# Advanced Computer Networks

# Content-Centric Networking (II)

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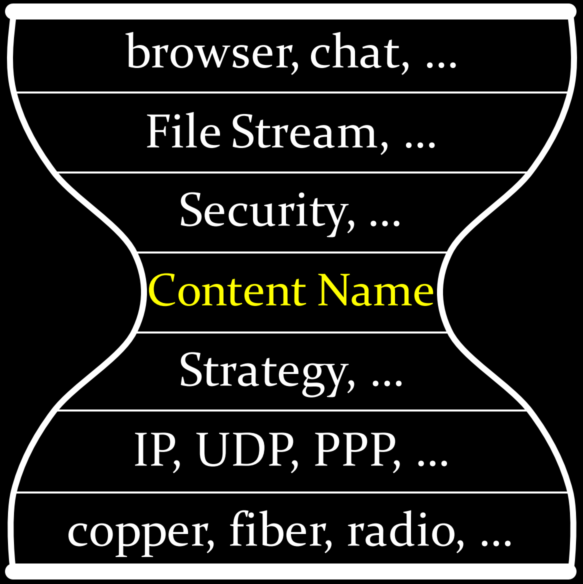
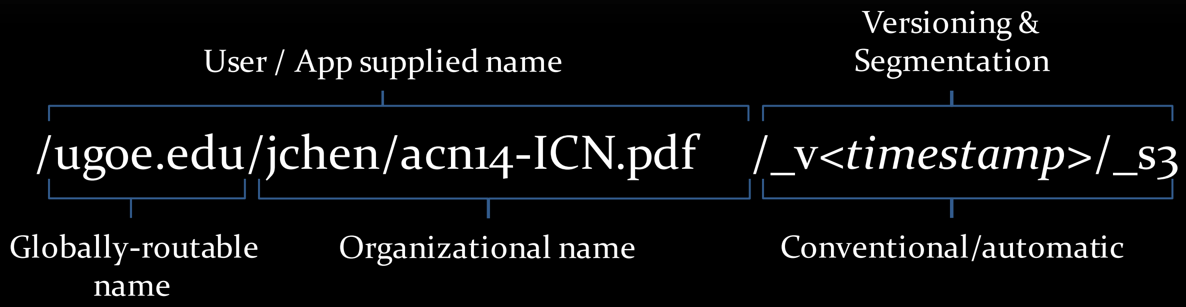
# REVIEW

- **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)**





# 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<br>(order preference, publisher filter, scope, ..) |
| Nonce |

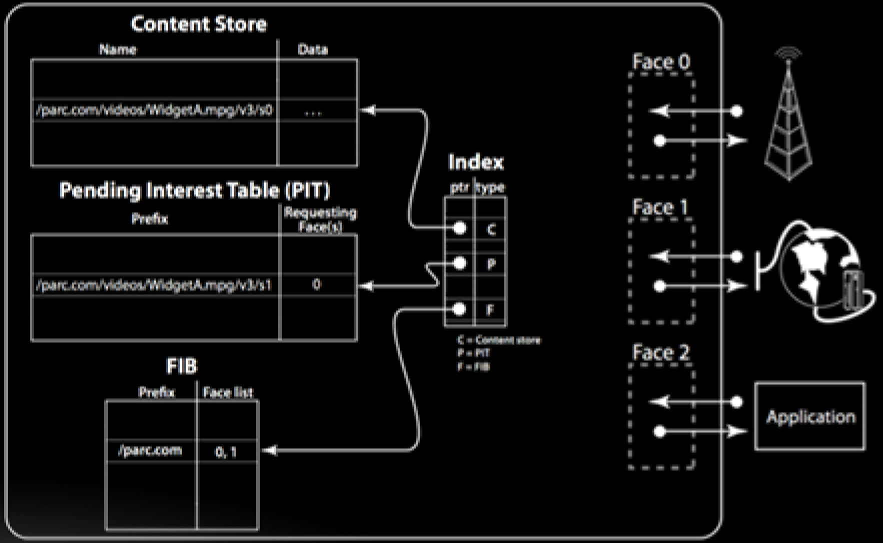
Interest (Request)

| Content Name |
|---|
| Content Descriptors |
| Signature<br>(digest algorithm, witness, …) |
| Signed Info<br>(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



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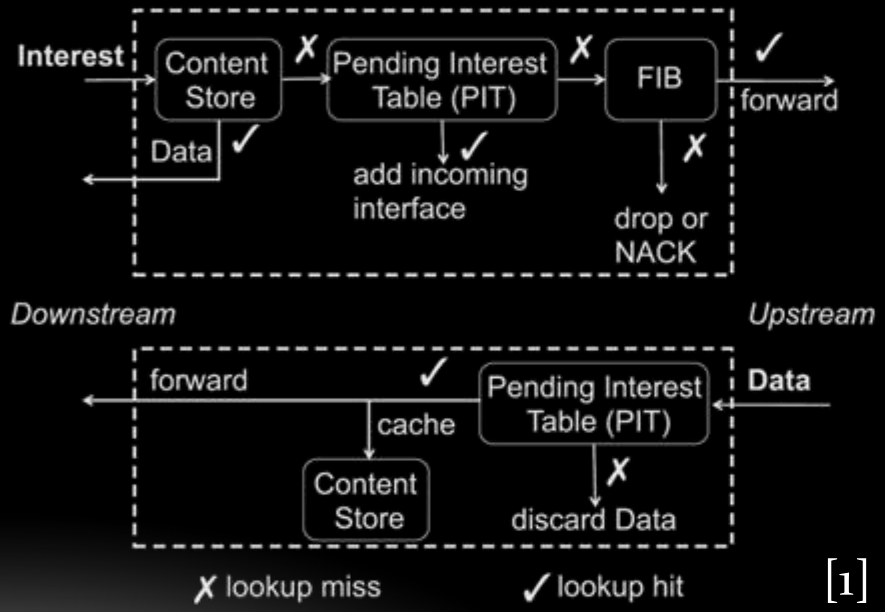
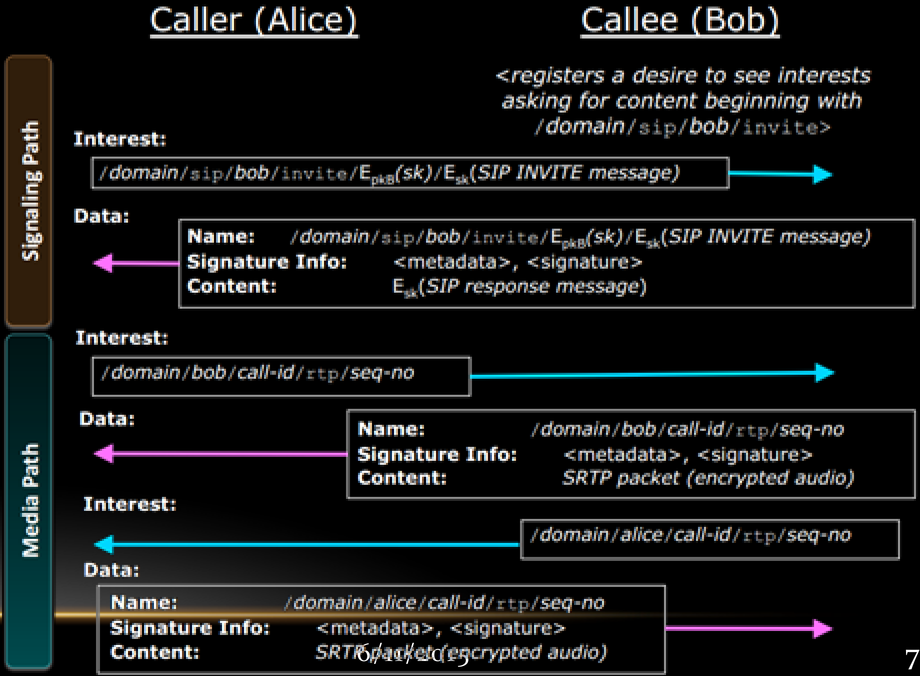


[1]

# 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.


Caller (Alice)
Callee (Bob)
Signaling Path
Media Path
<registers a desire to see interests asking for content beginning with /domain/sip/bob/invite>
Interest:
/domain/sip/bob/invite/$E_{pkB}$(sk)/$E_{sk}$(SIP INVITE message)
Data:
Name: /domain/sip/bob/invite/$E_{pkB}$(sk)/$E_{sk}$(SIP INVITE message)
Signature Info: <metadata>, <signature>
Content: $E_{sk}$(SIP response message)
Interest:
/domain/bob/call-id/rtp/seq-no
Data:
Name: /domain/bob/call-id/rtp/seq-no
Signature Info: <metadata>, <signature>
Content: SRTP packet (encrypted audio)
Interest:
/domain/alice/call-id/rtp/seq-no
Data:
Name: /domain/alice/call-id/rtp/seq-no
Signature Info: <metadata>, <signature>
Content: SRTP packet (encrypted audio)

