Pursuing a Software-Defined Information-Centric Network

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CERTH-ITI and University of Thessaly

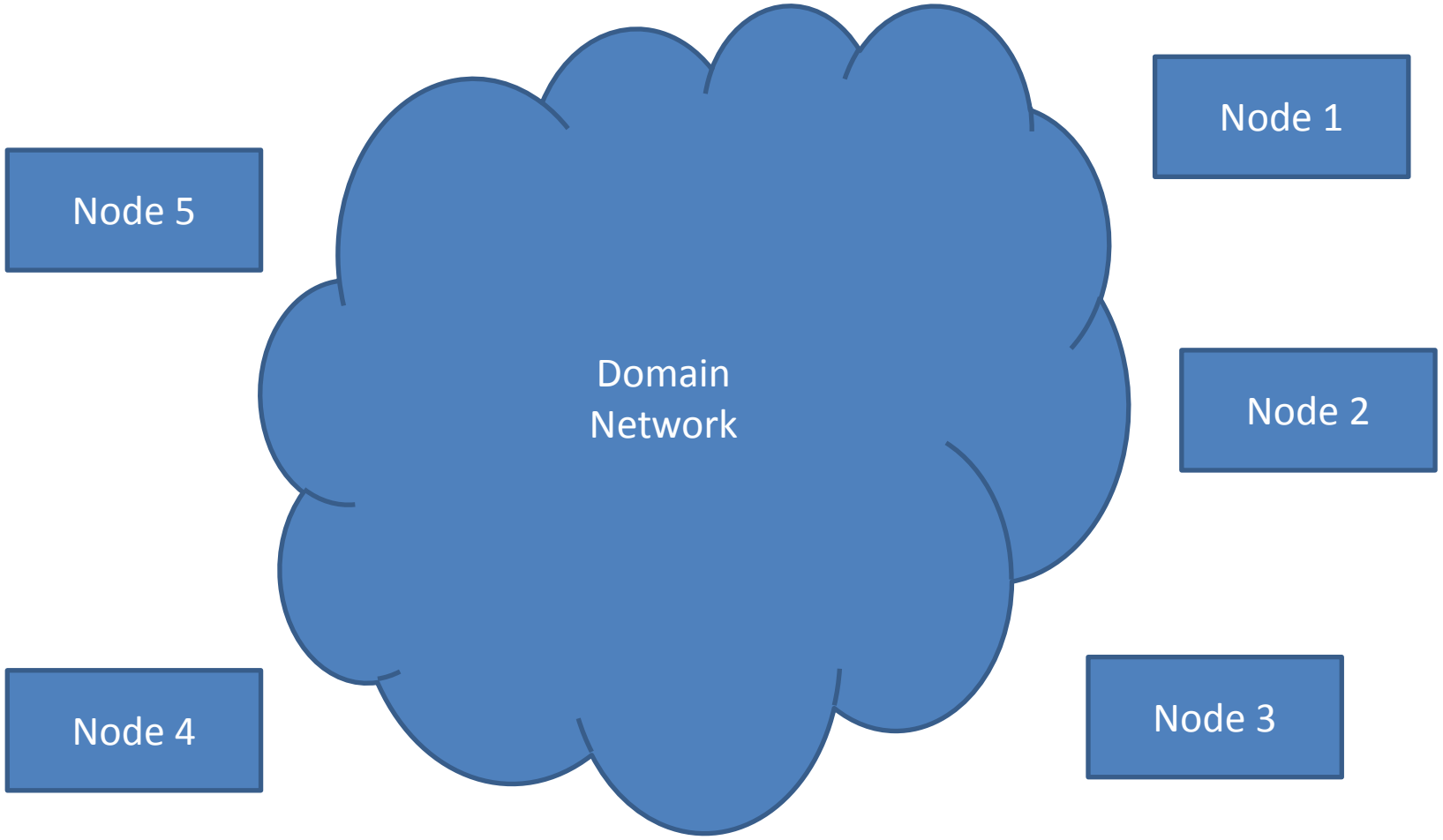
Contents

- 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

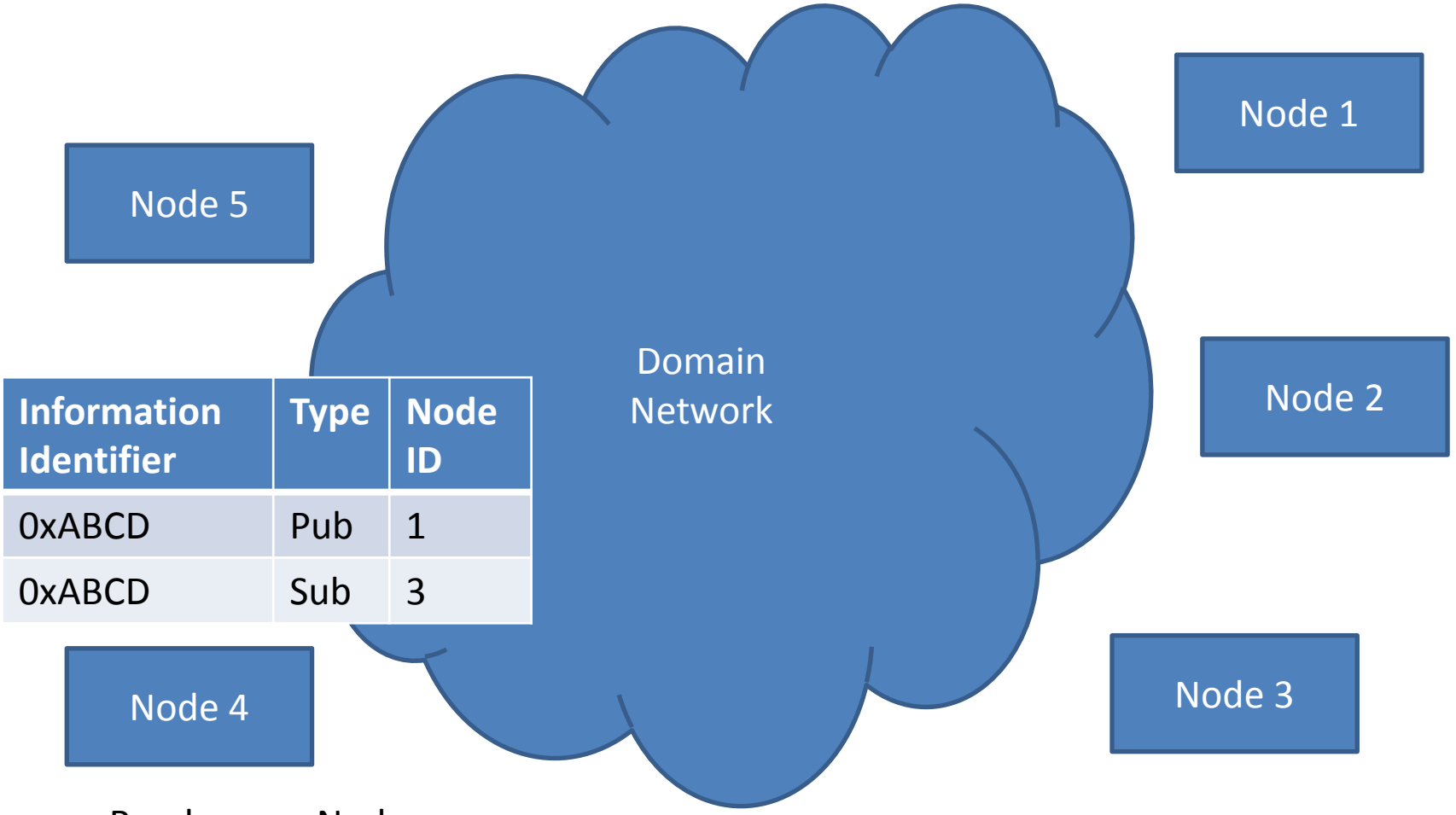
An ICN Network Architecture

- 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

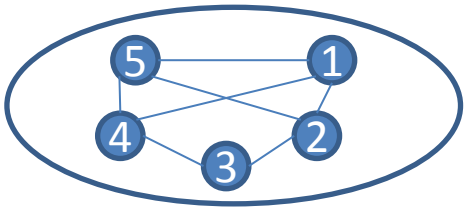


Rendezvous Function



Information Identifier	Type	Node ID
0xABCD	Pub	1
0xABCD	Sub	3

Topology Management Function



Node 5

Topology Manager

Domain Network

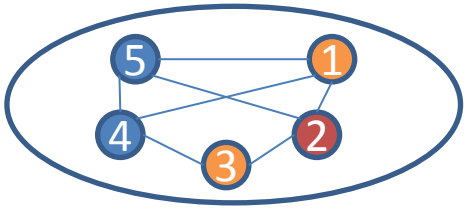
Node 1

Node 2

Node 3

Node 4

Topology Management/Forwarding



Node 5

Fw Logic

Topology Manager

Domain Network

Node 1

Fw Logic

Node 2

Fw Logic

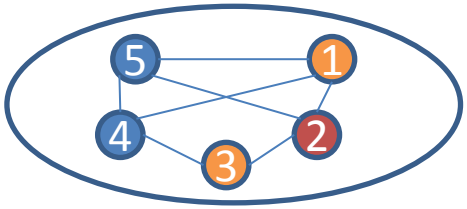
Node 4

Fw Logic

Node 3

Fw Logic

Topology Management/Forwarding



Node 5

Fw Logic

Topology Manager

Domain Network

Node 1

Fw Logic

Node 2

Fw Logic

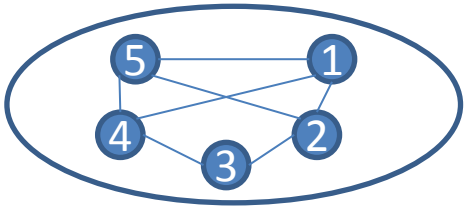
Node 3

Fw Logic

Node 4

Fw Logic

Example System Operation



Node 5

Fw Logic

Topology Manager

Information Identifier	Type	Node ID

Rendezvous

Node 4

Fw Logic

Domain Network

Node 1

Fw Logic

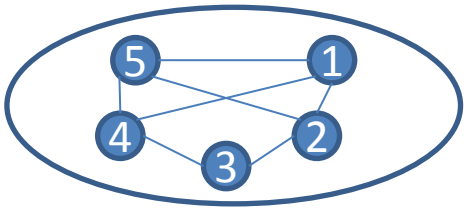
Node 2

Fw Logic

Node 3

Fw Logic

Example System Operation



Node 5

Fw Logic

Topology Manager

Information Identifier	Type	Node ID

Rendezvous

Node 4

Fw Logic

Domain Network

Pub

Node 1

Fw Logic

Rv Req

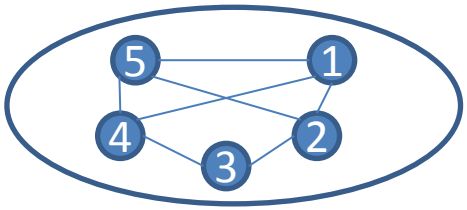
Node 2

Fw Logic

Node 3

Fw Logic

Example System Operation



Node 5

Fw Logic

Topology Manager

Information Identifier	Type	Node ID
0xABC1234	Pub	Node1

Rendezvous

Node 4

Fw Logic

Domain Network

Pub

Node 1

Fw Logic

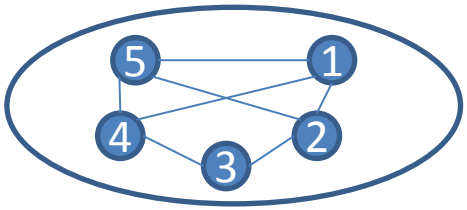
Node 2

Fw Logic

Node 3

Fw Logic

Example System Operation



Node 5

Fw Logic

Topology Manager

Information Identifier	Type	Node ID
0xABC1234	Pub	Node1

Rendezvous

Node 4

Fw Logic

Domain Network

Pub

Node 1

Fw Logic

Node 2

Fw Logic

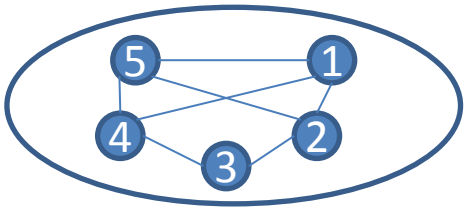
Sub

Node 3

Fw Logic

Rv Req

Example System Operation



Node 5

Fw Logic

Topology Manager

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

MATCH!

Rendezvous

Node 4

Fw Logic

Domain Network

Pub

Node 1

Fw Logic

Node 2

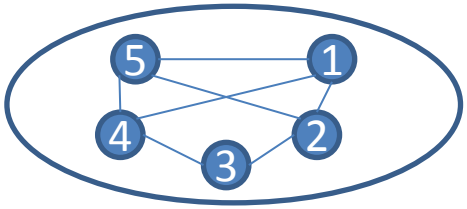
Fw Logic

Sub

Node 3

Fw Logic

Example System Operation



Node 5

Fw Logic

Topology Manager

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

Rendezvous

Node 4

Fw Logic

TM Req

Domain Network

Pub

Node 1

Fw Logic

Node 2

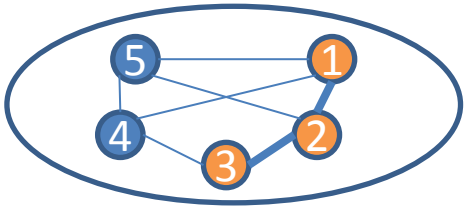
Fw Logic

Sub

Node 3

Fw Logic

Example System Operation



Node 5

Fw Logic

Topology Manager

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

Rendezvous

Node 4

Fw Logic

Domain Network

Pub

Node 1

Fw Logic

Node 2

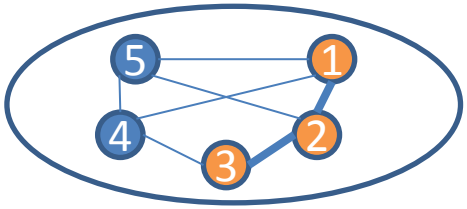
Fw Logic

Sub

Node 3

Fw Logic

Example System Operation



Node 5

Fw Logic

Start Publish Notification

Topology Manager

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

Rendezvous

Node 4

Fw Logic

Domain Network

Pub

Node 1

Fw Logic

Node 2

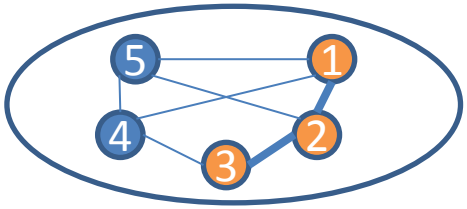
Fw Logic

Sub

Node 3

Fw Logic

Example System Operation



Node 5

Fw Logic

Topology Manager

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

Rendezvous

Node 4

Fw Logic

Domain Network

Pub

Node 1

Data

Fw Logic

Node 2

Fw Logic

Sub

Node 3

Fw Logic

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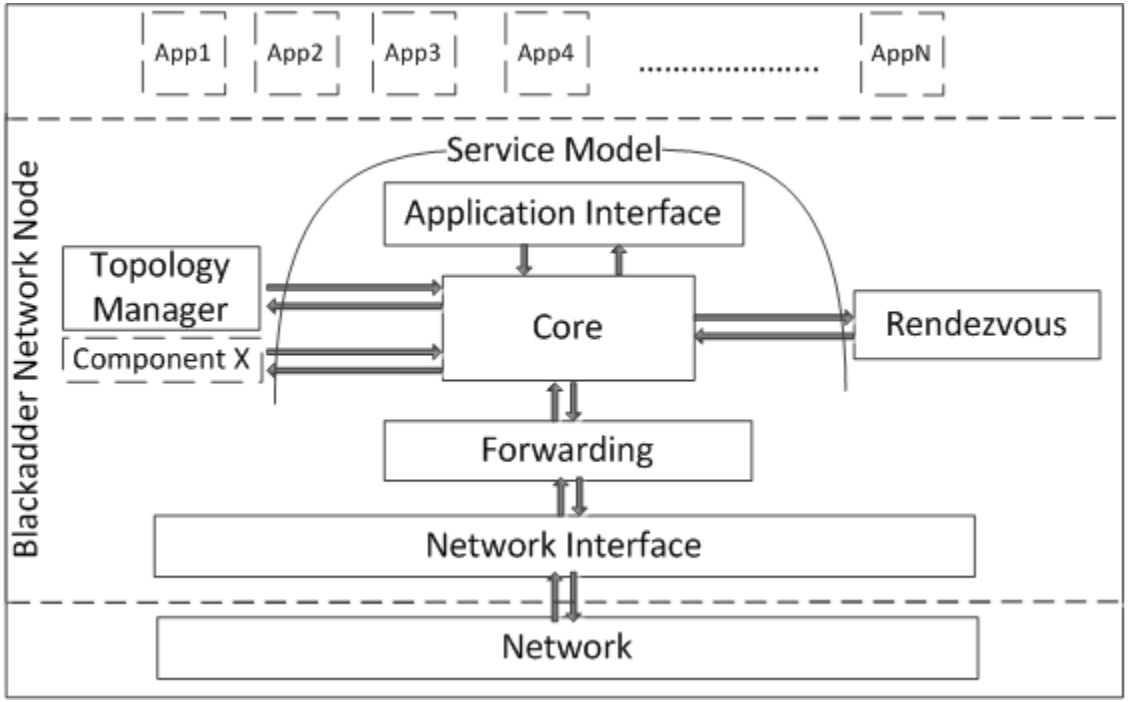
An ICN node architecture (BlackAdder prototype)



