Advanced Computer Networks

Content-Centric Networking (II)

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REVIEW

- **Why CCN?**

  - User behavior is already Content-Centric
  - But Network is still Location based
  - The add-on systems to mitigate the mismatch also introduces overhead

REVIEW

- Why CCN?

- **How does NDN achieve Content-Centric? (protocol level)**

| browser, chat, … |
| File Stream, … |
| Security, … |
| Content Name |
| Strategy, … |
| IP, UDP, PPP, … |
| copper, fiber, radio, … |

User / App supplied name

Versioning & Segmentation

/ugoe.edu/jchen/acn13-ICN.pdf /_v<timestamp>/_s3

Globally-routable name

Organizational name

Conventional/automatic

REVIEW

- Why CCN?

- How does NDN achieve Content-Centric? (protocol level)

- **What are the 2 packet types in NDN? Why NDN is inherit query/response?**

| Content Name |
|:---:|
| Selector
(order preference, publisher filter, scope, ..) |
| Nonce |

Interest (Request)

Content Name
Content Descriptors
Signature (digest algorithm, witness, ...)
Signed Info (publisher ID, key locator, stale time, ...)
Data

Data (Response)

REVIEW

- Why CCN?

- How does NDN achieve Content-Centric? (protocol level)

- What are the 2 packet types in NDN? Why NDN is inherit query/response?

- **What are the data structures in a NDN forwarding engine? And functions?**

  - Forwarding Information Base (FIB)
  - Pending Interest Table (PIT)
  - Content Store
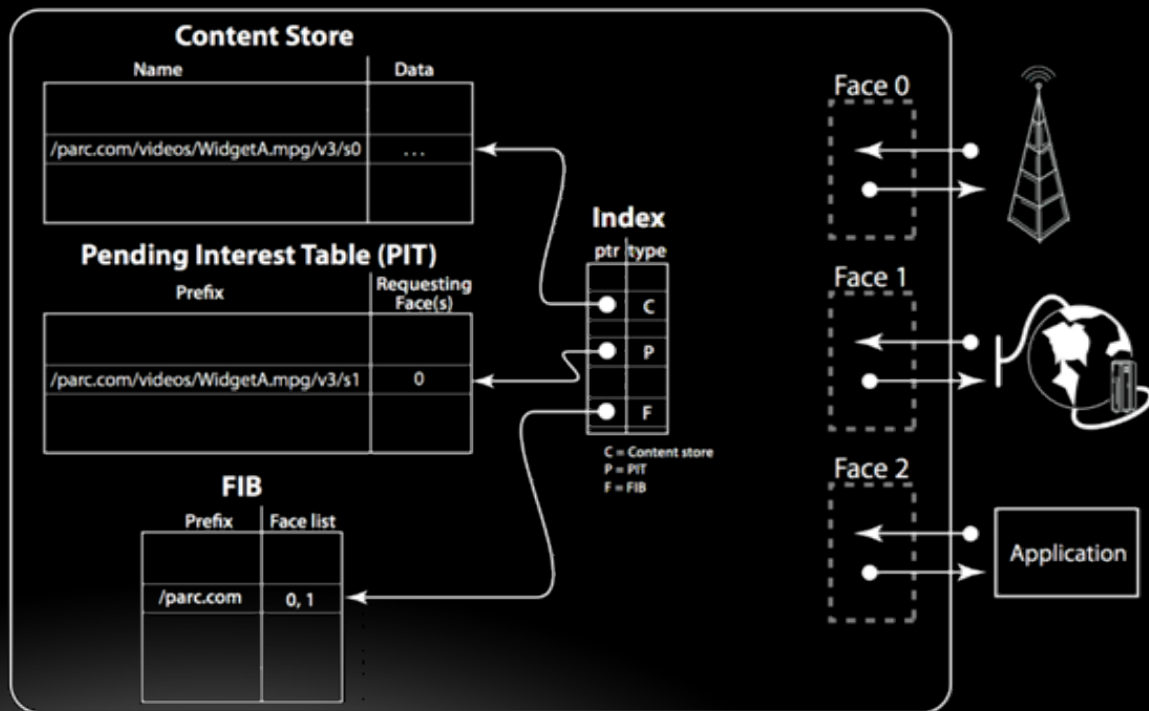
REVIEW

- Why CCN?

- How does NDN achieve Content-Centric? (protocol level)

- What are the 2 packet types in NDN? Why NDN is inherit query/response?

- What are the data structures in a NDN forwarding engine? And functions?

- **Can NDN transfer live audio/video information?**

  - Yes, VoCCN does it.
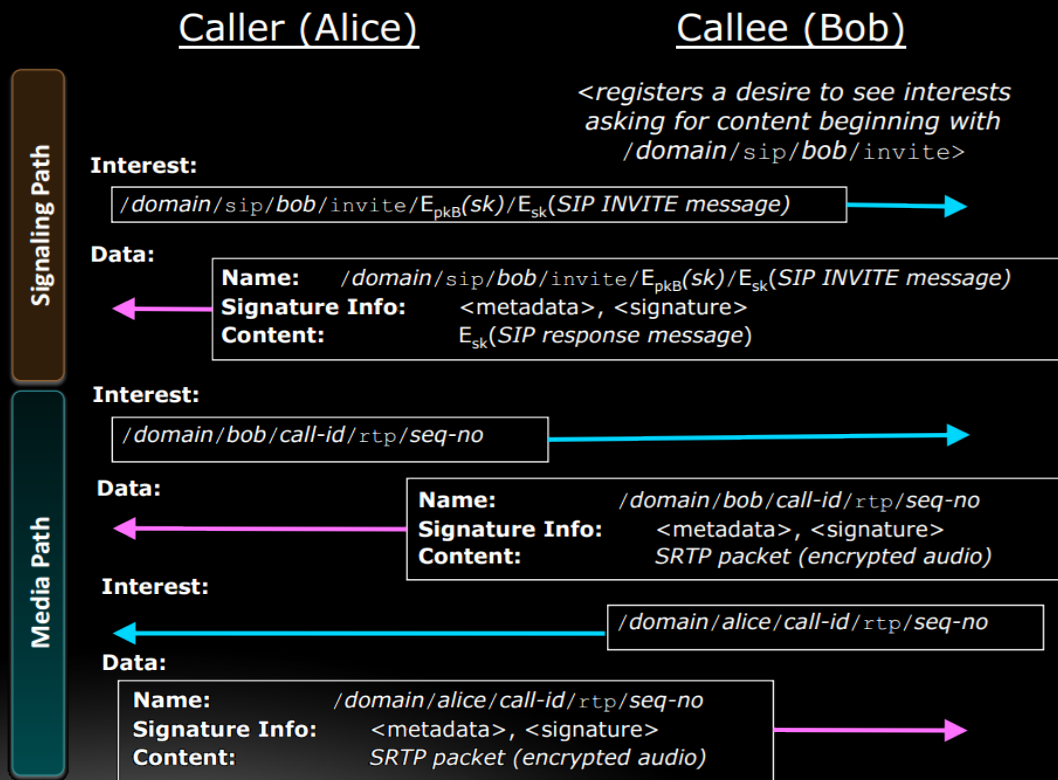
REVIEW

- Why CCN?

- How does NDN achieve Content-Centric? (protocol level)

- What are the 2 packet types in NDN? Why NDN is inherit query/response?

- What are the data structures in a NDN forwarding engine? And functions?

- Can NDN transfer live audio/video information?

- **Is query/response enough for Internet use?**

IS QUERY/RESPONSE (DATA PULLING) ENOUGH?

- **RSS Feed**
  - User doesn't know *what* is going to be the next data in his/her interest
  - Network doesn't know *where* to forward the request (if there is)
  - Existing solutions (in HTTP/TCP/IP):
    - Server-based solution (e.g., Twitter)
    - Information aggregators (e.g., Google)
  - Issues:
    - Overhead caused by polling server(s)
    - Timeliness
- **Gaming**
  - Player doesn't know *when* the next data might come
  - Existing solutions (in IP):
    - Long-term link
    - Browser games (slow paced)
  - Issues:
    - Overhead caused by maintaining links
    - NAT

Content-Oriented Pub/Sub Systems (COPSS)

Requirements of Efficient Pub/Sub

- Push

- Temporal Separation

- Scalability

- Efficiency

- Rendezvous-Point (RP) based communication

- Hierarchical topic management

- Two-step communication

- Offline-support

- Minimal changes, but significant architectural & functional improvement!

