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Enabling ICN in 3GPP's 5G NextGen Core Architecture
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Abstract

The proposed 3GPP's 5G core nextgen architecture (5GC) offers flexibility to introduce new user and control plane function within the context of network slicing that allows greater flexibility to handle heterogeneous devices and applications. In this draft, we provide a short description of the proposed 5GC, followed by extensions to 5GC's control and user plane to support packet data unit (PDU) sessions from information-centric networks. The value of enabling ICN in 5GC is discussed using two service scenarios which include mobile edge computing and support for seamless mobility for ICN sessions.

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1. Introduction

The objective of this draft is to propose an architecture to enable information-centric networking (ICN) in the proposed 5G Next-generation Core network architecture (5GC) by leveraging its flexibility to allow new user and associated control plane functions. The reference architectural discussions in three core 3GPP specifications [TS23.501][TS23.502][TS23.799] form the basis of our discussions. This draft also complements the discussions related to various ICN deployment opportunities explored in [I-D.rahman-icnrg-deployment-guidelines], where 5G technology is considered as one of the promising alternatives.

Though ICN is a general networking technology, it would benefit 5G particularly from the perspective of mobile edge computing (MEC). Following ICN features shall benefit MEC deployments in 5G:

- Edge Computing: Multi-access Edge Computing (MEC) is located at edge of network and aids several latency sensitive applications such as augmented and virtual reality (AR/VR) and ultra reliable and low latency class (URLLC) of applications such as autonomous vehicles. Enabling edge computing over an IP converged 5GC comes with the challenge of application level reconfiguration required to re-initialize a session whenever it is being served by a non-optimal service instance. In contrast, named-based networking, as considered by ICN, naturally supports service-centric networking, which minimizes network related configuration for applications and allows fast resolution for named service instances.

- Edge Storage and Caching : The principal entity for ICN is the secured content (or named-data) object, which allows location independent data replication at strategic storage points in the network, or data dissemination through ICN routers by means of opportunistic caching. These features benefit both realtime and non-realtime applications, where a set of users share the same content, thereby advantageous to both high-bandwidth and/or low-latency applications such as Video-on-Demand (VOD), AR/VR or low bandwidth IoT applications.

- Session Mobility: Existing long-term evolution (LTE) deployments handle session mobility using IP anchor points at Packet Data Network Gateway (PDN-GW) and service anchor point called Access Point Name (APN) functionality hosted in PDN-GW, and uses a tunnel between radio edge (eNodeB) and PDN-GW for each mobile device attached to network. This design fails when service instances are replicated close to radio access network (RAN) instances, requiring new techniques to handle session mobility. In contrast, application-bound identifier and name resolution split principle considered for the ICN is shown to handle host mobility quite efficiently [mas].

To summarize the draft, we first discuss 5GC’s design principals that allows the support of new network architectures. Then we summarily discuss the 5GC proposal, followed by control and user plane extensions required to support ICN PDU sessions. We then discuss specific network services enabled using ICN data networks, specifically MEC and ICN session mobility with aid from 5GC control plane.

2. Terminology

Following are terminologies relevant to this draft:

5G-NextGen Core (5GC) : Refers to the new 5G core network architecture being developed by 3GPP, we specifically refer to the architectural discussions in [TS23.501][TS23.502].

5G-New Radio (5G-NR): This refers to the new radio access interface developed to support 5G wireless interface [TS-5GNR].

User Plane Function (UPF): UPF is the generalized logical data plane function with context of the UE PDU session. UPFs can play many role, such as, being an flow classifier (UL-CL) (defined next), a PDU session anchoring point, or a branching point.

Uplink Classifier (UL-CL): This is a functionality supported by an UPF that aims at diverting traffic (locally) to local data networks based on traffic matching filters applied to the UE traffic.

Packet Data Network (PDN or DN): This refers to service networks that belong to the operator or third party offered as a service to the UE.

