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

Ravi Ravindran, Asit Chakraborti, Aytac Azgin
(Huawei Research Center, Santa Clara)
ravi.ravindran@huawei.com

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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

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# 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

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# 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.
  - Forwarding-label draft : https://tools.ietf.org/html/draft-ravi-ccn-forwarding-label-01
- 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.

[1] Aytac Azgin, Ravi Ravindran, G.Q.Wang, "**Scalable Mobility-Centric Architecture for Named data Networking**", IEEE, ICCCN (SCENE Workshop), 2014

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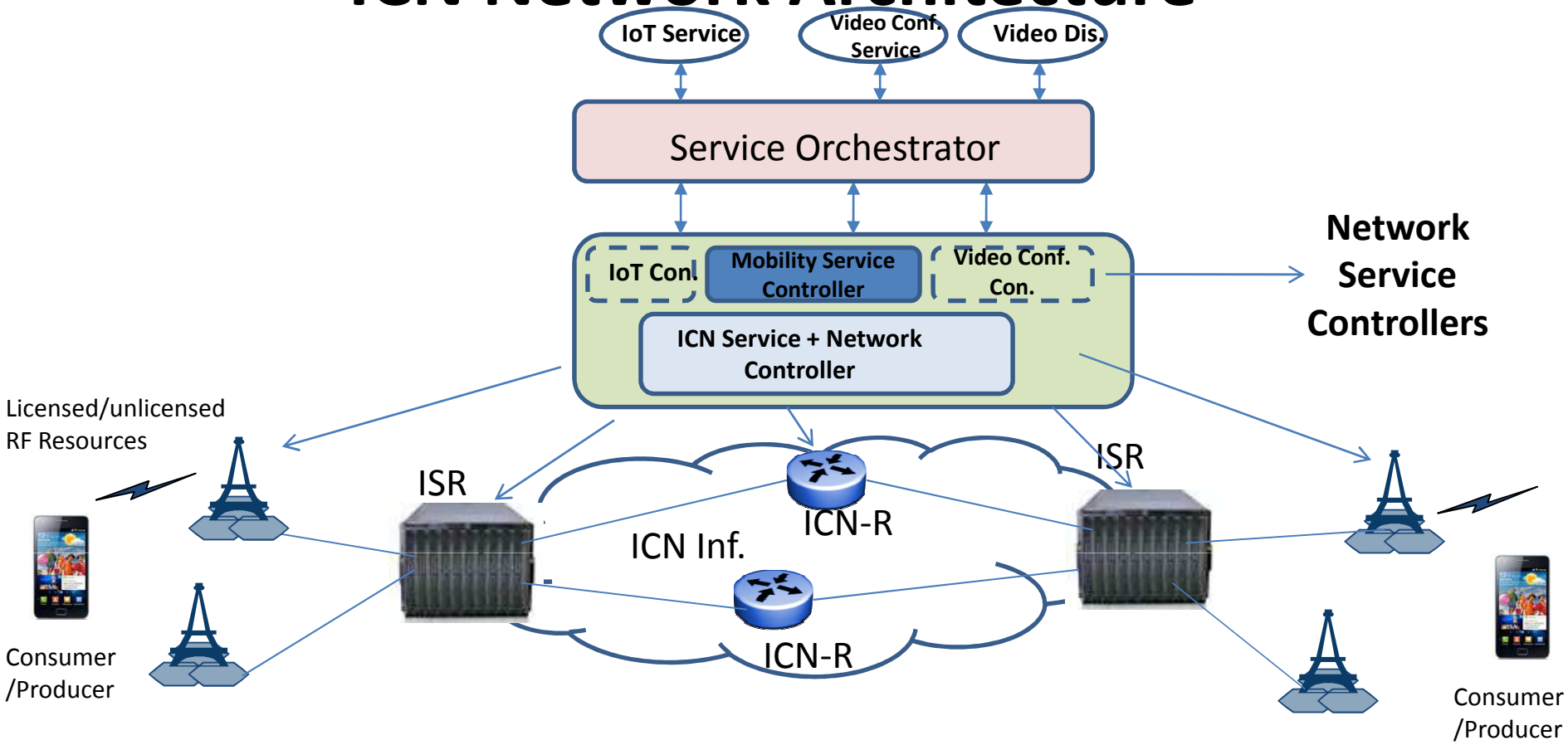
# ICN Network Architecture




- **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.

