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The Next Journey for 5G

--The Standardization and Application of mmWave

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WRC-19 Identified New 17.25GHz Spectrum Range for IMT

At WRC-2019 in November, several new frequency ranges were identified for IMT, to be used by IMT-2020 (5G)

Global

26 GHz

24.25-27.5GHz

Global

40 GHz

37-43.5GHz

Global

E band

66-71GHz

Local

46 GHz

45.5-47GHz

Local

47 GHz

47.2-48.2GHz

At 2017, MIIT released 26GHz (24.75-27.5GHz) and 40GHz (37-42.5GHz) for 5G technical trial

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mmWave Global Licensing and Usage for 5G

22 operators are known to be already deploying 5G networks using mmWave spectrum

China: 26GHz and 40GHz as the spectrums for the technical trial

Europe: 26GHz is one of the three pioneer 5G candidate spectrums

Japan: 28GHz has been commercially deployed

Korea: 28GHz has been commercially deployed

USA: 28GHz and 24GHz have been deployed, 26GHz is under consideration, 37GHz, 39GHz and 47GHz auctions have been completed

Austria: 26GHz, 40GHz and 32GHz auction plans have been announced

Latin and central America: 28GHz and 26GHz are under consideration/to be allocated as planned

Africa: 26GHz is under consideration

Source: GSA 2020.8

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mmW Standardization in 3GPP

Release 15

Basic functionality

- **Channel modeling** up to 100GHz
- **Multi-beam based** synchronization, broadcast and initial access procedure
- **Beam management**
  - Antenna port quasi co-location
  - L1-RSRP measurements
  - Beam failure recovery
  - SRS-based sweeping

Release 16

Enhancements to reduce latency and overhead

- **Default configurations and updates**
  - **Default** spatial relation for dedicated PUCCH/SRS
  - MAC CE based spatial relation **updates** for PUCCH and AP-SRS
- **Multi-carrier operation**
  - TCI state activation for a set of CCs/BWPs
  - beam failure recovery for SCells

Release 17

More scenarios e.g. higher mobility

- **Common beam** for data and control for higher mobility
- **Unified TCI framework** for UL and DL
- **Multi-panel** UE operations
- UL coverage loss mitigation due to **MPE**
- Study on supporting NR from **52.6GHz** to **71GHz**

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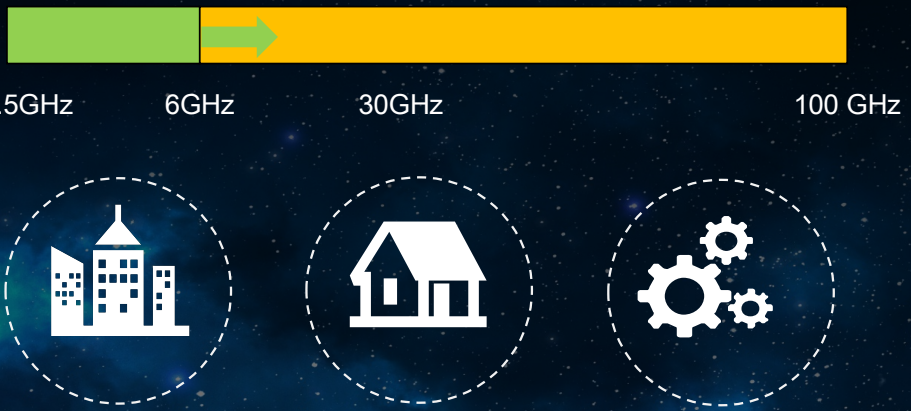
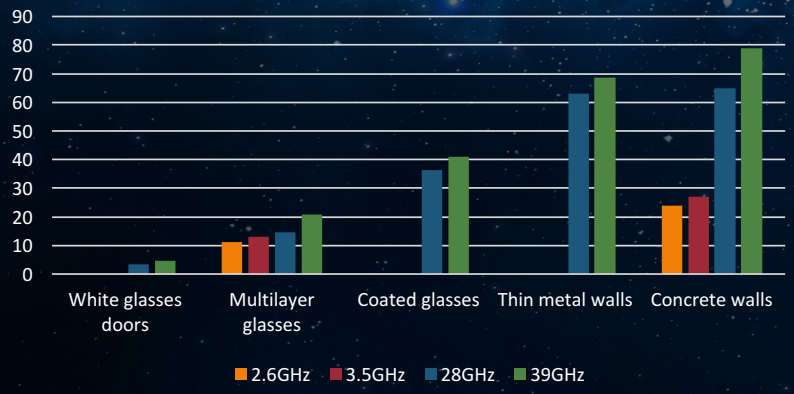
mmW Channel Modeling



Multiple matieral penetration losses



- Extend the frequency range to cover mmWave
- Consider the candidate deployment scenarios, e.g. Dense Urban, Indoor Office and even Indoor Factory (Rel-16)
- Channel Characteristics
  - Extreme higher propagation loss and penetration loss in mmWave
  - Sensitivity to the blockage, e.g. foliage, human body
- Consolidated channel modeling for mmWave technology development and evaluations

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3GPP mmWave Frequency Band Specification Progress

3GPP 5G specification has defined single NR FR2 band, FR2 intra-band CA and FR1+FR2 inter-band CA. No inter-band FR2 CA has been specified in R16.

