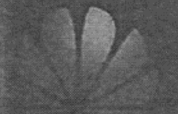


Security Level:

Paving the Way for 5G: Industry Insight

Dr. Abdurazak Mudesir,
VP 5G Marketing and Head of XLABs, Europe

30 October, Ottawa



HUAWEI

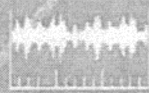
5G Industry Insight



Use Cases



Standard



Spectrum



Enabler

X Labs Wireless

a place for...

Use Case Standardization Spectrum Enabler

Exploration



Research together

Innovation



Produce new application together

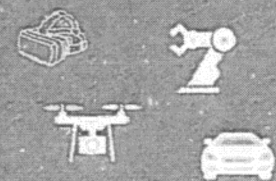
Ecosystem



Develop new market together



- R&D investment
- Applications development
- Joint labs' collaboration
- Business model research
- Cross-industry exchange platform



Innovation centers Today's focus



Europe

- Autonomous cars
- Smart factory
- eHealth



USA

- Video
- eHealth



Japan

- VR/AR
- Home applications
- Service Robots



China

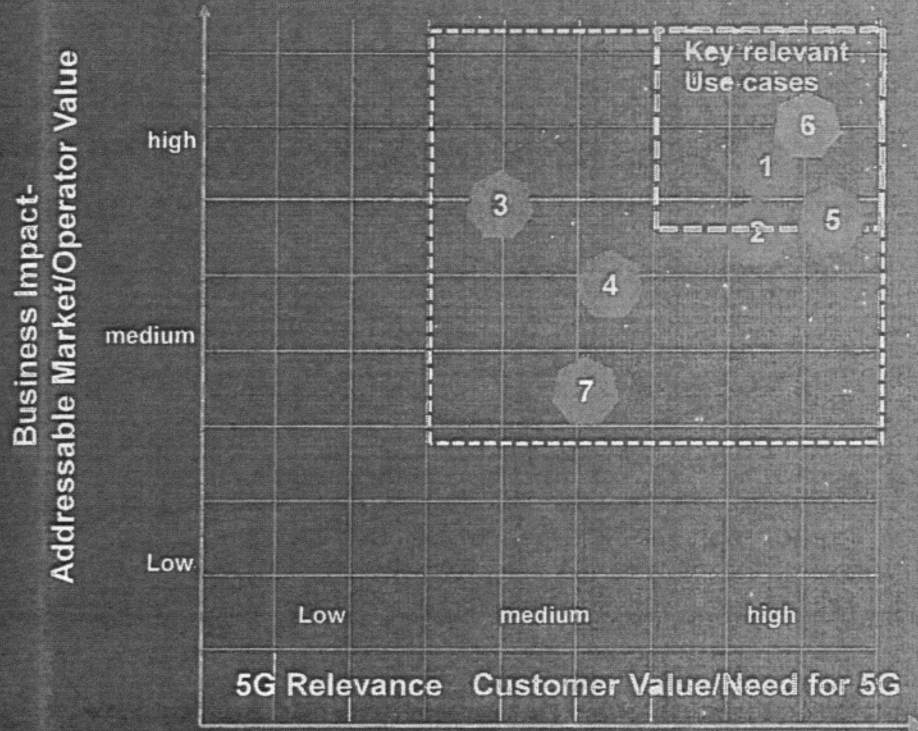
- Drones
- Service robots

Use Case Standardization Spectrum Enabler



Use Case Evaluation & Prioritization

Use Case Evaluation



Use Case Example

- 1 Augmented Reality
- 2 Virtual Reality
- 3 Driver Information
- 4 Entertainment in the Vehicle
- 5 Automation in the vehicle
- 6 Smart Grid
- 7 Delivery Drone

Use Case Standardization Spectrum Enabler



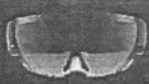
Cloud Based AR/VR to be Key Driving Force of 5G

Retina Experience
16K Resolution + 120fps

Avoid Motion Sickness
120fps + Rendering in Cloud

Throughput > **4.2Gbps**

Network E2E Latency < **5~9ms**



Qualcomm

Hololens

HTC Vive

Huawei VR

Surround 360

Odyssey

Youtube

Facebook

Chips

AR/VR Terminal

Content Producer

Broadcast Platform

Gradual formed Industry Chain

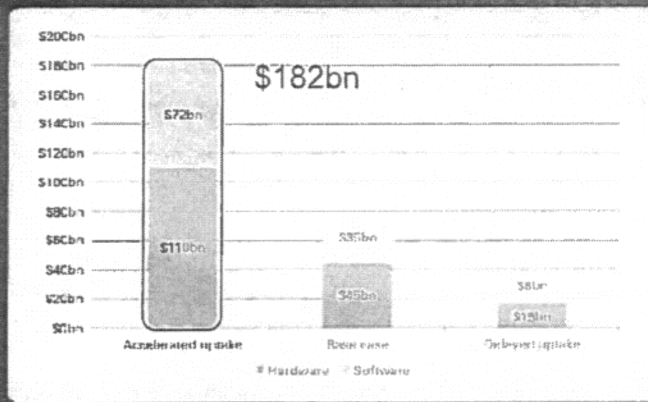


Use Case - Standardization - Spectrum - Enabler



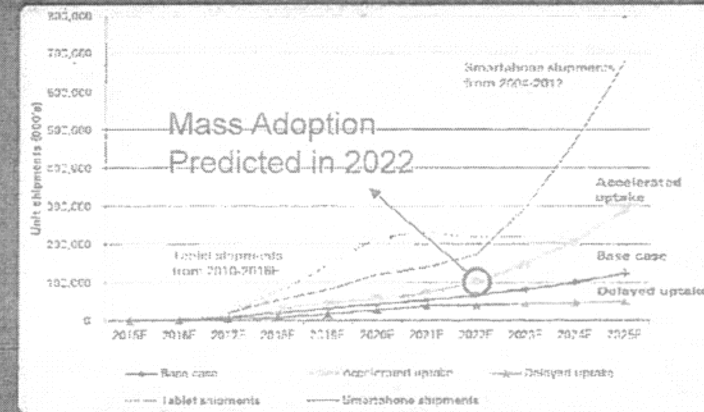
5G will be Important enabler for VR/AR Mass Adoption

