5G Mobile Communications in China

Xiaohu You
Professor & Director
National Mobile Communications Research Laboratory
Southeast University, P. R. China
Outline

• Background and Recent Research Advances in China
• National High-Tech R&D Program: 863-5G Project
• Open Platform and Some Enabling Technologies
Roadmap to 5G

- **1G**: AMPS, TACS (1980s)
- **2G**: GSM, cdmaOne (IS-95) (1990s)
- **3G**: WCDMA, TD-SCDMA, CDMA2000 (2000s)
- **4G**: LTE/LTE-Advanced, 802.16m (2010s)
- **5G**: M-MIMO, UDN, NFV, ...

Enabling Techniques:
- OFDM + MIMO
- TDMA
- CDMA
- FDMA

- **Roadmap**
  - Extremely improved cost and energy efficiency
  - 2020: 5G?

New Applications:
- 1000x more capacity
- Mobile data traffic forecast

Future Mobile Communication Forum
5G Application Scenarios & KPIs

Mainly for Mobile Internet

Seamless Wide-Area Coverage

- User experienced data rate: 100 Mbps

Mainly for IoT (new scenarios)

Low-Latency High-Reliability

- Air interface latency: 1 ms
- End-to-end latency: ms level
- Reliability: nearly 100%

High-Capacity Hot-Spot

- User experienced data rate: 1 Gbps
- Peak data rate: Tens of Gbps
- Traffic volume density: Tens of Tbps/km²

Low-Power Massive-Connections

- Connection density: $10^6$ / km²
- Ultra-low power consumption
- Ultra-low cost

Source: IMT2020 (5G) PG
5G Vision & Requirements

Identified 5G vision and requirements

Main Drivers: Mobile internet and Internet of Things

5G Vision: Information a finger away, everything in touch

5G Key Capability ---- 5G Flower

Promote global consensus on 5G vision

ITU IMT-2020 vision will be determined in 2015.

China’s Activities → ITU’s Activities

Source: IMT2020 (5G) PG
5G Concept = “A Core KPI + A Group of Key Technologies”

- **The core KPI**
  - Gbps User Experienced Data Rate
  - Traffic volume density
  - Connection density
  - E2E Latency
  - Peak data rate
  - Spectral efficiency
  - Energy efficiency
  - Mobility

- **Key technologies**
  - Massive MIMO
  - Ultra-Dense Network
  - Novel Multiple Access
  - All-Spectrum Access
  - New Network Architecture

- **Other technologies**
  - F-OFDM
  - Flexible Duplex
  - Polar codes
  - Full duplex
  - FBMC
  - M-ary LDPC
  - Network coding
  - D2D

Source: CATR
The 5G wireless technology roadmap consists of the new air interface (AI) and 4G evolution AI.
The new AI has two branches: low-frequency new AI (main body) and high-frequency new AI (supplement).

Source: CATR
Potential Candidate Bands for 5G

Low-frequency bands below 6GHz are always necessary for IMT

- Exploit the bands identified for IMT in the Radio Regulations, including 450-470MHz, 698-806MHz, and 3400-3600MHz

2015

High-frequency bands within 6-100GHz can be introduced in 2019 and beyond

- Several potential candidate bands within 6~100GHz are selected.
- With different channel properties and coexistence situations.
- Studies on channel measurement, modeling and coexistence are ongoing work.
- To promote establishing a new agenda item in WRC-19.

Get new bands below 6GHz in WRC-15 AI 1.1

Source: IMT2020 (5G) PG
• Background and Recent Research Advances in China
• National High-Tech R&D Program: 863-5G Project
• Open Platform and Some Enabling Technologies

Over 50 Participants from Domestic & Multi-National Entities

Phase 1
Framework/RTT/Wireless Net

Phase 2
mmW/HetNet/NFV

Phase 3
Core Chips/Testbed

Nation 863 5G Project

2013 2014 2015
Mission of 5G SIG:
Integrate the 5G research on user requirements, service applications, spectrum, air-interface transmission, and network architecture, coordinating cross-layer research, analyzing and summarizing progresses on technical research.

Vice Chairman: WANG Xizhi (HUAWEI)
GUAN Hao (Nokia)
SUN Chengjun (Samsung)

Chairman: Chih-Lin I (China Mobile)
Scenarios and Demonstration (1st Phase)

- **Denser cooperation network for hot-spot**
- **5G-863 Demonstrator**
- **Massive MIMO for Wide Range Coverage**
- **Intelligent Resource Management and SON**
- **Massive Distributed MIMO for Macro-Cells**

- **Scenarios and Demonstration (1st Phase)**
  - Denser cooperation network for hot-spot
  - 5G-863 Demonstrator
  - Massive MIMO for Wide Range Coverage
  - Intelligent Resource Management and SON
  - Massive Distributed MIMO for Macro-Cells
Potential Direction: Xplore Spatial Resource Utilization

Typical Examples:

✓ Massive MIMO via spatial beams over the coverage area;
✓ Denser cooperation network (cooperative small cells);
✓ ......
Possible Evolution of Radio Access Network

Flat, Cloud & Virtualization?

