Enabling ICN in 3GPP's 5GC Architecture

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Draft Outline

- **Motivating ICN for 5G**
- **Architectural differences from 4G**
- **5G Core Proposal**
- **Enabling ICN in 5G**
- **Use Case Scenarios**
  - **Edge Computing**
  - **Seamless Mobility**

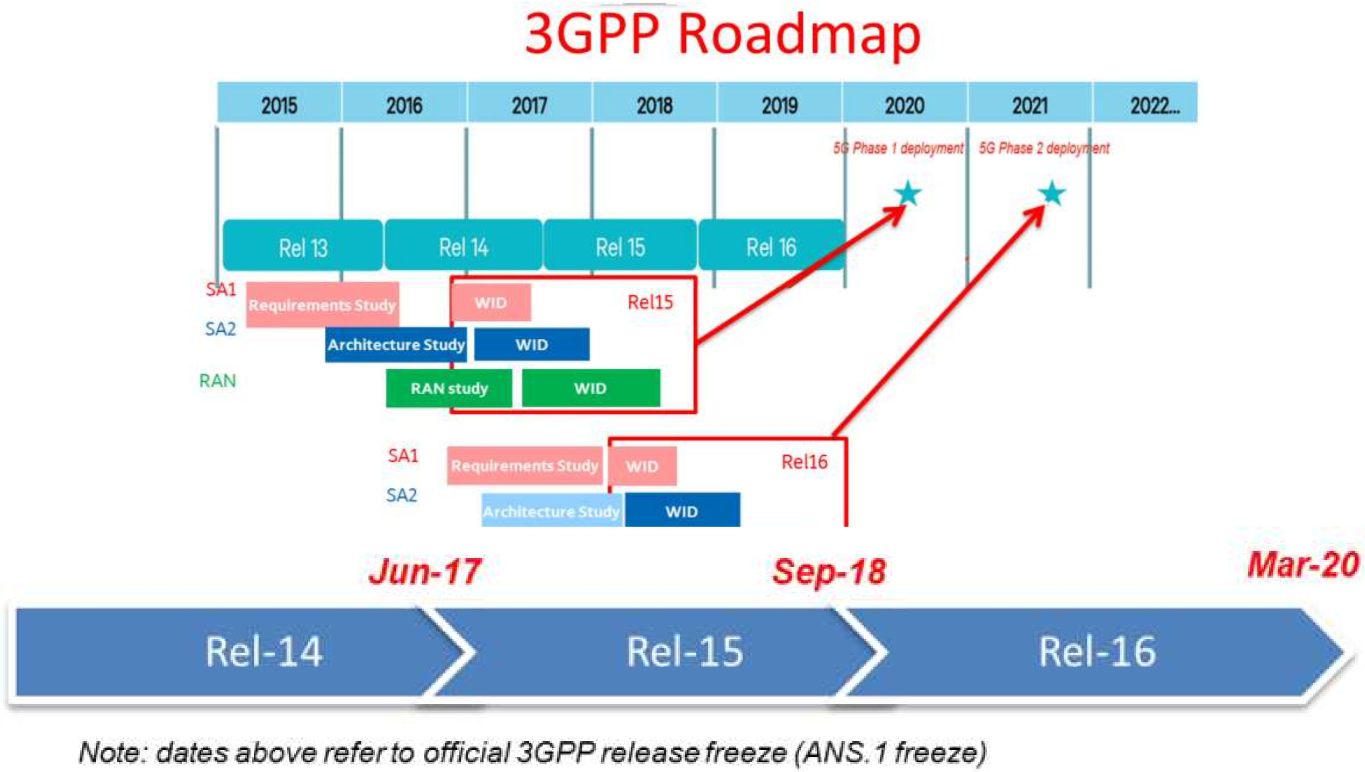
Motivating ICN for 5G

- **ICN draft [1] explores various deployment opportunities**
  - 5G being one of them
- **5G hopes to serve diverse heterogeneous applications**
  - eMBB, MMTC, URLLC (~1-10ms latency)
- **Network Slicing (NS) technology slices UE, RAN, Transport and Core in multi-tenancy environments for applications**
  - Granularity – a slice per service instance, or one slice made up of many sub slices to serve a service class etc.
  - Dynamic – Slices that are elastic and limited life span
  - End-to-end – UE, Radio, Core, Cloud, Optical backbone etc.
  - Leverage NFV and SDN frameworks for programmability and service management
- **NS introduces logical architectures to better serve some application classes**
  - Getting rid of per UE state management (GTP tunnels) in the data/control plane, e.g. considering large IoT devices
  - ICN can be a slice to serve eMBB, MMTC comprising many IoT applications [2]
  - ICN enables many features with a flat architecture (Naming, Security, Mobility, Multi-homing, Caching, In-network computing etc)

[1] Akbar Rehman et al, "Deployment Configurations for Information-Centric Networks", IETF/ICNRG, 2017

[2] R. Ravindran et al., "5G-ICN: Delivering ICN Services over 5G Using Network Slicing," IEEE Communications Mag., vol. 55, no. 5, May 2017, pp 101-107.