Forecasting \$182Bn Market Size for 2025



Source: Goldman Sachs VR/AR Report

VR/AR Accelerated Uptake after 5G



Source: Goldman Sachs VR/AR Report

- We believe with faster WiFi or cellular technologies to carry the heavily loaded data transmission required for virtual reality graphics would be an important enabler for mass adoption.
— Goldman Sachs Virtual and Augmented Reality 2016

Use Case Standardization Spectrum Enabler



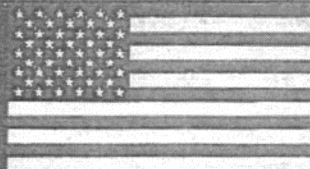
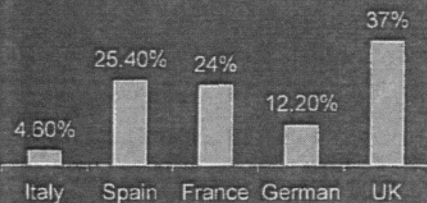
Fixed Wireless Access for Home Broadband

Target & Existing Gap



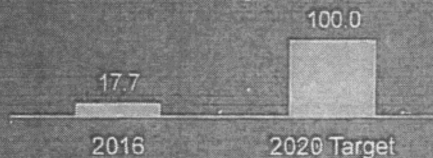
Target: By 2020 **50%**
Households > **100Mbps**

Households > 30Mbps(%)



Target: By 2020 **100M**
Households > **100Mbps**

Households > 100Mbps(million)



5G Home Access

X Gbps Throughput

Fast TTM & ROI

Major use case for 5G
early deployment

Source: Broadband Europe Strategy 2015/ FCC 2016



Automotive: 5G Focused on Realizing Full Automation

Use Case Standardization Spectrum Enabler

Stage 4 Full Automation
2020~



Tele-Operated Driving



Automated Platooning



Cooperative Autonomous Driving

Stage 3 Partial Automation
2015~



Road Assistance



Smart Warning

Stage 2 Telematics
2000~

infotainment, on-line navigation, remote diagnostics, e-call communications...

Stage 1 Roadside Communication
1990~

Wired / Wireless for RSU

2G/3G/4G

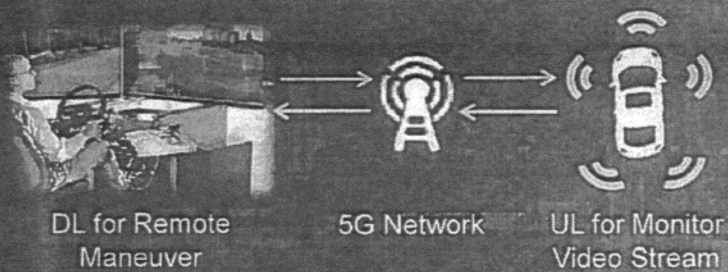
LTE-V

5G



Full Automation Case(1/3): Tele-operated Driving

Tele-operated Driving Keep Driver from High-risk Areas



Advantage

- Dangerous and closed region(harbour , mine)
- Less driver needed
- Less complex than full autonomous driving

Network Requirements for Tele-operated Driving

Scalable Joint KPIs for Connected Car



E2E Latency **5~20ms**

Reliability > **99.999%**

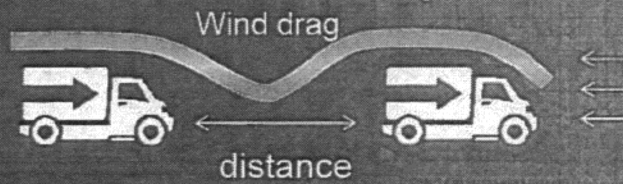
*UL Throughput > **40Mbps**

*2 x 4K HD stream(20Mbps per Camera)



Full Automation Case(2/3): High Density Platooning (V2V)

Shorter Distance,
Less Fuel Consumption



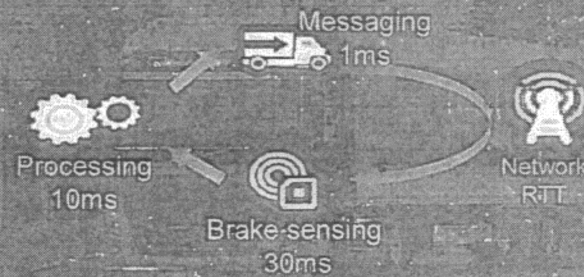
-10% Fuel @4m



-30% Fuel @1m
(5G Target)

