Realizing ICN as a Network Slice for Mobile Data Distribution

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Open Networking Summit (ONS)

April, 2017

Agenda

- ICN Introduction
- Multi-Access Convergence
- Realizing ICN as Network Slice
- VSER Architecture
- VSER Platform Features
- Conclusion

Future Internet Architecture：Design Targets

Holistic design for future Apps, Hyper-connection, Mobility and Security

Internet of （things/service/people/information）

Smart Home

Wearable Net

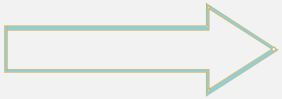
FIA

V2V

amazon
iTunes
YouTube
facebook

Info Net

Apps
L3/IP
L2/MAC
L1/PHYs



Apps
Info-centric
L3/L2/MAC
L1/PHYs

New “waist”, New architecture, New Apps

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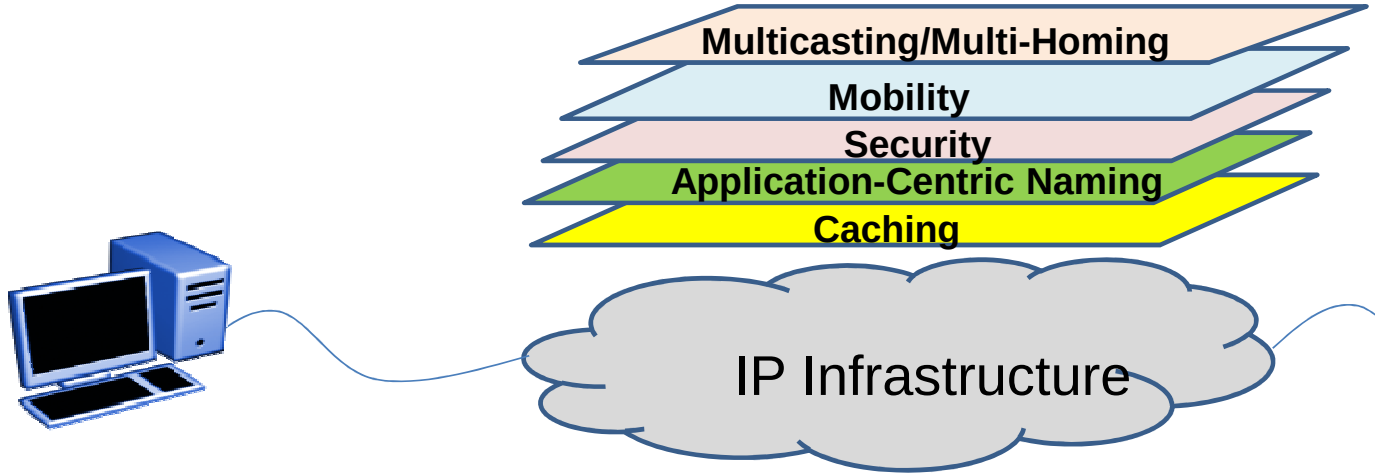
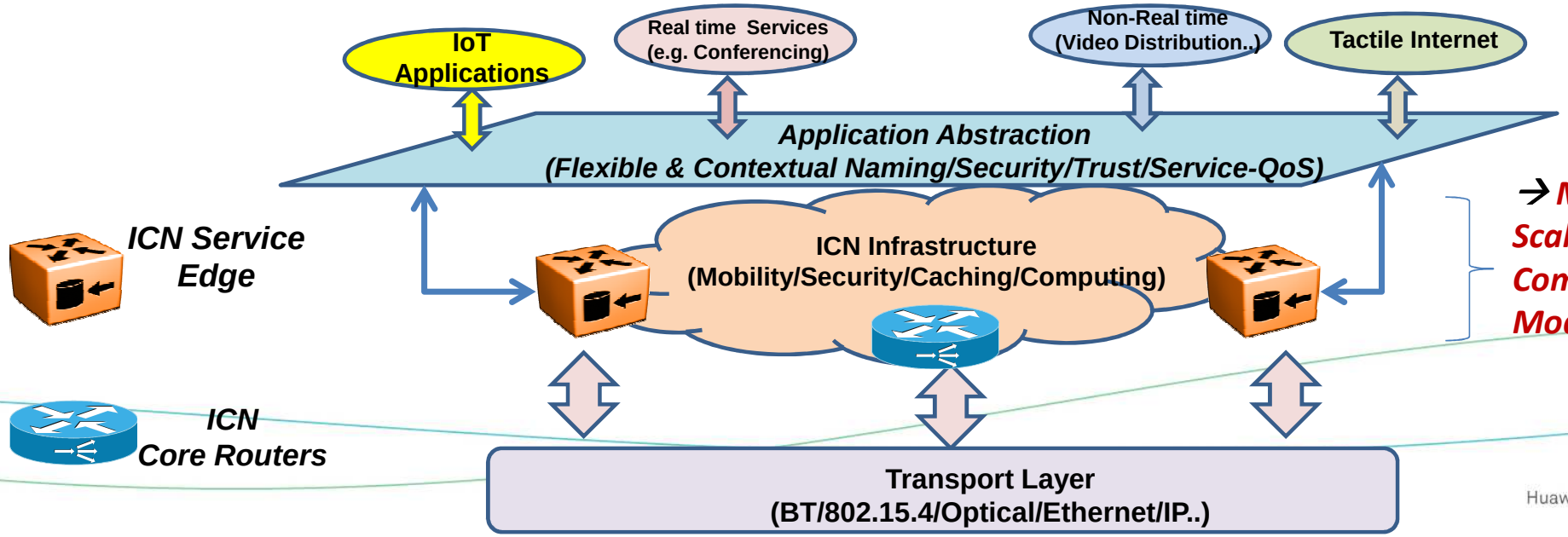
ICN as Application Abstraction Network Layer



→ *Original Internet to connect Hosts evolved to more complex overlay to support efficient Application Communication.*

IP

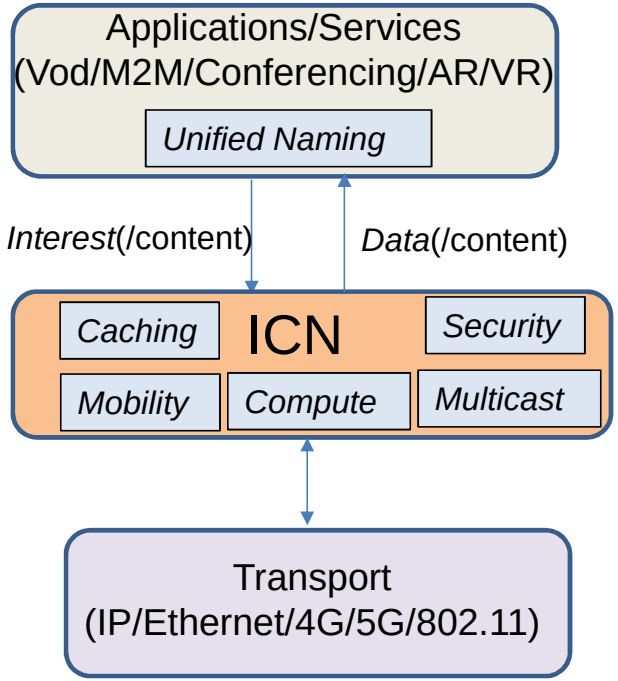
ICN



→ *Many challenges: Scalability, Complexity, Business Model*

What is ICN ?