Why this is relevant ?



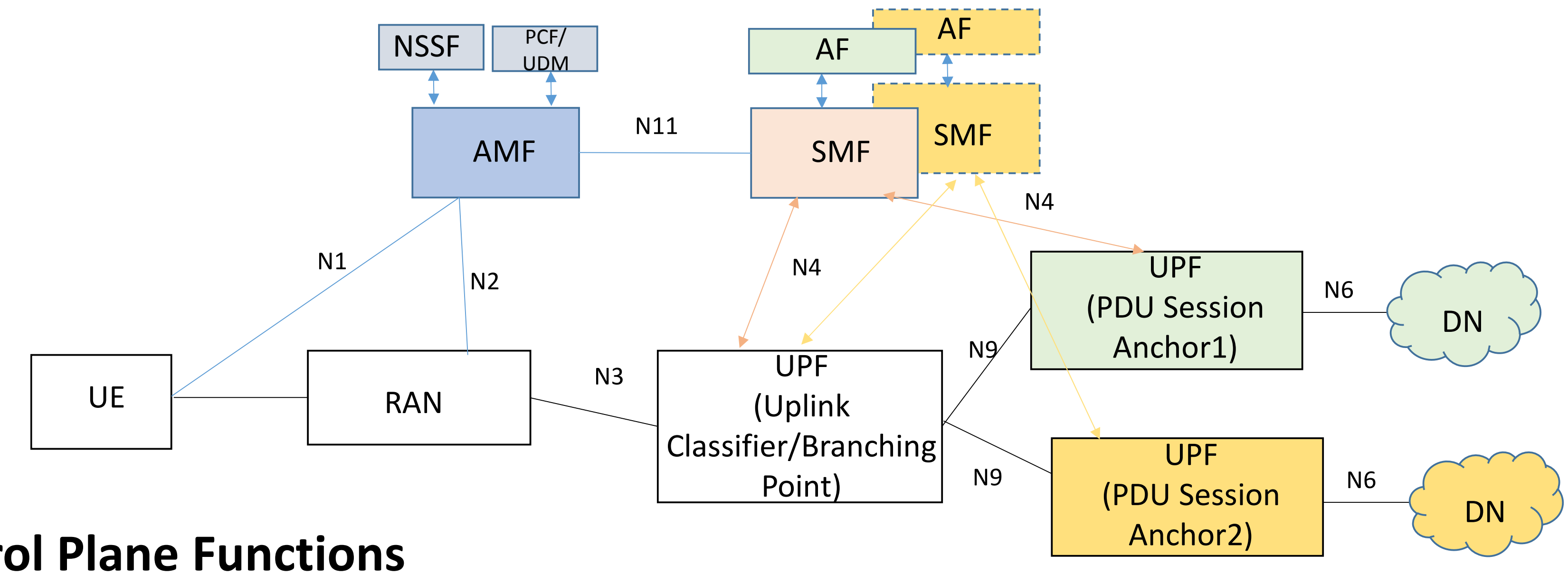
- Rel 15 will include the first 5G-NR and 5GC specifications, considering eMBB deployment
- Rel 16 will try to address all the other requirements identified as part of TS-22.261, which includes many requirements for MMTC and URLLC use cases as well.
  - ICN could potentially be a way to address some of the requirements.

Architectural Differences from 4G/LTE

- **Control User Plane Split (CUPS)**
  - NFV based design, unlike vertically integrated S-GW/P-GW appliances.
  - Allows control and user plane functions to be elastic
  - Allows introducing new control and user planes considering Network Slicing
- **Decoupling RAT from the User Plane**
  - 5G increases the maximum spectrum boundary from 6GHz to 100GHz
  - Allows heterogeneous RATs (possibly different MAC/PHY) to use diverse UP instantiations
  - RAT control plane separated from the Core Control Plane
- **Non IP-PDU Session support**
  - IPv4/IPv6/Ethernet/Unstructured PDUs
  - Considering many IoT LPWAN implementations
  - ICN can potentially leverage this feature and formalize it
- **Service Centric Design**
  - Uses top-down orchestration model – Application driven
  - Network Exposure functions to allow other application functions to use 5G network services
  - Enables Get/Put, Pub/Sub APIs instead of Procedural ones (e.g. in LTE)

5G Architecture

5G Architecture [1][2]



Control Plane Functions

- **Common control plane Function :** The NSSF and AMF are part of the NSSF allows to assign a PDU session to a particular UPF
- **Slice Specific Control Functions :** SMF/AF/UPFs(UL-CL, Session Anchor points) can be slice specific

User Plane Functions

- UE includes Smart phones, IoT, Industrial Robots etc/RAN offers the radio connectivity
- Forwarders that hold state to handle various PDU session states for different applications.

