Enabling Network Identifier (NI) in Information Centric Networks to Support Optimized Forwarding

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Draft ToC

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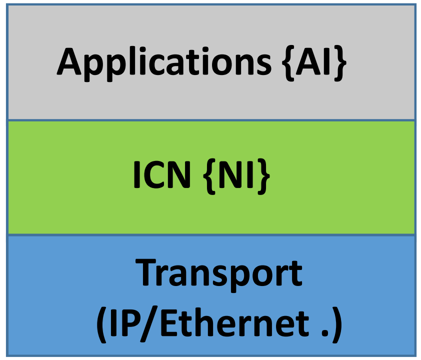
Draft Motivation

- Here ICN=CCN=NDN
- Over the last few IETFs, we proposed the Forwarding-Label draft. (https://www.ietf.org/internet-drafts/draft-ravi-icnrg-ccn-forwarding-label-00.txt)
- Forwarding-Label are network identifiers appended to Interest for efficient routing. Proposed as a network service to handle :
  - Edge Computing – replicated Services and Content, Off-Path Caching, Mobility, Routing Scalability.
- An implementation of this idea for producer mobility in CCN, and paper was presented at 5G/ICN workshop at ICN Siggcomm.
  - Aytac Azgin et al, "Seamless Producer Mobility Support as a Service in ICN" http://conferences2.sigcomm.org/acm-icn/2016/proceedings/p243-azgin.pdf
  - Demo of this solution was also made in ICN Sigcomm in the context of CCN.
- During recent harmonization discussion, there was discussion comparing Forwarding Labels and Link Objects proposed by NDN.
- FL are similar to Link Objects, but with more flexibility.
- The draft proposes the notion of a Network Identifier as an architectural construct to generalize FL or Link Object in ICN architecture to achieve maximum Interest routing and forwarding efficiency.

Application Identifiers Versus Network Identifiers.

- **Application Identifiers**
  - Persistent in nature, could name services, content and devices
  - Security and Trust associated with Names
  - Non Topological
  - Managed by Application Provider
  - Two well known formats, Hierarchical and Flat
    - Naming is application defined, hence should include both these formats
  - AI is a ever growing set :
    - New hundreds or millions domain registrations and second level goes to billions [1]
    - Naming IoT content and devices – 10-50B; ICN estimates 10^{15} [2]



- **Network Identifiers**
  - Topological or Mathematical embedding
  - Designed for scalable routing and high speed forwarding
  - Managed by the network provider
  - Names Network Entities (Domains, Routers, PoA and End Points)
  - NI name space grows at much slower rate than the AI space
  - NI name space can be identifiers from other realms e.g. IP, Ethernet etc.

→ Hence if is stability and scalability are ICN design factors, NI based routing and forwarding makes practical sense.

[1] Verisign, “The Domain Name Industry Brief”, 2016
[2] Borje Ohlman, “From ID/Locator Split to ICN”, IEEE, CCNC, 2015

Issues with ICN Routing with AI

- **Mobility**
  - AI based routing is infeasible with mobile producers.
  - Mobility [2] reports that a host changes more than 20% of hosts make more than 10 network address transitions a day
  - Also each mobility event associated with a device or a popular content may trigger updates on up to 14% of Internet routers.
- **Replication**
  - With Edge Computing and CDN like services replication of content and services will be a norm
  - [1] estimates that as replication increases from 10% to 200%, FIB size increases 200*X → 1000*X
- **Scalability**
  - AI has no topology aggregation properties, scalability is a challenge
  - Disaggregated AI name space is a very large set to scale routing
- **Different Objectives**
  - AI designed for to meet application requirements and not for routing/forwarding optimization
  - Direct correlation between Naming and Routing/Forwarding Stability and Scalability
  - This correlation also has other challenges such as name-suffix black holing [1]

[1] Adhatarao, S., Chen, J., Arumaithurai, M., Fu, X., and K. Ramakrishnan, "Comparison of Naming Schema in ICN", IEEE LANMAN, 2016

[2] Gao, Z., Venkataramani, A., Kurose, J., and S. Heimlicher, "Towards a Quantitative Comparison of Location-Independent Network Architectures", ACM SIGCOMM, 2014.