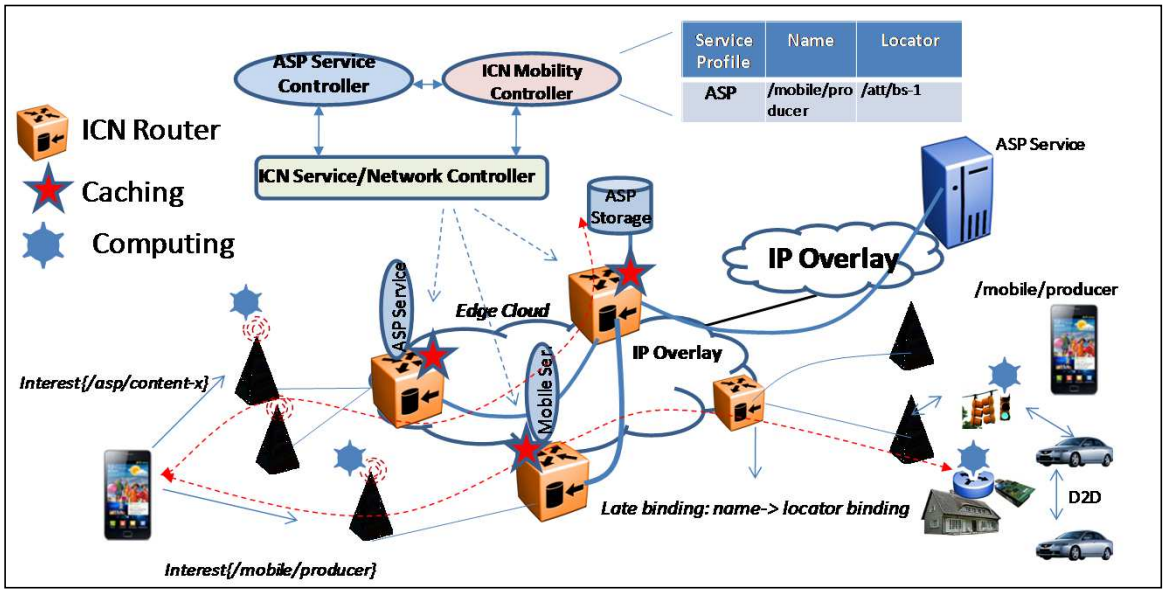
- ICN stands for "*Information-Centric Networking*" [1]
- Continued Networking Evolution
  - Circuits, Packets, Connectivity → Information Abstraction
- Provides name based abstraction to Application
  - Includes Content, Services and Devices
  - Location Independence of Cache and Compute
- Features : Naming, Mobility, Multicasting, Multihoming & Security
- Serves Realtime/Non-Real time, Ad hoc & IoT Apps.
- Currently evolving under IRTF/ICNRG Research Group [1]
- CCN/NDN is a popular candidate ICN protocol, though there are others like MobilityFirst, XIA, NetInf etc.



[1] George Xylomenos et al, "Survey of Information-Centric Networking Research", IEEE Communications Surveys & Tutorials, VOL. 16, NO. 2, Second Quarter 2014
[2] ICNRG: https://trac.ietf.org/trac/irtf/wiki/icnrg

Features ICN Provides to Satisfy Application Requirements

- **Three popular 5G use cases[1]:**
- **Extreme Mobile Broadband**
  - Edge Caching
  - UE Multi-Homing/Seamless Mobility
  - Content Multi-source/Multi-path Routing
  - Cross layer Optimization between ICN &MAC/PHY layers.
- **Massive Machine-type Communication**
  - In-network Hierarchical Computing
    - Lamp Posts, Home Gateways, Gateways in CO etc.
  - D2D Communication
    - Name based and Self Configuration features
  - New Routing Models
    - Constrained Network friendly, Ad hoc, Self-learning, Data Driven, p2p/multicast/broadcast mechanisms
- **Ultra-Reliable Machine Type Communication**
  - Extreme edge Computing
  - PUSH/PULL Named Chunks
  - Multi-level Caching, Store & Forward
  - Late-binding for Mobility/Migration of Resource Objects

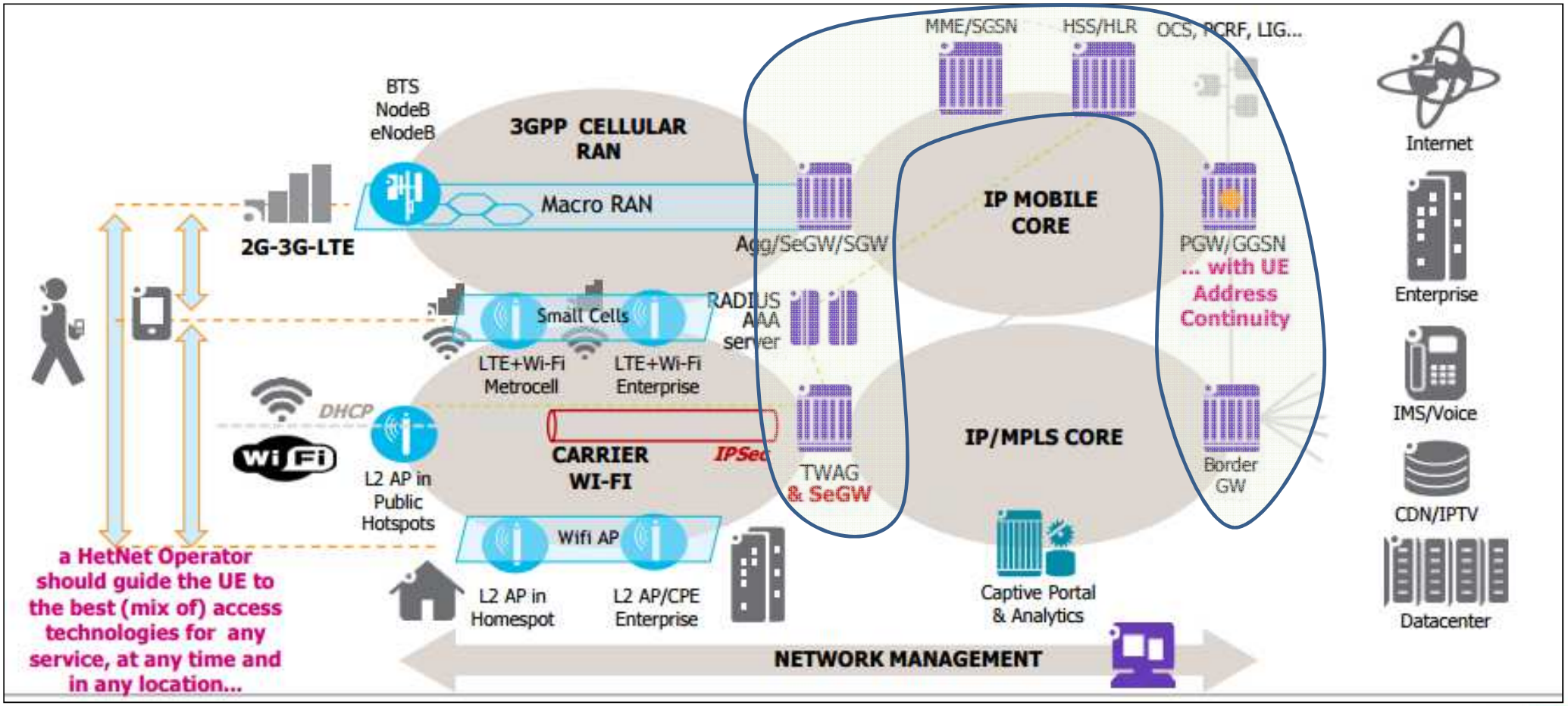


Flexible networking using ICN

[1] NGMN White Paper on 5G: https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf

Multi-Access Convergence

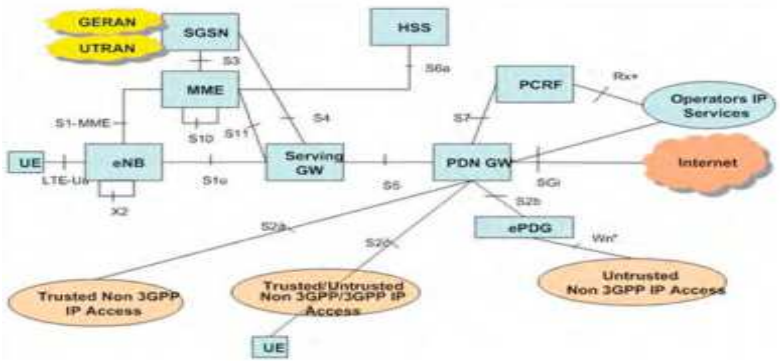
Current Industry Thinking of Integration of Wifi and LTE



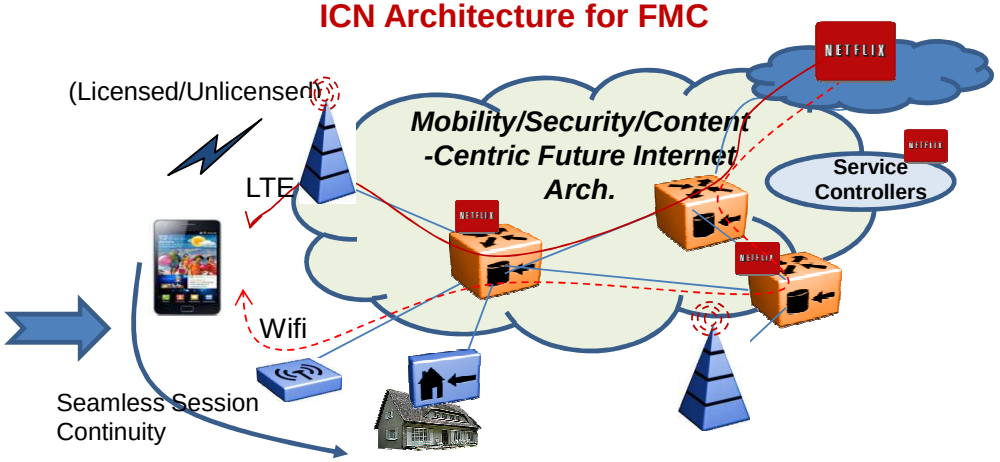
- Need for Identity, Security and Mobility complicates support for Multi-Access mobility.
- Integration is based on introducing more gateway functions increasing Control and User Plane Complexity.
- ICN offers them as part of its architecture.

Towards Fixed-Mobile (FM) Convergence

LTE Network Architecture



ICN Architecture for FMC



Current Architecture

- Hybrid 3GPP & IP Arch
- Disjoint Fixed and Cellular Access
- Complex Control interfaces.
- Technology Specific (2G/3G/4G)
- IP Tunneling in Data Path
- Gateways (…bottlenecks, sub optimal routing)

FM Converged ICN Architecture [1]

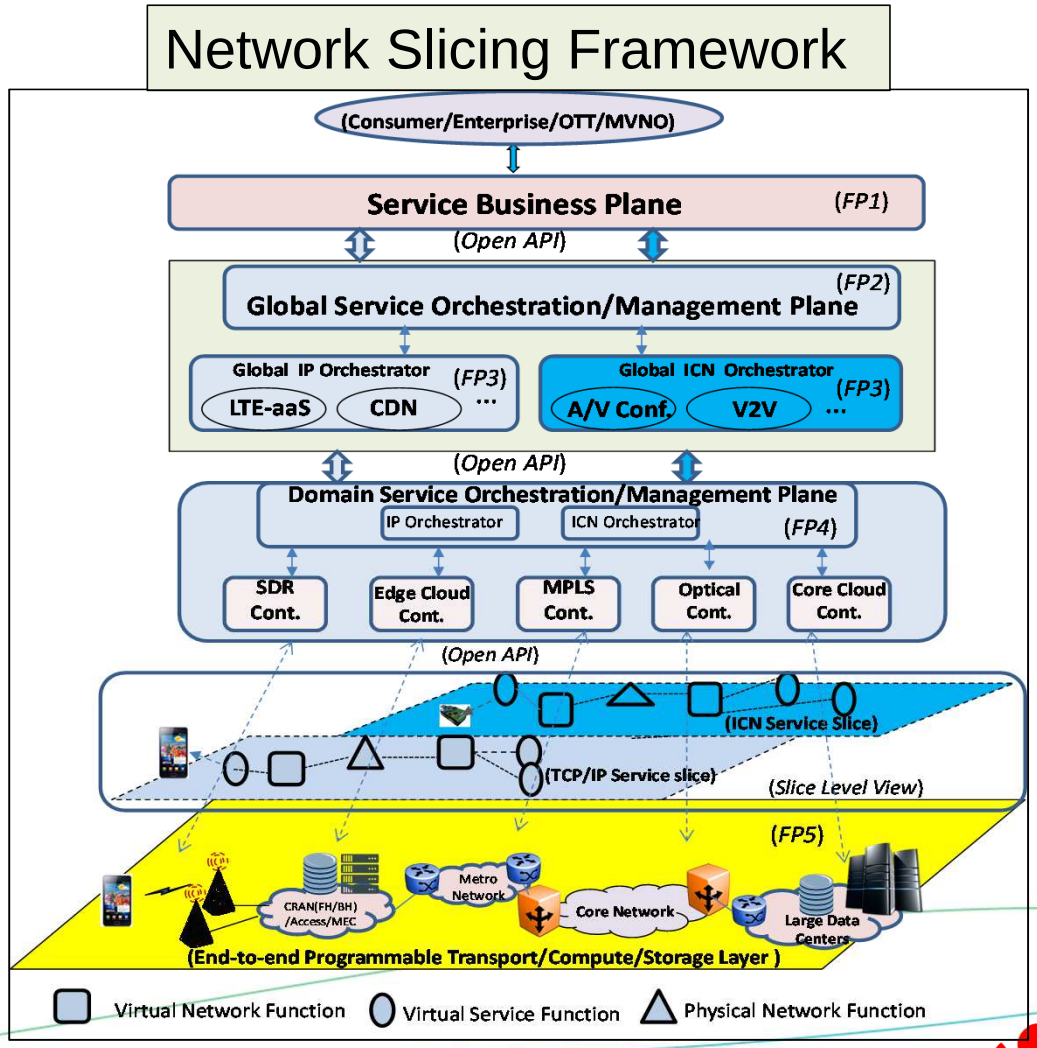
- ✓Flat Application-centric Network Architecture.
- ✓ Cellular/Fixed Access Convergence
- ✓No Gateways or Tunnels
- ✓In-build Network Layer Mobility
- ✓In-build Security, Storage and Computing
- ✓Technology Neutral (any RAN/RAT)
- ✓Application-Centric Virtualization

[1] Ravi Ravindran, Asit Chakraborti, Syed Obaid Amin, Aytac Azgin, G.Q.Wang, "*5G-ICN : Delivering ICN Services over 5G using Network Slicing*", http://arxiv.org/abs/1610.01182, (To appear in IEEE Communication Magazine, May, 2017)