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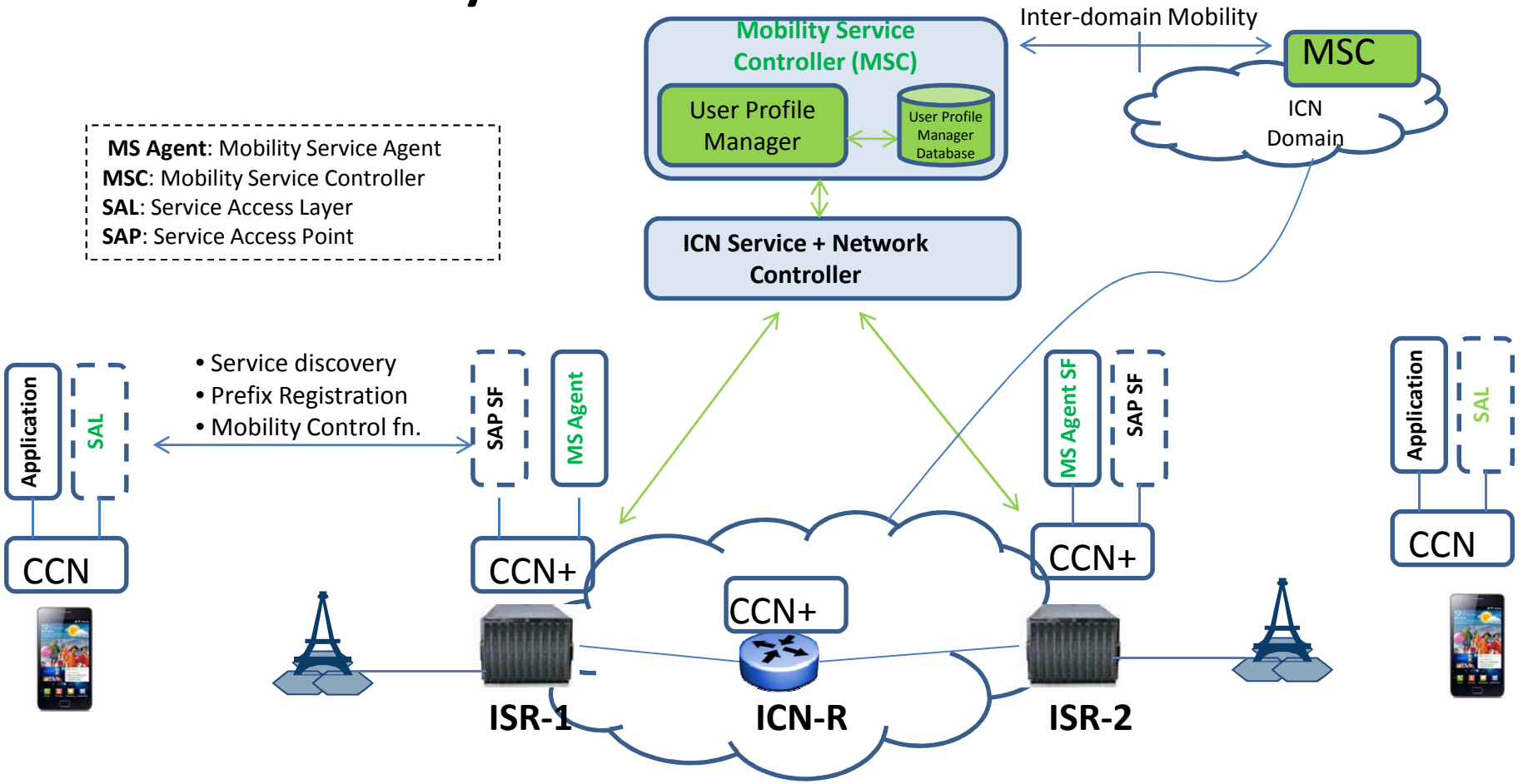
# Mobility Service Control Plane




- **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.

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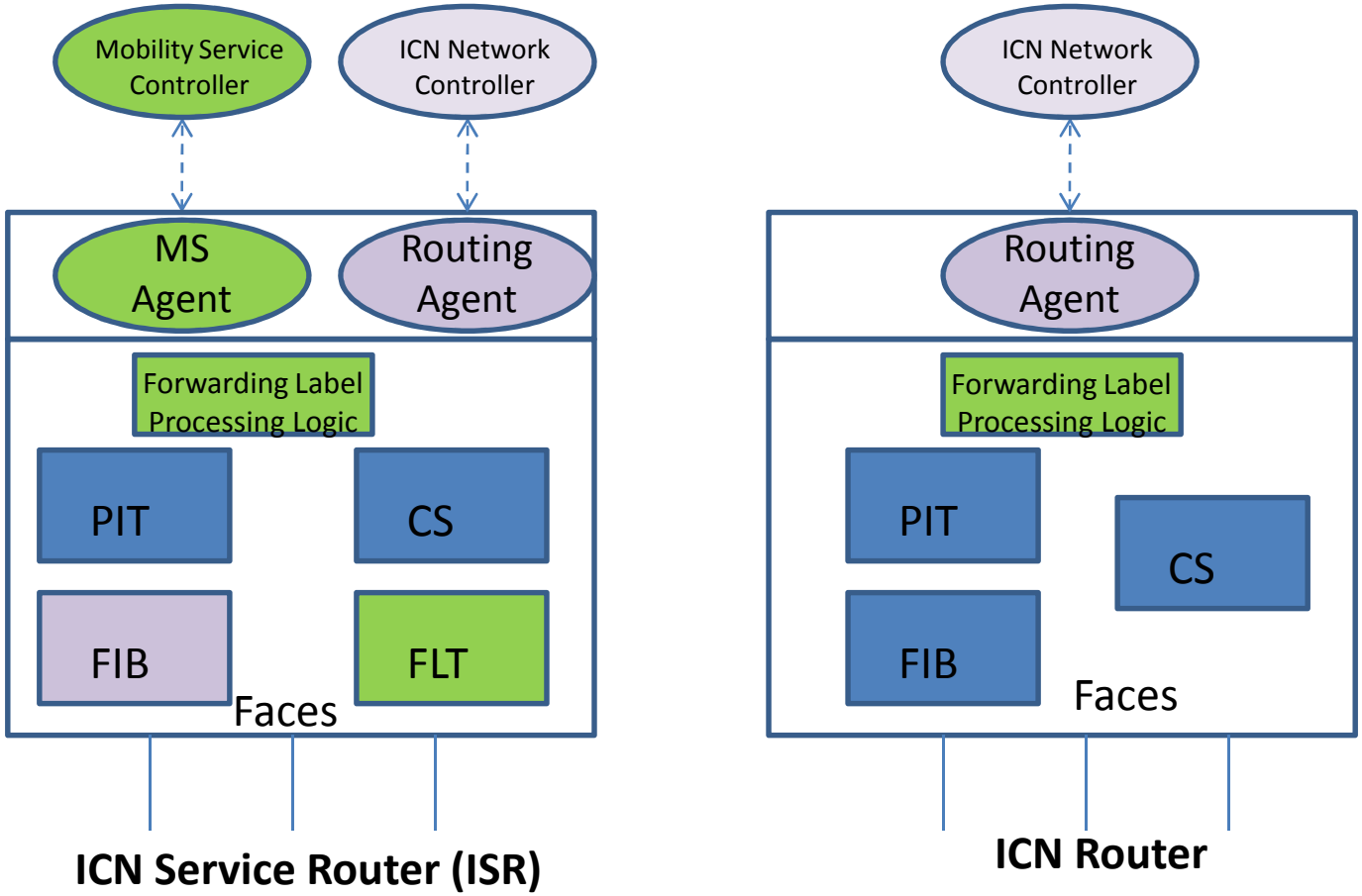
# ICN Data Plane




