ITU

Delivering heterogeneous services in ICN using Network Slicing

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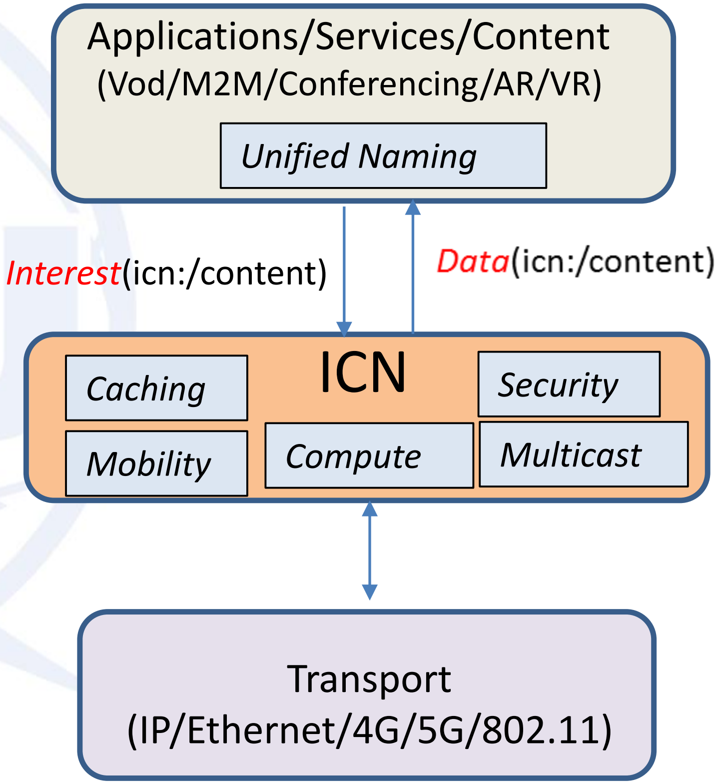
Agenda

- ICN Introduction
- Realizing ICN as a Slice
- ICN for Edge Deployment
- Virtual Service Edge Router (VSER) Platform
- ICN-IoT Requirements
- ICN-IoT Architecture and Prototype
- ICN Conferencing over VSER
- Conclusion

What is ICN ?

- ICN stands for "*Information-Centric Networking*" [1]
- Continued Networking Evolution
  - Circuits, Packets, Host Connectivity → Information Based Network APIs
- Provides name based abstraction to Application
  - Includes Content, Services and Devices
  - Location Independence of Cache and Compute
- Features : Naming/Security, Mobility, Multicasting, Multihoming, In-Network Computing
- Serves Realtime/Non-Real time, D2D, Ad hoc & IoT Apps.
- CCN/NDN is a popular candidate ICN protocol, though there are others like MobilityFirst, XIA, NetInf etc.
- Currently evolving under IRTF/ICNRG Research Group [2]



[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

ICN Benefits

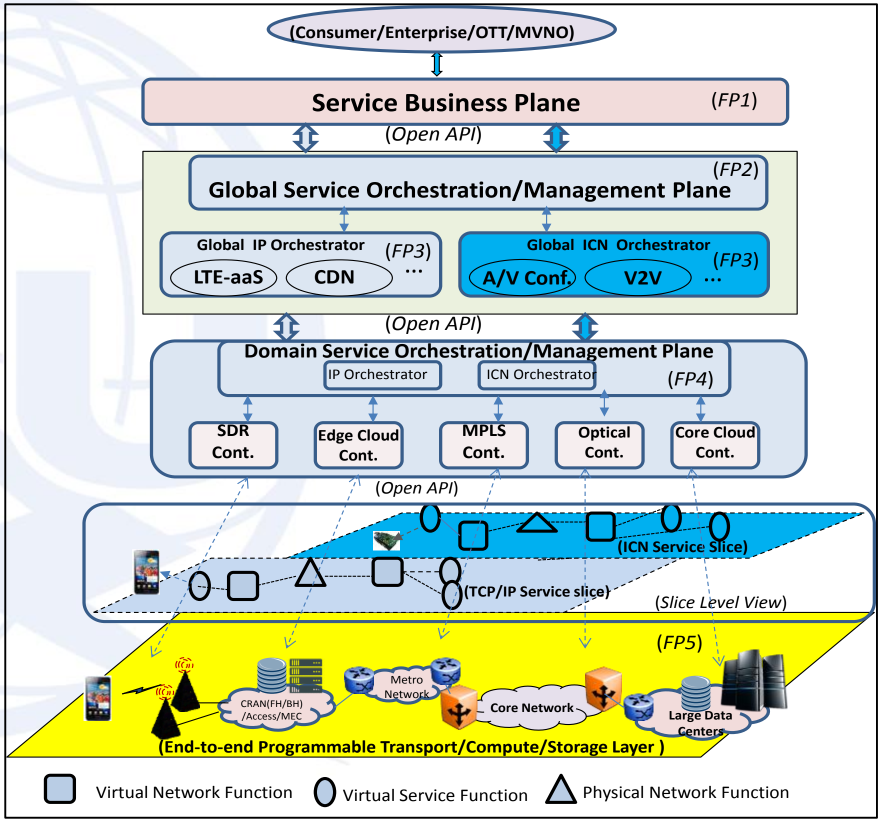
- Flatter Network architecture - embedded Mobility & Multicasting
- Saving Backhaul Link Cost
- Efficient Edge Compute deployments
  - Always routes to the optimal service point
  - In-network compute function enabled through Named Function Networking (NFN)
- Contextual Trust models [3]
  - Naming and Keys can be contextually related
- Increased reliability on wireless hop
  - Special adaptation layers at the face level (e.g. LTE) to improve reliability
- Allows DataMuling feature in Ad hoc networks [1]
- Memory and Power cost savings in Constrained devices [2]

