Towards 6G

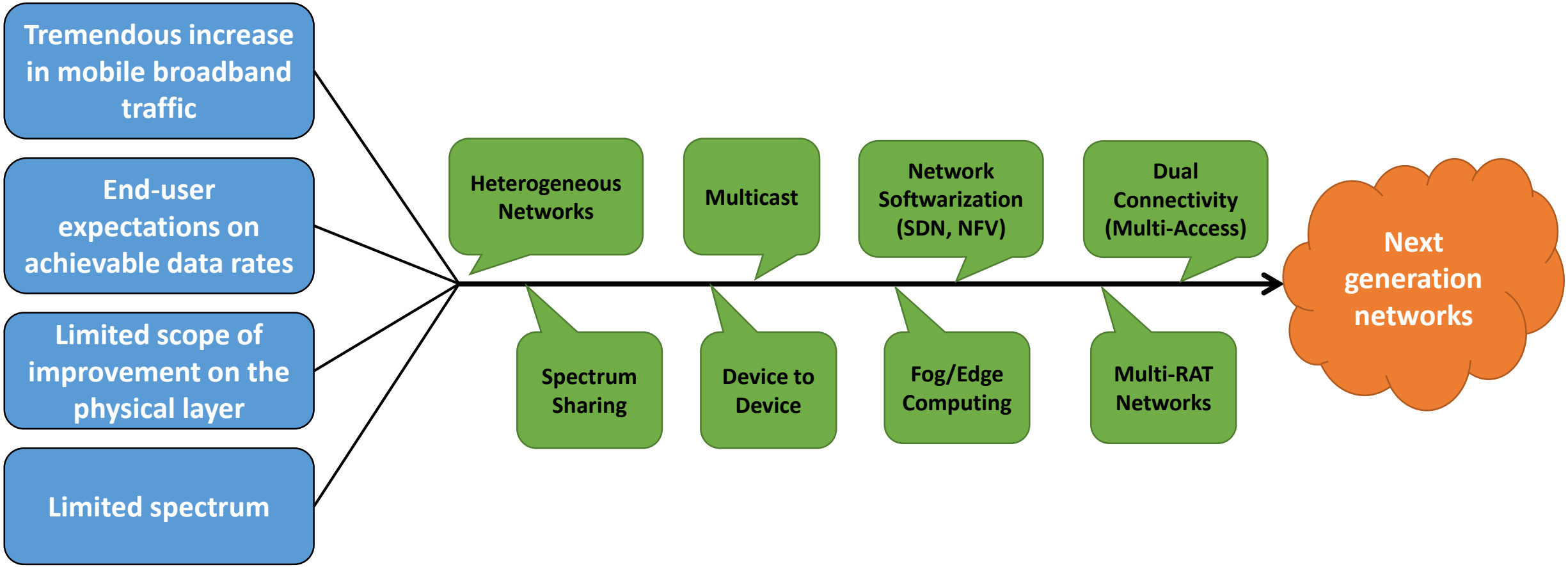
Resource Allocation for High Network Efficiency