Protocol Level Modification

- Adopt Content Descriptor (CD)
    - Using the same form of a Content Name
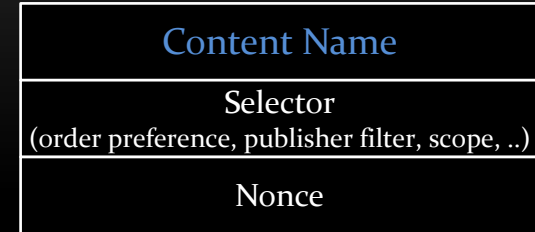   - Different relationship between CD vs. Data

| browser, chat, ... |
| File Stream, ... |
| Security, ... |
| Content |
| Strategy, ... |
| IP, UDP, PPP, ... |
| copper, fiber, radio, ... |
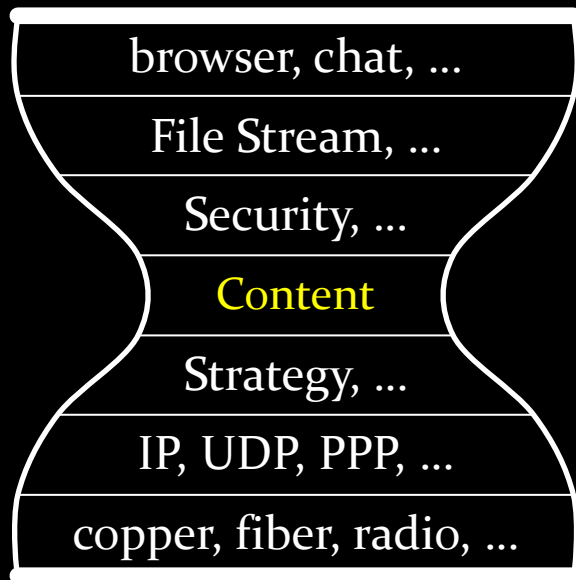
Content Name:

/ugoe.edu/jchen/acn13-ICN.pdf/_v1/_s1

Content Descriptors:

/networking/ICN
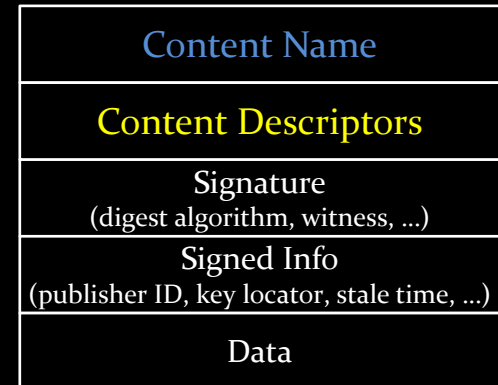/ugoe.edu/acn/2013
/ugoe.edu/jchen

PACKET LEVEL MODIFICATION

- Adopt 2 new packet types:
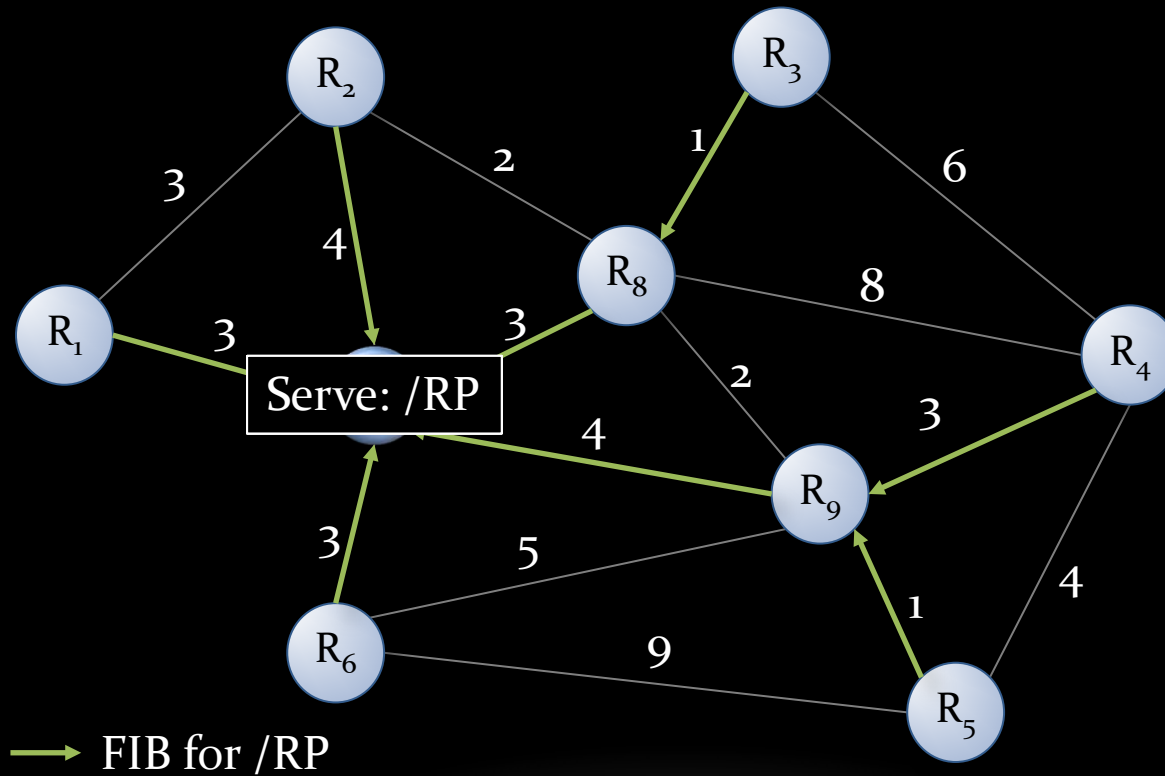
  - Subscription

  - Publish [reuse Data packet]

Content Name
Selector (order preference, publisher filter, scope, ..)
Nonce

Interest (Request)

Content Descriptor
Selector (order preference, publisher filter, scope, ..)
Nonce

Subscription

Content Name
Content Descriptors
Signature (digest algorithm, witness, ...)
Signed Info (publisher ID, key locator, stale time, ...)
Data
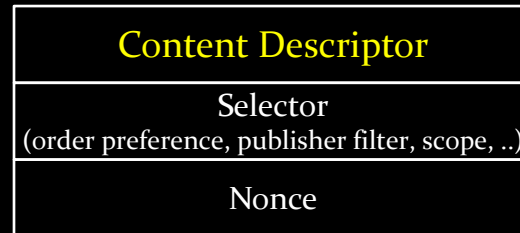
Data (Response)
or
Publish

ROUTER LEVEL MODIFICATION

- Adopt Subscription Table (**ST**):
  - Record the subscriptions downstream
  - CD → Face

- Global CD-RP Mapping Table:
  - CD → RP Name
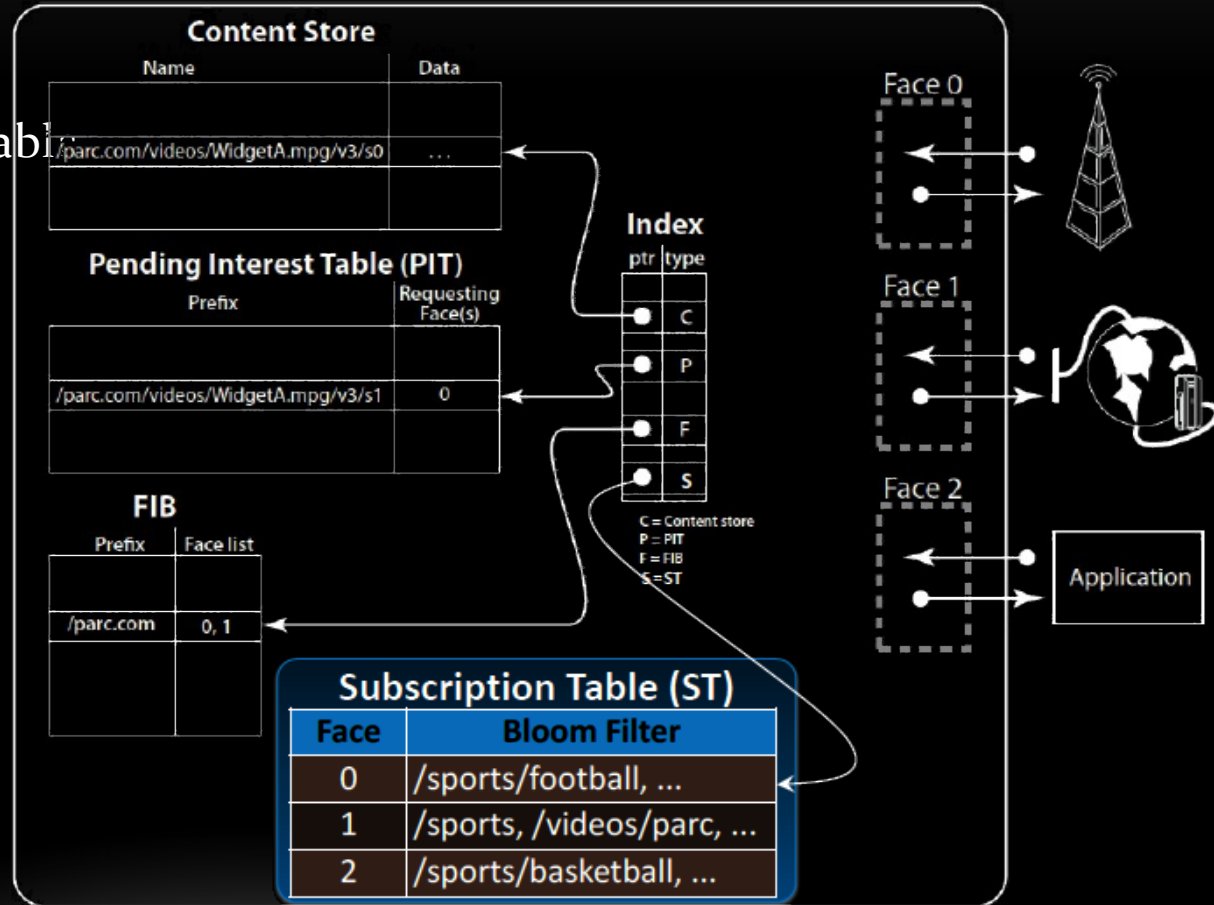
DATA FLOW IN COPSS – RP REGISTRATION

