ENDN: An Enhanced NDN Architecture with a P4-programmable Data Plane

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PRESENTED BY:
Ouassim Karrakchou

Agenda

- Motivation
- Proposed Architecture
  - ✓ EProcessing Module
  - ✓ Forwarding Logic Module
- Proof of Concept Experiments
- Conclusion and Future Work

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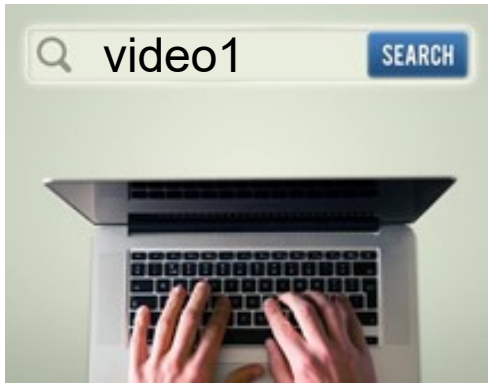

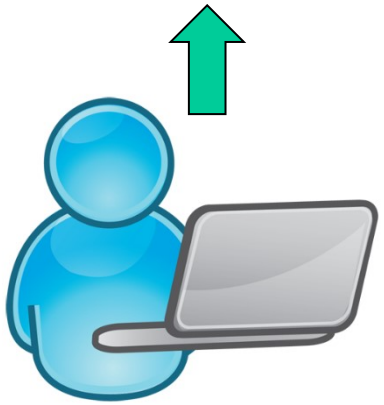

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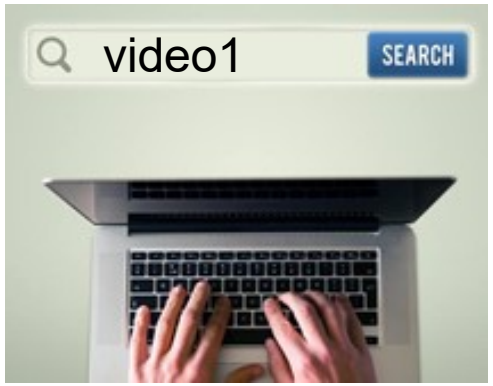
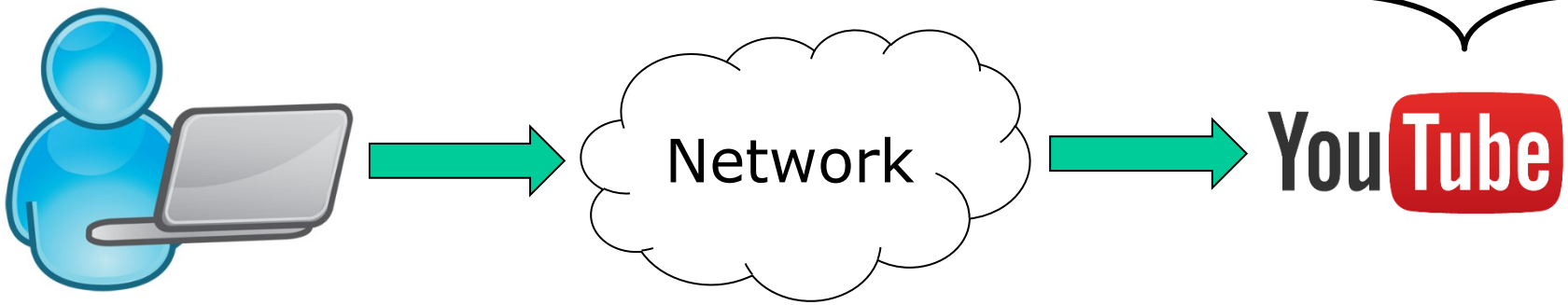


- Content Generation and Hosting



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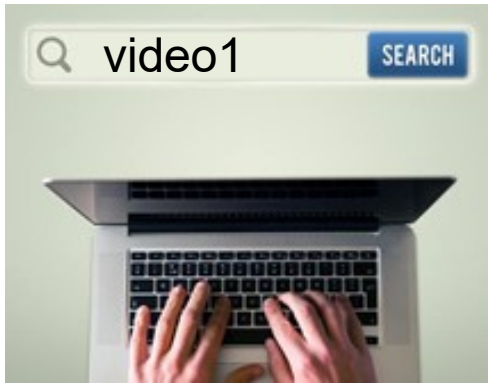
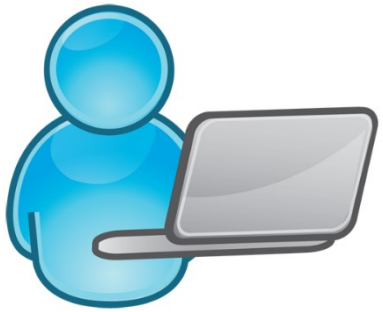


- Best-Effort Forwarding

- Content Generation and Hosting
- Congestion Control
- Firewall
- Bitrate Adjustment
- Geo-Fencing



Network

YouTube

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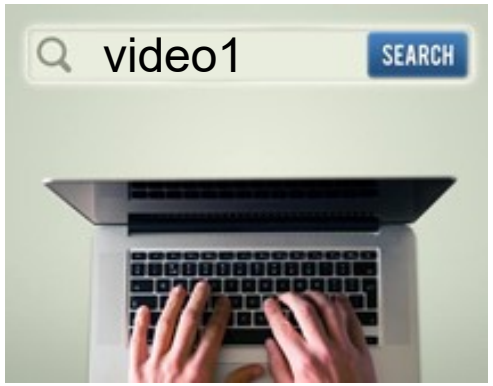
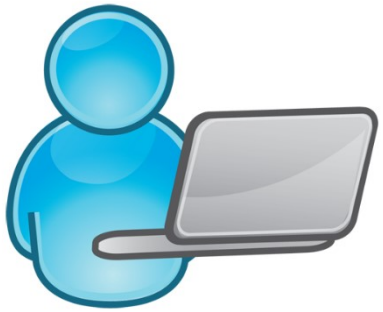


Intelligence in the application

- Content Generation and Hosting
- Congestion Control
- Firewall
- Bitrate Adjustment
- Geo-Fencing

- Best-Effort Forwarding



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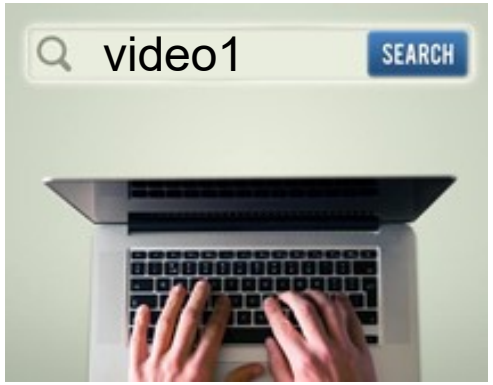
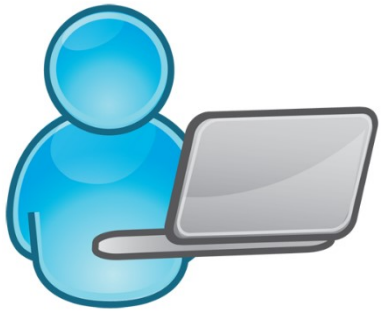
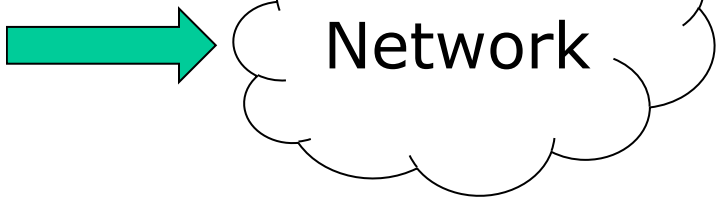


- Congestion Control
- Firewall
- Bitrate Adjustment
- Geo-Fencing

- Content Generation and Hosting





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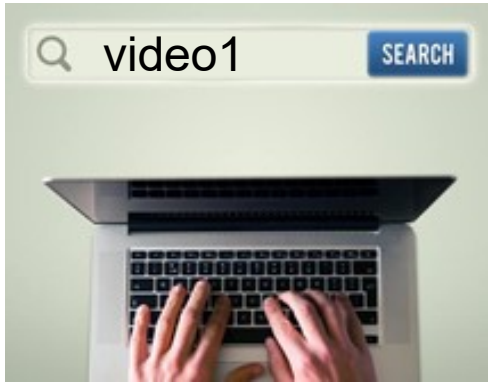
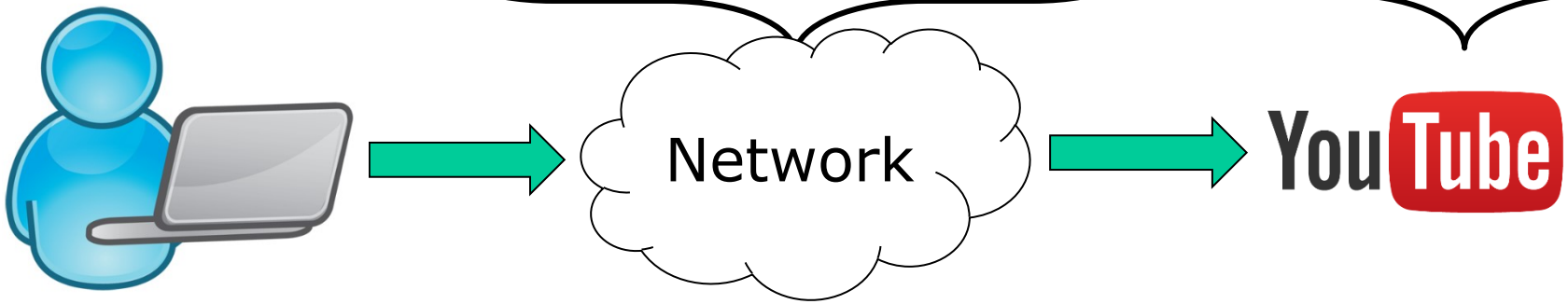


More intelligence in the network?

- Congestion Control
- Firewall
- Bitrate Adjustment
- Geo-Fencing
- Content Generation and Hosting



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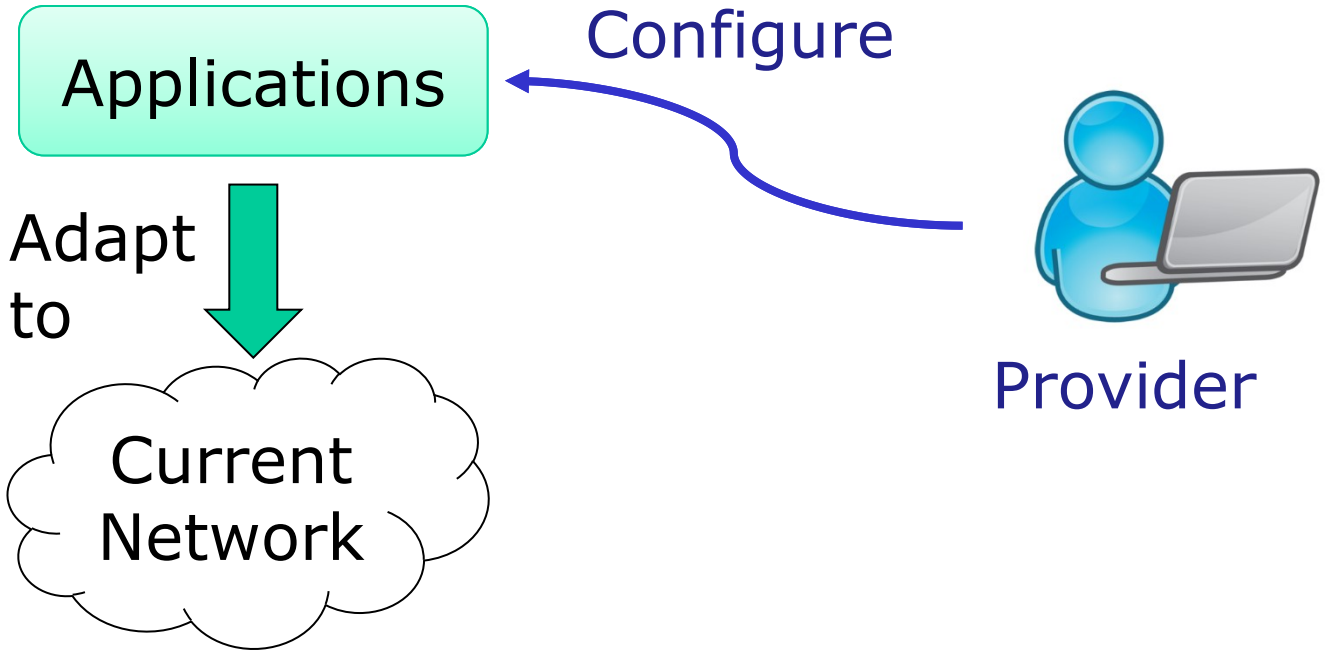
- Transition to an application-centric network:



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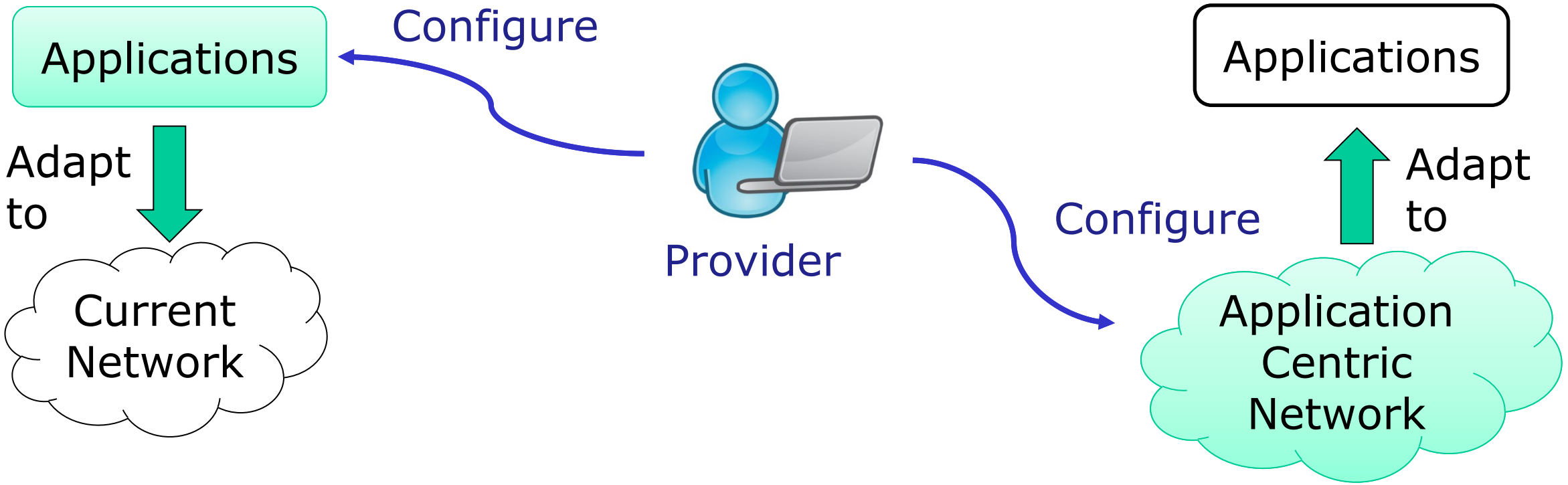