- **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.

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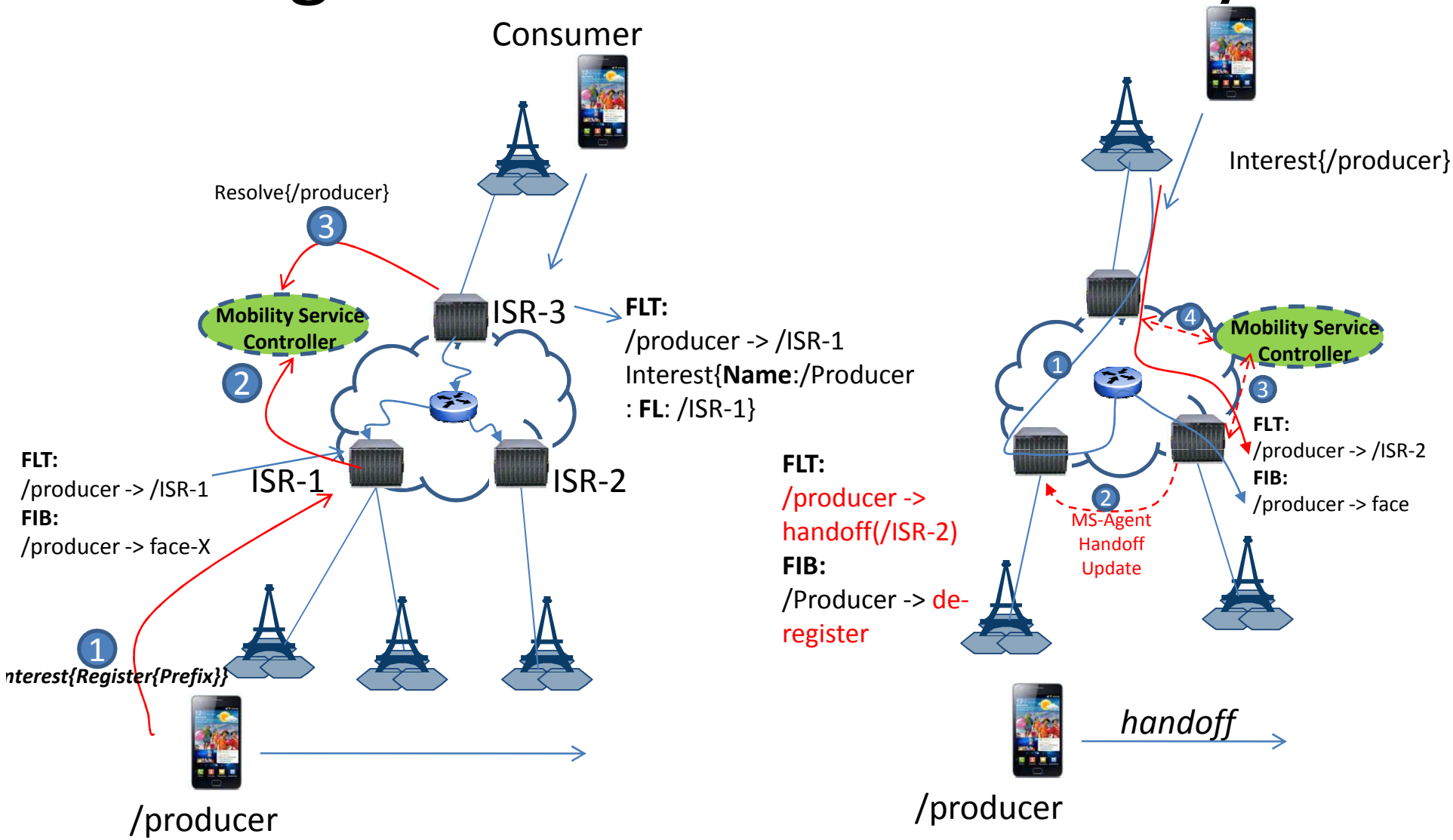
# High Level Producer Mobility