# 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

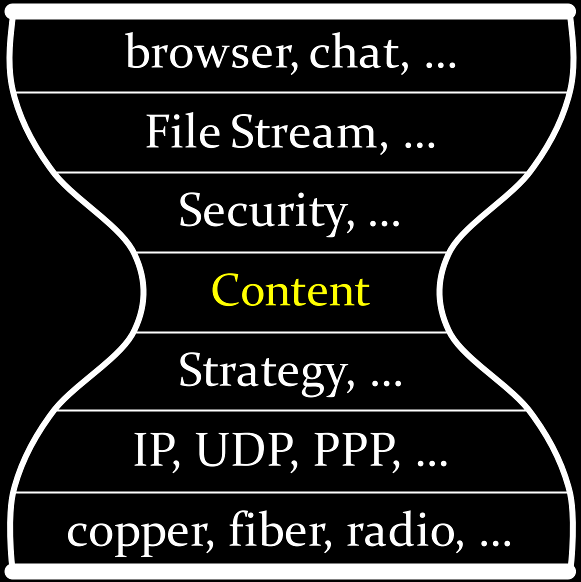
- Push
- Temporal Separation
- Scalability
- Efficiency
- Rendezvous-Point (RP) based communication

- 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



**Content Name:**

/ugoe.edu/jchen/acn14-ICN.pdf/_v1/_s1

**Content Descriptors:**

/networking/ICN
/ugoe.edu/acn/2014
/ugoe.edu/jchen

# Packet Level Modification

- Adopt 2 new packet types:
  - Subscription
  - Publish [reuse Data packet]

| Content Name |
|---|
| Selector<br>(order preference, publisher filter, scope, ..) |
| Nonce |

Interest (Request)

| Content Descriptor |
|---|
| Selector<br>(order preference, publisher filter, scope, ..) |
| Nonce |

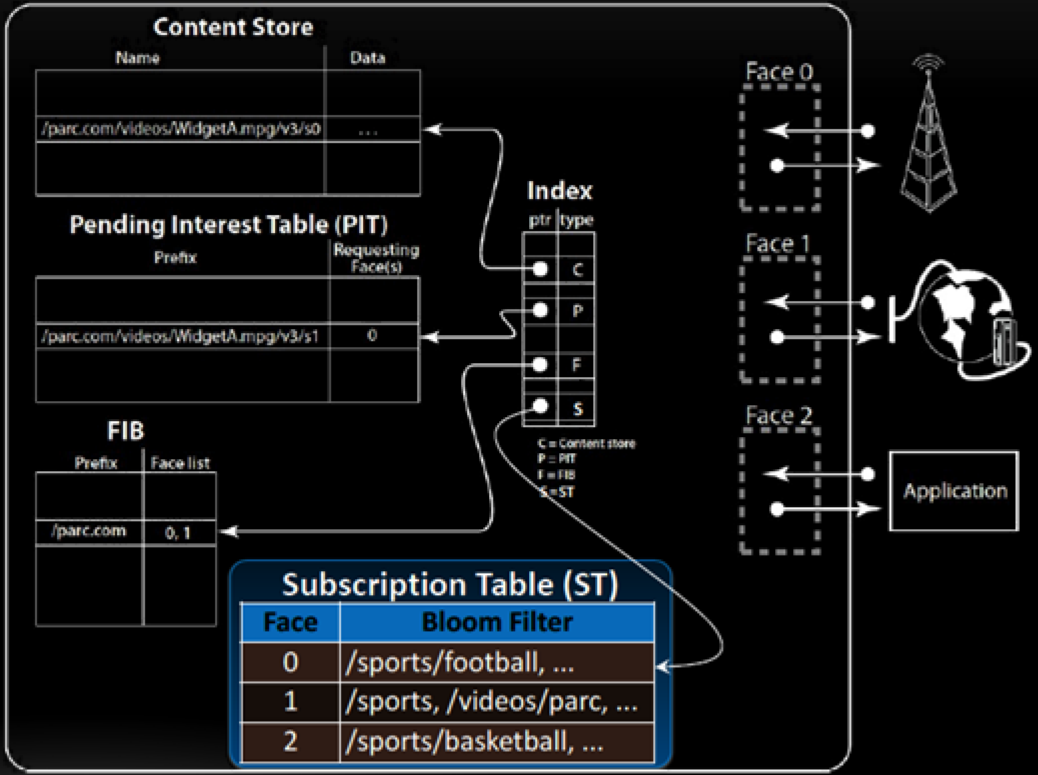
Subscription

| Content Name |
|---|
| Content Descriptors |
| Signature<br>(digest algorithm, witness, …) |
| Signed Info<br>(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



Content Store

| Name | Data |
|---|---|
| | |
| /parc.com/videos/WidgetA.mpg/v3/s0 | ... |
| | |

Pending Interest Table (PIT)

| Prefix | Requesting Face(s) |
|---|---|
| | |
| /parc.com/videos/WidgetA.mpg/v3/s1 | 0 |
| | |

FIB

| Prefix | Face list |
|---|---|
| | |
| /parc.com | 0, 1 |
| | |

Index

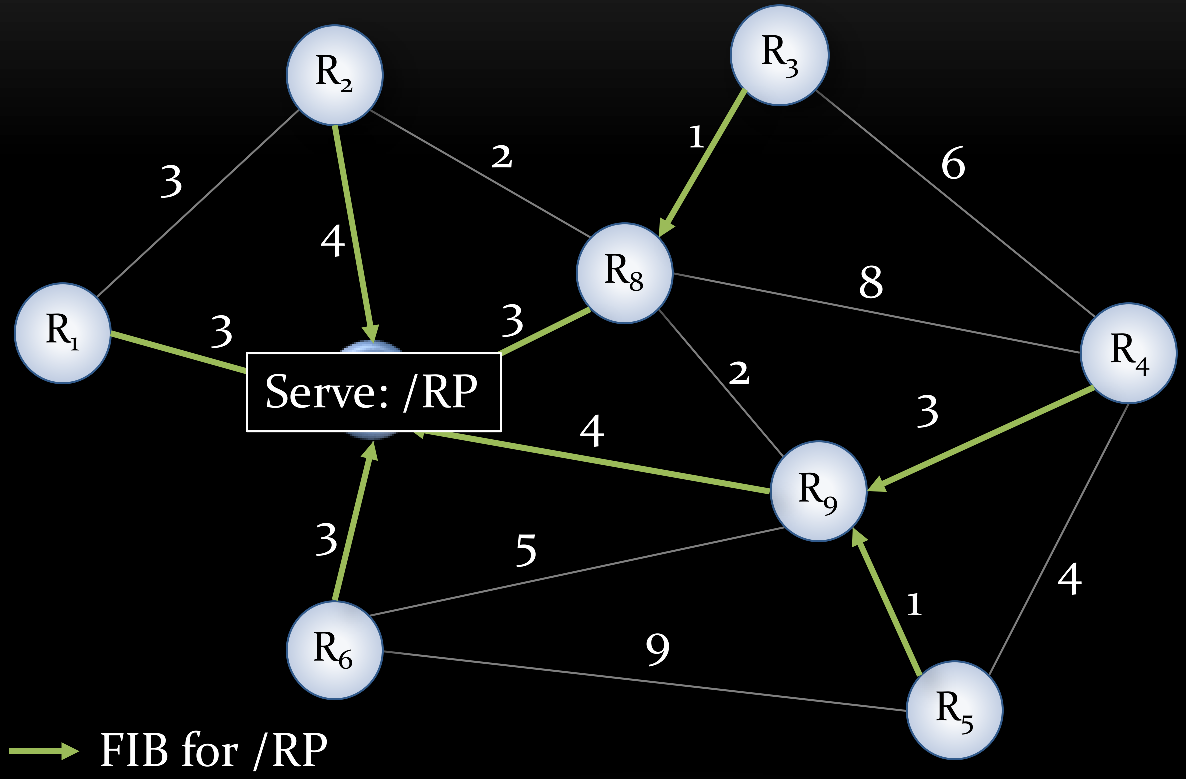
| ptr | type |
|---|---|
| ● | C |
| ● | P |
| ● | F |
| ● | S |

C = Content store
P = PIT
F = FIB
S = ST

Subscription Table (ST)

| Face | Bloom Filter |
|---|---|
| 0 | /sports/football, ... |
| 1 | /sports, /videos/parc, ... |
| 2 | /sports/basketball, ... |

