Pursuing a Software-Defined Information-Centric Network

Dimitris Syrivelis

CERTH-ITI and University of Thessaly
Contents

• An Information – Centric Network Architecture
  • An ICN Node Architecture
  • Using LIPSIN for packet forwarding
  • Designing a LIPSIN switch using Openflow and changes to ICN node architecture
  • Benefits of using SDN support
An ICN Network Architecture

• Proposed by FP7 PURSUIT Project
  http://www.fp7-pursuit.eu

• SDN support developed in FP7 OpenLab project
  http://www.ict-openlab.eu

• A modular design that supports publish/subscribe semantics with 3 discrete functions:
  – Rendezvous
  – Topology Management
  – Forwarding
A domain deployment example
Topology Management Function

Topology Manager

Node 1

Node 2

Node 3

Node 4

Node 5

Domain Network

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Topology Management/Forwarding

Domain Network

Node 1
Fw Logic

Node 2
Fw Logic

Node 3
Fw Logic

Node 4
Fw Logic

Node 5
Fw Logic

Topology Manager

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Example System Operation

Topology Manager

<table>
<thead>
<tr>
<th>Information Identifier</th>
<th>Type</th>
<th>Node ID</th>
</tr>
</thead>
</table>

Node 1
- Fw Logic

Node 2
- Fw Logic

Node 3
- Fw Logic

Node 4
- Fw Logic

Node 5
- Fw Logic

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Example System Operation

Topology Manager

Information Identifier | Type | Node ID
--- | --- | ---

Node 1
Node 2
Node 3
Node 4
Node 5

Domain Network

Rendezvous

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Example System Operation

<table>
<thead>
<tr>
<th>Information Identifier</th>
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<tbody>
<tr>
<td>0xABC1234</td>
<td>Pub</td>
<td>Node1</td>
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</table>

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Example System Operation

Topology Manager

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Node 1
Fw Logic

Node 2
Fw Logic

Node 3
Fw Logic

Node 4
Fw Logic

Node 5
Fw Logic

Domain Network

Pub

Sub

Rv Req
Example System Operation

Topology Manager

Information Identifier | Type | Node ID
--- | --- | ---
0xABC1234 | Pub | Node1
0xABC1234 | Sub | Node3

MATCH!

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Example System Operation

<table>
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<tr>
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<td>Node1</td>
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<td>Node3</td>
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An ICN node architecture (BlackAdder prototype)

The service model exports pure publish subscribe semantics, along with synchronization primitives for robust application development.

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LIPSIN for packet forwarding

• LIPSIN (Petri Jokela et al.) is a source-based routing system which uses bloom filters to encode routes to one or more destinations (multicast trees).
• LIPSIN encodes physical links by applying bloom filters on a fixed size, few-bytes long, identifier which is prepended on each packet.
• Once routes are encoded into a single forwarding identifier at the source, LIPSIN forwarding achieves line speed.
How LIPSIN works
How LIPSIN works

i) Assign fixed length deployment-unique identifiers to all physical links
How LIPSIN works

ii) For each set of destinations, you compute the route at the source as follows:
How LIPSIN works

ii) For each set of destinations, you compute the route at the source as follows:
How LIPSIN works

iii) The forwarding identifier can then be used on each forwarder to choose local outgoing links

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iii) The forwarding identifier can then be used on each forwarder to choose local outgoing links.
How LIPSIN works

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iv) Multihop routing is implemented also by the same operation on the Forwarding identifier on each local forwarder.
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Why using LIPSIN with SDN and not directly information identifiers?

ICN ethernet frame

<table>
<thead>
<tr>
<th>LIPSIN IDENTIFIER</th>
<th>INFORMATION IDENTIFIER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Payload</td>
</tr>
</tbody>
</table>

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Why using LIPSIN with SDN and not directly information identifiers?

ICN ethernet frame
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ICN ethernet frame

LIPSIN IDENTIFIER

INFORMATION IDENTIFIER

Payload

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</table>
Modifying LIPSIN functionality for Openflow datapaths

<table>
<thead>
<tr>
<th>Information Identifier</th>
<th>Type</th>
<th>Node ID</th>
<th>Fw Logic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rendezvous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node 1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Domain Network

Topology Manager

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Moving LIPSIN functionality to Openflow datapaths

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Node 1
Fw Logic

Node 2
Fw Logic

Node 3
Fw Logic

Node 4
Fw Logic

Node 5
Fw Logic

Topology Manager

Controller

OF Datapath

Rendezvous

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Moving LIPSIN functionality to Openflow datapaths

<table>
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</tbody>
</table>

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Example for 5-port OpenFlow datapath

Each switch port is assigned a deployment unique Identifier by the Topology Manager which is kept at the local controller

- Port 1: 1000 0000
- Port 2: 0100 0000
- Port 3: 0010 0000
- Port 4: 0001 0000
- Port 5: 0000 1000
Example for 5-port OpenFlow datapath

Openflow datapath is configured to match forwarding identifiers on each packet with respective delivery ports,
Example for 5-port OpenFlow datapath

Openflow datapath sends to the local controller packets with forwarding identifiers that don’t match any entry.