References:

[1] 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; System Architecture for the 5G System (Rel.15), TS-23.501

[2] 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Procedures for the 5G System (Rel. 15), TS-23.502

5G Core Key Control Plane Functions

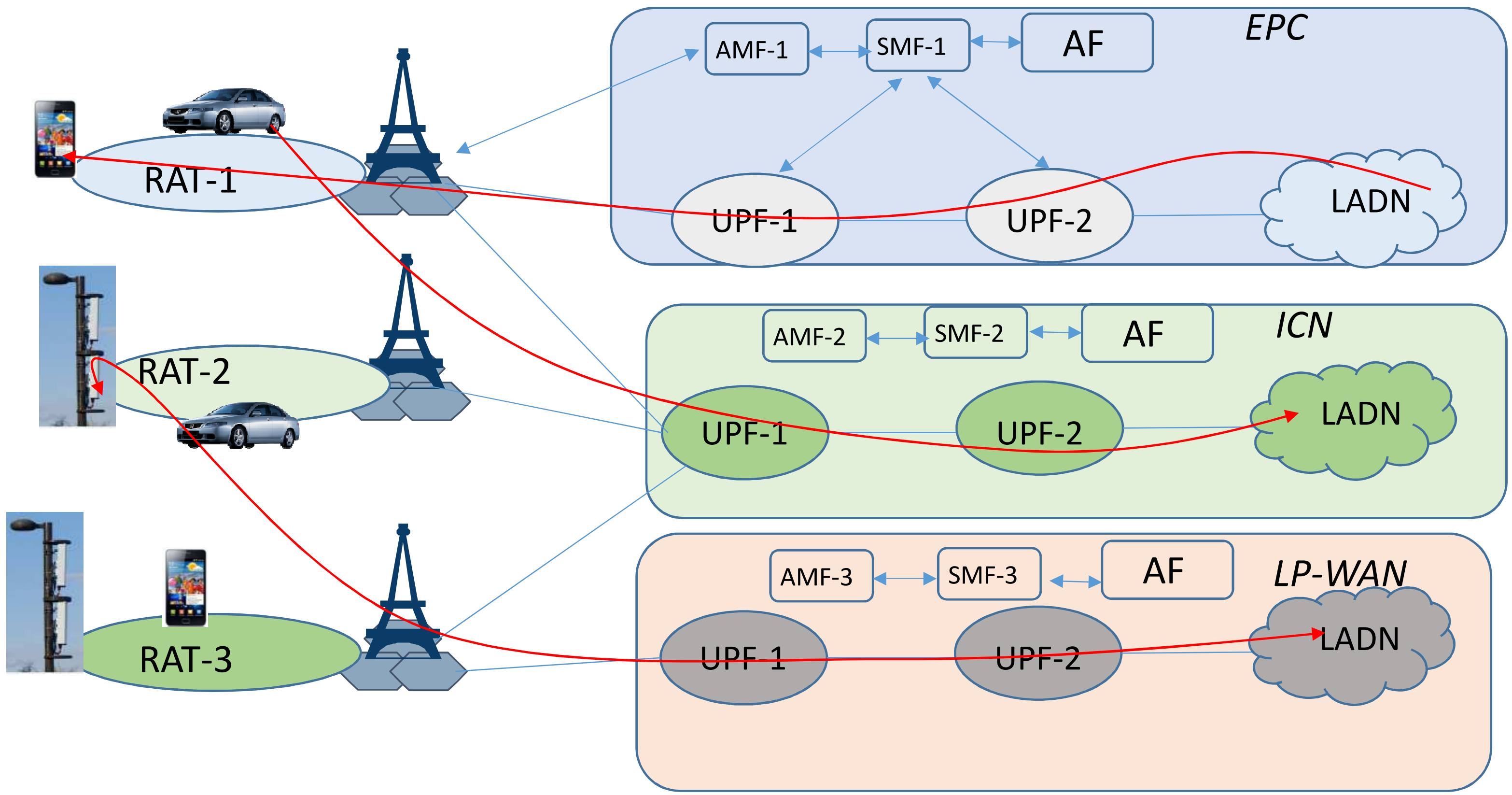
- AMF
  - UE Authentication/Authorization
  - Mobility Management
  - RAN Connection Management
  - Lawful Intercept
  - Relay to SMF signaling
- SMF
  - UPF/AN Session Management
  - IP Address Management
  - Traffic steering
  - Policy Enforcement and QoS
  - Lawful Intercept
  - Mobility Policy (SSC)
  - Roaming between HPLMN and VPLMN
- UPF
  - Mobility Anchor Point Functionality
  - Inter-connect to desired Data Network
  - Packet routing and Forwarding/LI
  - UL-CL/Branching Point
  - QoS/Rate enforcement
  - DL buffering and Data Notification Triggering
- PCF/UDM
  - All used to support UE's subscription, authentication, policy enforcement in the control/user plane
- NEF
  - Exposes Network Capabilities to third party application functions

