Resource Allocation Algorithms
Design for 5G Wireless Networks

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5G Overview

User Data Rate
0.1 – 1 Gbps

- UHD 3D Video
- Augmented Reality
- Mobile Cloud

Traffic

1000K Connections/km²

- M2M Devices
- Wearables
- Smart Phones

Devices

E2E Latency
< 10 ms

- Smart Home
- Industry
- e-Health
- Energy
- Transportation

Applications
3GPP Use Cases

- Enhanced Mobile Broadband (eMBB)

**Devices**
- Smart Phones
- Tablets

**Applications**
- UHD 3D Video Streaming
- Virtual / Augmented Reality
- Mobile Cloud / Cloud Gaming

**Requirements**
- Peak Data Rate ~ Tens of Gbps
- User Data Rate ~ 0.1-1 Gbps
3GPP Use Cases

- Massive Machine-type Communications (mMTC)

**Devices**
- Wearables
- Smart Home Appliances
- Smart Traffic Signs / Lights
- Sensors

**Applications**
- Home Automation
- Intelligent Transportation Systems
- Asset Tracking
- Environmental Monitoring

**Requirements**
- High Connection Density ~ 1000K Devices per km²
- Extended Battery Lifetime ~ 15 Years
## 3GPP Use Cases

### Ultra-Reliable Low Latency Communications (URLLC)

<table>
<thead>
<tr>
<th>Devices</th>
<th>Applications</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Autonomous Vehicles</td>
<td>• e-Health</td>
<td>• High Reliability</td>
</tr>
<tr>
<td>• Health Monitoring Devices</td>
<td>• Industrial Automation</td>
<td>Rate $\sim 0.99999$</td>
</tr>
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<td>• Remote Surgery Robotics</td>
<td>• Autonomous Driving</td>
<td>• Low E2E Latency $\sim &lt; 10$ ms</td>
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<td>• Industrial Sensors and Actuators</td>
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Key Technologies Filling the Gap

- NOMA
  - Network Densification
  - NB-IoT
- Multi-RAT
  - SDN / NFV
  - New Radio Forward Compatibility
- Shorter TTI
  - Network Architecture

Resource Allocation Algorithms

- Higher Data Rate
- Higher Connection Density
- More Network Flexibility
- Less E2E Latency

- Massive MIMO
  - Full Duplexing
- More Spectrum (above 6GHz, mmWave, Unlicensed Spectrum)
5G Network Architecture
Cloud Radio Access Network (C-RAN) Architecture

- Decouple the baseband unit (BBU) and the remote radio head (RRH)
- Place BBUs in a data center for centralized control and processing
- Reduce CAPEX and OPEX for system upgrade and maintenance
- Improve spectral efficiency via centralized interference control and coordinated multi-point transmission (CoMP)
Network Slicing

- Enables flexible and dynamic slicing of network resources
Problem Statement 1: User-Centric Resource Sharing for C-RAN

- **Goal**
  - Quality of service guarantee
  - Service isolation
  - Traffic variation, user mobility

- **Given**
  - Set of service providers
  - Capacity of fronthaul links

- **Variables**
  - Time slot, channel allocation
  - User association

- **Techniques**
  - Mixed integer non-linear programming
  - Multi-timescale resource allocation
    - Global (local) resource allocation at longer (smaller) time scale
Problem Statement 2: Beamforming Design in C-RAN

- **Goal**
  - Maximize users’ satisfaction
  - SINR and power constraints

- **Given**
  - Set of users and RRHs
  - Capacity of fronthaul links
  - Imperfect CSI

- **Variables**
  - Beamforming vector for each user

- **Techniques**
  - Non-linear programming
  - Convex relaxation
  - Semidefinite programming
Problem Statement 3: Non-Orthogonal Multiple Access (NOMA) for Narrowband IoT Systems

- Goal
  - Maximize connection density

- Given
  - Set of mMTC, URLLC devices
  - NB-IoT specification
  - Latency and power requirement

- Variables
  - Sub-carrier allocation
  - Transmit power

- Techniques
  - Non-orthogonal multiple access (NOMA)
  - Combinatorial optimization
Sample Publications in Wireless Networking in 2016


http://www.ece.ubc.ca/~vincentw/Homepage/Publication.html
Forthcoming Edited Book in 5G Wireless Systems

- Publisher: Cambridge University Press
- Hard copy will be available in April 2017
Questions

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