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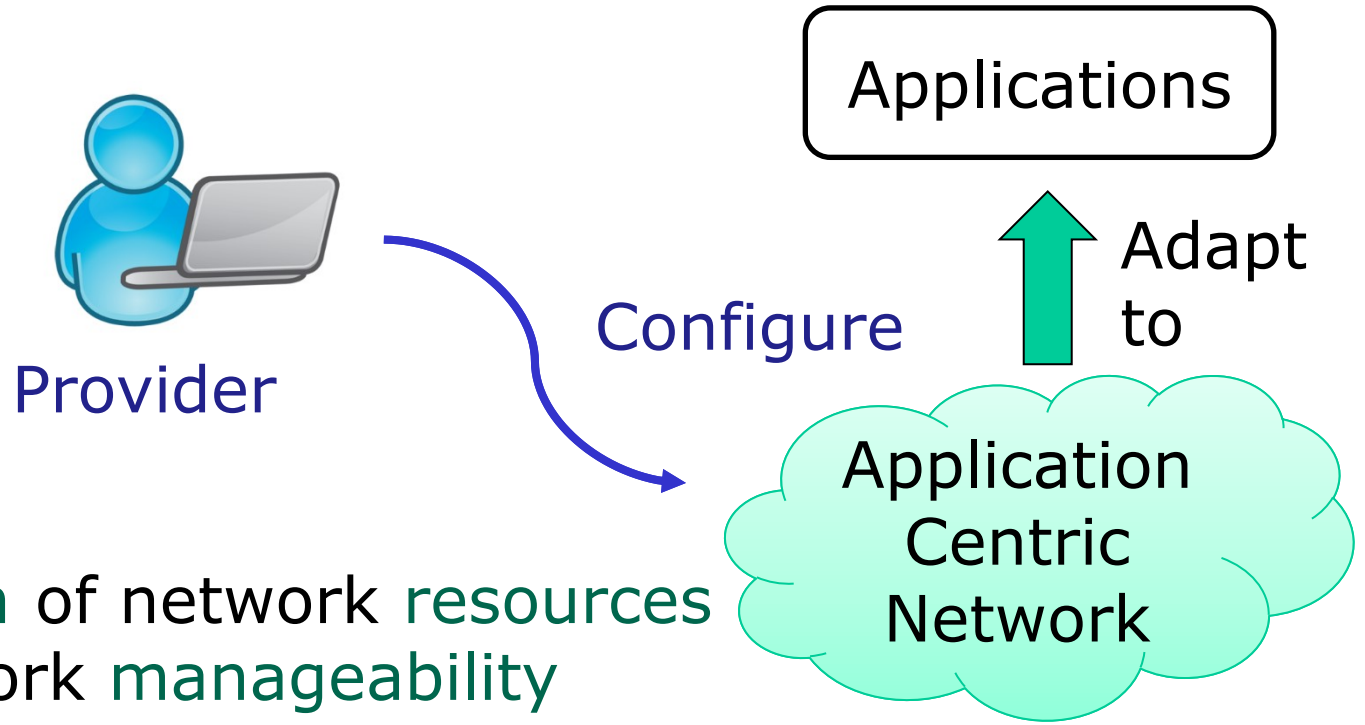
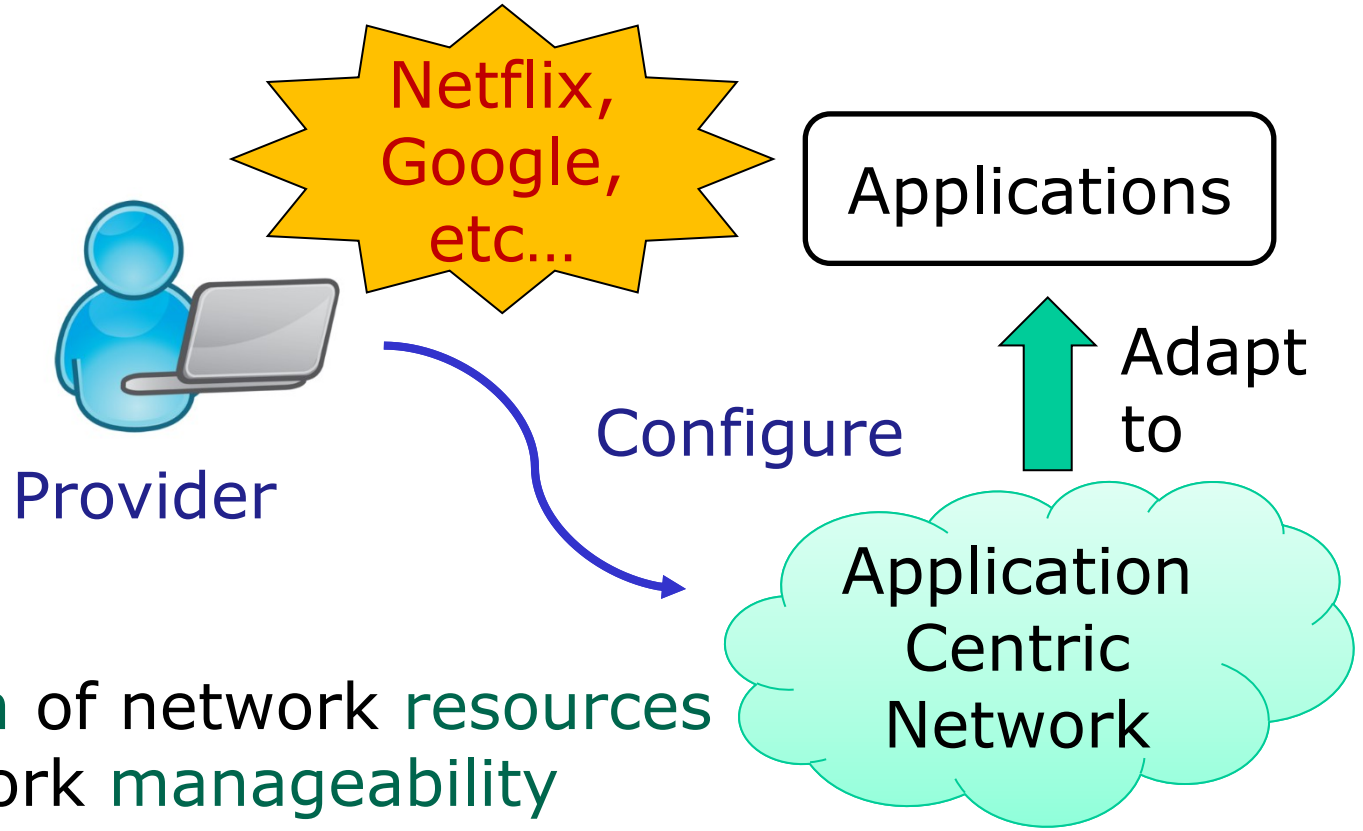


Advantages:

- Optimization of network resources
- Better network manageability
- Faster resolution of network issues

Motivation

- Transition to an application-centric network:



Advantages:

- Optimization of network resources
- Better network manageability
- Faster resolution of network issues

Existing Solutions

- **NDN**, a first step towards an application-centric network:
  - The network is aware of contents shared by applications.
  - Optimize the delivery of contents to requesters.

- **Network Programmability**:
  - Allow providers to completely specify their custom forwarding behaviors.
  - SDN: programmability in the control plane.
  - P4: a language to program the data plane.

Existing Challenges

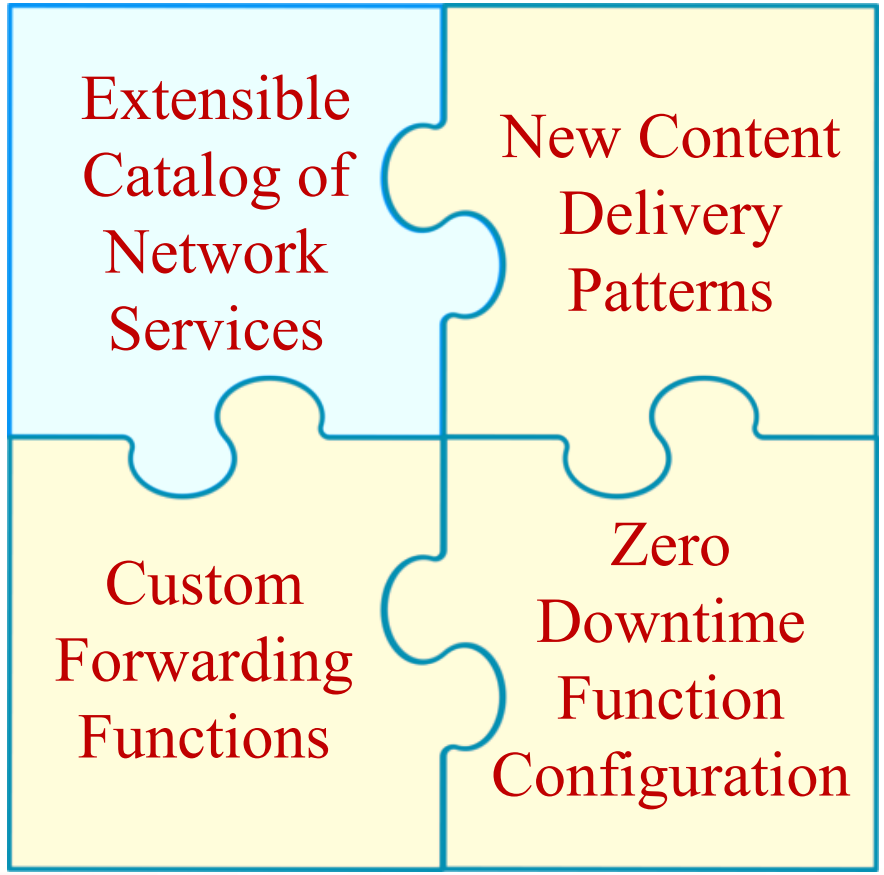
- **NDN:**
  - NDN suitable for pull traffic, but challenges in other content delivery patterns (e.g., pub/sub or push).

- **P4:**
  - Current P4 data planes allow a single large P4 program to run on a switch. Hence, downtime is needed for updates.
  - P4 has limitations when processing string-based protocols as in the case of NDN.

=> Application-centric network architecture still missing

Contributions

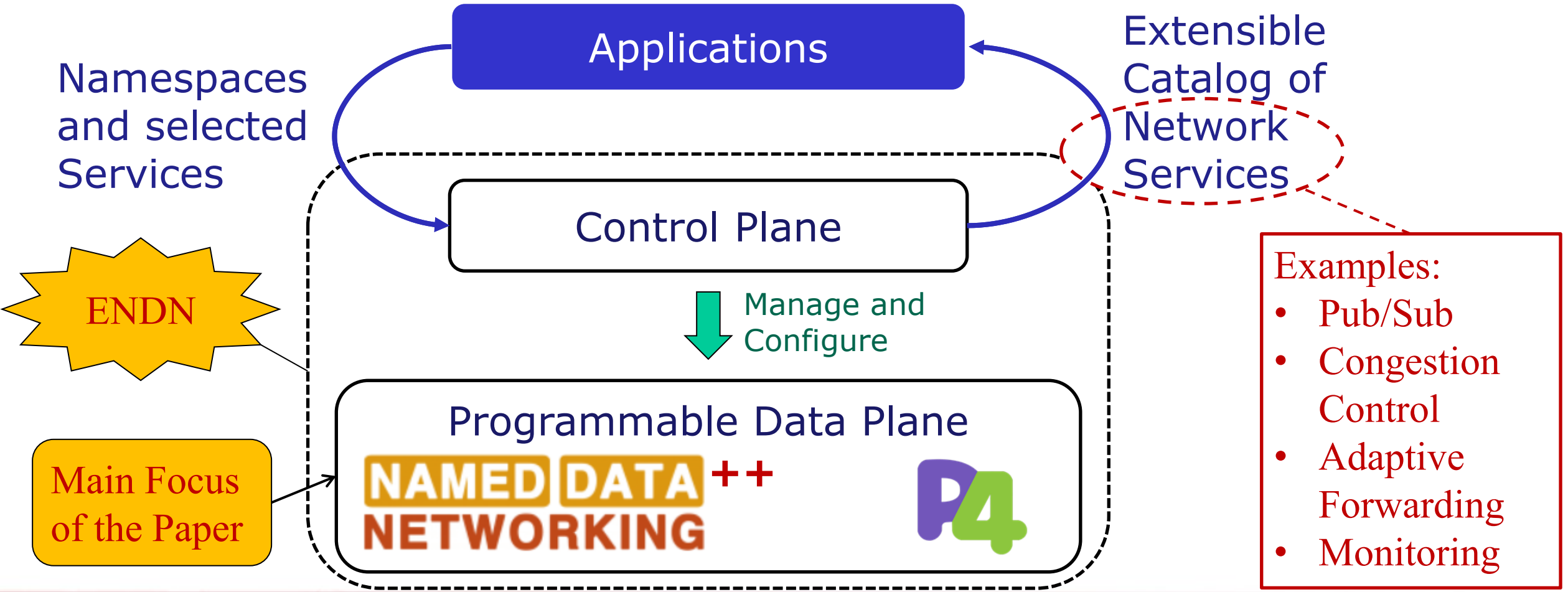
- Design ENDN, a novel NDN architecture with the following features:



Control Plane

Data Plane

Overview of ENDN



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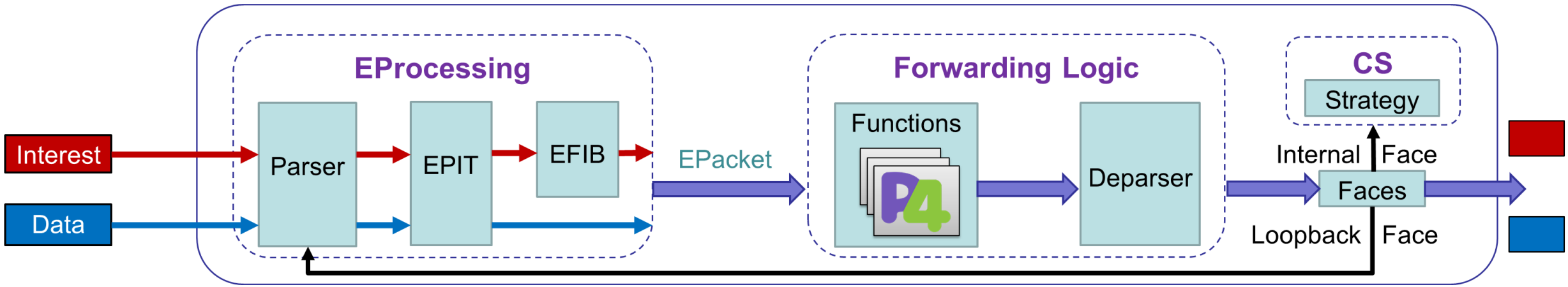
Proposed Data Plane Architecture



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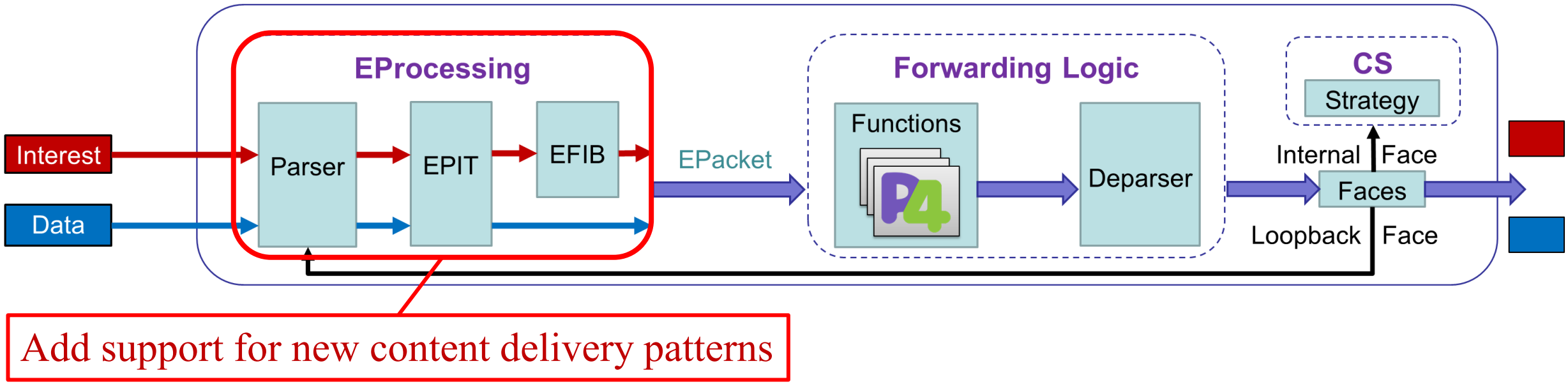

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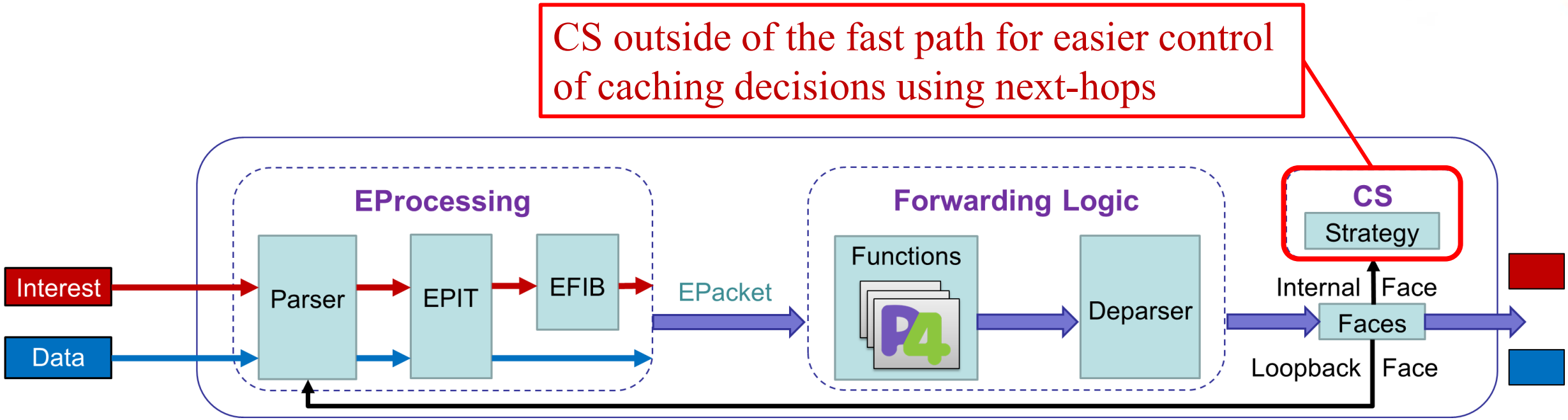

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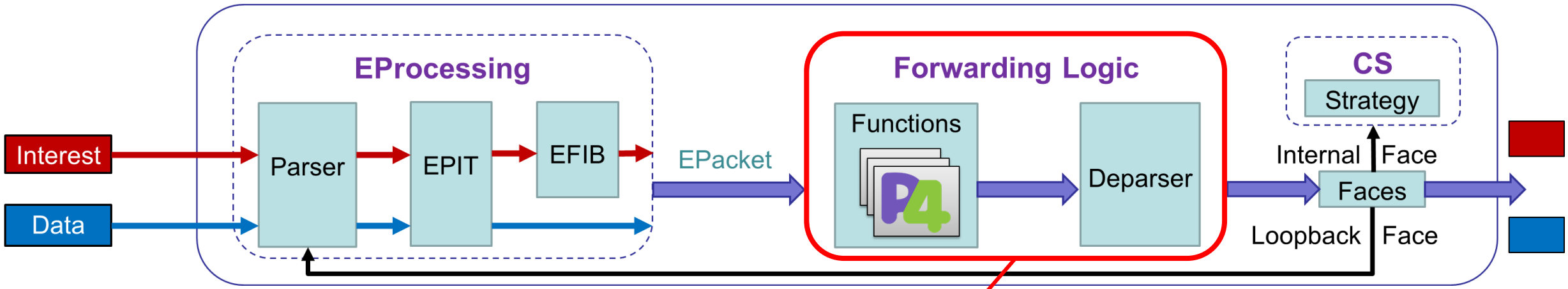
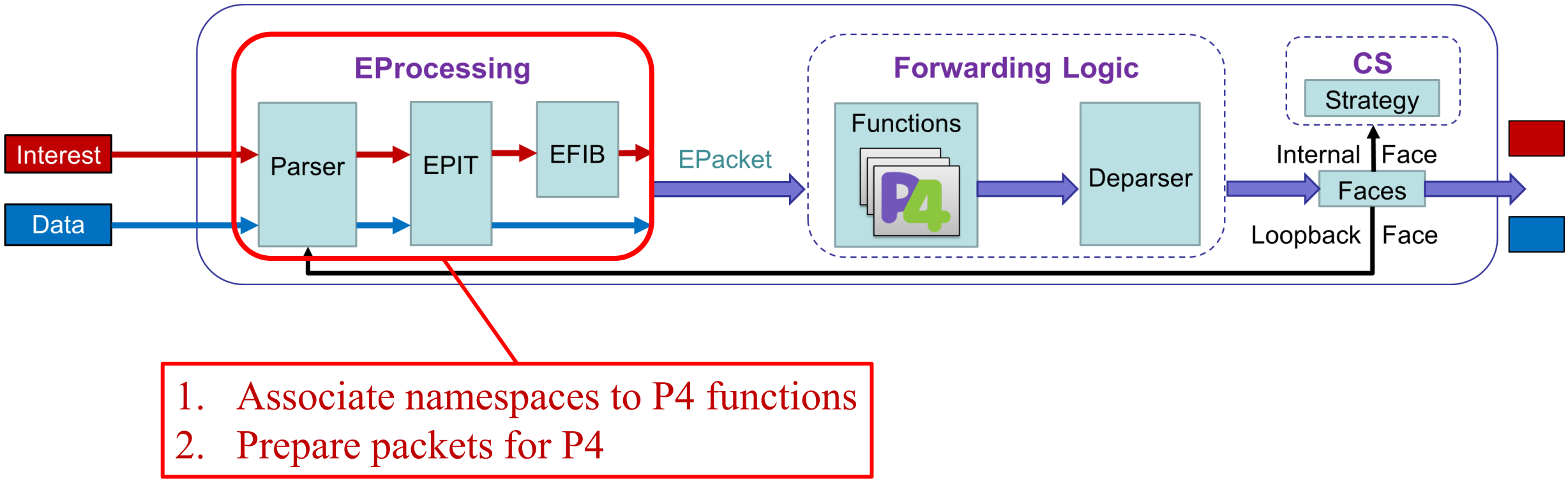


Configure complex stateful forwarding behaviors per namespace.
Examples: telemetering, geo-fencing, and stateful firewall.