Unified Data Management (UDM): Manages unified data management for wireless, wireline and any other types of subscribers for M2M, IOT application etc. UDM report subscriber related vital information e.g. virtual edge region, list of location visits, sessions active etc. UDM work as subscriber anchor point that means OSS/BSS systems will have central monitoring/access of the system to get/ set subscriber information.

Authentication Server Function (AUSF): Provides mechanism for unified authentication for subscribers related to wireless, wireline and any other types of subscribers such as M2M and IOT applications. The functions performed by AUSF are similar to HSS with additional functionalities to related to 5G.

Session Management Function (SMF): Perform session management functions for attached users equipment (UE) in 5G Core. SMF can thus be formed by leveraging the CUPS (discussed in the next section) feature with control plane session management.

Access Mobility Function (AMF): Perform access mobility management for attached user equipment (UE) to the 5G core network. The function includes, network access stratus (NAS) mobility functions such as authentication and authorization.

Application Function (AF): Helps with influencing the user plane routing state in 5GC considering service requirements.

Network Slicing: This conceptualizes the grouping for a set of logical or physical network functions with its own or shared control, data and service plane to meet specific service requirements.

3. 5G NextGen Core Design Principles

The 5GC architecture is based on the following design principles that allow it to support new service networks like ICN efficiently compared to LTE networks:.

- Control and User plane split (CUPS): This design principle moves away from LTE's vertically integrated control/user plane design (i.e., Serving Gateway, S-GW, and Packet Data Network Gateway, P-GW) to one espousing an NFV framework with network functions separated from the hardware for service-centricity, flexibility and programmability. In doing so, network functions can be implemented both physically and virtually, while allowing each to be customized and scaled based on their individual requirements, also allowing the realization of multi-slice co-existence. This feature also allows the introduction of new user plane functions (UPF). UPFs can play many roles, such as, being an uplink flow classifier (UL-CL), a PDU session anchor point, a branching point function, or one based on new network architectures like ICN with new control functions, or re-using/extending the existing ones to manage the new user plane realizations.

- Decoupling of RAT and Core Network : Unlike LTE's unified control plane for access and the core, 5GC offers control plane separation of the RAN from the core network. This allows the introduction of new radio access technologies (RAT) along with slices based on new network architectures, offering the ability to map heterogeneous RAN flows to arbitrary core network slices based on service requirements.

- Non-IP PDU Session Support : A PDU session is defined as the logical connection between the UE and the data network (DN). 5GC offers a scope to support both IP and non-IP PDU (termed as "unstructured" payload), and this feature can potentially allow the support for ICN PDUs by extending or re-using the existing control functions.

- Service Centric Design: 5GC's service orchestration and control functions, such as naming, addressing, registration/authentication and mobility, will utilize cloud based service APIs. Doing so

      enables opening up interfaces for authorized service function
      interaction and creating service level extensions to support new
      network architectures. These APIs include the well accepted Get/
      Response and Pub/Sub approaches, while not precluding the use of
      procedural approach between functional units (where necessary).

4. 5G NextGen Core Architecture

In this section, for brevity purposes, we restrict the discussions to the control and user plane functions relevant to an ICN deployment. More exhaustive discussions on the various architecture functions, such as registration, connection and subscription management, can be found in[TS23.501][TS23.502].

```
                                   +---------+              +---------+
                        +---------+ | PCF/UDM |    +-------+ |  AF-2  |
                        | NSSF   | |         |    | AF-1 | +-----+--+
                        +---+----+ +-----+---+    +--+---+       |
                            |            |            |        +--+--------+
                        +---+------------+-+   +-----+------+ |           |
                        |                  |N11|            | |   SMF-2   |
                        |     AMF          +---+   SMF-1    | |           |
                        |                  |   |            | +---------+-+
                        +--------+-+-------+   +----+-------+           |
                                 | |                |--------------------------
--------+
             +------------------+ |                |                   |N4
        |N4
           N1 |                   |N2               |N4                 |      +
--------+-----------+
             |                    |                 |                +---------+
        UPF          | N6 +------+
+-------------+-+      +----------+------+     +---+-----------+    |  |      |
(PDU Session Anchor)+----+  DN  |
|             |       |                 |     |               | N9 |  |      |
                    |   |      |
|     UE      |       |      RAN        | N3  |    UL-CL      +----+  |      +
--------------------+    +------+
|             +-------+                 +-----+               |       |
|             |       |                 |     |               +----+  +-------
----------+
+---------------+      +-----------------+     +---------------+ N9 |
          |
                                                                    |         +
----------+---------+
                                                                    +---------+
                    |    +--------+
                                                                              |
        UPF         | N6 |  DN    |
                                                                              |
(PDU Session Anchor)+----+        |
                                                                              |
                    |    +--------+
                                                                              +
--------------------+
```

