# Prototype of a Programmable Computing/Networking Switch for Multi-Screen Content Consumption

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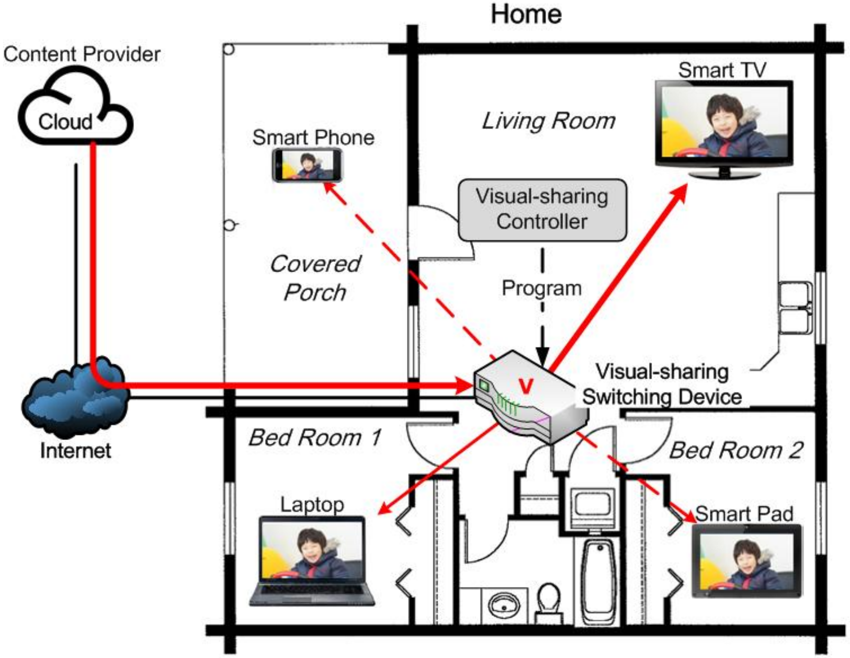
# Contents

- Introduction
- NetOpen Networking Service
- Design of a NetOpen Switch Node with In-network Processing Support
- Experimental Verification
- Conclusion

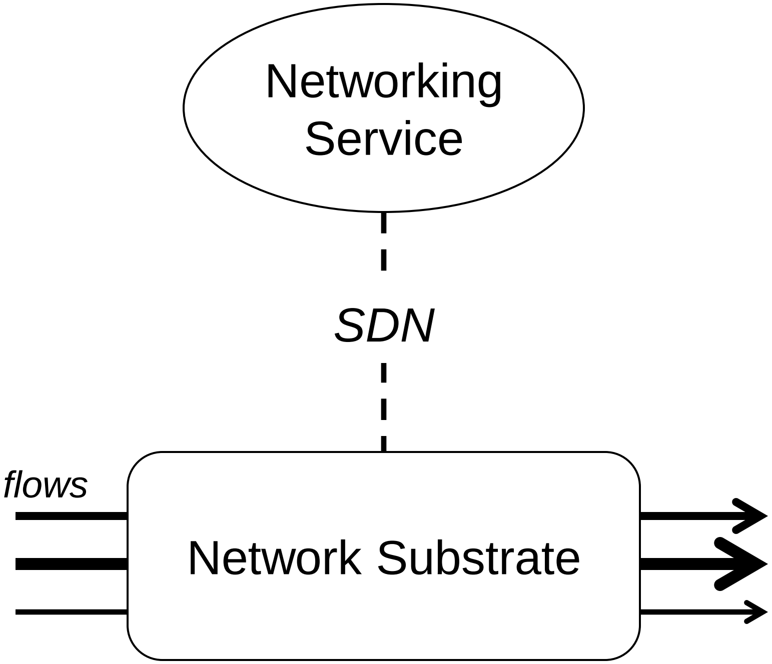
# Introduction

- Emergence of various IP-enabled consumer devices
  - The demands of accessing video contents from heterogeneous devices with different screens and different capabilities are increasing
- Real-time content adaptation is challenging
  - Transcoding the content while maintaining good video quality
  - Maintaining appropriately short input to output latency
- We introduce a programmable switching node supporting in-network processing with balancing its use of computing/networking resources