Realizing ICN as a Slice

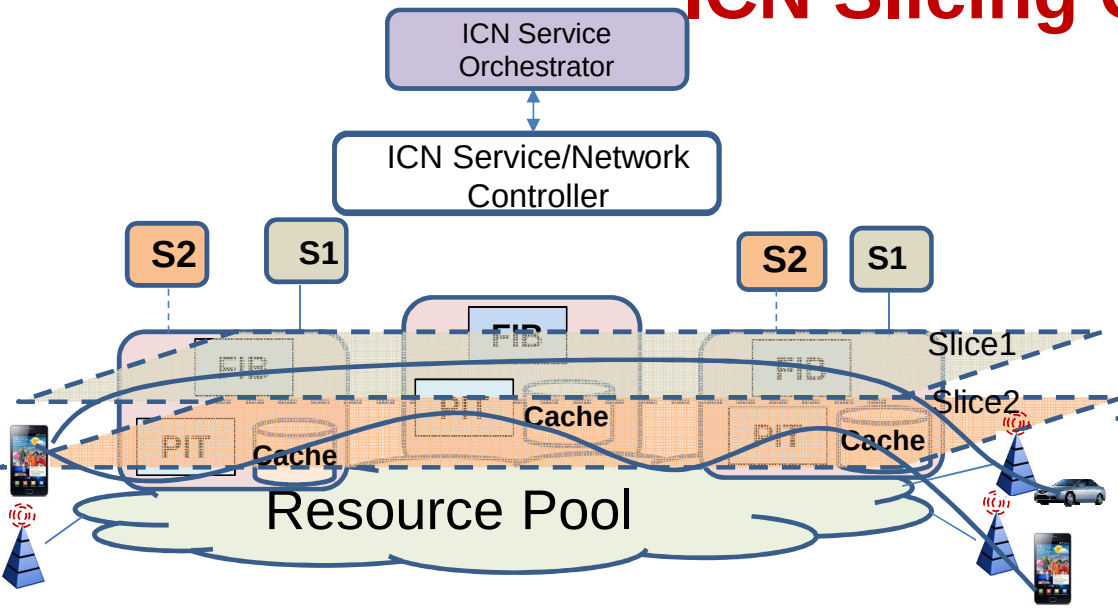
Realizing ICN as a Network Slice

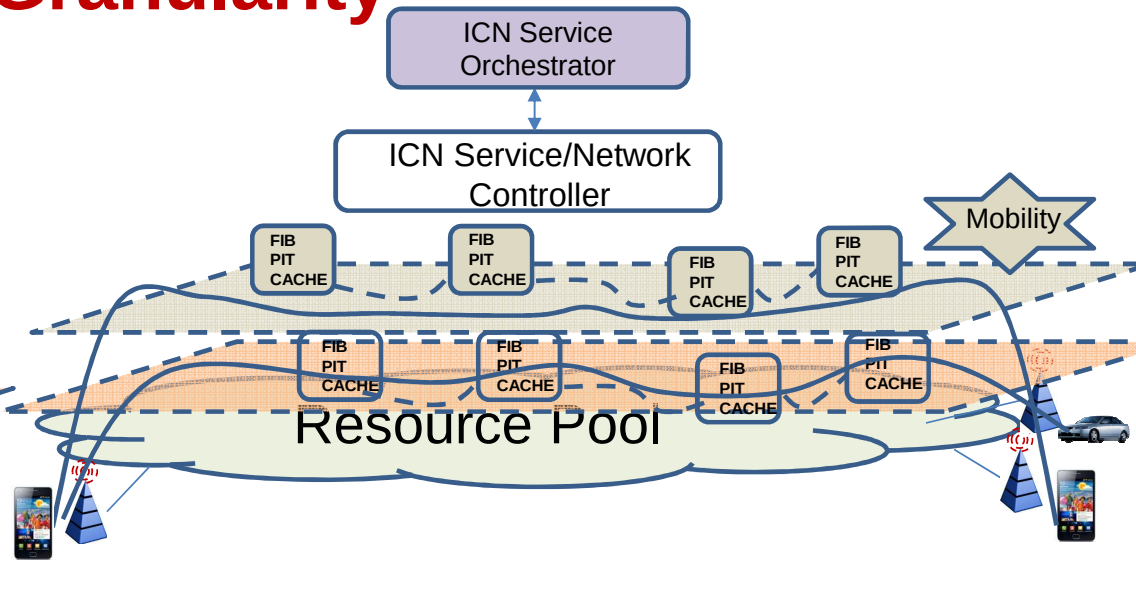
- **Realize end-to-end dedicated network for specific service scenario eMBB, URLLC, mMTC.**
  - Spans UE, RAT, Transport, Edge Clouds, DCs
- **Meet specific service objectives of Security, Latency, QoS, Reliability etc.**
- **End-to-end virtualization of Compute, Bandwidth, Storage, Data , Device resources.**
  - Virtualization allows resources to be efficiently flexibly managed among various slices.
- **Specialized Data/Control Plane and Service Control functions to enable rich services.**
  - Software Network Functions, P4/POF Platforms
  - Mobility-as-a-service, Security-as-a-service , Context Processing etc.
- **Creates scope for new network Architectures like ICN to address 5G Challenges**
  - **Multi-modal delivery connectivity: M2M, P2P, P2MP and MP2MP**
  - **Handle Mobility within the Slice**
  - **New APIs and Service Functions in the Network Architecture**



[1] ITU, FG, IMT 2020 Phase-1 – "Network Standardization Requirement for 5G"
http://www.itu.int/en/ITU-T/focusgroups/imt-2020/Documents/T13-SG13-151130-TD-PLEN-0208!!MSW-E.docx
[2] ITU, FG, IMT, 2020, Phase-2, - Architecture and Technology enablers for Network Softwarization & Prototyping

ICN Slicing Granularity





ICN as Narrow Waist for Services

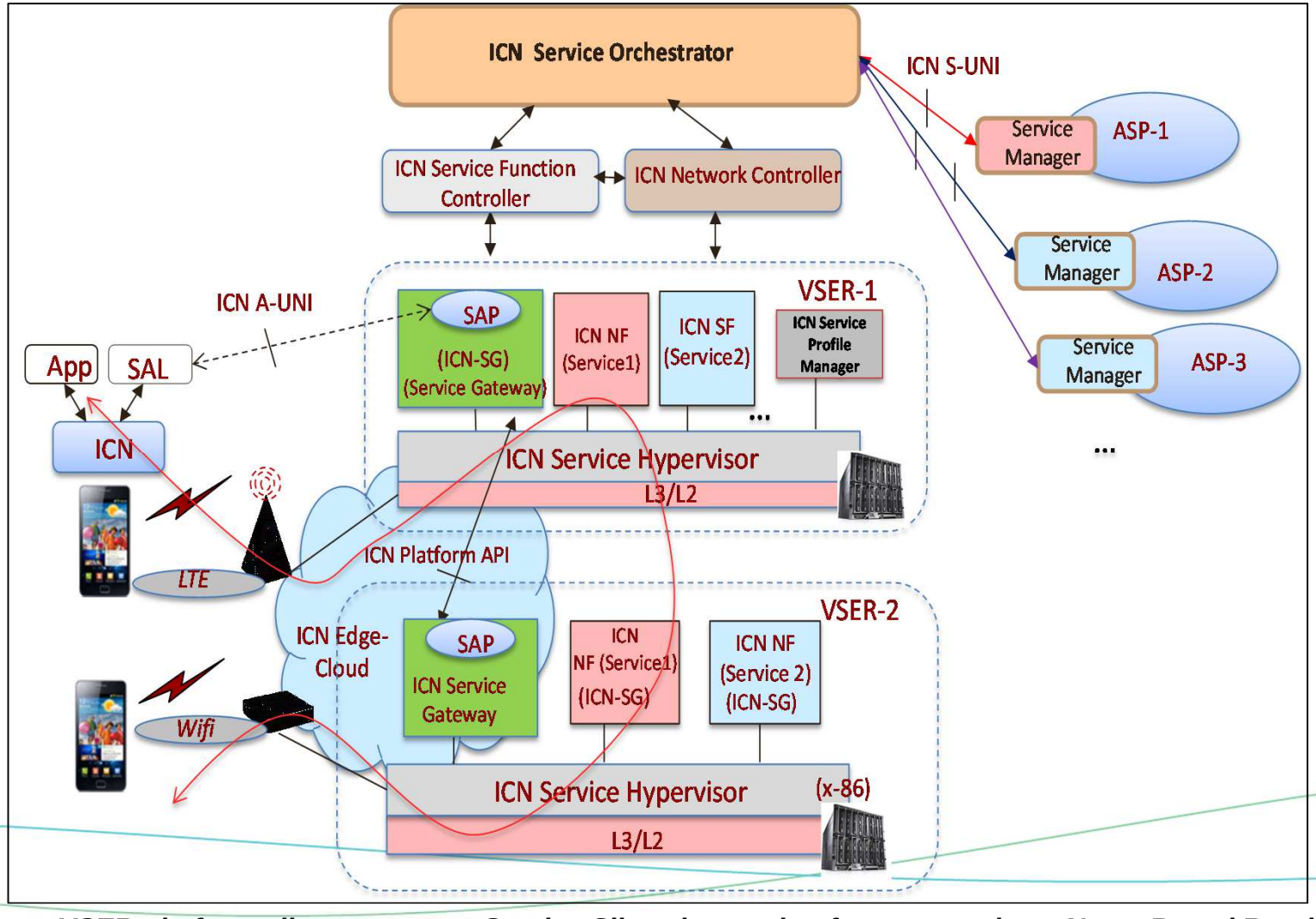
- Share Virtual ICN forwarders among multiple service slices
- Multiple applications use the same ICN service gateway
- Enables all ICN features
- Efficient resource utilization
- Poor Service isolation
- Privacy, Access Control are issues in this scenario.