Single NR FR2 band

Operating Band	Uplink (UL) operating band BS receive UE transmit			Downlink (DL) operating band BS transmit UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	
n257	26500 MHz	–	29500 MHz	26500 MHz	–	29500 MHz	TDD
n258	24250 MHz	–	27500 MHz	24250 MHz	–	27500 MHz	TDD
n259	39500 MHz	–	43500 MHz	39500 MHz	–	43500 MHz	TDD
n260	37000 MHz	–	40000 MHz	37000 MHz	–	40000 MHz	TDD
n261	27500 MHz	–	28350 MHz	27500 MHz	–	28350 MHz	TDD

FR2 Intra-band CA

NR CA Band	NR Band (Table 5.2-1)
CA_n257	n257
CA_n258	n258
CA_n259	n259
CA_n260	n260
CA_n261	n261

FR1+FR2 Inter-band CA

NR CA Band	NR Band
CA_n1-n257[1]	n1, n257
CA_n3-n257[1]	n3, n257
CA_n5-n260[1]	n5, n260
CA_n5-n261[1]	n5, n261
CA_n8-n258	n8, n258
CA_n25-n260[1]	n25, n260
CA_n25-n261[1]	n25, n261
CA_n28-n257[1]	n28, n257
CA_n41-n260[1]	n41, n260
CA_n41-n261[1]	n41, n261
CA_n66-n260	n66, n260
CA_n66-n261	n66, n261
CA_n71-n257[1]	n71, n257
CA_n71-n260[1]	n71, n260
CA_n71-n261[1]	n71, n261
CA_n77-n257[1]	n77, n257
CA_n77-n258[1]	n77, n258
CA_n77-n261[1]	n77, n261
CA_n78-n257[1]	n78, n257
CA_n78-n258[1]	n78, n258
CA_n79-n257[1]	n79, n257
CA_n79-n258[1]	n79, n258

NOTE 1: Applicable for UE supporting inter-band carrier aggregation with mandatory simultaneous Rx/Tx capability.

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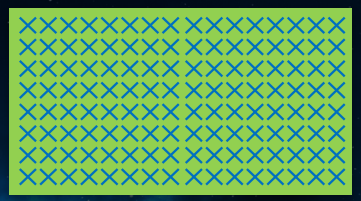
mmWave System Design

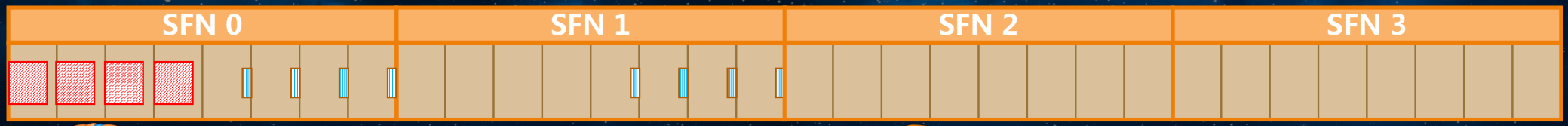
Hybrid analog and digital system architecture



- Analog beam forming
- Multi-beam based synchronization and initial access
- Beam management and reporting

- Beam based scheduling
- Other system parameters
  - 400MHz system bandwidth, 800MHz with CA
  - 120kHz SCS
  - PTRS

Maximum 64 SSB ⟷ Associated Rach occasion



Synchronization and Broad Casting

Random Access

Measurement and Reporting

PDCCH and PDSCH

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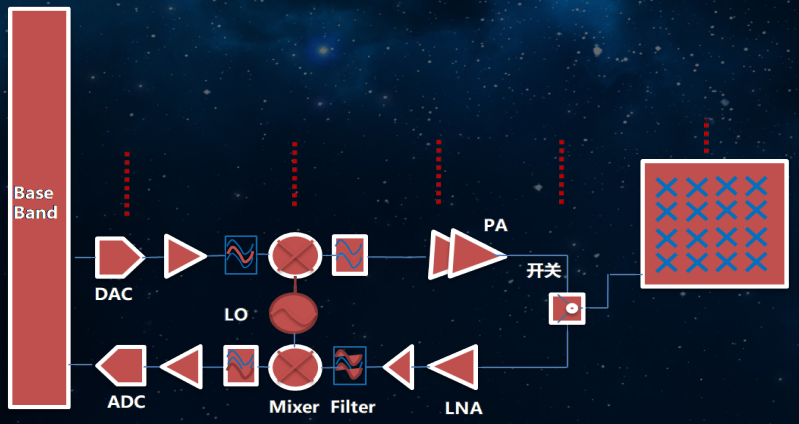
mmWave base station architecture