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

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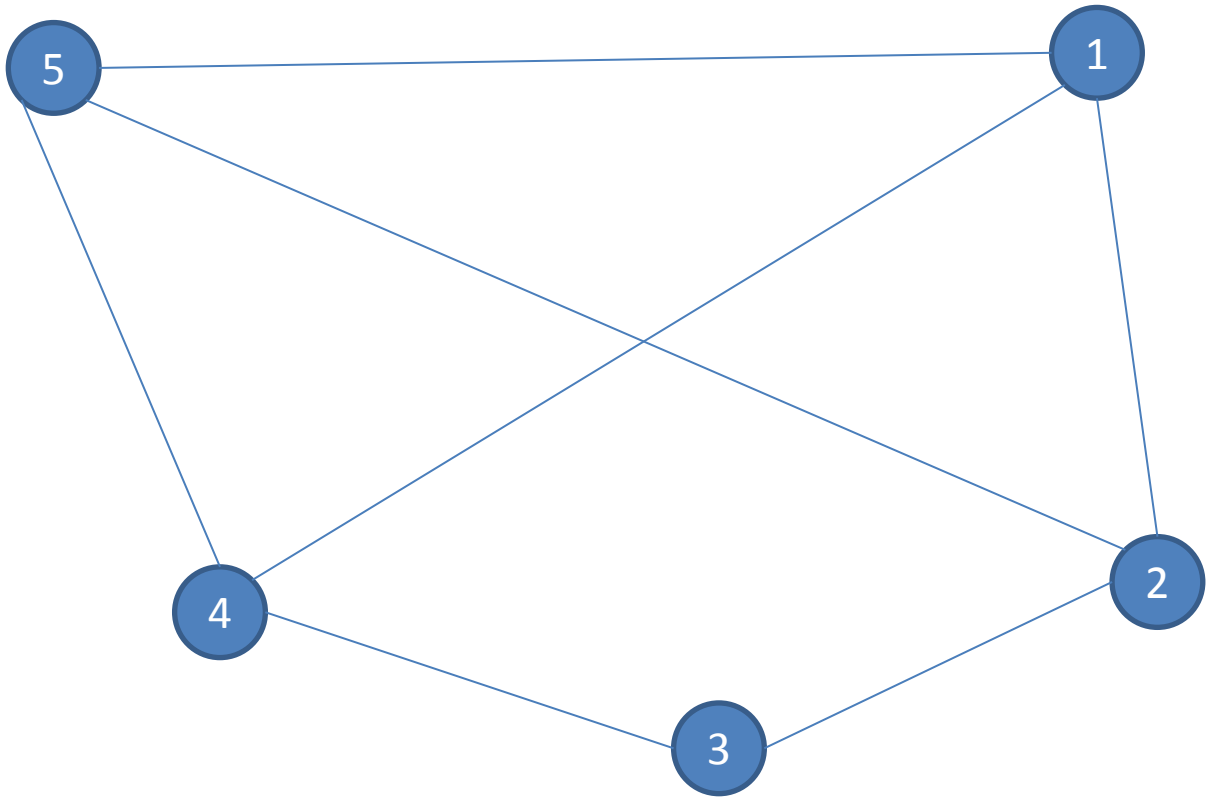
LIPSIN for packet forwarding

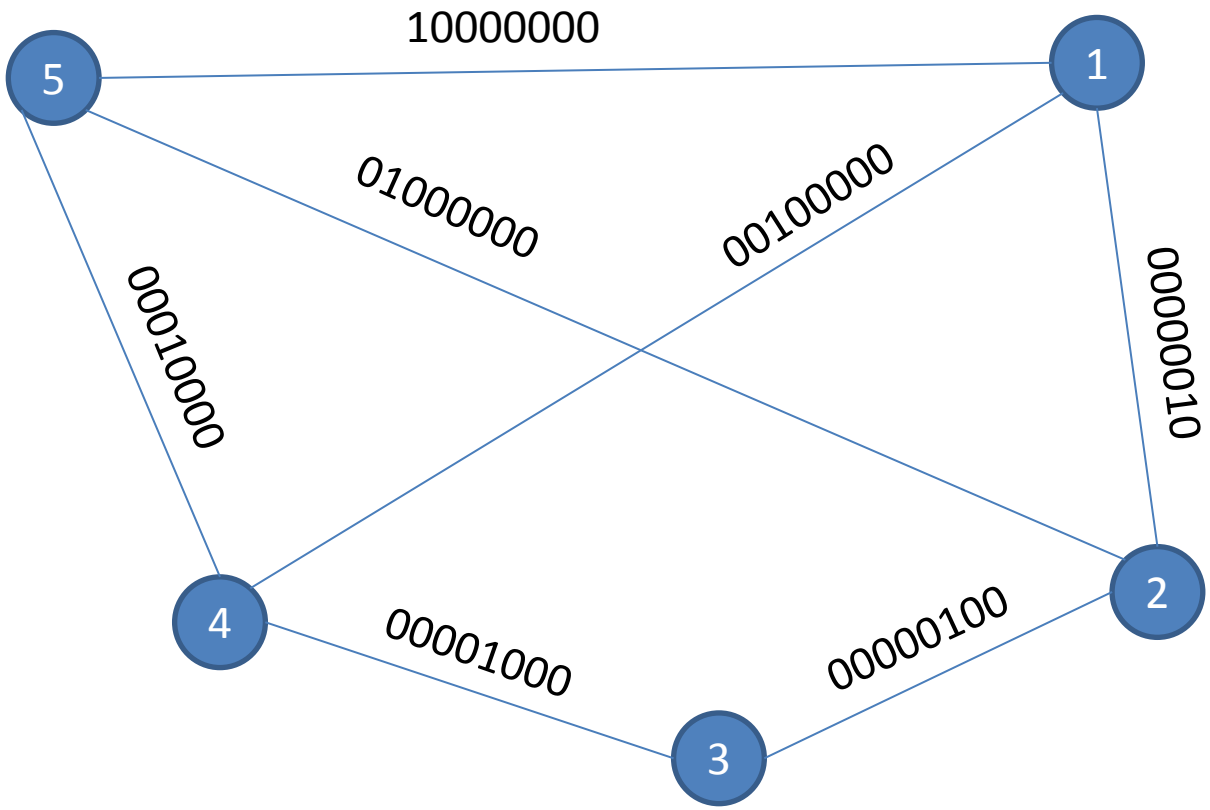
- LIPSIN (Petri Jokela et al.) is a source-based routing system which uses bloom filters to encode routes to one or more destinations (multicast trees).
- LIPSIN encodes physical links by applying bloom filters on a fixed size, few-bytes long, identifier which is prepended on each packet.
- Once routes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

How LIPSIN works



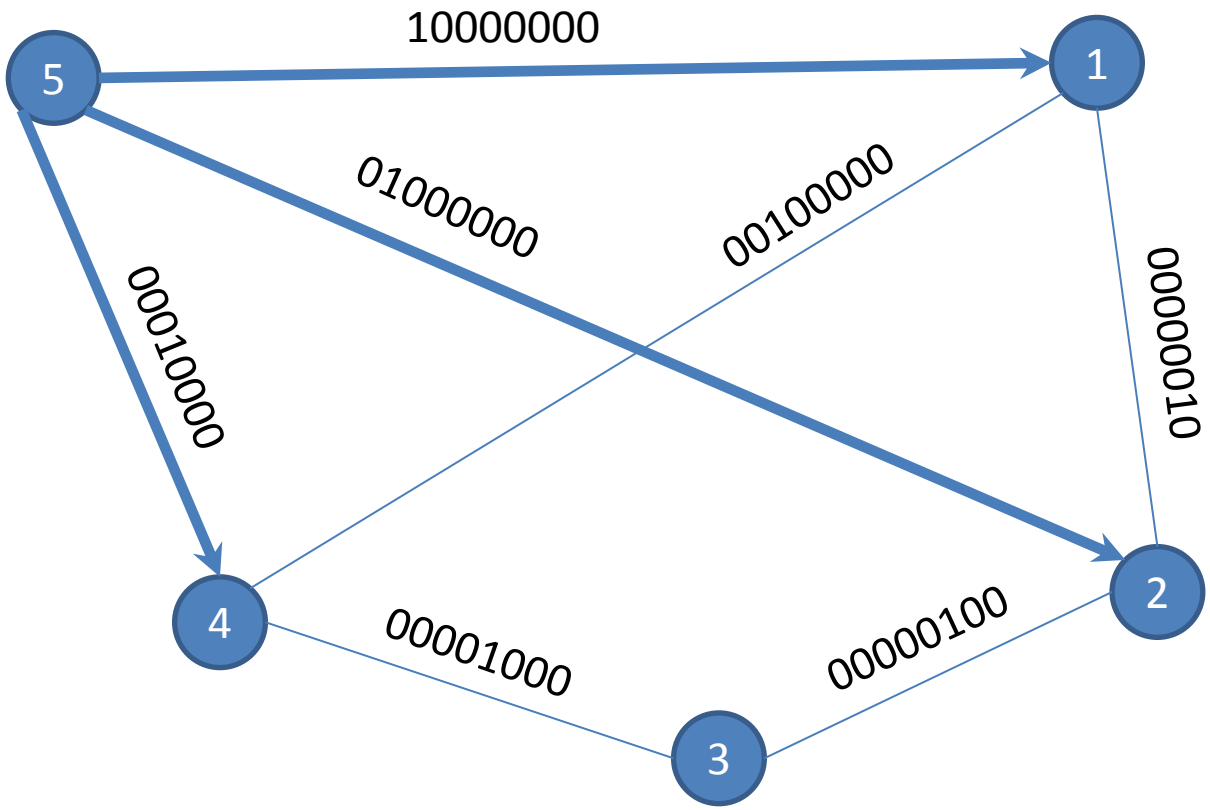
How LIPSIN works

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

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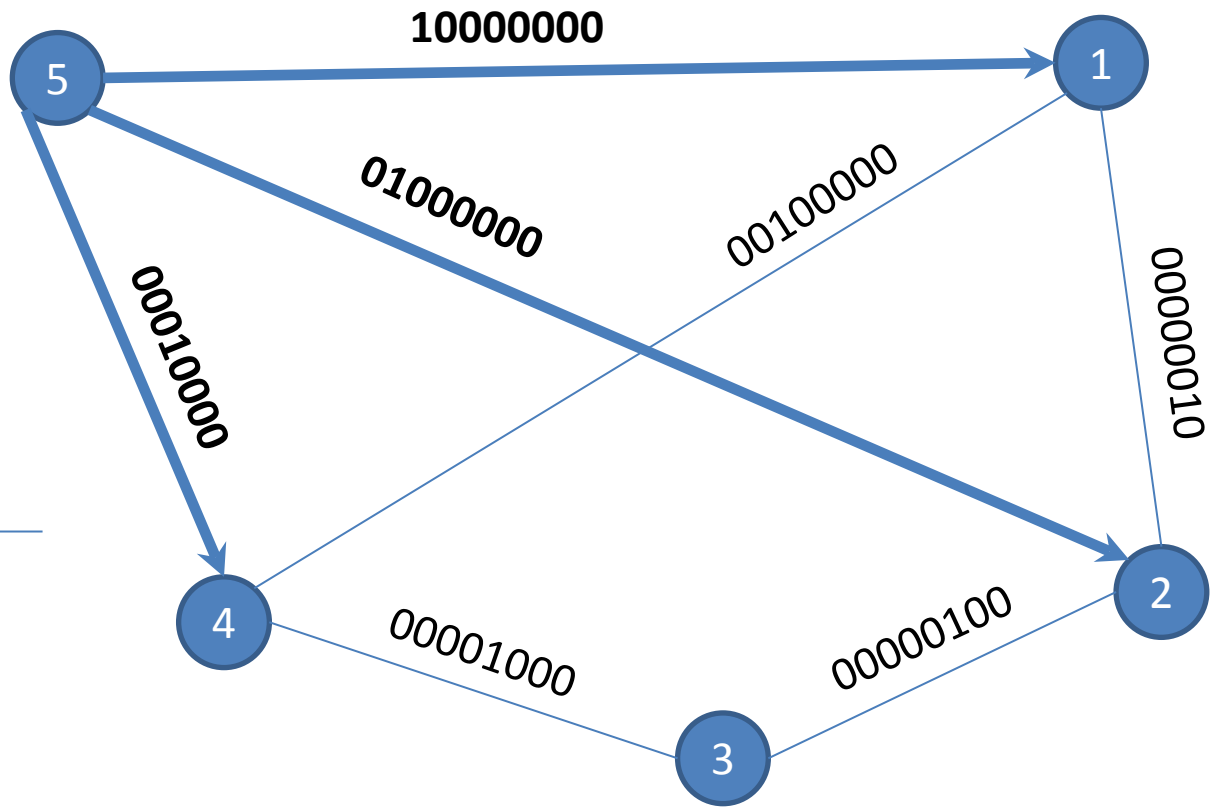