- **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.**

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# Interest Processing

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

1

2

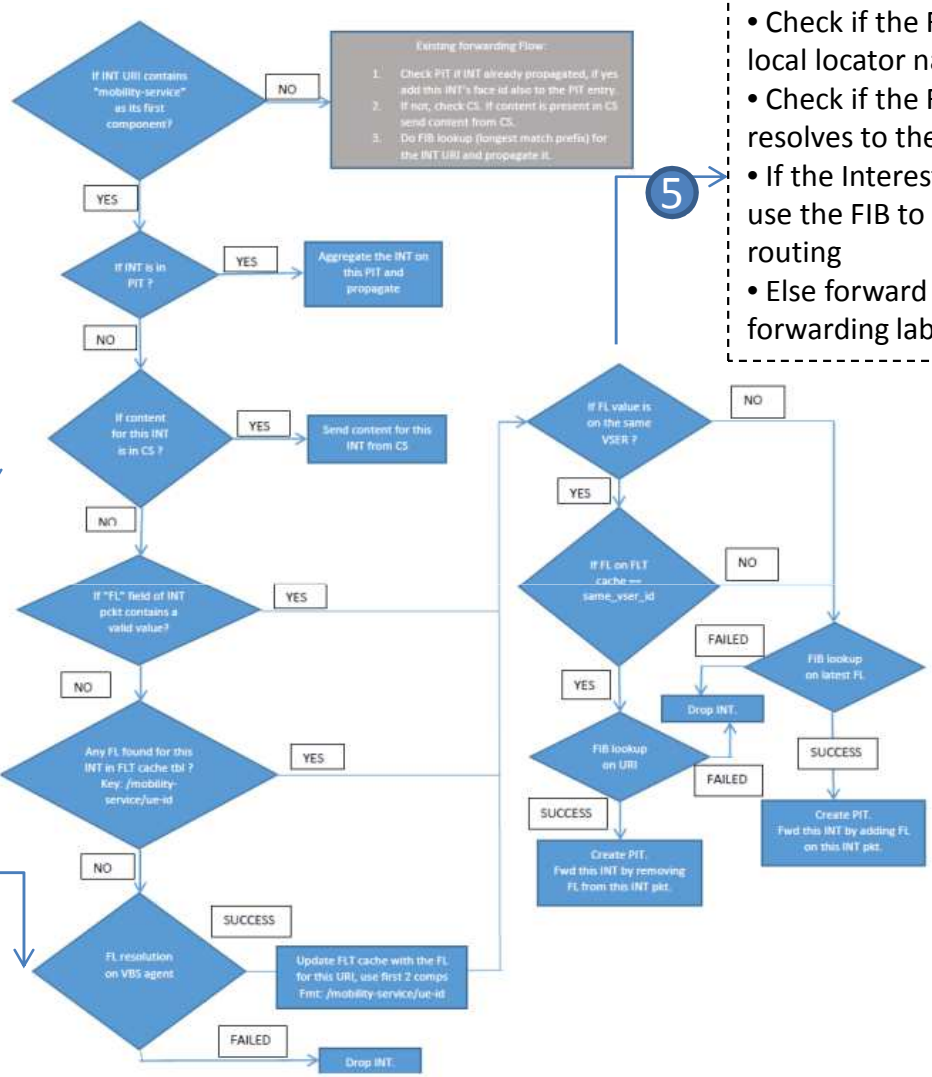
Normal PIT/CS processing

Check if the FL is set ?

3

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

4




5

• Check if the FL matches the local locator name.
• Check if the FLT cache resolves to the locator.
• If the Interest terminates, use the FIB to do name based routing
• Else forward on the forwarding label.

- Flows can be identified using any other metadata in the Interest payload.
- FL are swapped based on the FLT policies

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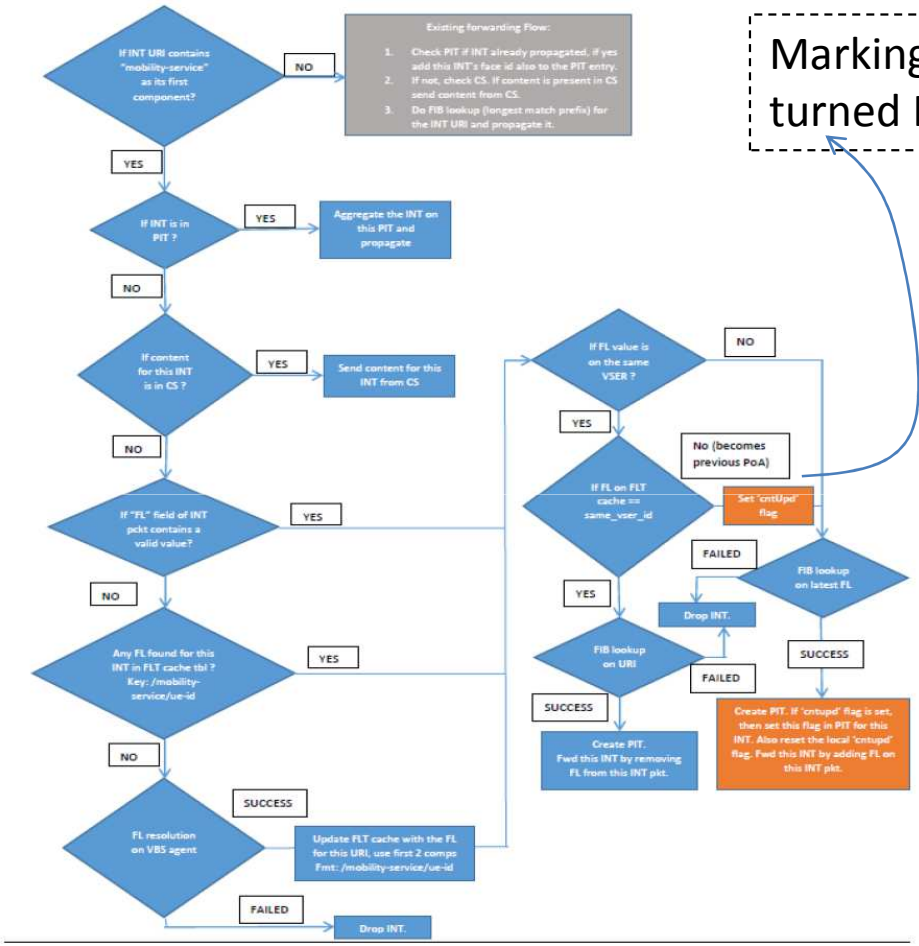
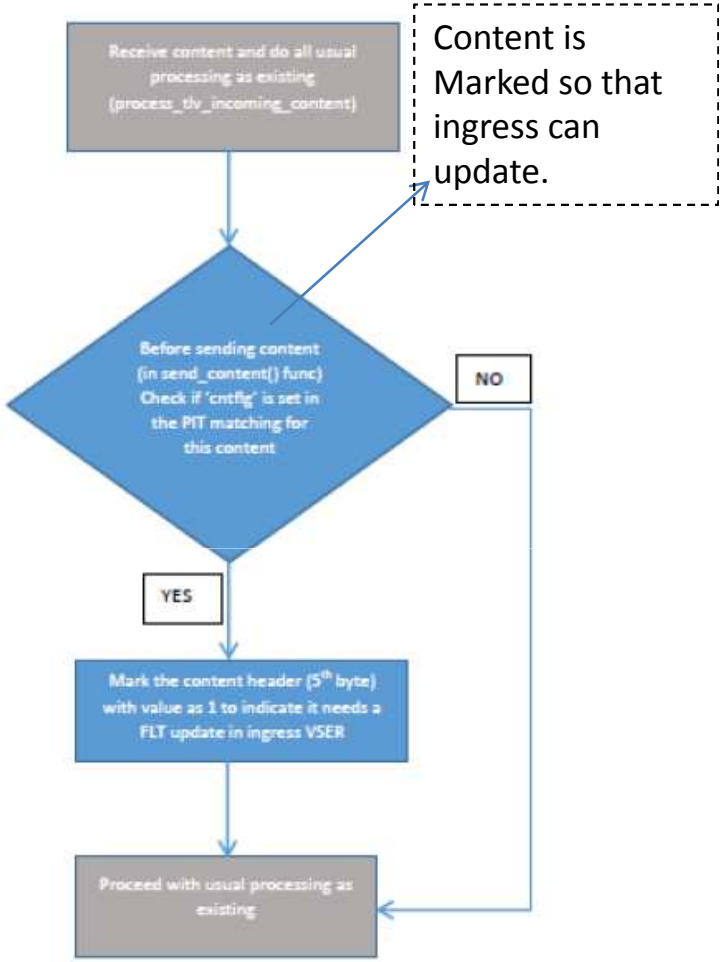
# Seamless Mobility Handling Details