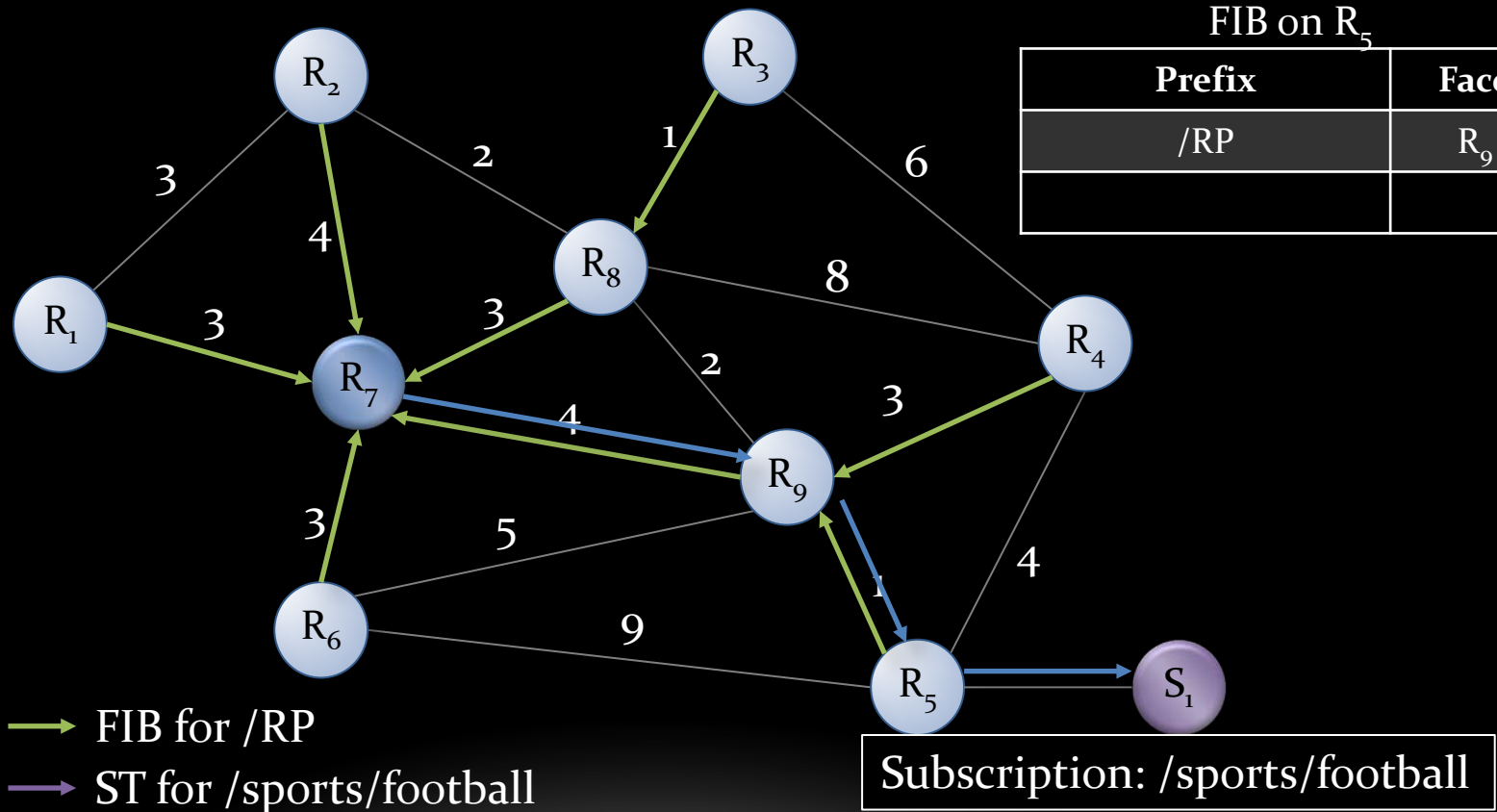# DATA FLOW IN COPSS – SUBSCRIPTION

Global CD-RP Mapping

Prefix	RP
/sports	/RP

ST of R_5

Prefix	Face
/sports/football	S_1

FIB on R_5

Prefix	Face
/RP	R_9

→ FIB for /RP

→ ST for /sports/football

Subscription: /sports/football

Global CD-RP Mapping

Prefix	RP
/sports	/RP

Subscription: /sports

FIB for /RP

ST for /sports/football

ST for /sports

Global CD-RP Mapping

Prefix	RP
/sports	/RP

Publish: /sports/football
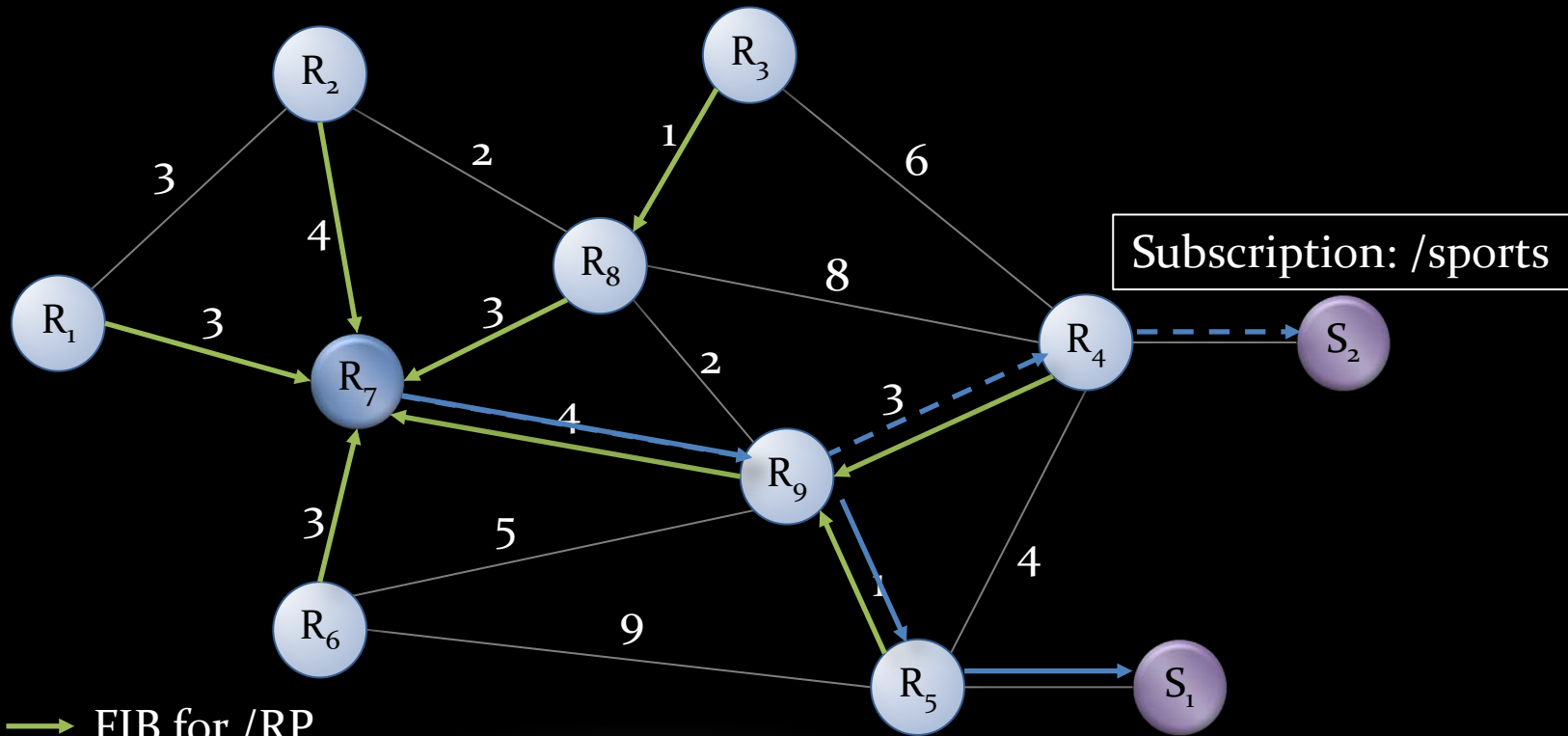
FIB for /RP

ST for /sports/football

ST for /sports

DATA FLOW IN COPSS – PUBLICATION

Global CD-RP Mapping

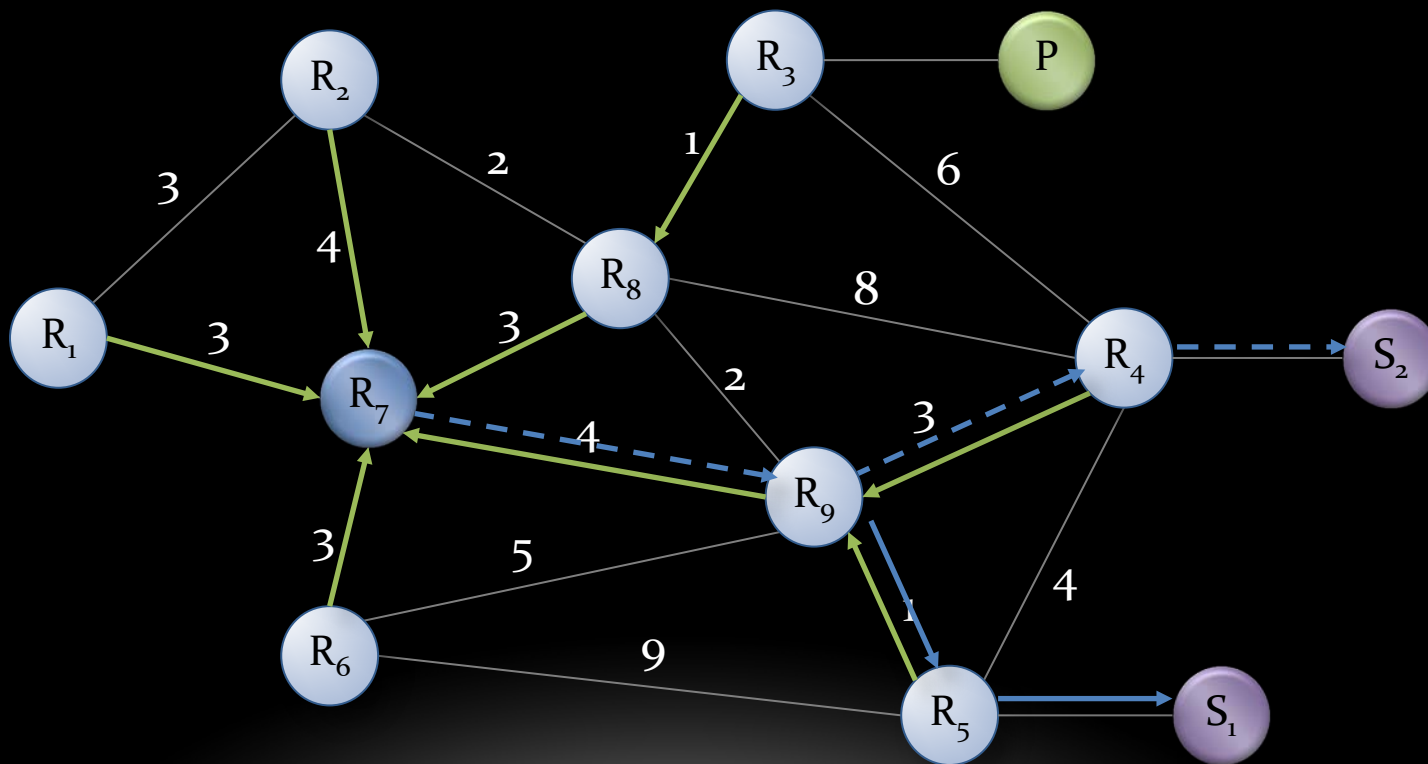| Prefix	RP
/sports	/RP

Interest: /RP

Publish: /sports/football