# Data Flow in COPSS – RP Registration



# Data Flow in COPSS – Subscription

Global CD-RP Mapping

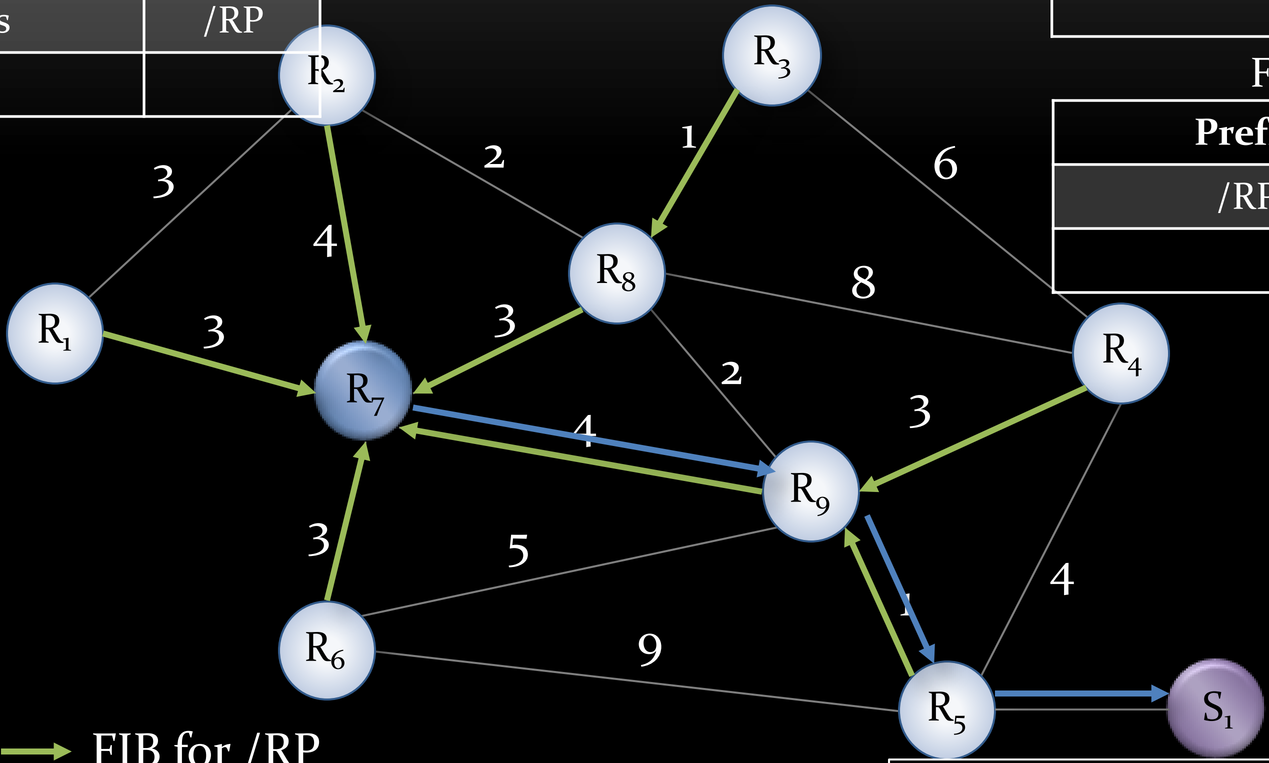
| Prefix | RP |
|---|---|
| /sports | /RP |
| | |