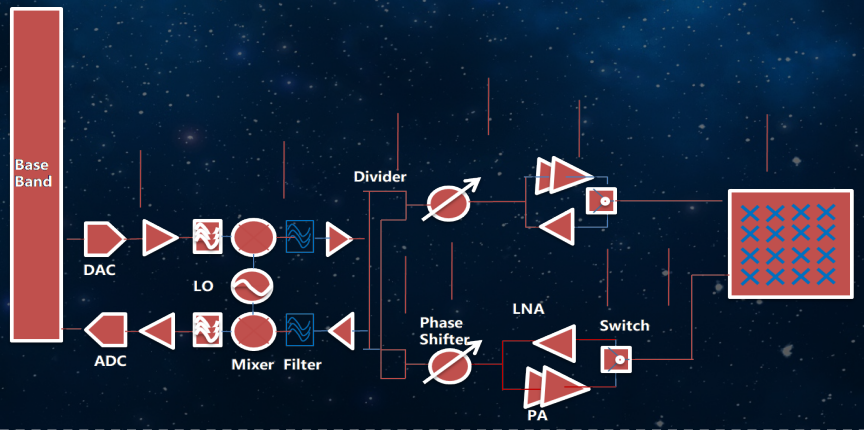
Loss Increases 20 ~ 30dB

The number of antennas increased by 10-100 times

Digital Beam forming Architecture ✗



hybrid Beam forming Architecture ✓



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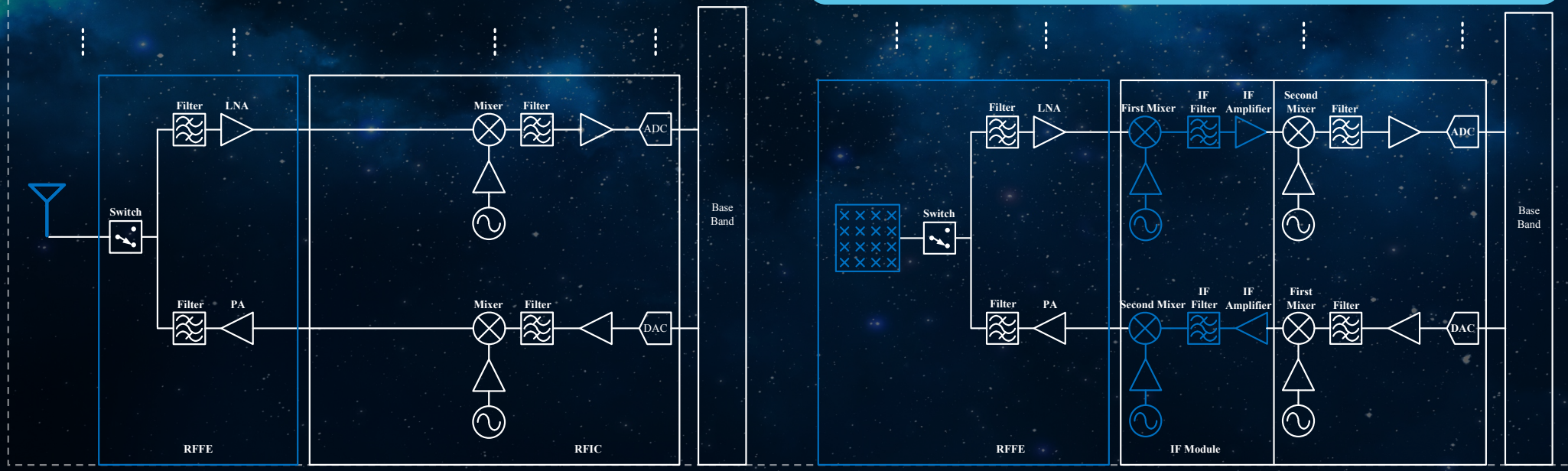
mmW Chipset Architecture

Frequency bands increase to 24GHz and above

Antenna size decreases significantly

Sub6G: Antenna is separated from RFFE, Zero-IF

mmW: Antenna is integrated with RFFE(AiP), IF module is needed



mmWave Indusdry

Base Station

>60dBm; 800MHz; 4TR
For dense urban coverage

>50dBm; 800MHz; 2TR
For stadium coverage

pico
For office buildings coverage

Device & Chipset

Device: Some 5G devices have supported mmW.

