Towards building ICN network Slice in mobile networks

Context:

Knowing the variety of services and applications that should be supported in the upcoming 5G systems, the current "one fits all" network architecture is no more efficient. Indeed, each 5G service may require different needs in terms of latency, bandwidth and reliability; which cannot be sustained by the same network infrastructure. In this context, network virtualization represents a viable way to provide a Network Slice tailored to each service. Several 5G initiatives (from industry and academia) have been pushing for solutions to enable Network Slicing in mobile networks, mainly based on Software Defined Networking (SDN), Network Function Virtualization (NFV) and cloud computing as key enablers.

Meanwhile, Information Centric Networking (ICN) aims at enriching network-layer functions with content awareness, hence routing, forwarding, caching and data-transfer operations are performed on topology-independent content names rather than on IP addresses. Data is divided into a sequence of chunks uniquely identified by a name and permanently stored in one or more servers. Naming data chunks allows the ICN network to directly interpret and treat content per its semantics without the need for deep packet inspection (DPI) or delegation to the application layer. 5G systems may take advantage of using ICN in several areas:

- Internet of Things (IoT): Sensor devices can translate directly to ICN URIs, and the use of caches at the ICN forwarders can remove duplicate data.
- Media distribution: with its inherent ability to cache data, ICN will naturally improve performances of media distribution for mobile network and users. Particularly, current trend toward edge computing ease the deployment of ICN in mobile networks.

Even though ICN promises improving mobile performances, its deployment in 3GPP-based LTE and beyond mobile networks is still challenging. So far, two ways to have ICN running in mobile networks exist: (i) add ICN as a 3GPP service using a dedicated Packet Data Network (PDN) – Access Point (AP); meaning that a ICN-based service is assigned a dedicated bearer; (ii) run ICN as an overlay network. Both solutions are not optimal and complex to deply. Recent published work, in [1], highlights different possibilities to integrate ICN in 5G. However, the proposed solutions are too generic and do not include any detailed specifications. It is only about concepts.

Challenges

In this thesis, we envision to enable ICN in mobile network by using the concept of Network Slicing. As mentioned earlier, Network Slicing is intended to run its own control plane and data plane functions in an isolated environment. Therefore, ICN slices could be deployed, as a Network Slice, where the required modifications are related to the core network functions. Indeed, the modification of the control plane as well as the data plane should be envisioned.

During this thesis, we want to go beyond the state of the art, to integrate ICN mobile networks, via the concept of Network Slicing. Hence, the following challenges should be addressed:

- Instantiate and build an end-to-end ICN Slice

To address this challenge, there is a need to study service orchestration solutions used in cloud computing. Obviously, these solutions have to be adapted to the ICN specific,

particularly the fact that an ICN slice is composed by ICN routers/switches and ICN-capable User Equipment (UE), running a specific data and control planes. Therefore, the template describing the ICN slice should be carefully designed, where techniques based on Topology and Orchestration Specification for Cloud Application (TOSCA) [2] will be investigated to define ICN network slice.

- Programmable data plane to enable ICN Network Slice

To tackle this challenge, we may rely on the recent findings in control plane as well as data plane programmability. While SDN and Openflow represent the widely-used solutions to manage control plane, p4 language is a promising solution to deeply program the data plane. Recent work has issued an early version of p4-based ICN switch [3], which demonstrates the data plane programmability of ICN. However, there is a need to enrich this model by using more dynamic ICN cache management, for example, derive a Southbound API to manage ICN content and modify the p4 switches.

- Integrate the ICN control and date planes with eNodeB and UE?

To address this question, it is important to study the different possibilities to integrate the ICN control plane; for example, does the eNodeB should integrate the ICN data plane, or it should encapsulate ICN data and control planes into GPRS Tunneling Protocol (GTP) tunnels. Ultimately, we can rely on our Network Slicing system done in [4], to integrate ICN slicing in mobile networks.

- Algorithms to manage ICN VNF instance within a Slice

This challenge is related to the placement of ICN VNF (Caching) in the network. Indeed, since a Network Slice is a virtual network, it needs storage, network and CPU resources, which should be provisioned by the network operator. Therefore, according to the ICN Slice type (IoT or video streaming), the needed number of caches and their location in the network, including cloud and edge cloud, is different. Indeed, the optimal placement and ICN slice composition (in terms of VNF), may depend on different criteria, such as cost, QoS, QoE, etc. Accordingly, to address this issue, there is a need to study different multi-criteria optimization techniques, using algorithms using optimization theory or game theory to find the optimal number of ICN caches as well as their location, having as inputs the traffic type, number of users, etc.

- Inter ICN slices management

This challenge is related to the scalability of the system. Indeed, running several parallel slices may impact the overall system performances, in term of QoS. Therefore, inter-slice management solution, which consist in control admission algorithms or smart management mechanisms are needed. For the latter, we may mention solutions that identify common ICN functions among different slices, in order to share resources and ensure scalability.

Organization

During this thesis we envision two main phases. The first phase will be dedicated to related work and providing a detailed survey on Network Slicing, SDN, NFV, ICN; particularly focusing on how ICN is envisioned in mobile network (in 5G and beyond). The second phase will consist in devising algorithms and mechanisms to address the above-cited challenges. The PhD program starts by defining the need of ICN network slice in term of control plane and data plane functions. Then, novel algorithms to deploy and manage an ICN slice over a mobile network architecture should be devised, focusing on the above-mentioned challenges. The proposed solutions should be first evaluated using computer simulation or

analytical model, then a proof of concept is envisioned to demonstrate these concepts, using OpenAirInterface (OAI) and network virtualization tools available at Eurecom.

Contact:
Prof. Adlen Ksentini, adlen.ksentini@eurecom.fr

References
[1] R. Ravindran et al. “5G-ICN: Delivering ICN Services over 5G using Network Slicing”, arXiv:1610.01182
[2] TOSCA, http://www.oasis-open.org/
[3] S. Signorello et al. “NDN.p4: Programming Information-Centric Data-Planes”, in Proc. of IEEE NetSoft 2016, Seoul, Korea.
[4] A. Ksentini et al. “Towards enforcing Network Slicing on RAN: Flexibility and Resources abstraction”, to appear in IEEE Communications Magazine, SI on 5G Agile Radio Networks.