R_2

R_3

P

R_8

R_1

R_7

R_4

S_2

R_9

R_6

R_5

S_1

3

2

1

6

4

8

3

3

2

3

4

3

5

1

9

4

→ FIB for /RP

→ ST for /sports/football

--→ ST for /sports

computer
N-E-T
W-O-R-K-S

Global CD-RP Mapping

Prefix	RP
/sports	/RP

Publish: /sports/football
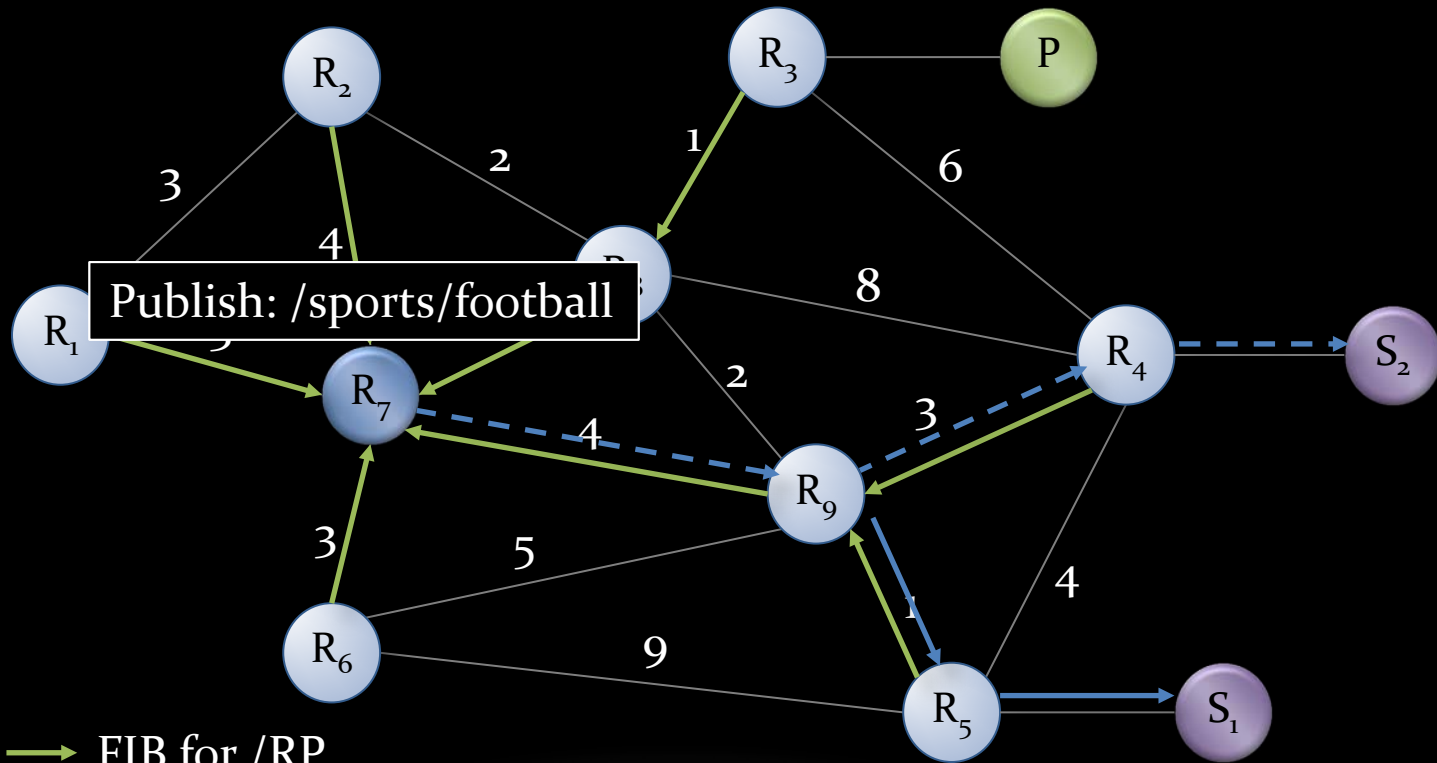
Legend:
- → FIB for /RP
- → ST for /sports/football
- ⇢ ST for /sports

# PROBLEM 1: INFORMATION CONCENTRATION

- Description: Publish packets concentrated at RP(s)

- Solution: Automatic RP balancing

- How?

  - CD-RP mapping

  - RP is a Name, not a router

Global CD-RP Mapping

Prefix	RP
/sports	/RP

PROBLEM 1: INFORMATION CONCENTRATION

- Description: Publish packets concentrated at RP(s)