SDN, NFV and Fog/Edge Networking

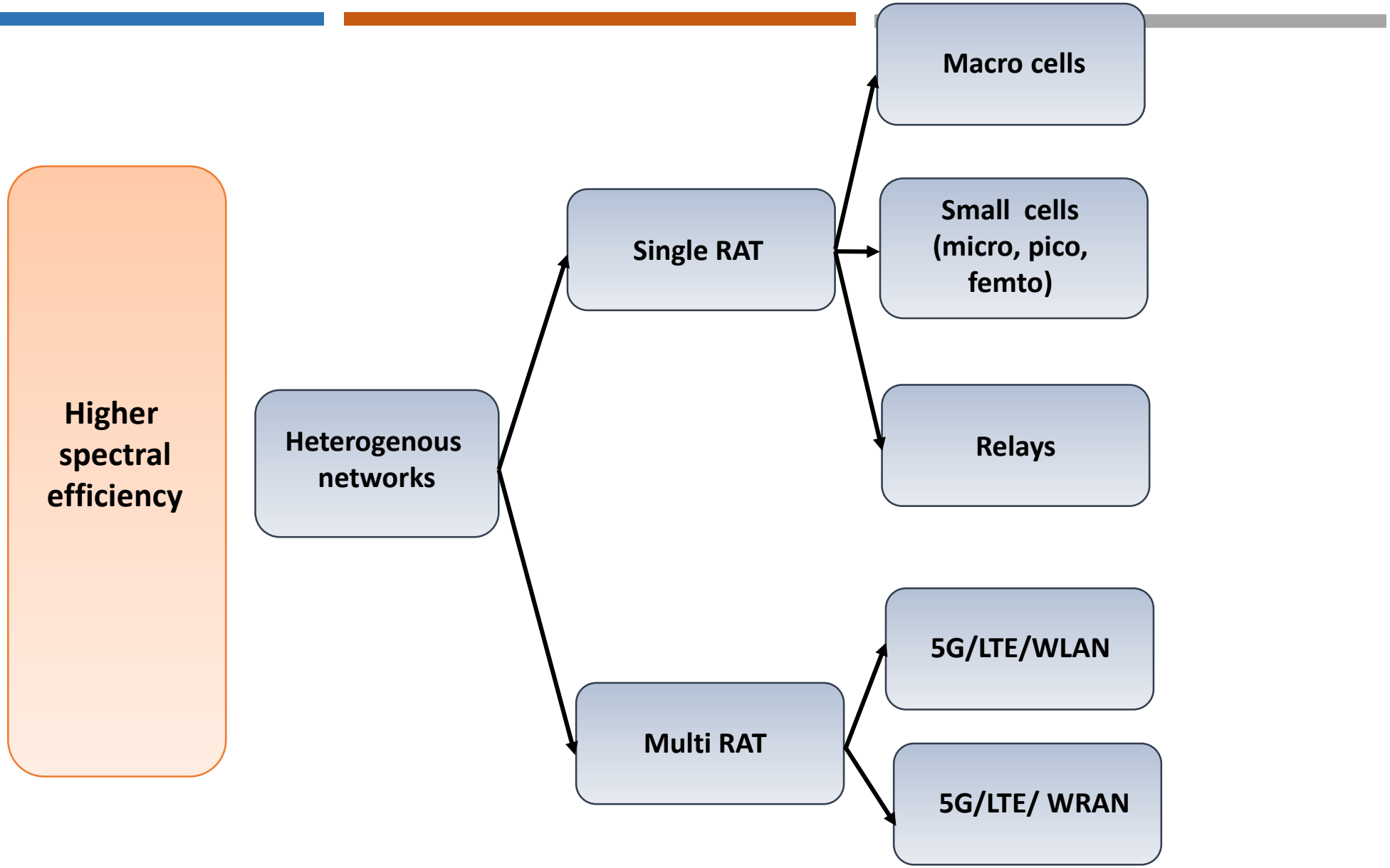
AI/Ml Driven Network Design

5G Wireless Networks-Resource Allocation

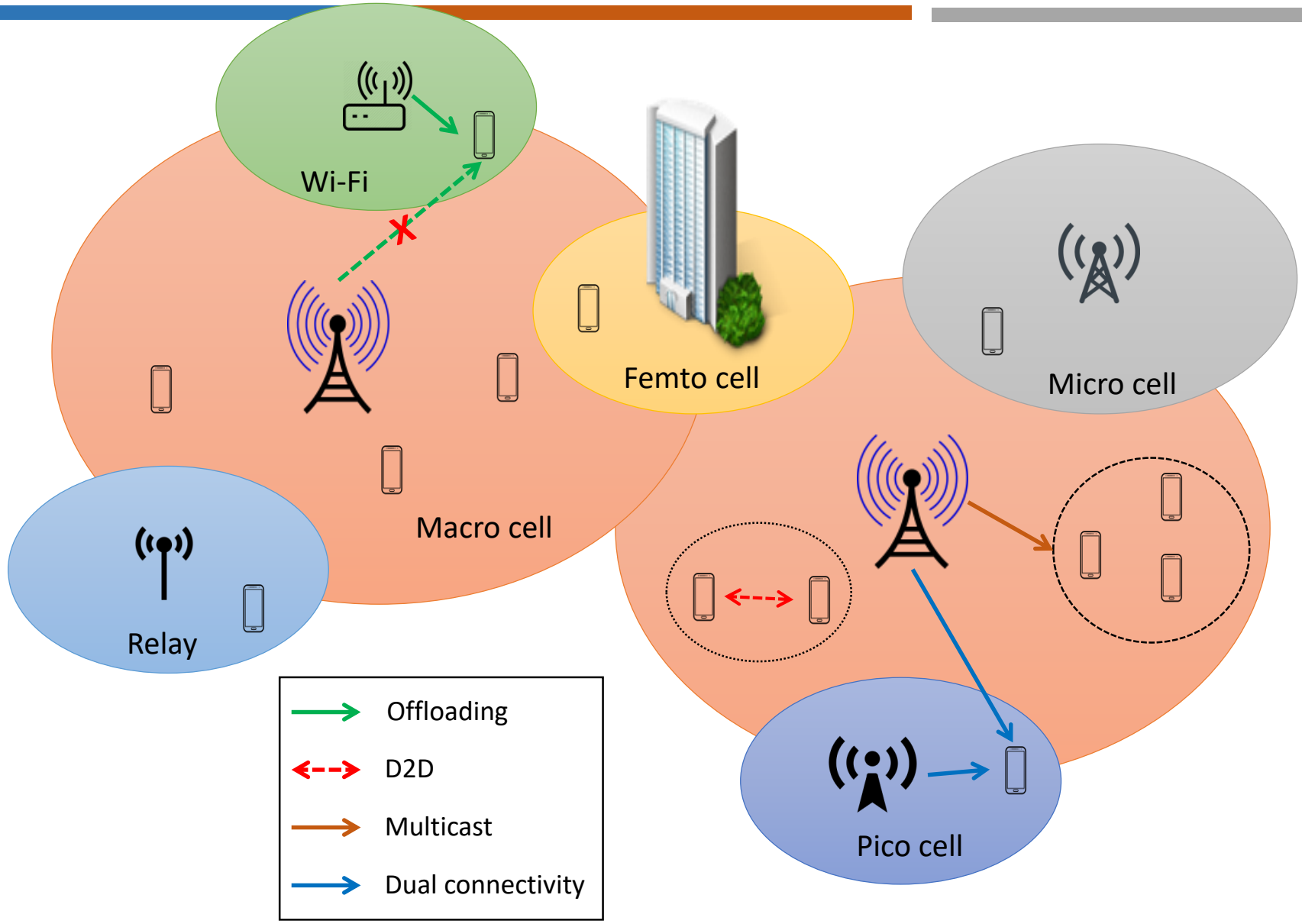
Introduction



Heterogeneous Networks