[1] ATIS Report: eCON Value Assessment Report – A Comparative Study of ICN Versus Conventional Approaches, Issue 2
[2] Baccelli, E., Mehlis, C., Hahm, O., Schmidt, T., and M. Wahlisch, "Information Centric Networking in the IoT:Experiments with NDN in the Wild", ACM, ICN Siggcomm, 2014.
[3] Ying di Yu et al, "Schematized Trust in Named Data Networking", ICN, Sigcomm, 2015

ICN in a Network Slice [1]

- **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**

Network Slicing Framework



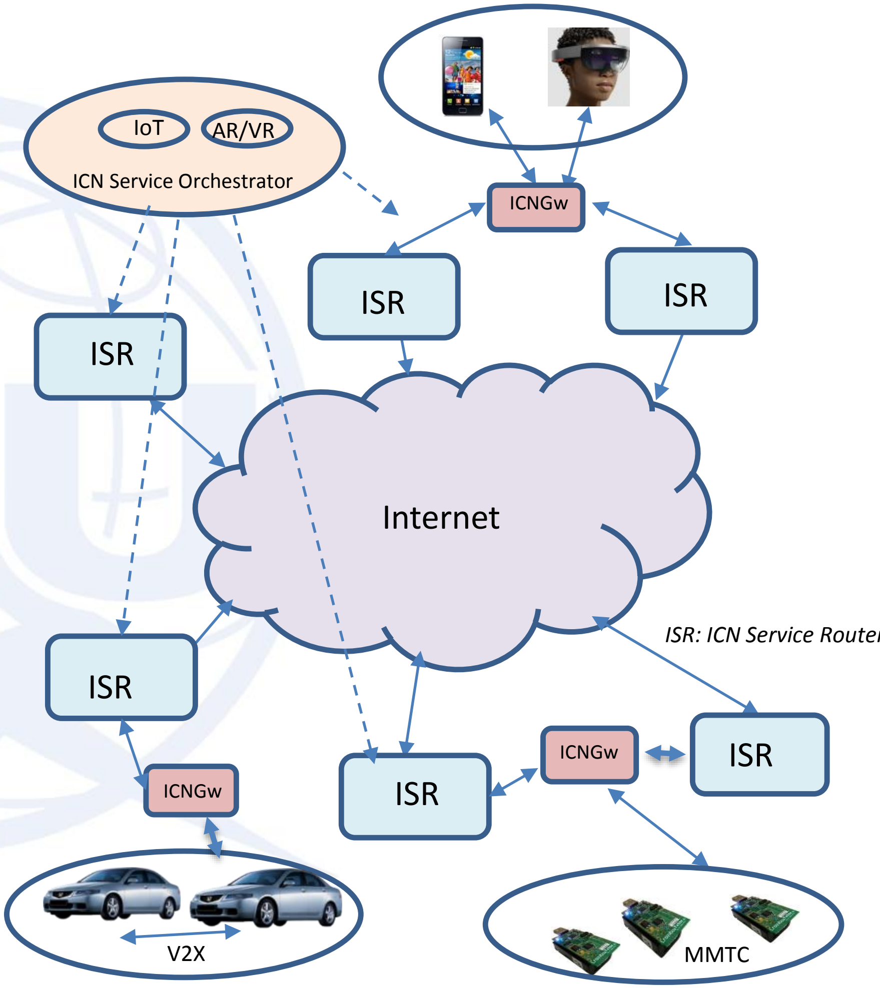
[1] R. Ravindran, Asit Chakraborti, Syed Obaid Amin, Aytac Azgin, G.Q.Wang, “5G-ICN: Delivering ICN Services over 5G Using Network Slicing,” IEEE Comm., Mag., vol. 55, no. 5, May 2017, pp 101-107.
[2] ITU, FG, IMT 2020 Phase-1 – “Network Standardization Requirement for 5G”
http://www.itu.int/en/ITU-T/focusgroups/imt-2020/Documents/T13-SG13-151130-TD-PLEN-0208!!MSW-E.docx
[3] ITU, FG, IMT, 2020, Phase-2, - Architecture and Technology enablers for Network Softwarization & Prototyping