Marking the 'U' turned Interests




Content is Marked so that ingress can update.

→ 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.

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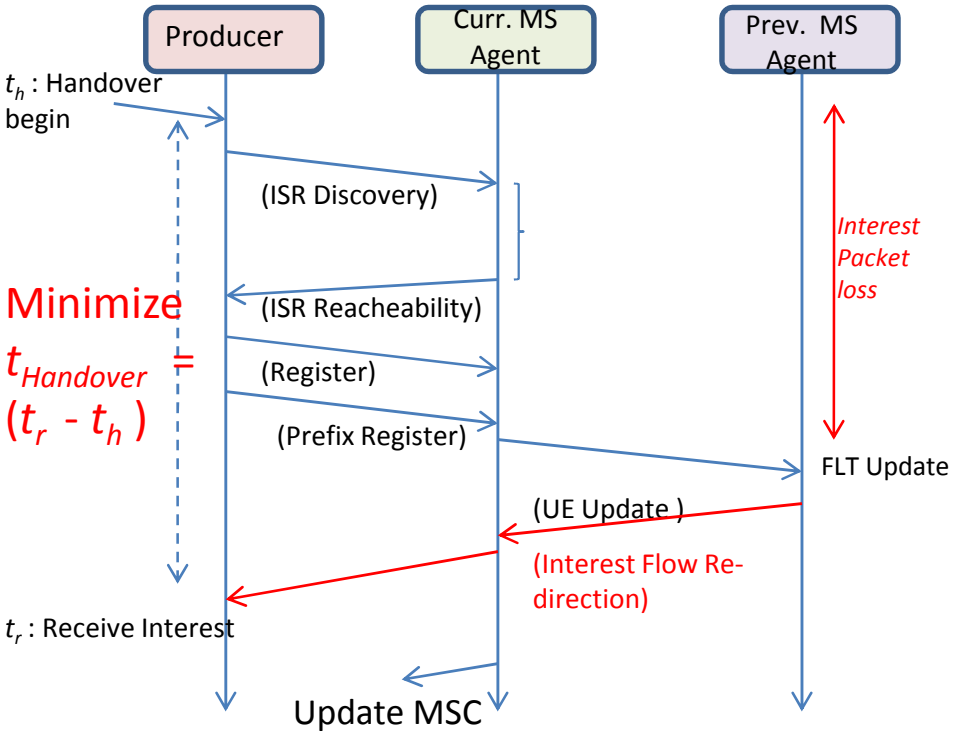
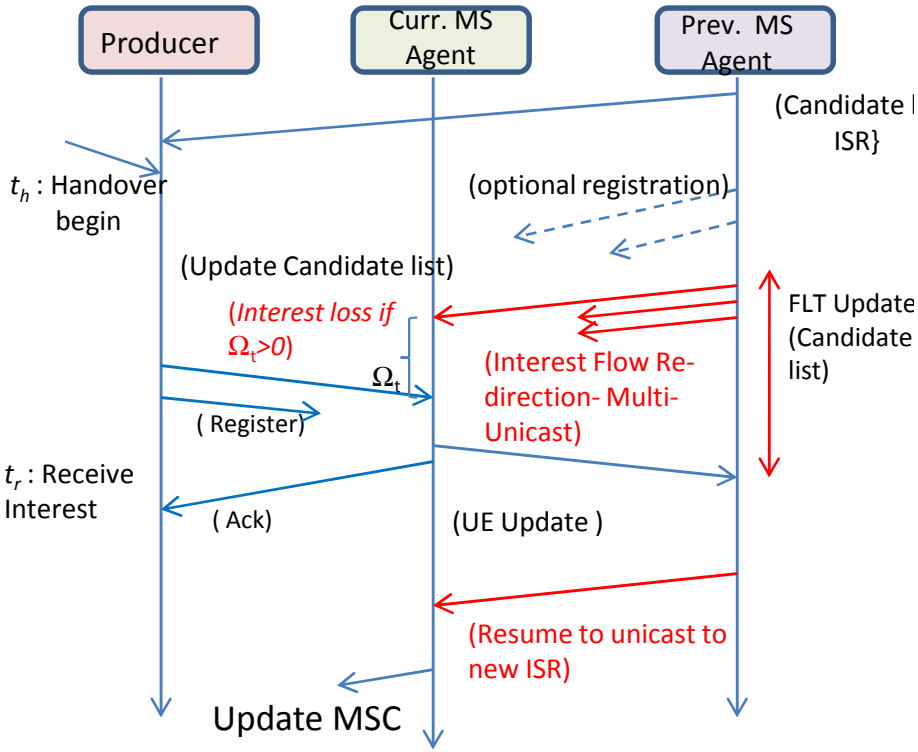
# UE Based Versus Network Based Mobility