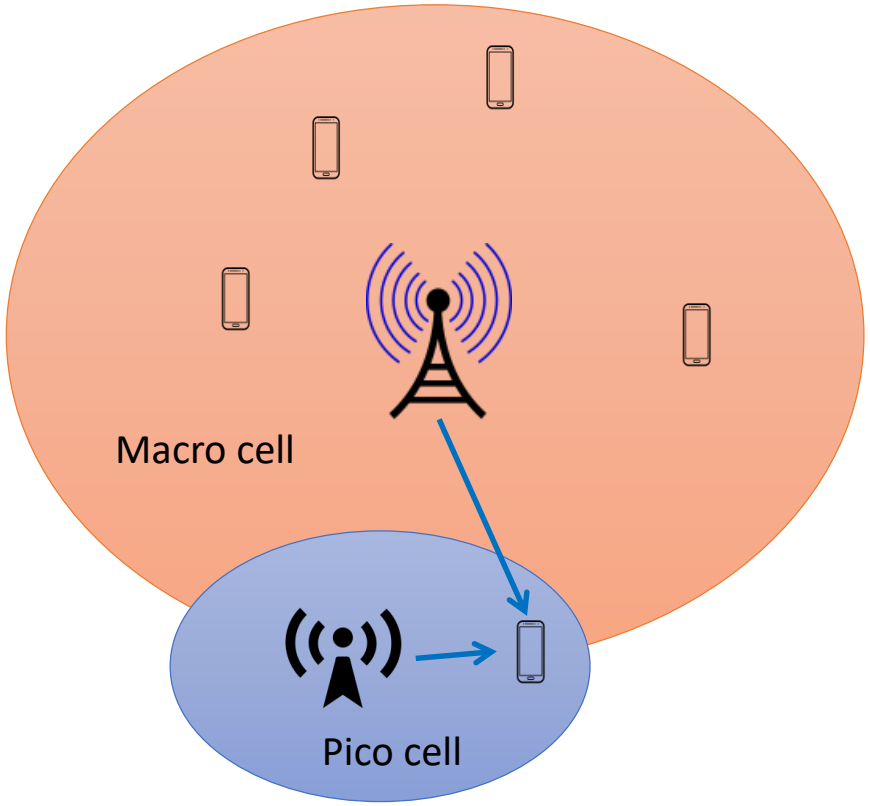


Heterogeneous Networks



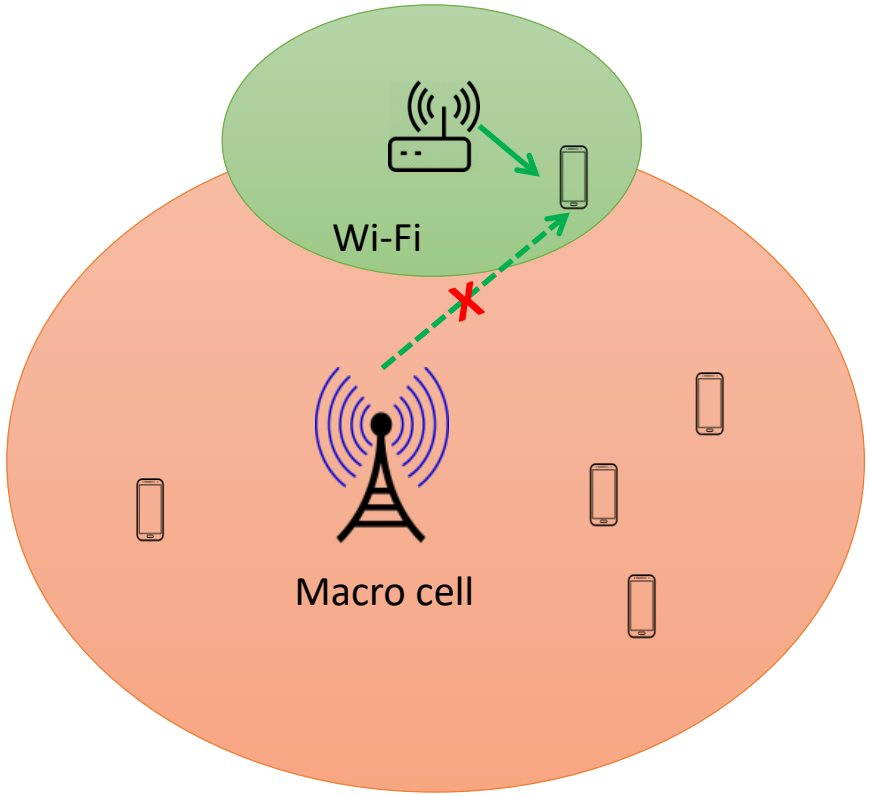
Dual Connectivity

- 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



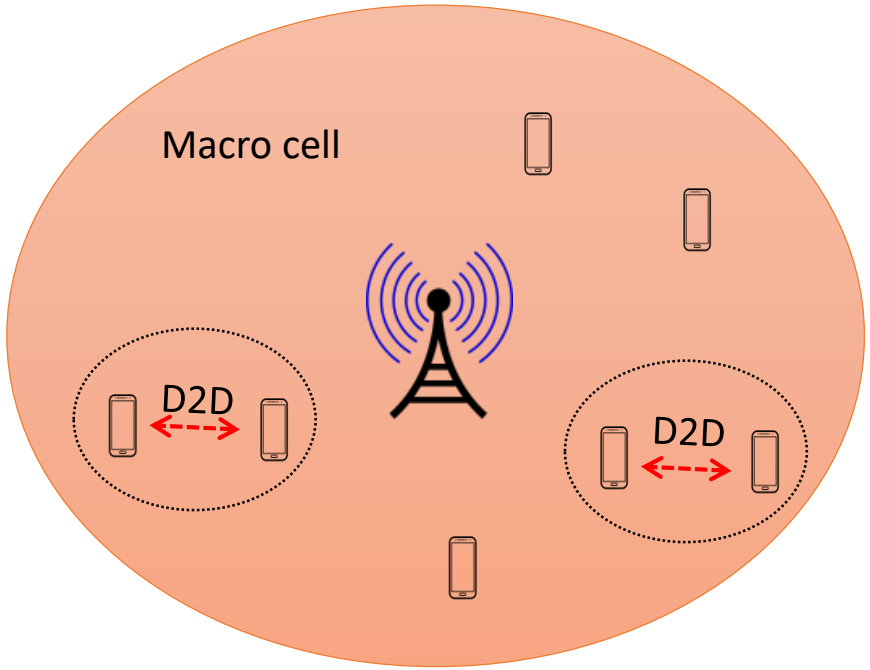
Mobile Data Offloading