ST of $R_5$

| Prefix | Face |
|---|---|
| /sports/football | $S_1$ |
| | |

FIB on $R_5$

| Prefix | Face |
|---|---|
| /RP | $R_9$ |
| | |



FIB for /RP

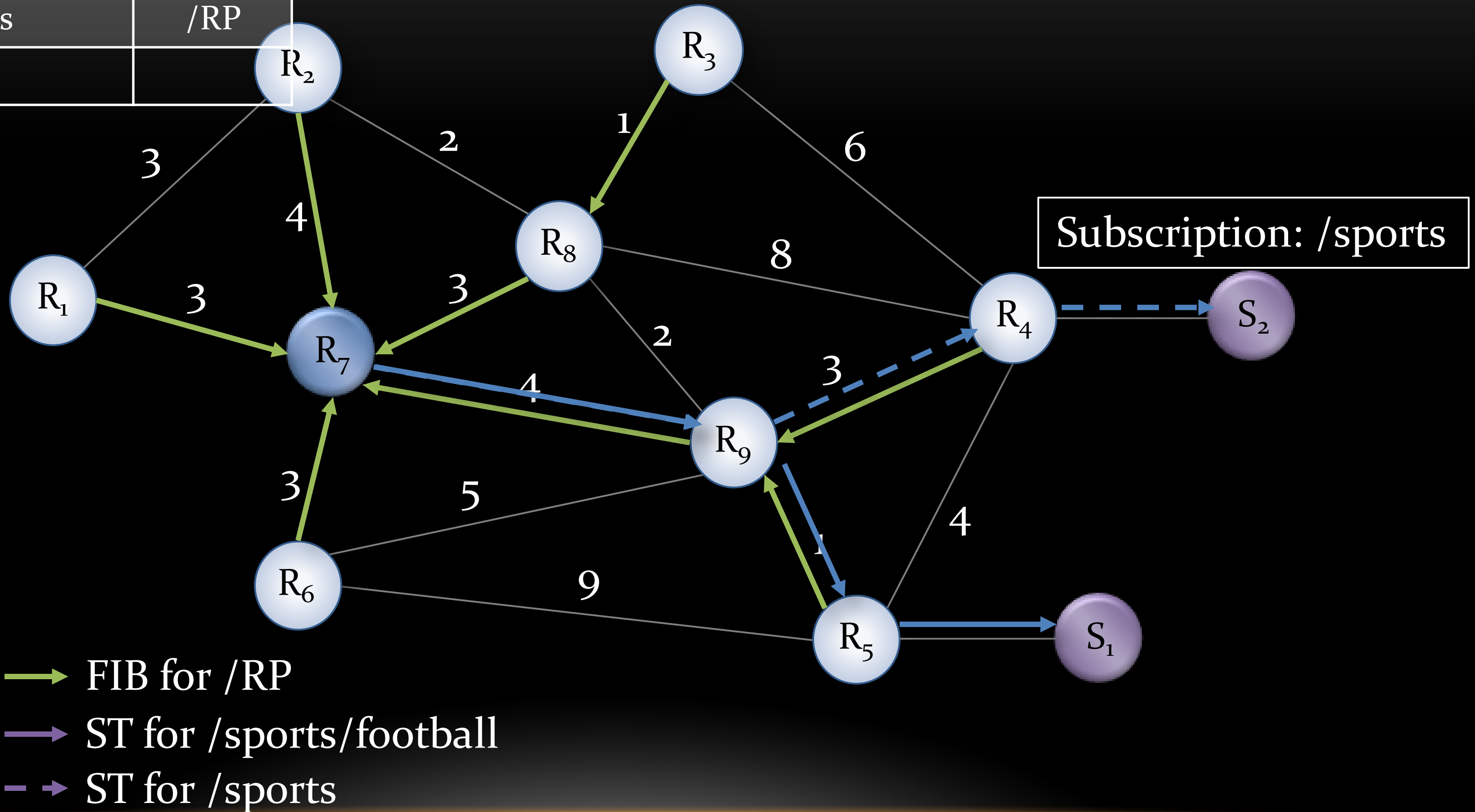
ST for /sports/football

Subscription: /sports/football

# Data Flow in COPSS – Another Subscription

Global CD-RP Mapping

| Prefix | RP |
|---|---|
| /sports | /RP |
| | |



Subscription: /sports

FIB for /RP

ST for /sports/football

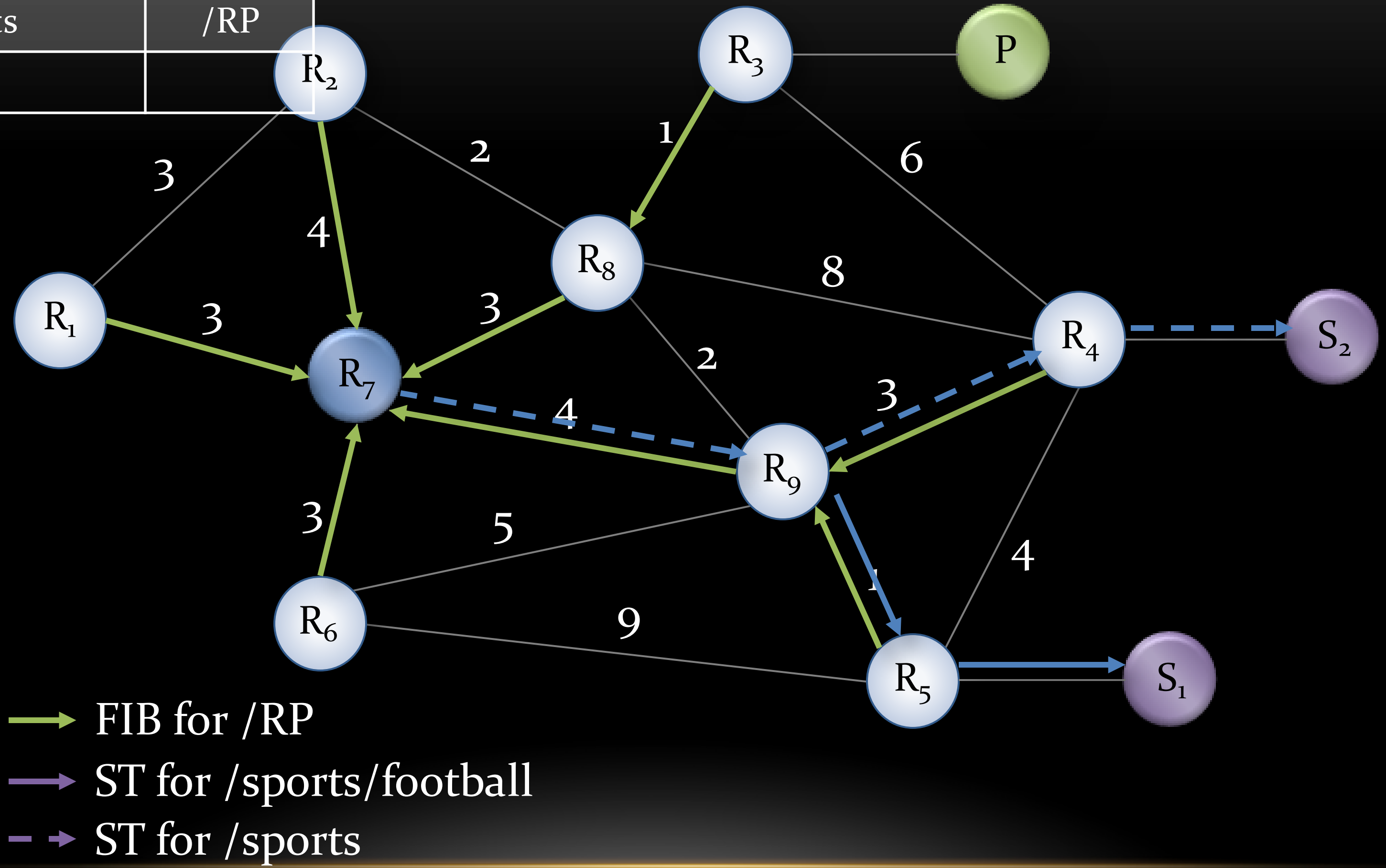
ST for /sports

# Data Flow in COPSS – Publication

Global CD-RP Mapping

| Prefix | RP |
|---|---|
| /sports | /RP |
| | |

Publish: /sports/football



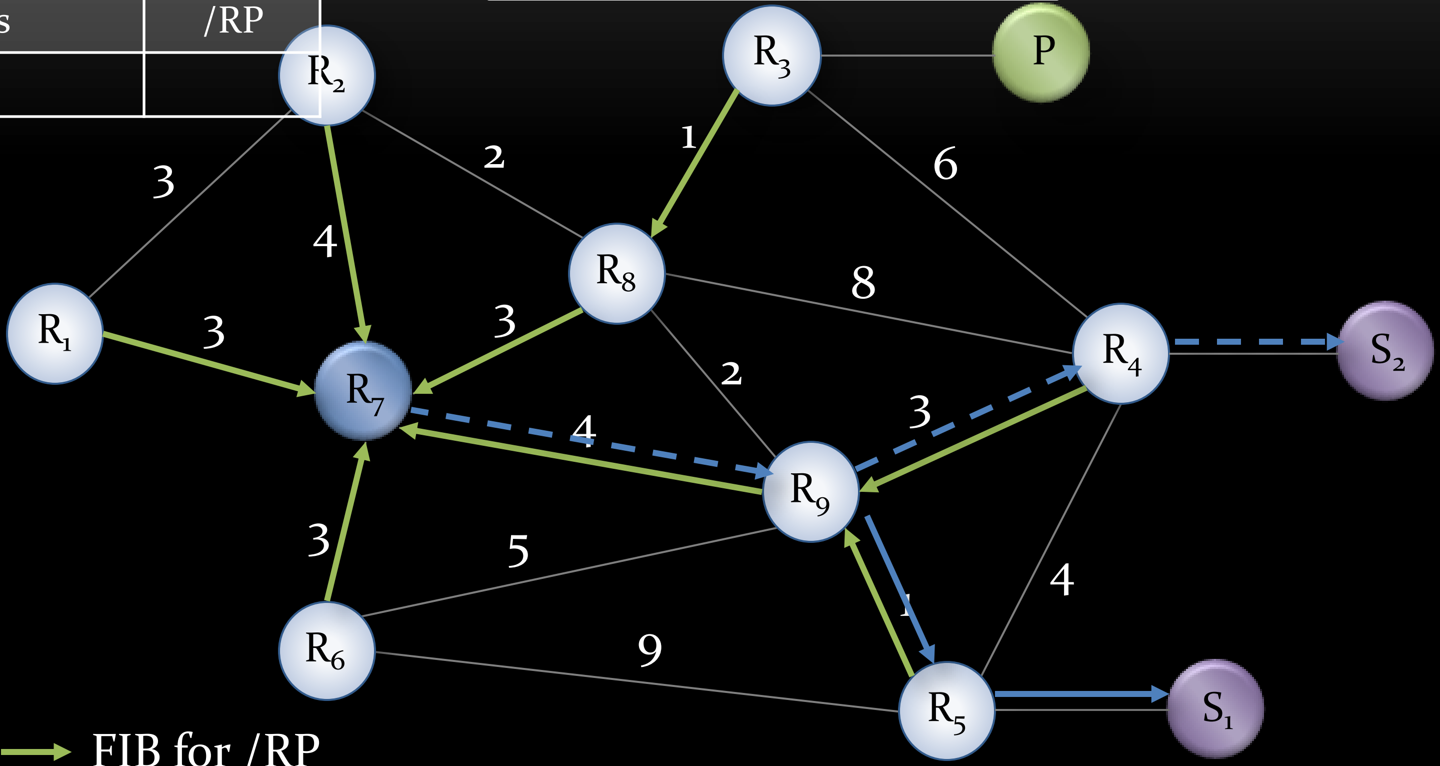
# Data Flow in COPSS – Publication

Global CD-RP Mapping

| Prefix | RP |
|---|---|
| /sports | /RP |
| | |

Interest: /RP