5GC User Plane Functions

- **5G-NR**
  - The new radio access technology
- **User Plane Function (UPF) can be a**
  - *IP Anchor Function*
    - For Mobility Support
  - *Branching Function*
    - Supports UE Multi-homing
  - *Classifier Function*
    - Supports Edge Computing using Local Area Data Networks (LADN)
- From a Network Slicing perspective these functions can be customized to individual services

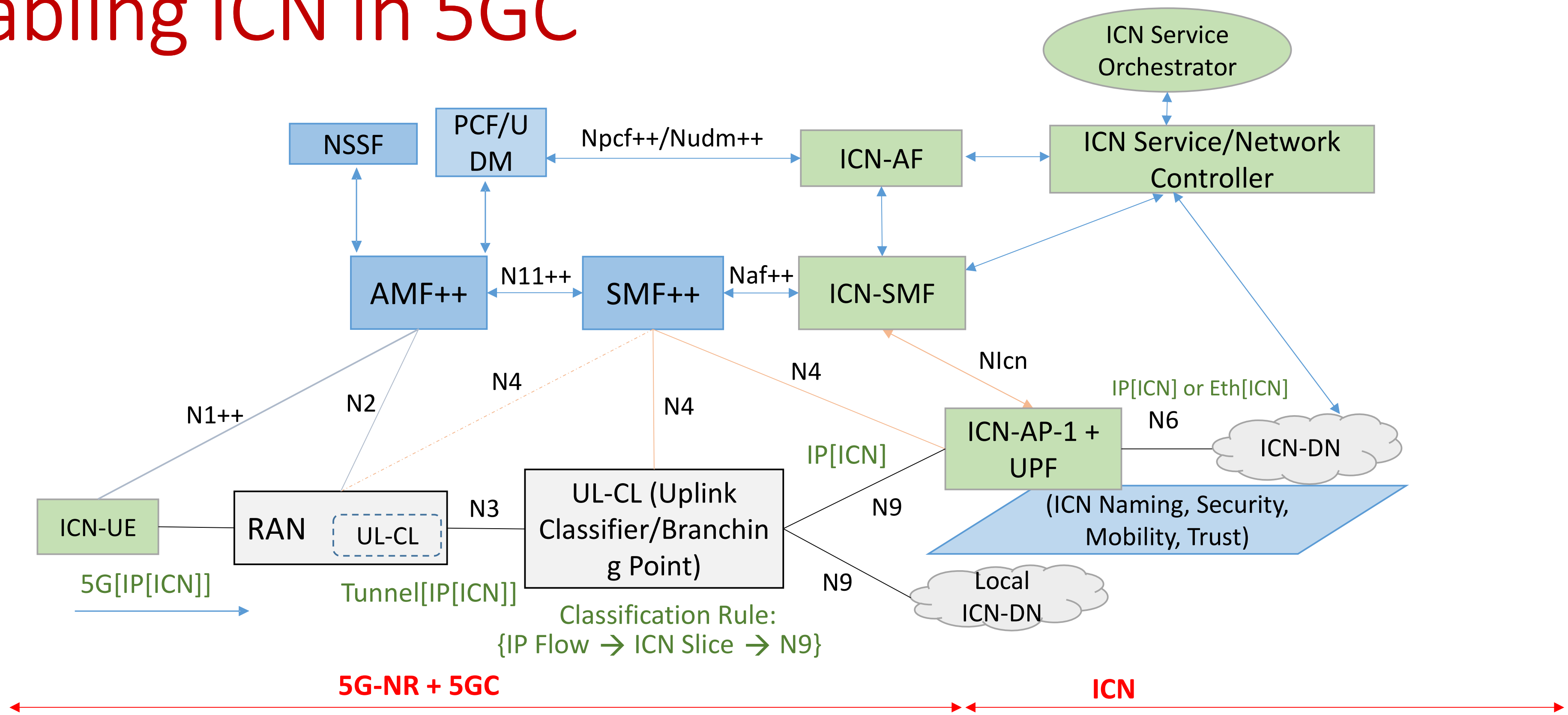
5G Architecture Flexibility

- Allows custom control and user planes for different services.
- Same AMF/SMF can be used among multiple RATs and slices, or dedicated for each slice.