Figure 1: 5G Next Generation Core Architecture

In Figure 1, we show one variant of a 5GC architecture from [TS23.501], for which the functions of UPF’s branching point and PDU

session anchoring are used to support inter-connection between a UE and the related service or packet data networks (or PDNs) managed by the signaling interactions with control plane functions. In 5GC, control plane functions can be categorized as follows:

- o Common control plane functions that are common to all slices and which include the Authentication and Mobility Function (AMF), Network Slice and Selection Function (NSSF), Policy Control Function (PCF), and Unified Data Management (UDM) among others.

- o Shared or slice specific control functions, which include the Session and Management Function (SMF) and the Application Function (AF).

AMF serves multiple purposes: (i) device authentication and authorization; (ii) security and integrity protection to non-access stratum (NAS) signaling; (iii) tracking UE registration in the operator’s network and mobility management functions as the UE moves among different RANs, each of which might be using different radio access technologies (RAT).

NSSF handles the selection of a particular slice for the PDU session request from the user entity (UE) using the Network Slice Selection Assistance Information (NSSAI) parameters provided by the UE and the configured user subscription policies in PCF and UDM functions. Compared to LTE’s evolved packet core (EPC), where PDU session states in RAN and core are synchronized with respect to management, 5GC decouples this using NSSF by allowing PDU sessions to be defined prior to a PDU session request by a UE (for other differences see [lteversus5g]). This de-coupling allows policy based inter-connection of RAN flows with slices provisioned in the core network.

SMF handles session management functions including IP address assignment functionality, policy and service capabilities. Furthermore, it manages the data plane state in the user plane through PDU session establishment, modification and termination, and management of RAN (through the AMF) and UPF states related to a particular service or slice.

In the data plane, UE’s PDUs are sent to the RAN using the 5G RAN protocol [TS-5GNR]. From the RAN, the PDU’s five tuple header information (IP source/destination, port, protocol etc.) is used to map the flow to an appropriate tunnel from RAN to UPF. The UPF in this case also offers flexibility as a flow classifier and a branching point interconnecting PDUs from diverse services (within UEs) to their respective DNs. Though [TS23.501] follows LTE on using GTP tunnel from NR to the UPF to carry data PDU and another one for the control messages to serve the control plane functions; there are ongoing discussions to arrive upon efficient alternatives to GTP.