Heterogeneous ICN Slices

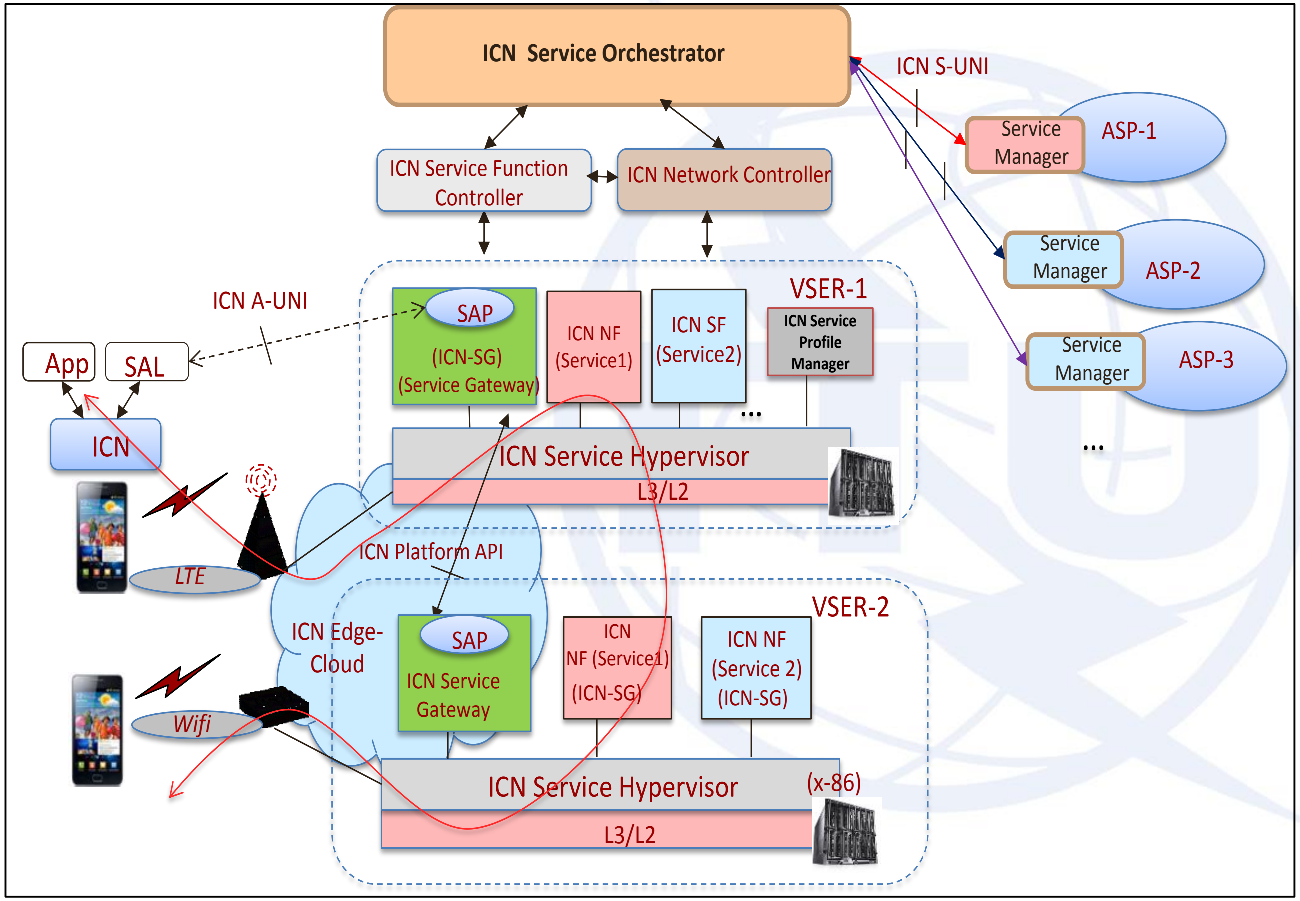
- Meet requirements for differing service requirements
- Softwarization of network functions including the ICN forwarder allows better resource isolation with slices
  - Cache can be managed based on application nature
  - FIB is more manageable per slice
  - Different flavors of ICN protocols can be used
- Service and in-network compute functions in ICN get better isolation in slices
- Mobility management per slice

ICN in the Edge

- **ICN makes lot of sense in the edge**
  - Seamless contextual networking platform to connect heterogeneous devices, applications with edge compute, cache and storage resources.
  - Contextual routing to service points
    - E.g. DNS would have scalability problems in a decentralized edge.
  - Efficiently deployed in-network compute with ICN can make proper use of precious edge resource and reduce backhaul bandwidth use
  - Reusing shareable data via location independent caching both upstream and downstream
  - Receiver oriented Communication – Multi-homing, Mobility and Multicasting
  - Challenges: privacy, security, data accountability



