Information-Centric Networking

AW2

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Agenda

Retrospection AW1

Information-Centric Networking

Related Work
  NDN / CCNx
  NetInf
  PSIRP

Comparison

Future Work
Retrospection AW1
Content Delivery Networks

- Approach to deliver large amounts of content in an efficient manner
- Objectives
  - Reduced latency
  - Improved Quality of Experience (QoE)
  - Reduced backbone load
- Utilises DNS and HTTP redirection mechanisms
- Steer users towards caches
CDN components

![CDN Components Diagram]

Figure: CDN components [13, 8, 9, 15]

- Delivery System
  - Deliver content
- Request-Routing System
  - Steer clients
- Distribution System
  - Distribute content
- Accounting System
  - Billing / statistic creation
Information-Centric Networking
Motivation

Internet use cases shift

- From *host-centric*
  Communicate via end-points (host/port)
- To *information-centric*
  Access content via the network itself

- Researchers take the view that the network should account stronger for content distribution

Target

- Designing a scalable and efficient content-aware network infrastructure
General ICN building blocks[6]

Publish / Subscribe paradigm

- Publish data In-network
- Receive data through subscription
- Matching publication and subscription through rendezvous mechanism

Caching

- In-network
  - Utilise content routers for caching
- At-the-edge
  - Utilise end-nodes for caching
General ICN building blocks[6]

Naming

▶ Via location independent identifiers

Security

▶ Secure content instead of communication channels
  ▶ Data integrity (e.g. self-certifiability)
  ▶ Author & origin authentication
▶ Popular to be coupled with content naming
▶ Receiver initiated data transfer

Routing and Forwarding

▶ Immediate routing of content requests (one-step resolve/retrieve)
▶ Name Resolution Service (NRS) (two-step resolve/retrieve)
General ICN building blocks[6]

One-step resolve/retrieve

Figure: Conceptual view of one-step resolve/retrieve

Phases

- Finding (rendezvous)
- Delivering (forwarding)
Two-step resolve/retrieve

Phases

- Finding (rendezvous)
- Constructing (topology)
- Delivering (forwarding)

**Figure:** Conceptual view of two-step resolve/retrieve
Related Work

- NDN / CCNx
- NetInf
- PSIRP / PURSUIT
Related Work

- Taken into account here
  - NDN / CCNx from Parc\textsuperscript{1, 11}
  - NetInf of the 4WARD and SAIL project\textsuperscript{2}
  - PSIRP / PURSUIT project\textsuperscript{3, 4}
- Early projects
  - TRIAD project of Stanford University (2001)
  - Data Oriented Network Architecture (DONA) (2007)
Related Work

- NDN / CCNx
NDN / CCNx Overview

- Named Data Networking (NDN)$^{[1]}$
- Research project of Palo Alto Research Center (PARC)
- Prototype implementation named CCNx$^{[11]}$
Naming

- Naming structure
  - Hierarchical
  - Aggregatable
  - Human-friendly format
  - Naming on chunk basis
  - Example: `ccnx:/parc/videos/intro.avi`

- Name resolution / routing
  - Interest packets are routed towards sources
  - Longest prefix match on content names
  - One-step resolve/retrieve
  - Multiple distributed sources possible
  - Reverse Path Forwarding through use of Pending Interest Table (PIT)
Discussing Information-centric Network Architectures

Based on the identified building blocks in section 3, we will now discuss the instantiation of these blocks for the specific approaches. In subsection 4.1, we first provide an overview of CCN, PSIRP, 4WARD-NetInf, and DONA before we compare with respect to naming/security (subsection 4.2), name resolution and naming (4.3), in-network storage for caching (subsection 4.4), and APIs (subsection 4.5).

4.1 Overview of Information-centric Networking Approaches/Related work

In this subsection we will present the existing approaches to Information-Centric Networks: Content Centric Networking (CCN), Publish-Subscribe Internet Routing Paradigm (PSIRP), Network of Information (NetInf) and Data-Oriented Network Architecture (DONA).

4.1.1 CCN

The main idea of CCN is that a request for an information object is routed towards the location in the network where that information object (IO) has been published. At the nodes traversed on the way towards the source the caches of the nodes are checked for copies of the requested IO. As soon as an instance of IO is found (a cached copy or the source IO) it is returned to the requester along the path the request came from. All the nodes along that path caches a copy of the IO in case they get more requests for it.

4.1.2 PSIRP

In PSIRP IOs are published into the network by the sources. Receivers can then subscribe to IOs that have been published. The publications and subscriptions are then matched by a Rendezvous system. The matching procedure results in a rendezvous identifier (RI) that can be seen as an identifier for a communication channel. The RI then, in turn, can be resolved (within a scope) to a forwarding identifier that can be used for routing of data object through the forwarding network.