- 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



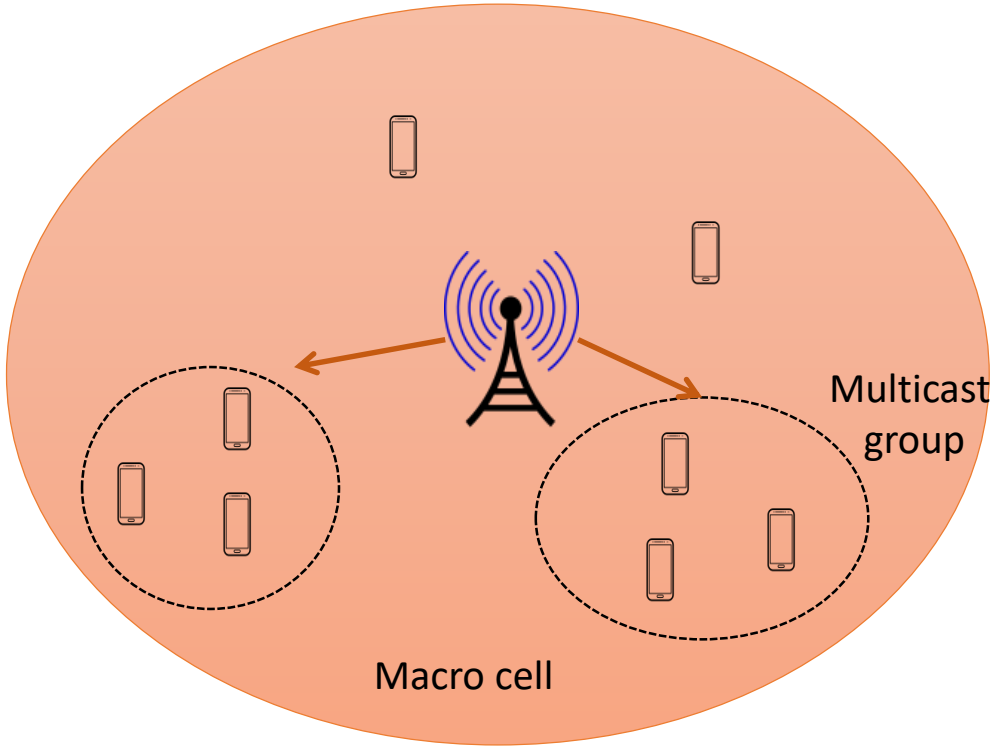
Device-to-Device Communication

- 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



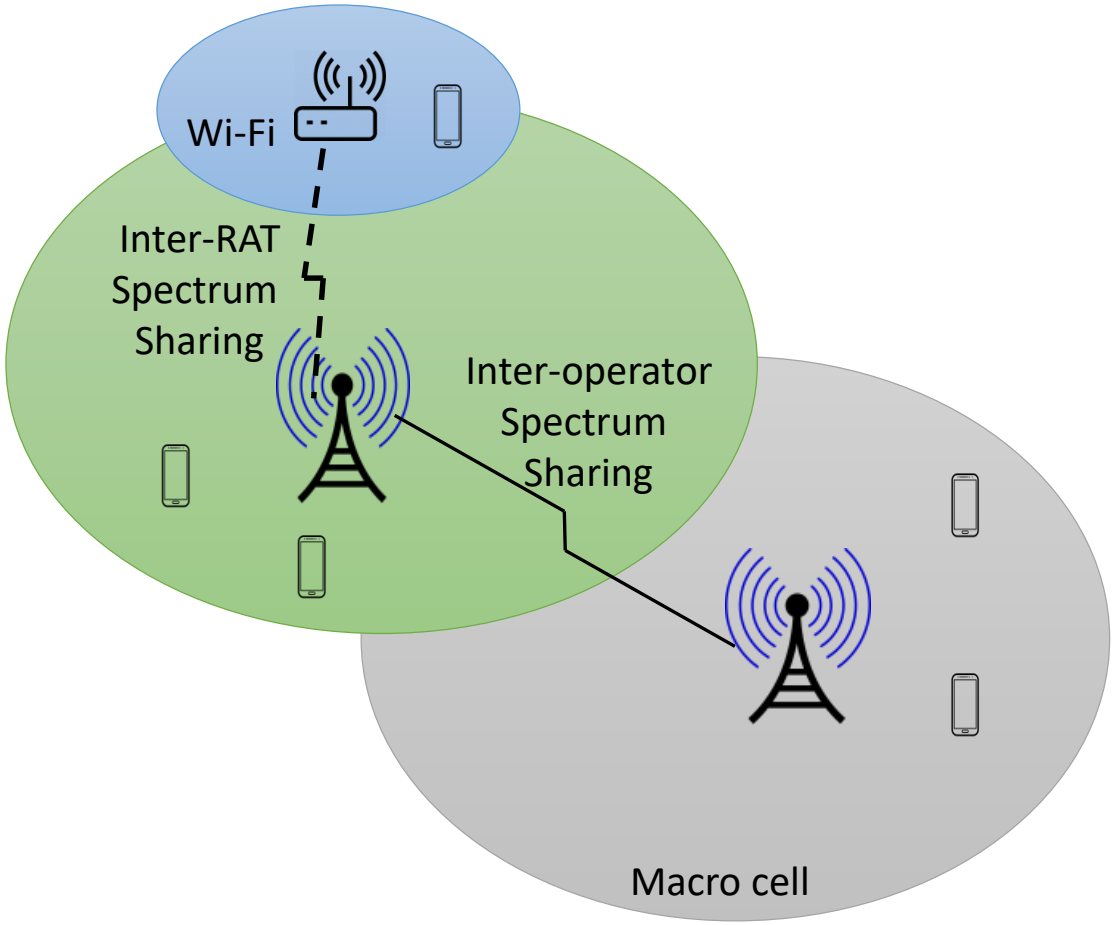
Multicast Communication

- 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



Towards 6G - SDN, NFV, Fog/Edge Networking and AI/ML Driven Network Design

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
- What Role AI/ML can play in network/protocol design?