Virtual Service Edge Router (VSER) Architecture [1]

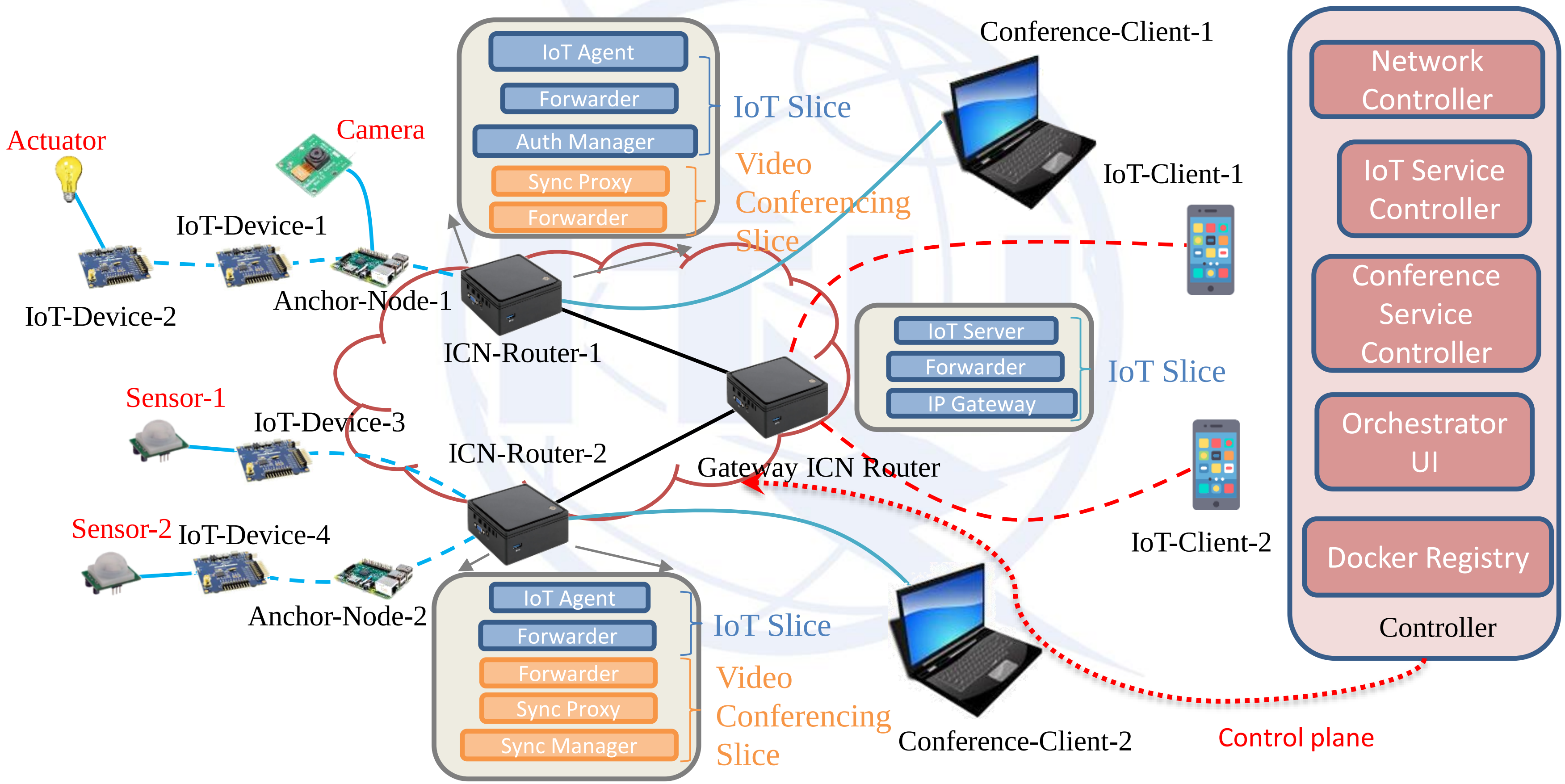


- ***ICN Service Orchestrator***
  - Service Abstraction to Services
  - Service Graph and Resource Abstraction
- ***ICN Service Function Controller***
  - ICN Service and Network Function Life Cycle Manager
- ***ICN Network Controller***
  - ICN Network Virtualization
  - Name based Routing Virtualization
- ***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.**

[1] Ravi Ravindran et al, "**Towards Software defined ICN based Edge Cloud Services**", IEEE, CloudNet, 2012
[2] Asit Chakraborti, Ravi Ravindran et al, "**Multi-party Conference over Virtual Service Edge Router (VSER) Platform** " ICN Sigcomm, 2015

Multiple ICN Service Slices



ICN for IoT

Referred from "***Design Considerations for Applying ICN to IoT***", Ravi Ravindran, Yanyong Zhang, et al IETF/ICN-RG Draft. (WinLab/Huawei/INRIA/UCLA) – "draft-irtf-icnrg-01"

→Considering 50B Things to be connected to the Internet (*Heterogeneous, physical things (assets), low power requirements, M2M, Mobile, Ad Hoc* etc.)

