Realizing Mobility-as-a-Service (MAS) over CCN

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Agenda

• Mobility-as-a-Service
• ICN Network Architecture
• Mobility Service Control/Forwarding Plane
• Interest/Data Processing
• Producer Mobility Handling
  – UE versus Network Based Seamless Mobility
• Test Setup and Results
• Other Proposals
• Conclusions
Mobility as a Service Requirements

• **Realize mobility as a network service that can be enabled or disabled**
  – Leverage SDN/NFV framework tailored for ICN services.
  – On demand MAS provisioning
  – Realize mobility per application slice (5G)
  – With sufficient flexibility in the ICN network architecture this can be achieved

• **Enable mobility as a service for applications**
  – Name based networking allows that, as services can explicitly seek mobility service for a name.

• **Routing Stability**
  – Avoid Routing instability and churn due to end point mobility.

• **Scalability**
  – Both Intra- and Inter- domain scalability
    • Considering IoT devices for example.
  – Reduce Control/Data plane overhead

• **Name Persistence**
  – Application shouldn’t require any name reconfiguration due to mobility
ICN Network Architecture

• Many ICN architectures build on splitting ID and Locators e.g. MobilityFirst, NetInf etc.

• Introduces separation between ID and Locator Names in CCN.

• Separation has many use cases, mobility is only one of them.
  – Others include opportunistic routing, edge service affinity, in-network computing etc.

• **Forwarding-labels are carried as a fixed optional header**

• Network manages the mapping between the two name spaces
  – Doesn’t preclude the case of application using it e.g. towards Manifests.

• This is enabled through incremental enhancement over CCN to provide richer services in the network edge.

ICN Network Architecture

- **ISRs** are CCN Service Routers, where service functions can be plugged in to aid several edge services.
  - Mobility is one such service function
- **ICN-R** are CCN Relay Routers
- **ICN Service Controller** manages ICN Service Functions which can be plugged in any ISR nodes.
- **ICN Network Controller** allows dynamic provisioning of CCN FIBs based on Service Requirements.
- **Mobility Service Controller** manages the user profiles and the names to the locator name mapping.
  - Resolves the mapping from requests from the ICN infrastructure
- **This can also be realized within a transport capable of creating ICN slice.**
**Mobility Service Control Plane**

- **MS Agent** is a MS specific SF orchestrated by the Mobility Service Controller.
  - Registration/De-Registration of Service Names which require mobility.
  - Resolves Interest Names to locators through the MSC.
- **MSC** establishes a full meshed routing for the locator names, e.g. /isr-x
- **User Profile Manager** maps Services and the Names for which mobility is being handled
- **SAL/SAP** are control plane functions aiding ISR and MobilityService discovery, and mobility control.
- **SAL** also handles Mobility Service Signaling on behalf of the Application.
The mobility state is limited to the edges, i.e. in the ICN Service Router.

We introduce a new **Forwarding-Label Cache Table**, which is a cache table mapping the name to the locator name mapping.

The MSC controls the FLT entries, either through on-demand resolution or pro-active provisioning.

FLT is software defined and used by any other service, e.g. opportunistic routing.

The ISR applies LPM to match Interests to the FLT state.

Local MS Agent is used to resolve names to locators through the mobility service controller.
High Level Producer Mobility

- Seamless mobility is handled by the ISRs in the edges.
- The returned Content Objects are marked, triggering update by the ingress ISR.
- The state change to aid mobility can be UE or Network driven.
Interest Processing

Mobility Service requiring flows have prefix “/mobility-service”

Normal PIT/CS processing

Check if the FL is set?

• Here FL is not set.
  • Resolve FL using the MS agent in the ISR.
  • Update FLT Cache

1. Check if the FL matches the local locator name.
2. Check if the FLT cache resolves to the locator.
3. If the Interest terminates, use the FIB to do name based routing
4. Else forward on the forwarding label.
5. Flows can be identified using any other metadata in the Interest payload.
6. FL are swapped based on the FLT policies
Seamless Mobility Handling Details

Marking the ‘U’ turned Interests

→ Deals with MS-Agent Updates from new PoA to the previous one, and Interest Re-direction

→ Deals with Content Object Marking and Ingress ISR FLT Cache Update.
In UE based mobility, ISR discovery, Prefix Registration is handled by the UE.