Proposed Data Plane Architecture



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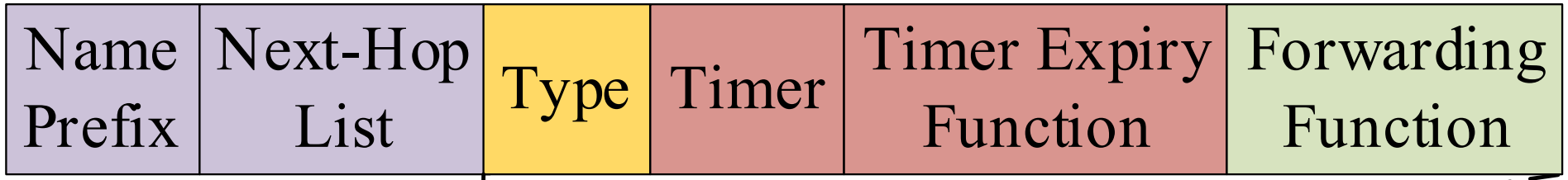
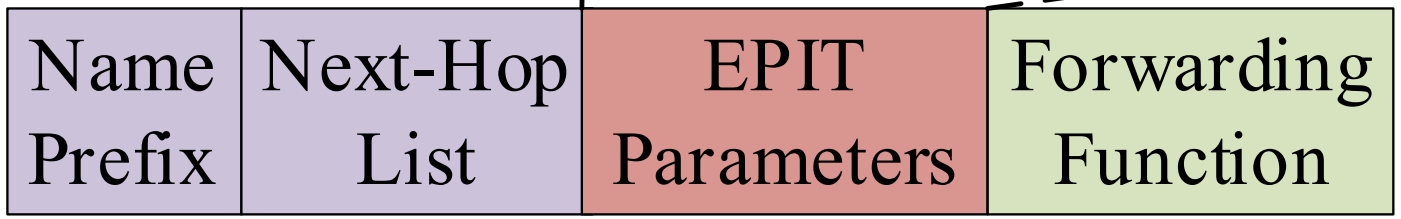
EPIT and EFIB entries

EPIT entry:



EFIB entry:



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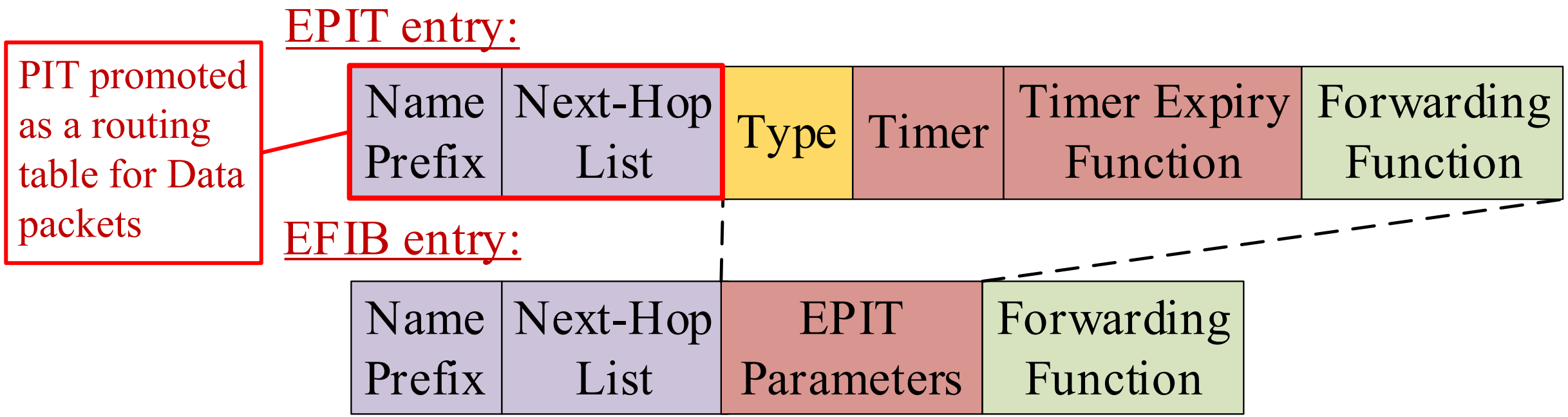

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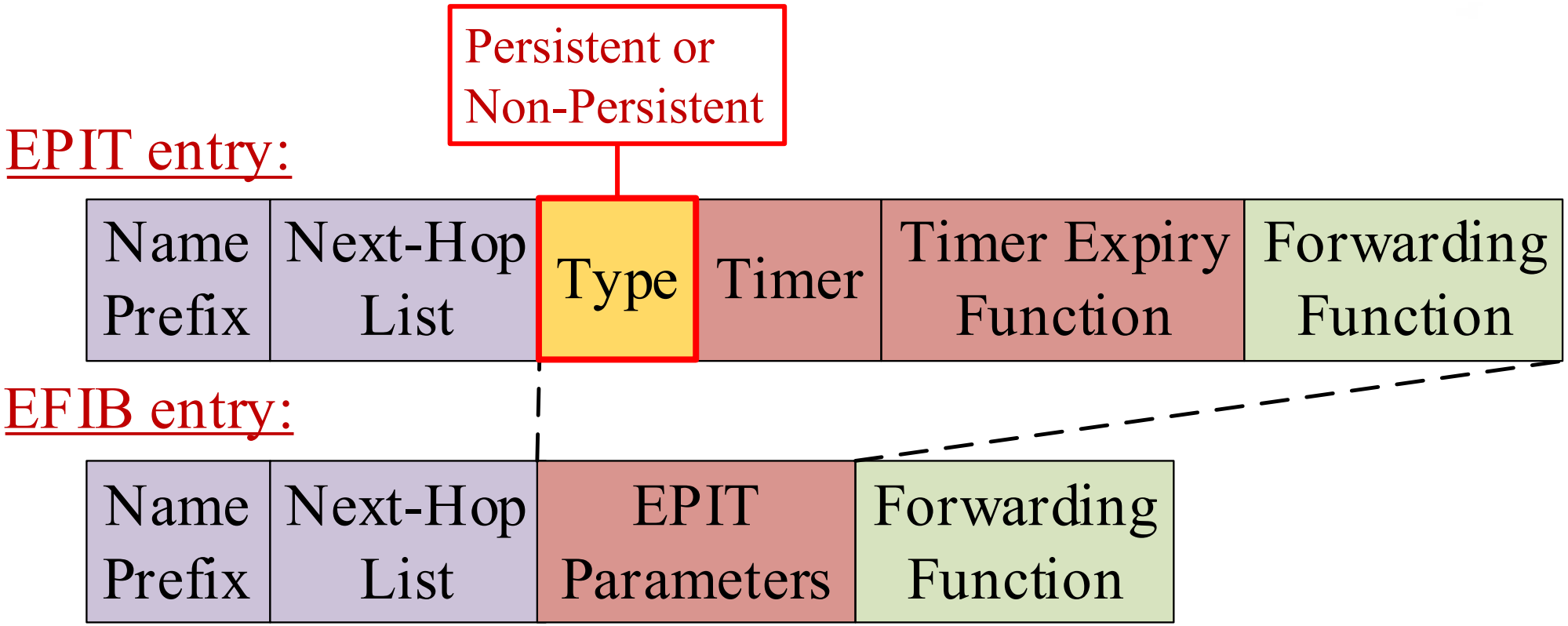
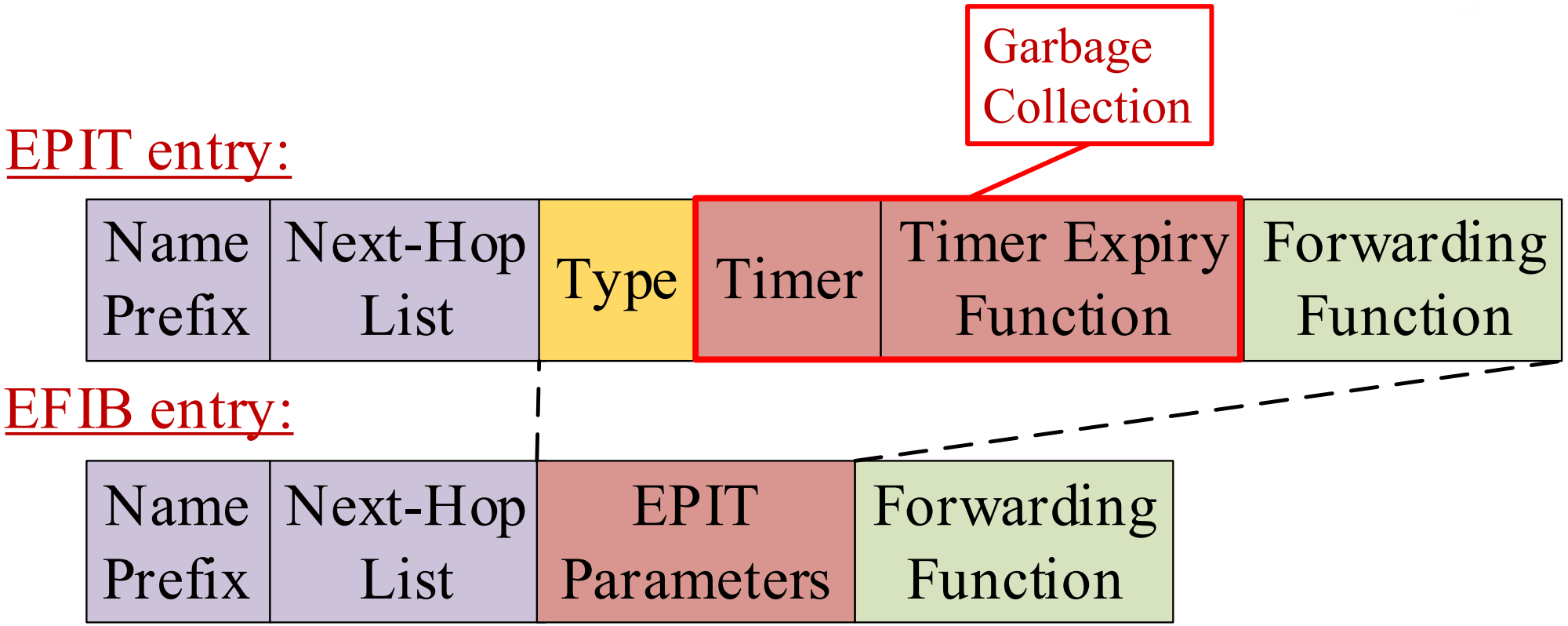


- Persistent: EPIT entry not deleted after a Data packet is forwarded

EPIT and EFIB entries



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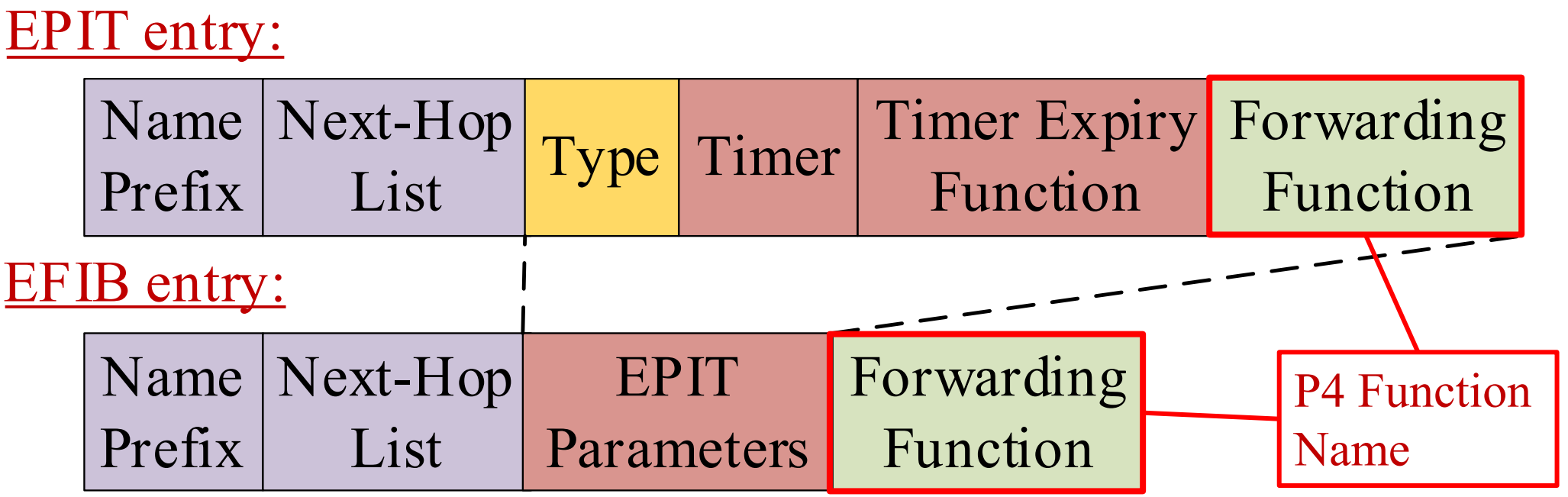
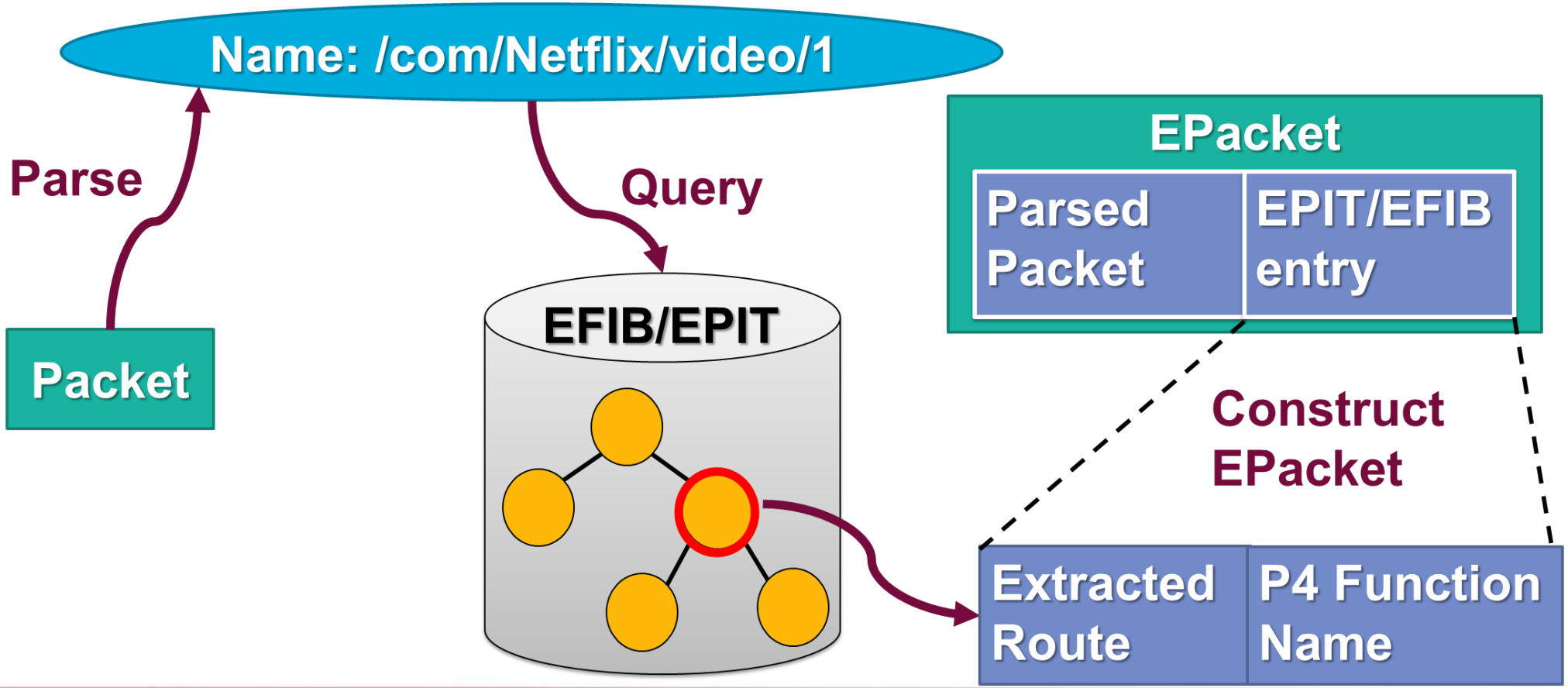


New Content Delivery Patterns

- The modifications to the NDN PIT and FIB tables allow ENDN to support new content delivery patterns:
  - **Publish/Subscribe**:
    - The EFIB route is configured to create persistent EPIT entries when Interest packets are forwarded.
  - **Push**:
    - Persistent EPIT routes are proactively configured by the control plane along the desired push route.