Inter-operability

- Unified Naming of Devices/Services/Content (IPv6 may not be sufficient)
- Flexible Naming (sensors, embedded devices, wearables, smart devices etc.)
- Naming (Persistent (Contextual), Secure, Human friendly)
- Open-API at all levels

Security , Privacy & Trust

- Access Control/Trust/Provanance/Data Integrity/Regulations
- Data Privacy/Secure Names

Scalability

- ID/Locator Split
- Enable Decentralized Communication (P2P)

Mobility

- Devices/Services accessible irrespective of Mobility or Migration

Reliability/Availability

- Storage and Caching (Sharing information, reducing upstream bandwidth, Processing)
- Disruption tolerance (QoS, Wireless, Redundancy, Flow Control, Opportunistic transmission)
- Near real-time requirements
- Multi-path & Multi-homing

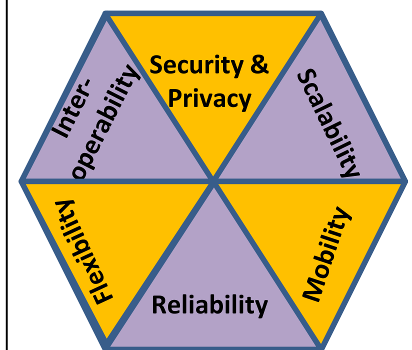
Flexibility

- **Heterogeneity (Lossy Radios; Traffic** (Push/Pull, Latency, Critical Events))
- **Contextual Communication** (Varies with IoT application, generally includes Location, Time, Policies etc.)
- **Self Organizing** (Edges, Simple Networking, Zero Configuration, Minimum Management)
- **Adhoc and Infrastructure Mode** (Topology /Service Discovery, Routing, Scalable Name Resolution)

Management

- FCAPS to IoT Services, Network , Devices, Protocols
- Scale to Large Number of Devices
- Requirements management of in-network Content, Services

IoT Requirements



Requirements vary with the Scenario such as Health Care/Smart Grid/Transportation/Home Networks/Industrial etc.

ICN IoT Slice Operation

- **Node distinction**
  - IoT network
    - Resource constrained IoT nodes with sensors and actuators
    - Aggregator node with more resources
  - Network slice ISR components
    - Authentication Manager
    - IoT Agent
    - IP gateway/server
- **All components communicate using lightweight ICN protocol (ccn-lite) [1]**
- **Discovery**
  - The new nodes serve /service-discovery interests with data indicating the details about its services and sensor/actuator details
  - discover IOT services in its network by sending /service-discovery interests with exclusion mechanism
- **Policies**
  - IoT Agent maintains user policy settings
  - Handles IoT data and logs, executes policies
  - Can scale up with more users

