 5G Systems



Overall Game Plan



- More spectrum: 10
  - < 6GHz: dynamic spectrum sharing
  - mmWave: channel modeling and measurement and Radio-Frequency circuit design challenge, e.g. Power Amplifier
- Spectrum efficiency: 5
  - Massive MIMO
  - Beam forming and beam tracking
- Spatial reuse of spectrum: 20
  - Loose inter-cell coordination: Self-Organizing Network
  - Tight inter-cell coordination: Network MIMO
  - Device-to-Device

Advanced RF IC Design

- Phased antenna array
  - Bean forming and tracking
- Power amplifier with good efficiency and linearity
  - By 2020: Below 6GHz
  - After 2020: Above 6GHz or mmWave
- High-speed ADC/DAC and RF filter
- High gain and linearity LNA, VCO, mixer
- Efficient RF filter and self-calibration mechanism
- Advanced transceiver design
- Thermally efficient packaging

Scalable Baseband Processing

- Low latency and high throughput
- Grouping and scheduling of UEs
- Fast beam acquisition and switching for UE groups
- Massive MIMO operation
  - Low-overhead channel state estimation
  - Efficient and accurate pre-coding matrix computation
- Transmission Power control
- Interference mitigation and management

Ultra-Dense Networks

- Multi-cell coordination
  - Passively minimize inter-cell interference: SON and COMP
  - Actively exploit inter-cell interference: Network MIMO
    - Single user MIMO ➔ Multi-user MIMO ➔ Network MIMO
  - Strict inter-cell synchronization
- Architecture choices:
  - A centralized BBU + multiple RRHs
    - All payloads go through the centralized BBU
  - A centralized controller + multiple standard small cell base stations
- Application of SDN design principle to Network MIMO
  - Channel state collection
  - Pre-coding matrix calculation
  - Distribution of pre-coding matrix to constituent base stations

Network-Level Optimizations

- SDN-based front-haul and back-haul network design
- Seamless integration of multiple licensed and unlicensed frequency bands
- Edge computing for low-latency communication (e.g. vehicle-to-vehicle) and scalable video delivery
- Device-to-device communication
  - Carrier-assisted
  - Carrier-independent
- Network slicing for multi-tenancy RAN

Network Function Virtualization Platform

- Virtualization infrastructure for NFV applications must be low-latency, real-time, scalable, fault-tolerant and oriented towards VM groups
- Server virtualization
  - Container: OS level
  - Hypervisor: HAL level
- Network virtualization vs. I/O virtualization
- Service chaining using SDN
  - Mainstream Ethernet vs. Openflow
  - SDNv1 vs. SDNv2
- Applications:
  - Core network functions: vIMS and vEPC
  - Multi-tenant or Cloud RAN

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EU-Taiwan Cooperation on 5G

- ICT-08-2017 (part b) : 5G PPP Convergent Technologies
- Scope : Cooperation in access convergence

  This activity takes advantage of the supporting 5G research and demonstration facilities offered by Taiwan towards collaborative 5G research with the EU, and aims at developing and demonstrating an integrated convergent access across different air interface technologies and the fronthaul/backhaul/core network. Test beds making use of facilities offered by Taiwanese partners are targeted. It demonstrates the capabilities of new spectrum access schemes, including for co-working with the network. A system demonstrator showing applications potential is thus favoured, e.g. for high speed moving vehicles.
- Type of funding : Research and Innovation Actions (RIA)
- Level of Funding : €5 million

ICT-08-2017 Call Information

- Call Opens : 10 May 2016
- Call Closes : 08 November 2016
- Team composition:
  - At least 3 organizations from different EU member states
  - At least 1 participant from Taiwan and is funded by the Taiwan government
  - Industry driven activity considered as key
- Proposal evaluation : two evaluators each from EU and Taiwan
- Number of projects expected : 2

Possible Topics for EU-Taiwan Collaboration

1. 5G Network Planning Tool for High Frequency Bands
   - Use channel measurements and ray tracing-based models to implement and evaluate the effectiveness of a 5G RRH deployment tool
2. Highly Coordinated Ultra Dense Network
   - Efficient implementation techniques of applying network MIMO to a large number of small cell base stations
3. Mobile Edge Networking for 5G Communications
   - Network-driven D2D, edge computing, moving networks, and front-haul/back-haul network integration
4. Scalable M2M Communications for IoT