Binding between AI and NI

- AI based routing and forwarding is feasible within local domains
  - Scalability is not a concern and when dynamism is minimal
  - Using hierarchical or even flat names in local domain context
  - Useful in Ad Hoc scenarios, where AI is not pre-known, but requires suffix name filters
- AI and NI binding required for multi-domain connectivity when scalability and dynamism is involved
- **Hence this binding is optional in the sense that - Interest may be routed based on AI, NI or both based on the network segment**
  - Most requests crosses local domains, hence support for NI becomes crucial

- Introducing NI in ICN doesn’t affect any current properties: Location Independence, Consumer Mobility, Symmetric Routing, Multi-Homing or Multi-Path Routing.
- Rather it enables : Off-Path Caching, Producer Mobility, Conversational session requirements.

Two proposals of Network Identifier (NI)

- Forwarding Label Object [1]
  - Towards more Routing Flexibility. FL identifies domains, routers, PoA etc.
  - Appended to the Interest by the Network based on service requirements.
  - Part of the fixed header
  - FL is mutable – it can be swapped or removed by network elements
    - Enables Late Binding feature
  - FL Object has the NI and an optional security object to bind AI to the NI.
  - Allows network service metadata to allow FL management based on its use case scenario
  - FL takes precedence over AI in the Interest
  - One can route on AI in one domain and then swap with FL in another domain.
  - AI to FL mapping is managed by a cache table in the edge routers

[1] Ravi Ravindran Aytac Azgin, Asit Chakraborti, "Forwarding-Label support in CCN" https://www.ietf.org/internet-drafts/draft-ravi-icnrg-ccn-forwarding-label-00.txt

[2] Afanasyev, A., Yi, C., Wang, L., Zhang, B., and Zhang, L., "Map-and-Encap for Scaling NDN Routing", NDN Technical Report, ndn-004-02, 2015.

Proposals for NI

- Link Object [1]
  - Towards Routing Scalability. Identifies Zones or Domains.
  - Serves as an hint to the forwarder, so is used only if name based routing fails
  - Part of the Application Payload
  - Resolved by the Consumer – an Application level construct
  - Immutable, hence cannot change during forwarding
    - Similar to Early binding
  - Contains a link header and signed by the Producer for authentication
  - May contain multiple Links which the forwarder can choose to forward on
  - A delegation header is used to represent the link choice by the previous forwarder, hence is changeable

[1] Afanasyev, A., Yi, C., Wang, L., Zhang, B., and Zhang, L., "Map-and-Encap for Scaling NDN Routing", NDN Technical Report, ndn-004-02, 2015.

Side-by-Side Comparison

Feature	Forwarding Label Object	Link Object
Requirement	Routing Flexibility and Scalability	Routing Scalability
Scope	Network Scope	Application Scope
Resolution	Network and End Points	End points
Mutability	Mutable (Late binding)	Immutable (Early Binding)
Security Binding	Binding Optional	Binding is Mandatory
Priority	Prioritized over AI	Names Before Link Object always

Name Resolution System Design Choices

- **Hierarchical System**
  - AI/NI mapping is managed by Application Providers
  - Follows DNS hierarchical architecture
  - NDNS is an example of such a system
  - Good for static named resources rather than dynamic entities
  - Has to scale to a large set of named resource, beyond just the set of host names

- **Network Integrated Flat System**
  - Flat Architecture
  - Routers uses a part of its compute and storage to enable this as a network service
  - The Integration allows multiple ways of designing an NRS
  - Good scalability and proven handling of dynamic updates
  - MobilityFirst's GNRS is an example of this

- **Distributed System**
  - A distributed domain based NRS
  - Exploits the context in name to map the resources to their home controller
    - E.g. /company/content-id maps to /company/resolver-id.
  - Home Controllers further doesn't sync with any higher controllers
  - Scalable and can handle dynamic updates

AI/NI in ICN versus ID/Locator Systems

- Here we are compare with HIP/ILNP/LISP proposals
- They address the problem of routing scalability, multihoming, mobility, security challenges preserving IP’s host-centric communication model.
- ICN focusses on a network layer where name based routing, caching, mobility, multihoming are integral features

Conclusions

- Considering Link Object, Forwarding Label, Locators in Nameless Objects proposals – suggest to formalize the notion of AI/NI in ICN
- Make it part of the terminology document
- Next steps would be understand its incorporation into the ICN protocol architecture
- FL and Link Objects are two proposals, harmonize this to afford maximum flexibility towards ICN routing and forwarding.
- More comments ?