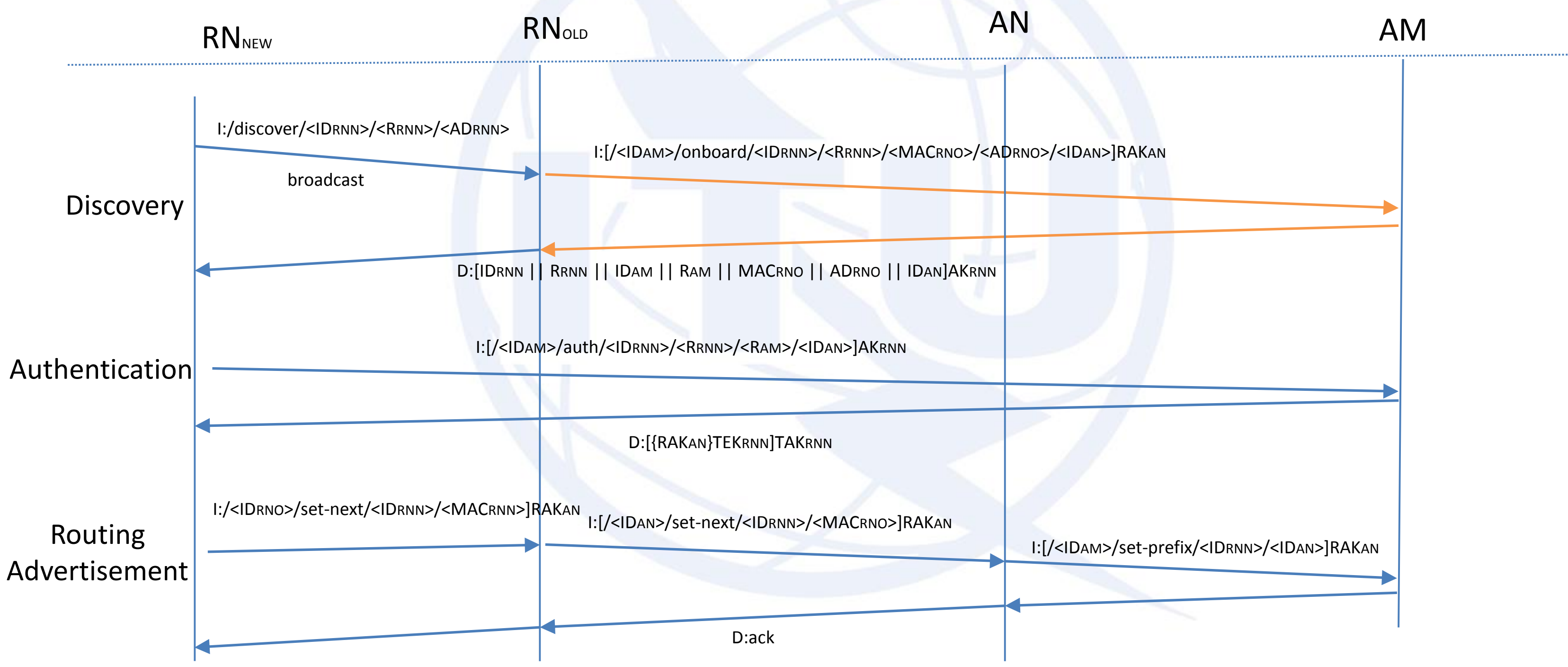
[1] https://ccn-lite.net

ICN IoT device onboarding

- **Secure onboarding of ICN IoT devices is a challenge, our model is based on LASeR a 3 phase protocol [1]**
- **Network discovery**
  - New IOT devices and IoT service share a Key before onboarding (Pre-shared Key)
  - New devices send a /discover interest to verify if it can trust the network and also to find its next hop
    - Include ID, Nonce, distance from Aggregator Node (AN)
  - Renamed by neighbor that serves it to include its own information (MAC) and signature
  - Destined for Authentication Manager (AM)
  - AM derives the new devices' Authentication Key (using Pre-shared Key and the new device ID present in the message) and uses it to generate signature, also including a nonce in the data
  - The new device verifies the signature and extracts the data
  - The response tells the new device its next-hop for unicast packets
- **Device Authentication**
  - Then the new devices send information about itself so that AM can verify it
  - Include previous nonces, IDs of all parties, signed using its Authentication Key
  - AM verifies signature, responds with Routing Key (signed and encrypted by the Transient Keys for the new devices that it derived) that should be used inside the AN's network
- **Path advertisement**
  - New IOT device use a set-next interest to allow upstream nodes to set routing entries towards it
  - Provide own ID and that of neighbor, and interface information
  - Every node till AM processes it to set downwards FIB (with device ID and next hop MAC) and resends it upwards
  - Device ID is used for routing

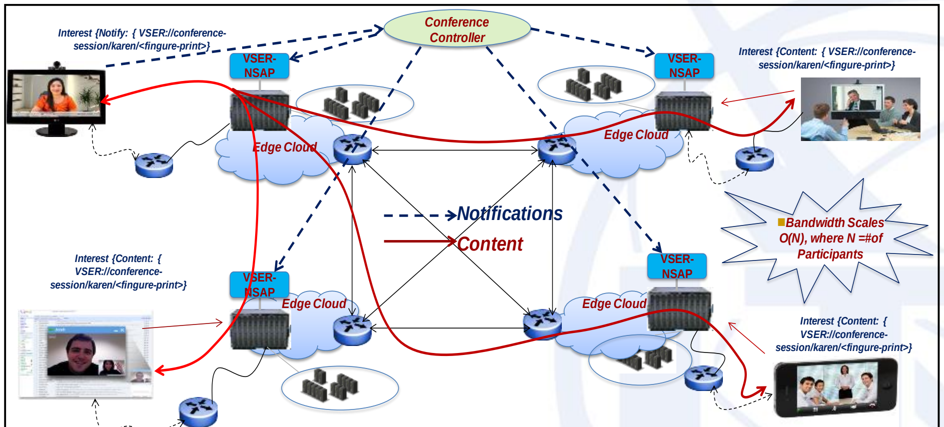
[1] Travis Mick, Reza Tourani, and Satyajayant Misra. Laser: Lightweight authentication and secured routing for ndn iot in smart cities. *IEEE Internet of Things Journal*, 5(2):755–764, May 2017.