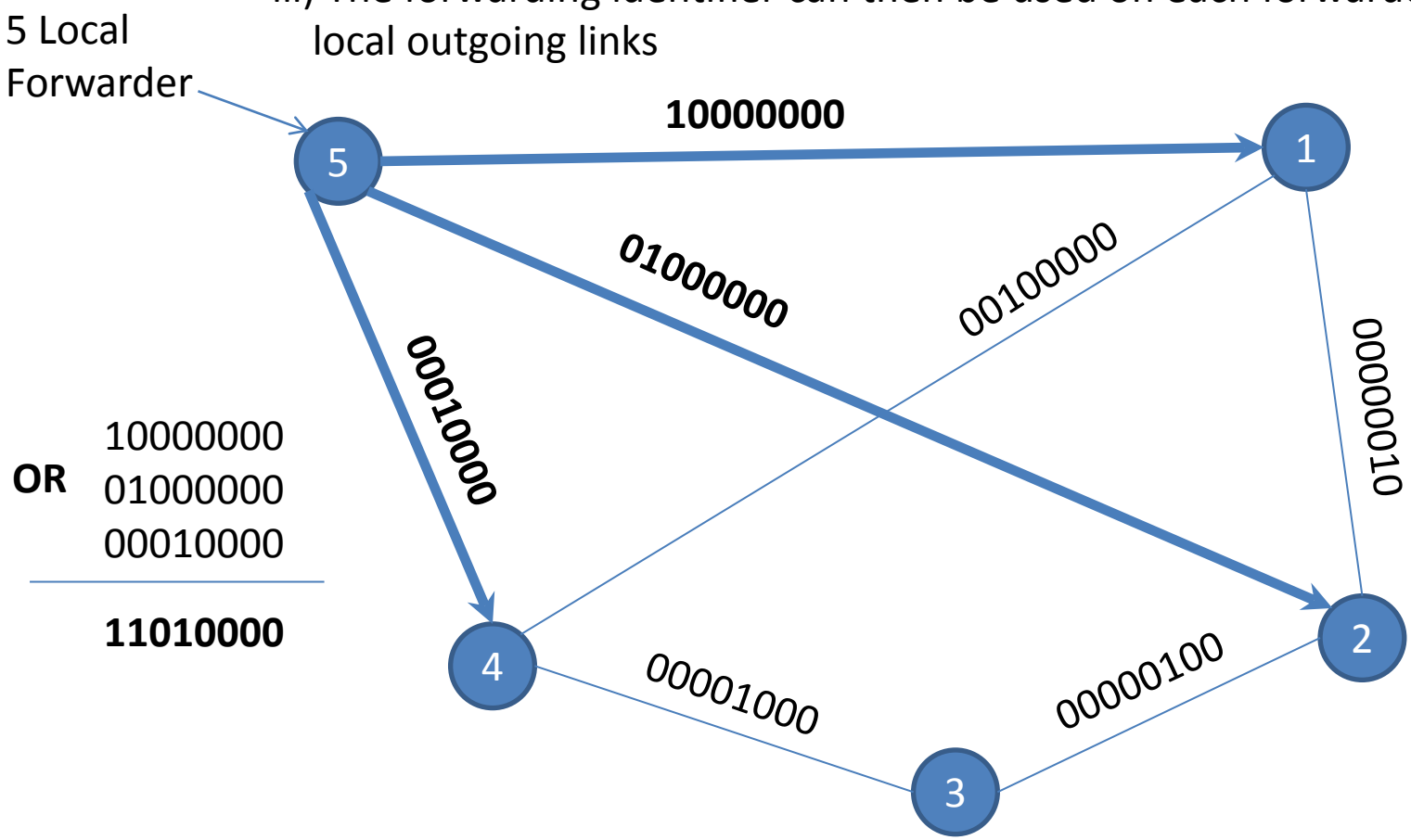
OR

10000000
01000000
00010000

11010000

How LIPSIN works

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



How LIPSIN works

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

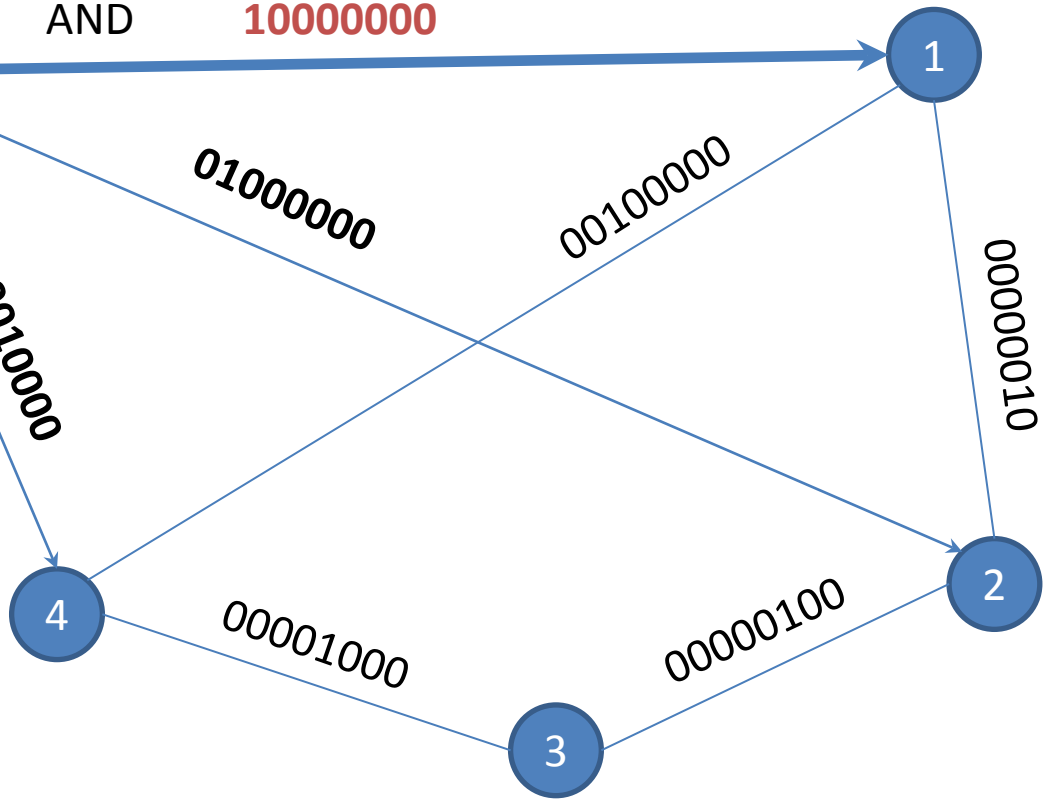
5 Local Forwarder

11010000

AND **10000000**

OR

10000000
01000000
00010000



How LIPSIN works

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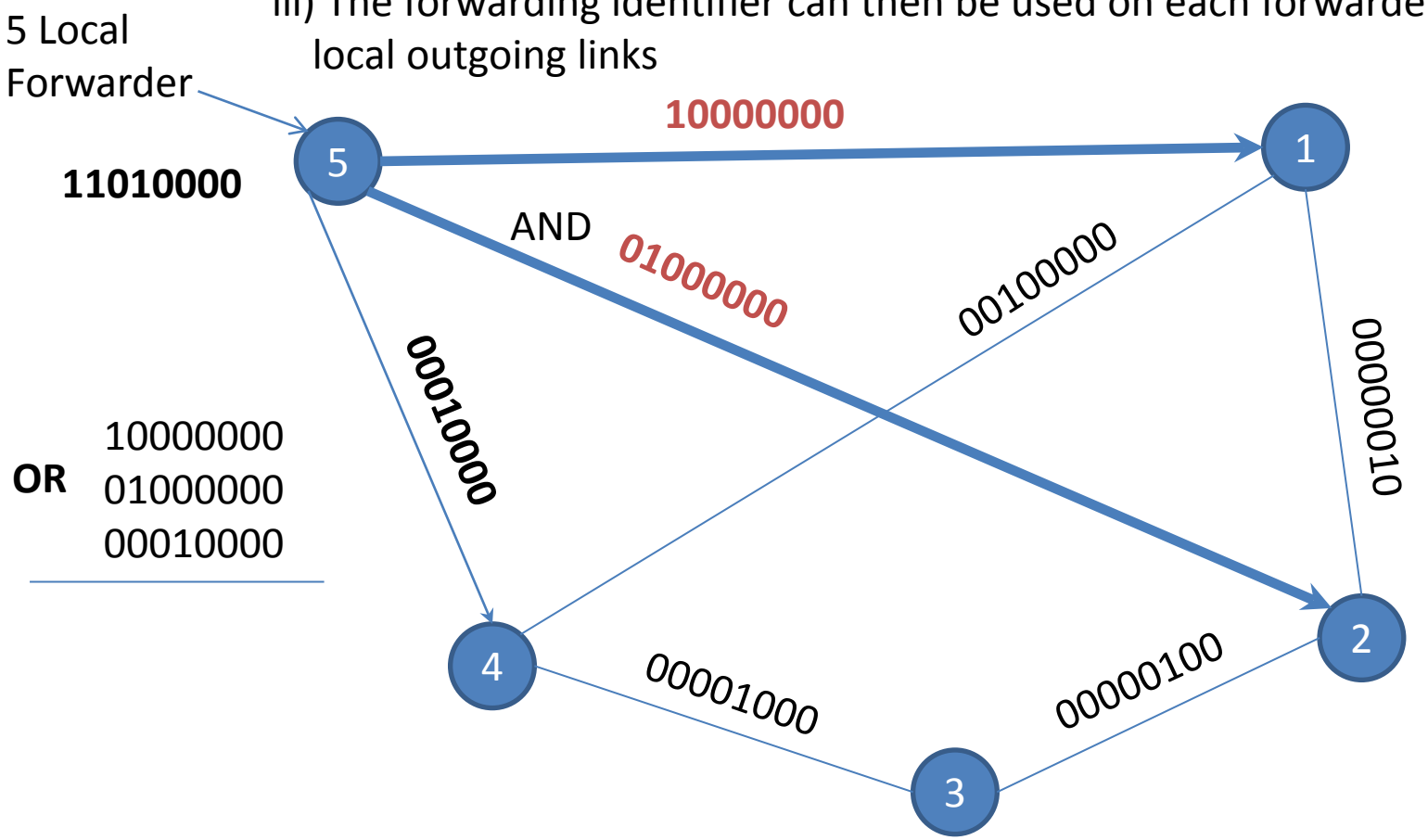

How LIPSIN works

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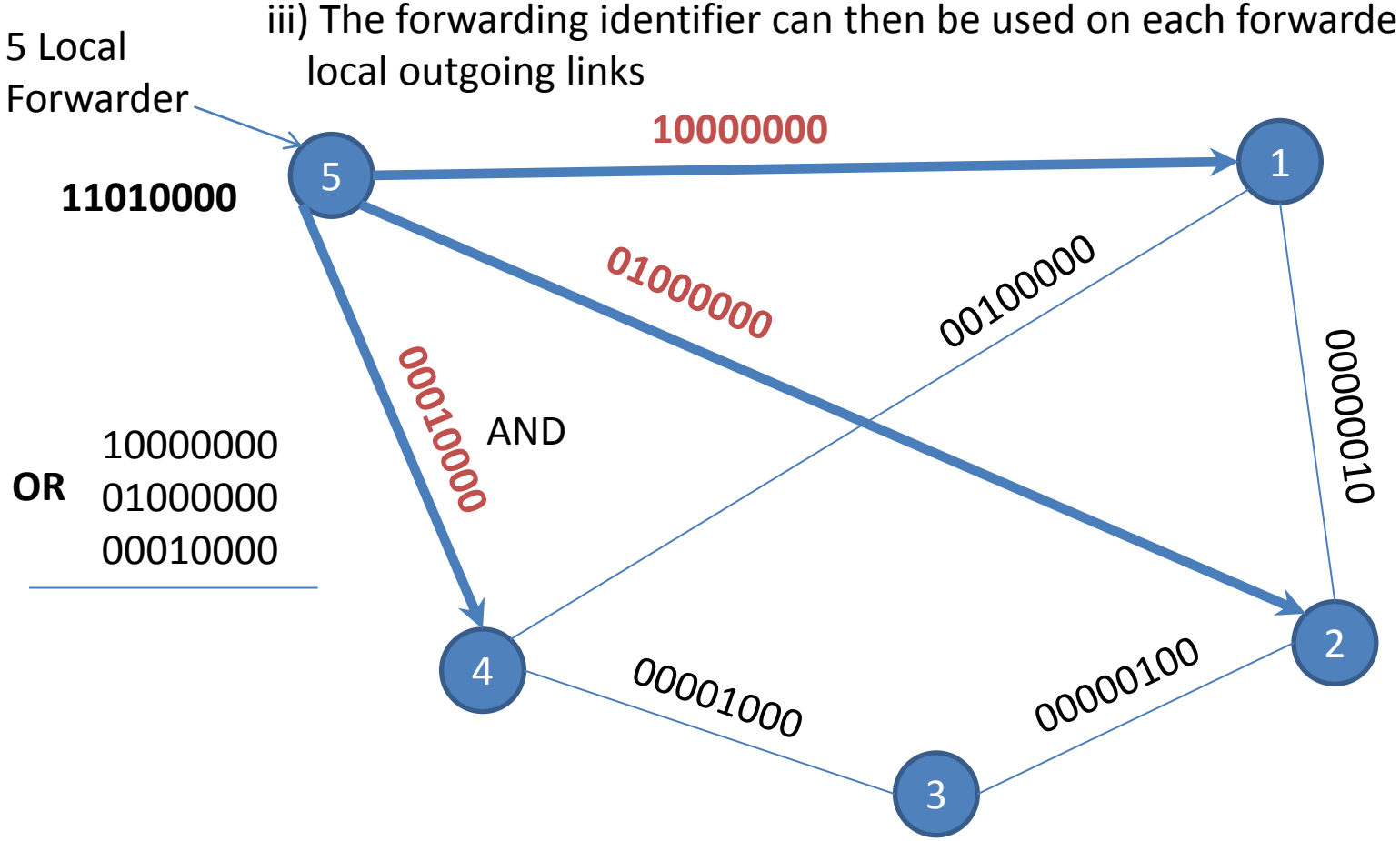
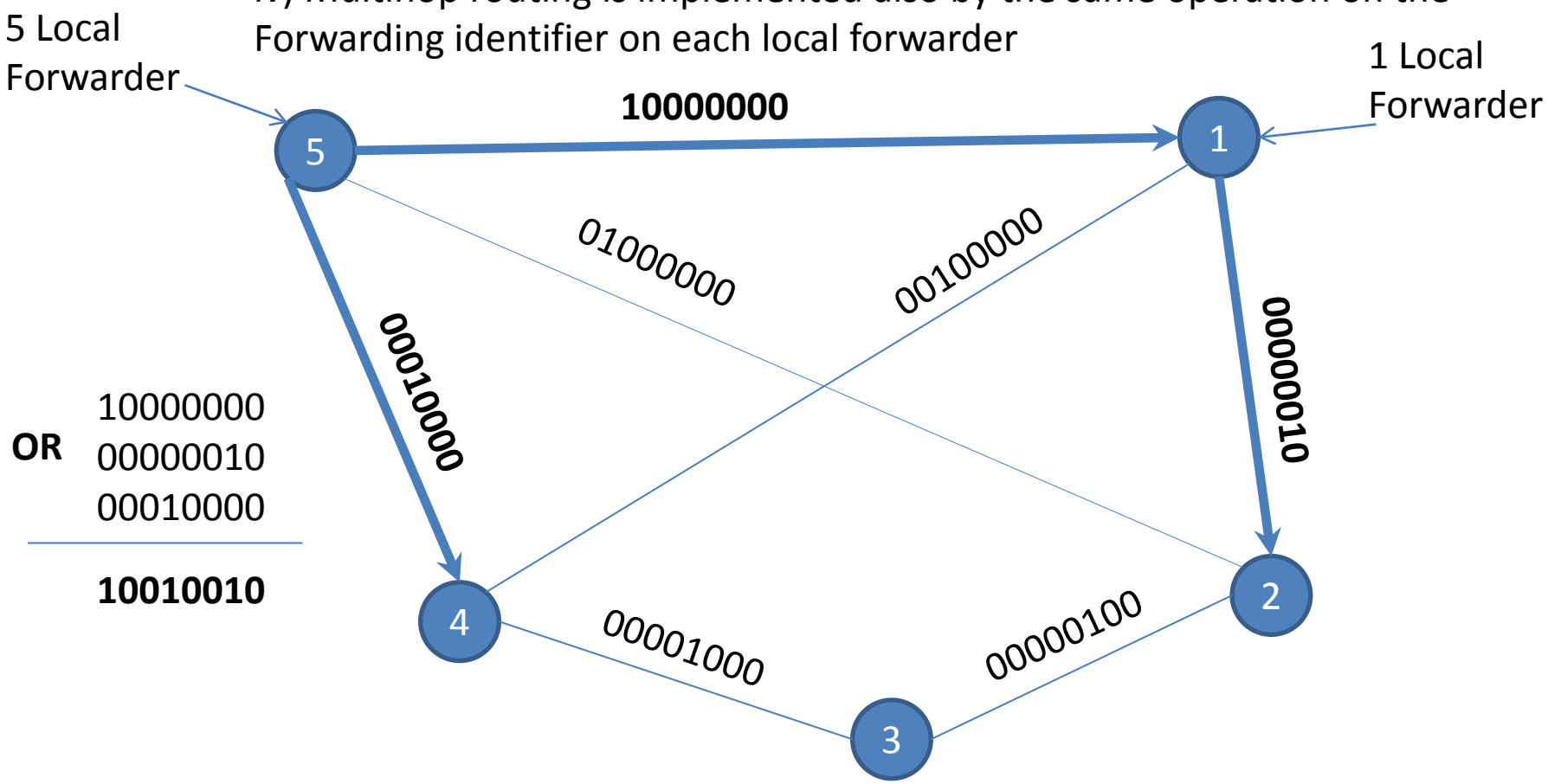


How LIPSIN works

iv) Multihop routing is implemented also by the same operation on the Forwarding identifier on each local forwarder



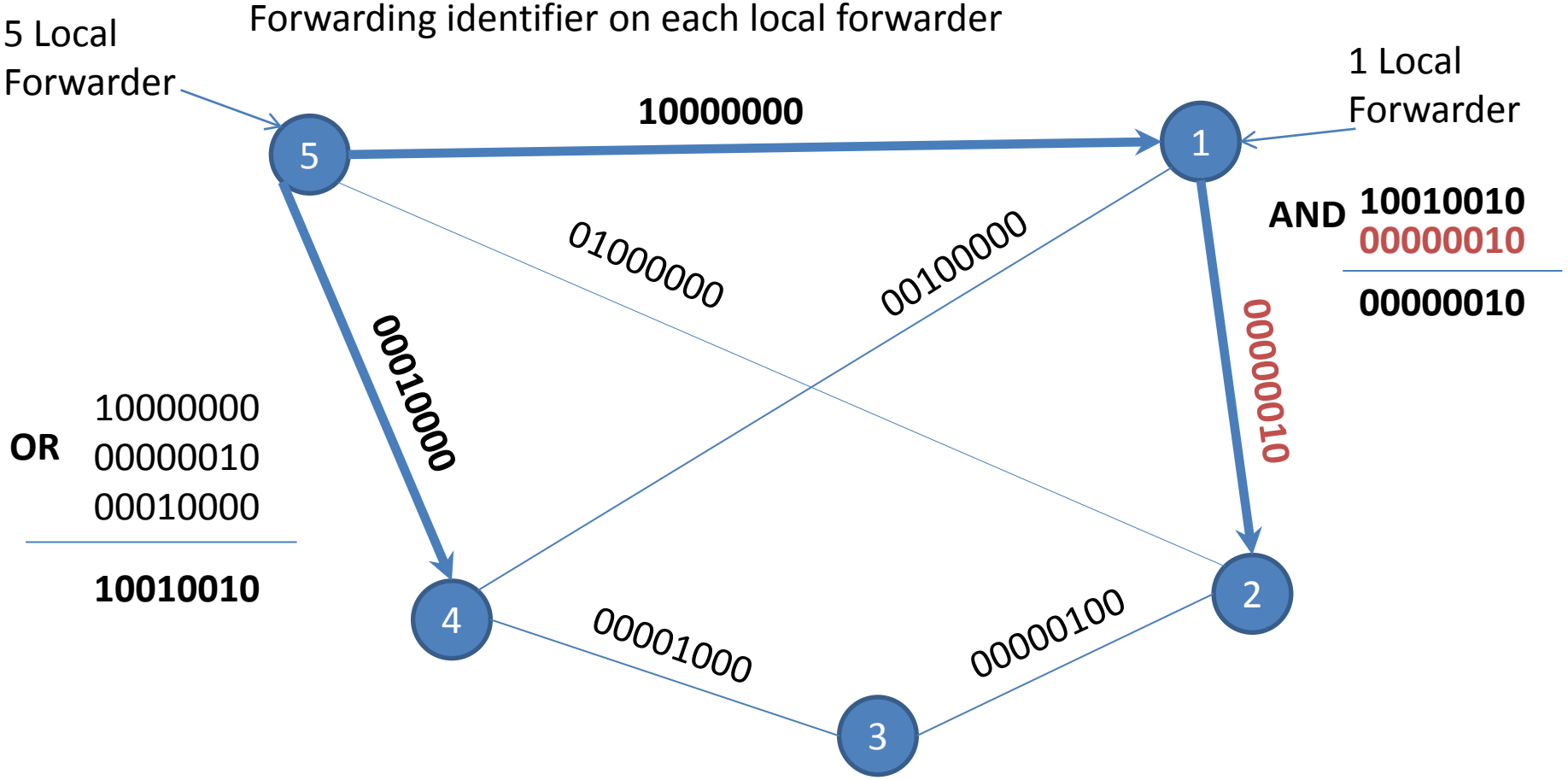
OR

10000000
00000010
00010000

10010010

How LIPSIN works

iv) Multihop routing is implemented also by the same operation on the Forwarding identifier on each local forwarder