Chipset:

- Some commercialized chipsets have supported mmW.
- More chipsets supporting mmW are coming on the way.

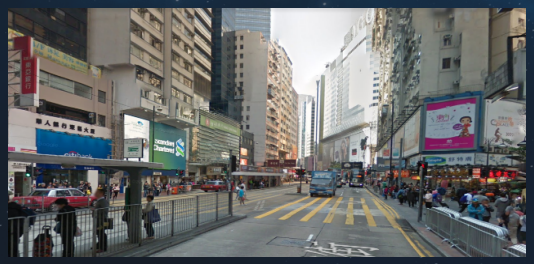
International application of mmWave

Application Scenarios

- mmWave commercial and pilot projects are concentrated in the United States, Japan and South Korea. The application scenarios mainly focus on hot coverage, FWA and other downlink services, mainly for 2C services.
  - US:
    - Scenarios: FWA, hot coverage, eMBB
    - Service users: mainly 2C smart phone users
  - Japan and South Korea:
    - Scenarios: hot coverage, eMBB, NO FWA
    - Service users: 2C smart phone users
- Deployment Status
  - FWA: suitable to be deployed at the roofs/windows of the low and single buildings
  - Micro station deployment: indoor hot spots, including offices, shopping malls, stadiums, etc.
  - Macro station deployment: outdoor streets and squares

eMBB

mmWave and LTE co-site deployment for outdoor dense urban areas



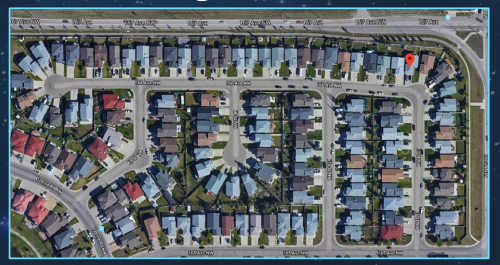
- ✓ Outdoor: mmWave and C-band LTE roof macro stations co-site deployed
- ✓ Indoor: Hot spots deployed

Seamless deployment for outdoor dense urban areas

- ✓ mmWave and LTE macro stations co-site deployed. Combining with smart light poles, to achieve seamless coverage

FWA

Single House



- ✓ Basing on the deployment of roof macro stations, big EIRP is required to improve the coverage

Apartment fiber replacement

- ✓ Combing roof macro stations with smart light poles stations, a large vertical and horizontal scanning range is necessary

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China's mmWave Test Status

Function Verification

- Band bandwidth
  - ✓ Test frequency band: 24.75GHz~27.5GHz
  - ✓ System bandwidth: Support cell bandwidth of 100MHz, 200MHz or 400MHz
  - ✓ Support 400MHz, 800MHz RF bandwidth
- Frame structure
  - ✓ SCS=120KHz, Frame length=0.625ms
- Beam management
  - ✓ Broadcast beam, random access
  - ✓ Terminal beam measurement and reporting
  - ✓ Beam indication, mobility management

Performance Test

14.7Gbps/3Gbps

Cell Peak Throughput (DL/UL)

800MHz, 4TR, DDDSU

1~1.5ms

One-way User Plane Latency

2.6 Km

Farthest Access Distance, EIRP=65dBm

LOS with few small trees

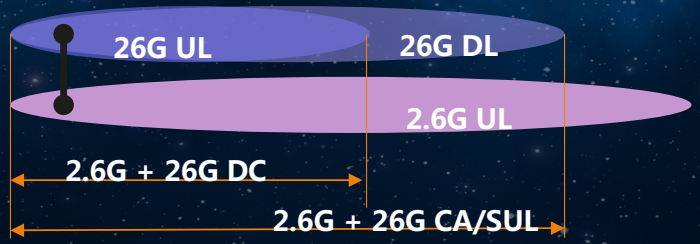
mmWave Application Outlook

Architecture

- SA architecture with mature industry may be a good choice for mmWave

Reliability and Coverage Enhancement

- It is a challenge to enhance the robustness of mmWave with poor penetration performance. Reliability enhancement methods need to be further studied, such as Multi-TRP
- To combine high and low frequency networks (by CA/DC/SUL) can enhance the coverage of mmWave.
- The applicable scenarios of different networking modes need to be further studied.



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THANKS!

To Explore More Possibilities

5G can be Far Beyond Outlook…