Onboarding timeline



Serverless Scalable Audio-Video Conferencing over VSER [1-3]

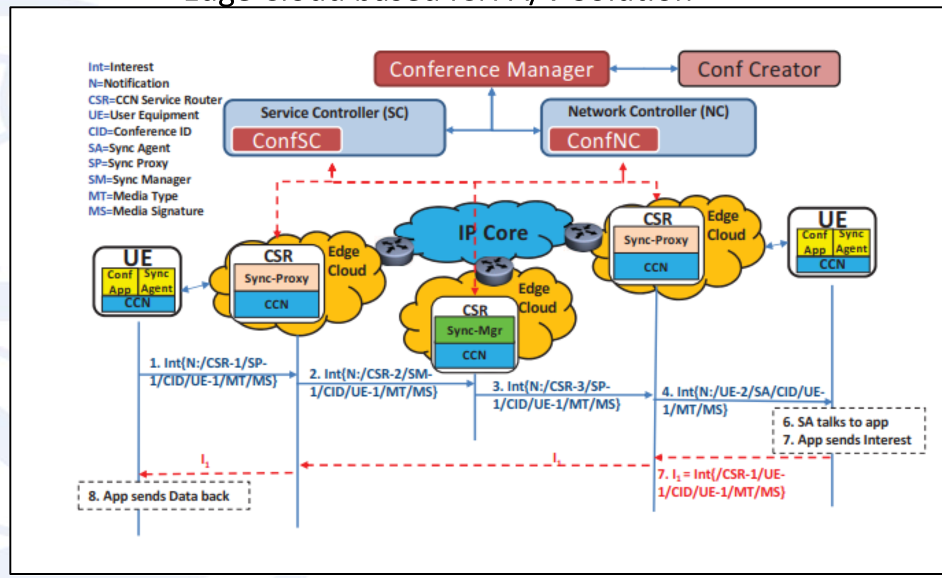
Edge Cloud based ICN A/V Deployment



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

Edge Cloud based ICN A/V Solution



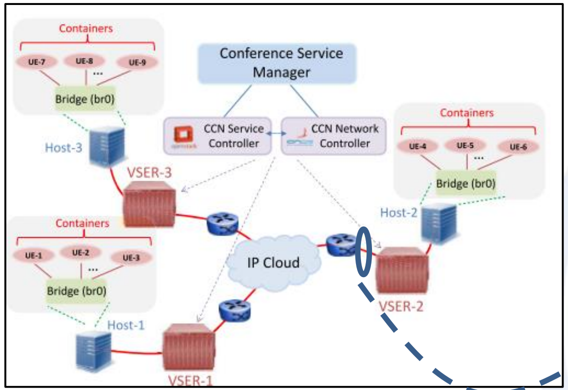
- Current solutions such as Skype, Goto-Meeting, Webex follows a client-server model and are made to scale restricting the number of active producers of media.
- CCN/NDN has to emulate PUSH behavior to meet realtime application requirements.
- Ad hoc participant joint requires immediate synchronization among producers and consumers
- The bottleneck in our design is the VSER because of unicast towards the participants and consumer due its producer state tracking algorithms

[1] Asit Chakraborti Syed Obaid Amin, Aytac Azgin, Ravi Ravindran, G.Q.Wang,, "**ICN Based Scalable Audio/Video Conferencing over Virtual Service Edge Router (VSER) Platform** " ICN Sigcomm, 2015

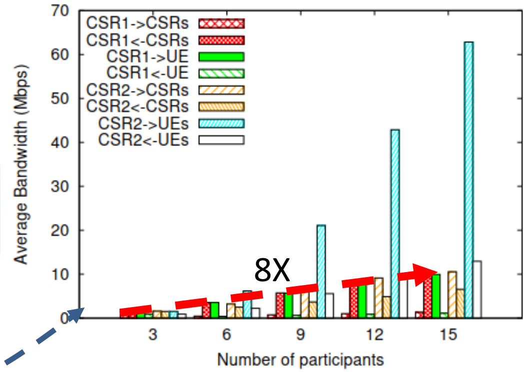
[2] Anil Jangam, Asit Chakraborti, Ravi Ravindran et al, "**Realtime Multi-Party Video Conferencing Service over Information-Centric Network**", Workshop on Mutimedia Streaming in ICN (MuSIC), 2015

[3] Asit Chakraborti et al, "**Design and Evaluation of a Multi-source Multi-destination Real-time Application on Content Centric Network**", HotIcn, 2018.

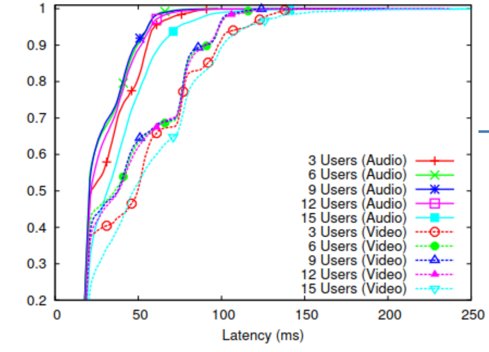
ICN A/V Conferencing Evaluation



Test Bed for Evaluation

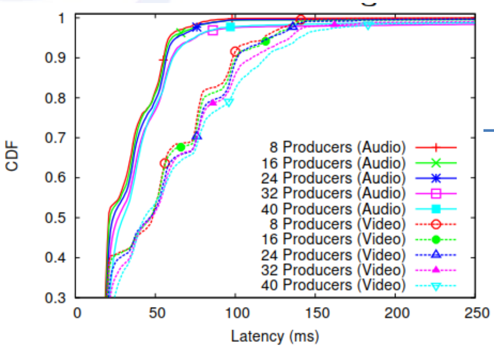


(b) Bandwidth utilization



(a) Audio/video latency performance

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



(a) Audio/video latency performance

→ For 40 producers and I Consumer Conferencing mostly < 150ms and 250ms for Audio/Video