EProcessing Module

- Construction of the EPacket:



EProcessing Module

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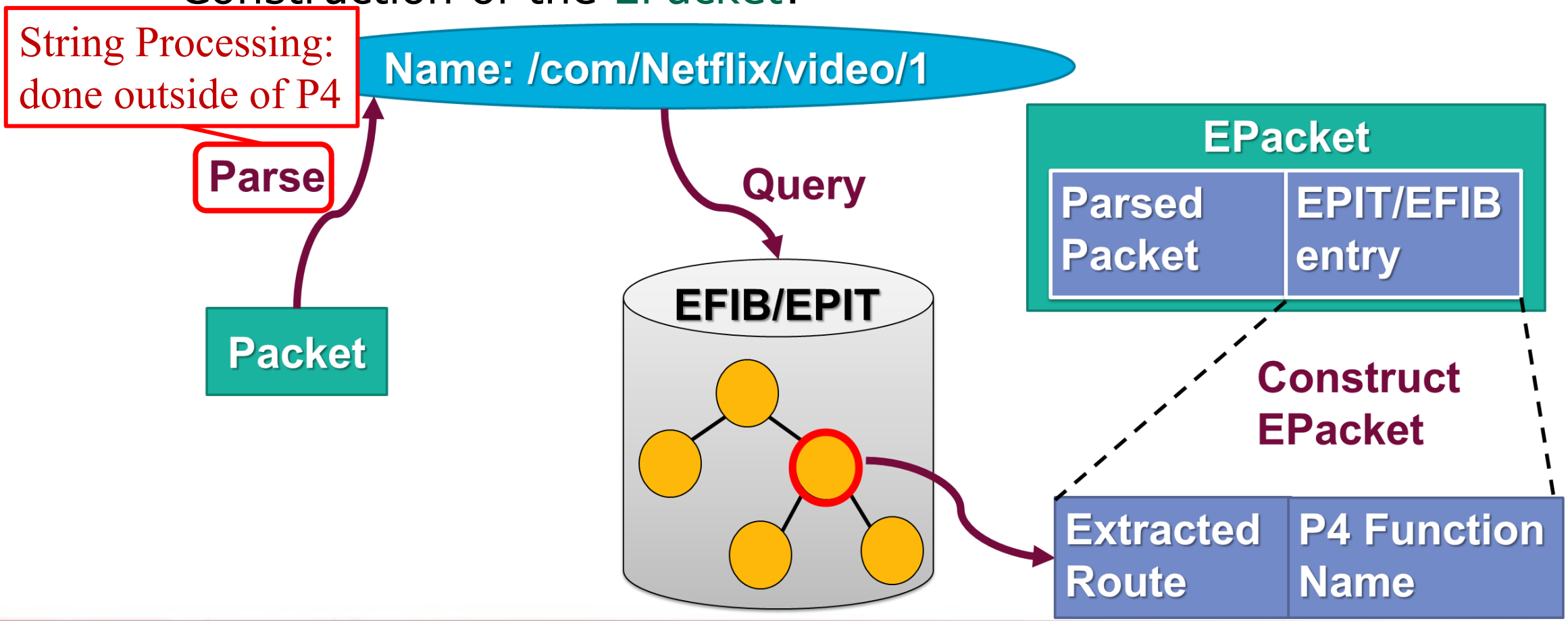

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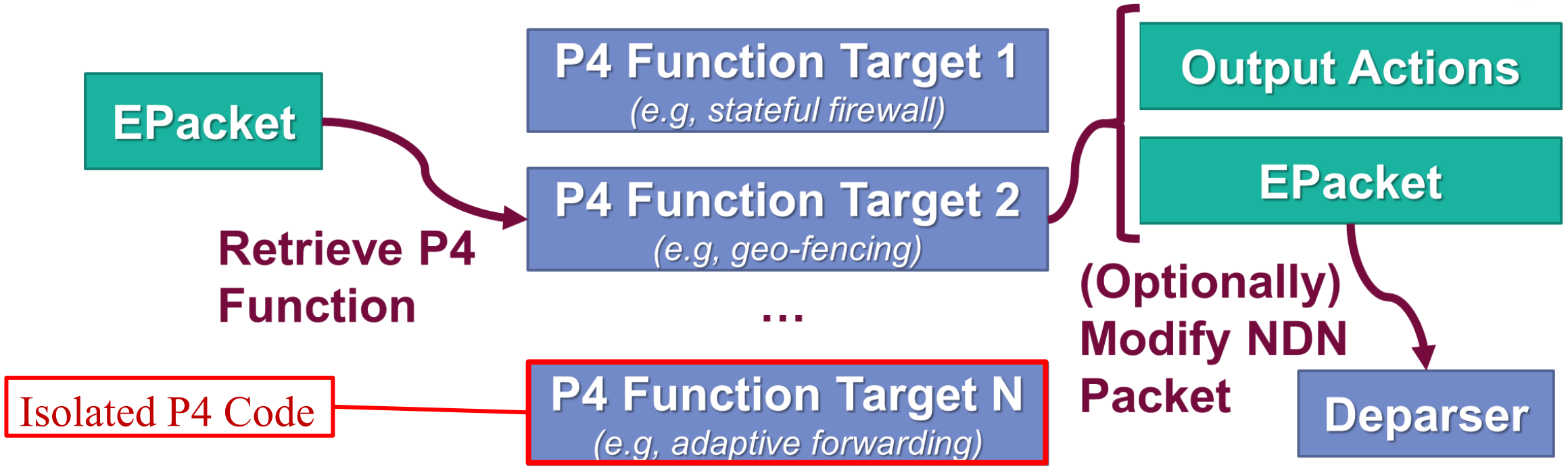
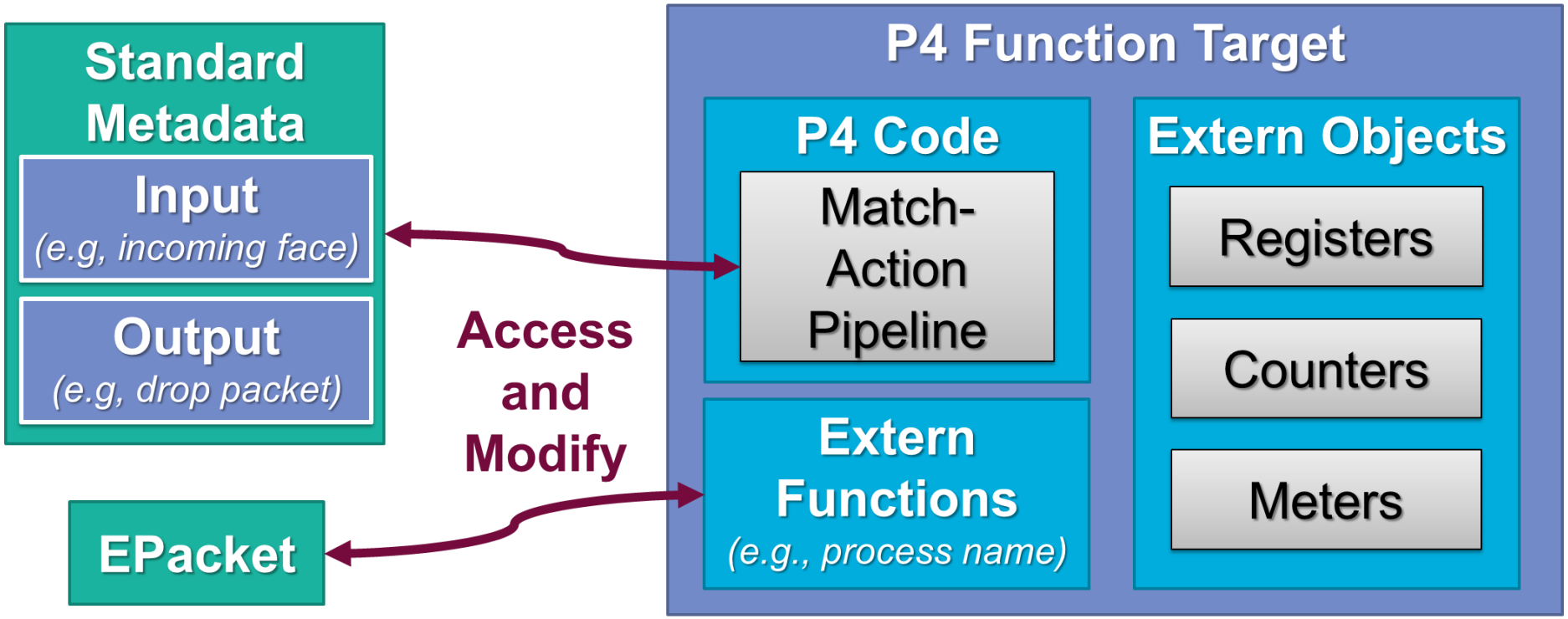


Forwarding Logic Module

- Examples of output actions: forward to next-hop, drop, notify the controller, modify header field, execute metering functionalities.

P4 Function Target



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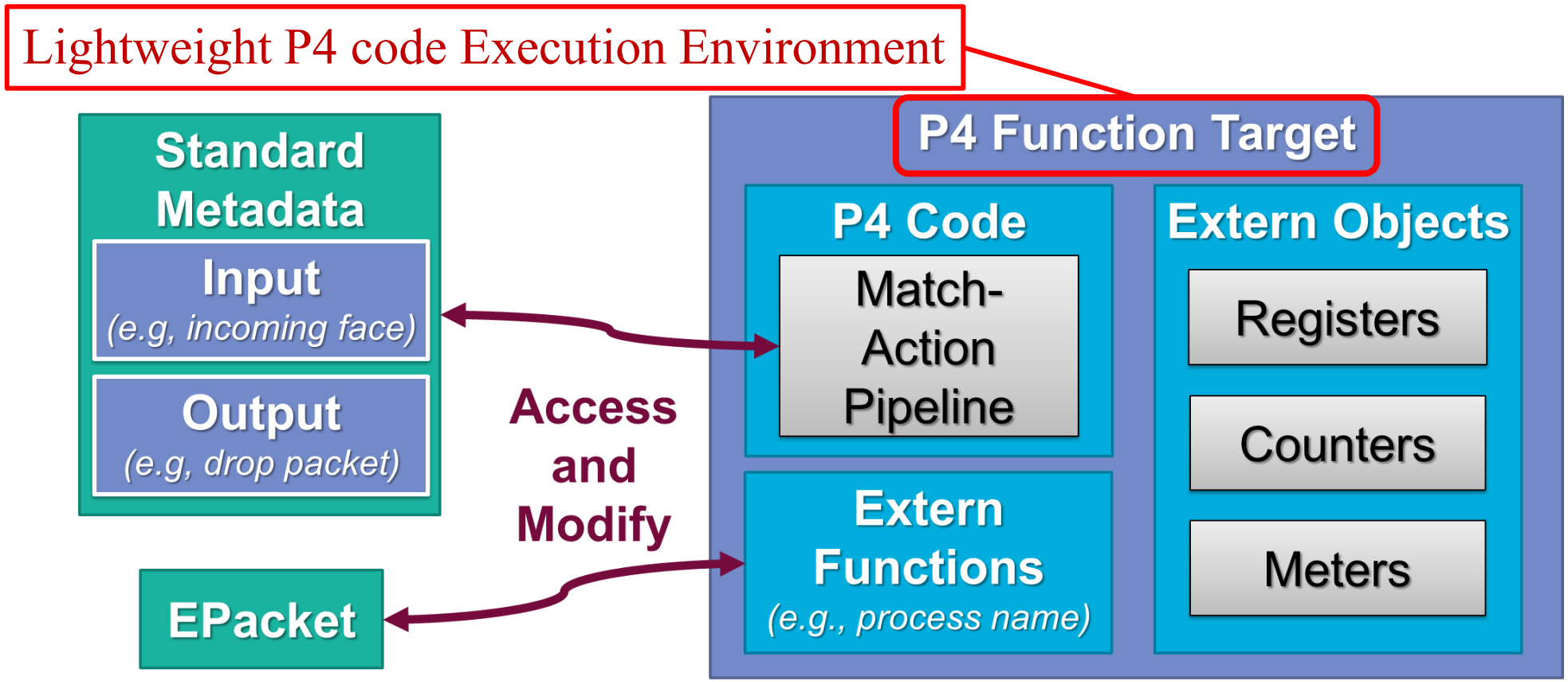