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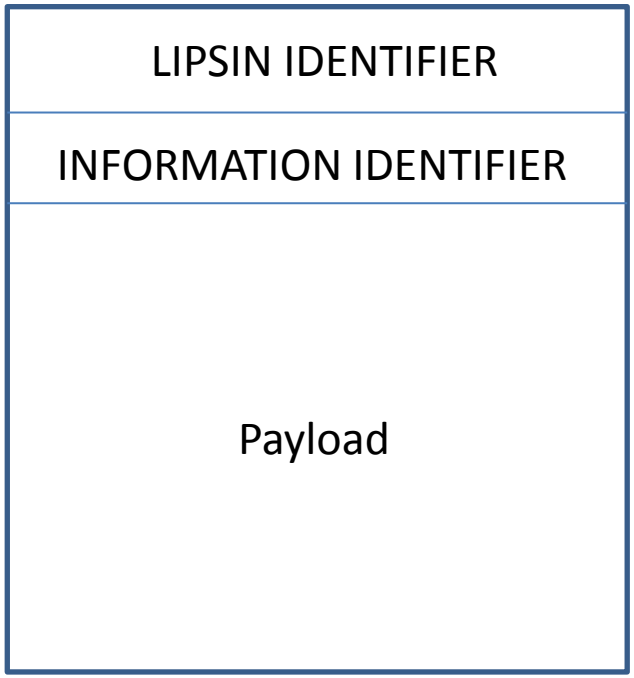
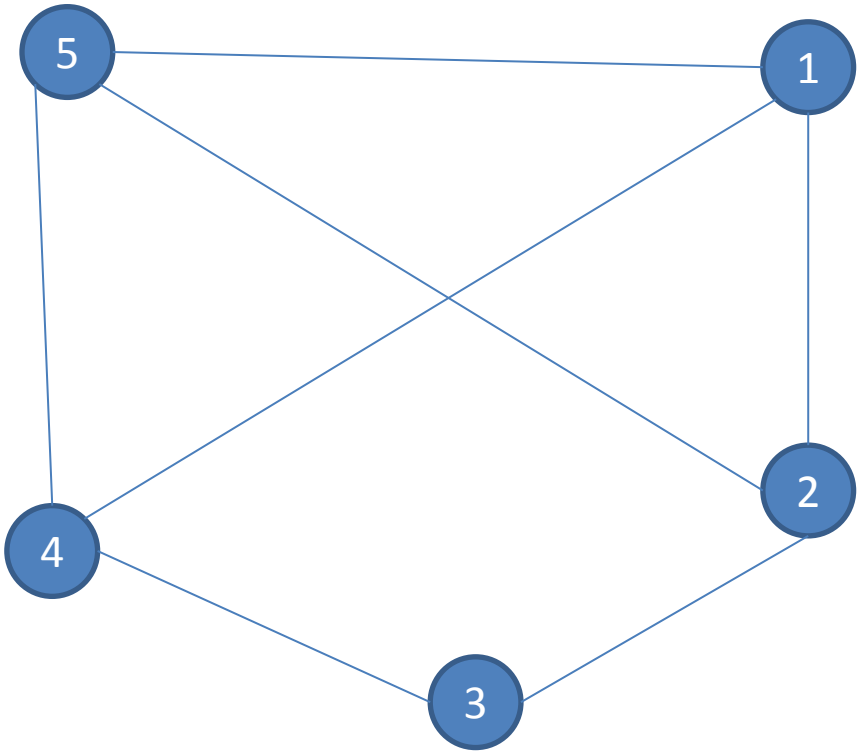
Why using LIPSIN with SDN and not directly information identifiers?

ICN ethernet frame





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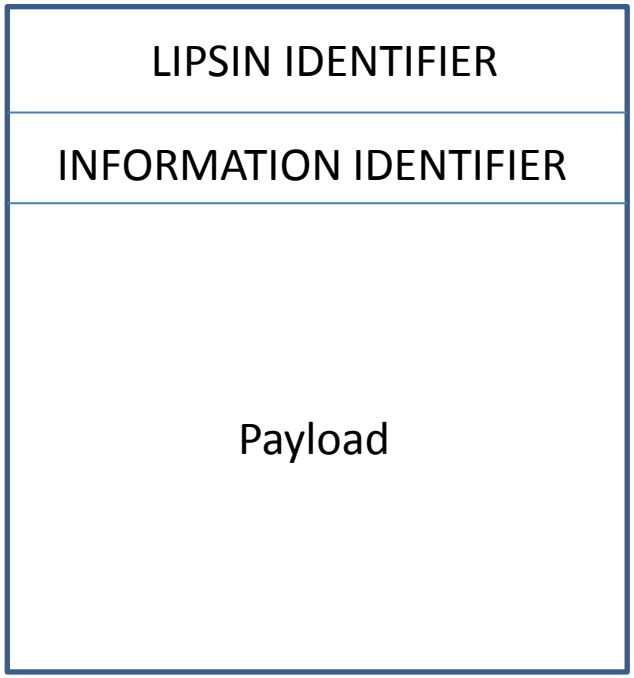

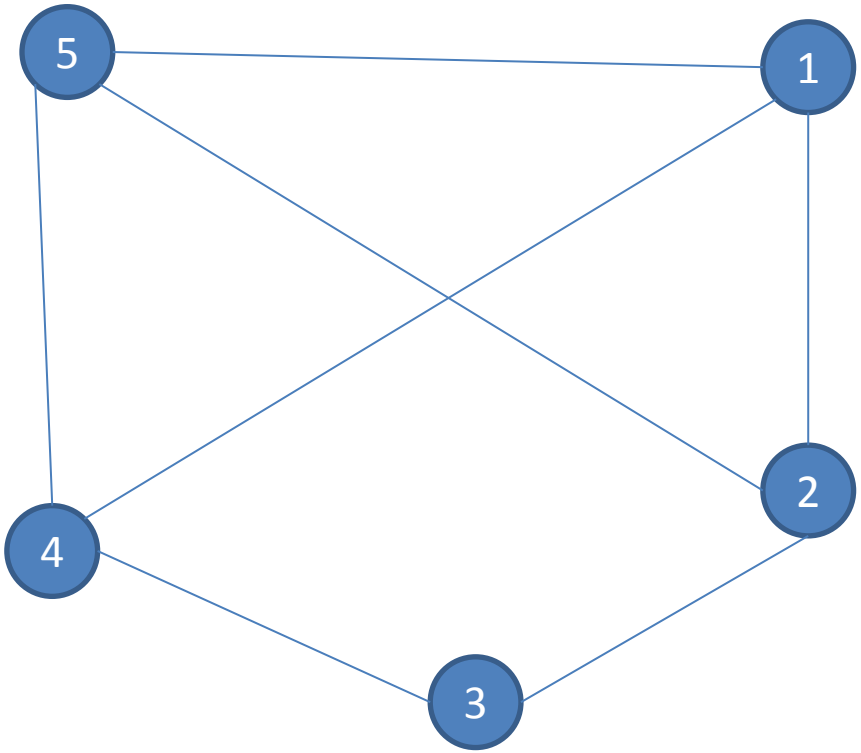

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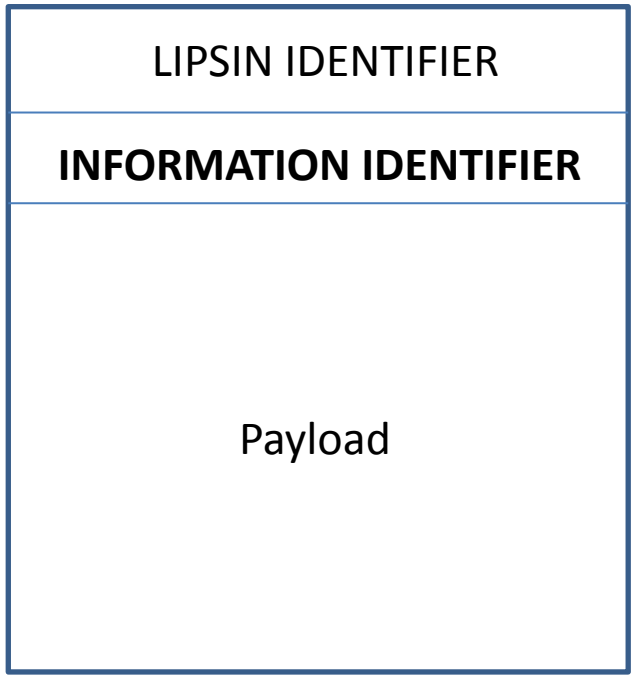

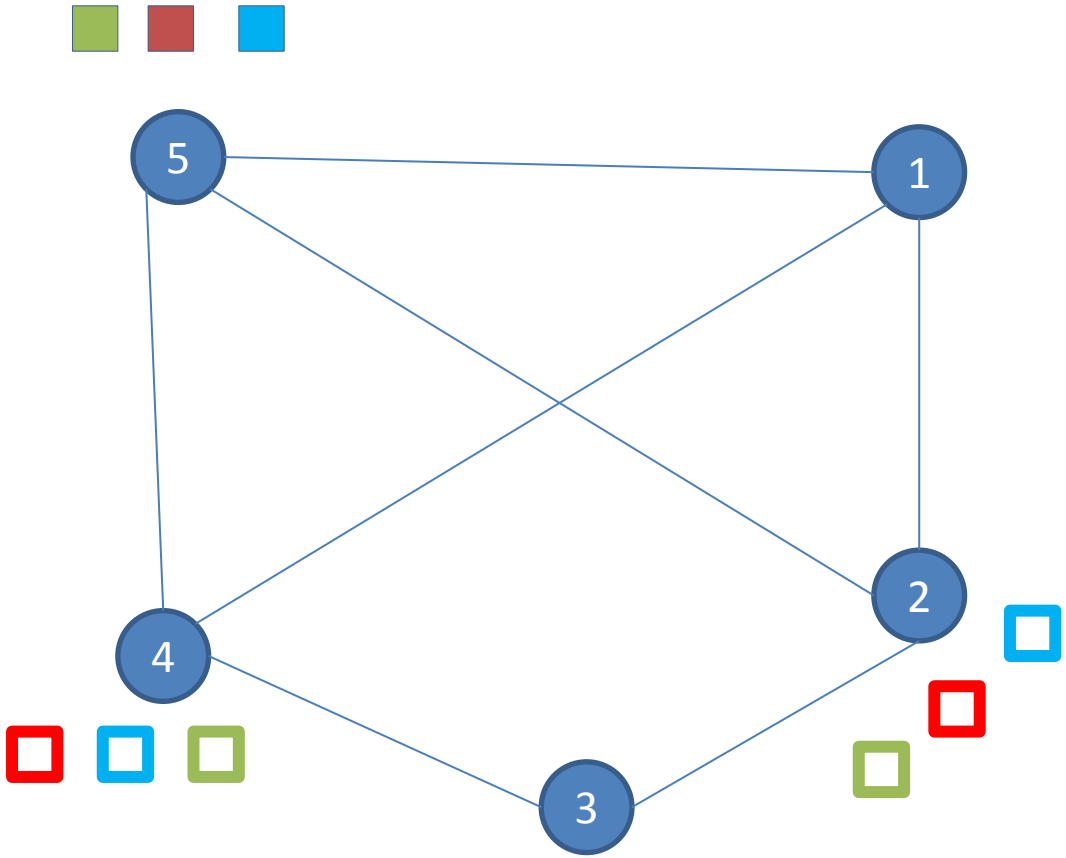

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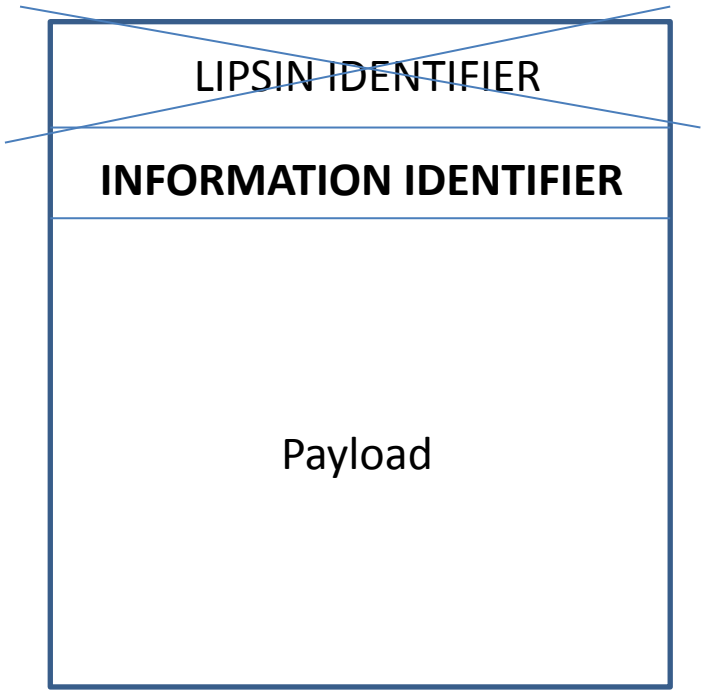

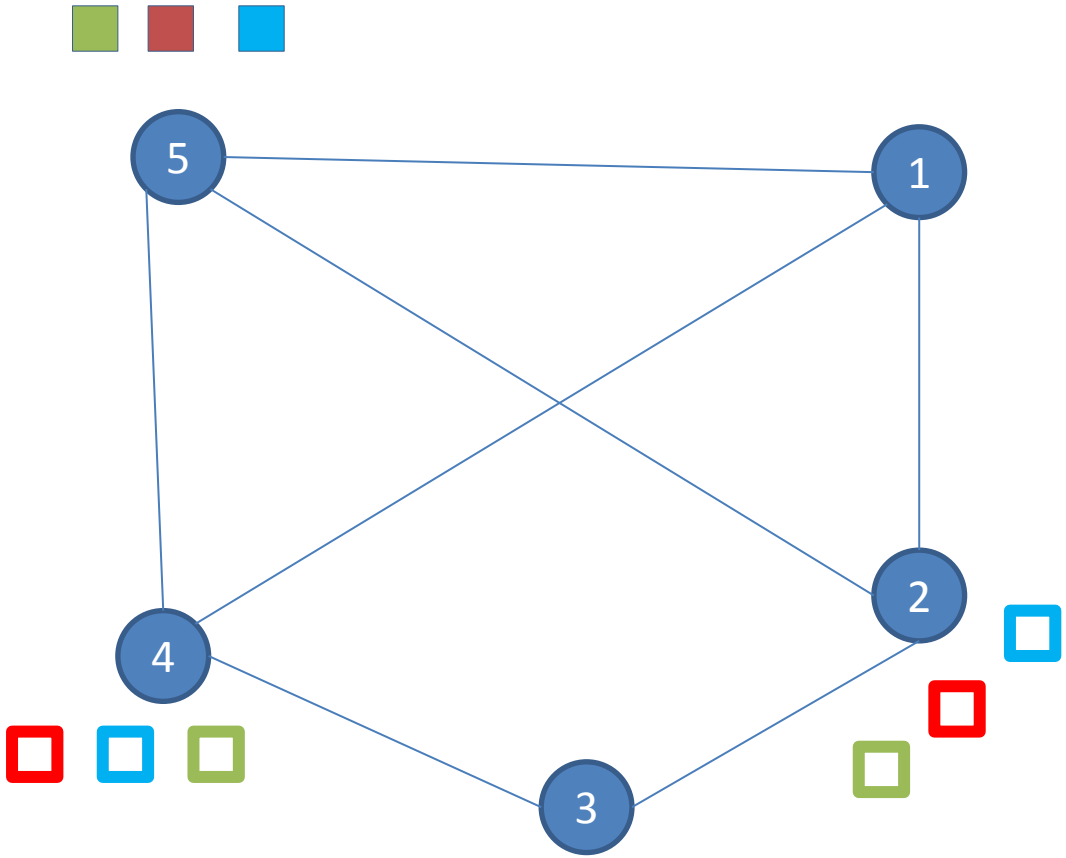

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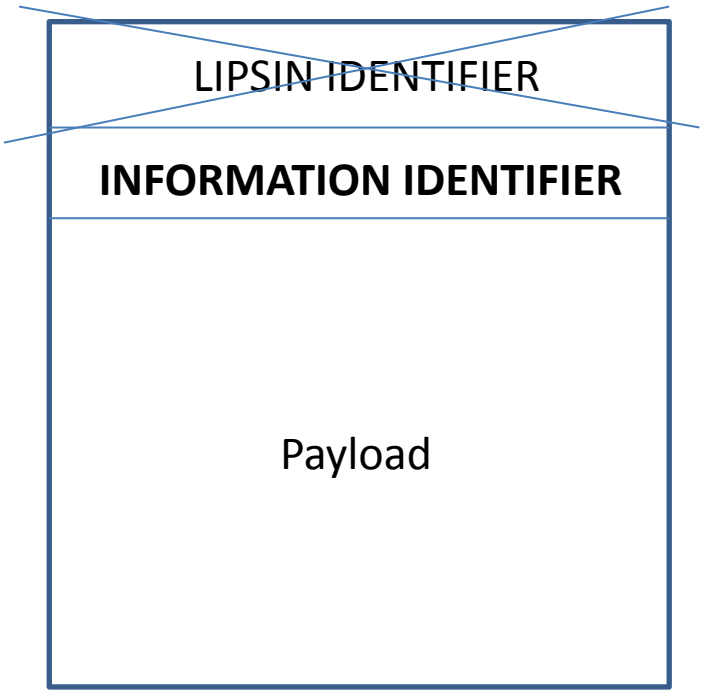