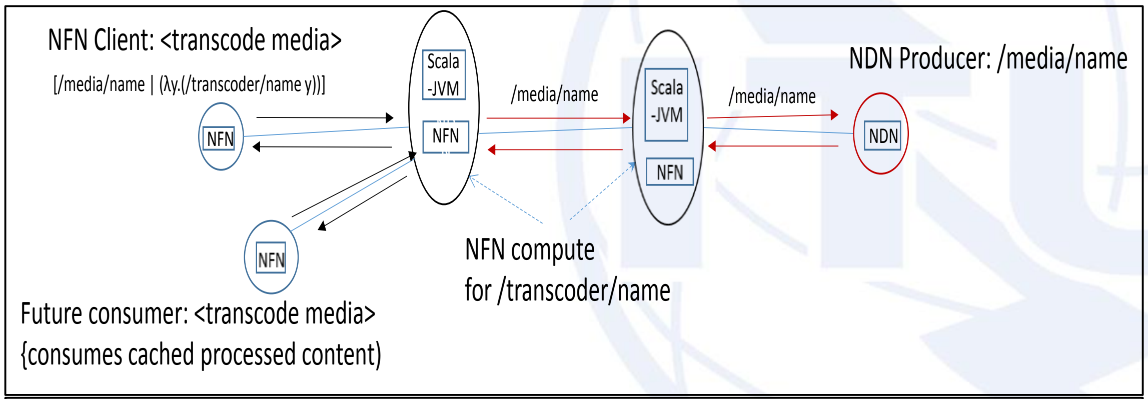
Set Up:
- 3 VSER and Host Nodes (*Intel – i7 family*)
- Participants emulated in Containers
- End-to-end IP Latency (15)ms

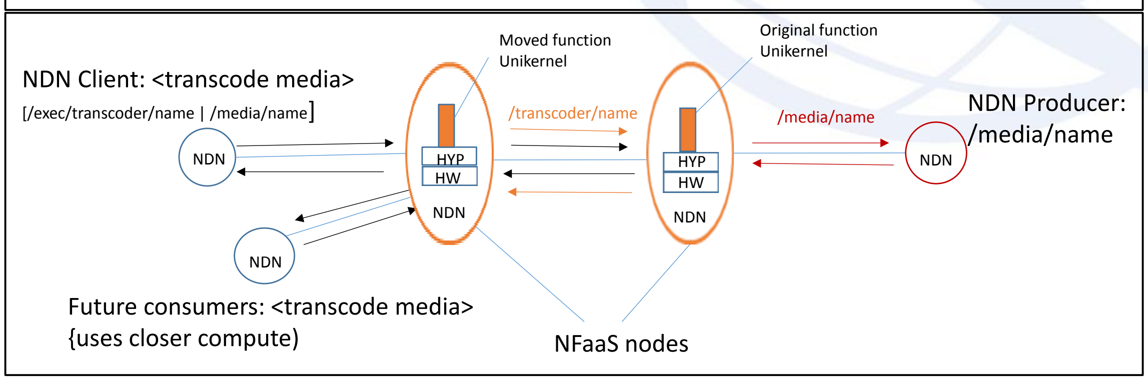
O(*N*) growth instead of O(N^2)
From 3 → 15 Participants :
~1 → 8 Mbps
(8X Instead of 25X)

[1] Asit Chakraborti et al, "**Design and Evaluation of a Multi-source Multi-destination Real-time Application on Content Centric Network**", (To Appear in HotICN, 2018).

Conclusion/Future direction

1. Edge computing based on host based networking
2. ICN slice (edge processing at the network layer – caching/aggregation)
3. ICN service slice (mobility/contextual routing to service)
4. In-network compute (NPU/GPU, dynamic compute allocation): including but not limited to NFN [1]/NFaaS [2]





NFN Characteristics:

- Goal is to delegate compute to stateless functions in-network
- Client requests contain expression with data and function name, NFN nodes can compute, forward or separate name and data and then forward
- Can pull compute towards data path, or push execution towards function repositories, functions move synchronously to client requests
- Challenges : New APIs, Latency

NFaaS Characteristics:

- Goal is to allow stateless service functions in-network and move them in strategic directions (i.e., towards edge)
- Routing based on service names, services figure out how to get data based on ICN principles
- Network layer uses context of passing data and heuristics to determine which functions to host
- Functions move asynchronous to client requests, using NDN like pull based mechanism
- Challenges : Unikernel acceptance

[1] named-function.net

[2] Michal, Krol, Ioannis Psaras; **NFaaS: Named Function as a Service**; ACM ICN 2017

Thank You and Questions ?