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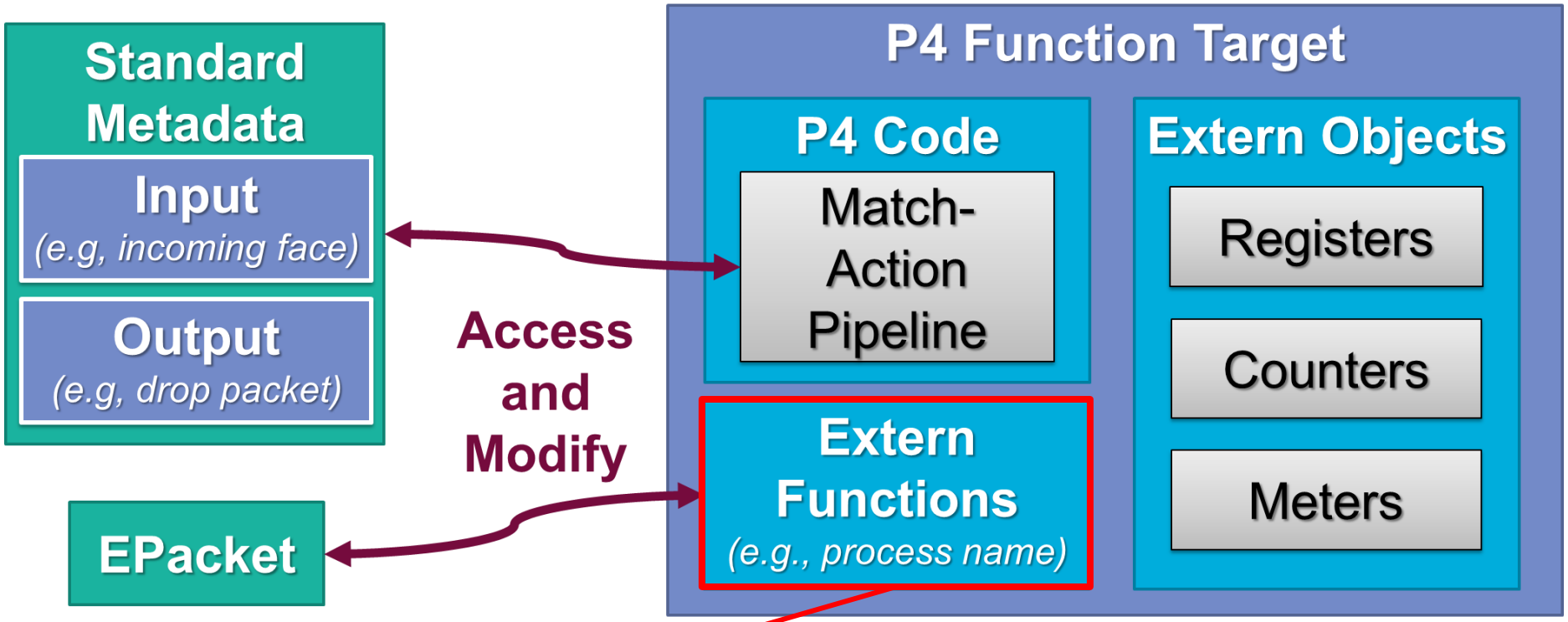
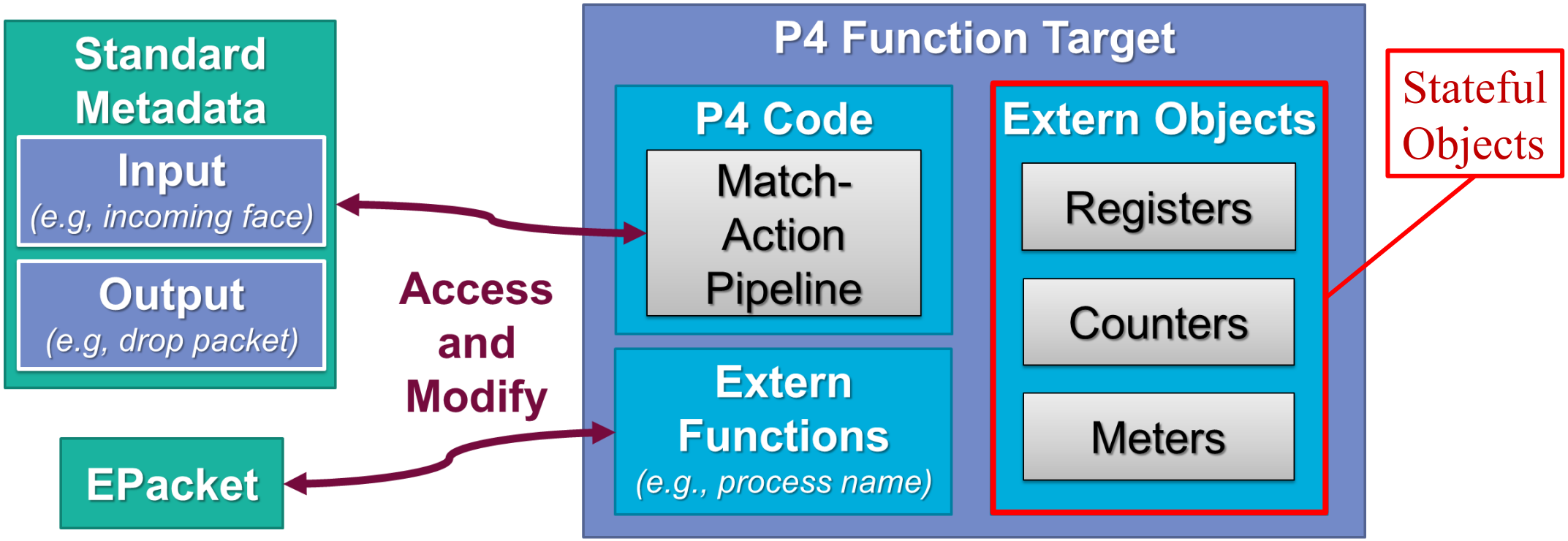
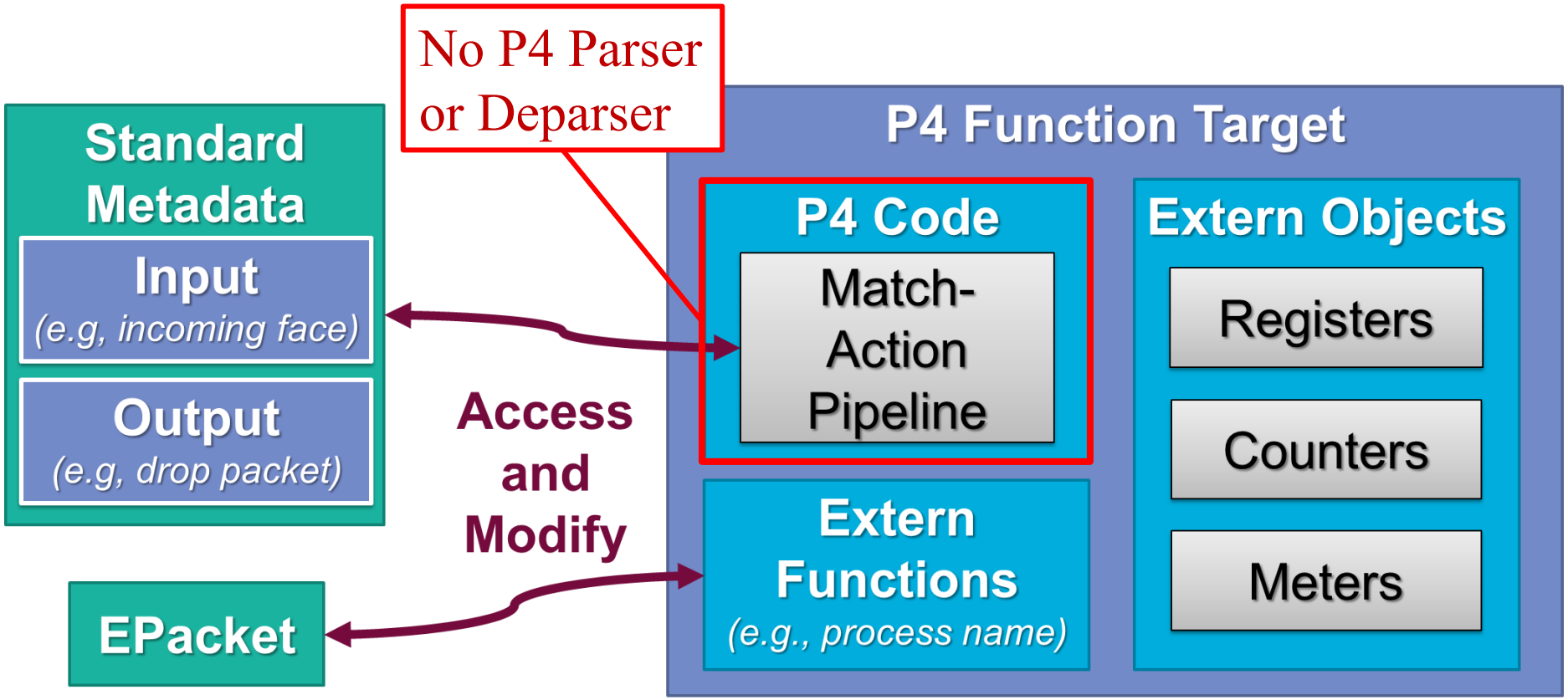


String processing is done through extern functions outside of P4

P4 Function Target



P4 Function Target



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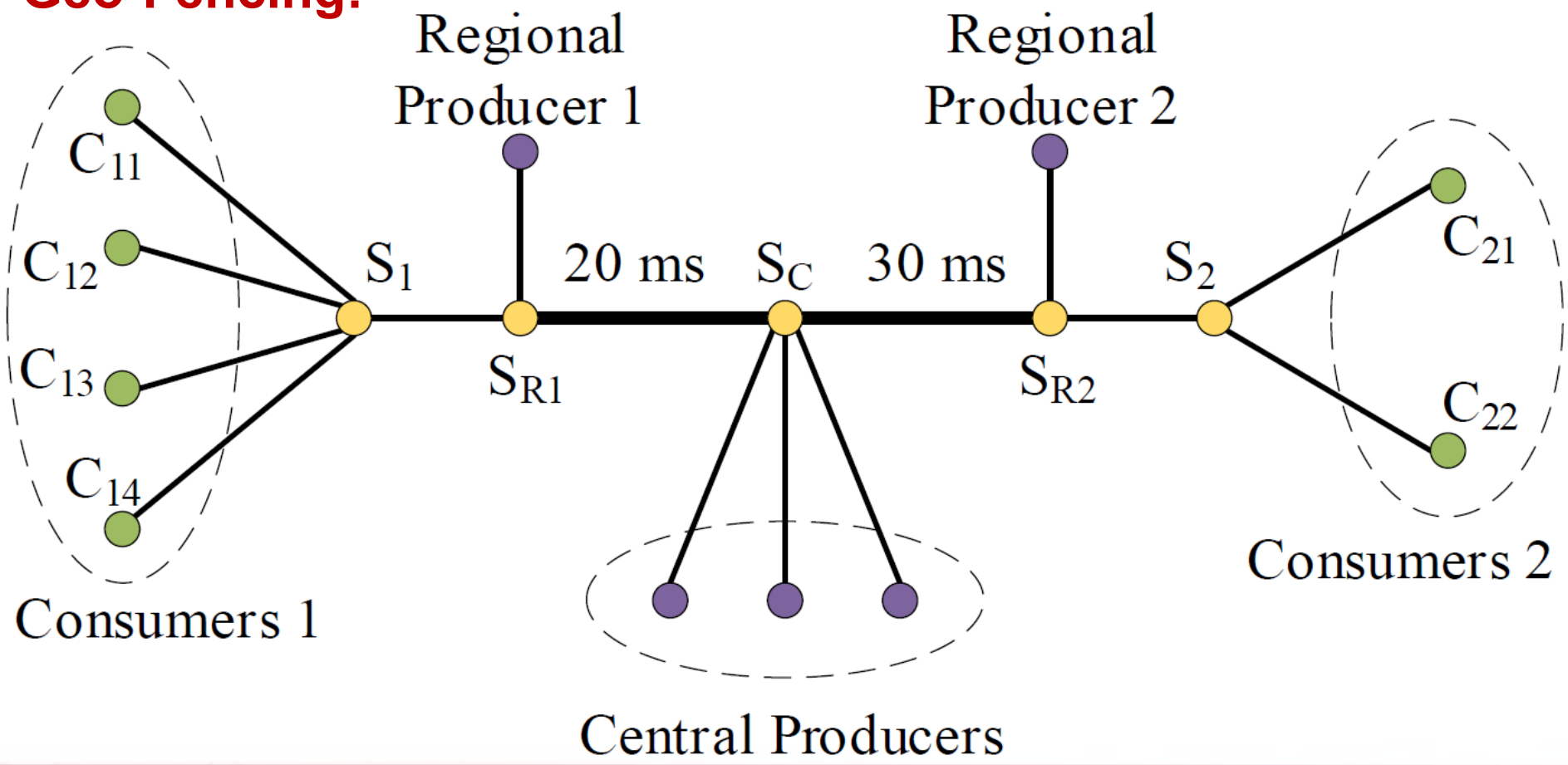
Implementation Feasibility

- Software Feasibility: we implemented ENDN by modifying the NDN Forwarding Daemon (NFD) to use libraries from the P4 Behavioral Model software target (BMv2). Our experiments were then simulated using ndnSIM.

- Hardware Feasibility: FPGA-based P4 hardware like the NetFPGA-SUME card can be used where string-processing is done in HDL (e.g., EProcessing and extern functions).

Experiment 1

- **Geo-Fencing:**



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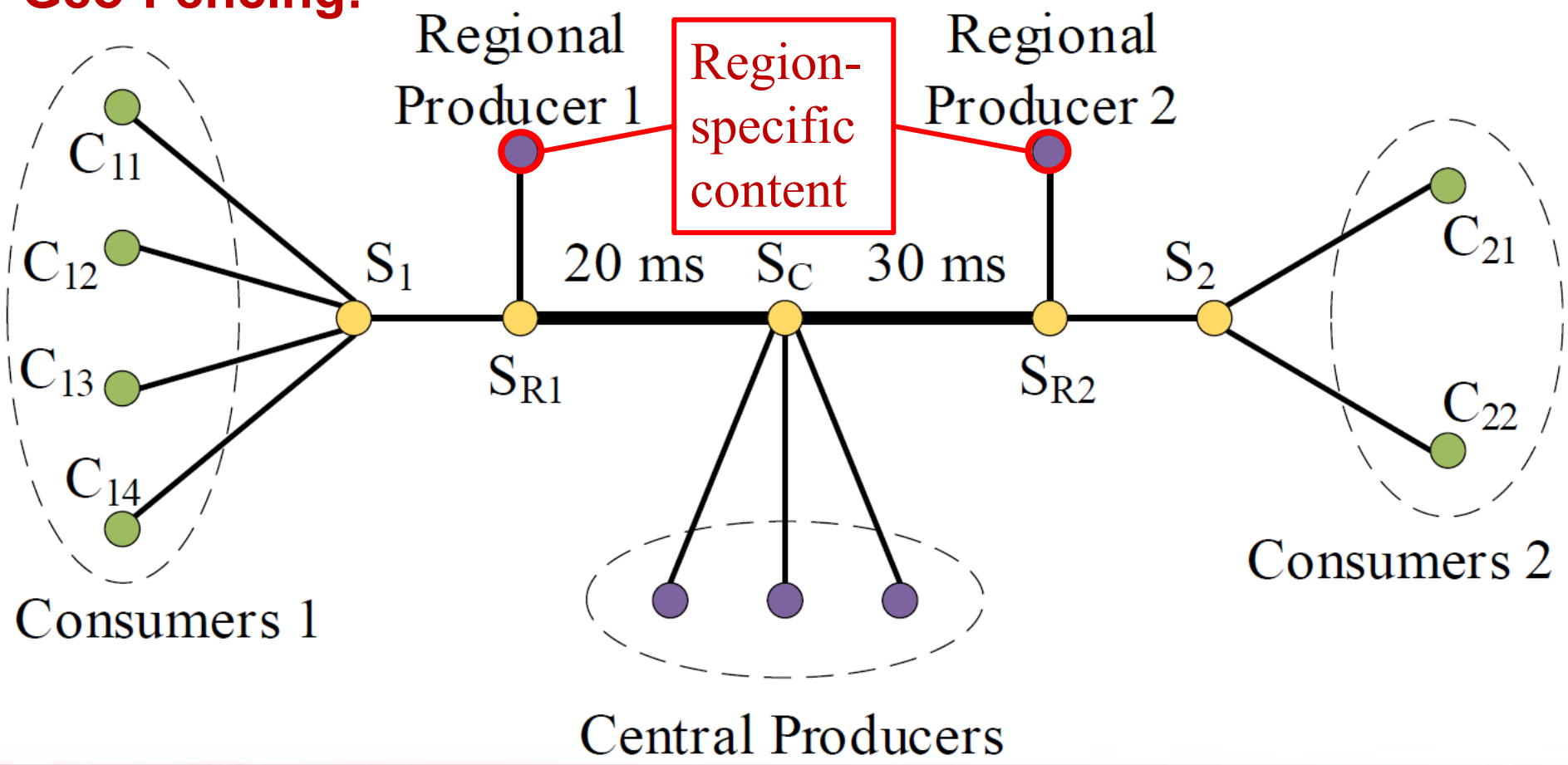

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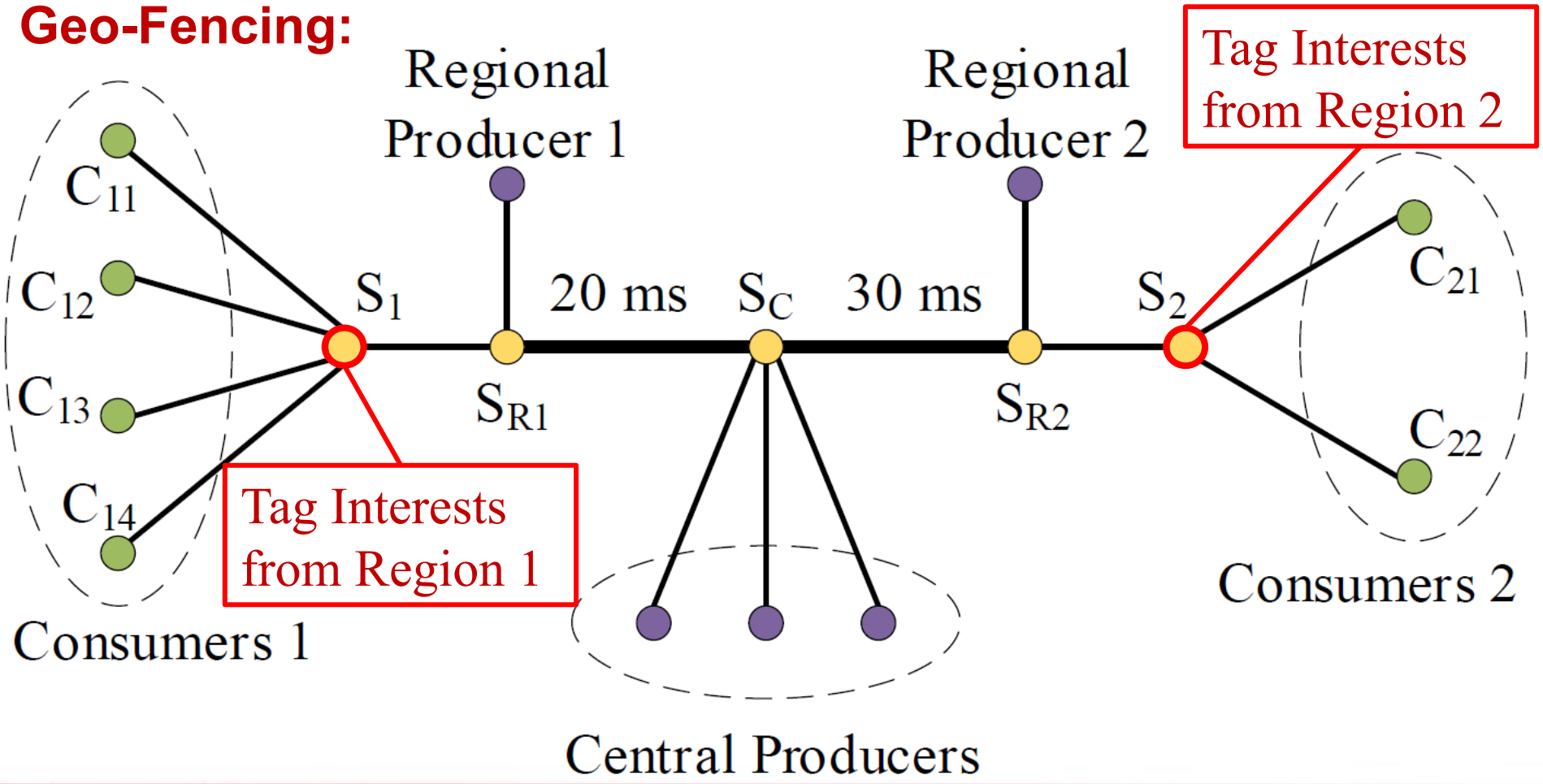