Enabling ICN in 5GC

Enabling ICN in 5GC



- Here we have assumed as the IP transport being used to classify ICN Service flows.
- ICN-SMF handles session management of ICN-AP NF. AMF++/SMF++ enforce functions to allow UE subscription authentication to ICN DN, and provision rules in RAN, UL-CL and other intermediate UPFs to enable UE-ICN to anchor to ICN-AP.
- ICN-AF can push ICN PDU session requirements to PCF/UDM for slice selection or session management functions between the RAN and the ICN-AP

Control Plane Function Extensions

- ICN-UE
  - UE with ICN/IP applications with transport convergence (discussed in [1])
  - ICN Applications can be overlay but 5GC aware, or
  - Can use the Unstructured PDU provision, but standardized for ICN PDU handling, with minimal UPF functionality
- AMF++
  - Extensions to authenticate ICN-UE
  - Extensions to handle UE ICN configuration
    - Functions include Naming, Forwarding, Security and more
- SMF++
  - ICN PDU Session Configuration
  - IP address management to handle ICN flows for overlay deployments
  - UL/CL and UPF configuration to allow ICN-DN interconnection
  - Extensions to handle UE ICN configuration
- ICN-SMF
  - Manages the ICN state in ICN-AP
  - Interfaces with SMF++ for ICN PDU session management

[1] Prakash Suthar et al "Native Deployment of ICN in LTE, 4G Mobile Networks", draft-suthar-icnrg-icn-lte-4g-03 (work in progress), September 2017.

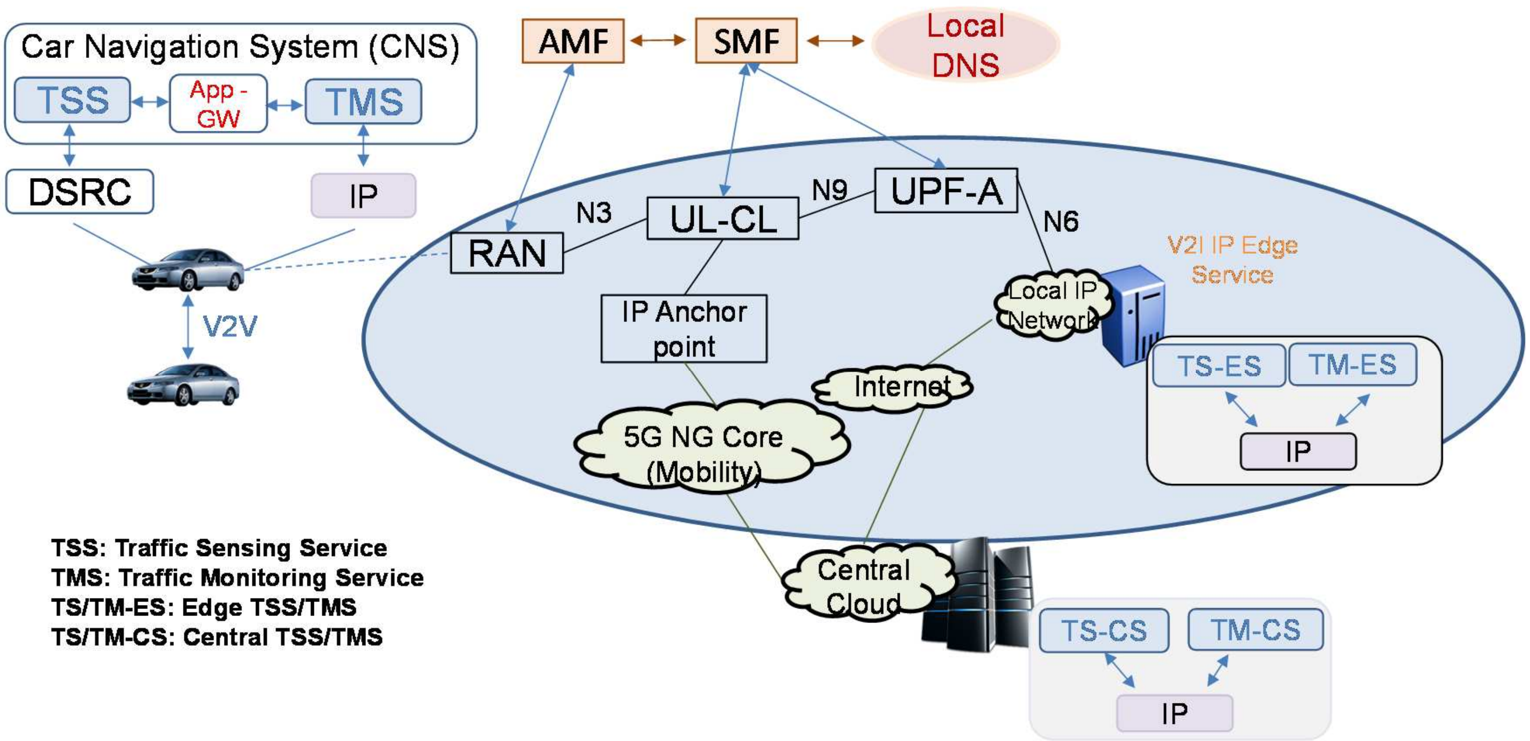
User Plane Function Extensions

- Considering an incremental deployment, 5GC UPF state will exist between the AN and the ICN-DN
  - Deployment could co-locate Cloud RAN/UPF/ICN-AP functions
- UL-CL
  - The ICN PDU session classification and traffic steering to appropriate ICN-DN (Slice aware)
  - Potential extension of ICN features in UL-CL such as caching.
- ICN-AP
  - Integrates UPF function along with ICN stack
  - Mobility state to handle Producer Mobility
  - Maps the FIB to directed the Interest/Data flows to appropriate PDU session
- ICN-DN
  - Is the ICN network that offers several ICN network and application services.