Publish: /sports/football



→ FIB for /RP

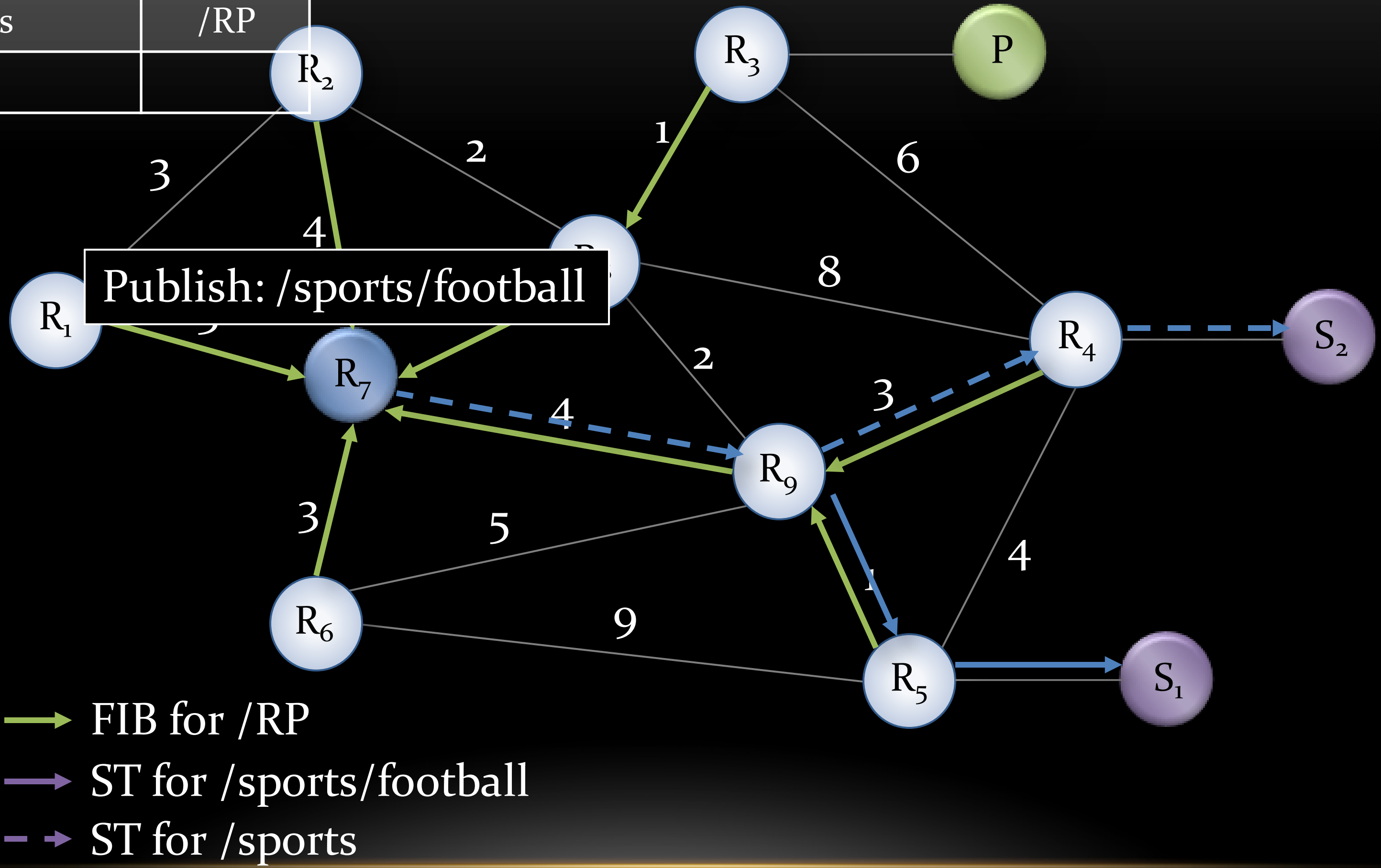
→ ST for /sports/football

- - → ST for /sports

# Data Flow in COPSS – Publication

Global CD-RP Mapping

| Prefix | RP |
|---|---|
| /sports | /RP |
| | |



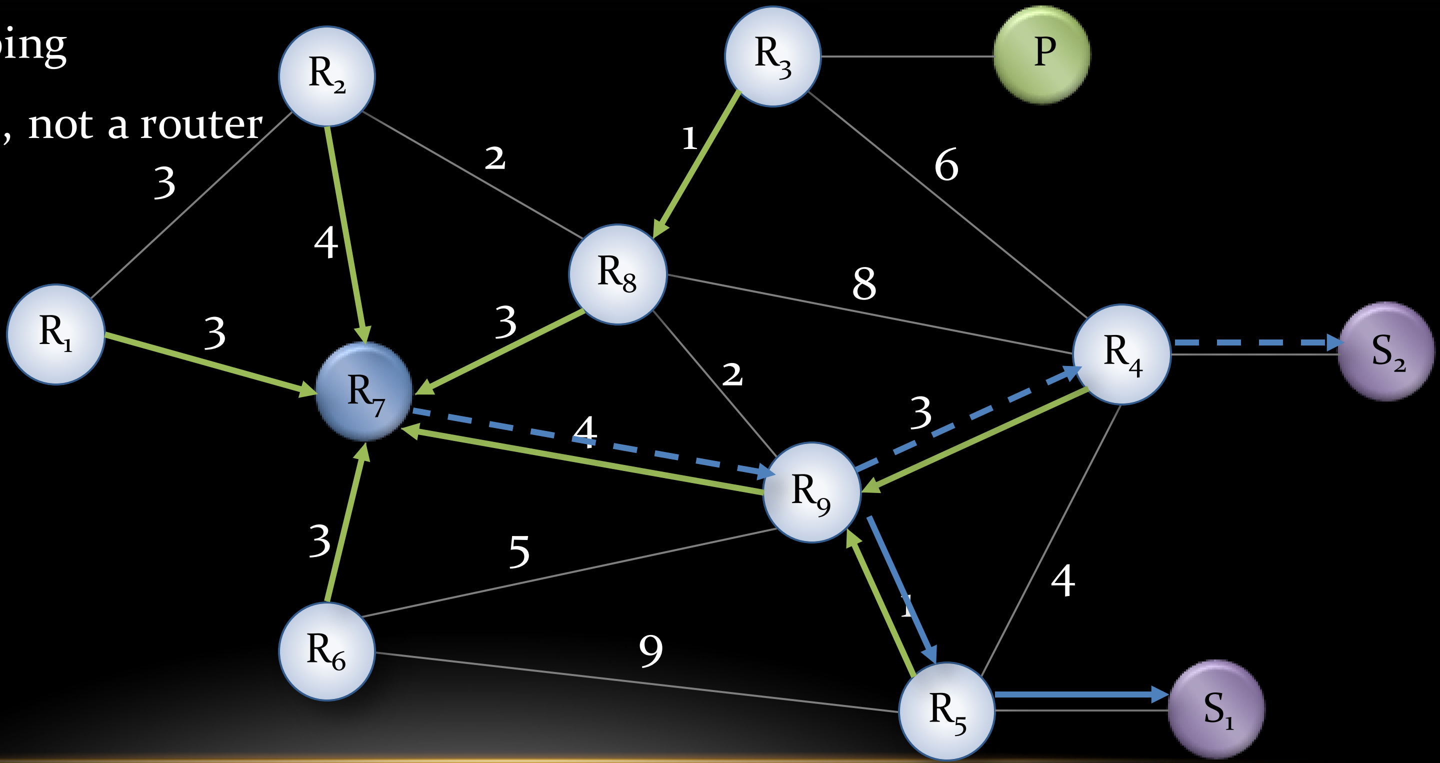
Publish: /sports/football

# 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 |
| | |

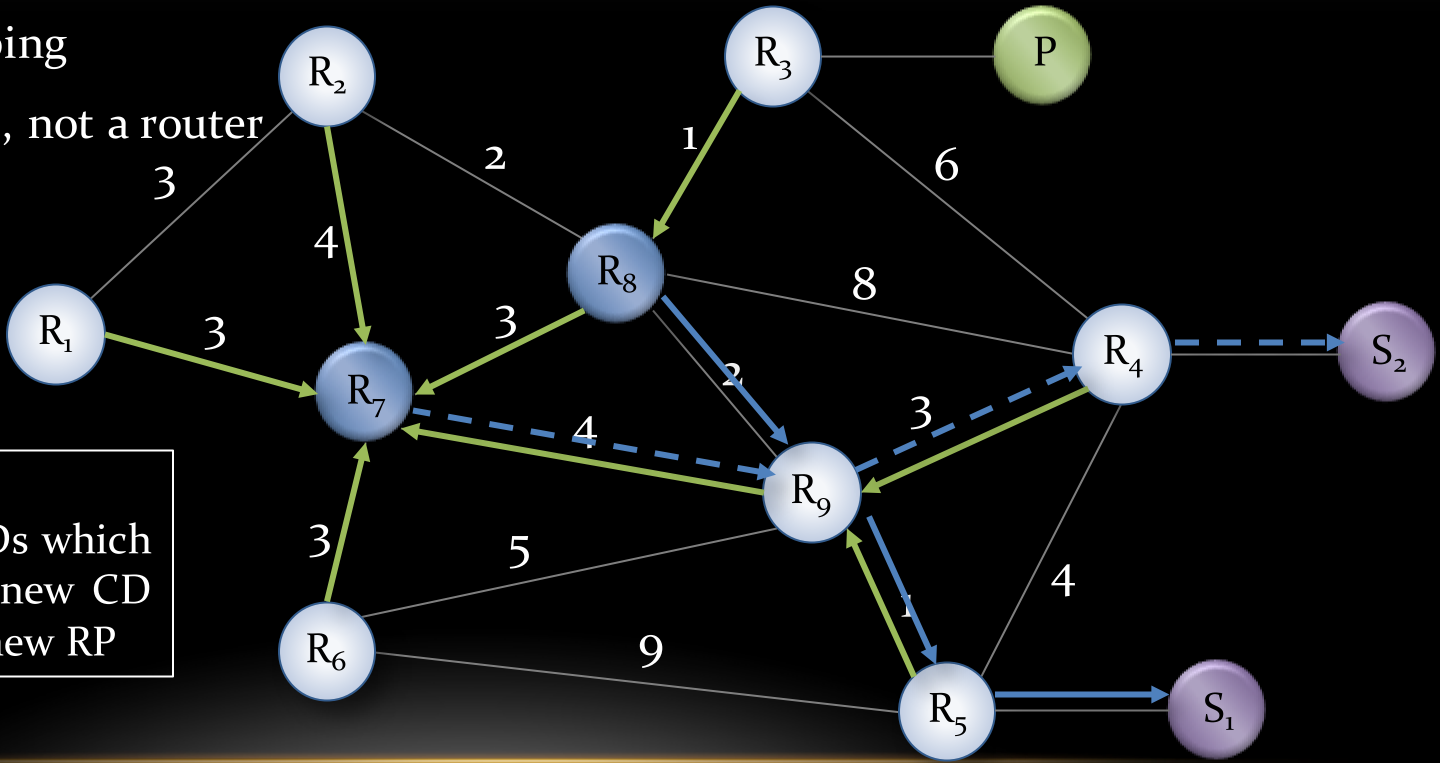


# Problem 1: Information Concentration

- Description: Publish packets concentrated at RP(s)
- Solution: Automatic RP balancing
- How?
  - CD-RP mapping
  - RP is a Name, not a router

Global CD-RP Mapping

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



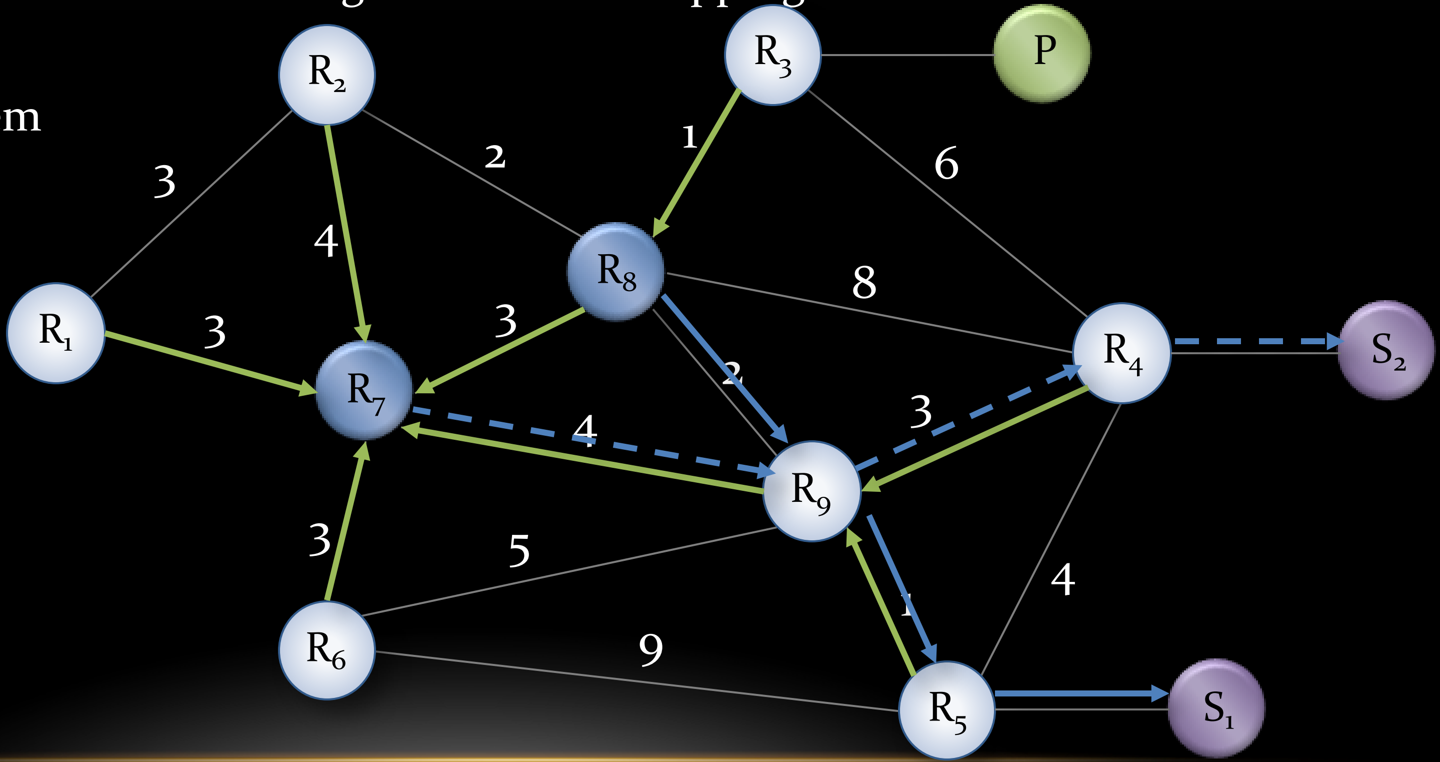
Note:
Any router that has CDs which are the prefix of the new CD shall subscribe to the new RP