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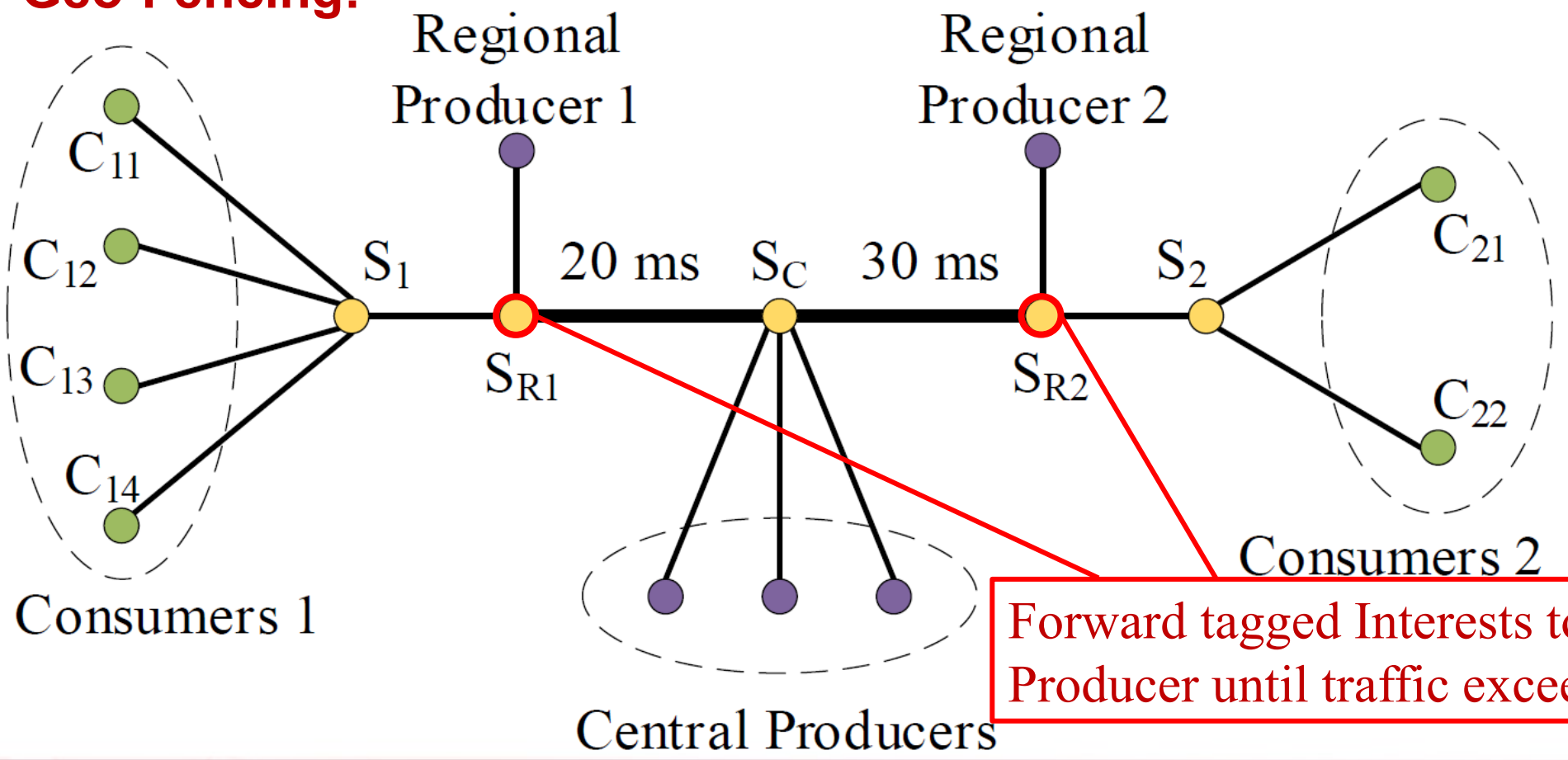

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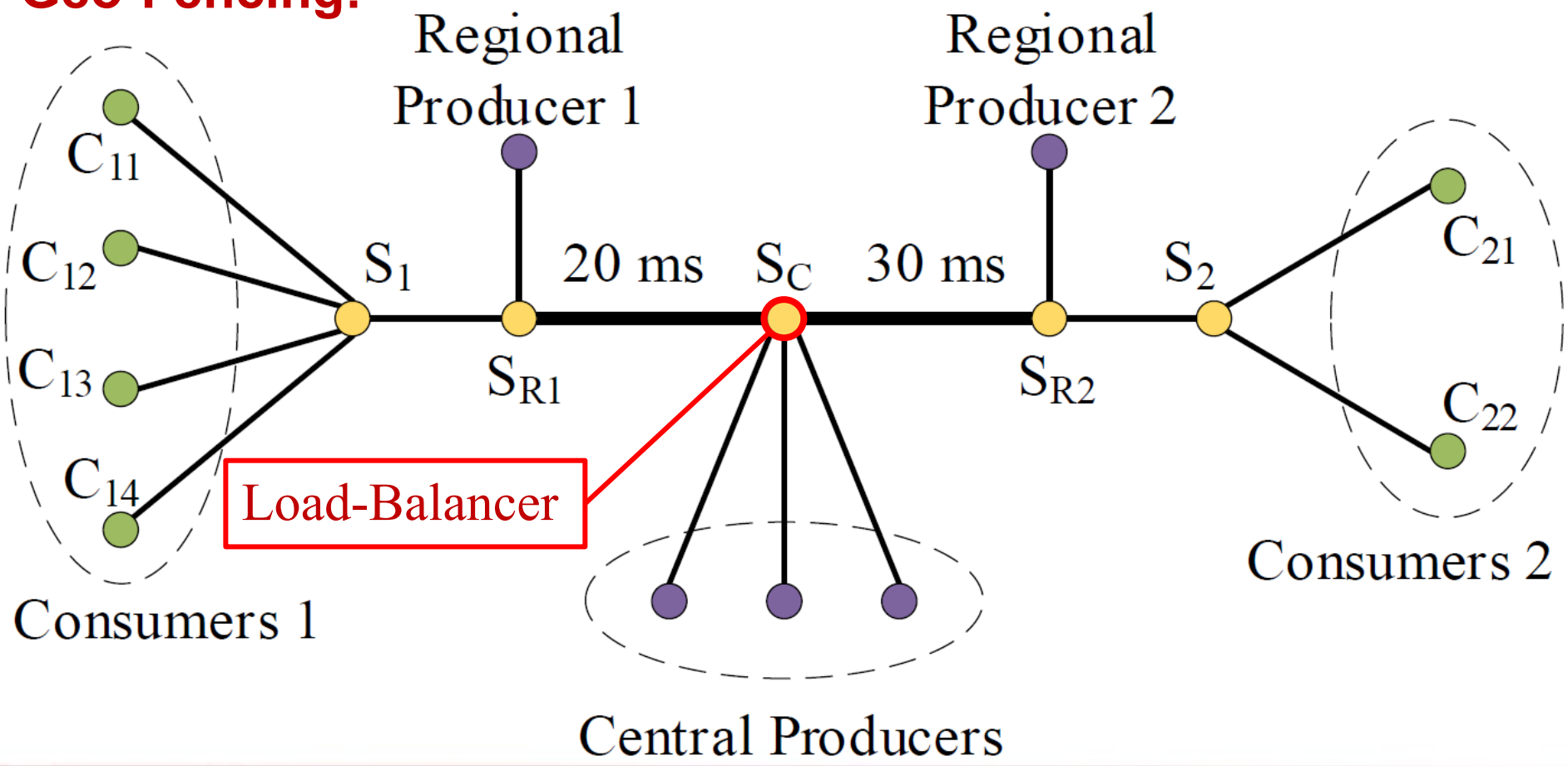

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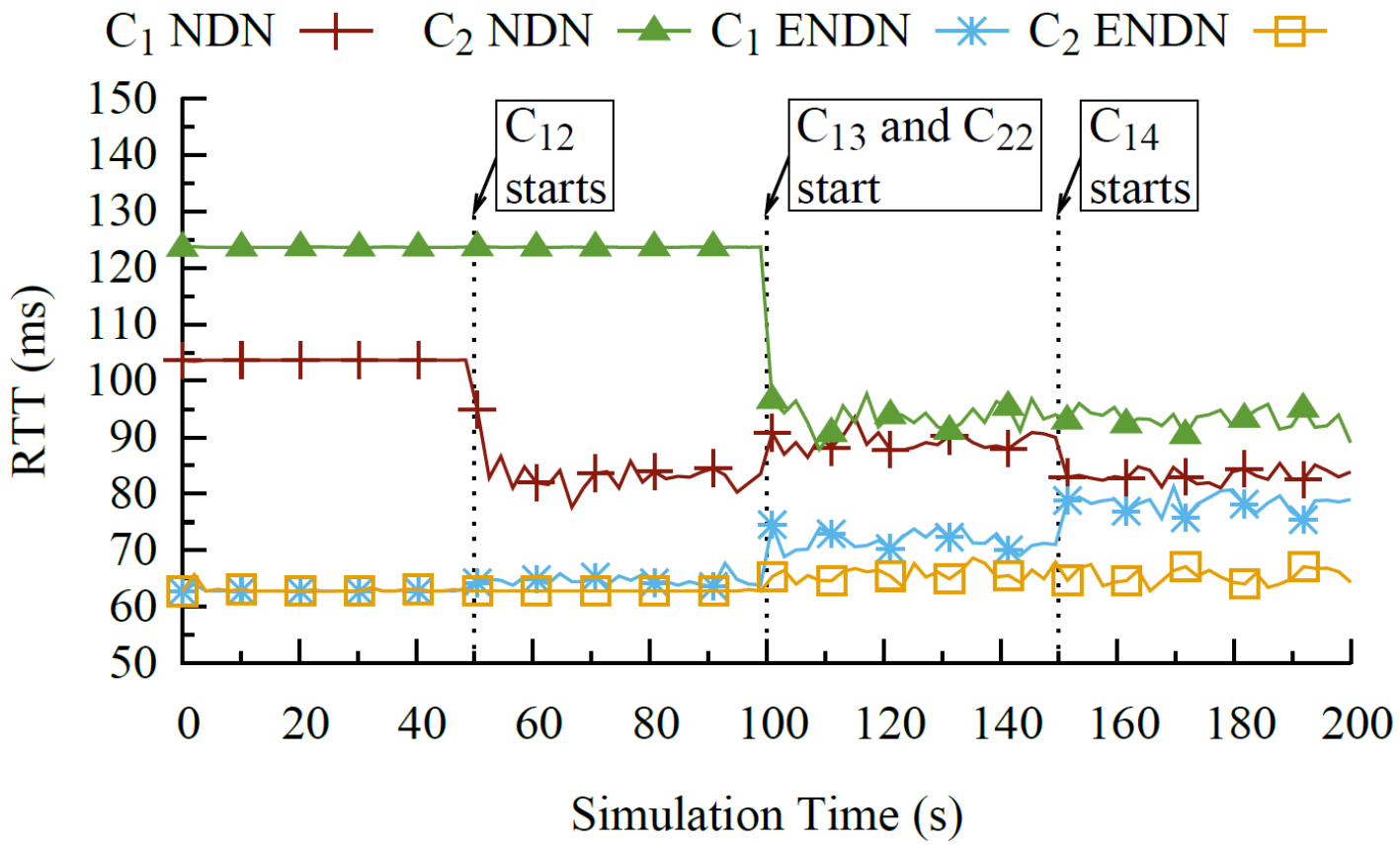

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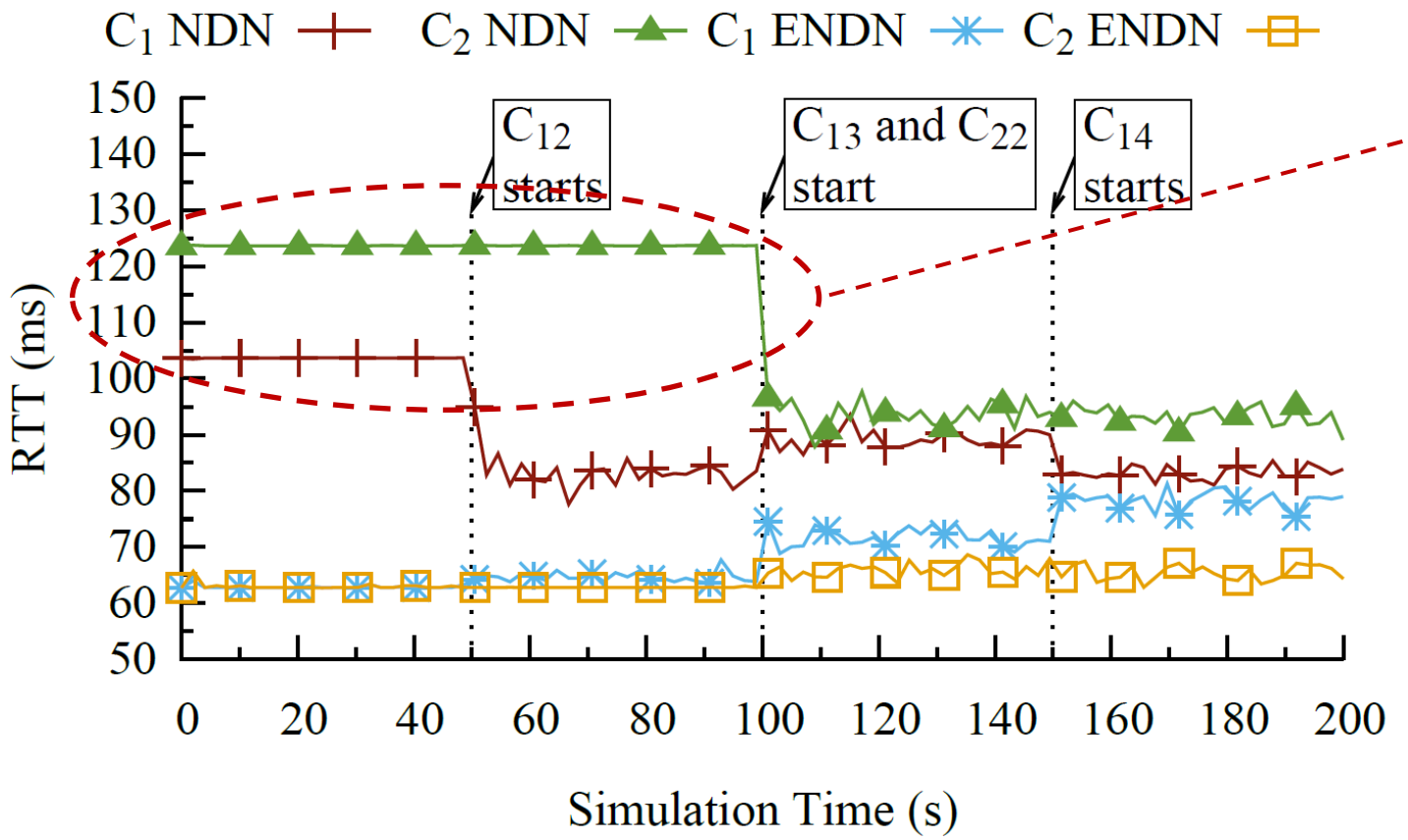

NDN: Geo-Fencing managed at the central producers

Experiment 1

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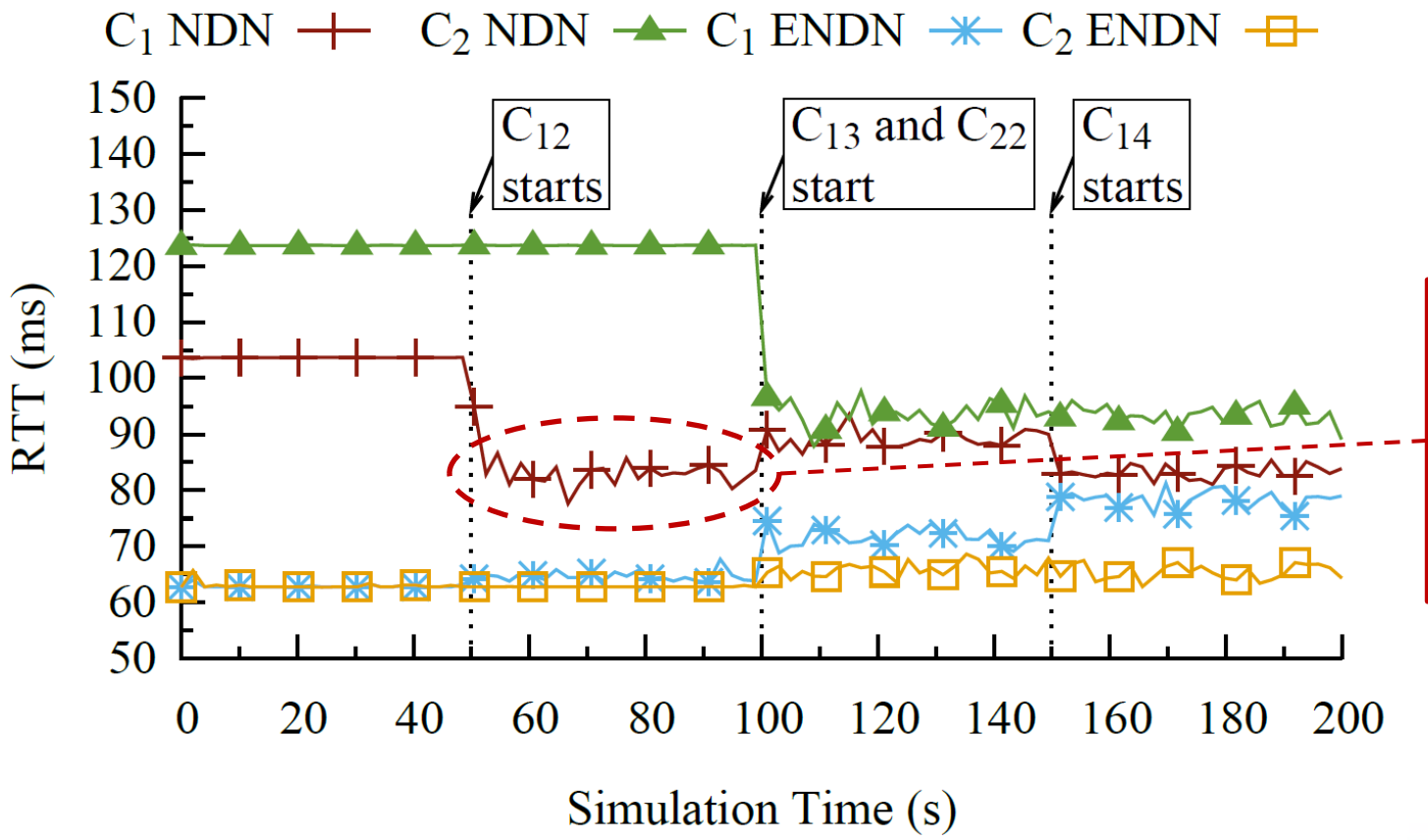