Speed: 80kmh

Network Requirement to Realize
1 meter Distance



$$Distance(1m) = (RTT + 1 + 30 + 10) \times 80km/h$$

Network RTT < 10ms

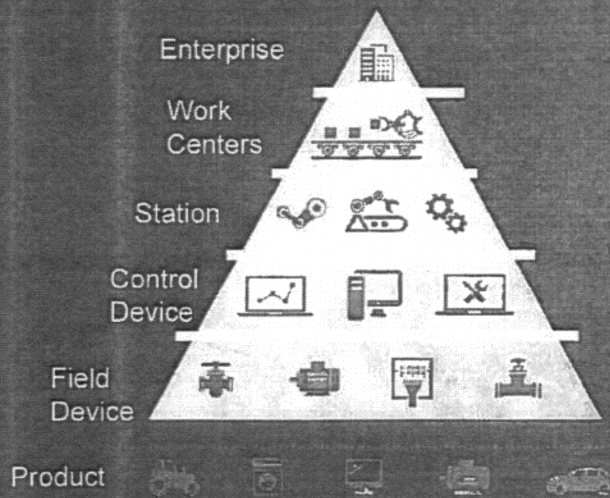
Reliability > 99.999%

Use Case Standardization Spectrum Enabler



Industrial Internet: 5G Enables Smart Manufacturing

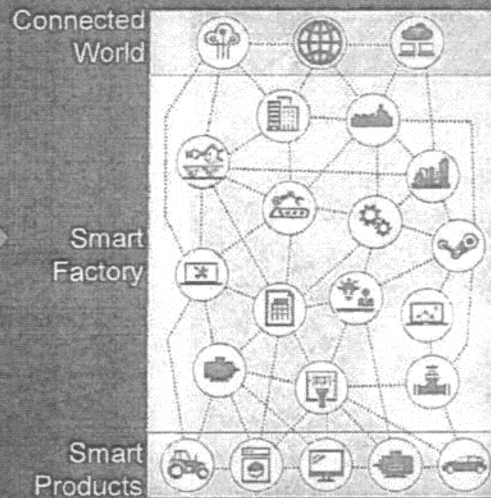
Industry 3.0



From Pyramid Mode
Hierarchy-based communication

Source: RAMI 4.0

Industry 4.0



To Flat Mode
Communication among all participants

Needs for Communication

- Globally standardized
- Connect Everything
- Easy Installation & Operation
- Satisfy Diversified Requirements

5G

Use Case Standardization Spectrum Enabler



5G NR Satisfies Diverse Requirements of Smart Factory

Motion Control

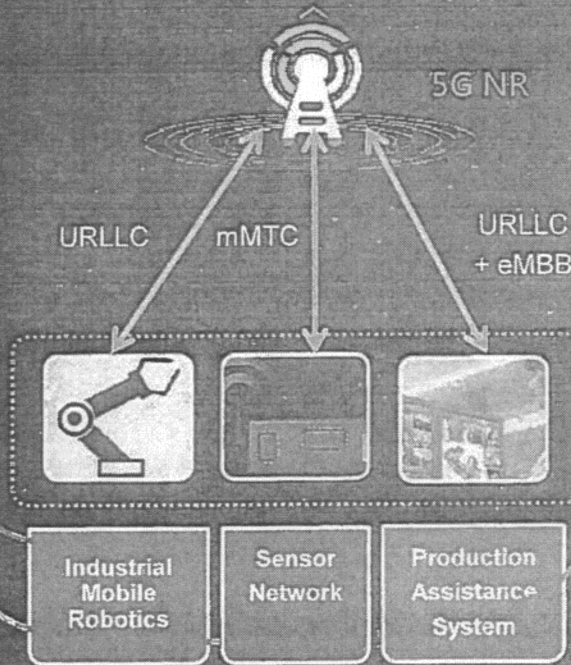


| | |
|-------------------|---------------|
| Latency | 250us-1ms |
| Reliability | 1e-8 |
| Throughput | Kbit/s-Mbit/s |
| Battery Lifecycle | n/a |

Dynamic Monitoring



| | |
|-------------------|----------|
| Latency | 100ms |
| Reliability | 1e-8 |
| Throughput | Kbit/s |
| Battery Lifecycle | 10 years |



Augment Reality



| | |
|-------------------|---------------|
| Latency | 10ms |
| Reliability | 1e-5 |
| Throughput | Mbit/s-Gbit/s |
| Battery Lifecycle | 1 day |

Use Case

Standardization

Spectrum

Enabler



Huawei Efforts on Exploration of Smart Factory

Wireless coordinated robot via 5G



Loading work at port



Smart manufacturing



E2E Network
Latency

5~100ms

5G Enabled Output in Manufacturing by 2035:

\$3.4 Trillion

Source: IHS The 5G Economy Report, 2017

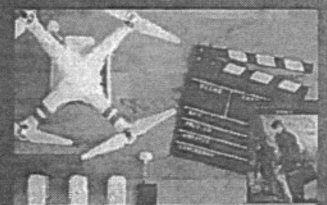
Use Case Standardization Spectrum Enabler



Connected Drones: Wide Commercial Applications



Transport



Entertainment



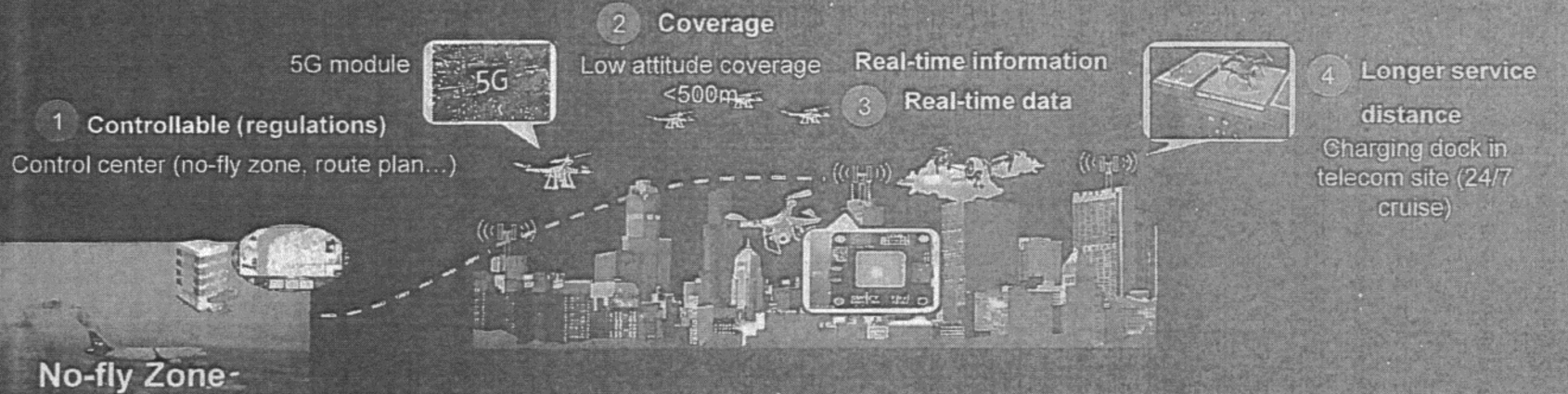
Agriculture



Security



Telecommunication



Through cellular network, we can realize low-altitude coverage, NLOS control, 24/7 autonomous flight, etc.