**(a) UE Based Mobility**




**(b) Network Based Mobility**

- 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.

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# Handover Delay Components

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

Transport delay (PHY/MAC/IP)

ICN Signaling + Interest Re-direction Delay *(Interest Packet Loss)*

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

Transport delay (PHY/MAC/IP)

*→ Components NBM tries to avoid, using network provided information as the candidate ISR list.*

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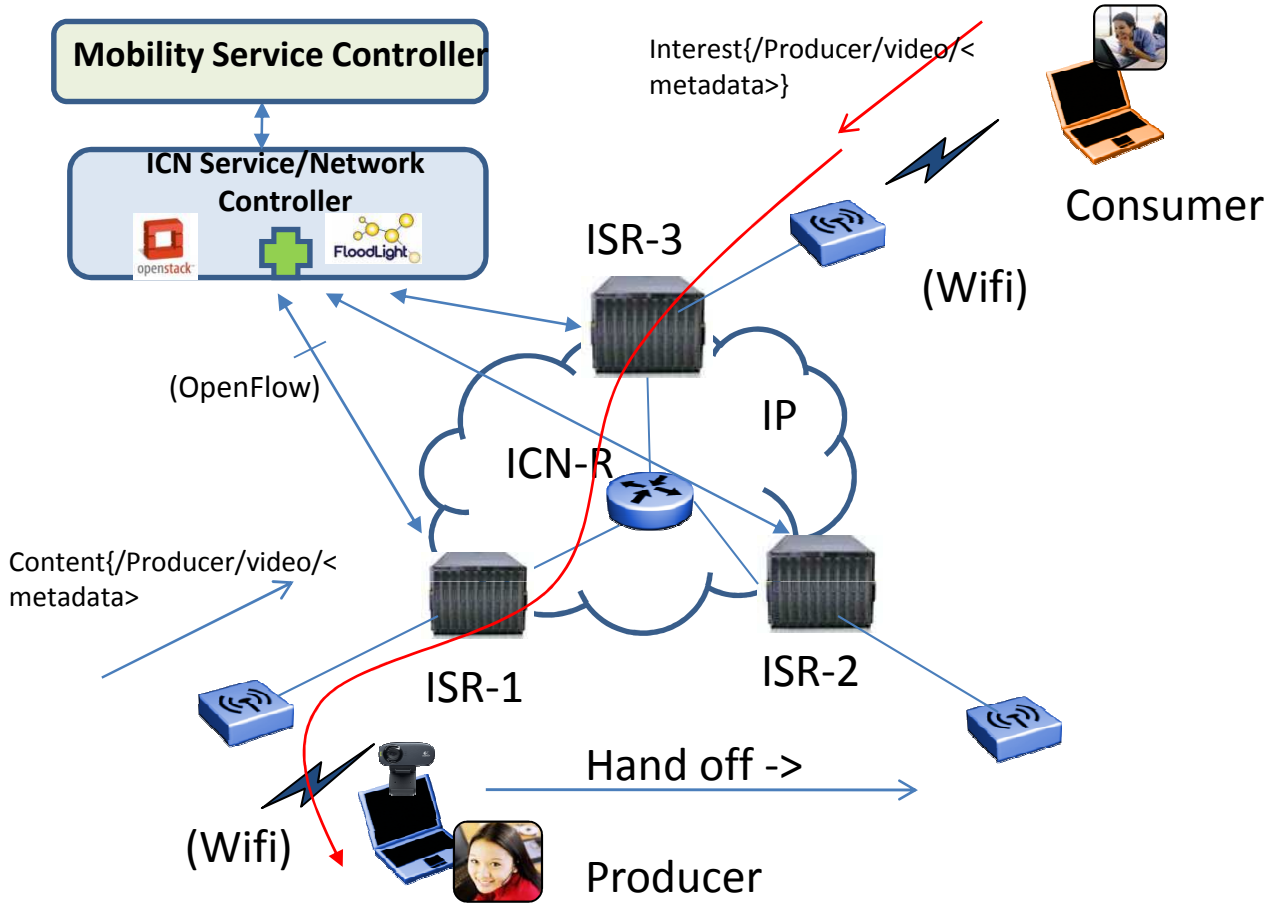
# Test Setup and Evaluation




- **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


[1] Asit Chakraborti, Aytac Azgin, Ravi Ravindran, G.Q.Wang, "**A Scalable Video Conferencing Framework over Virtual Service Edge Router (VSER) Platform**", ICN, Siggcomm, 2015 (Demo)