C-RAN/D-RAN
5G Demonstrator: An Open Architecture

- Massive MIMO
- Denser Net
- Wireless Optical Millimeter Waves
- SON/SDN/NFV

Cloud Architecture based on massive GPPs, Sync-Ethernet with dense 100/40/10Ge interconnection.

Source: Cooperative Wireless Center @ SEU
Outline

• Background and Recent Research Advances in China
• National High-Tech R& D Program: 863-5G Project
• Open Platform and Some Enabling Technologies
Demonstration Scenarios: Centralized vs Distributed

- Large number of antenna at BS.
- Large number of beams for SDMA.
- Used for large area coverage.

- Introduce the denser nodes to explore spatial domain resource.
- Used for hotspot and indoor.

Massive MIMO

Distributed RAN
The Common Model for both Massive MIMO and D-RAN
With ideal Connections

\[ S = HY + n \]

\[ ZF: \hat{Y} = (H^*H)^{-1}H^*S \]

Co-located or Distributed Antennas

Global Joint Precoder/Receiver

The bottleneck
Why Massive Cooperation Nodes:
More Cooperation, More Gain - the Uplink Case

X. You et al, Cooperative distributed antenna for mobile communication systems, IEEE Wireless Communications, June, 2010
5G Open Platform Ongoing in 2014-2015

- Freq: 3.5GHz/6-11GHz
- Bandwidth: 100/500MHz
- Antenna Number: up to 1024
- Centralized/Distributed
- Tx Timing Sych < 30ns with IEEE 1588 PTPv2
- Rx Processing Delay < 15uS
- Massive GPPs up to 10K CPU Cores
- Auxiliary HW Accelerators
- Private Ethernet & MSTP/Trill
- SON/SDN/NFV Applicable

A Hybrid Cloud RAN Architecture Based on Sync-Ethernet & MSTP/Trill

Source: Cooperative Wireless Center @ SEU
Massive MIMO – Beam-Domain Sparsity

Implementation of Massive MIMO

Source: SEU-Huawei Joint Research
D-RAN – Complexity Reduction via Spatial Sparsity

Cluster MU Joint Processing

Large-scale sparse matrix

Large-scale bipartite graph
Simulation Conditions:
720 APs & 720 users, with single antenna for each.
A factor of 24 for pilot reuse.
Spatial sparse is set to 97%.
Parallel Implementation in Frequency Domain

Distributed Joint Processing over the MSTP
Parallel Implementation in Frequency Domain – Filter Bank

General Multi-Carrier (GMC) Link

Parallel Implementation in Time Domain
Overall Parallel Implementation

Frequency Domain

Sub-Carrier #1
- CPU Core #1
- OFDM Symbols #1
- CPU Core #2
- OFDM Symbols #2
- CPU Core #3
- OFDM Symbols #3
- CPU Core #4
- OFDM Symbols #4
- CPU Core #N
- OFDM Symbols #N

Sub-Carrier #2
- CPU Core #1
- OFDM Symbols #1
- CPU Core #2
- OFDM Symbols #2
- CPU Core #3
- OFDM Symbols #3
- CPU Core #4
- OFDM Symbols #4
- CPU Core #N
- OFDM Symbols #N

Sub-Carrier #M
- CPU Core #1
- OFDM Symbols #1
- CPU Core #2
- OFDM Symbols #2
- CPU Core #3
- OFDM Symbols #3
- CPU Core #4
- OFDM Symbols #4
- CPU Core #N
- OFDM Symbols #N

Further Complexity Reduction via Spatial Sparse

Distributed Processing with a Degree of Parallel N*M
System Synchronization via SyncE/1588v2

Ethernet MAC Frame for BB Signal Transmission

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Destination</th>
<th>Source</th>
<th>Length/Type</th>
<th>Row BB Data</th>
<th>FCS</th>
</tr>
</thead>
</table>

RRU OC Timing Sync Test

<table>
<thead>
<tr>
<th>Test Period</th>
<th>Average Delay</th>
<th>Std Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>24H</td>
<td>16.1ns</td>
<td>1.2ns</td>
</tr>
</tbody>
</table>

RRU OC Timing Sync Test (Non-Symmetric)

<table>
<thead>
<tr>
<th>Test Period</th>
<th>Average Delay</th>
<th>Std Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>24H</td>
<td>16.5ns</td>
<td>1.2ns</td>
</tr>
</tbody>
</table>
5G: our common wireless future!