Use Case Standardization Spectrum Enabler

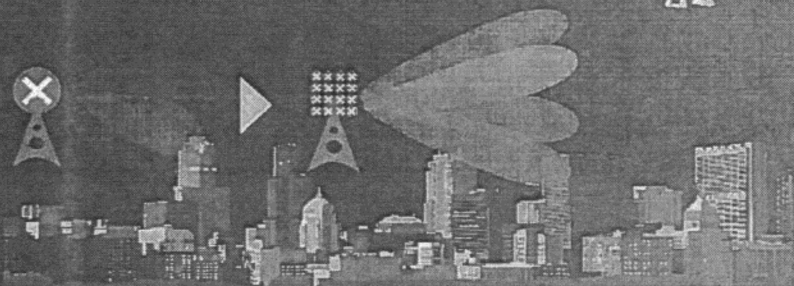


5G will Empower Connected Drones with more Possibilities

5G Massive MIMO Can Better Support Low-Attitude Coverage

Traditional Network

Massive MIMO Enable 3D Coverage



3D Traffic System



LiDAR based 3D Ground Mapping



Reliability
>99.999%

E2E Latency
In ms level

Throughput
>250Mbps



Huawei X Labs Keep Exploring 5G Use Case in the Future

Cloud VR/AR

- VR Meeting/Game
- Video Holography
- 4K/8K Video Streaming
- Machine Vision

Connected Car

- TOD
- Platooning

Remote Surgery

Remote Drone

- Drone in Verticals
- Drone Taxi

Mobile Robot

- Smart Factory
- Cooperative Robot
- Seeing Eye Helmet

Smart Grid

825 x 465 - weather.com

2017

2018

(Candidate)

Use Case Standardization Spectrum Enabler



5G comprises LTE R15, onwards and 5G NR



5G comprises:

- New Radio
- evolution of LTE Advanced Pro
- NextGen
- Evolution of EPC

Use Case Standardization Spectrum Enabler

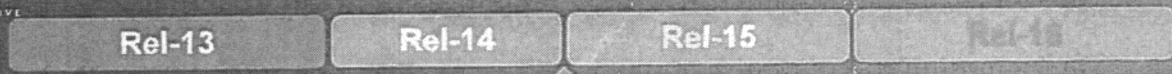


3GPP accelerates 5G standardization

2014 2015 2016 2017 2018 2019 2020

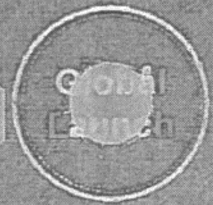
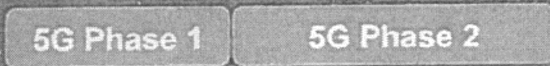


RAN

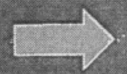


↑
March

Previous Timeline



Accelerating Decision



First stage accelerated to meet early demands

Use Case Standardization Spectrum Enabler



3GPP Services Goals for 5G Standards



Q1-2020 Submission to ITU for IMT2020 Recommendation (Official ITU Decision by Q4-2020)

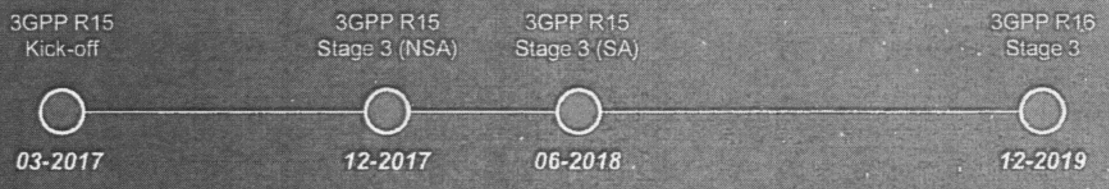
mMTC
Massive Machine Type Communication



uRLLC
ultra Reliable Low Latency Communication



eMBB
enhanced Mobile Broadband



Note: By default the slide shows the status of 3GPP WI (technical specifications). If it is Study Item work then there is a specific statement indicating SI.

Use Case Standardization Spectrum Enabler



3GPP Services Goals for 5G Standards



mMTC

Massive Machine Type Communication



uRLLC

ultra Reliable Low Latency Communication

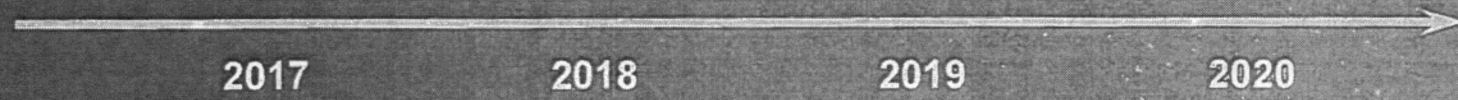


eMBB

enhanced Mobile Broadband



Q1-2020 Submission to ITU for IMT2020 Recommendation (Official ITU Decision by Q4-2020)



Note: By default the slide shows the status of 3GPP WI (technical specifications). If it is Study Item work then there is a specific statement indicating SI.