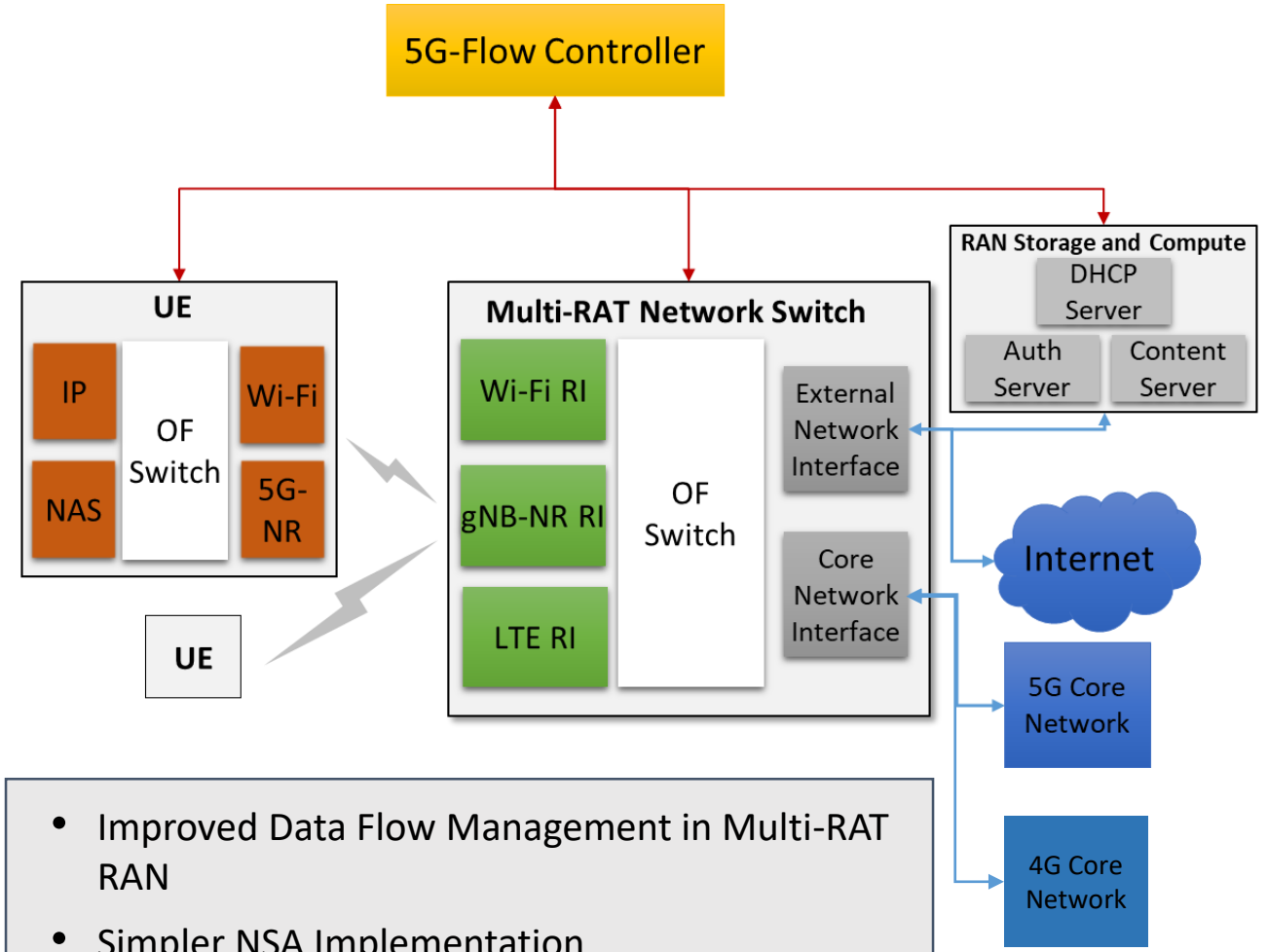
5G-Flow : Decoupling RAN From Core

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



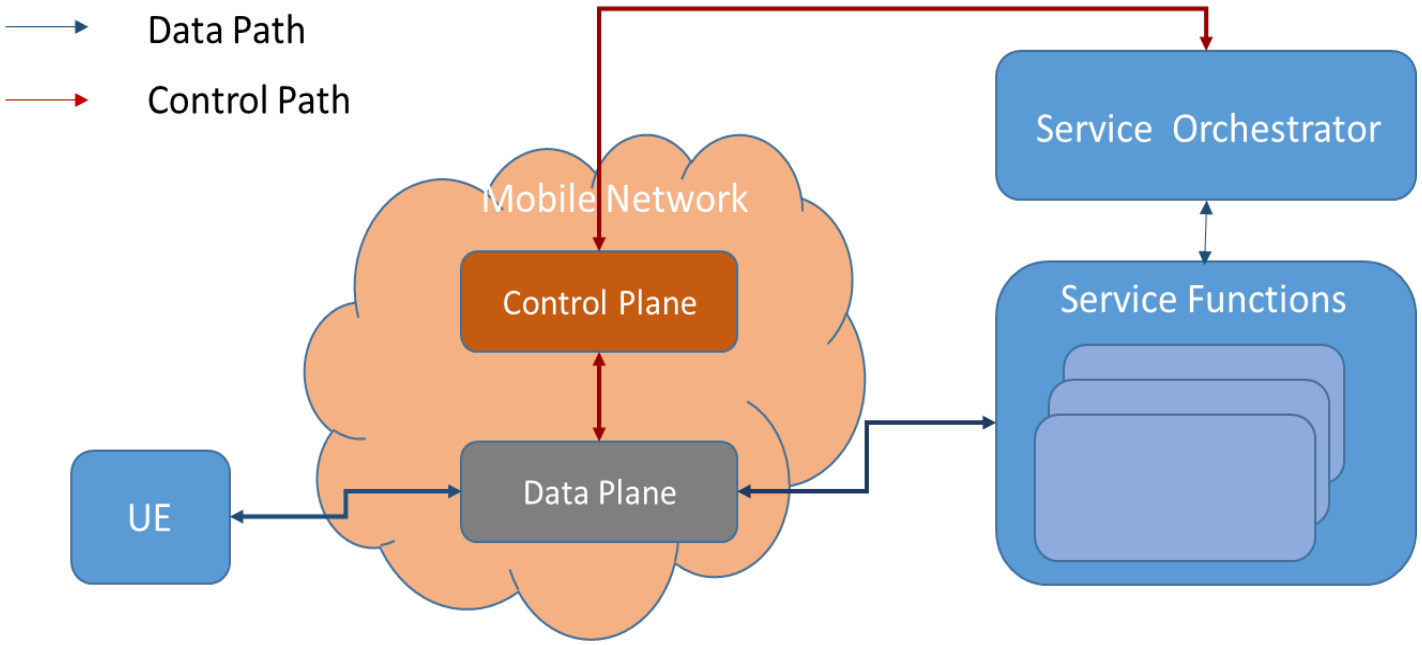
- Improved Data Flow Management in Multi-RAT RAN
- Simpler NSA Implementation
- Support for Captive Networks/Rural Broadband Connectivity
- Dynamic Spectrum Sharing across RATS (LTE/5G)