NDN: Some consumers can access the regional producers by querying the correct namespace

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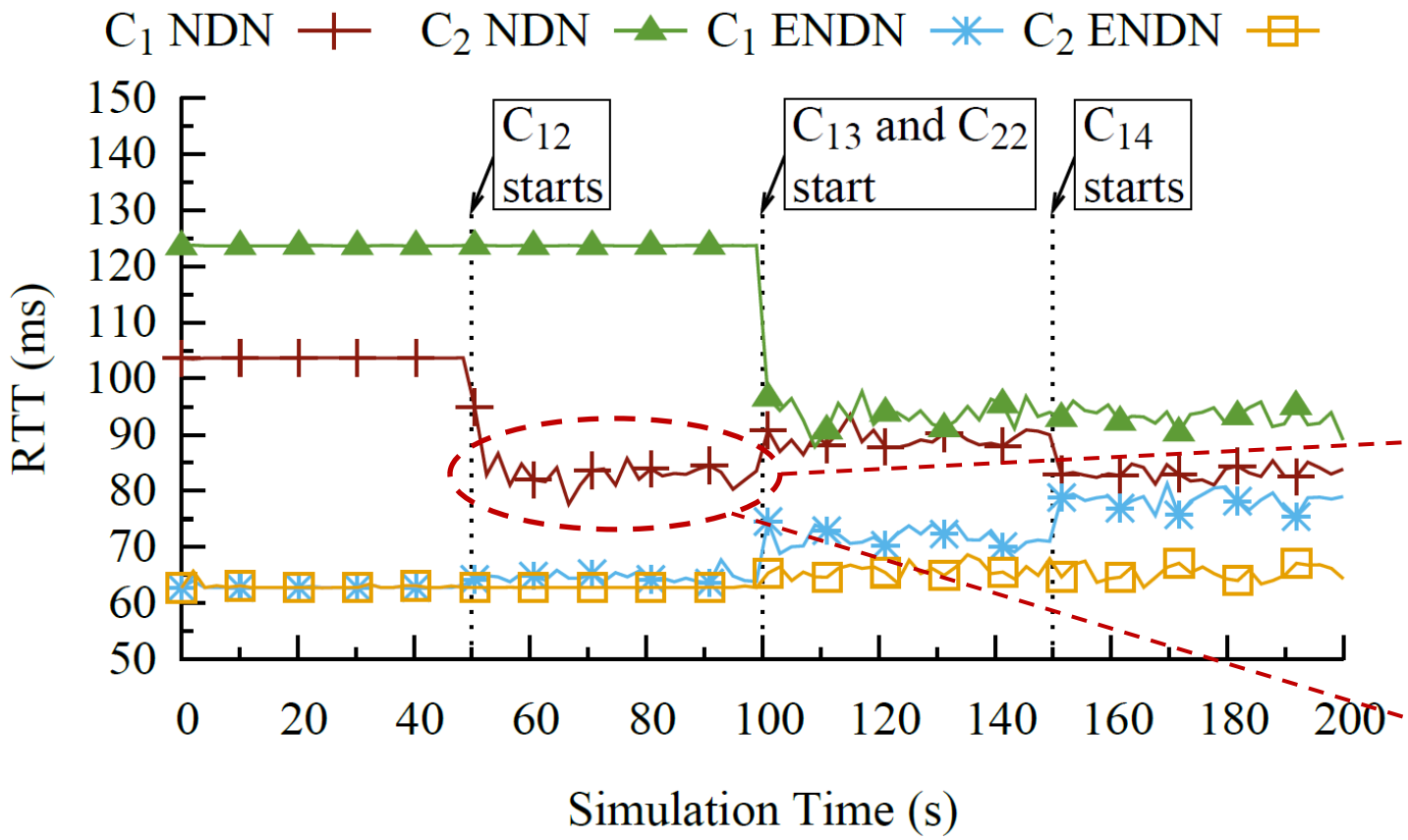

NDN: Some consumers can access the regional producers by querying the correct namespace

NDN: Geo-Fencing using available routes

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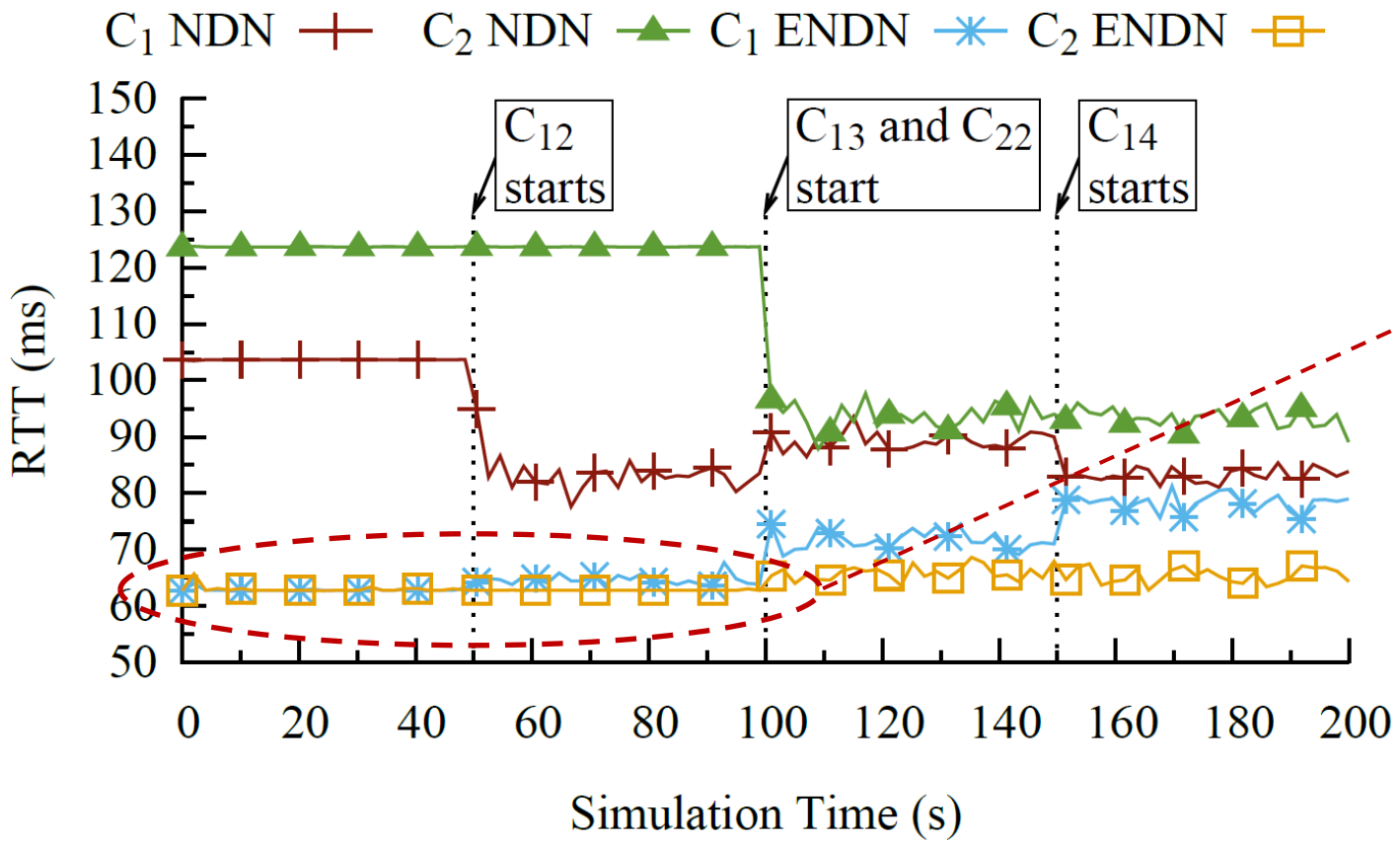

ENDN: Geo-Fencing managed by the network

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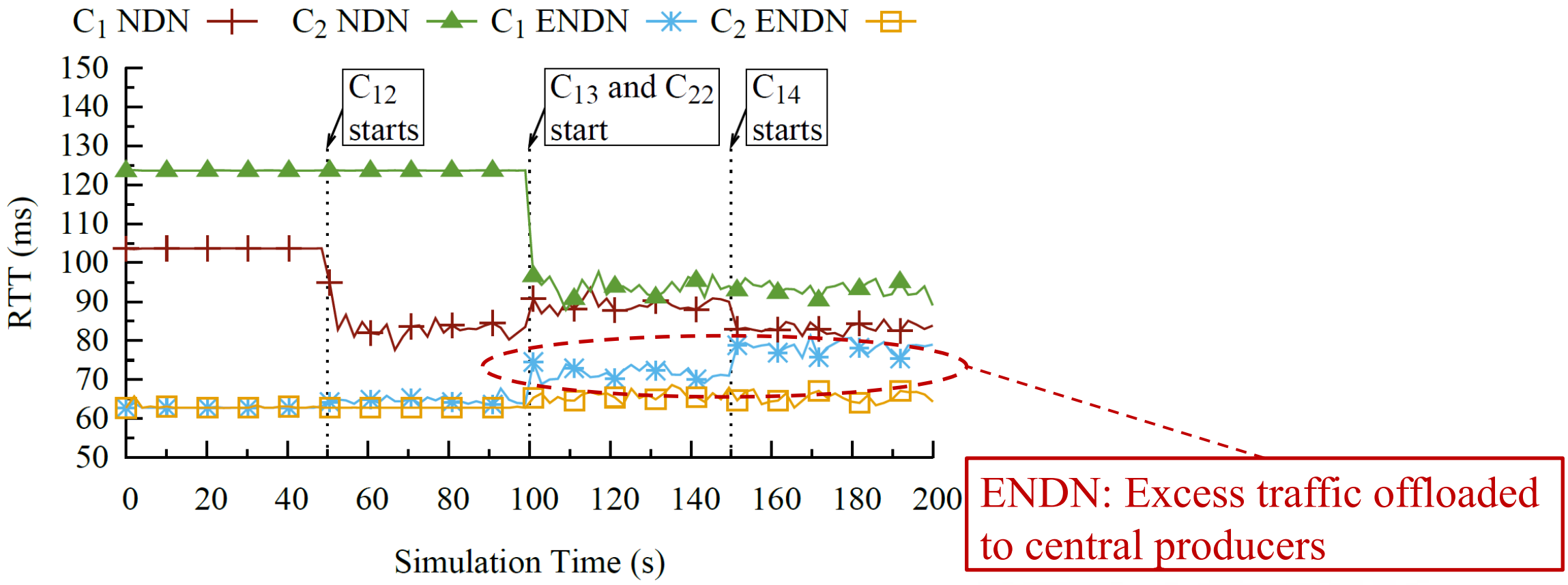

ENDN: Excess traffic offloaded to central producers

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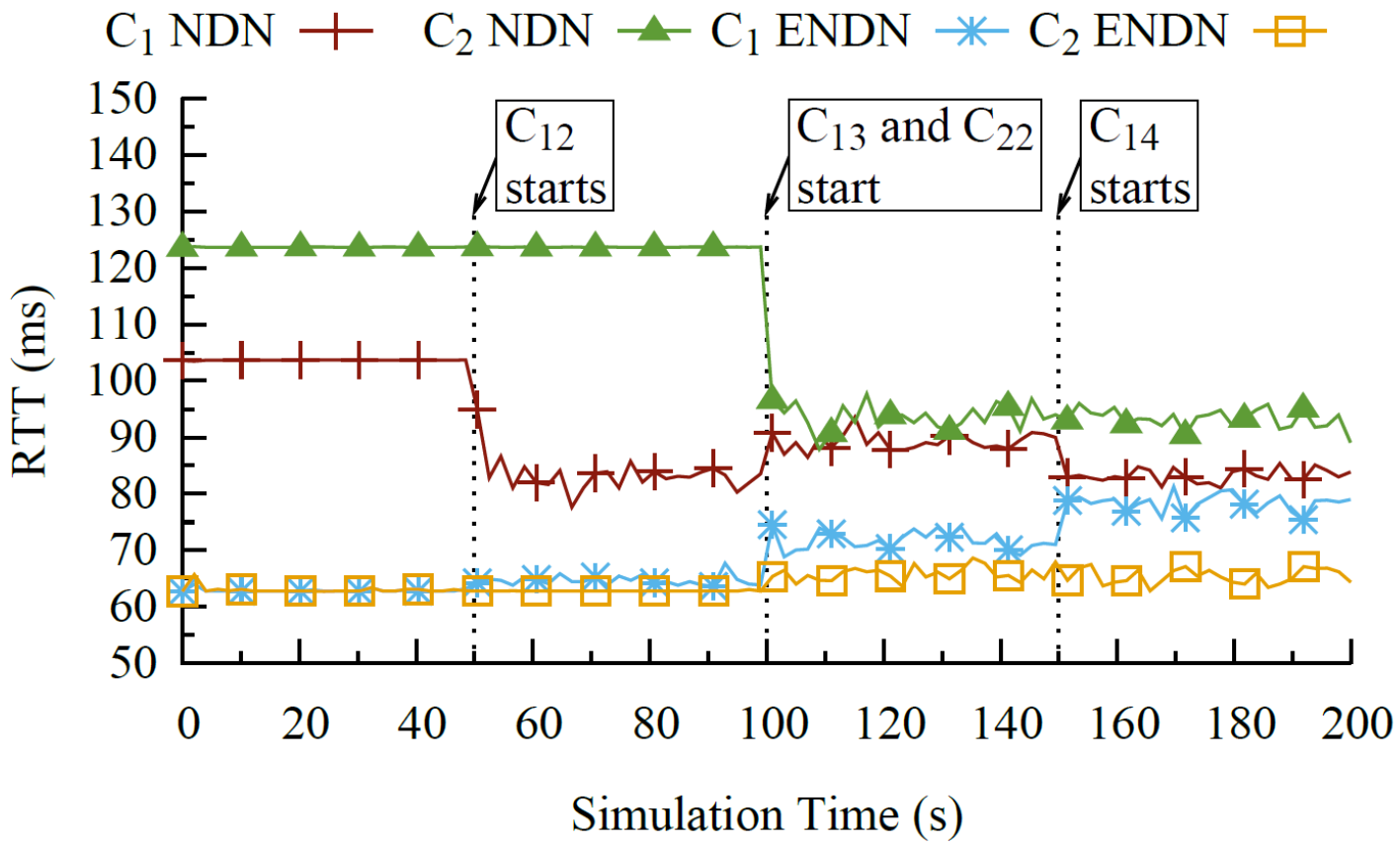
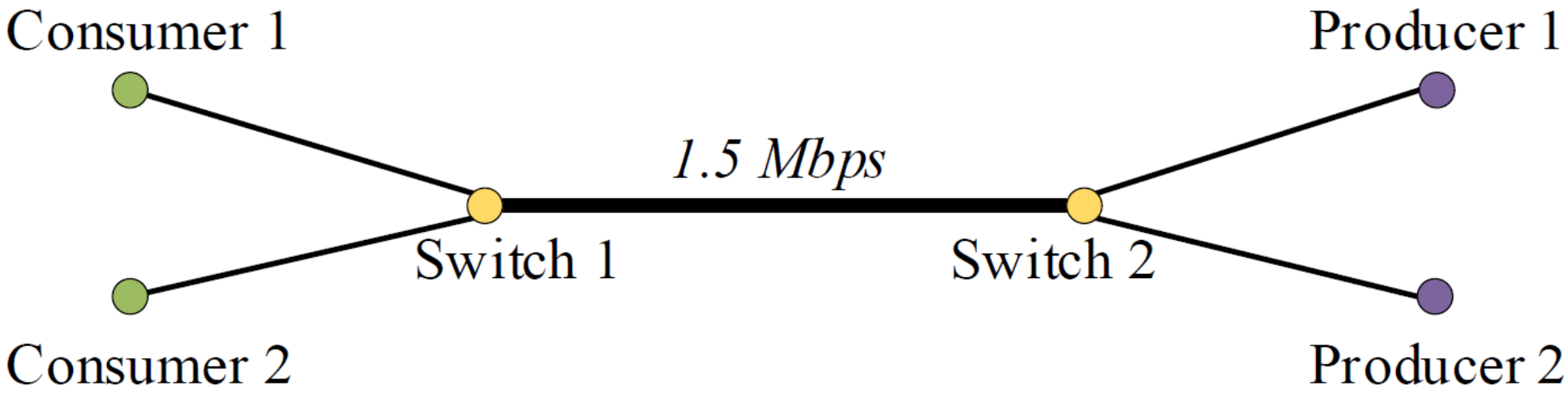