5. 5GC Architecture with ICN Support

In this section, we focus on control and user plane enhancements required to enable ICN within 5GC, and identify the interfaces that require extensions to support ICN PDU sessions. Explicit support for ICN PDU sessions within access and 5GC networks will enable applications to leverage the core ICN features while offering it as a service to 5G users.

```
                                                               +------------+
                                                               |     5G     |
                                                               | Services   |
                                                               |   (NEF)    |

      +----------------+                                       +-------+----+

      |      ICN       |
                                                                       |   +----
------+    Service     |
                                                                       |   |
      |  Orchestrator  |
                                                                       |   |
      +-----------+----++
               +--------+  +----------+          Npcf++/Nudm++          ++------+
                  |
               | NSSF   |  | PCF/UDM +----------------------------------+ ICN-AF|
                  |
               +----+--+  |          |                                  |       |
              +---+---------------+
                    |     +--+-------+                                  +---+---+
              |       ICN         |
                    |        |                                              |
       +------+  Service/Network |
                 +-+--------+--+           +----------------+      +------+-----
--+    |      |    Controller    |
                 |            |   N11++    |               |Naf++ |
  +----+      +------------+-----+
                 |   AMF++     +------------+   SMF++       +-------+    ICN-SMF
  |                          |
                 |            |            |               |      |
  |                          |
                 +-------+-+-----+           +----+-----+----+      +------------
+-+                          |
                        | |                            |
| NIcn                       |
       +-----------------+ |                            |
+----------+                 |
       |                     |                            |
          |                  |
       |                     +------+                N4 |
          |                  |
  N1++ |                            |                     |
          |                  |
       |                            | N2                  |                  +-
-----------+-+       +----+-----+
       |                            |                     |          +-----------+
             |        |          |
       |                            |                     |          |   N9      |
  ICN-AP     +---------+  ICN-DN   |
       |                            |                +-----+-----+    |           |
  + UPF      |    N6    |          |
+------+--+            +---------+--+                |           |    |           +-
--+----------+         +----------+
|         |            |RAN         |                |  UL-CL/  +-----+
| ICN-UE  +-------------+           +------------+ Branching |
|         |            |  +-------+ |     N3      |   Point   +-----+           +
------------+
+---------+            |  | UL-CL | |                +-----------+    |           |
  Local     |
                       |  +-------+ |                                |    N9     |
  ICN-DN    |
                       +------------+                                +-----------+
            |
```

+

------------+

Figure 2: 5G Next Generation Core Architecture with ICN support

For an ICN-enabled 5GC network, the assumption is that the UE may have applications that can run over ICN or IP, for instance, UE's operating system offering applications to operate over ICN [Jacobson] or IP-based networking sockets. There may also be cases where UE is exclusively based on ICN. In either case, we identify an ICN enabled UE as ICN-UE. Different options exist to implement ICN in UE as described in [I-D.suthar-icnrg-icn-lte-4g] which is also applicable for 5G UE to enable formal ICN session handling, such as, using a transport convergence layer above 5G-NR, through IP address assignment from 5GC or using 5GC provision of using unstructured PDU session mode during the PDU session establishment process. 5G UE can also be non-mobile devices or an IOT device using radio specification which can operate based on [TS-5GNR].

5GC will take advantage of network slicing function to instantiate heterogeneous slices, the same framework can be extended to create ICN slices as well [Ravindran]. This discussion also borrows ideas from[TS23.799], which offers a wide range of architectural discussions and proposals on enabling slices and managing multiple PDU sessions with local networks (with MEC) and its associated architectural support (in the service, control and data planes) and procedures within the context of 5GC.

Figure 2 shows the proposed ICN-enabled 5GC architecture. In the figure, new/modified functional components are identified to interconnect an ICN-DN with 5GC. The interfaces and functions that require extensions to enable ICN as a service in 5GC can be identified in the figure with a '++' symbol. We next summarize the control, user plane and normative interface extensions that help with the formal ICN support.

5.1. Control Plane Extensions

To support interconnection between ICN UEs and the appropriate ICN DN instances, we require five additional control plane extensions, which are discussed as follows.

- o Authentication and Mobility Function (AMF++) : Applications in the UEs have to be authorized to access ICN DNs. For this purpose, as in[TS23.501], operator enables ICN as a service-DN to support ICN PDU session flows. As a network service, ICN-UE should also be subscribed to it and this is imposed using the PCF and User Data and Management (UDM) functions, which may interface with the ICN Application Function (ICN-AF) for policy management of ICN PDU sessions. Hence, if the UE policy profile in the UDM doesn't enable this feature, then the ICN applications in the UE will not be allowed to connect to ICN DNs. To enable ICN stack in the UE, AMF function has to be modified to understand ICN type UE registration request and handle authentication and registration requests. AMF++ will support ICN specific bootstrapping and forwarding functions (such as naming and security) to configure UE's ICN applications. With appropriate enhancements, it should also support forwarding rules for the name prefixes that bind the flows to appropriate 5G-NR logical tunnel or slice interfaces. These functions can also be handled by the ICN-AF after setting

PDU session state in 5GC. Here, we are not recommending modification of 5G UE attach procedures but use existing attach procedures messages to carry ICN capabilities extensions in addition to supporting existing IP based services. 5G UE can request authentication for attaching to 5GC either in ICN, IP or dual-stack (IP and ICN) modes.