SDN & 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 6G

- 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

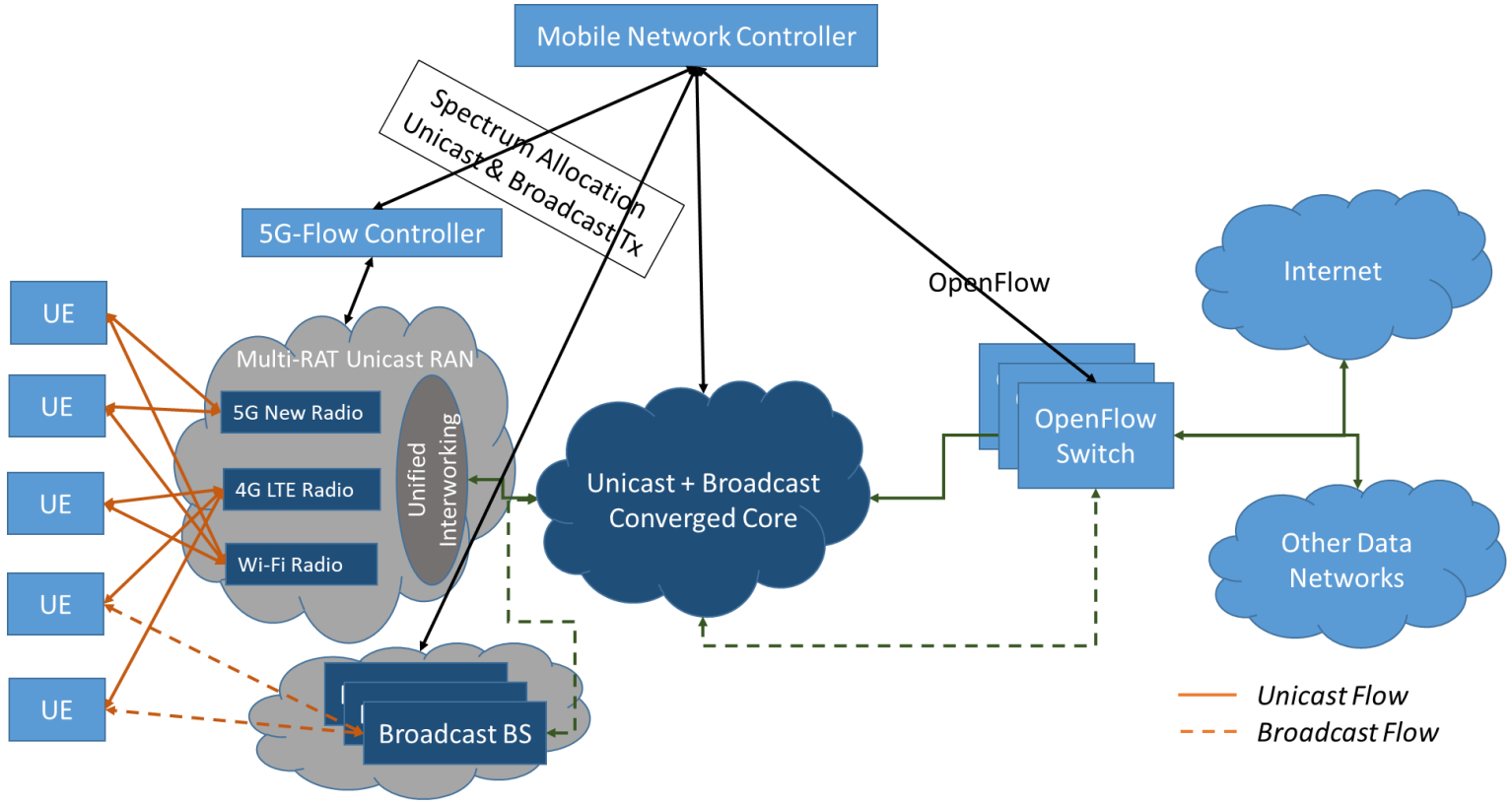


- Service Functions (including UE Control Functions) can be viewed as Data Plane entities

