5G & Beyond

Resource Allocation for High Network Efficiency

SDN, NFV and Fog/Edge Networking
5G Wireless Networks-Resource Allocation
Introduction

Limited scope of improvement on the physical layer

Limited spectrum

Tremendous increase in mobile broadband traffic

End-user expectations on achievable data rates

Limited scope of improvement on the physical layer

Limited spectrum

Next generation networks

- Heterogeneous Networks
- Multicast
- Network Softwarization (SDN, NFV)
- Dual Connectivity (Multi-Access)
- Spectrum Sharing
- Device to Device
- Fog/Edge Computing
- Multi-RAT Networks

Fog/Edge Computing

Multi-RAT Networks
Heterogeneous Networks

Higher spectral efficiency

Heterogenous networks

Single RAT

Small cells (micro, pico, femto)

Relays

Multi RAT

5G/LTE/WLAN

5G/LTE/WRAN

Macro cells
Heterogeneous Networks

- Pico cell
- Micro cell
- Wi-Fi
- Femto cell
- Macro cell
- Relay

- Offloading
- D2D
- Multicast
- Dual connectivity
Dual Connectivity

- Introduced in 3GPP Release 12
- Architectures:
  - Split at Core Network
  - Bearer Split at Macro eNB
- Research challenges:
  - Selection of dual connected users
  - Routing and traffic splitting
  - Traffic aggregation at receiver
  - Multi-RAT dual connectivity

Diagram showing a macro cell and a pico cell with a user connected to both.
Mobile Data Offloading

- Proposed in 3GPP Release 12
- User-initiated offloading
  - Distributed approach: Greedy solution
  - Easy to implement
- Network-initiated offloading
  - System-wide view at centralized controller
  - In harmonization with SDN approach towards 5G
- Research challenges:
  - Optimal association and offloading decisions
Device-to-Device Communication

- Introduced in 3GPP Release 12
- Research interest:
  - Resource allocation
- Research challenges:
  - Resource and power allocation
  - Interference mitigation
  - Pricing schemes
  - Device relaying
  - D2D in unlicensed bands

Diagram:
- Macro cell
- D2D communication
**Multicast Communication**

- Multicast introduced using MBMS in 3GPP Release 6
- Two main research challenges:
  - Multicast group formation
  - Resource allocation
- Use cases:
  - Video streaming from platforms like Netflix
  - News alerts
  - Streaming live events e.g. sports matches
  - Mobile TV
  - Software updates
Spectrum Sharing

- Licensed Spectrum sharing
- Unlicensed Spectrum sharing
  - Static sharing: Inefficient spectrum utilization
  - Dynamic sharing: Improves spectrum utilization
- Cooperative and non-cooperative approaches
- Challenges:
  - Interference management
  - Selfish behavior of operators
5G & Beyond - SDN, NFV and Fog/Edge Networking
Beyond 5G - Research Problems

- Is Core always required?
  - Should we decouple Core and RAN?

- Has 5G employed SDN well?
  - Is there another way to organize mobile control plane?
  - Can UE Signaling be treated as data, just like UE IP packets?

- Convergence of Unicast & Multicast
  - How to bring together Unicast and Multicast(/Broadcast) Communication?

- An Improved Relay Architecture for 5G & beyond
5G-Flow: Decoupling RAN From Core

Decoupling of RAN from Core

- Decoupling CN & Radio Stacks at UE & RAN Nodes
  - Through OF-Switch and OF-Controller
- UE-Core Communication treats RAN as Underlay
- Core becomes Optional
- Flexible RAN and Core Connectivity
- Use any RAT to connect to any CN/Internet directly - Use 5G NR with 4G CN

Unified Multi-RAT RAN

- Logically Centralized Multi-RAT RAN Control
  - Light-weight unified OF-Controller
- Unified CN Interworking Replacing RAT Specific CN Interworking
- Protocol Stacks Interfaces of OF-Switch
- NAS Signaling Exchange treated as data passing through an OF-Switch

Improved Data Flow Management in Multi-RAT RAN

- Simpler NSA Implementation
- Support for Captive Networks/Rural Broadband Connectivity
- Dynamic Spectrum Sharing across RATS (LTE/5G)
Has 5G employed SDN well?

Control plane Functions in 5G performs two types of tasks

#1 - Control Network (Data Plane Functions)
- SMF Controls UPF through PFCP Protocol
- gNB-CU-CP Controls gNB-DU (F1AP) and gNB-CU-UP (E1AP)

#2 - Perform UE Control & State Management
- CN CP (AMF/SMF)
  - Exchanges Signalling (NAS) Messages with UEs
  - Maintains UE’s State (MM/SM states)
- RAN CP (gNB-CU-CP)
  - Exchanges Signaling (RRC) Messages with UEs
  - Maintains UE’s Radio Connection State (RRC States)

3GPP 5G Architecture

- Both UE Control & Network (Data Plane) Control Tasks as part of Control Plane
- Is it aligned with SDN paradigm?
- Typically SDN Control Plane (Controller)
  - Controls Network (DP) – Establishes Data Path
  - Does not Control Network Users (UEs)
- Should UE Control be separated from Network Control in 5G & Beyond?
A Generic Architecture for 5G & Beyond

- **Three types of Network Functions**
  - **Data Plane Functions**
    - Responsible for Data Transfer
  - **Control Plane Functions**
    - Establishes Data Path through Network (DP)
      - Enable Communication between UE & other end points (Service Functions as specified below)
    - Not Responsible for Signaling Exchange with UEs or UE Control/State Mgmt. That is part of ‘UE Control’ or ‘Service’ Functions
  - **Service Functions**
    - Serves UE
    - Numerous Types - CDN, IMS, and also UE Signalling & Control - RRC, NAS(AMF...)
    - May trigger CP to establish Supplementary Data Paths when needed

- **Service Functions (including UE Control Functions)** can be viewed as Data Plane entities

- **A Recursive Architecture for Networks**
  - Setting up UE Data or Signaling Path a Recursive Process – setup in a loop
  - ‘UE Signaling’ another form of Data
Convergence of Unicast & Multicast

- Converged Unicast & Multicast Control
- Usage of Multi-Access Capability at UE
- Simplified BM-SC Architecture
Using Mobile Edge for an Improved Relay Architecture

- Relay Node is a standard gNB-DU (with an additional UE radio stack)
- Donor/Controller Node is a standard gNB-CU
- Relay (gNB-DU) and Donor (gNB-CU) Nodes Connected via IP
  - IP connectivity between gNB-DU and gNB-CU enabled by 5G Network
  - gNB-DU acts as a UE for the 5G Network
  - gNB-CU acts as a Server connected to UPF over N6 Interface
- UPF, which carries data from gNB-DU to gNB-CU can be deployed in the Mobile Edge alongside the gNB-CU & gNB

- Key ideas behind the Solution
  - IP connectivity between two parts of the gNB is enabled through the same 5G network of which they are a part
  - Usage of Edge Cloud for Deployment of Donor (gNB-CU) and the connecting UPF
Thank you