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Global CD-RP Mapping

Prefix	RP
/sports	/RP
/sports/football	/RP2
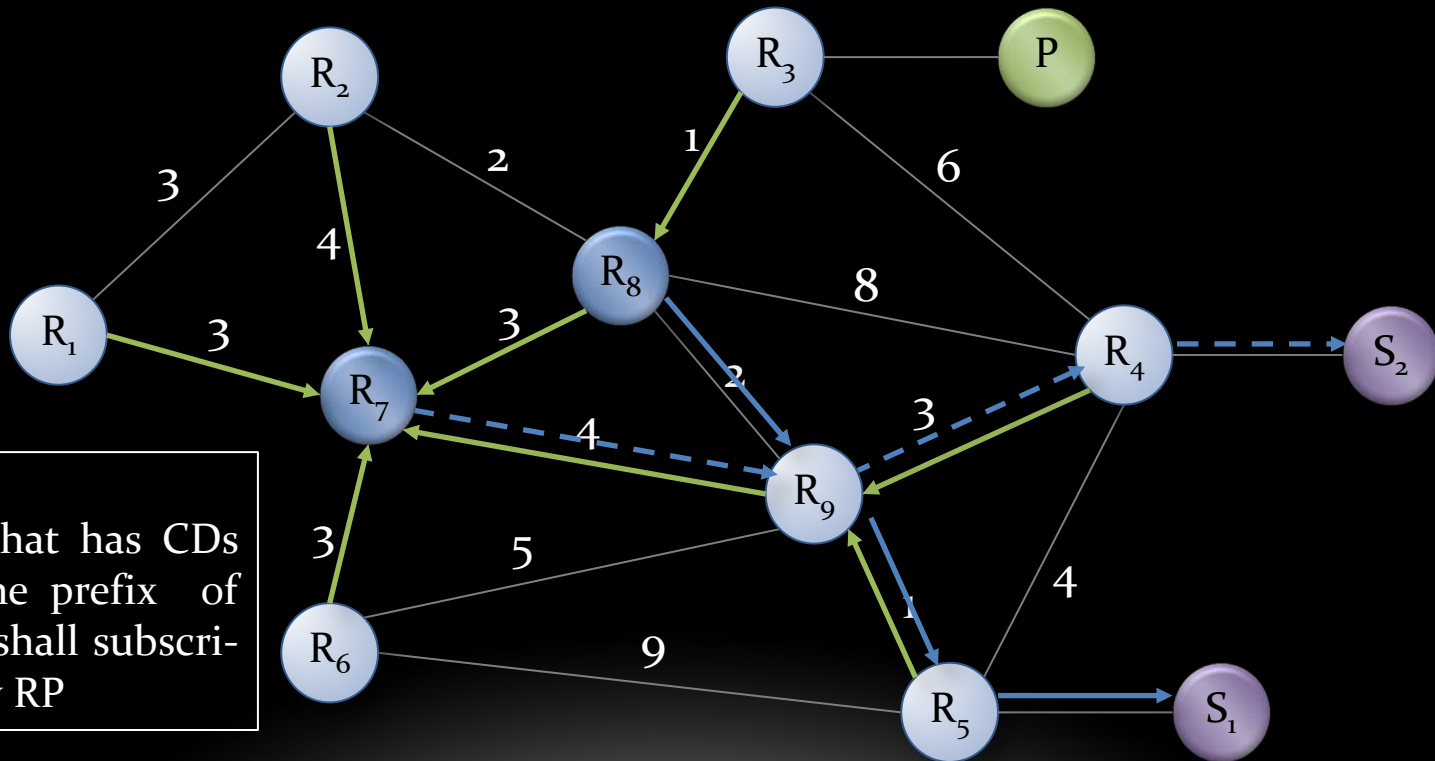
Note:
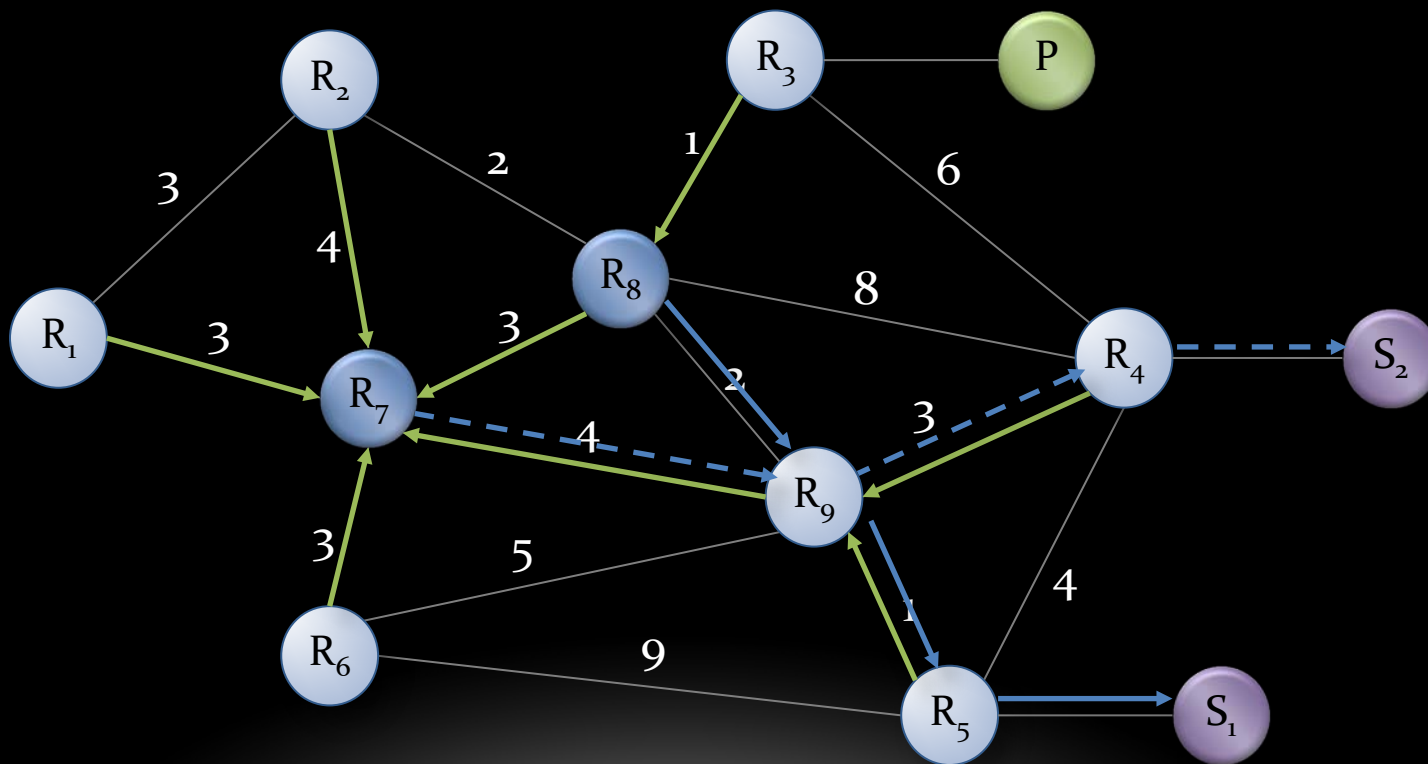Any router that has CDs which are the prefix of the new CD shall subscribe to the new RP
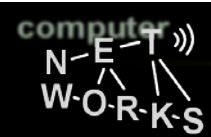
PROBLEM 2: GLOBAL CD-RP MAPPING

- Description: Maintaining global CD-RP mapping table introduces overhead
- Solution part 1:
  - Only 1st hop routers maintain global CD-RP mapping
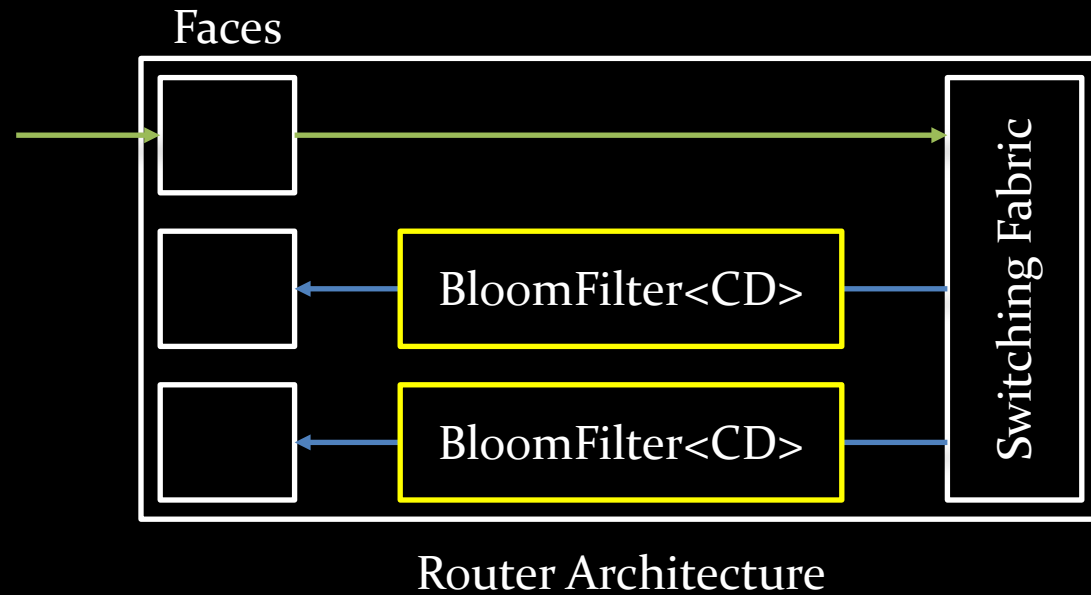- Solution part 2:
  - Lookup system