Network based mobility assumes that the UE is provided the candidate list of ISRs by the network, based on SNR of the potential BS provided by the UE.

- The UE then chooses one from the list to handoff.
- The previous ISR then pro-actively replicates Interest to the set of potential ISRs in the candidate list.
  - Accurate prediction can reduce the replicated Interest traffic.
- MS Agent sets the FLT cache table to multi-unicast the Interest to these candidate list of ISRs.
Handover Delay Components

- **UE Based Mobility:**
  \[ t_{\text{handover}} = t_{\text{attach}} + t_{\text{isr-discovery}} + t_{\text{isr-update}} + t_{\text{path-redirection}} \]

  - Transport delay (PHY/MAC/IP)
  - ICN Signaling + Interest Redirection Delay (Interest Packet Loss)

- **Network Based Mobility:**
  \[ t_{\text{handover}} = t_{\text{attach}} + t_{\text{isr-discovery}} + t_{\text{isr-update}} + t_{\text{path-redirection}} \]

  - Components NBM tries to avoid, using network provided information as the candidate ISR list.
**Test Setup and Evaluation**

- **Topology**: 3 ISR, ICN-R, and Wifi Radio
- **Controllers**: Open Stack for Service Functions and Floodlight for Network Control.
- **Producer**: Real-time video conferencing, 25fps, Xuggler (FFMpeg Library/H.263), 1-2Mbps
- **Consumer**: Notification driven content fetching

The results show the Consumer side performance, frames are aggregated every 250ms

- Producer Handoff is varied b/w 3/5/7 sec.
- From (a) Packet loss in Network Based Mobility scheme correlates with the handoff duration.
  - As the network handles the Producer state transfer, and immediate re-direction of traffic to the set of candidate ISRs
- While in CBM (a), it correlates with hand-off and the signaling required to set up prefix state in the new ISR and signaling between the new and the old VSER before the traffic is re-directed.
- Fig (b), shows the performance remains unaltered with varying handoff duration.
Other Proposals.
Anchor-based Approach to Mobility (Kite)

Basic Issues
- Overhead
- more Static than Dynamic
- Path Stretch
- Security

Update on Interest packet format
- Trace Name
- Trace Only
- Traceable
  - Trace + FIB, or Trace Only
  - Traceable flag
  - Trace, or not to Trace

Content Router components
- Content Store (CS)
- Pending Interest Table (PIT)
- Forwarding Information Base (FIB)
- Trace Name Table: to store tracing Interests (from PIT)
- Trace Forwarding Table: to store traced Interests

- Propose new components at the content router: **Trace Name Table** and **Trace Forwarding Table**
- Propose new Interest packet headers: **Trace Name**, **Trace Only** flag, and **Traceable** flag
- Potential issues: overhead of setting up and maintaining traces, path stretch due to use of application-specific anchors, concerns on security, etc.

Anchor-less Approach to Mobility

As Producer moves, Interest Update messages are sent to Producer’s previous location (using FIB) to update Temporary-FIB entries.

Interest Notification messages are sent to Point of Attachments to trigger local Temporary FIB update, with previous PoAs broadcasting received Interests to its neighbors.

- Propose new component at the content router: Temporary FIB
- Propose new types of Interests: Interest Update and Interest Notification
- Routing Churn issue due producer mobility
- Potential issues: scalability (in number of mobile hosts and traffic rate), limitations due to PoA support requirements (if not supported at all points, seamless mobility cannot be guaranteed)

Conclusions

• ICN-centric SDN/NFV framework allows one to realize Mobility as a service, useful towards 5G services.
• Distinguishing ID and locator names in the protocol can be used for many purposes, we showed its use for Mobility.
• The seamless mobility is handled by the service edge routers.
• Incremental changes proposed for CCN to handle ID-Locator state information in the packet.
• Two types of mobility have been proposed to address seamless mobility handling: UE and Network based mobility.
• More study to be done on these proposed mobility mechanisms considering practical radio conditions and mobility patterns.