FW Logic

Controller

OF Datapath

<table>
<thead>
<tr>
<th>Port</th>
<th>Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000 0000</td>
</tr>
<tr>
<td>2</td>
<td>0100 0000</td>
</tr>
<tr>
<td>3</td>
<td>0010 0000</td>
</tr>
<tr>
<td>4</td>
<td>0001 0000</td>
</tr>
<tr>
<td>5</td>
<td>0000 1000</td>
</tr>
</tbody>
</table>

0010 1000

INFORMATION IDENTIFIER

Payload

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Example for 5-port OpenFlow datapath

Local openflow controller uses the LIPSIN bloom-filter approach to decode the identifier and find the local datapath ports where the packet should be delivered and installs the rule.

```
Port 1 1000 0000
Port 2 0100 0000
Port 3 0010 0000
Port 4 0001 0000
Port 5 0000 1000
```
ICN architecture using SDN

Node 1

Node 2

Node 3

Node 4

Node 5

Topology Manager

OF Datapath 1

FW Logic

Controller

OF Datapath 2

FW Logic

Controller

Rendezvous

Information Identifier | Type | Node ID
---|---|---


ICN architecture using SDN Example

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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Node 1
- Controller
- FW Logic
- Port 1: 1000 0000
- Port 2: 0100 0000
- Port 3: 0010 0000
- Port 4: 0001 0000

Node 2
- OF Datapath 1
- Port 1: 0000 1000
- Port 2: 0000 0100
- Port 3: 0000 0010

Node 3
- OF Datapath 2
- Port 1: 0000 1000
- Port 2: 0000 0100
- Port 3: 0000 0010

Node 4
- Rendezvous

Node 5
- Topology Manager
- OF1
  - Port 1: 0001 0000
  - Port 2: 0100 0000
  - Port 3: 0010 0000
  - Port 4: 0001 0000
- OF2
  - Port 1: 0001 0000
  - Port 2: 0100 0000
  - Port 3: 0010 0000
  - Port 4: 0001 0000
ICN architecture using SDN Example

- **Topology Manager**
  - Node 1
  - Node 2
  - Node 3
  - Node 4
  - Node 5

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<tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</table>

- **OF Datapath 1**
  - FW Logic
  - Controller
  - Port 1: 1000 0000
  - Port 2: 0100 0000
  - Port 3: 0010 0000
  - Port 4: 0001 0000

- **OF Datapath 2**
  - FW Logic
  - Controller
  - Port 1: 0000 1000
  - Port 2: 0000 0100
  - Port 3: 0000 0010

- **Rendezvous**
  - Node 4

- **Pub**
ICN architecture using SDN Example

Topology Manager

<table>
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</table>

Node 1

Node 3

Node 5

Node 2

Node 4

Rendezvous

FW Logic

Controller

OF Datapath 1

Port 1: 1000 0000
Port 2: 0100 0000
Port 3: 0010 0000
Port 4: 0001 0000

OF Datapath 2

Port 1: 0000 1000
Port 2: 0000 0100
Port 3: 0000 0010

Node 1

Node 3

Node 2

Node 4

Node 5

FW Logic

Controller

OF1

OF2

1 2 3 4 5

0001 1000
Rv Req
ICN architecture using SDN Example

Node 1
Node 3
Node 5

Topography Manager

Information Identifier | Type | Node ID
--- | --- | ---
0xABCD123 | Pub | Node1

Node 4

Rendezvous

Node 1
Node 2
Node 3

Sub

0000 1000
Rv Req

FW Logic
Controller

OF Datapath 1

Port 1: 1000 0000
Port 2: 0100 0000
Port 3: 0010 0000
Port 4: 0001 0000

FW Logic
Controller

OF Datapath 2

Port 1: 0000 1000
Port 2: 0000 0100
Port 3: 0000 0010
ICN architecture using SDN Example

Node 1
Node 2
Node 3
Node 4
Node 5

Topology Manager

Information Identifier | Type | Node ID
--- | --- | ---
0xABCD123 | Pub | Node1
0xABCD123 | Sub | Node3

