ICN Research Challenges

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Document Purpose

- **WHY**
  - Problems and pain points in today's networks
- **HOW** can ICN help
  - Fundamental ICN concepts
- **WHAT** to do in ICNRG
  - Research challenges, important topics
- Possible **RESULTS**
  - Impact on IETF work

Note:

- Originally titled "Problem Statement"
- Discussion whether this is useful
- General consensus: rather describe expected challenges, i.e., topics to be worked on
- Want to add
  - some motivation (what are the critical issues, why do we do this)
  - explanation: what is the general idea (concepts)
- Hence the following structure...

Structure

1. Introduction
   - example pain point, example ICN solution, brief concept overview
2. Problems with information distribution today
   - Inefficiencies, security issues
3. Concepts
   - Requesting named-data as a first-order network service
4. Research Challenges
   - naming, security, routing, name resolution, transport, caching, interconnection, management, mobility management
5. Impact on IETF work
   - anticipated changes to Internet architecture and protocols, relation to existing work (e.g., CDNI)

Problems with Information Distribution Today

- Today's overlay approaches to CDN, M2M vs. accessing named data on network layer
- Sub-optimal routing
- Difficulties in leveraging multicast/broadcast capabilities
- Difficulties in establishing direct communication
- Application-specific approaches to caching, replication

ICN Concepts

- Accessing named data objects as a first-order network service
- Name-content binding validation and other features
- Leveraging ubiquitous storage
- New options for transport

Naming and Security

- Currently describing hierarchically structured and flat names
- Describing static and dynamic object naming challenges
- Requestor privacy
- Updating and versioning
- Managing object accessibility

Transport Services

Research challenges:

- Several possible path between a sender and a receiver
  - How to utilize multiple sources?
  - How to control data rate on multiple paths?
- Requests can be aggregated by routers
  - How to make the distinction between retransmissions or new requests?
  - How can a source determine the number of requesters?
- Receiver-driven communication or Router-driven communication?

In-Network Caching (1/2)

Three main challenges:

- Cache Placement
  - On-path vs off-path
  - Is on-path on-shortest(-BGP)-path?
  - Off-(shortest-)path has been investigated a lot
  - On-path is more challenging
- Content Placement - Content-to-Cache Distribution
  - What is to be cached and who decides?
  - What are the criteria/metrics to decide where to cache what?
    - Popularity, traffic characteristics?
  - How big should caches be?

In-Network Caching (2/2)

- Request-to-Cache Routing
  - Relates to name-based routing
  - Relates to collaboration between the data and control places
  - Do we allow for cache-aware routing? And who is "aware"?
    - Cache-aware routing introduces complexity, but
    - Cache-unaware routing reduces chances of cache hits
  - Affects traffic dynamics through request redirection

Routing and Resolution System Scalability [1/2]

	Numbers	Comments & reference
Size of BGP routing table	**4.5*10^5**	Now, an up-to-date BGP router is working with this number. [bgp.potaroo.net]
Technically speaking	**10^11**	Back in 2007, that number of data objects could be supported technically - DONA.
Domains	**4.6*10^7**	Routing with domain names? [www.domainworldwide.com]
Indexed web pages	**5*10^10**	Google's indexed web pages [www.worldwidewebsize.com/]
Indexed URLs	**10^12**	Google's indexed URLs back in 2008 [www.pcworld.com]
Do we expect more ?	**10^22**	Updated or version up data object, a group of data objects, or more and more.

Routing and Resolution System Scalability [2/2]

<table>
<tr><th></th><th>Route-By-Name Routing (RBNR)</th><th>Lookup-By-Name Routing (LBNR)</th><th>Hybrid Routing (HR)</th></tr>
<tr><td>Operation</td><td>Discovery - Delivery</td><td>Resolution - Discovery - Delivery</td><td>RBNR + LBNR</td></tr>
<tr><td rowspan="4">Challenges</td><td>How to aggregate the names of data objects to reduce the number of routing entries?</td><td>Fast lookup: mapping the name of data object to its locators (copies as well?)</td><td rowspan="3">How to design a scalable mapping system, which given the name of data object, it should return a destination domain locator so that a user request can be encapsulated and forwarded to the domain?</td></tr>
<tr><td>How does user learn the name which is designed for aggregation by provider?</td><td rowspan="2">Fast update: location of data object is expected to change frequently. Multiple data objects may change their location simultaneously, e.g. data objects in a laptop?</td></tr>
<tr><td>Can we still achieve a scalable routing without name aggregation? e.g., compact routing, random walk, greedy routing, etc?</td></tr>
<tr><td colspan="3">How to incorporate copies of a data object in in-network caches in these routing schemes?</td></tr>
</table>

Mobility Management [1/2]

- Different ICN deployments provide intrinsic mobility support
- However, such support is not optimized
  - Seamless handover for real-time multimedia?
  - Network resources negotiation and activation
- Moreover, client-mobility and source-mobility are different
  - How the intrinsic caching and forwarding will be impacted?
- Finally, with the different access technologies available today, how will their unique mechanisms impact an optimized mobility-supported scenario?

Mobility Management [2/2]

Research Challenges:

- How can content reaching mechanisms interface with specific link operations, such as identifying which links are available for a certain content
- How to make mobility as a service that is only activated when the specific user/content/conditions require it
- How to coordinate mobility management between the node and the network for optimization and policing procedures?

Network Management [1/2]

- Current management support tools (ranging from SNMP to full-fledged AAA and policing infrastructures) are currently host-centric or end-to-end oriented
- In ICN, not only content becomes the core aspect for management requirements
  - it also sees network management leveraging intrinsic ICN mechanisms
- On one hand, such mechanisms need to be used to address common network management procedures
  - How to identify nodes, networks, segments using ICN naming?
- On the other hand, native ICN aspects can open up new scenarios and considerations for network management as a concept
  - E.g., content-oriented management and caching

Network Management [2/2]

Research Challenges:

- Manage and control content reception at the destination
- Coordination of management information exchange and control between ICN nodes and ICN network control points
- Identification of management and controlling actions and items through information naming
- Relationship between NDOs and host identities identification

Status and Next Steps

- Section about "Problems today": rather talk about goals
- Align level of detail for sections
- Separate Naming and security sections
  - have more detailed TODO list for those
- "Other challenges"
  - want to at least other related challenges not discussed here: business models
- Got volunteers for additional input
  - Thomas/Matthias: mobility/security
  - Damien: security
- Plan is to update this after IETF-86

Feedback?