[2] Anil Jangam, Ravi Ravindran, Asit, Xili, G.Q," **Real time Mutli-Party Video Conferencing Service over Information-Centric Network**", ICN, MUSIC Workshop, 2015.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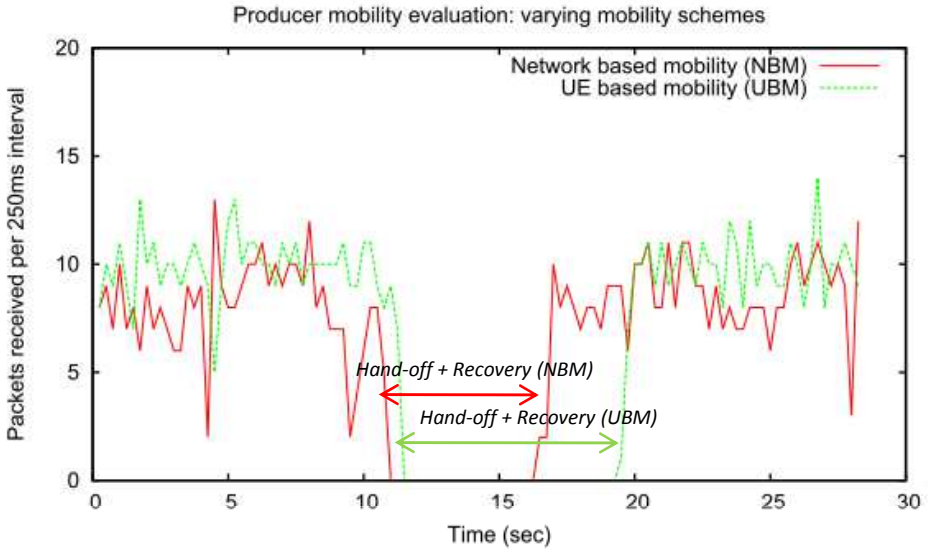
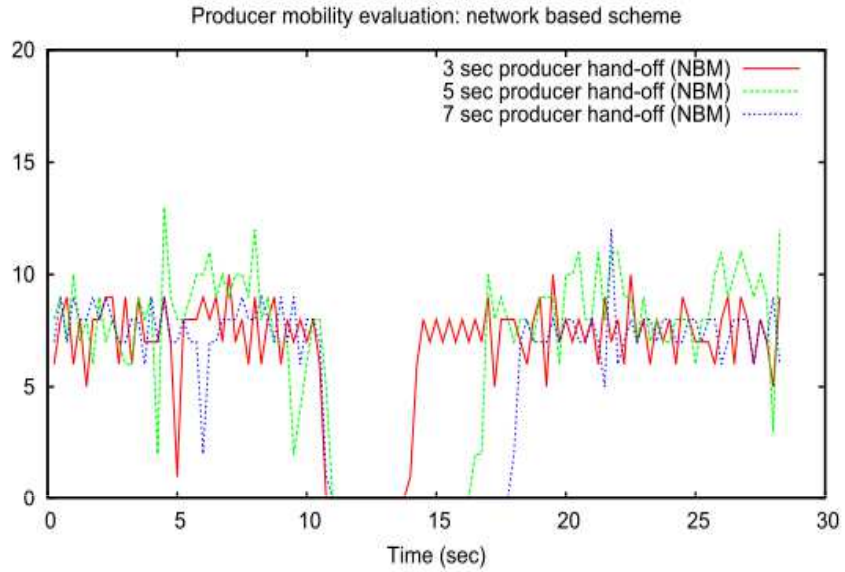
# Producer Mobility Evaluation




**(a) Consumer Performance for NBM and UBM with 5s handoff.**




**(b) Consumer Performance for NBM with varying Handoff (3/5/7s).**

- 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.