# 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

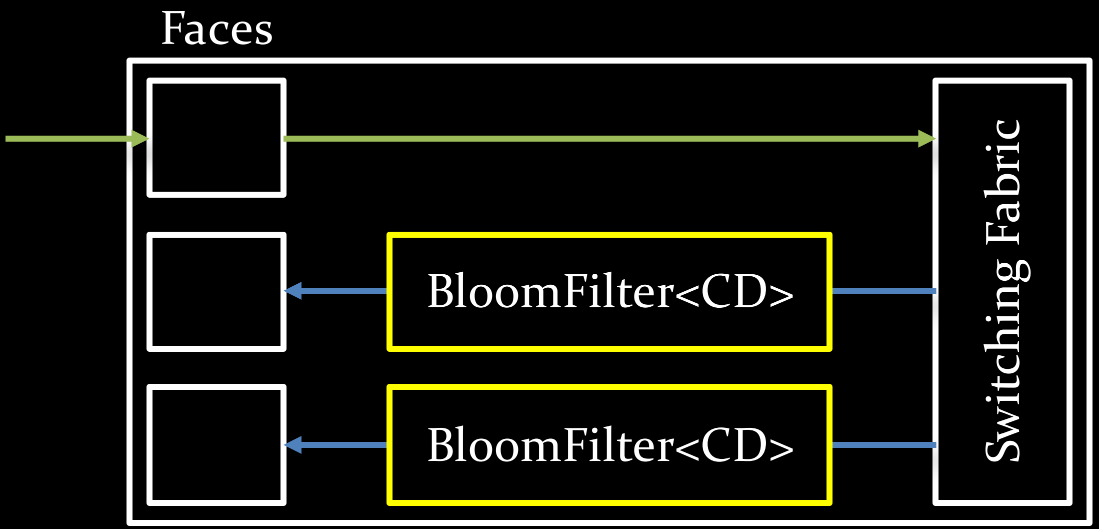
Global CD-RP Mapping

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



# Problem 3: ST Size

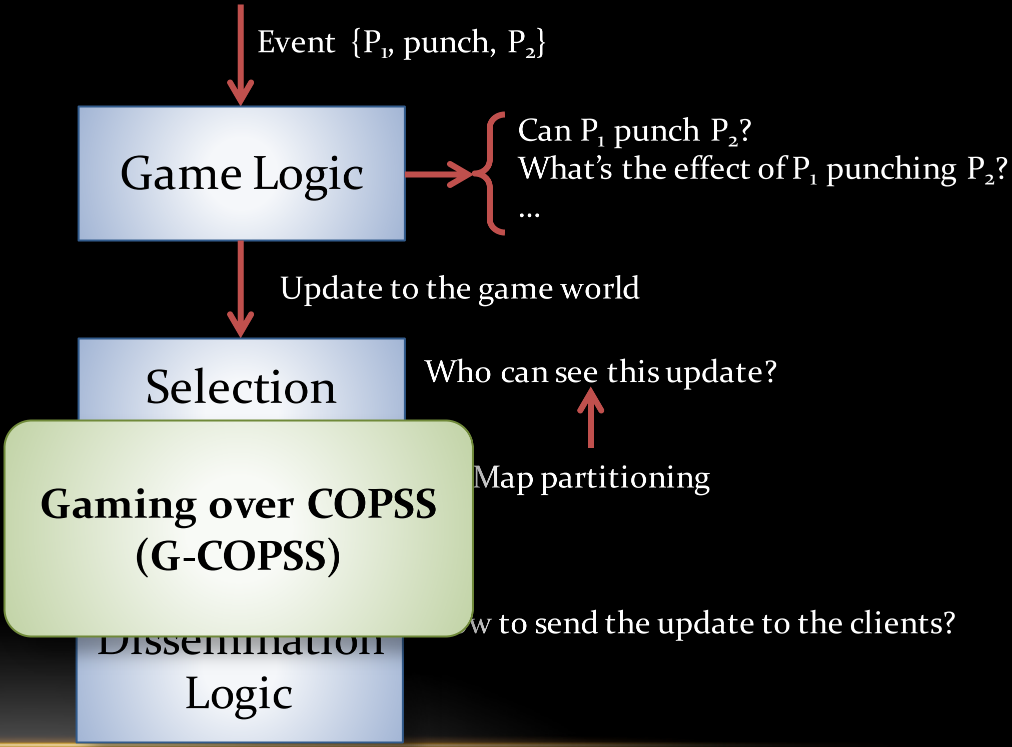
- Description: ST will have too many entries due to the unbounded CD space
- Solution:
    - From CD-Face(s) mapping to Face-BloomFilter<CD> mapping



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?

Map partitioning

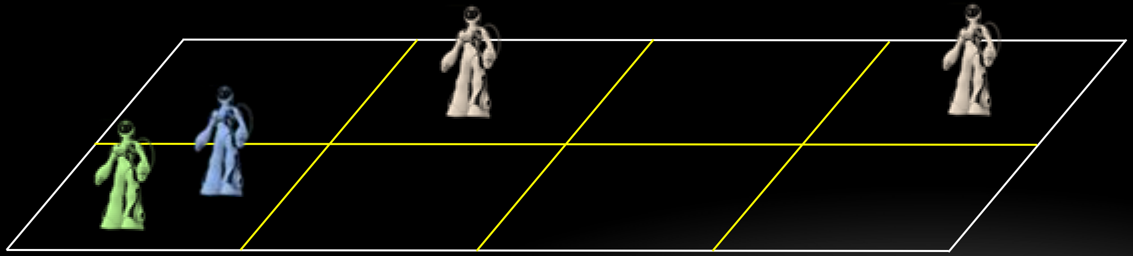
**Gaming over COPSS (G-COPSS)**

w to send the update to the clients?

Dissemination Logic

# Example 1: Online Gaming

- Hierarchical Map Partitioning



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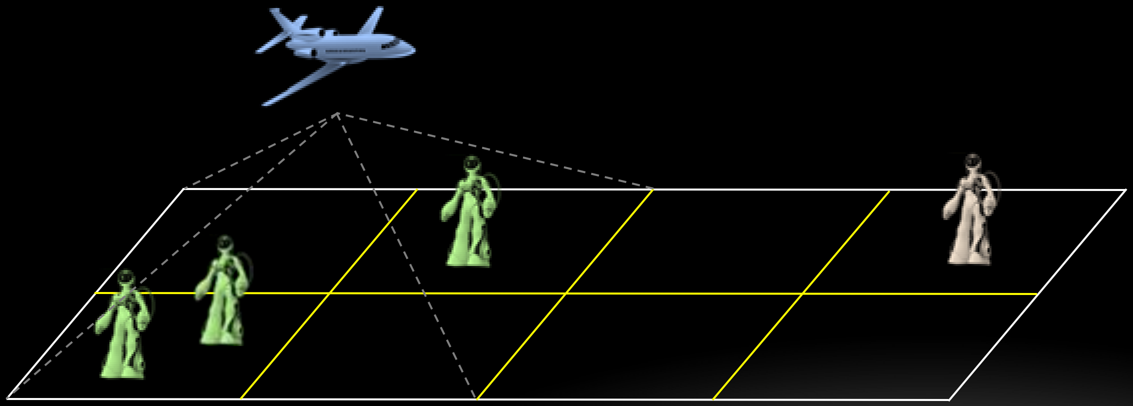
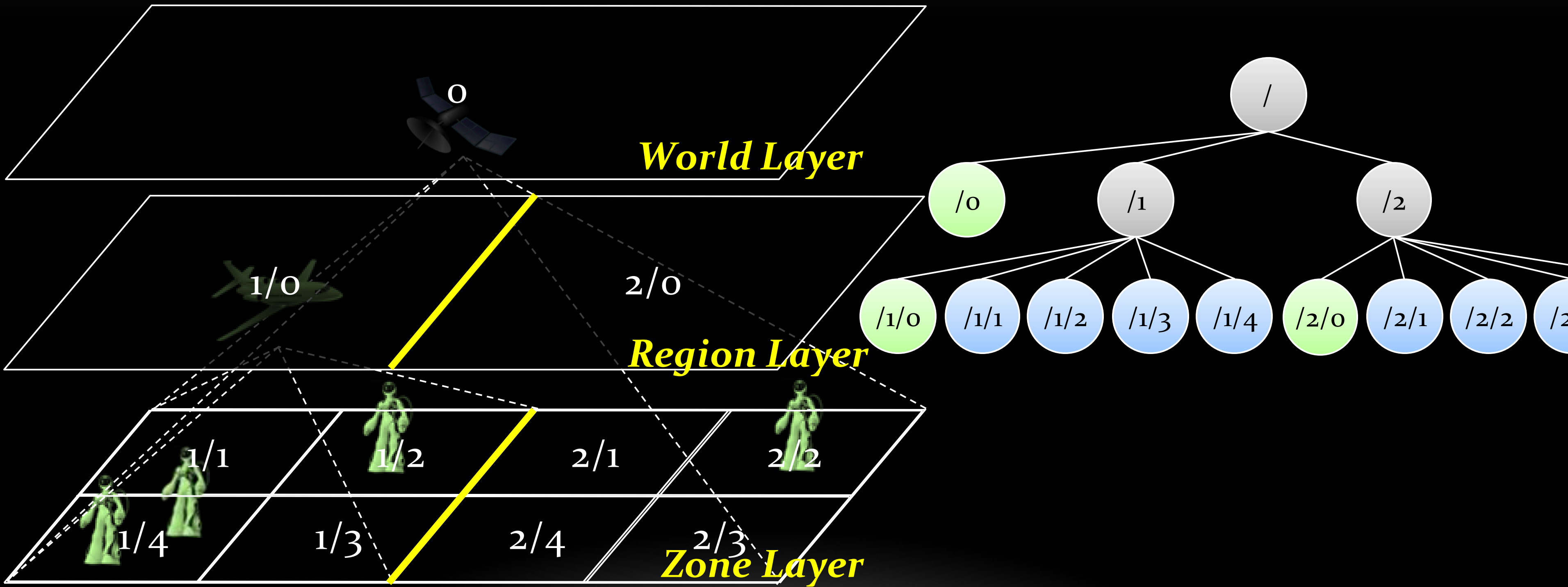