Delay Reduction

Experiment 2

- **Application-aware congestion avoidance:**



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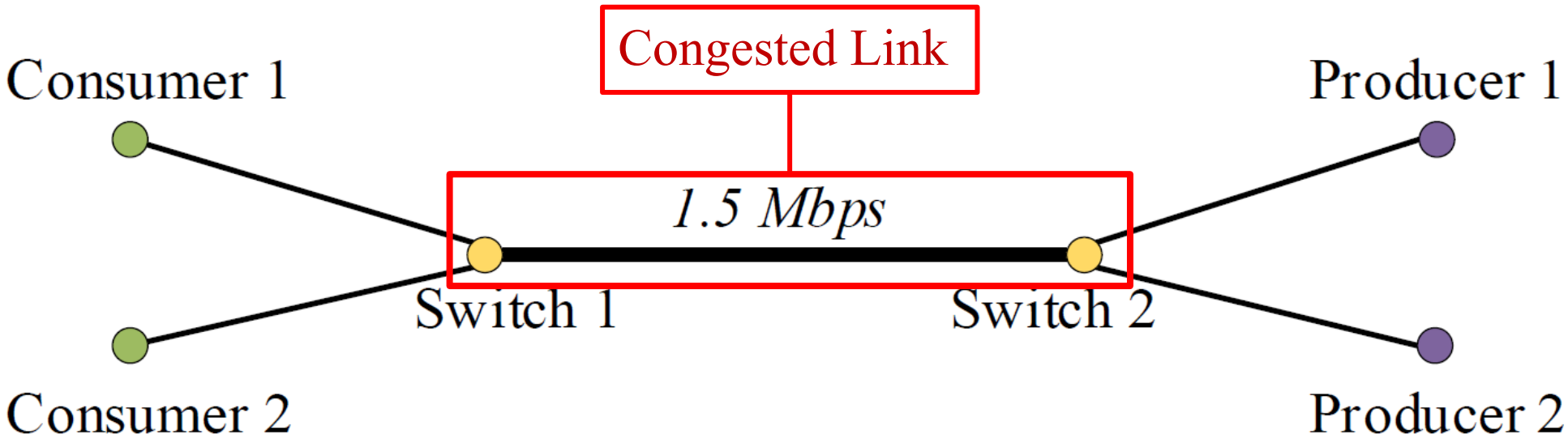
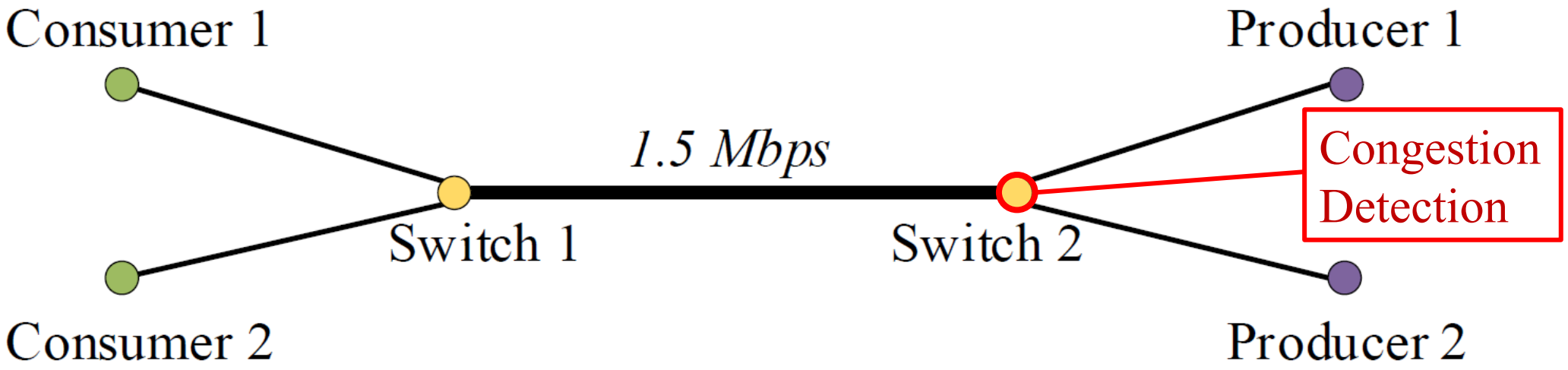


Experiment 2

- **Application-aware congestion avoidance:**



Experiment 2

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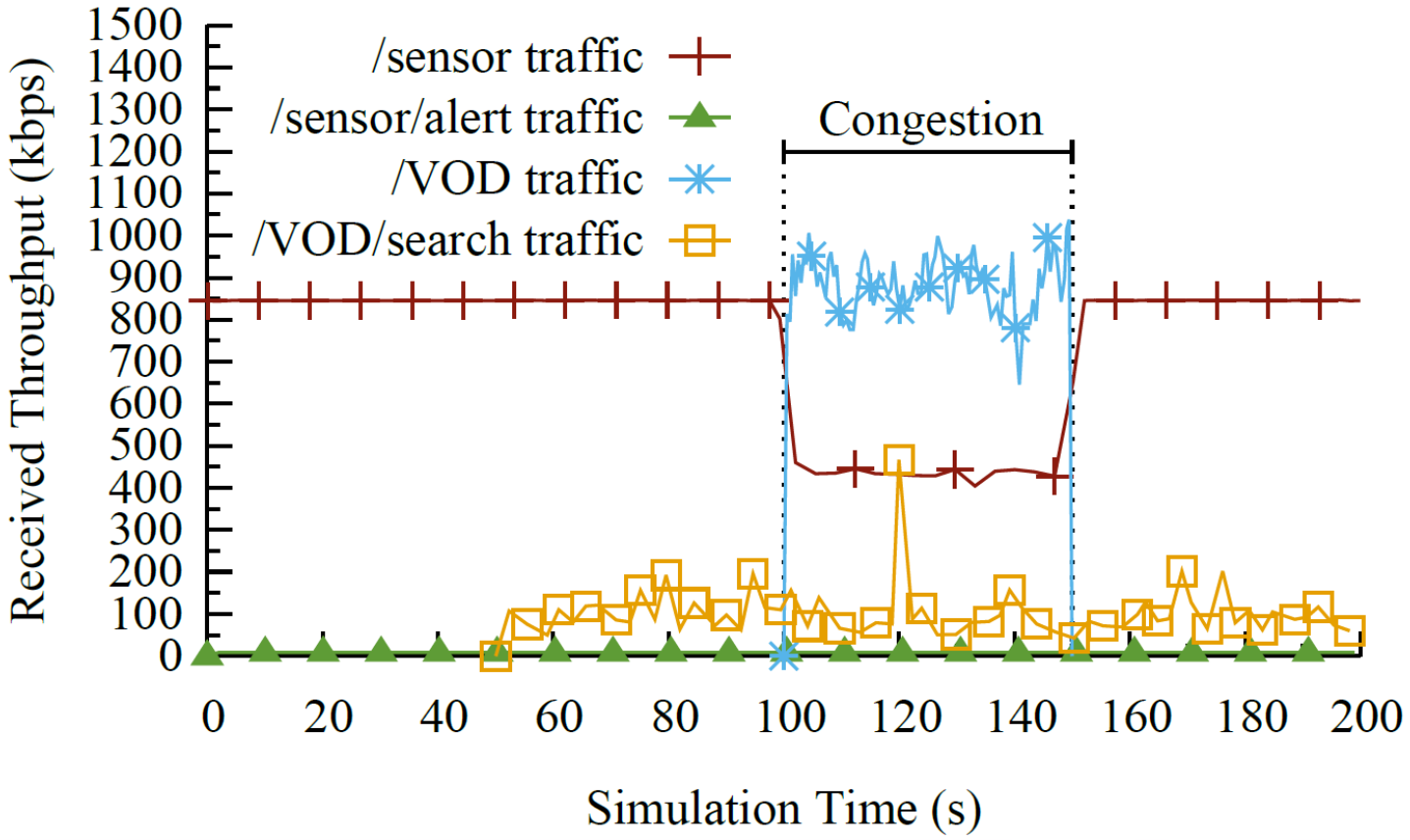

Experiment 2

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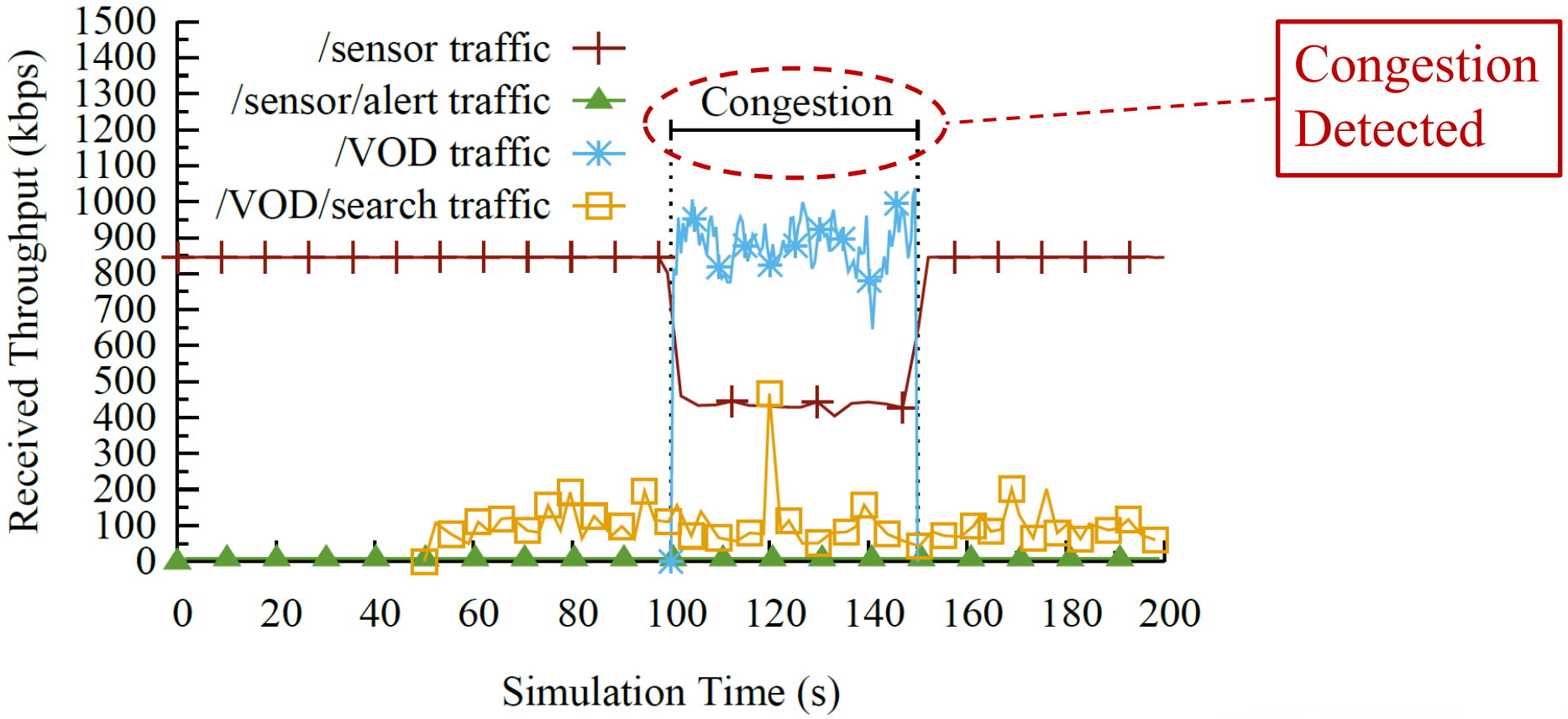
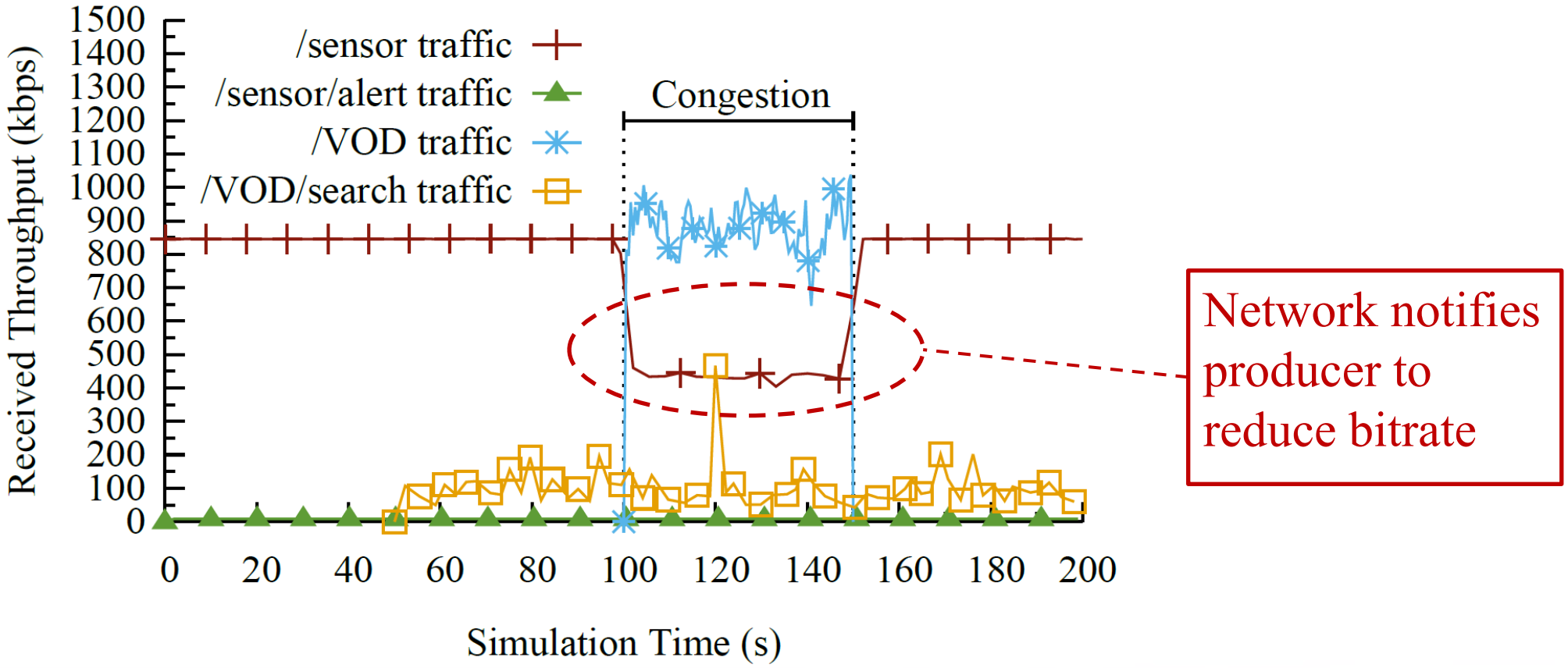


Experiment 2

- **Application-aware congestion avoidance:**



Experiment 2

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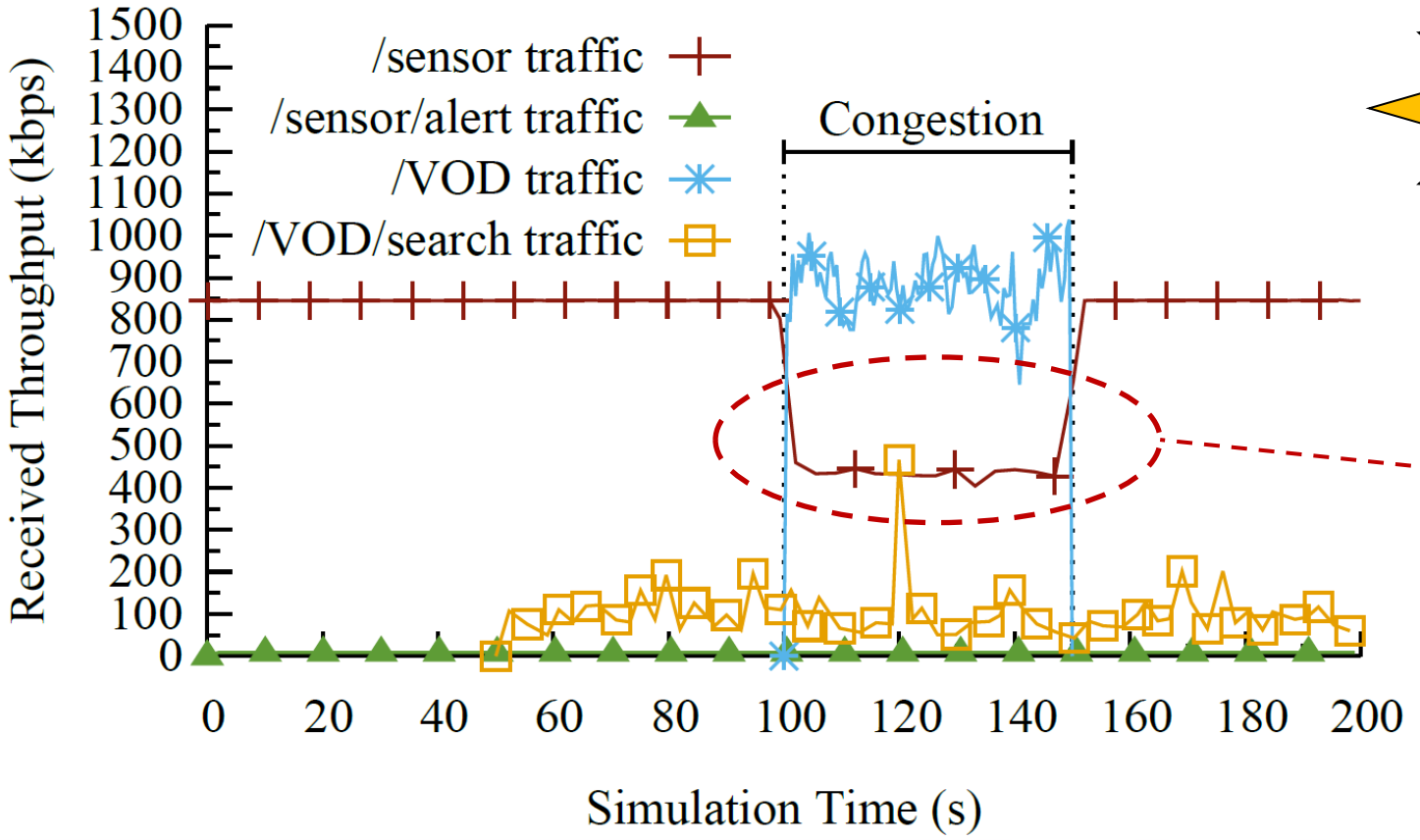

Congestion Avoided

Network notifies producer to reduce bitrate

Agenda

- Motivation
- Proposed Architecture
  - ✓ EProcessing Module
  - ✓ Forwarding Logic Module
- Proof of Concept Experiments
- Conclusion and Future Work

Conclusion and Future Work

- Contributions:
  - A new Enhanced NDN (ENDN) architecture.
  - Extensible catalog of network services to applications.
  - New delivery patterns with modifications to the PIT and FIB tables.
  - Programmability in the NDN data plane using isolated P4 functions.

- Future Work:
  - Control Plane: Northbound Interface, Consistency and Scalability.
  - Security: Vulnerabilities and Mitigation.

Thank you