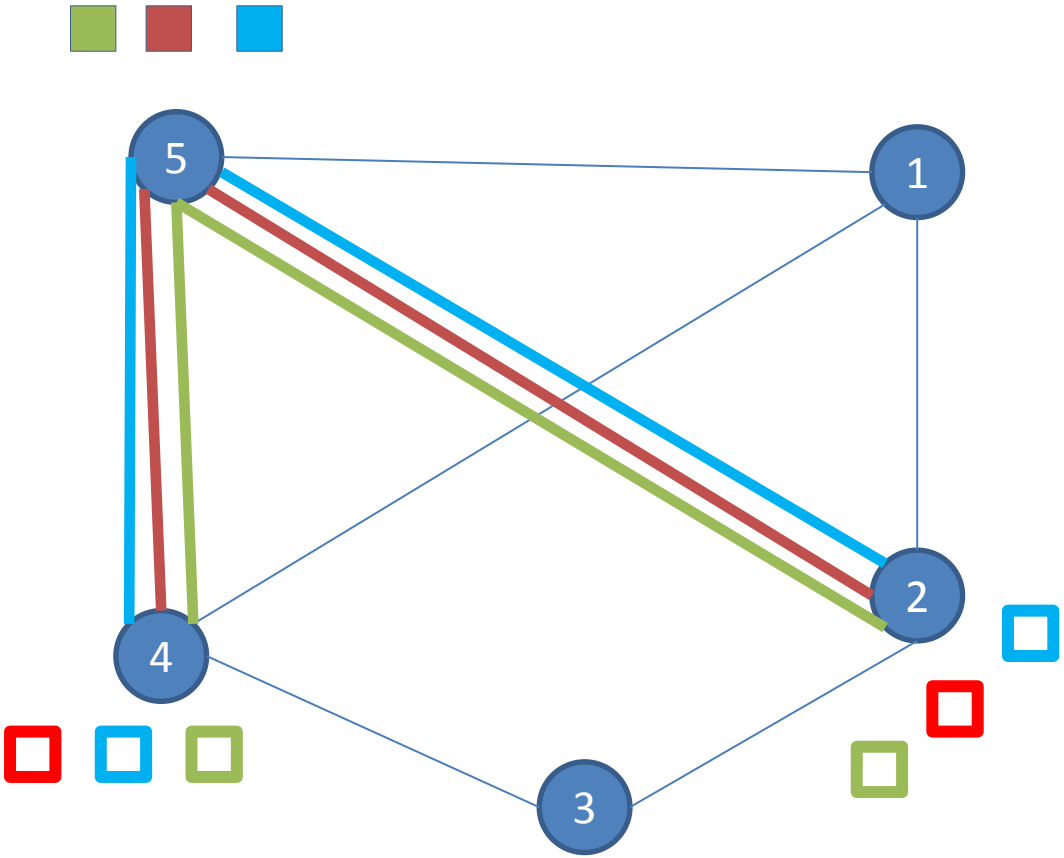

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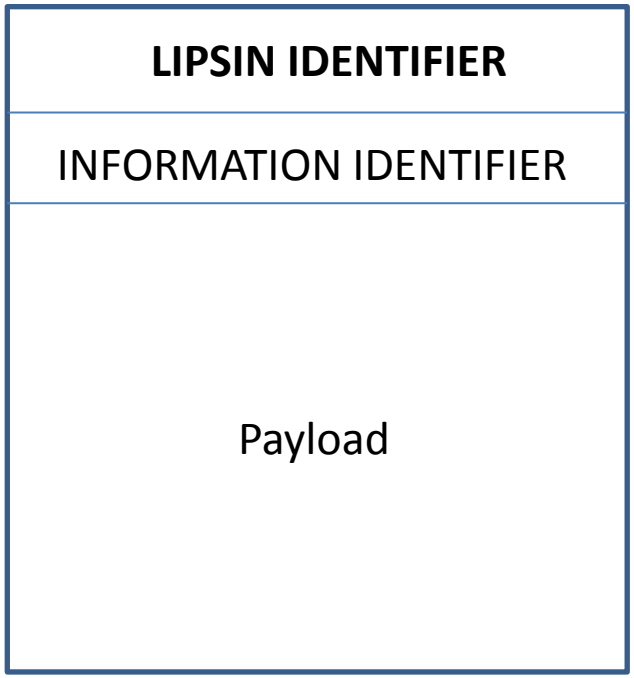
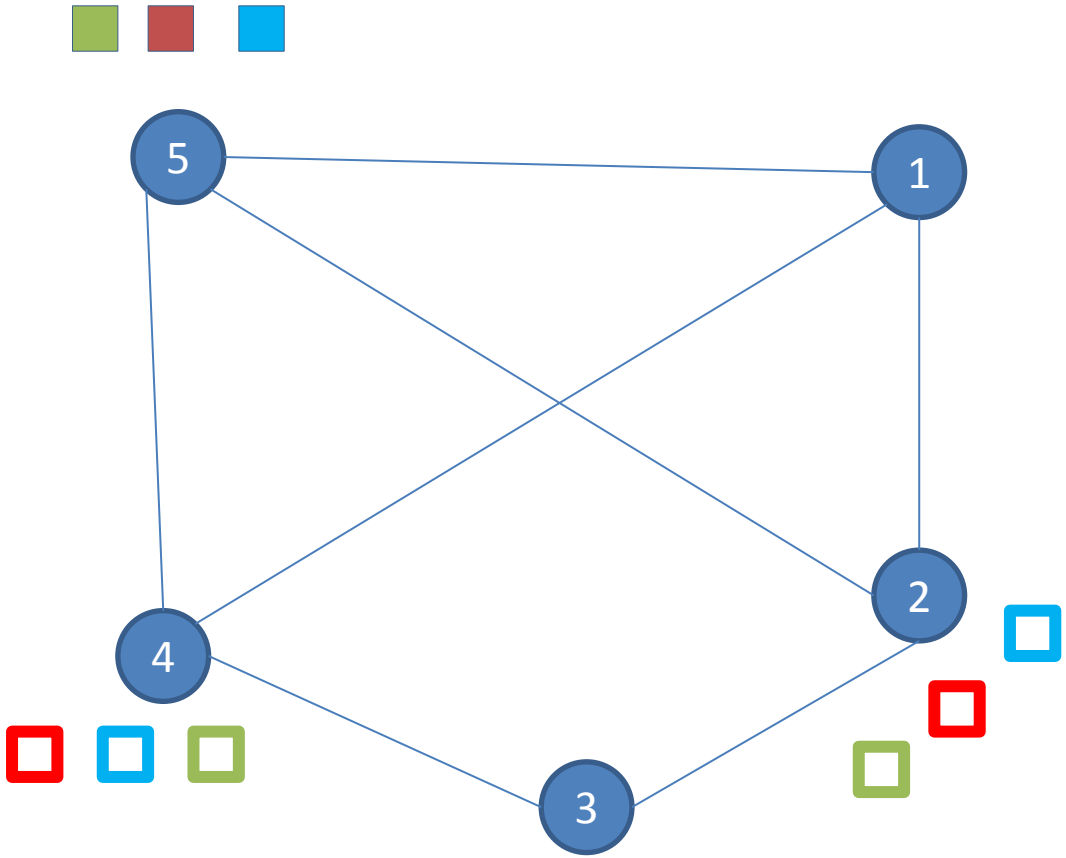
ICN ethernet frame





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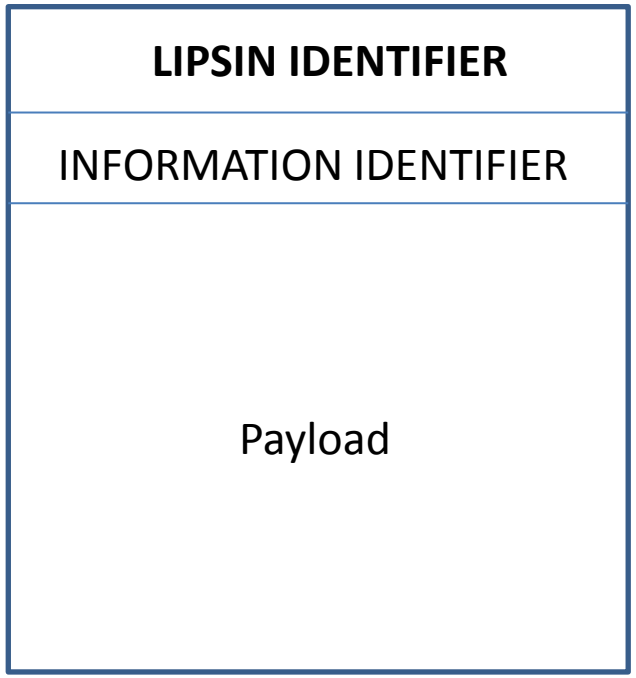
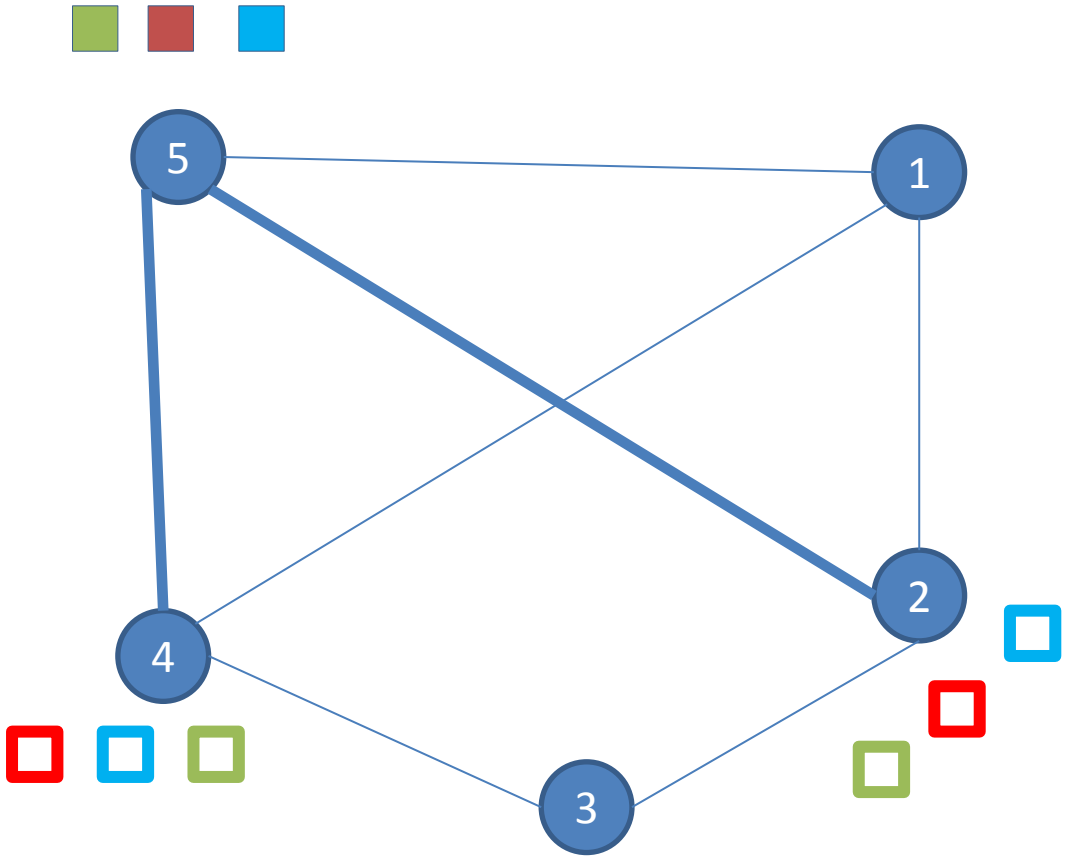
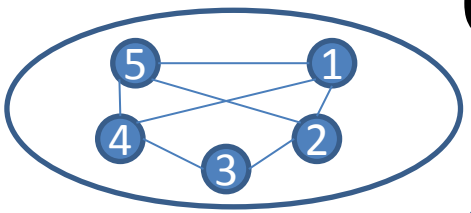
ICN ethernet frame





Modifying LIPSIN functionality for Openflow datapaths



Node 5

Fw Logic

Topology Manager

Information Identifier	Type	Node ID

Rendezvous

Node 4

Fw Logic

Domain Network

Node 1

Fw Logic

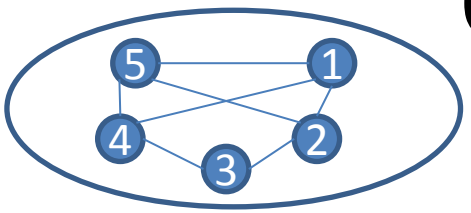
Node 2

Fw Logic

Node 3

Fw Logic

Moving LIPSIN functionality to Openflow datapaths



Node 5

Fw Logic

Topology Manager

Information Identifier	Type	Node ID

Rendezvous

Node 4

Fw Logic

Controller

OF Datapath

Node 1

Fw Logic

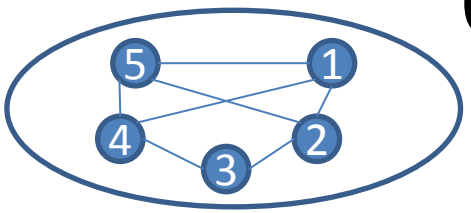
Node 2

Fw Logic

Node 3

Fw Logic

Moving LIPSIN functionality to Openflow datapaths



Node 5

Node 1

FW Logic

Controller

OF Datapath

Node 2

Topology Manager

Information Identifier	Type	Node ID

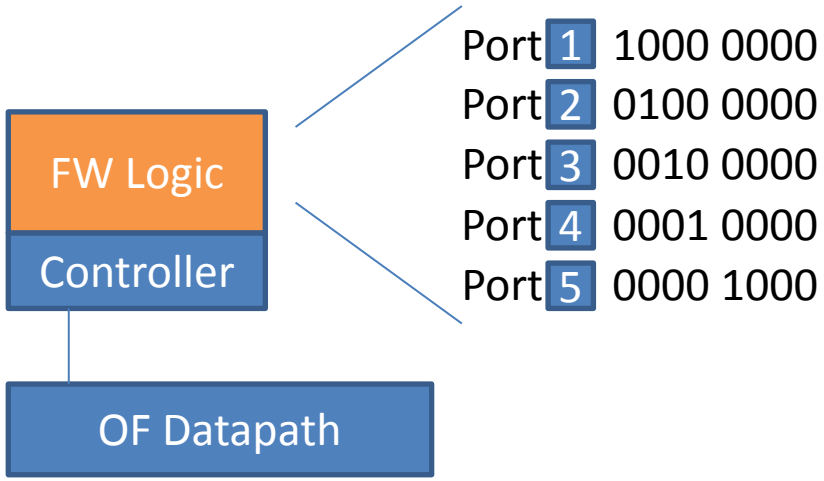
Rendezvous

Node 4

Node 3

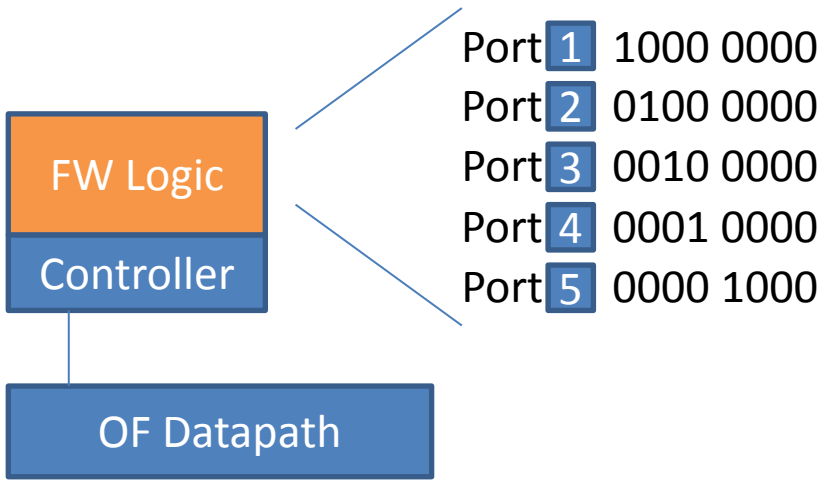
Example for 5-port OpenFlow datapath

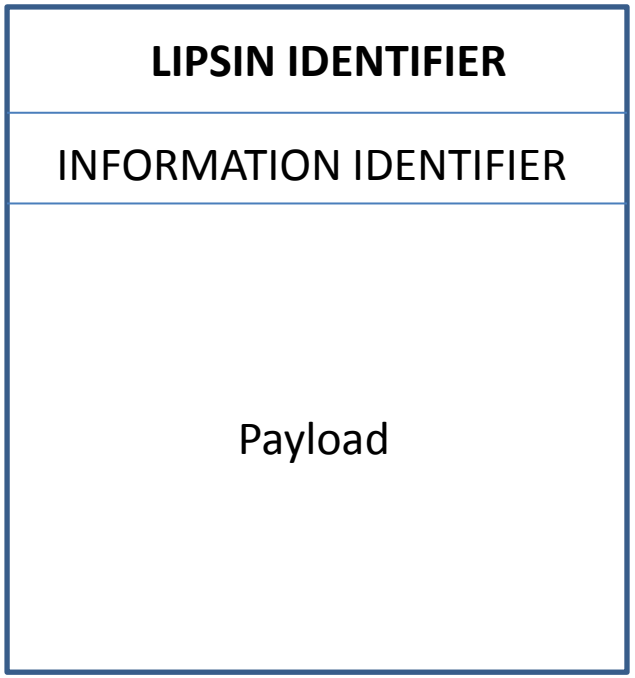
Each switch port is assigned a deployment unique Identifier by the Topology Manager which is kept at the local controller