Use Case Standardization Spectrum Enabler



C-band/G30/G40 Potentially Global Harmonized 5G Bands

Sub6GHz 3,3 3,4 3,5 3,6 3,7 3,8 3,9 4,0 4,1 4,2 4,3 4,4 4,5 4,6 4,7 4,8 4,9 5,0 GHz

Europe



China



Korea

mmWave

G30

G40

- RSPG candidate pioneer bands
- FCC R&O bands
- WRC-19 AI 1.13 studies concentrate on
- JPN MIC
- KOR MSIP

| | | | |
|--|-----------|--|--|
| | Confirmed | | WRC-19 candidate, global primary Mobile Service band |
| | Likely | | WRC-19 candidate, not global primary Mobile Service band |
| | TBD | | Not in scope of WRC-19, AI1:13 |



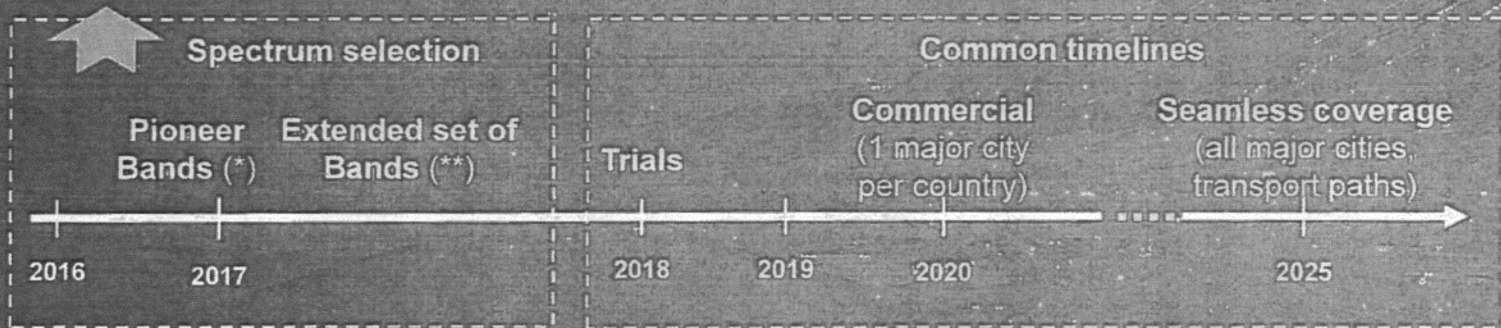
Use Case Standardization Spectrum Enabler



EU 5G Action Plan

EU 5G pioneer bands:
700 MHz
3400 – 3800 MHz ("primary")
24.25 – 27.5 GHz

"EC 5G Action Plan"
&
"ECC 5G spectrum
roadmap"



FCC rules for 28, 37 and 39 GHz bands (Jul '15)



Korea Winter Olympics Product R&D trials (Feb '18)
China (2018-2020)
Japan Summer Olympics (Jul '20)



(*) "Radio Spectrum Policy Group strategic roadmap towards 5G for Europe – Opinion on spectrum related aspects for next generation wireless systems (5G)"
(**) Supplementary Opinion from RSPG (under development)

Use Case Standardization Spectrum Enabler



Acceleration of C-Band Ecosystem Worldwide

C-band globally harmonized

C-band Status in Australia

| | | |
|---------------|---------|-------------------------------|
| | 3.3-3.4 | Available for 5G in 2018~2019 |
| | 3.4-3.6 | Already used for 5G Trial |
| | 4.8-5.0 | Available for 5G in 2018~2019 |
| | 3.4-3.6 | Issued |
| | 3.6-3.8 | Issued for 5G in 2017 |
| | 4.4-4.9 | 5G spectrum for Tokyo Olympic |
| | 3.6-3.8 | Will be reallocated for 5G |
| | 3.4-3.7 | Issued for 5G in 2018 |
| Other Regions | 3.4-3.6 | Available for IMT use |



C-band availability for IMT-2020 services in Australia

- Already partly allocated to operators in Australia (NBN, Optus, etc.)
- Expected for allocation of the remaining part (total of 125MHz) of C-band in Australia in 2018