Figure: Abstract CCNx overview

- Interest packets create soft-state (Pending Interest entry)
- Soft-states timeout or are cleared by corresponding data packet
Figure: Conceptual CCNx router architecture[16]
Caching

- Performed on chunk basis
- Takes just on-path copies into account

(on-path from subscriber to publisher)
Related Work

♦ NetInf
NetInf Overview

- Network of Information (NetInf)\(^2\)
- Part of 4Ward and SAIL (European FP7 research Projects)
Name resolution / routing

- Two-step resolve/retrieve
- Utilises Multilevel-DHT for rendezvous-system
- Rendezvous-system yields topology based address

Security

- Provides self-certifying data structures
  - No external trust mechanism needed to verify data integrity
Caching

- Two ways to find cached copy
  - Registered copy in Name Resolution Service (NRS)
  - On-net copy found while routing subscription to the source that the NRS returned

Naming

- Flat names
- Non human-friendly

<table>
<thead>
<tr>
<th>Type</th>
<th>Hash(PublicKey)</th>
<th>Label</th>
</tr>
</thead>
</table>

*Figure: content id / name*[^5]
In NetInf IOs are also published into the network. They are registered with a Name Resolution Service. The NRS also is used to register network locators that can be used to retrieve data objects that represents the published IOs. When a receiver wants to retrieve an IO the request for the IO is resolved by the NRS into a set of locators. These locators are then used to retrieve a copy of the data object from the 'best' available source(s).

**Figure 3:** PSIRP overview

**4.1.3 4WARD-NetInf**

Resolution Service

Content

Registration

Response

Client

Data

**Figure 4:** 4WARD-NetInf overview

- NRS is queried for topology based address
- Content is transferred

**Figure 5:** DONA overview

(a) IP based connection

(b) Purely data-oriented operation
Related Work

♦ PSIRP
PSIRP Overview

- Publish-Subscribe Internet Routing Paradigm
- European FP7 research project
- Continues as PURSUIT (Publish-Subscribe Internet Technologies)
Name resolution / routing

- Two-step resolve/retrieve
- Topology Manager creates zFilter (Bloom filter) describing path from subscriber to publisher
- Namespace scopes are restricted
PSIRP

Figure: Abstract CCNx overview[6]

- Uses source routing
- NRS is queried for zFilter
- Request is routed to content source
- Content is transferred
zFilter\textsuperscript{[10]}

- Use Link IDs to construct Bloom filter
- $x_1$ and $x_2$ are Link IDs
- Attached to every packet
- Hop-by-hop evaluation against link table
- False-positives possible

![Bloom filter construction][7]

**Figure:** Bloom filter construction\textsuperscript{[7]}
PSIRP

Figure: zFilter based forwarding[10]

- Uses source routing
Caching

- Along transmission path
- Registered within Name Resolution System

Naming

- Non human-friendly
- Split into various abstraction levels
3.3 Functional Entity Relationships

Figure 3 illustrates the relationships between the key entities of the PSIRP architecture.

- **Application ID**
  *Used by publishers and subscribers*

- **Rendezvous ID**
  *Bridge higher level with lower layer identifiers*

- **Scope ID**
  *Delimit reachability of given information*

- **Forwarding ID**
  * Defines network transit paths*
Comparison
Comparison: Routing & Forwarding

Data path

- In NDN/CCNx data can only flow along the reverse path the interest packets take
- NetInf and PSIRP allow for different paths

Network states

- In CCNx soft-states are created by each interest packets what may lead to resource exhaustion (CPU/Memory)[14]
- PSIRP utilises zFilters attached to packets thus no states need to be maintained in the network
Comparison: Naming

Naming

- CCNx names are human-friendly
- NetInf and PSIRP are not human-friendly hence may require mapping service

Versioning

- NetInf and CCNx support versioning of content
- PSIRP leaves versioning to the application through the Application ID
Comparison: Information scope

Scoping

- NetInf has no mechanism of restricting the availability scope of content so far\(^1\)
- PSIRP utilises a Scope ID to restrict the accessibility
- CCN\(x\) can use export policies to restrict routing information

\(^{1}\text{possible approaches are mentioned in}^{6}\)
Future Work
Future Work

Open topics

- Scalability
- Non human-friendly names
  Secure name mapping service needed
- Scoping of content
  Limiting the reach of information
- Source mobility
- Disruption Tolerance / Delay Tolerant Networking (DTN)
- Security
  Infrastructure attacks
Thanks for your attention!
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