Example for 5-port OpenFlow datapath

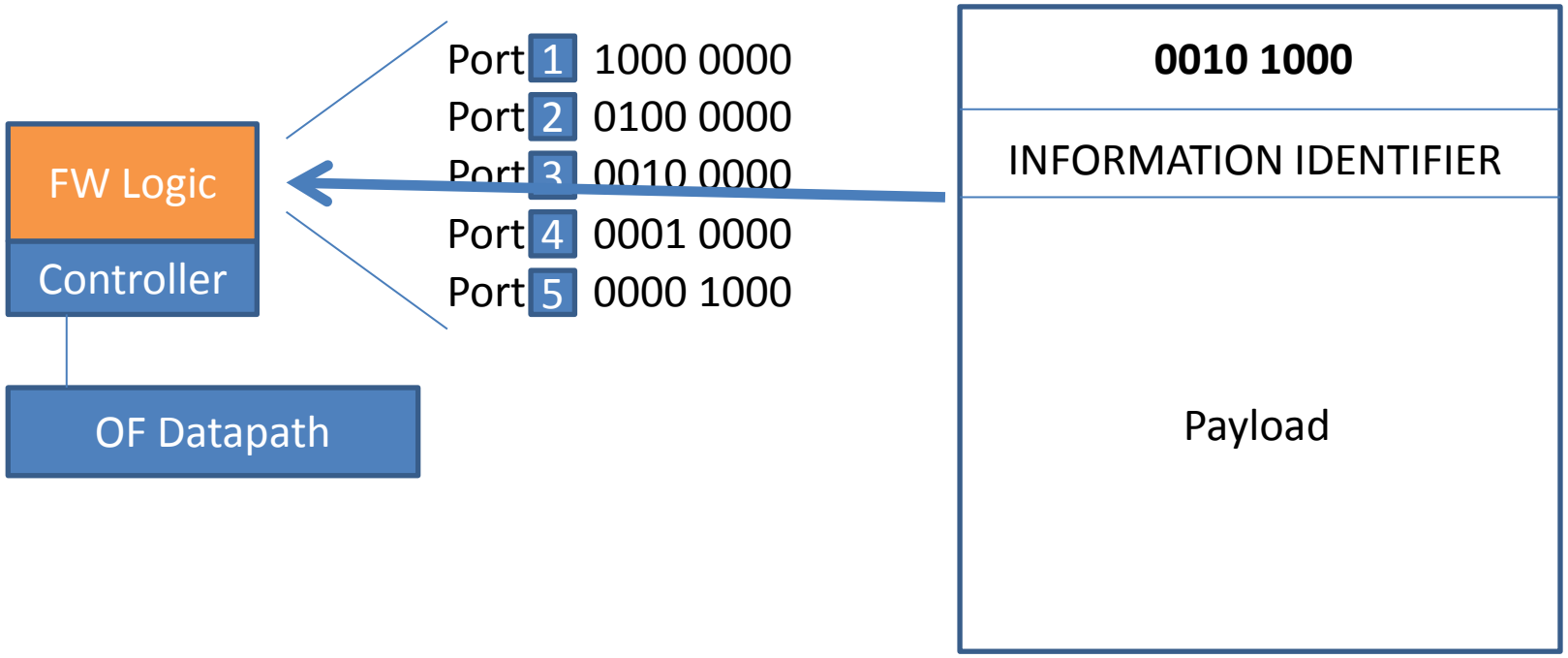
Openflow datapath is configured to match forwarding identifiers on each packet with respective delivery ports,





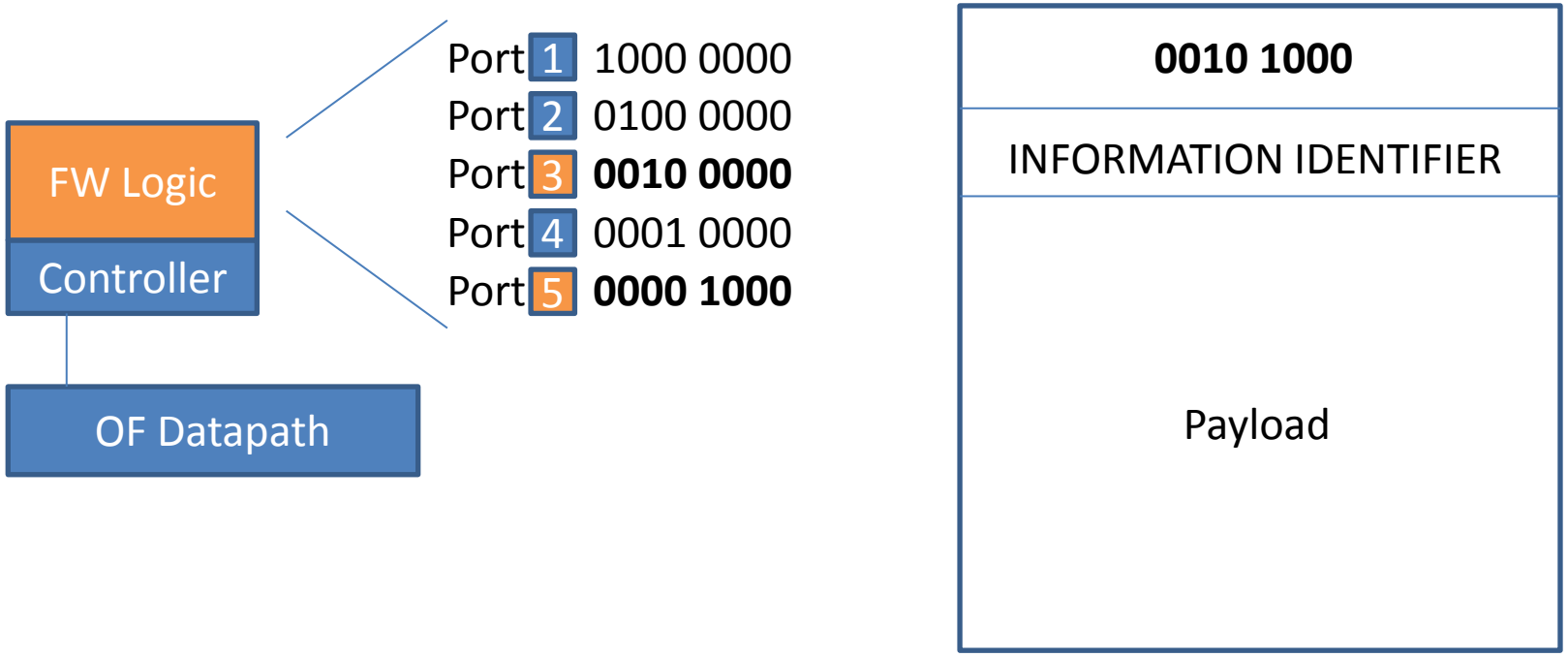
Example for 5-port OpenFlow datapath

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

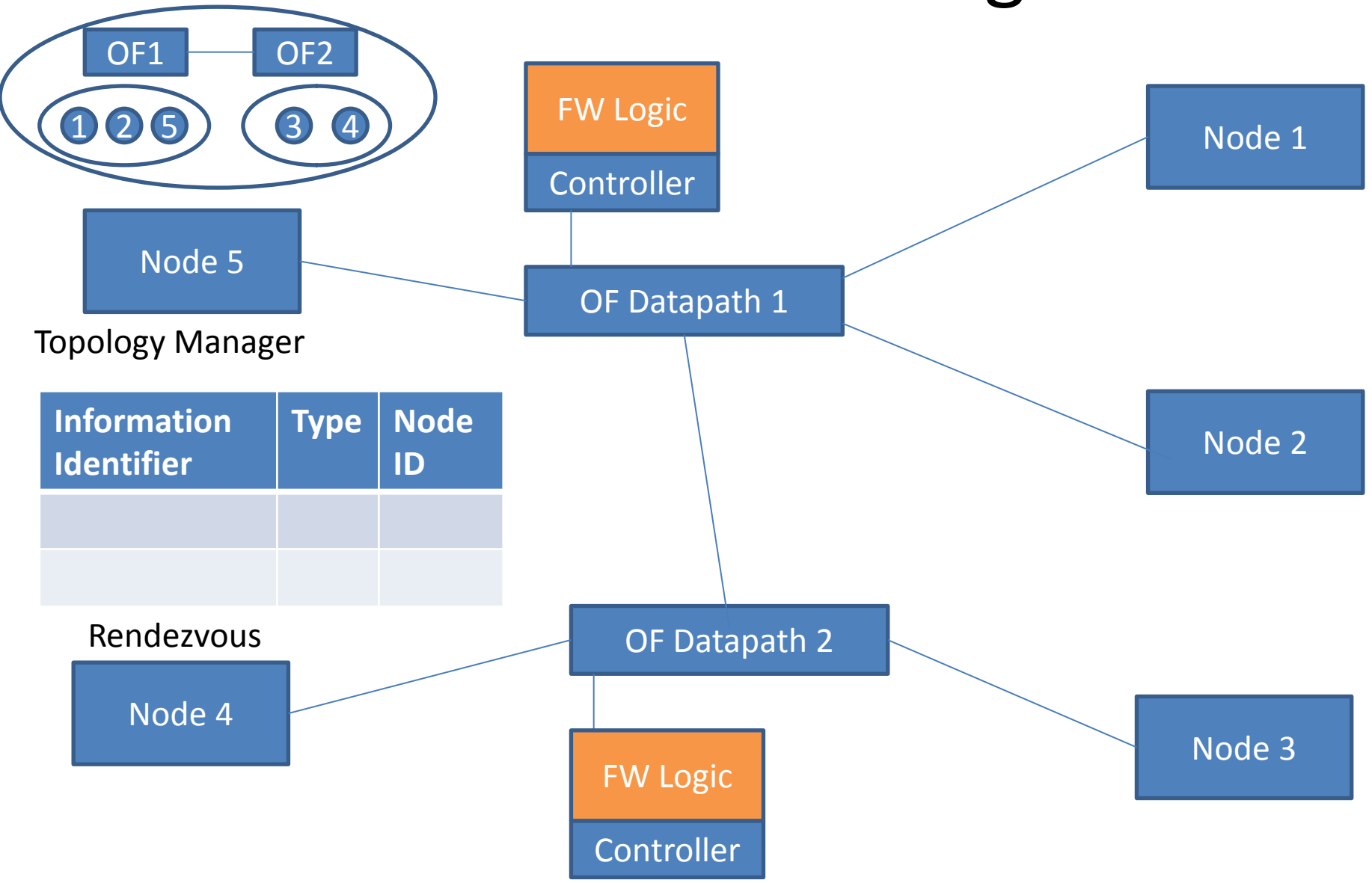


Example for 5-port OpenFlow datapath

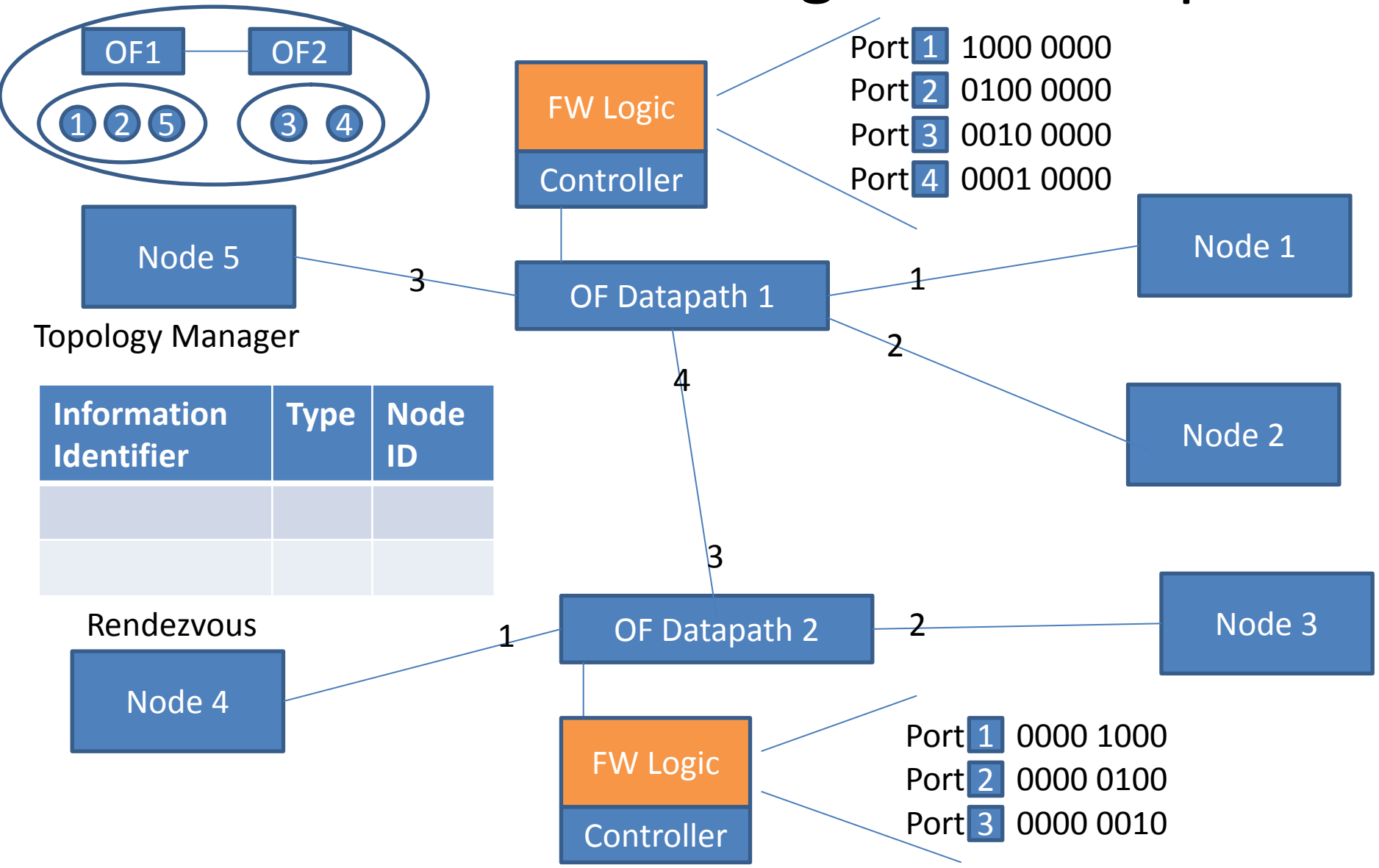
Local openflow controller uses the LIPSIN bloom-filter approach to decode the identifier and find the local datapath ports where the packet should be delivered and installs the rule.