ICN as Service Slices

- Dedicated virtual ICN forwarders for each slice
- Enables all ICN features
- Services uses different ICN Gateways.
- Poor resource utilization without active management
- Improved Service isolation
- Privacy, Access Control issues are better handled in this case
- Mobility-per-slice feature

Virtual Service Edge Router Platform and Features

VSER Architecture



- ***ICN Service Orchestrator***
  - Service Abstraction to Services
  - Service Graph and Resource Abstraction
- ***ICN Service Function Controller***
  - ICN Service and Network Function Life Cycle Manager
- ***ICN Network Controller***
  - ICN Network Virtualization
  - Name based Routing Virtualization
- ***ICN Service Hypervisor***
  - Host ICN Agent to manage Service and Network functions
  - Interface to ICN Network and Service Controller
- ***Service Access Point (SAP)***
  - Service Discovery and ICN Service Gateway Discovery
- **Service Access Layer (SAL)**
  - UE service agent fore Service Discovery for local applciations

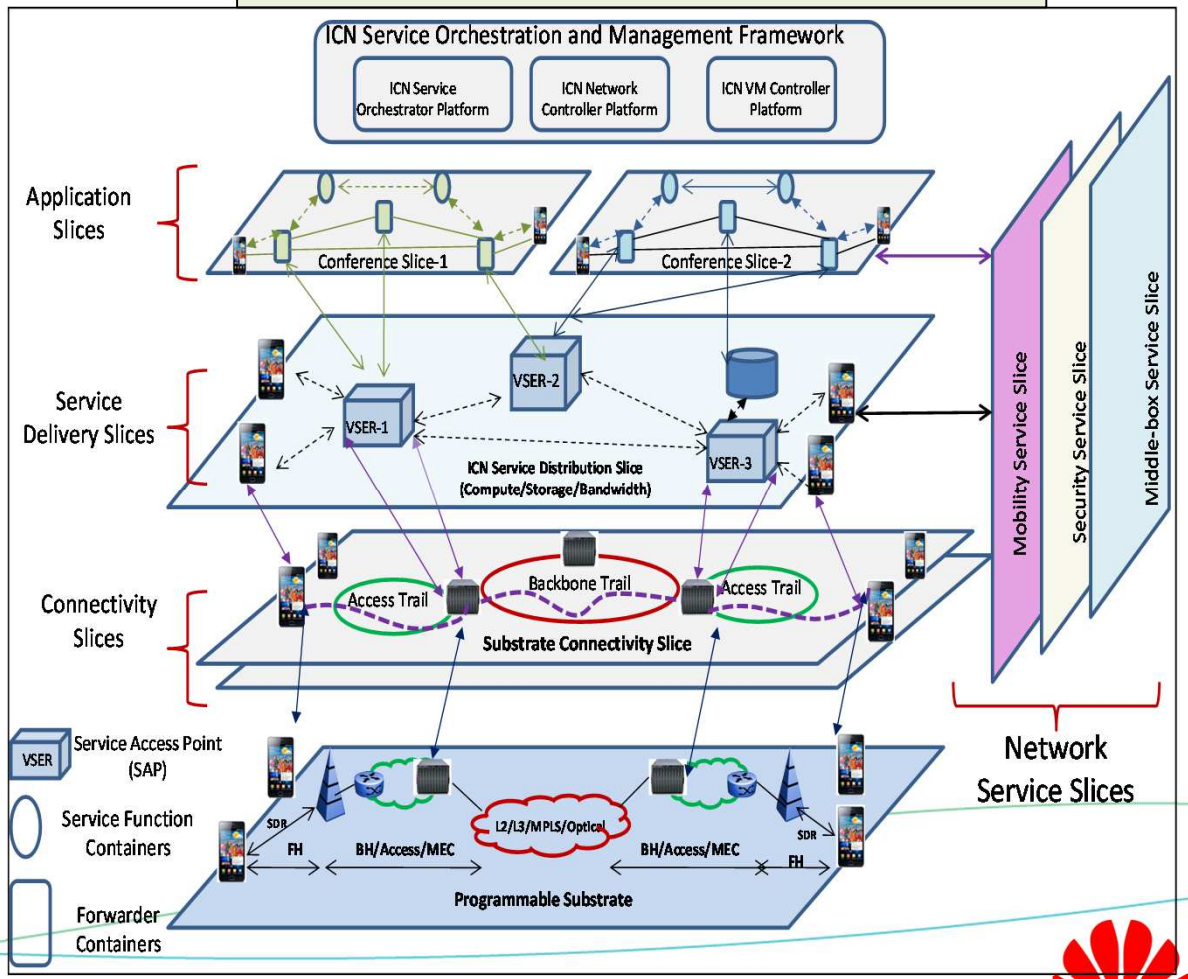
- **VSER platform allows to create Service Slices leveraging features such as Name Based Routing, Seamless Mobility Support, Caching, Multicasting and Multihoming.**

VSER Platform Features

- **Virtual Service Edge Route Platform**
  - ICN Service Orchestrator/Service& Network Controllers (Docker Swarm +ONOS)
  - Delivers both Real time and Non-Real time services
  - Solution for realtime A/V Conferencing
  - Resource pool assumes a General Purpose Platform (x-86)
- **Multiple Service Slicing**
  - We create dynamic Conference Slices on demand
  - Base, Mobility, and multiple Conference Slices
  - Each conference slice has Arbitrary real-time MP-2-MP participants
  - In-Network Multicast support
- **Seamless Mobility across Heterogeneous Access**
  - LTE (from Open Air Interface [1])
  - Wifi
  - Ethernet
- **Mobility as a Service features**
  - Mobility over a slice can be enabled On-Demand using Mobility Slice APIs