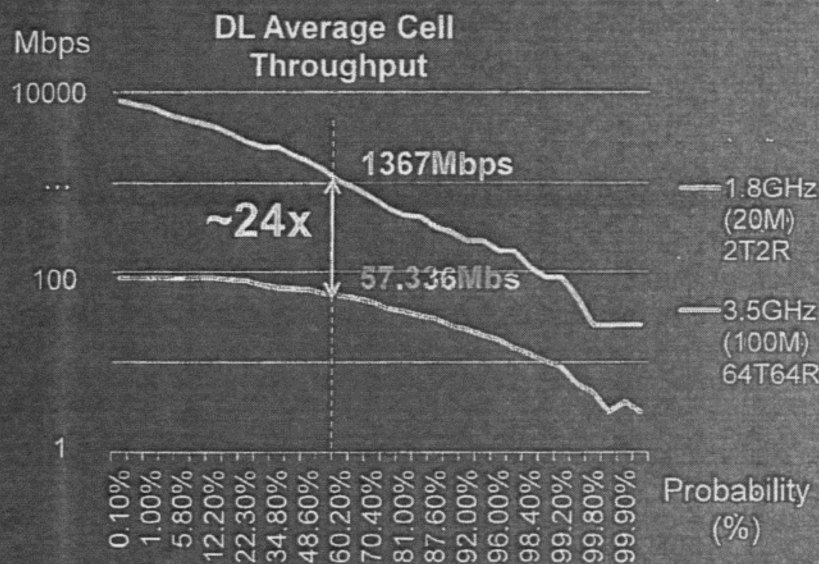
Unit: GHz

Ofcom has decided to recall 3.6-3.8 spectrum and auction if for 5G usage

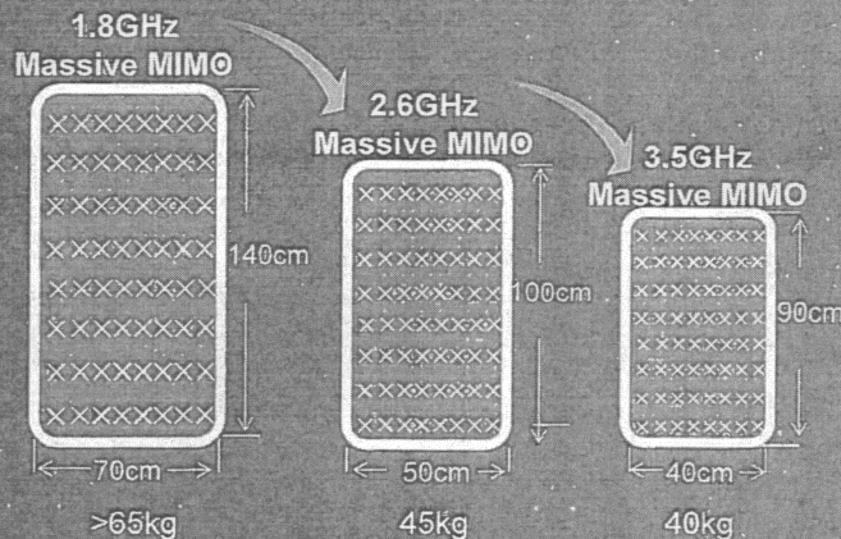


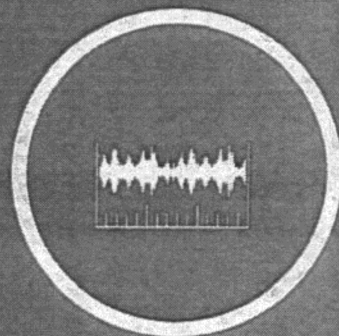
C-band M-MIMO Boosts Capacity with Affordable Complexity

C-Band + M-MIMO Boosts DL Capacity

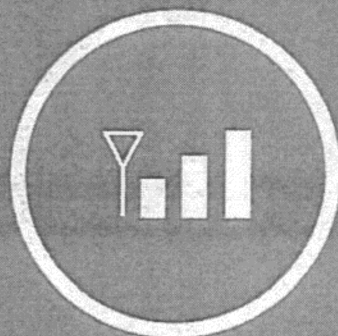


Support M-MIMO with Affordable Complexity

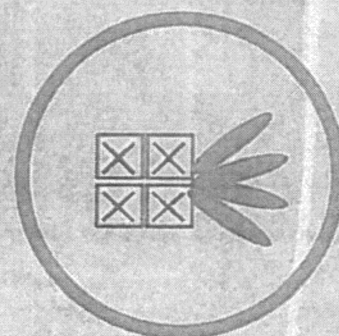




Higher Bands
Higher Propagation Loss &
Penetration Loss



Higher Power @RAN
Greater Gap between
RAN & UE



NR Technology
Beamforming mainly for DL
enhancement

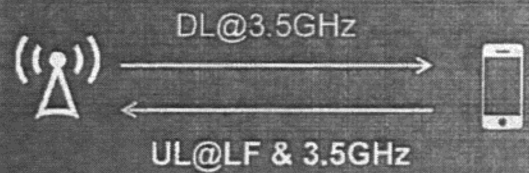
**UL&DL unbalance could be worse in 5G network,
How to solve it?**



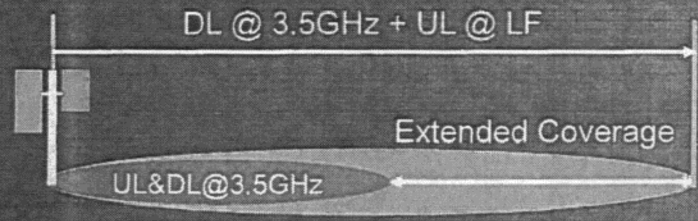
UL & DL Decoupling Extends C-Band Coverage

Extend C-Band Coverage

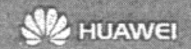
NR-LTE co-existence has been adopted into R15 NR-WID scope(RAN#75)



Proposed frequency ranges for NR/LTE Co-existence






- 1710-1785MHz (UL)/3.3-4.2 GHz*(DL&UL)
- 832-862MHz (UL)/3.3-4.2 GHz*(DL&UL)
- 880-915MHz (UL)/3.3-4.2 GHz*(DL&UL)
- 703-748MHz (UL)/3.3-4.2 GHz* (DL&UL)





Use Case Standardization Spectrum Enabler

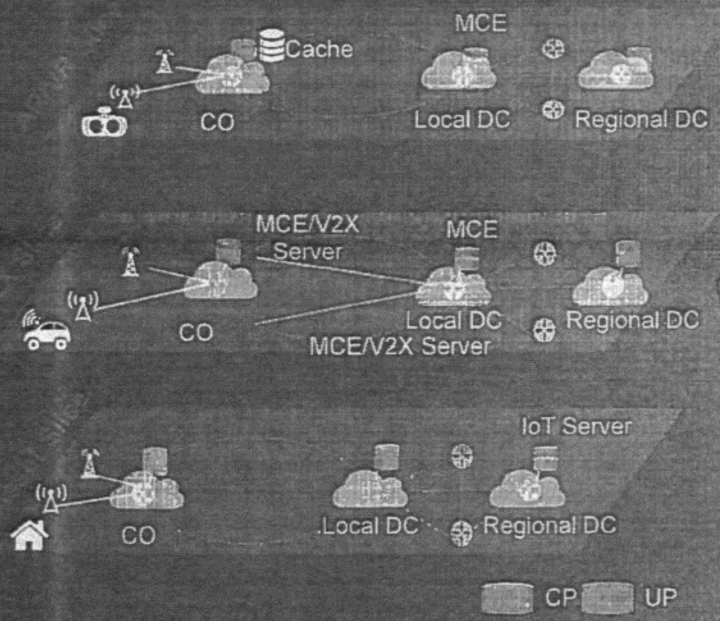
5G RAN Design Methodology & Key Enablers

| | | | | |
|---|--|--|--|---|
|  Framework | UCNC (User Centric No Cell) | UAI (Unified Air Interface) | Higher Spectral Efficiency | RAT Agnostic Technologies |
|  Focus | <ul style="list-style-type: none"> • UDN • HF & LF • Macro & Micro • Simplify Mobility | <ul style="list-style-type: none"> • Future proof • Radio slicing • Full spectrum access • Mix-Numerology • Narrow band & wide band | <ul style="list-style-type: none"> • New waveform & Multiple Access & channel coding • Grant free access • Light signaling overhead | <ul style="list-style-type: none"> • Further spectral efficiency improvement • 5G innovations applied to 4G |
|  Enablers | Hyper Cell CloudRAN | F-OFDM/Window-OFDM Flexible Numerology | F-OFDM/Window-OFDM SCMA LDPC/Polar Code | Massive MIMO |