Global CD-RP Mapping

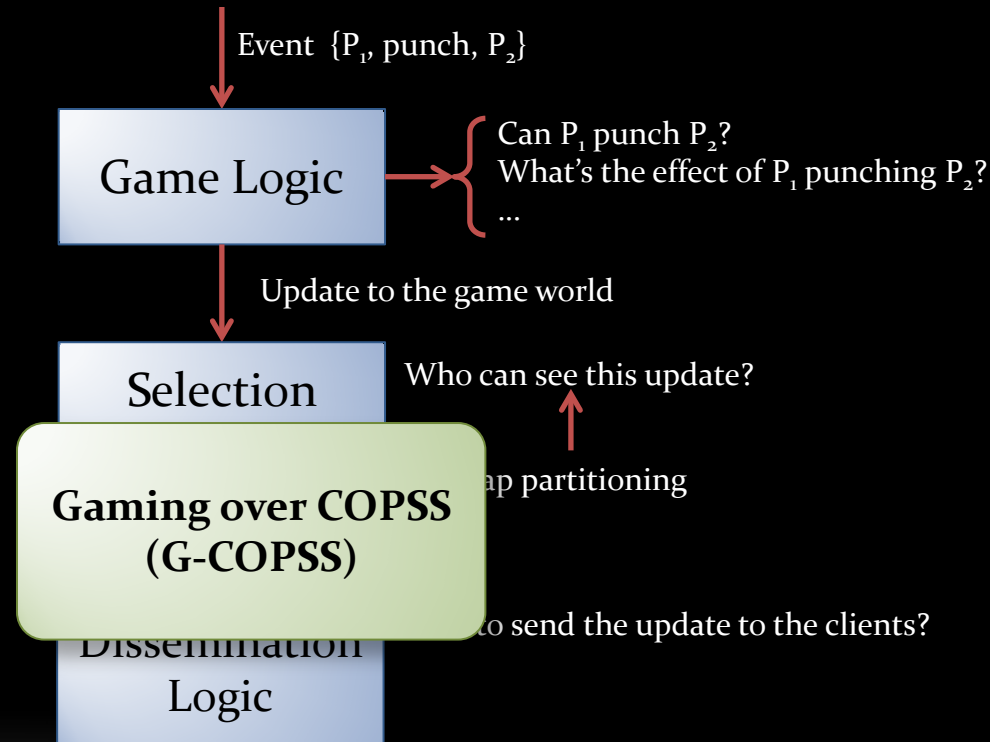| Prefix	RP
/sports	/RP
/sports/football	/RP2

PROBLEM 3: ST SIZE

- Description: ST will have too many entries due to the unbounded CD space

- Solution:

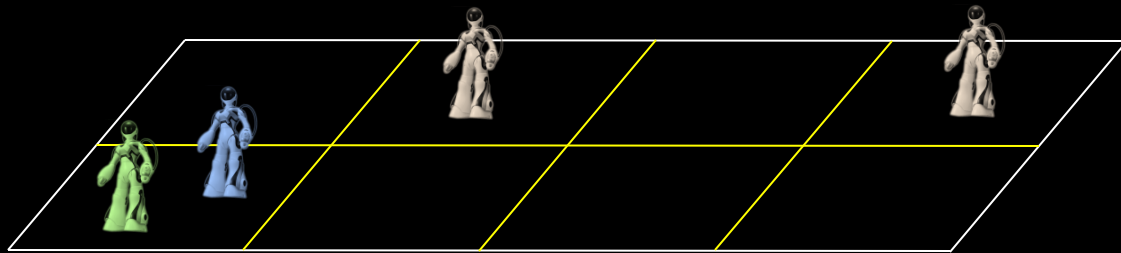 - From CD-Face(s) mapping to Face-BloomFilter<CD> mapping

Faces

Router Architecture

EXAMPLE 1: ONLINE GAMING

- Gaming is Content-Oriented Pub/Sub??

  - Players *publish* updates (actions) *to an area*, without regard to who's supposed to receive it

 - Players *subscribe* to their *current region*, without knowing who else in the region sending updates

Event {P_1, punch, P_2}

Game Logic

Can P_1 punch P_2?
What's the effect of P_1 punching P_2?
...

Update to the game world

Selection

Who can see this update?

Gaming over COPSS (G-COPSS)

ap partitioning

Dissemination Logic

to send the update to the clients?

Example 1: Online Gaming
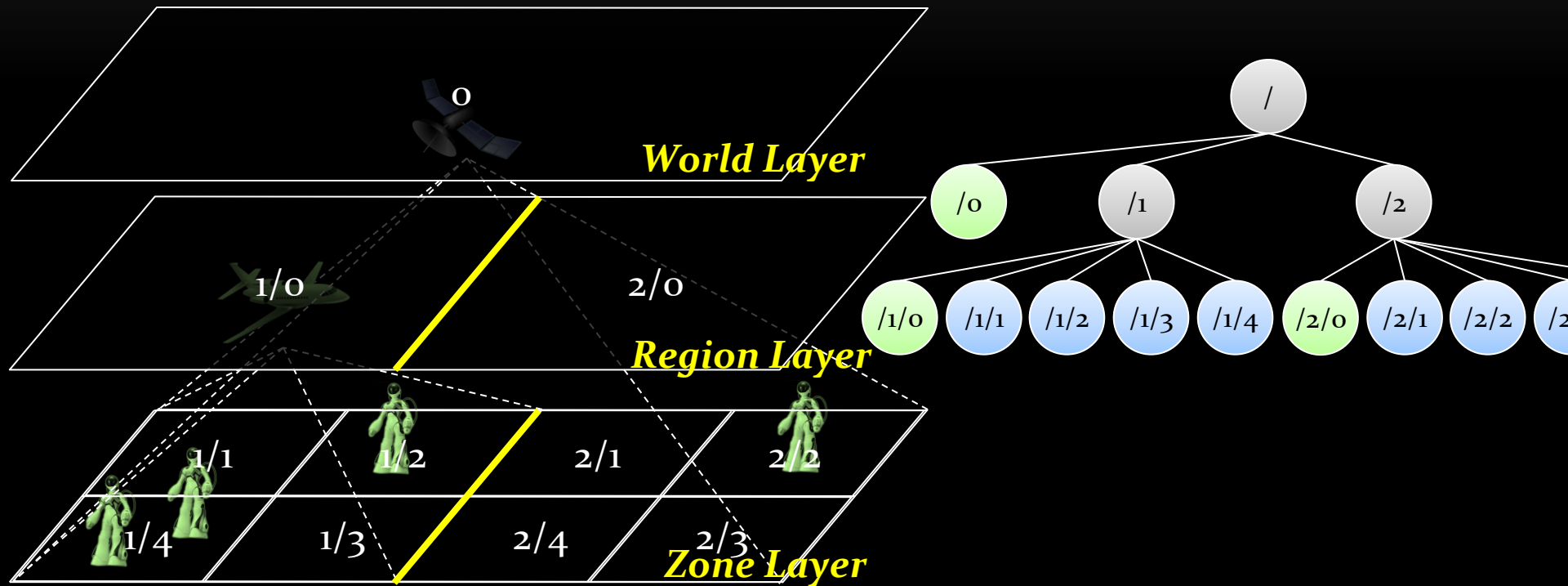
- Hierarchical Map Partitioning

EXAMPLE 1: ONLINE GAMING
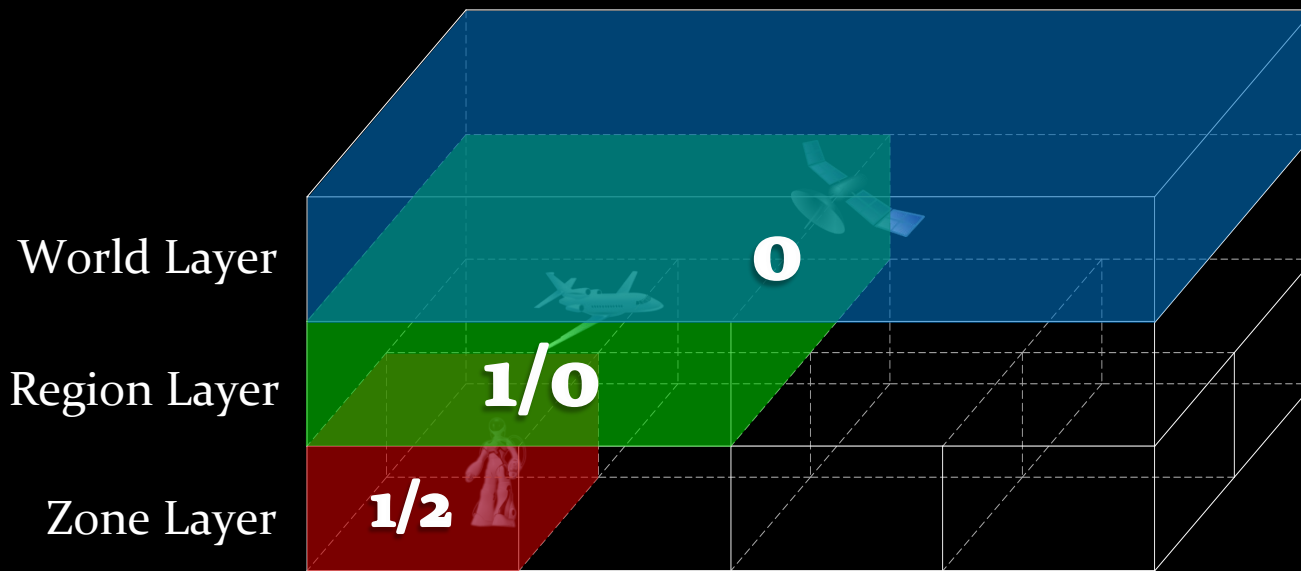
- Hierarchical Map Partitioning
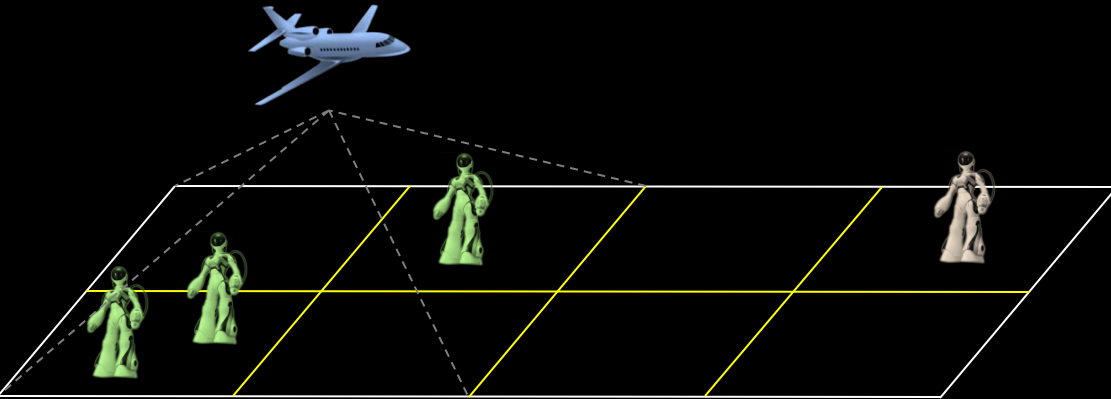
EXAMPLE 1: ONLINE GAMING
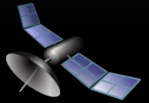
- Hierarchical Map Partitioning
  - Hierarchical CDs