- o Session Management Function (SMF++) : Once a UE is authenticated to access ICN service in network, SMF manages to connect UE's ICN PDU sessions to the ICN DN. SMF++ capabilities should be able to manage both IP, ICN or dual stack UE with IP and ICN capabilities. SMF++ creates appropriate PDU session policies in the UPF, which include UL-CL and ICN anchor point (ICN-AP). For centrally delivered services, ICN-AP could also be an IP anchor point for IP applications. If MEC is enabled, these two functions would be distributed, as the UL-CL will re-route the flow to a local ICN-DN. SMF++ interfaces with AMF over N11++ to enable ICN specific user plane function, which includes IP address configuration and associated traffic filter policy to inter-connect UE with the appropriate radio slice. Furthermore, AMF++ sets appropriate state in the RAN that directs ICN flows to chosen ICN UL-CL.

- o ICN Session Management Function (ICN-SMF) : ICN-SMF serves as control plane for the ICN state managed in ICN-AP. This function interacts with SMF++ to obtain and also push ICN PDU session management information for the creation, modification and deletion of ICN PDU sessions in ICN-AP. For instance, when new ICN slices are provisioned by the ICN service orchestrator, ICN-SMF requests a new PDU session to the SMF++ that extends to the RAN and UE. While SMF++ manages the tunnels to interconnect ICN-AP to UL-CL, ICN-SMF creates the appropriate forwarding state in ICN (using the forwarding information base or FIB) to enable ICN flows over appropriate tunnel interfaces managed by the SMF++.

- o ICN Application Function (ICN-AF) : ICN-AF represents the application controller function that interfaces with ICN-SMF and user data management (UDM) function in 5GC. In addition to transferring ICN forwarding rules to ICN-SMF, ICN-AF also interfaces with UDM to transfer user profile and subscription policies required to map UE's ICN PDU session request to an appropriate ICN slice through NSSF. ICN-AF is an extension of the ICN service orchestration function, which can influence both ICN-SMF and UPF to steer traffic based on UE (or changing service) requirements. ICN-AP can also interact with the northbound 5G operator's service functions, such as network exposure function (NEF) that exposes network capabilities, for e.g. location based services, that can be used by ICN-AF for proactive ICN PDU session and slice management and offer additional capabilities to UE.

5.1.1. Normative Interface Extensions

- N1++/N11++: This extension enables ICN specific control extensions to support ICN programmability at the UE via AMF++, and also impose QoS requirements to ICN PDU session in 5GC based on service requirements.

- NIcn: This extension shall support two functions: (i) control plane programmability to enable ICN PDU sessions applicable to 5GC to map to name based forwarding rules in ICN-AP; (ii)control plane extensions to enable ICN mobility anchoring at ICN-AP, in which case it also acts as POA for ICN flows. Features such as ICN mobility as a service can be supported with this extension [mas].

- Naf++: This extensions shall support 5GC control functions such as (i.e. naming, addressing, registration/authentication and mobility) for ICN UE and PDU sessions respectively with interaction with the PCF and UDM functions. The PCF and UDM functions interacts with ICN-AF function for service or slice specific configuration.

- Npcf++/Nudm++: This extension creates an interface to push ICN PDU session requirement to PCF and UDM functions, which is enforced during ICN application registration, authentication, during ICN slice mapping, and provisioning of resources for these PDU sessions in the UPFs.

5.2. User Plane Extensions

As explained in detail in [TS23.501], UPFs are service agnostic functions, hence extensions are not required to operate an ICN-DN. The inter-connection of UE to ICN-DN comprises of two segments, one from RAN to UL-CL and the other from UL-CL to ICN-AP. These segments use IP tunneling constructs, where the service semantic check at UL-CL and ICN-AP is performed using IP’s five tuples to determine both UL and DL tunnel mappings. We summarize the relevant UPFs and the interfaces for handling ICN PDU sessions as follows.