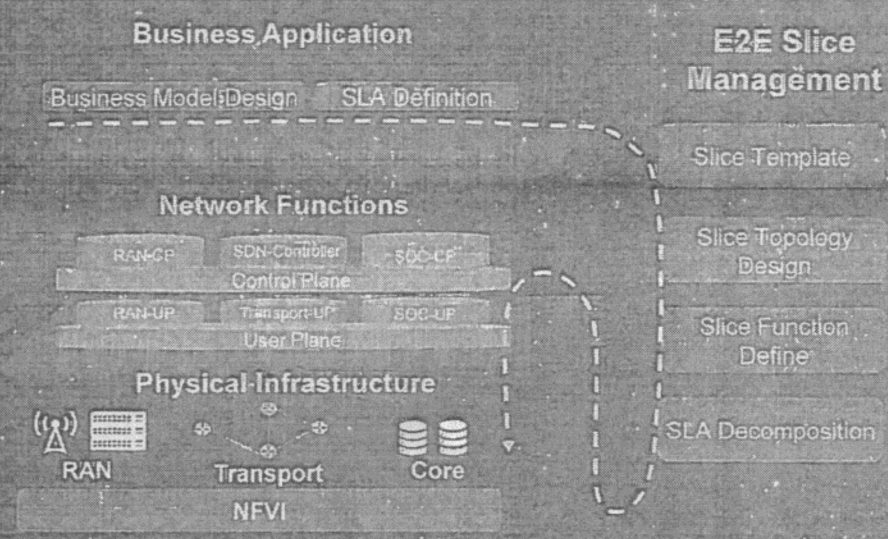
Use Case Standardization Spectrum Enabler



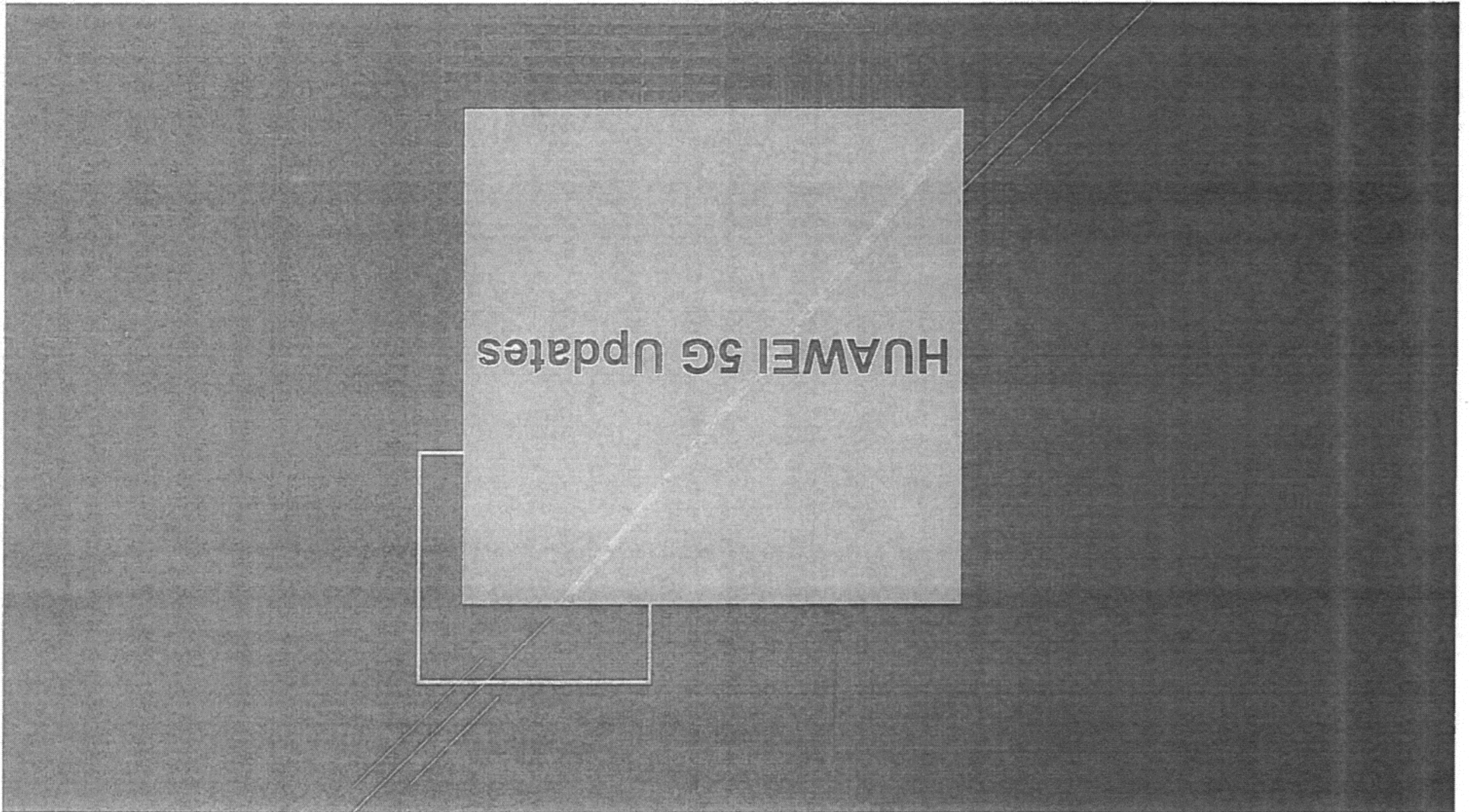
5G Target Architecture for E2E Network Slicing