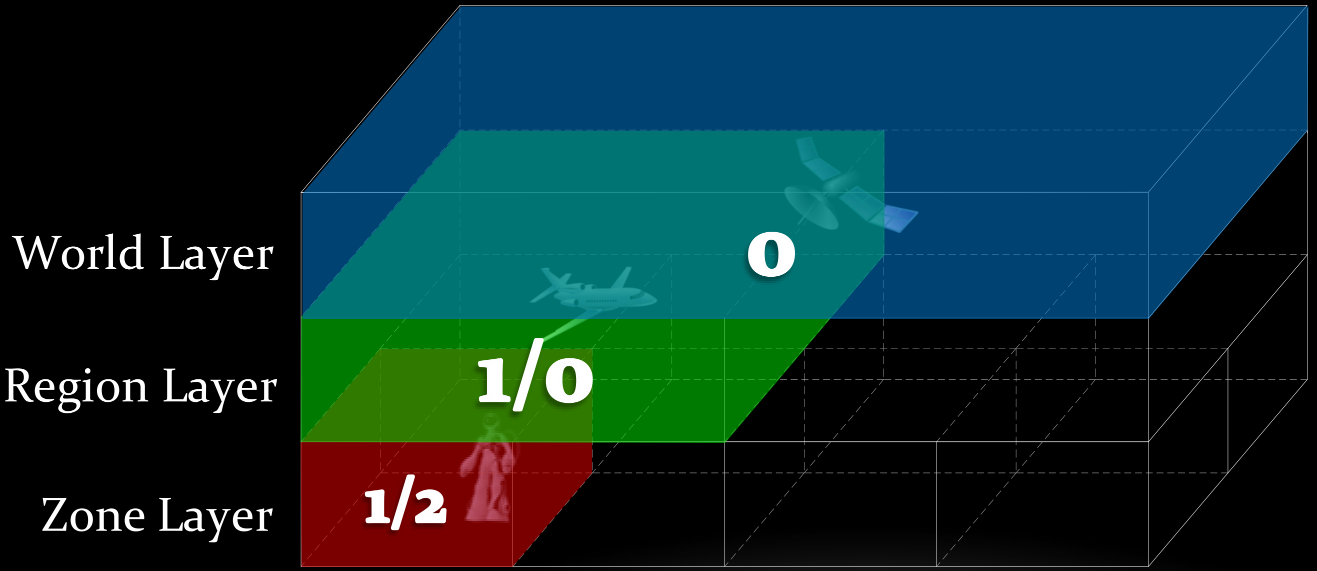
# Example 1: Online Gaming

- Hierarchical Map Partitioning
  - Hierarchical CDs



# Example 1: Online Gaming

- Hierarchical Map Partitioning
  - Pub/Sub rules



**Satellite:**

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

**Plane:**

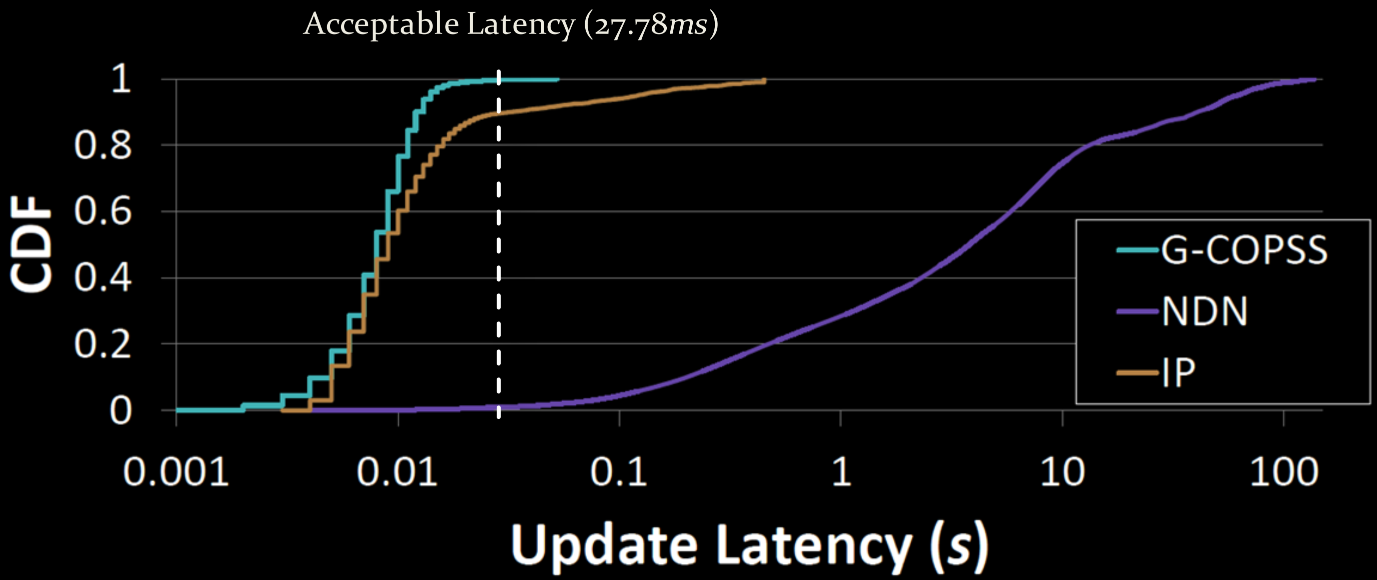
- Location: 1/0
- Pub: /1/0
- **Sub: /1, /0**