Rendezvous

Node 4

0010 0010 TM Req

OF1
OF2

1 2 5
3 4

FW Logic
Controller

OF Datapath 1

Port 1 1000 0000
Port 2 0100 0000
Port 3 0010 0000
Port 4 0001 0000

Port 1 0001 0000
Port 2 0000 1000
Port 3 0000 0100

OF Datapath 2

FW Logic
Controller

Match!
ICN architecture using SDN Example

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<tr>
<td>0xABCD123</td>
<td>Sub</td>
<td>Node3</td>
</tr>
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</table>

Node 1

Node 2

Node 3

Node 4

Controller

FW Logic

OF Datapath 1

OF Datapath 2

Port 1: 1000 0000
Port 2: 0100 0000
Port 3: 0010 0000
Port 4: 0001 0000

Port 1: 0000 1000
Port 2: 0000 0100
Port 3: 0000 0010

Rendezvous

1000 0000 START_PUBLISH 0001 0100
ICN architecture using SDN Example

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<td>Sub</td>
<td>Node 3</td>
</tr>
</tbody>
</table>

Rendezvous

Node 4

Node 5

Topology Manager

OF1

OF2

Node 1

Node 2

Node 3

Node 4

Node 5

FW Logic

Controller

Controller

FW Logic

OF Datapath 1

OF Datapath 2

OF 1 Flow tables

<table>
<thead>
<tr>
<th>FID</th>
<th>PORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 0000</td>
<td>1</td>
</tr>
</tbody>
</table>

Port 1: 1000 0000
Port 2: 0100 0000
Port 3: 0010 0000
Port 4: 0001 0000

Sub

Pub

0001 0100 DATA
ICN architecture using SDN Example

Node 1

Node 3

Node 5

Node 4

Node 2

Node 3

OF Datapath 1

OF Datapath 2

FW Logic

Controller

Controller

Toplogy Manager

Port 1 1000 0000
Port 2 0100 0000
Port 3 0010 0000
Port 4 0001 0000

Port 1 0000 1000
Port 2 0000 0100
Port 3 0000 0010

OF 1 Flow tables

FID | PORT
--- | ---
1000 0000 | 1
0001 0100 | 4

Information Identifier | Type | Node ID
--- | --- | ---
0xABCD123 | Pub | Node1
0xABCD123 | Sub | Node3

Rendezvous
ICN architecture using SDN Example

![Diagram of ICN architecture using SDN Example]

- **Topography Manager**
- **OF Datapath 1**
  - Controller
  - FW Logic
- **OF Datapath 2**
  - Controller
  - FW Logic

**Information Identifier**

<table>
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**OF 1 Flow tables**

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<tbody>
<tr>
<td>1000 0000</td>
<td>1</td>
</tr>
<tr>
<td>0001 0100</td>
<td>4</td>
</tr>
</tbody>
</table>

**Ports**

- Port 1: 1000 0000
- Port 2: 0100 0000
- Port 3: 0010 0000
- Port 4: 0001 0000
- Port 1: 0000 1000
- Port 2: 0000 0100
- Port 3: 0000 0010
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• Benefits of using SDN support
Benefits of using SDN

- ICN node architecture gets simplified and forwarding is carried by the network and is completely decoupled from the nodes.
Benefits of using SDN

• Network bootstrap gets very simplified
Benefits of using SDN

- Network bootstrap gets very simplified

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Benefits of using SDN

• Network bootstrap gets very simplified
Benefits of using SDN

- Network bootstrap gets very simplified
Benefits of using SDN

- Topology Management internal structures get simpler and response is improved
Future Work

• Use Multi-stage Bloom filters to avoid having different FID labels for the same delivery ports within a datapath
The problem

Topology Manager

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Rendezvous

Node 4

OF1

1 2 5

OF2

3 4

Node 5

Node 1

Node 2

Node 3

OF Datapath 1

FW Logic

Controller

Port 1

1000 0000

Port 2

0100 0000

Port 3

0010 0000

Port 4

0001 0000

OF Datapath 2

FW Logic

Controller

OF 2 Flow tables

<table>
<thead>
<tr>
<th>FID</th>
<th>PORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000 1000</td>
<td>1</td>
</tr>
<tr>
<td>0001 1000</td>
<td>1</td>
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</table>

Port 1

0000 1000

Port 2

0000 0100

Port 3

0000 0010
Future Work

• Future work
  – Use SDN to simplify handover in ICN mobility
Thank You!

Pursuit BlackAdder Prototype:
https://github.com/fp7-pursuit/blackadder

Questions ?