- 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

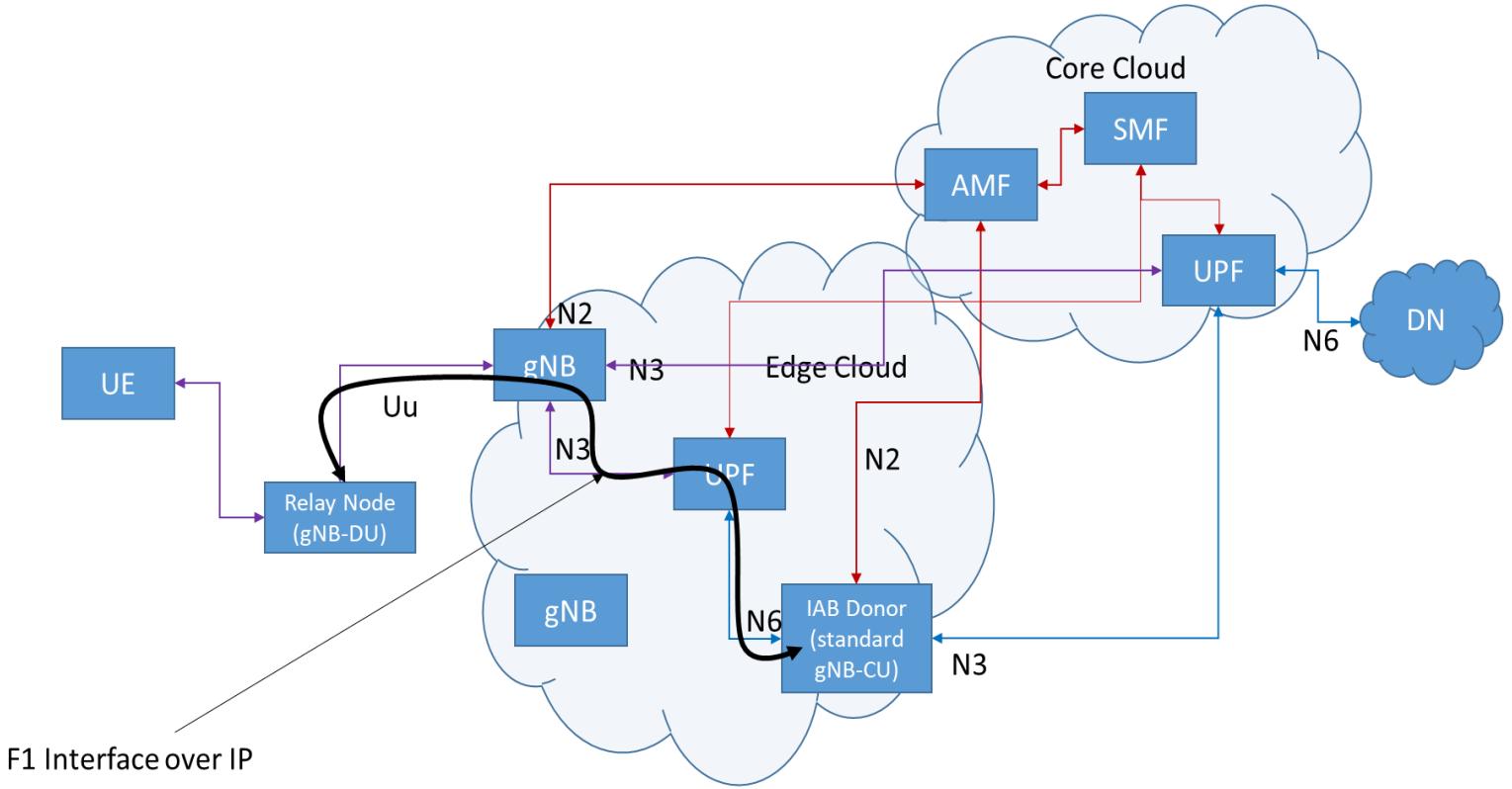
Convergence of Unicast & Multicast

- 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

AI/ML Driven Network Design for 6G

- Existing Protocols and Network Architecture
  - Specified by engineers/designers
  - Typically as part of telecom standardization (3GPP, IEEE, IETF)
- We are looking at following fundamental problems
  - Is it possible to “learn” and not “specify” communication protocols?
  - Is it possible to “learn” network architecture?
  - Will “learning” based protocols/architecture lead to
    - a more flexible & efficient mobile network?
  - What happens to telecom standardization if
    - Protocols/Network Architecture can be “learnt”
    - What will be standardized in such a scenario?
  - What can be “learnt” and what needs to be “specified”?

Thank you