**Soldier:**

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

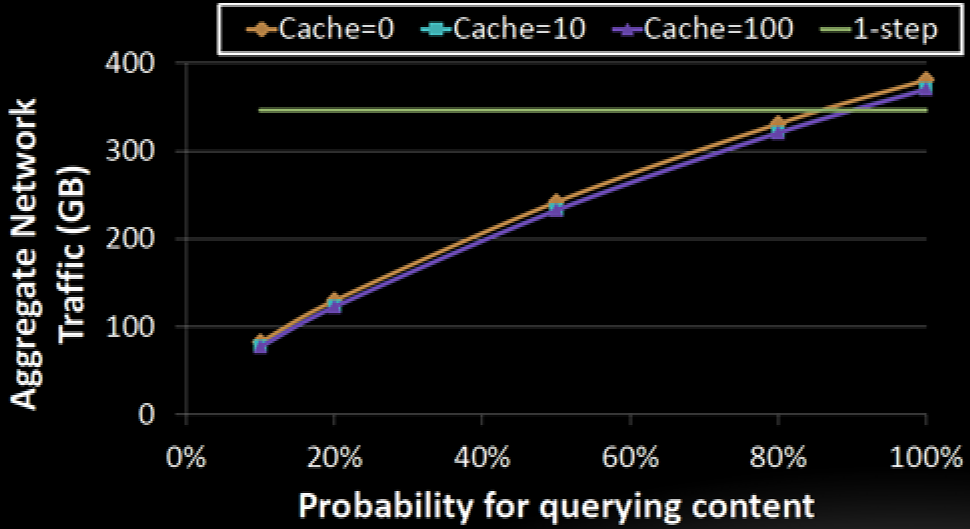
# EXAMPLE 1: ONLINE GAMING

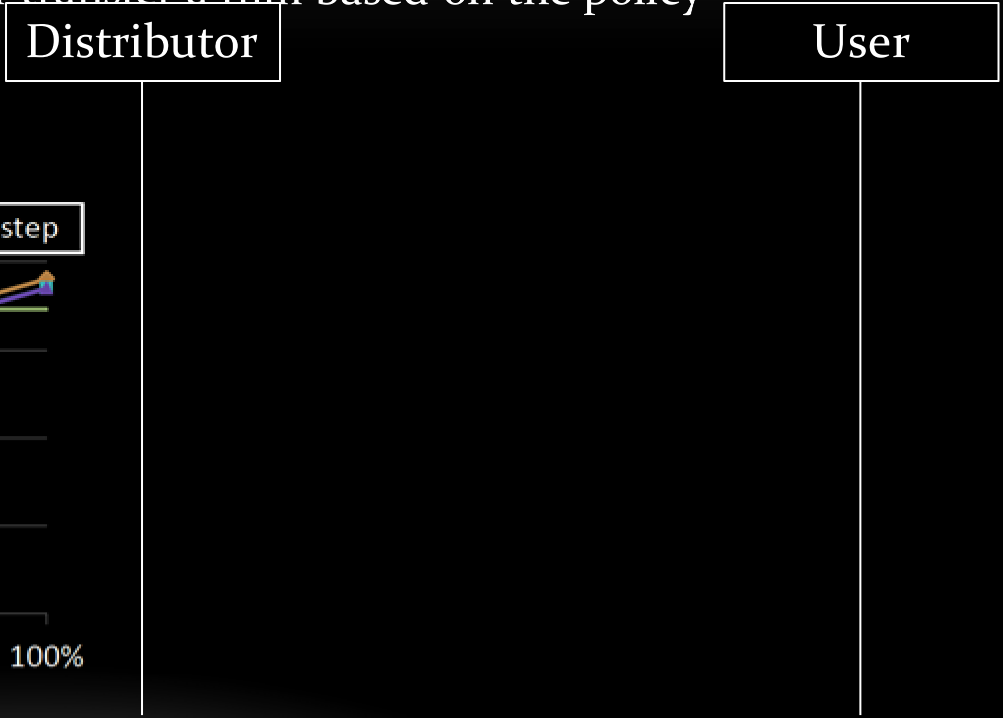
- Performance Comparison



# 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

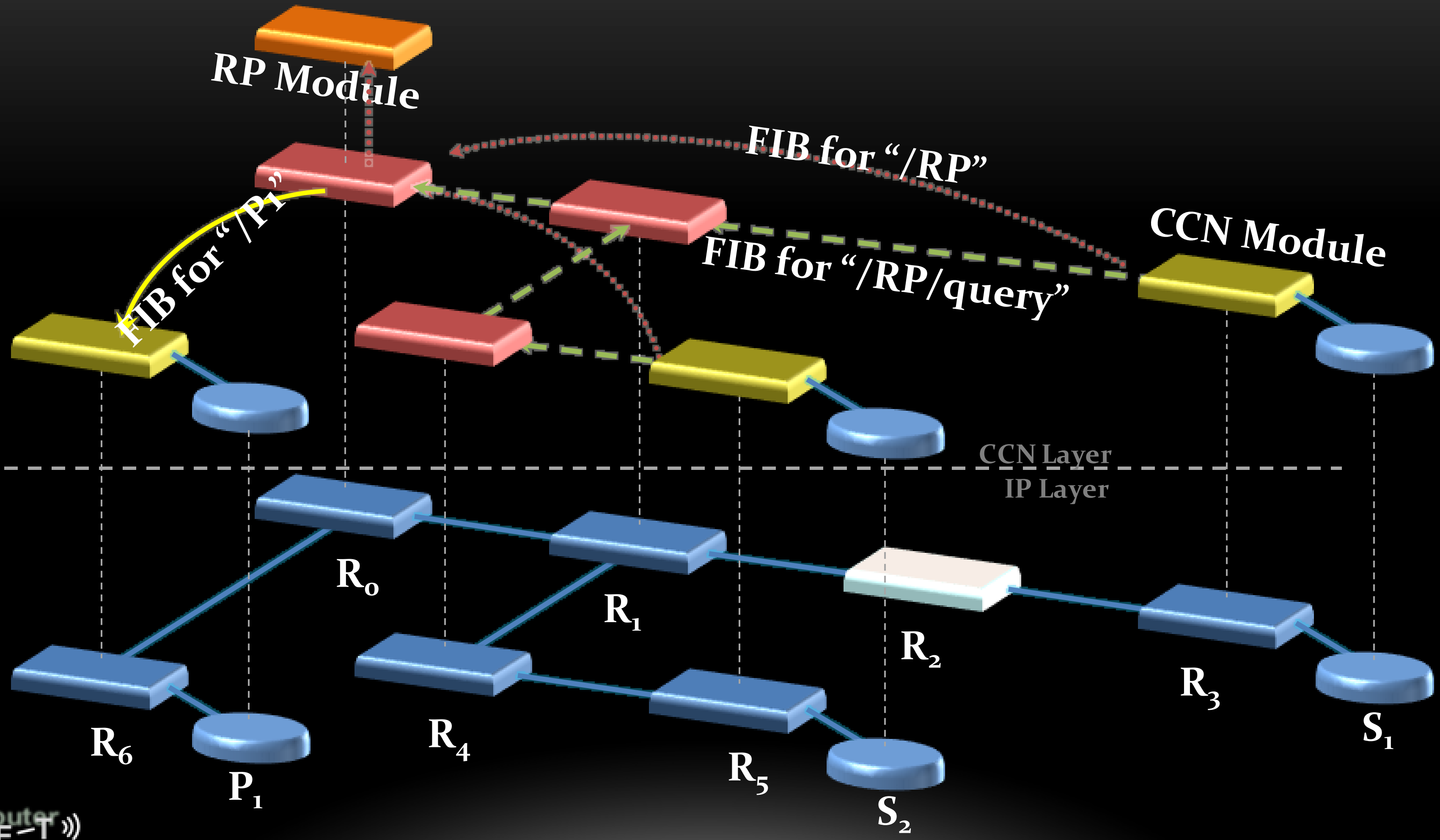




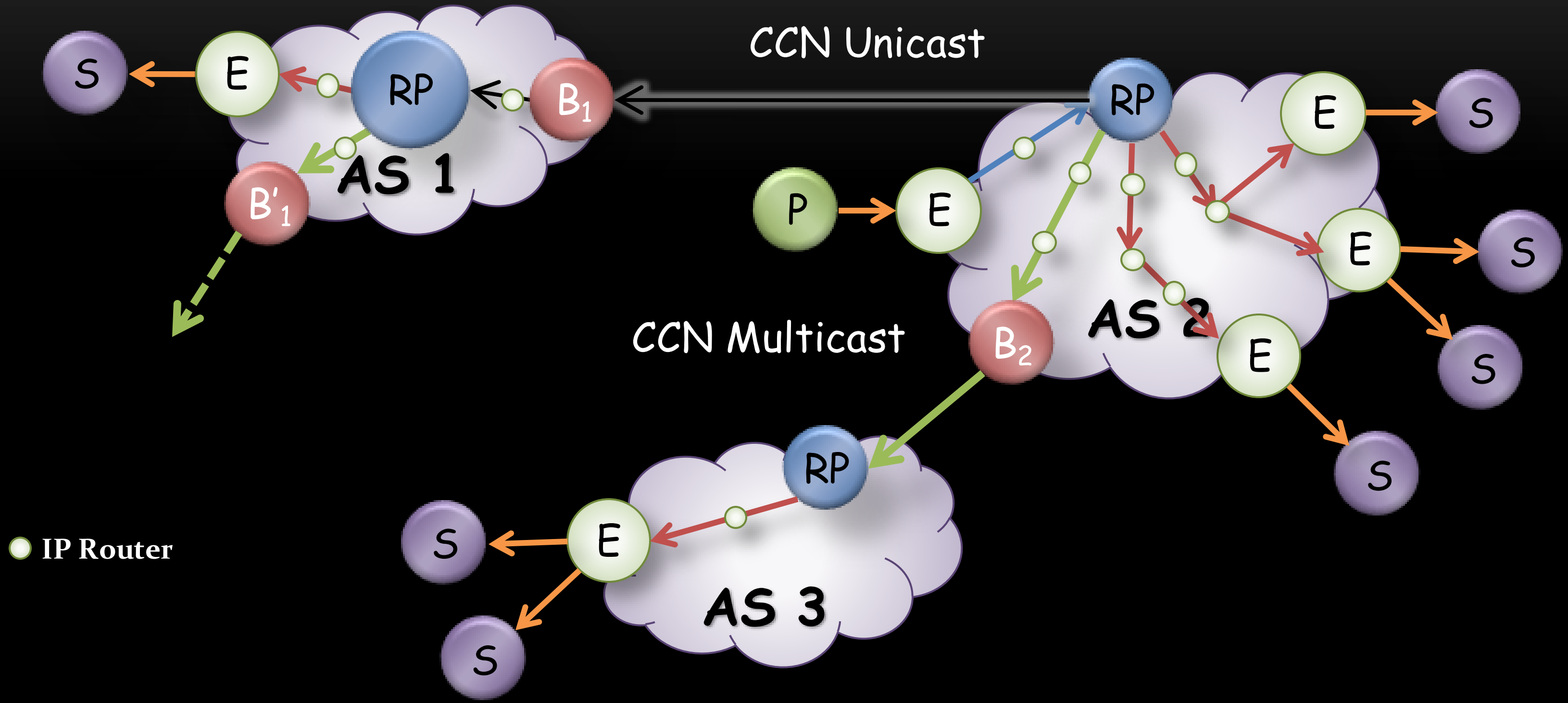
# INCREMENTAL DEPLOYMENT

- 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. Yi, Cheng, *et al.* "*A case for stateful forwarding plane*." Computer Communications 36.7 (2013): 779-791.
2. Chen, Jiachen, et al. "Copss: An efficient content oriented publish/subscribe system." *ANCS, 2011*.
3. Chen, Jiachen, et al. "G-COPSS: A Content Centric Communication Infrastructure for Gaming Applications." *ICDCS, 2012*.
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5. FP-7 EU Project: "Green ICN." http://www.greenicn.org/

# Acknowledgment

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