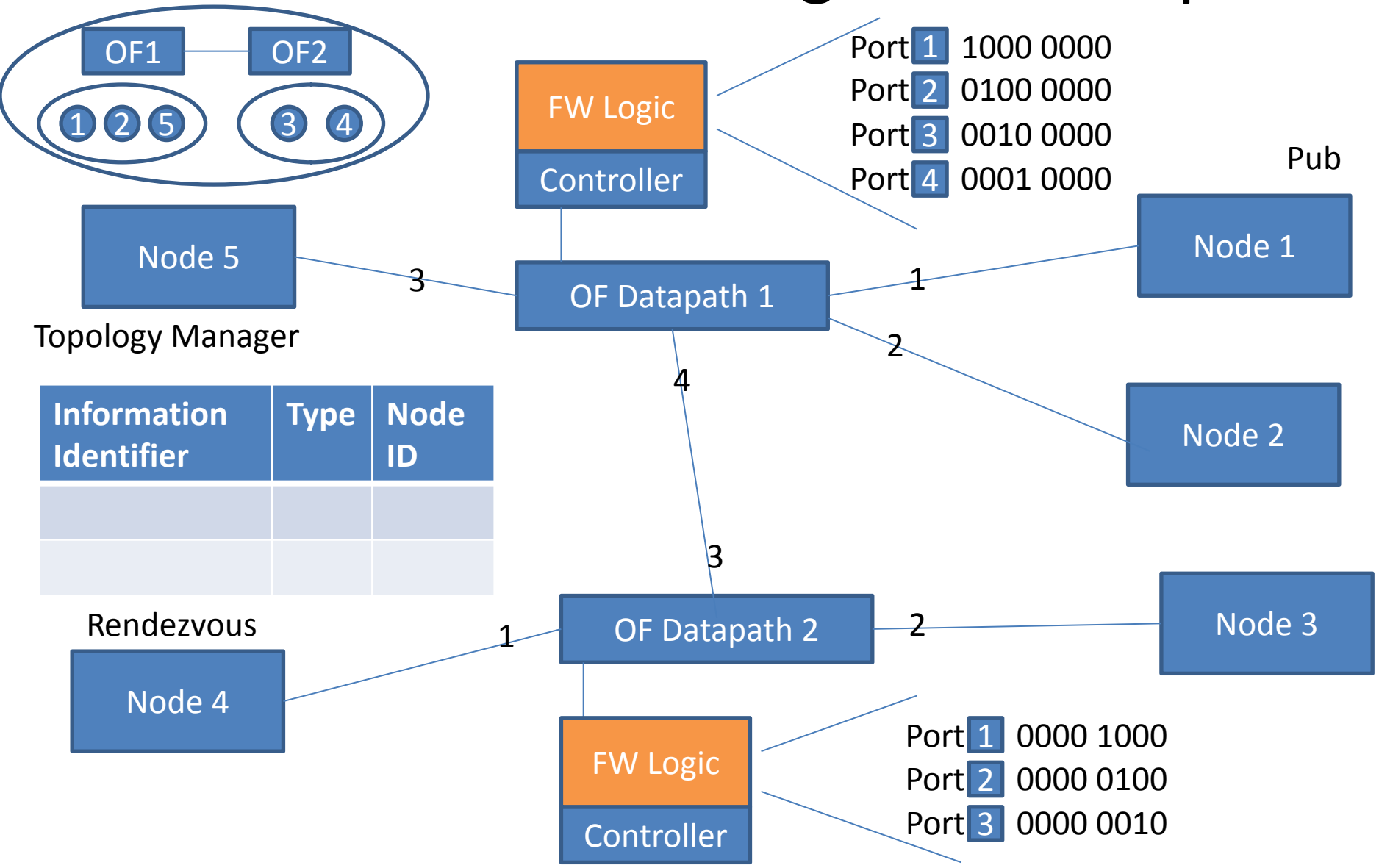
ICN architecture using SDN



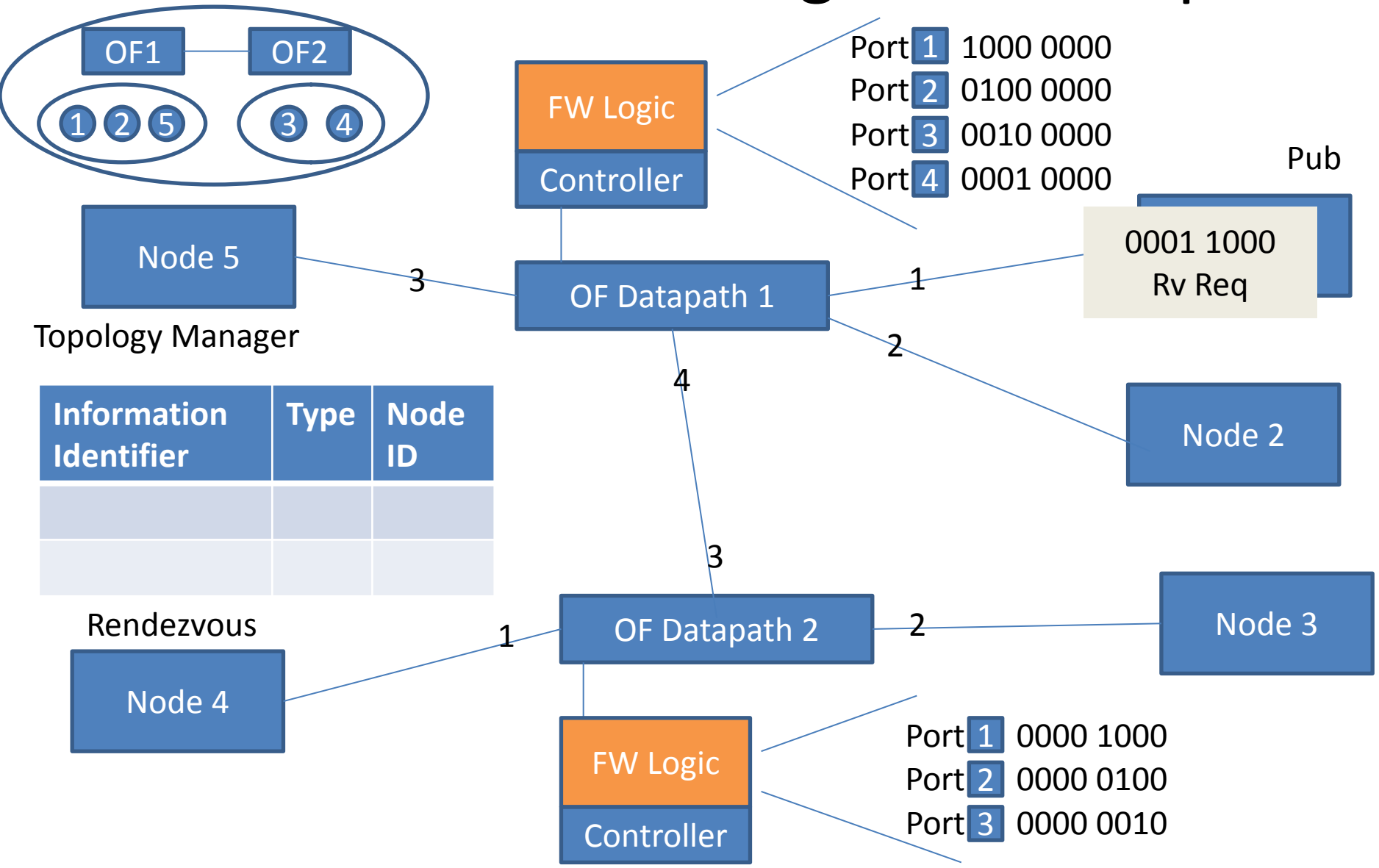
ICN architecture using SDN Example



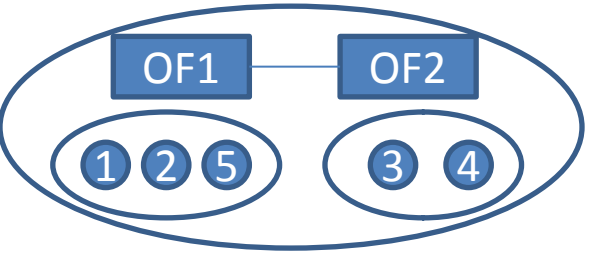
ICN architecture using SDN Example



ICN architecture using SDN Example



ICN architecture using SDN Example



FW Logic

Controller

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

Pub

Node 1

Node 5

3

OF Datapath 1

1

2

Node 2

Topology Manager

4

Information Identifier	Type	Node ID
0xABCD123	Pub	Node1

Sub

Node 3

0000 1000
Rv Req

3

Rendezvous

Node 4

1

OF Datapath 2

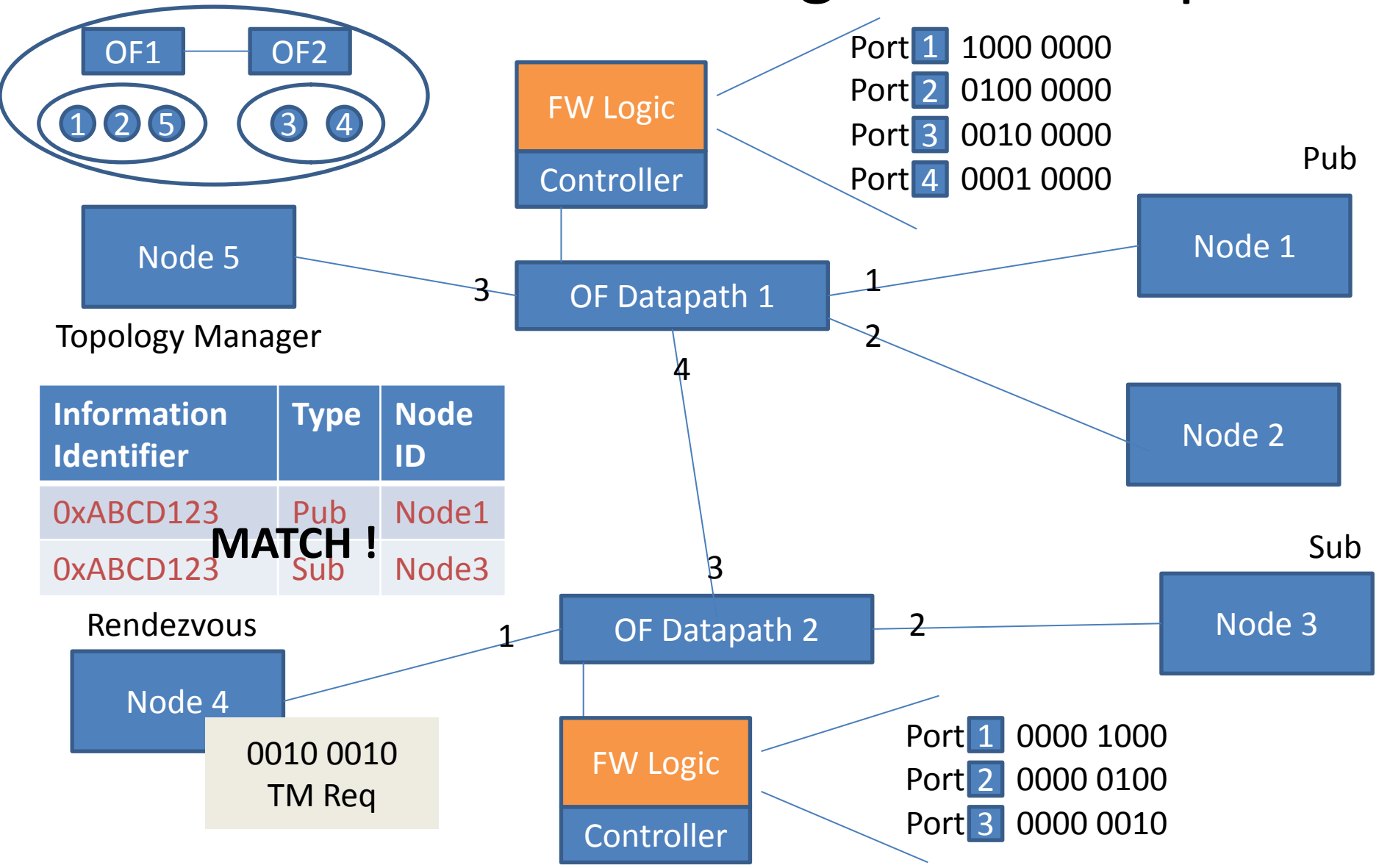
2

FW Logic

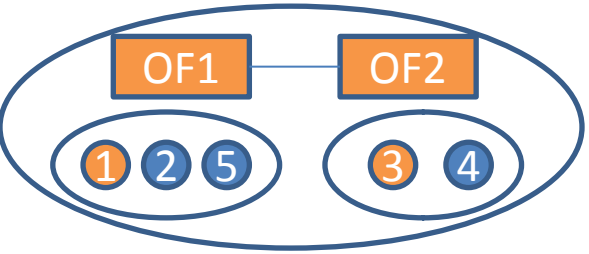
Controller

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

ICN architecture using SDN Example



ICN architecture using SDN Example



FW Logic

Controller

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

Pub

Node 1

1000 0000
START_PUBLISH
0001 0100

Top

3

OF Datapath 1

1

2

4

Node 2

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

Sub

3

Node 3

Rendezvous

Node 4

1

OF Datapath 2

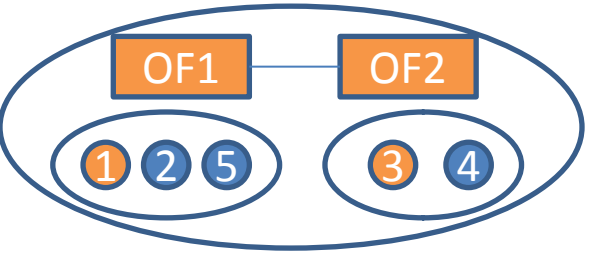
2

FW Logic

Controller

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

ICN architecture using SDN Example



1000 0000
START_PUBLISH
0001 0100

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

Pub

Node 5

Topology Manager

OF Datapath 1

Node 1

Node 2

3
1
2
4

OF 1 Flow tables

FID	PORT
1000 0000	1

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

Sub

Rendezvous

Node 4

OF Datapath 2

Node 3

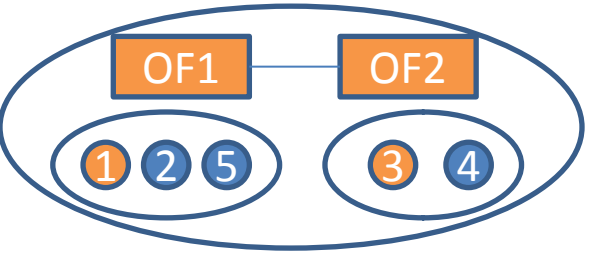
3
1
2

FW Logic

Controller

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

ICN architecture using SDN Example



FW Logic

Controller

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

Pub

0001 0100
DATA

Node 5

Topology Manager

3

OF Datapath 1

1

2

4

Node 2

OF 1 Flow tables

FID	PORT
1000 0000	1

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

Sub

Node 3

3

Rendezvous

Node 4

1

OF Datapath 2

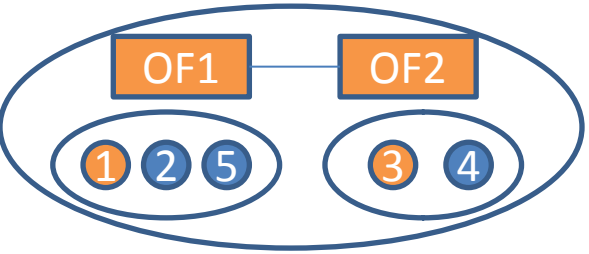
2

FW Logic

Controller

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

ICN architecture using SDN Example



0001 0100
DATA

Controller

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

Pub

Node 5

Node 1

3

OF Datapath 1

1

2

Topology Manager

4

OF 1 Flow tables

FID	PORT
1000 0000	1
0001 0100	4

Node 2

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

Sub

3

Rendezvous

1

OF Datapath 2

2

Node 3

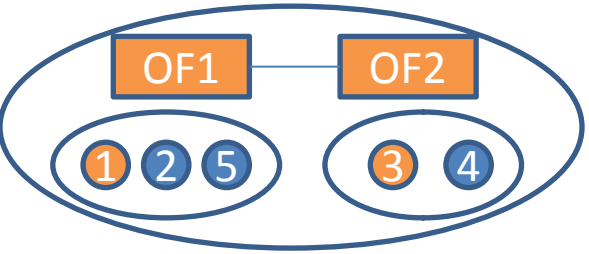
Node 4

FW Logic

Controller

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

ICN architecture using SDN Example



FW Logic

Controller

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

Pub

Node 1

Node 5

Topology Manager

3

OF Datapath 1

1

2

4

Node 2

OF 1 Flow tables

FID	PORT
1000 0000	1
0001 0100	4

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

Sub

3

Rendezvous

1

OF Datapath 2

2

Node 3

Node 4

0001 0100
DATA

Controller

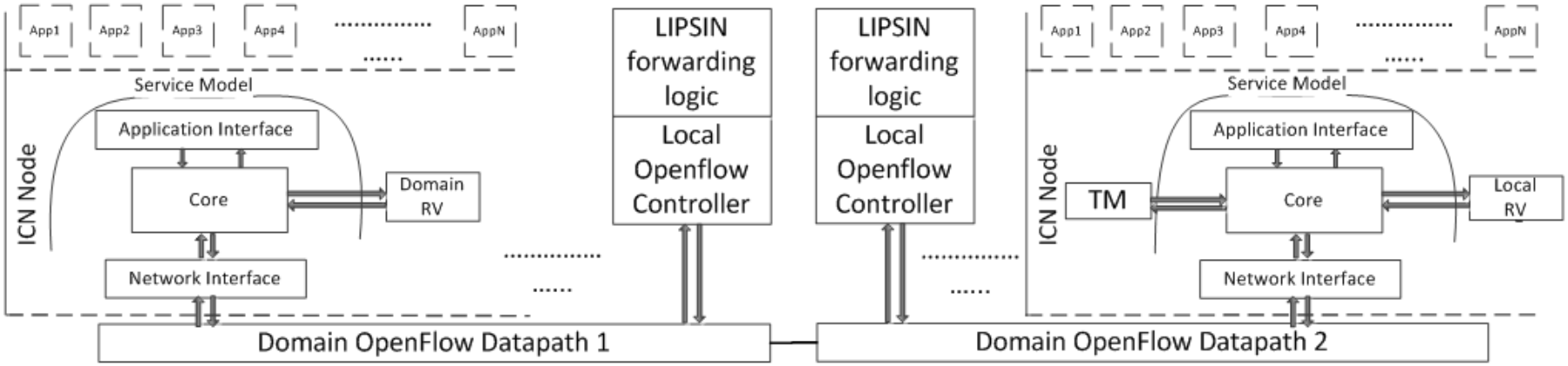
Port 1 0000 1000
Port 2 **0000 0100**
Port 3 0000 0010