- ICN Anchor Point (ICN-AP): ICN-AP shall host the 5GC PDU sessions and offer inter-connection to the ICN-DNs. It manages multiple logical interfaces with ICN capable UE and relays ICN packets to the appropriate ICN PDU session instances in the DL. ICN-AP shall be logical service anchor point and it should be capable of serving different ICN services. ICN-AP also manages the mobility state of ICN-UE after session is established such as in the case of handover or roaming.

- ICN Packet Data Network (ICN-(P)DN) : ICN-DN represents a set of ICN nodes used for ICN networking and with heterogeneous service resources such as storage and computing points. An ICN network enables both network and application services, with network services including caching, mobility, multicast, multi-path routing (and possibly network layer computing), and application services including network resources (such as cache, storage, network state resources) dedicated to the application. This UPF requires service, control and data plane mechanisms to understand the application requirements and translate them to control signaling to provision the required state in the data plane.

- Uplink Classifier (UL-CL) :UL-CL enables classification of flows based on source or destination IP address and steers the traffic to an appropriate network or service function anchor point. Within the current context, with the assumption that ICN-AP is identified based on service IP address associated with the UE's flows, UL-CL checks the source or destination address to direct traffic to an appropriate ICN-AP. As UL-CL is a logical function, it can also reside in RAN, as shown in Figure 2, where traffic classification rules can be applied to forward the ICN payload towards the next ICN-AP, as an extension classification can also be performed over 5G-NR or ICN protocol to determine the next logical hop. For native ICN UE, ICN shall be deployed on layer-2 MAC, hence there may not be any IP association; for such packet flow, new classification schema shall be required.

5.2.1. Normative Interface Extensions

- N3: Though the current architecture supports heterogeneous service PDU handling, future extensions can include user plane interface extensions to offer explicit support to ICN PDU session traffic, for instance, an incremental caching and computing function in RAN or UL-CL to aid with content distribution.

- N9: Extensions to this interface can consider UPFs to enable richer service functions, for instance to aid context processing. In addition extensions to enable ICN specific encapsulation to piggyback ICN specific attributes such as traffic characteristics between the UPF branching point and the ICN-AP. The intermediate nodes between the UL-CL and the ICN-AP can also be other caching points.

- N6: This interface is established between the ICN-AP and the ICN-DN, whose networking elements in this segment can be deployed as an overlay or as a native Layer-3 network.

6. ICN Deployement Use Case Scenarios

Here we discuss two relevant network services enabled using ICN in 5G.

6.1. Mobile Edge Computing

We consider here a radio edge service requiring low latency, high capacity and strict quality of service. For the discussion in this draft, we analyze connected vehicle scenario, where the car's navigation system (CNS) uses data from the edge traffic monitoring (TM-E) service instance to offer rich and critical insights on the road conditions (such as real-time congestion assisted with media feeds). This is aided using traffic sensing (TS) information collected through vehicle-to-vehicle (V2V) communication over dedicated short-range communications (DSRC) radio by the TS-E, or using road-side sensor units (RSU) from which this information can be obtained. The TS-E instances then push this information to a central traffic sensing instance (TS-C). This information is used by the central traffic monitoring service (TM-C) to generate useable navigation information, which can then be periodically pushed to or pulled by the edge traffic monitoring service (TM-E) to respond to requests from vehicle's CNS. For this scenario, our objective is to compare advantages of offering this service over an IP based MEC versus one based on ICN. We can generalize the following discussion to other MEC applications as well.

6.1.1. IP-MEC Scenario

Considering the above scenario, when a vehicle's networking system comes online, it first undergoes an attachment process with the 5G-RAN, which includes authentication, IP address assignment and DNS discovery. The attachment process is followed by PDU session establishment, which is managed by SMF signaling to UL-CL and the UPF instance. When the CNS application initializes, it assumes this IP address as its own ID and tries to discover the closest service instance. Local DNS then resolves the service name to a local MEC service instance. Accordingly, CNS learns the IP service point address and uses that to coordinate between traffic sensing and monitoring applications.