EXAMPLE 1: ONLINE GAMING

- Hierarchical Map Partitioning
  - Pub/Sub rules

Satellite:
- Location: 0
- Pub: /0
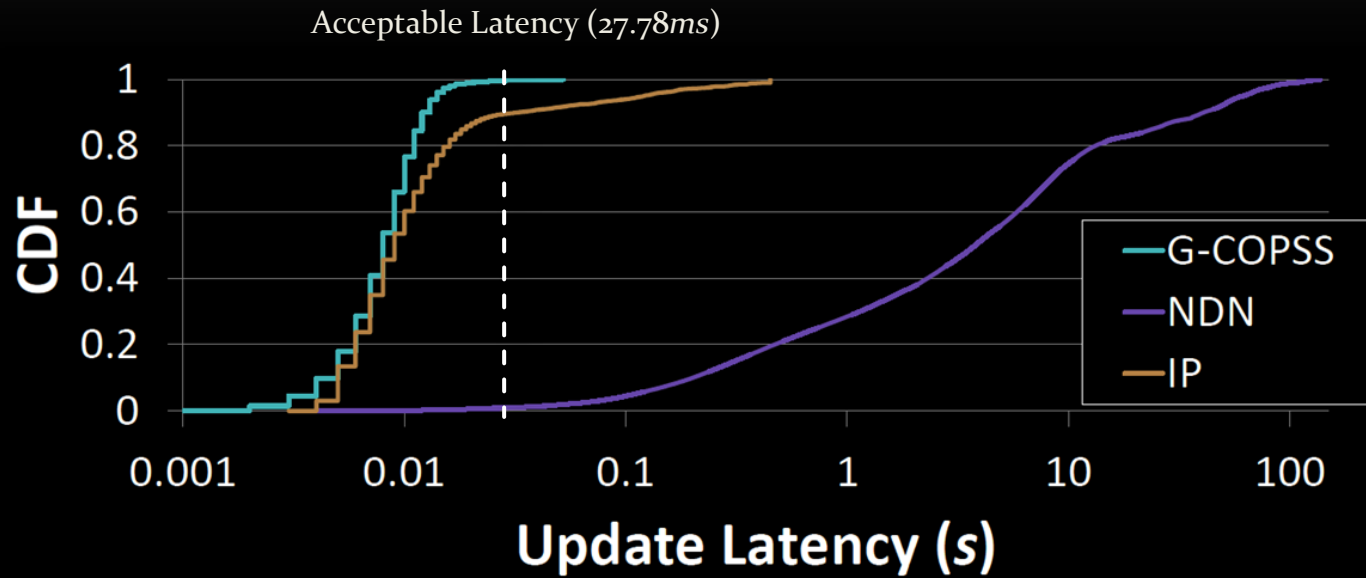- **Sub: /**

Plane:
- Location: 1/0
- Pub: /1/0
- **Sub: /1, /0**

Soldier:
- Location: 1/2
- Pub: /1/2
- **Sub: /1/2, /1/0, /0**

World Layer

Region Layer

Zone Layer

0

1/0

1/2

EXAMPLE 1: ONLINE GAMING

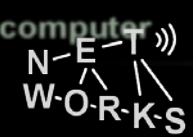- Performance Comparison
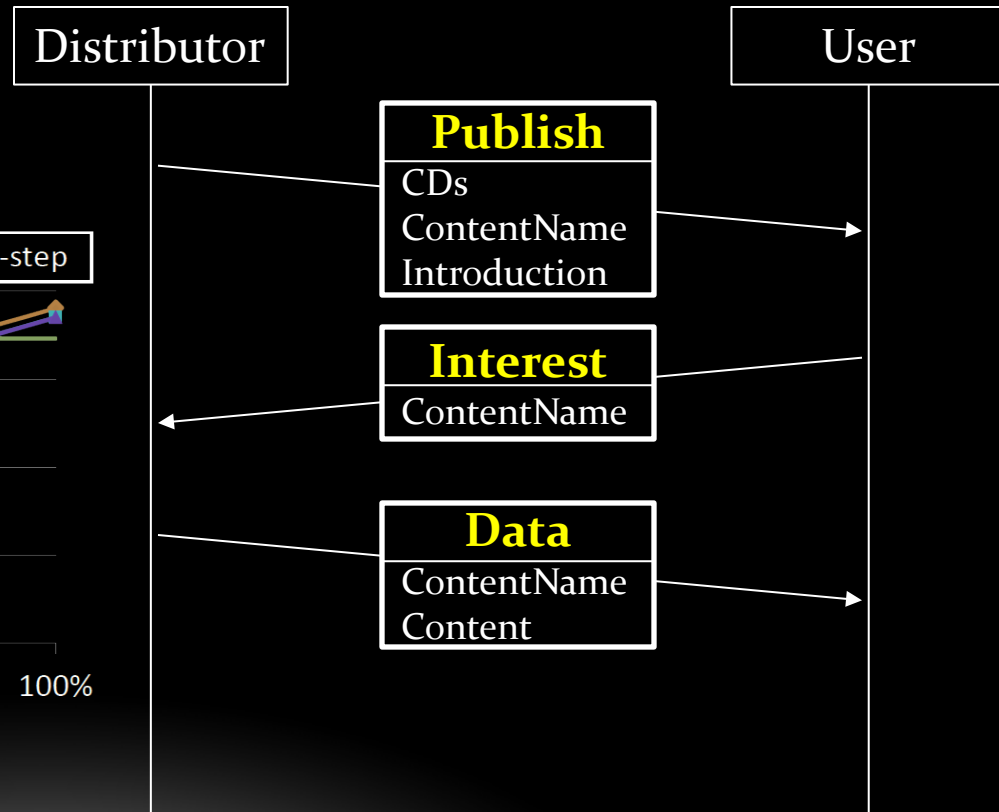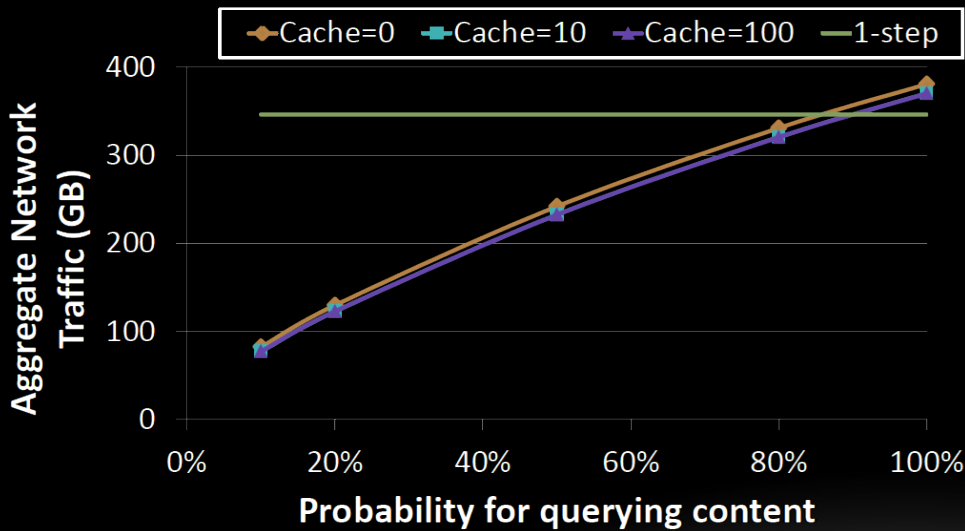

Acceptable Latency (27.78ms)

EXAMPLE 2: FILM DELIVERY SYSTEM

- Requirement:

  - Distributors notify users as soon as they get a new film

  - Users can choose if they are going to download a specific film

  - Distributors can choose if they will transfer a film based on the policy

- Solution:

  - 2-step dissemination

    - Snippet

Distributor	User

Publish
CDs
ContentName
Introduction

Interest
ContentName

Data
ContentName
Content

INCREMENTAL DEPLOYMENT

- Incremental deployment is desirable for infrastructure change

- How can CCN be enabled in the network at *large scale*? And *efficient*?

    - A *reasonable number* of nodes that are able to provide CCN functionality

    - The other nodes provide *high-speed*, *efficient* forwarding

    - As we go forward, we can have more nodes CCN enabled for *scalability* and *performance*.