Adaptive New Radio and Topology as a Service



Cloud-Native Architecture & Internet Architectural Operation



Open Collaboration for Global Unified Standard

Industry Collaborations

Europe



Board Member

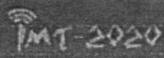


5G Innovation Center

Key Founder Asia



Key Founder



Board Member (China)



Leading R&D Partner (Japan)



Leading R&D Partner (Korea)

Operator Collaborations



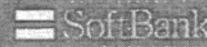
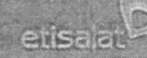
Leading R&D Partner



中國移動 China Mobile



NTT



30+ operators

5G Research Centers (11)



Stockholm, Sweden
•System Architecture
•Algorithms



Paris, France
•Standardization



Munich, Germany
•Verticals



5G Research Centers in China
•Shenzhen •Beijing
•Shanghai •Hangzhou
•Cheng du



New Jersey, USA
•5G Transmission



Ottawa, Canada
•5G Radio
•Network Architecture

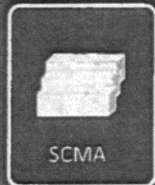


Moscow, Russia
•Fundamental Algorithms



Joint Efforts to Bring 5G into Reality

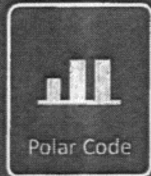
5G NR Technologies Trial



SCMA



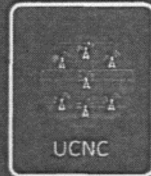
F-OFDM



Polar Code

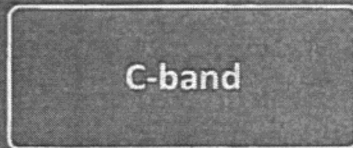


MU-MIMO

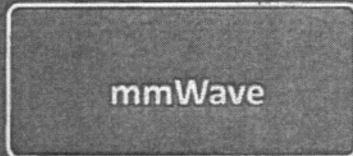


UCNC

Full Spectrum Access Field Trial

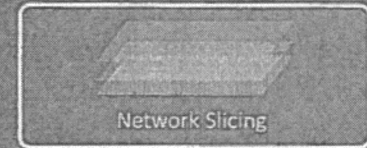


C-band



mmWave

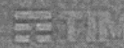
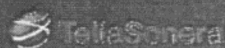
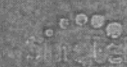
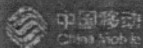
5G Network Architecture Trial



Network Slicing

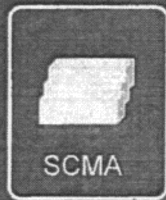


CloudRAN



Sub6G Multi-User Field Trial

World's First Large Scale Trial



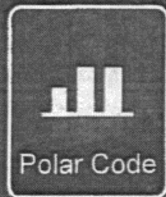
SCMA

UL 3X connections
DL >1.5X throughput



F-OFDM

Saving guard band
Asynchronous transmission



Polar Code

0.5~2dB gain compared with
LTE Turbo Code



MU-MIMO

24 layers
3.6Gbps Peak Rate

China • Chengdu

24 TUE

Sub6GHz

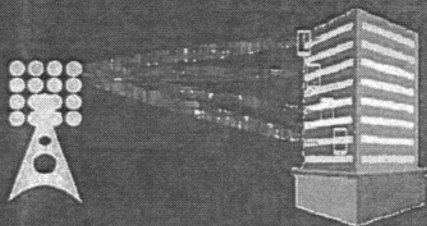
100MHz



High & Low Band Hybrid Networking

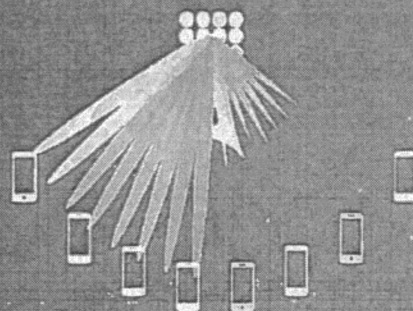
High Spectral Efficiency

C-band
MU-MIMO



- 10+Gbps@200MHz BW
- 3D Beamforming
- 26 Layers

28GHz
MU-MIMO



- 40+Gbps@1GHz BW
- 8 Users
- 16 Layers

C-band & 28GHz
Dual Connectivity



- 5Gbps+15Gbps
- 8 + 8 Layers



Compact Design for Verification in Commercial Environment



Unified platform for low & high band

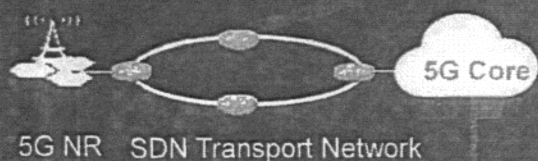


中国移动
China Mobile



DT & Huawei Slicing Joint Demo@MWC 2017

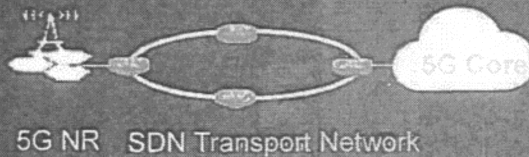
xMBB Slice(AR)



Latency
1 ms
E2E Latency

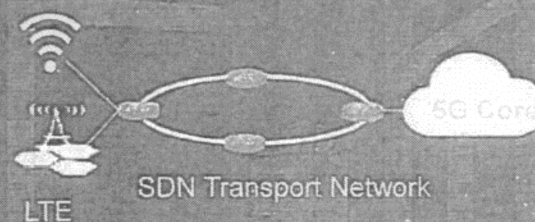
Throughput
1Gbps
Per Connection

GLA Slice(Robot Arm)



E2E
Guaranteed
Low Latency

FMC Slice(4K Video)



Seamless
User Experience



Thank You!