Use Case Scenarios

1. Edge Computing
2. ICN Seamless Mobility

V2V/V2I using IP-MEC

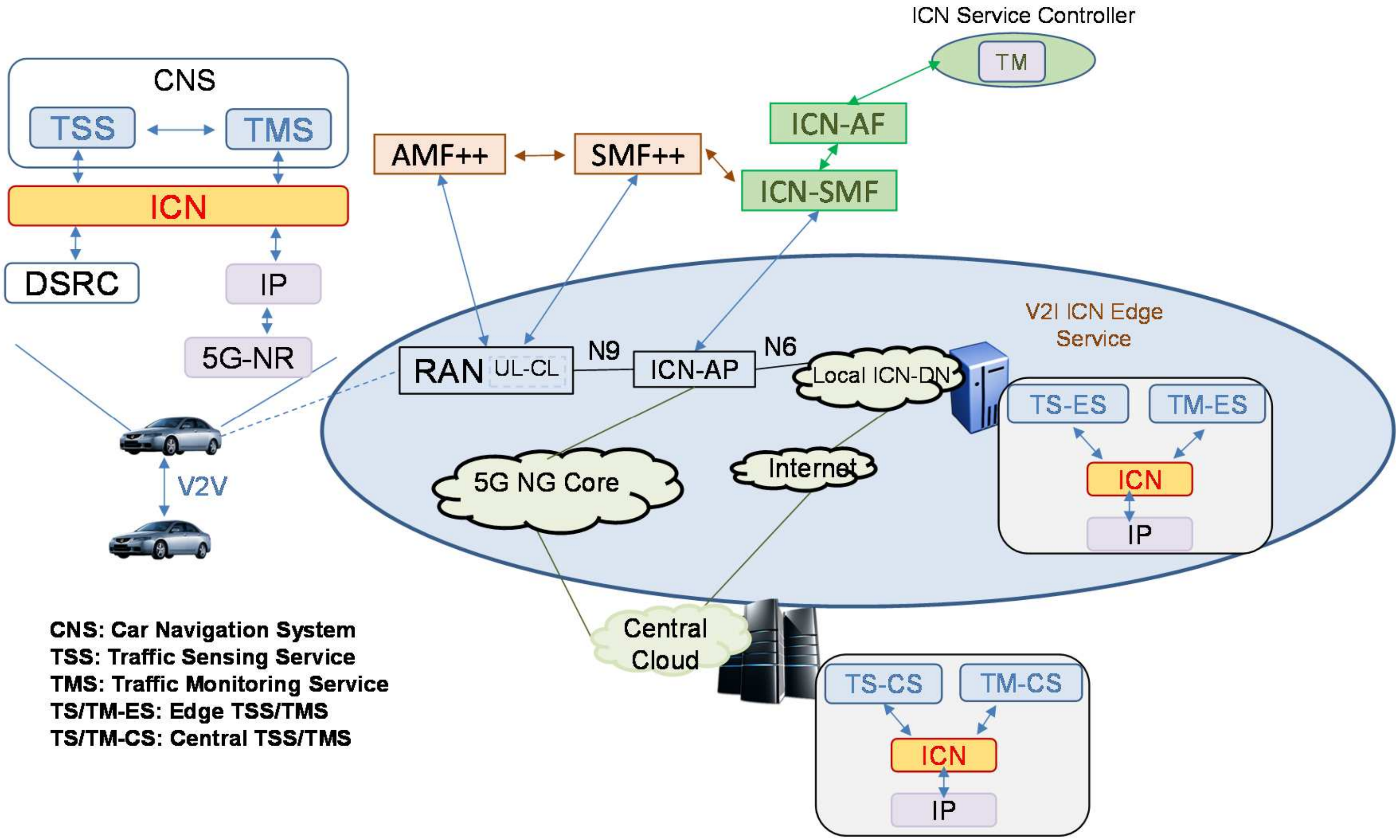


TSS: Traffic Sensing Service
TMS: Traffic Monitoring Service
TS/TM-ES: Edge TSS/TMS
TS/TM-CS: Central TSS/TMS

IP-MEC Challenges

- Need for Application level Adaptation
- Session Mobility handling Challenge when UE or IP of Service Instance changes
- Local DNS involvement for service resolution
- Control plan overhead when ever underlying PDU session is affected.