[1]Open Air Interface, http://www.openairinterface.org/

Realizing ICN Service Slices



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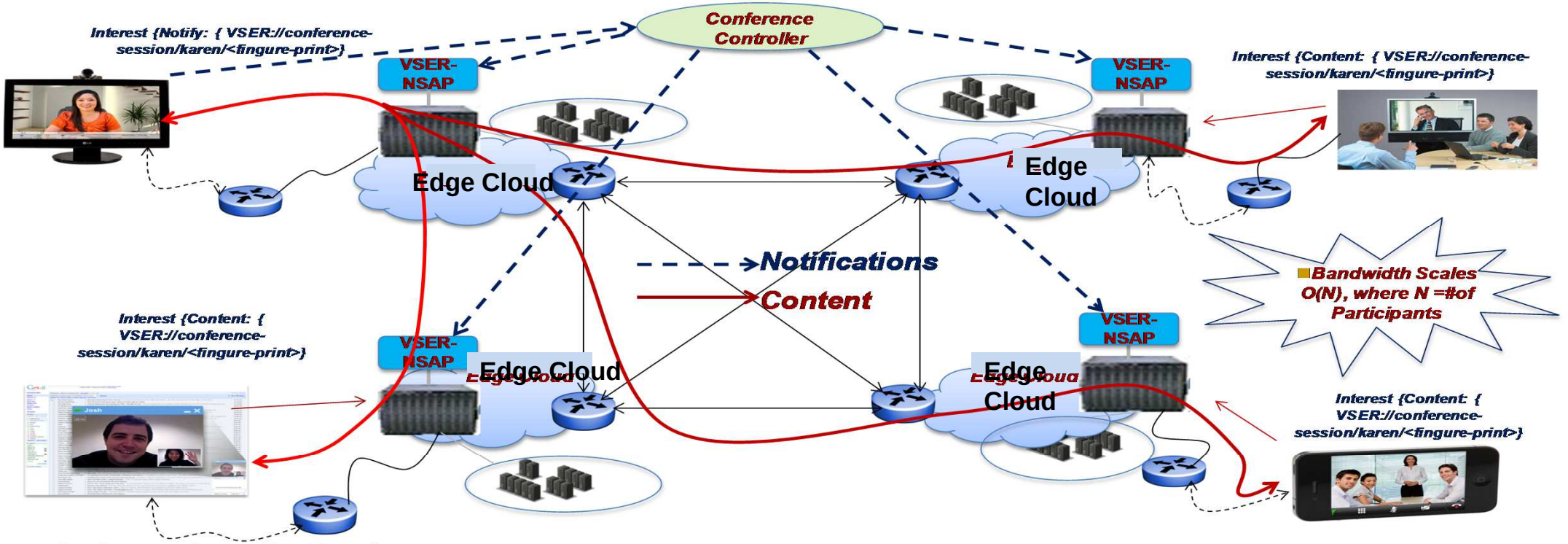
Serverless Scalable Audio-Video Conferencing over VSER



Conference Controller Functions

- Enable MP-2-MP Connectivity
- Conference Level Virtualization : ***Multiple Simultaneous Conferences , Service Scaling, Dynamic Name Based Routing, Conference Monitoring and Management.***
- Context level Adaptation

[1] Asit Chakraborti, Ravi Ravindran et al, "**ICN Based Scalable Audio/Video Conferencing over Virtual Service Edge Router (VSER) Platform** " ICN Sigcomm, 2015

[2] Anil Jangam, Ravi Ravindran et al, "**Realtime Multi-Party Video Conferencing Service over Information-Centric Network**", Workshop on Mutimedia Streaming in ICN (MuSIC), 2015

ICN A/V Conferencing Evaluation- Status Quo

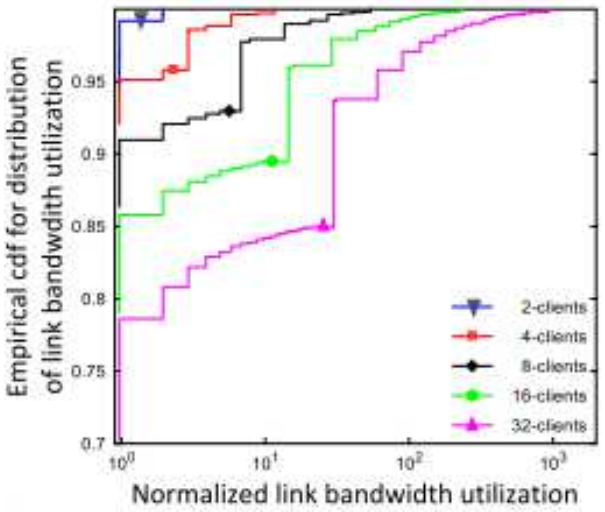


Fig1. Single Server Conferencing Scenario

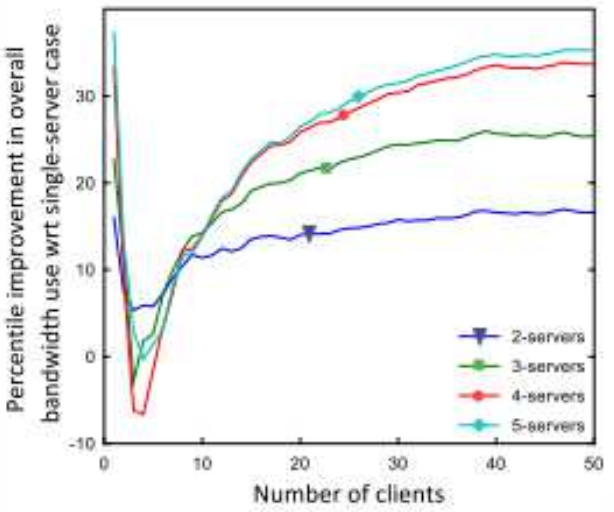


Fig 2. Multiple Server Conferencing Scenario

1. With single server scenario, for *n* users, the bandwidth utilization increases in the order of O(n^2).
   → From 2 to 32, the number of flows go from 4 → 1000,~ O(16^2)
2. Even if we enable multiple server, and multicasting between the servers, the maximum improvement is around 40% with 5 servers.Uses Application level Multicast
   1. Depends on the placement of these servers
   2. Uses Application level Multicast

[1] Asit Charkraborti, Syed Obaid Amin, Aytac Azgin, Ravi Ravindran, G.Q.Wang, "SRMCA: Scalable and Resilient Mutimedia Conferencing Architecture" (submitted to IEEE Transactions on Multimedia) (https://arxiv.org/ftp/arxiv/papers/1703/1703.03070.pdf)

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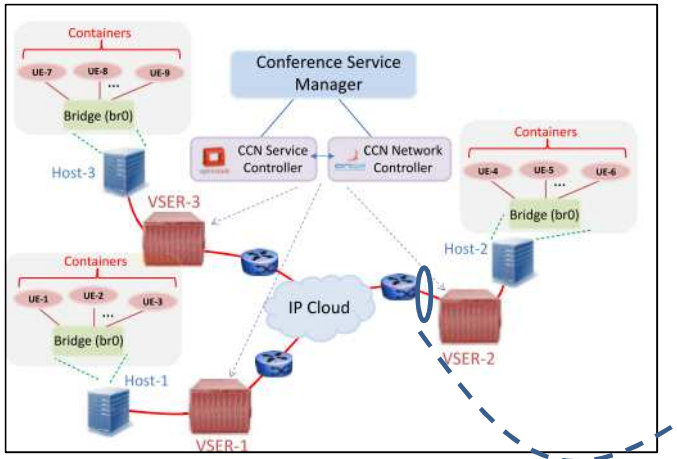
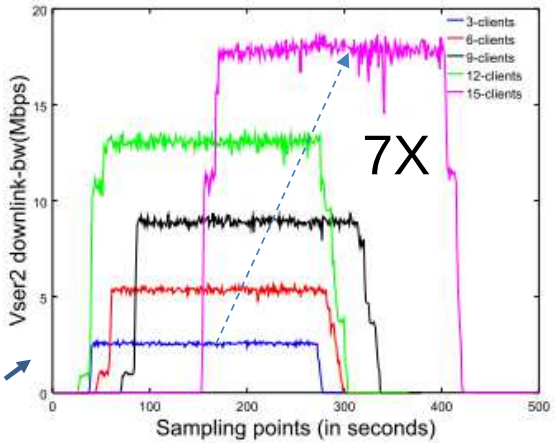
ICN A/V Conferencing Evaluation