CNS is a mission critical application requiring instant actions which is accurate and reliable all the time. Delay of microsecond or non-response could result in fatalities. Following are main challenges with the IP-MEC design:

- o At the CNS level, non-standardization of the naming schema results in introducing an application level gateway to adapt the sensing data obtained from DSRC system to IP networks, which becomes mandatory if the applications are from different vendors.

- As the mobility results in handover between RAN instances, service-level or 5GC networking-level mechanisms need to be initiated to discover a better TM-E instance, which may affect the service continuity and result in session reestablishment that introduces additional control/user plane overheads.

- Data confidentiality among multiple CNS attached 5G RAN, authentication and privacy control are offered through an SSL/TLS mechanism over the transport channel, which has to be re-established whenever the network layer attributes are reset.

6.1.2. ICN-MEC Scenario

If the CNS application is developed over ICN either natively or as an overlay over IP, ICN shall allows the same named data logic to operate over heterogeneous interfaces (such as DSRC radio, and IP transport-over-5G, unlicensed radio over WiFi etc. link), thereby avoiding the need for application layer adaptations.

We can list the advantages of using ICN-based MEC as follows:

- As vehicles within a single road segment are likely to seek the same data, ICN-based MEC allows to leverage opportunistic caching and storage enabled at ICN-AP, thereby avoiding service level unicast transmissions.

- Processed and stored traffic data can be easily contextualized to different user requirements.

- Appropriate mobility handling functions can be used depending on mobility type (as consumer or producer), specifically, when an ICN-UE moves from one RAN instance to another, the next IP hop, which identifies the ICN-AP function, has to be re-discovered. Unlike the IP-MEC scenario, this association is not exposed to the applications. As discussed earlier, control plane extensions to AMF and SMF can enable re-programmability of the ICN layer in the vehicle to direct it towards a new ICN-AP, or to remain with the same ICN-AP, based on optimization requirements.

- As ICN offers content-based security, produced content can be consumed while authenticating it at the same time (i.e., allowing any data produced to diffuse to its point of use through named data networking).

6.2. ICN Session Mobility

Mobility scenario assumes a general ICN-UE handover from S-RAN to T-RAN, where each of them is served by different UPFs, i.e., UL-CL-1 and UL-CL-2. We also assume that UL-CL-1 and UL-CL-2 use different ICN-APs as gateways, referred to as ICN-AP-1 and ICN-AP-2. From an ICN perspective, we discuss here the producer mobility case, which can be handled in multiple ways, one of which is proposed in [mas].However, the details of the ICN mobility solution are orthogonal to this discussion. Here, ICN-UE refers to an application producer (e.g., video conferencing application, from which ICN consumers request real-time content. Here we also assume the absence of any direct physical interface, Xn, between the two RANs. The current scenario follows the handover procedures discussed in [TS23.502], with focus here on integrating it with an ICN-AP and ICN-DN, where mobility state of the ICN sessions are handled.

The overall signaling overhead to handle seamless mobility also depends on the deployment models discussed in Section 4. Here we consider the case when RAN, UL-CL and ICN-AP are physically disjoint; however in the case where RAN and UL-CL are co-located then a part of the signaling to manage the tunnel state between the RAN and UL-CL is localized, which then improves the overall signaling efficiency. This can be further extended to the case when ICN-APs are co-located with the RAN and UL-CL, leading to further simplification of the mobility signaling.

Next, we discuss the high-level steps involved during handover.

- Step 1: When the ICN-UE decides to handover from S-RAN to T-RAN, ICN-UE signals the S-RAN with a handover-request indicating the new T-RAN it is willing to connect. This message includes the affected PDU session IDs from the 5GC perspective, along with the ICN names that require mobility support.