V2V/V2I using ICN-MEC



ICN-MEC Benefits

- Benefits from Name based networking, applications agrees on naming semantics
- Any PDU session state reset will minimally affect applications
- Mobility can be handled in the ICN layer
- Name based routing allows Name resolution to optimal Service instance

Comparison of IP/MEC and ICN for V2I/I2V

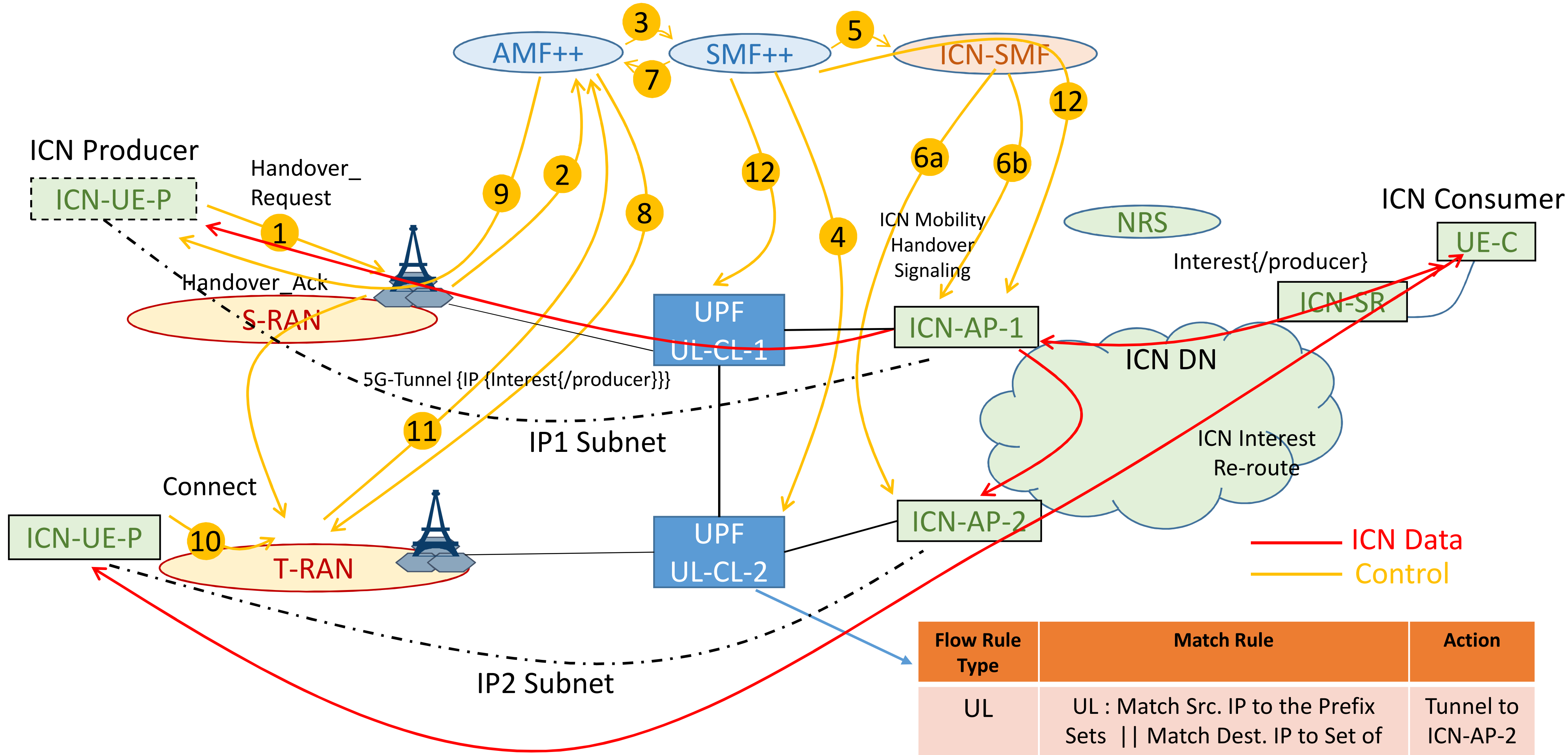
Features	IP/MEC	ICN
Networking Paradigm	• Host-to-Host Communication based on Addresses • Application use Address as Names too • Session Based (TCP/UDP/QUIC..) • Session disruption during mobility or service migration	• Persistent Name Based (Content, Services, Devices) • Session-less (Interest/Data semantics) • Applications oblivious of resource dynamics (mobility, replication etc.)
Adhoc	• Not Capable	• Capable • Suitable for V2V and V2I scenarios
Configuration Requirement	• IP Address Management (Vehicles & MEC Services) • UE still requires an anchor point. • Local Mapping system names to IP mapping (DNS)	• Names can be well known or assigned • Zero Configuration Possible within trusted environments • Depends on Security/Trust requirements
Name Resolution	• Edge Service Discovery • Local/Global DNS • TTL Cache issue using DNS • Latency (multiple RTT) • Virtualization Challenges (Virtual IP to Phyiscal IP mapping)	• Names pre-known to applications • Name Based Routing (Shortest path, no additional RTT) • Unified App/Network Naming (no mapping cost) • Scalability Challenges (but closer to the edge, very less FIB state) • ICN virtualization is only a optional deployment mode, can be native over L2 (5GNR, LTE, etc)
Computing/Caching/Storage	• Possible in the eNodeB • Explicit in-packet signaling or traffic classification for service level indirections • Service level data replication	• In-Network Computing/Caching/Storage anywhere eNodeB, RSUs etc • Explicit service semantics through naming
Mobility	• Challenging with services are at eNodeB Proximity • Anchor based Mobility in L2, has to be moved from SGW to eNodeB. • Still maintains signaling (control+data) to maintain tunnels. • Ensuring seamless session mobility avoiding path stretches is a challenge • Challenges for Low Latency applications	• Application binds to names, ICN resolves names to locations • In-Network Mobility support for both Consumers and Producers
Security	• On the channel, IP as identifiers and SSL/TLS/DTLS based mechanisms	• Name-based and in-network security/trust verifiability • Applications obtain data with explicit name/key binding