Test Bed for Evaluation

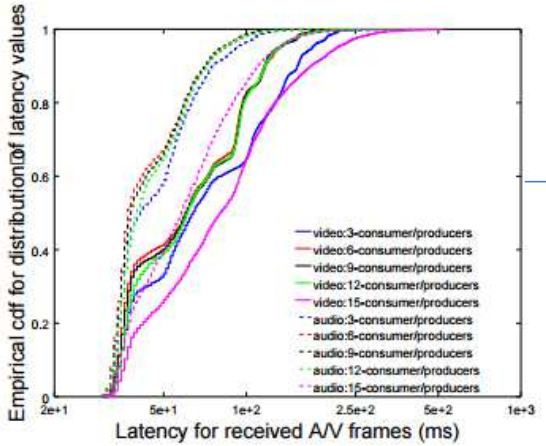
Set Up:

- 3 VSER and Host Nodes (*Intel –i7 family*)
- Participants emulated in Containers
- Random IP Latency (30,40)ms



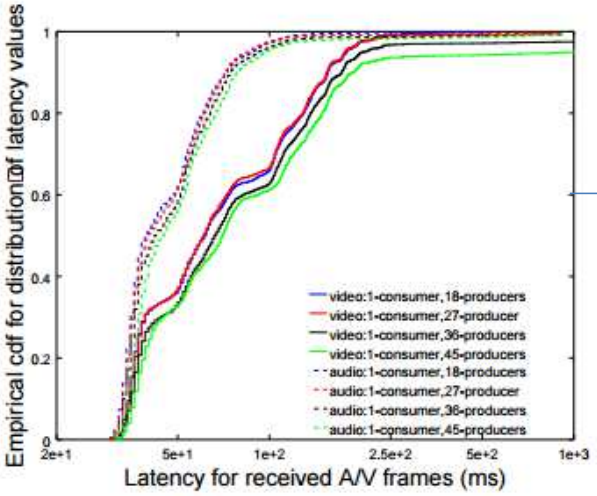
(a) VSER downlink bandwidth utilization

O(*N*) growth instead of O(N^2)
From 3 → 15 Participants :
2.5 → 17 Mbps
(7X Instead of 25X)



(b) Audio and video latency performance

→ For 15 All Party Conferencing mostly < 150ms and 250s for Audio/Video



(c) Audio and video latency performance with single consumer and multiple producer nodes

→ For 45 producers and I Consumre Conferencing mostly < 150ms and 250s for Audio/Video

[1] Asit Charkraborti, Syed Obaid Amin, Aytac Azgin, Ravi Ravindran, G.Q.Wang, "SRMCA: Scalable and Resilient Mutimedia Conferencing Architecture" (submitted to IEEE Transactions on Multimedia) (https://arxiv.org/ftp/arxiv/papers/1703/1703.03070.pdf)

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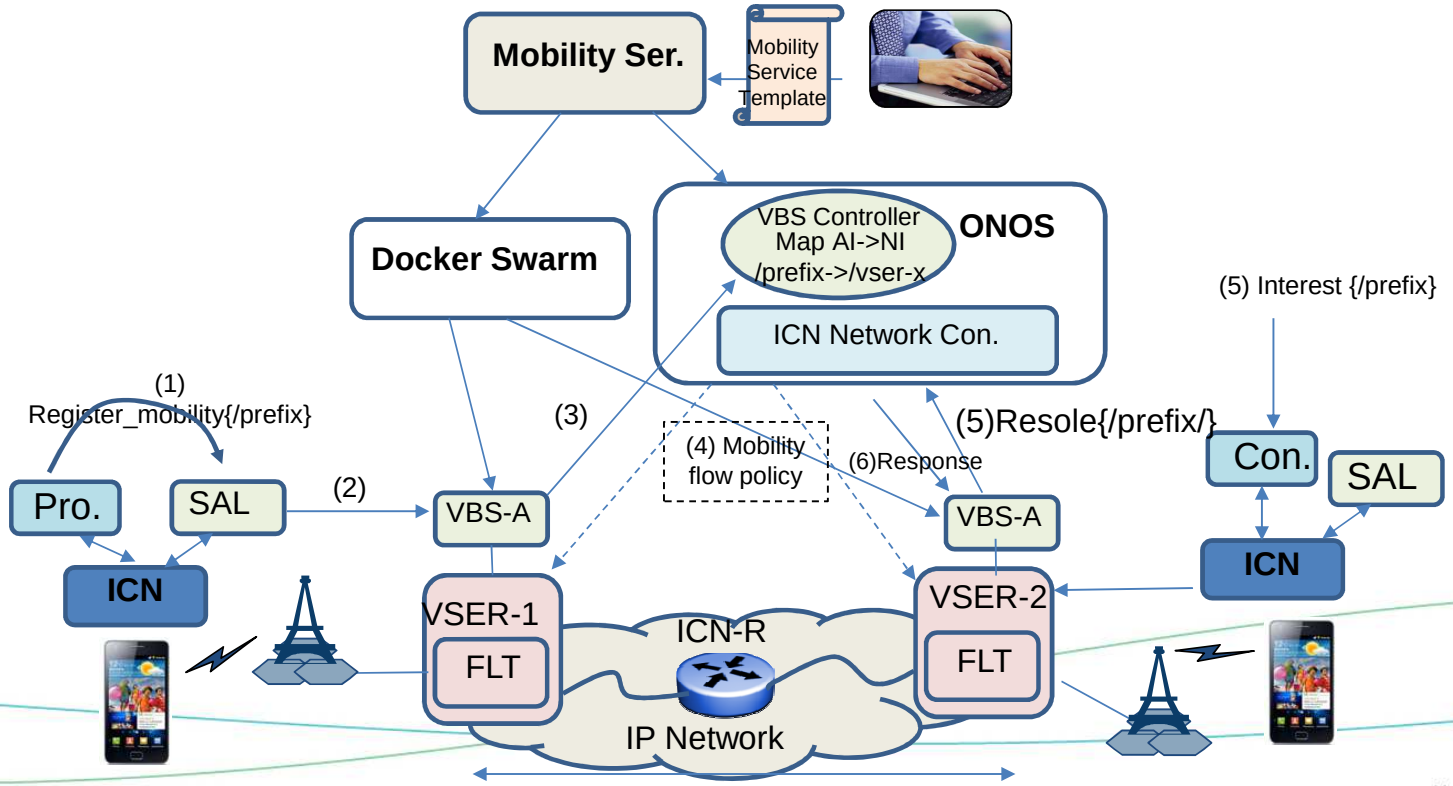
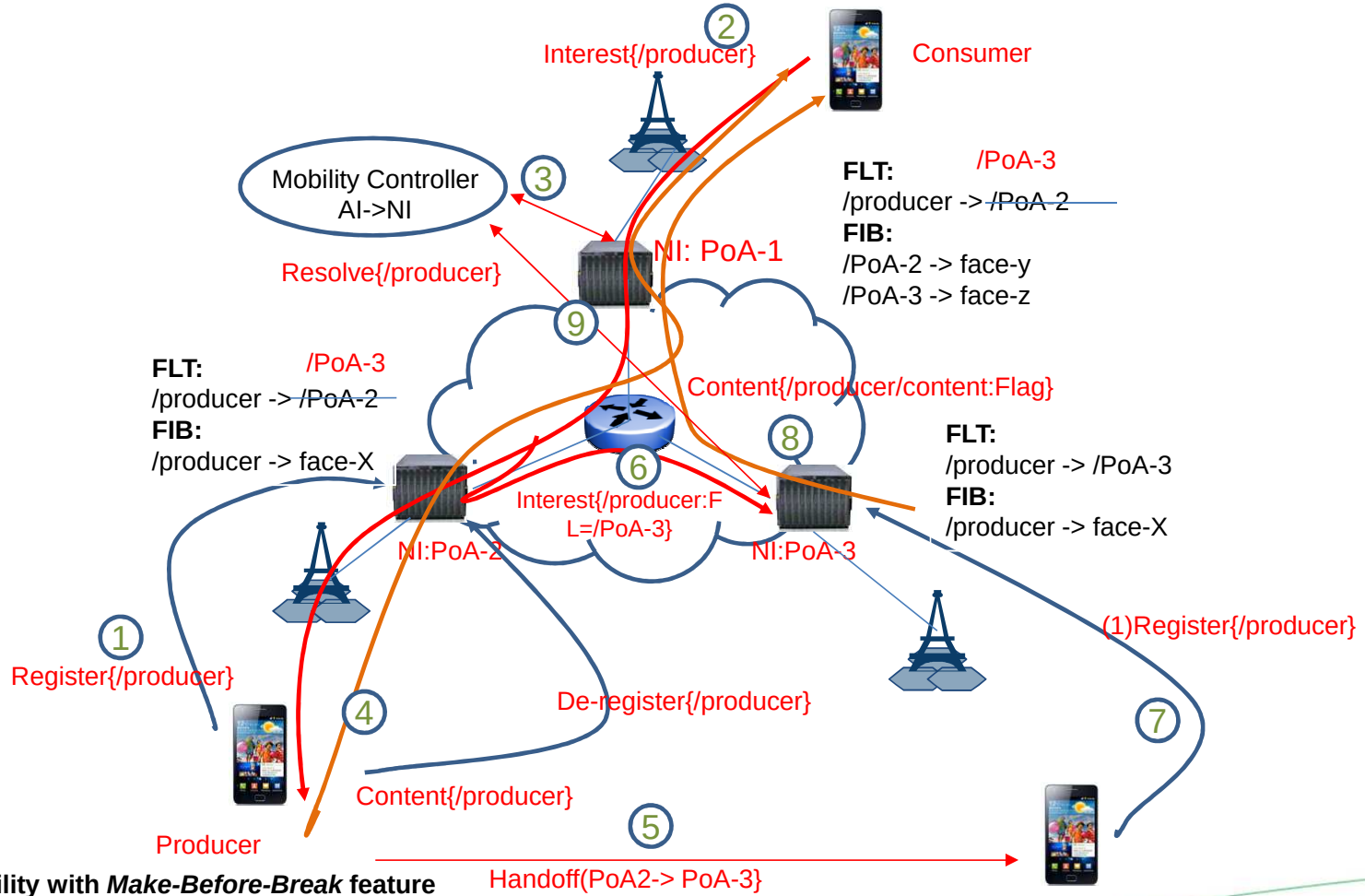
VSER's Mobility-as-a-Service Feature