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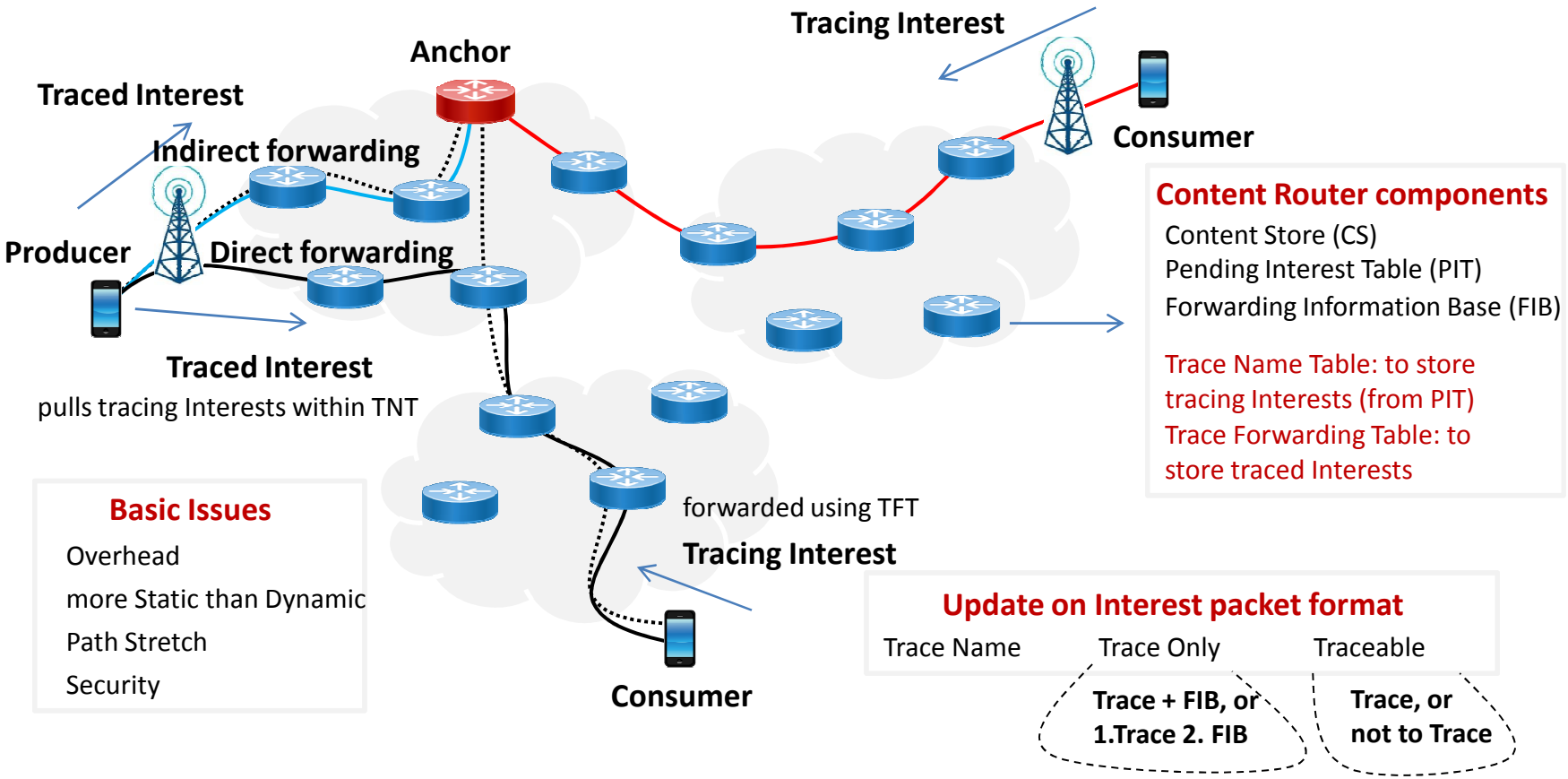
# Other Proposals.

# Anchor-based Approach to Mobility (Kite)




- 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.

"Kite: A Mobility Support Scheme for NDN", Y. Zhang, H. Zhang, L. Zhang, ACM ICN 2014.

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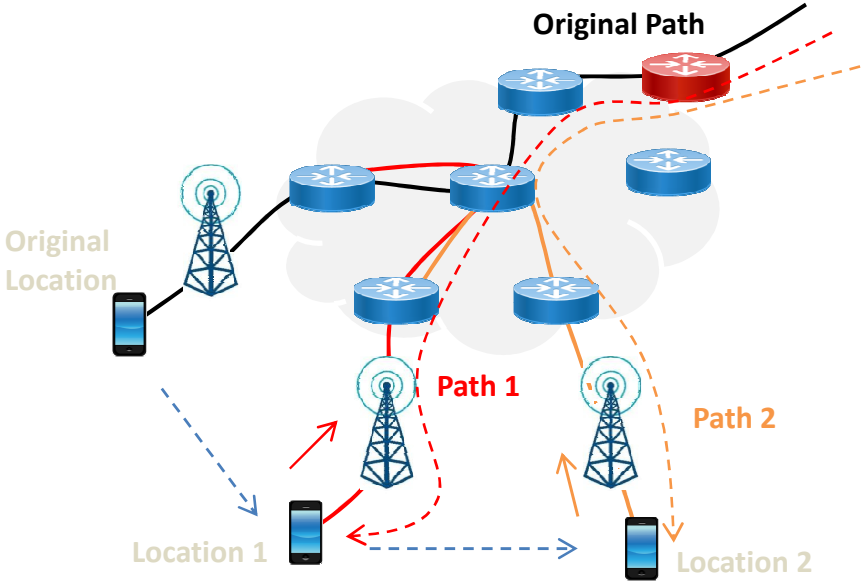
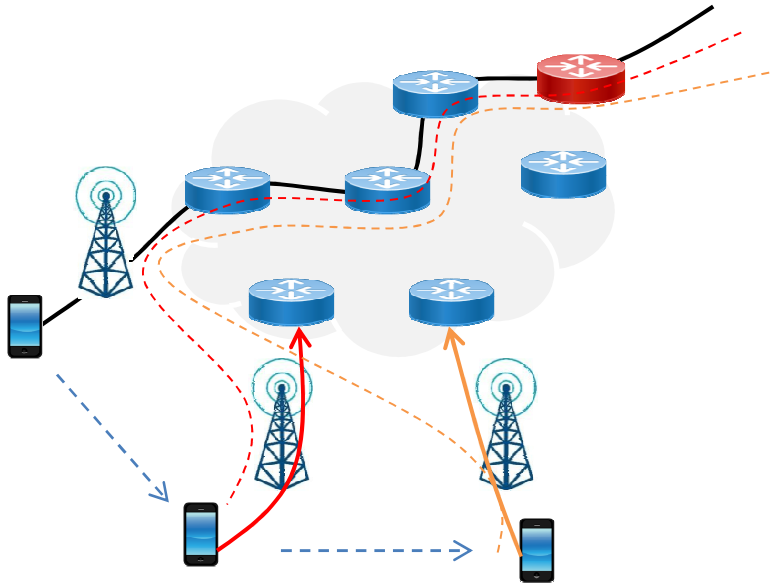
# Anchor-less Approach to Mobility




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)

"Anchor-less Producer Mobility in ICN", J. Auge, G. Carofiglio, G. Grassi, L. Muscariello, G. Pau, X. Zeng, ACM ICN 2015.

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# 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.

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