ICN Session Mobility

- **ICN in 5GC can enable a flat architecture with in-build mobility**
  - More research is required for Policy, Charging, LI functions
  - Mobility is handled at the ICN-AP
- **Mobility also affects the 5GC state when UL-CL and RAN is involved**.
  - With Co-location, this part of the signaling is localized
- **The situation we assume is an extreme case**
  - Source to Target RAN Transitions (S-RAN to T-RAN)
  - SMF targets a new UL-CL and ICN-AP
  - Signaling is simplified if UL-CL/ICN-AP transition is not assumed.
  - ICN producer mobility technique is orthogonal here, but we assume use of forwarding-labels [1]

[1] Ravi Ravindran et al, "Forwarding-label Support in CCN Protocol", IETF/ICNRG, 2017, https://tools.ietf.org/html/draft-ravi-icnrg-ccn-forwarding-label-01

Handling ICN Session Mobility



Flow Rule Type	Match Rule	Action
UL	UL : Match Src. IP to the Prefix Sets || Match Dest. IP to Set of ICN-UPFs	Tunnel to ICN-AP-2
DL	DL : Destination IP	Tunnel to T-RAN

** These step enumerations map to those in the draft, but not to the ones in the next slide !*

High Level Steps

Initiating Handover

- UE signaling S-RAN with a handover request and the T-RAN it is willing to handover to.
- S-RAN signals the AMF serving the ICN-UE with T-RAN along with affected ICN PDU sessions.
- AMF signals SMF about the mobility for the affected PDU sessions. SMF chooses a new UL-CL and ICN-AP-2 for the new ICN PDU session configuration.

Handle 5GC State

- SMF signals UL-CL-2 and ICN-AP-2 to provision the new ICN PDU session state both for UL and DL, and then signals ICN-SMF.
- ICN-SMF notifies ICN-AP-1 about the handover for the PDU sessions along with the new ICN-AP-2, and the PDU session tunnel provisioned for this PDU sessions.

Make-before-break in ICN-DN

- ICN-AP-1 uses ICN-AP-2's locator-ID to begin forwarding the incoming packets to ICN-AP-2.
- Further ICN-SMF also provisions the forwarding state in the ICN-AP-2 to map the ICN flows to the PDU session tunnel(s).

High Level Steps

Update RAN state and Radio Resource Assignment

- ICN-SMF then acknowledges SMF, which inturn acknowledges AMF with the UL-CL-2 tunnel information.
- AMF then provisions the T-RAN with the PDU session state to forward packets to the UL-CL-2 in the UL and DL.
- AMF then initiates radio resource configuration in T-RAN to serve ICN-UE.

UE Hand-Over to new RAN

- The AMF then acknowledges the ICN-UE to handover to the T-RAN, henceforth the packets can be send and received from UL-CL-2 relaying through ICN-AP-2.

Freeing Previous State

- After successful handover i.e. attachment with T-RAN, AMF/SMF removes the session and resource state from S-RAN/UL-CL-1/ICN-AP-1

Evolving the draft

- More contributors are welcome considering the scope of 5G applications and how ICN can uniquely address them.
- Design choices leveraging 5G architectural flexibility to support ICN
  - How Unstructured PDU support can be used towards ICN
  - Cross layer integration between ICN and 5G-NR can allow more efficiency, e.g. handling dynamic multicast.
- There is a good chance to use it to influence ICN adoption in Rel 16
- More comments…?

Thanks !!