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

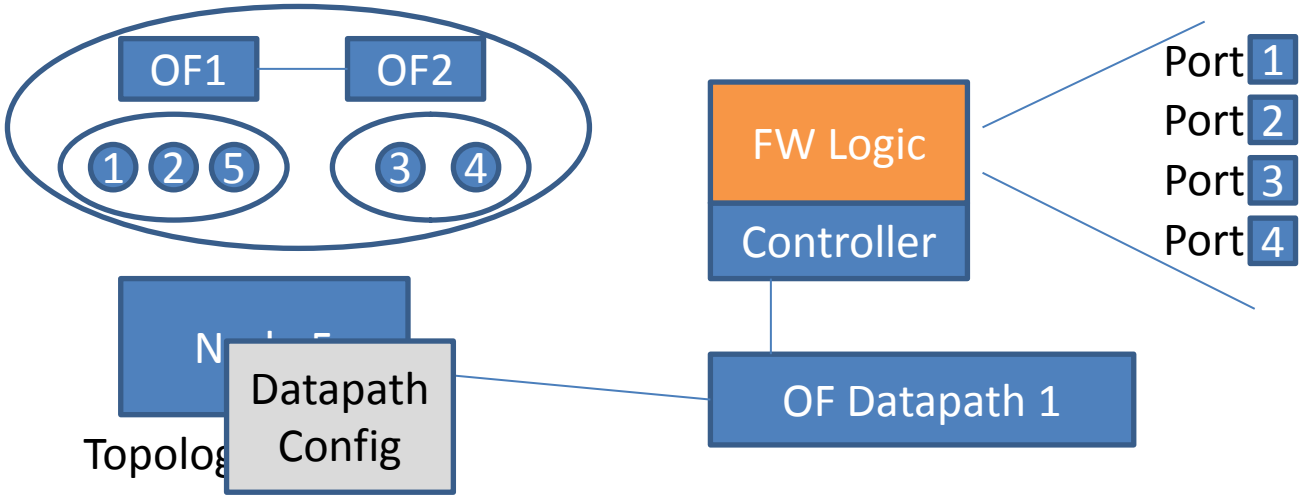
Benefits of using SDN

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



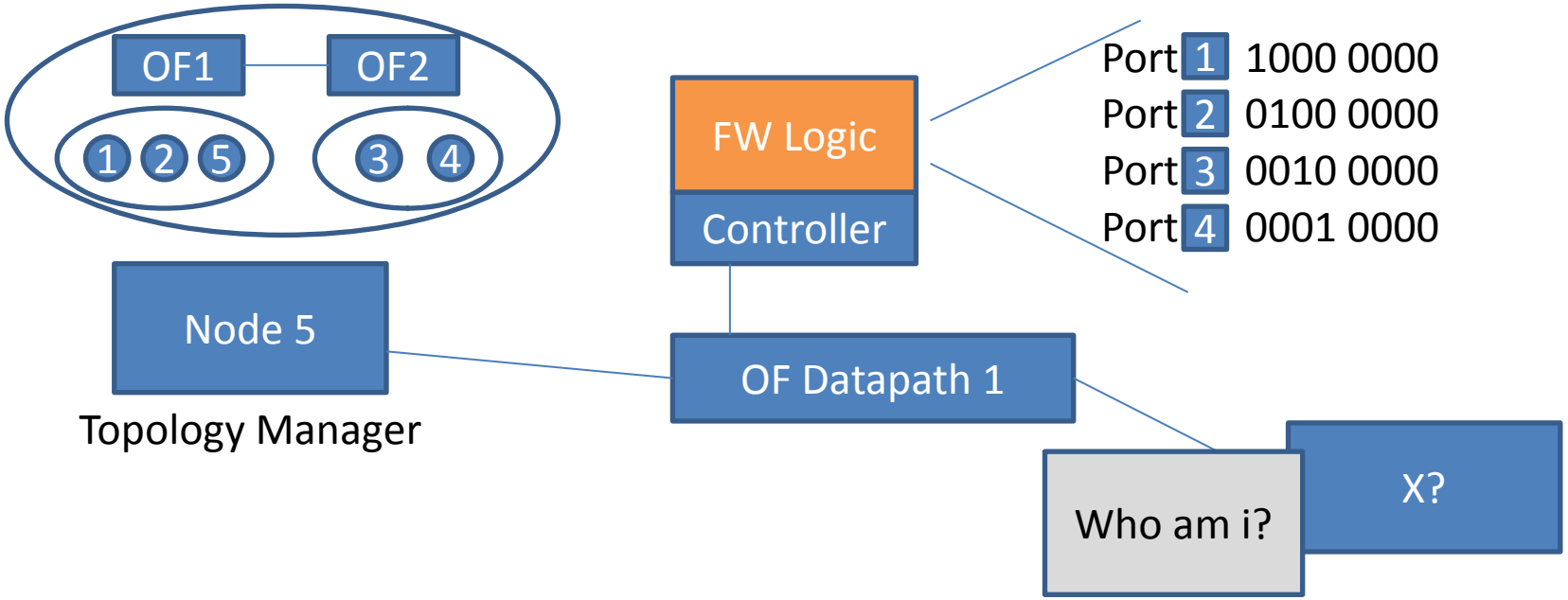
Benefits of using SDN

- Network bootstrap gets very simplified



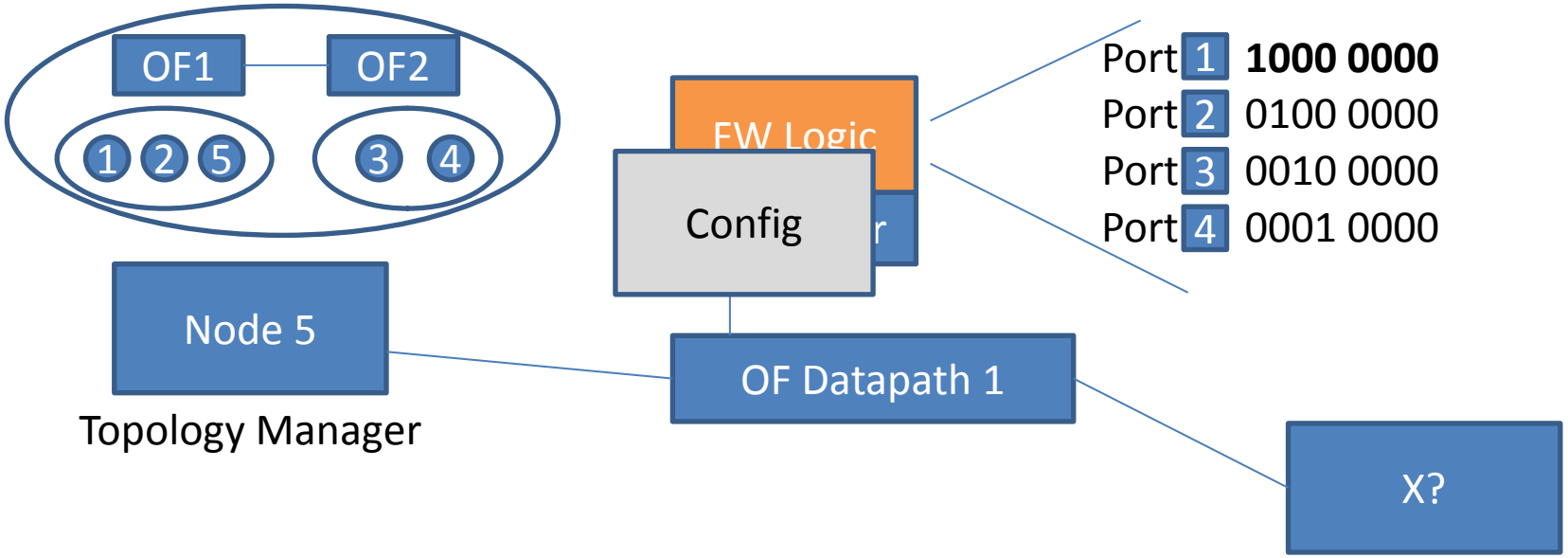
Benefits of using SDN

- Network bootstrap gets very simplified



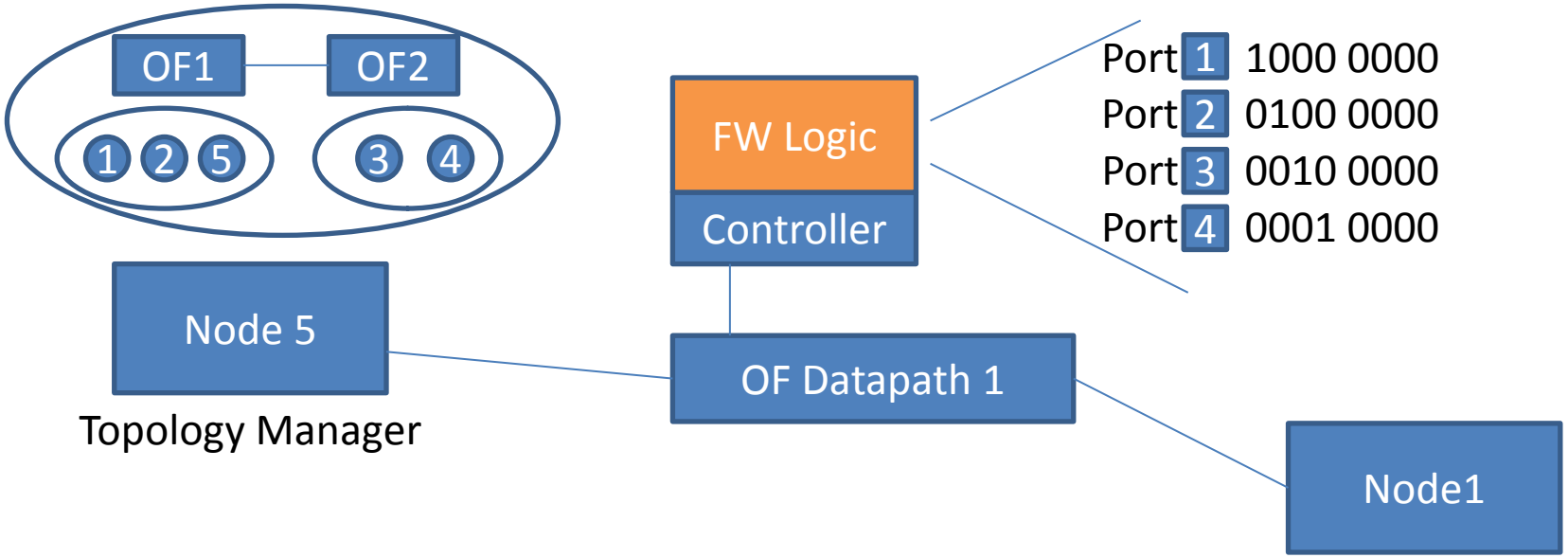
Benefits of using SDN

- Network bootstrap gets very simplified



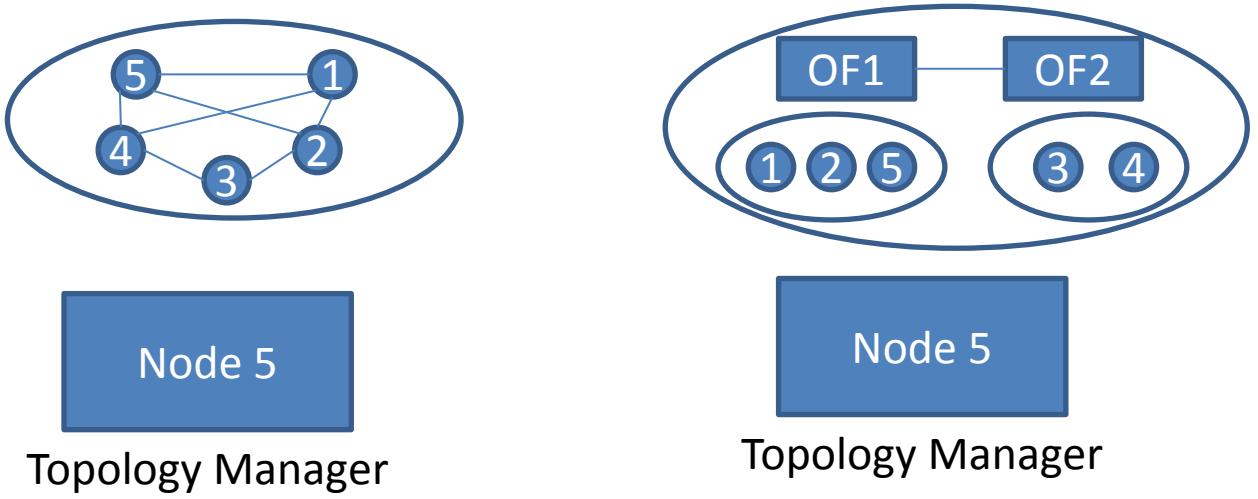
Benefits of using SDN

- Network bootstrap gets very simplified



Benefits of using SDN

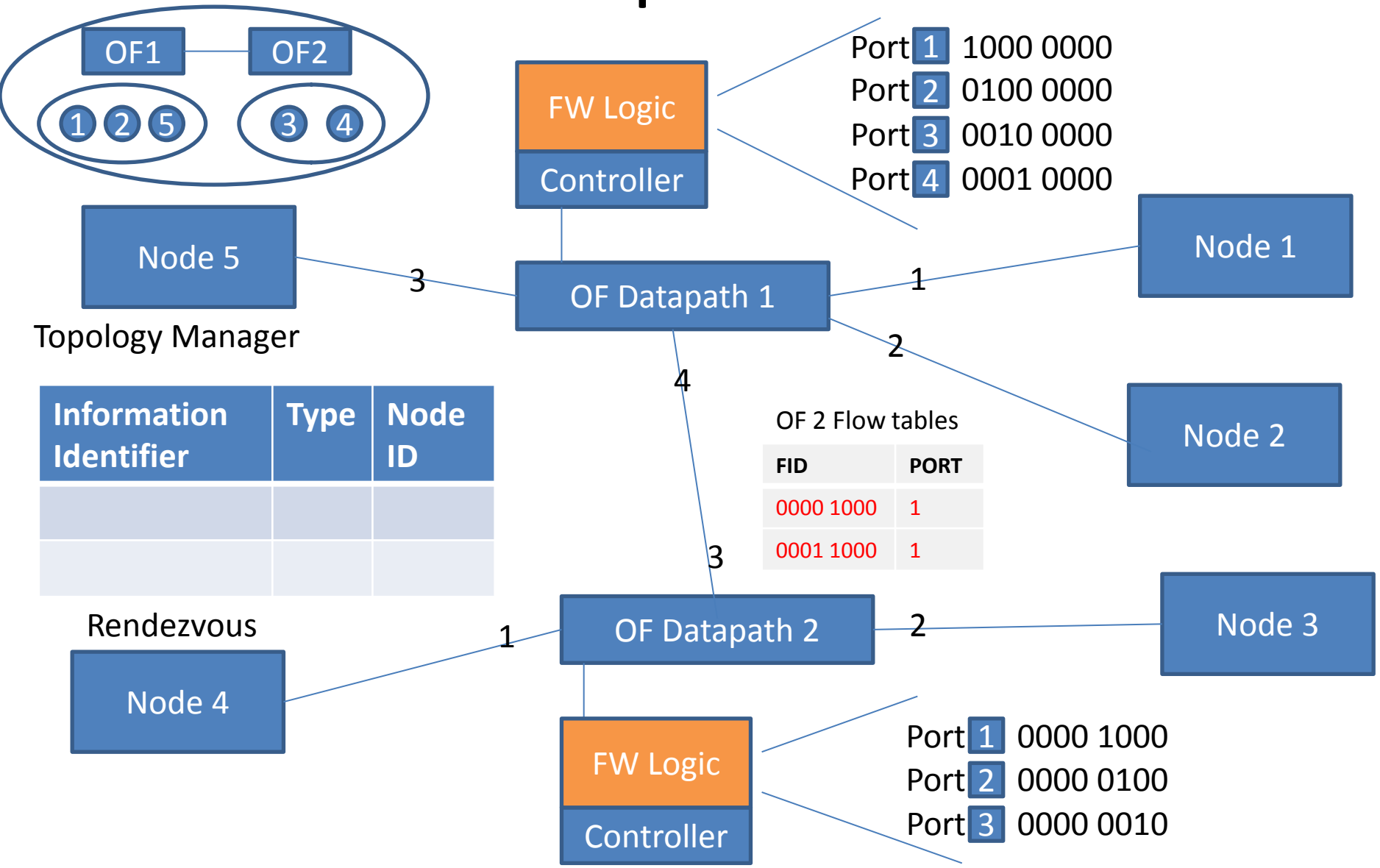
- Topology Management internal structures get simpler and response is improved



Future Work

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

The problem


OF1
OF2
1 2 5
3 4
FW Logic
Controller
Port 1 1000 0000
Port 2 0100 0000
Port 3 0010 0000
Port 4 0001 0000
Node 5
Topology Manager
3
OF Datapath 1
1
Node 1
2
Node 2
4
Information Identifier
Type
Node ID
Rendezvous
OF 2 Flow tables
FID
PORT
0000 1000
1
0001 1000
1
3
1
OF Datapath 2
2
Node 3
Node 4
FW Logic
Controller
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 ?