- Our target:

    - **Evolve**: IP infrastructure → content-oriented network

        - Co-exist with the IP network throughout the evolution

        - An approach tightly integrated with IP network (using IP multicast)

    - **Efficiency**: Identify the key points

        - Content-centric forwarding *at key points* while using hash-based forwarding (IP) at the other nodes

        - Cache content *at key points*

INCREMENTAL DEPLOYMENT
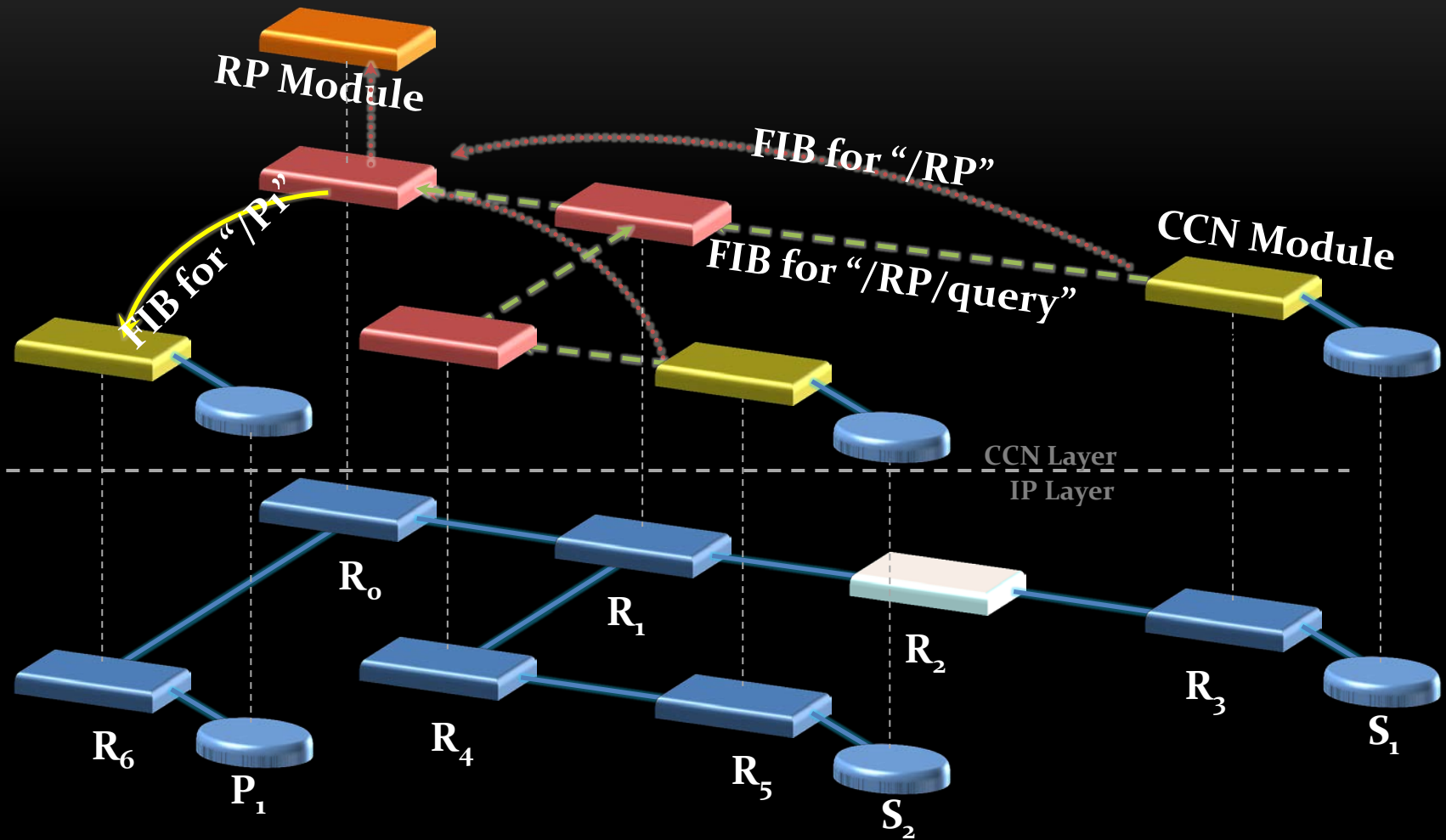
Inter-Domain Multicast
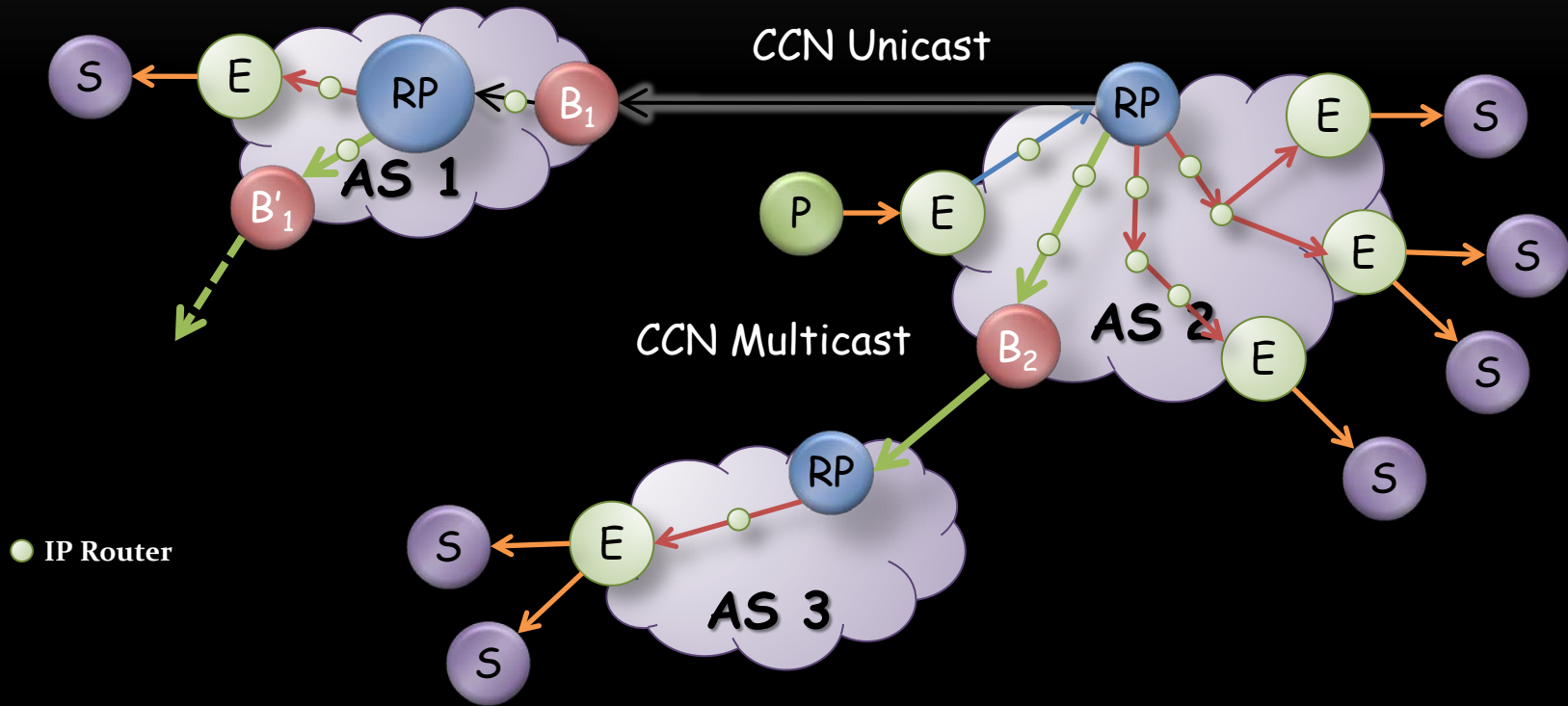
CONCLUSION

- **Why COPSS?**

  - Temporal separation between providers (publishers) and consumers (subscribers)

- **How does COPSS work?**

  - Content Descriptor (CD)

  - Subscription and Publish packet

  - Subscription Table (ST)

- **Optimizations in COPSS?**

  - Automatic RP balancing

  - CD-RP Mapping

  - BloomFilter-based ST

- **Hierarchical Map Partitioning**

- **2-step Dissemination**

  - Subscriber Interest

  - Policy Control

- **Incremental Deployment**

  - Using IP as underlay

  - Using IP multicast

- **Inter-domain multicast**

Advertisement

Student projects on COPSS
(Under EU-FP7 GreenICN Project)

Topics:
- Disaster management
- (Live) video transfer
- Routing
- Name processing...

REFERENCES

1. Chen, Jiachen, et al. "Copss: An efficient content oriented publish/subscribe system." *ANCS, 2011*.

2. Chen, Jiachen, et al. "G-COPSS: A Content Centric Communication Infrastructure for Gaming Applications." *ICDCS, 2012*.

3. Chen, Jiachen, et al. "Coexist: integrating content oriented publish/subscribe systems with ip." *ANCS, 2012*.

4. FP-7 EU Project: "Green ICN." http://www.greenicn.org/

ACKNOWLEDGMENT