- **Mobility control plane can be realized as a slice.**
- **Service slice can request Mobility-on-Demand using control plane APIs**
- **Producers explicitly (de-)register request for their name space mobility**
- **In forwarders in the slice ensures mobility to the named resources.**



[1] Aytac Azgin, Ravi Ravindran, G.Q.Wang, "Seamless Mobility as a Service in Information Centric Networks", 5G/ICN Workshop, ACM ICN Sigcomm, 2016, http://conferences2.sigcomm.org/acm-icn/2016/proceedings/p243-azgin.pdf

Seamless Mobility Through Late Binding [1]



- **Seamless mobility with *Make-Before-Break* feature**
- **In Network based mobility, network provides the PoA information allowing proactive late binding after the de-registration from the UE**
- **If there is a candidate list of PoA, then the Interest can be multi-unicast to each one, until signaling from the new PoA**

[1] Aytac Azgin, Ravi Ravindran, G.Q.Wang, “Seamless Mobility as a Service in Information Centric Networks”, 5G/ICN Workshop, ACM ICN Sigcomm, 2016
[2] Aytac Azgin, Ravi Ravindran, “Enabling Network Identifier in Information Centric Networks”, IETF/ICNRG,
[3] IETF/ICNRG, “Forwarding Label Support in CCN Protocol”, https://tools.ietf.org/html/draft-ravi-icnrg-ccn-forwarding-label-00

Demo Prototype Platform (ONS, 2017)

ICN Service Manager

ICN Slicing Control Plane

Docker Swarm

Swarm Manager

Docker Registry

ICN Service Orchestrator

Service Orchestrating module

Service Topology module

[REST API]

[REST API]

[OpenFlow]

ONOS Controller

ICN APPs

VBS Controller

Conference Controller

ICN Network Controller

Device

Packet

Applic ation

Core

(OpenFlow)

M2M A/V Conf.

M2M A/V Conf.

ICN Data Plane

OVS Switch

Sync Proxy Conf-1

Conf-1 ICN Forwarder

ICN Hypervisor

Sync Ctrl. Conf-2

MaaS VBS Agent

SAP

Conf-4 Sync Proxy

Conf-5 Sync Ctrlr

VSER1

LTE (*Open Air Interface*)

Producer Mobility

Wifi

APP

SAL

ICN

VSER1

(*Data Path*)

IP Network

VSER1

LTE

Wifi

Consumer Mobility

APP

SAL

ICN

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VSER: Virtual Service Edge Router **VBS : Virtual Base Station** **SAL: Service Access Layer** **SAP : Service Access Point**

Demo Features (ONS, 2017)

- **Realization of ICN as a Network Slice**
  - End-to-end Orchestration of ICN services as Virtual Slices using Docker Swarm and ONOS to achieve service specific objectives over GPP platform.
  - On-demand provisioning of Service, Mobility and Base Network slice on-demand
  - Policy driven interaction between slices - here we show Mobility-as-a-Service feature where Mobility service can be turned on/off any conference slice instance

- **ICN for Fixed-Mobile Convergence and Access Agnostic Mobility**
  - Integration of ICN with LTE eNodeB and Wifi AP to enable **Heterogeneous** and **Service Aware Seamless Mobility** of Consumers and Producers.
  - Seamless mobility follows "**Make-before-Break**" paradigm
  - Session disruptions will be ~100ms switching the UE between the Heterogeneous interfaces.
  - Mobility is handled by ICN Point-of-Attachment (PoA) nodes integrated with the eNodeB.

- **ICN as Generic Data Distribution Platform**
  - A flat architecture to service heterogenous services
  - The platform serves both Real and non-Real time Content.
  - We show this by demonstrating real-time multipoint-to-multipoint (MP-2-MP) A/V Conferencing Application also suitable for non-realtime VoD content Distribution.
  - Leverages ICN's in-network mobility, multicasting and caching features

Conclusion

- Network Slicing allows to realize new data planes hence new network architectures
- ICN enables many network features desirable for applications
- ICN's in-network mobility allows a flat architecture while being friendly to mobile edge computing
- ICN slicing uses the industry recognized compute and network virtualization platforms, i.e Docker and ONOS suite.
- ICN has been gaining momentum under ICNRG/IETF research group.

Thank You.