- Step 2: S-RAN then signals the AMF serving the ICN-UE about the handover request. The request includes the T-RAN details, along with the affected ICN PDU sessions.

- Step 3: Here, when SMF receives the ICN-UE’s and the T-RAN information, it identifies UL-CL-2 as the better candidate to handle the ICN PDU sessions to T-RAN. In addition, it also identifies ICN-AP-2 as the appropriate gateway for the affected ICN PDU sessions.

- Step 4: SMF signals the details of the affected PDU sessions along with the traffic filter rules to switch the UL traffic from UL-CL-2 to ICN-AP-2 and DL flows from UL-CL-2 to T-RAN.

- o Step 5: SMF then signals ICN-SMF about the PDU session mobility change along with the information on UL-CL-2 for it to provision the tunnel between ICN-AP-2 and UL-CL-2.

- o Step 6: Based on the signaling received on the ICN PDU session, ICN-SMF identifies the affected gateways, i.e., ICN-AP-1 and ICN-AP-2: (i) ICN-SMF signals ICN-AP-2 about the affected PDU session information to update its DL tunnel information to UL-CL-2. Then, based on the ICN mobility solution, appropriate ICN mobility state to switch the future incoming Interests from ICN-AP-1 to UL-CL-2; (ii) ICN-SMF also signals ICN-AP-1 with the new forwarding label[mas] to forward the incoming Interest traffic to ICN-AP-2. This immediately causes the new Interest payload for the ICN-UE to be send to the new ICN gateway in a proactive manner.

- o Step 7: ICN-SMF then acknowledges SMF about the successful mobility update. Upon this, the SMF then acknowledges AMF about the state changes related to mobility request along with the tunnel information that is required to inter-connect T-RAN with UL-CL-2.

- o Step 8: AMF then updates the T-RAN PDU session state in order to tunnel ICN-UE’s PDU sessions from T-RAN to UL-CL-2. This is followed by initiating the RAN resource management functions to reserve appropriate resources to handle the new PDU session traffic from the ICN-UE.

- o Step 9: AMF then signals the handover-ack message to the UE, signaling it to handover to the T-RAN.

- o Step 10: UE then issues a handover-confirm message to T-RAN. At this point, all the states along the new path comprising the T-RAN, UL-CL-2 and ICN-AP-2 is set to handle UL-DL traffic between the ICN-UE and the ICN-DN.

- o Step 11: T-RAN then signals the AMF on its successful connection to the ICN-UE. AMF then signals S-RAN to remove the allocated resources to the PDU session from the RAN and the tunnel state between S-RAN and UL-CL-1.

- o Step 12: AMF then signals SMF about the successful handover, upon which SMF removes the tunnel states from UL-CL-1. SMF then signals the ICN-SMF, which then removes the ICN mobility state related to the PDU session from ICN-AP-1. Also at this point, ICN-SMF can signal the ICN-NRS (directly or through ICN-AP-2) to update the UE-ID resolution information, which now points to ICN-AP-2 [mas].

Note that, inter-RAN handover mapping to the same UL-CL represents a special case of the above scenario.

7. Conclusion

In this draft, we explore the feasibility of realizing future networking architectures like ICN within the proposed 3GPP's 5GC architecture. Towards this, we summarized the design principles that offer 5GC the flexibility to enable new network architectures. We then discuss 5GC architecture along with the user/control plane extensions required to handle ICN PDU sessions formally. We then apply the proposed architecture to two relevant services that ICN networks can enable: first, mobile edge computing over ICN versus the traditional IP approach considering a connected car scenario, and argue based on architectural benefits; second, handling ICN PDU session mobility in ICN-DN rather than using IP anchor points, with minimal support from 5GC.

8. IANA Considerations

This document requests no IANA actions.

9. Security Considerations

This draft proposes extensions to support ICN in 5G's next generation core architecture. ICN being name based networking opens up new security and privacy considerations which have to be studied in the context of 5GC. This is in addition to other security considerations of 5GC for IP or non-IP based services considered in [TS33.899].

10. Acknowledgments

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