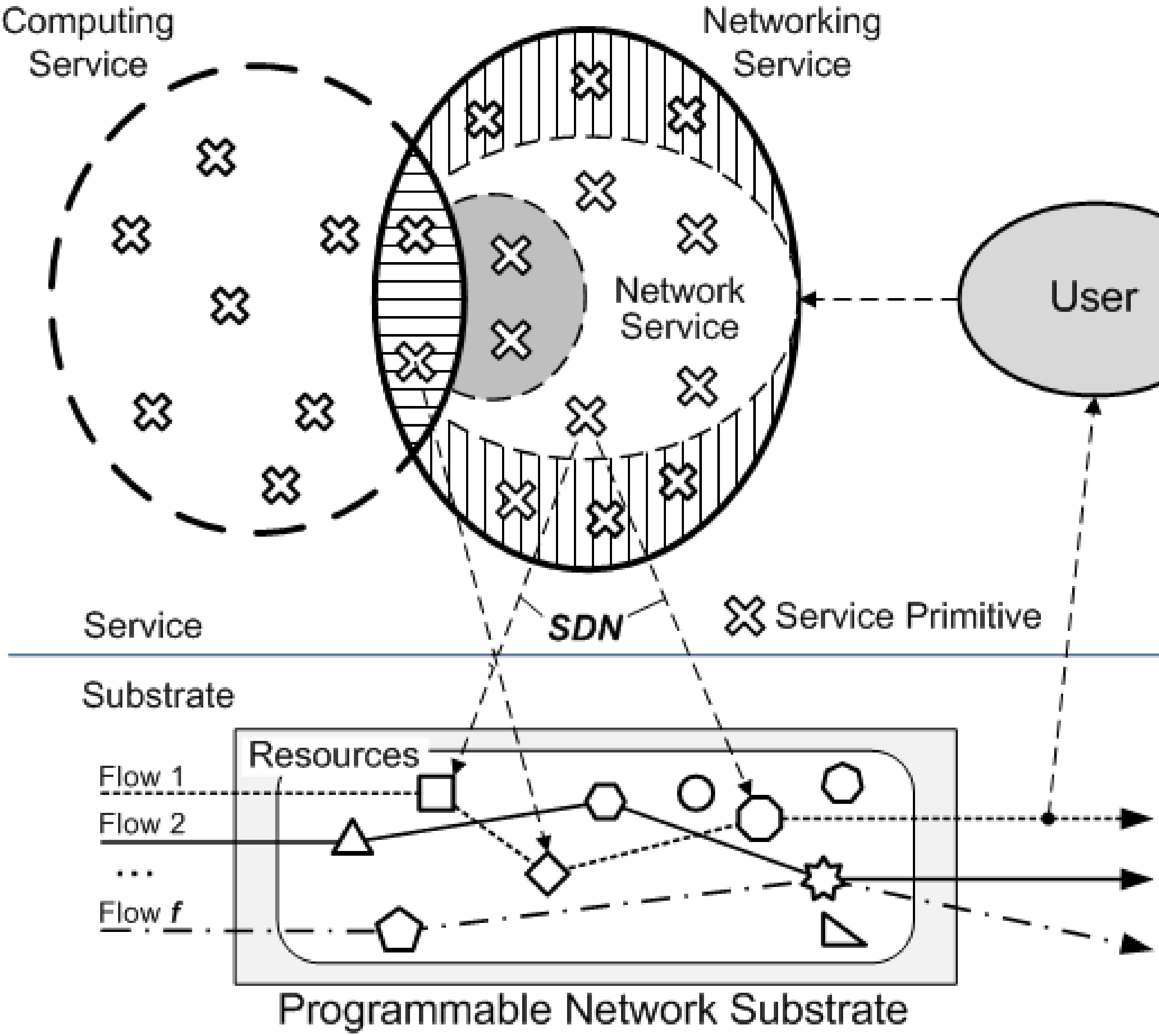


# Networking Service and SDN

- Networking Service
  - The collection of network-centric services that assist the transport of diverse flows for computing–centric services
- SDN (Software-Defined Networking)
  - Restructures network and exposes network APIs so that any software can program the network as they want
- By employing the network programmability of SDN, we attempt to fill the gap caused by existing network services

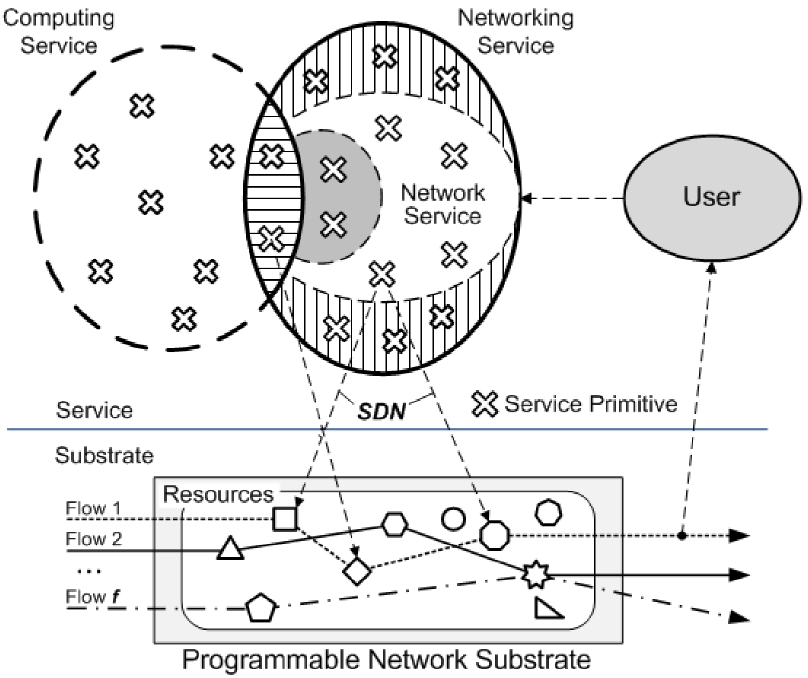


# NetOpen Networking Service

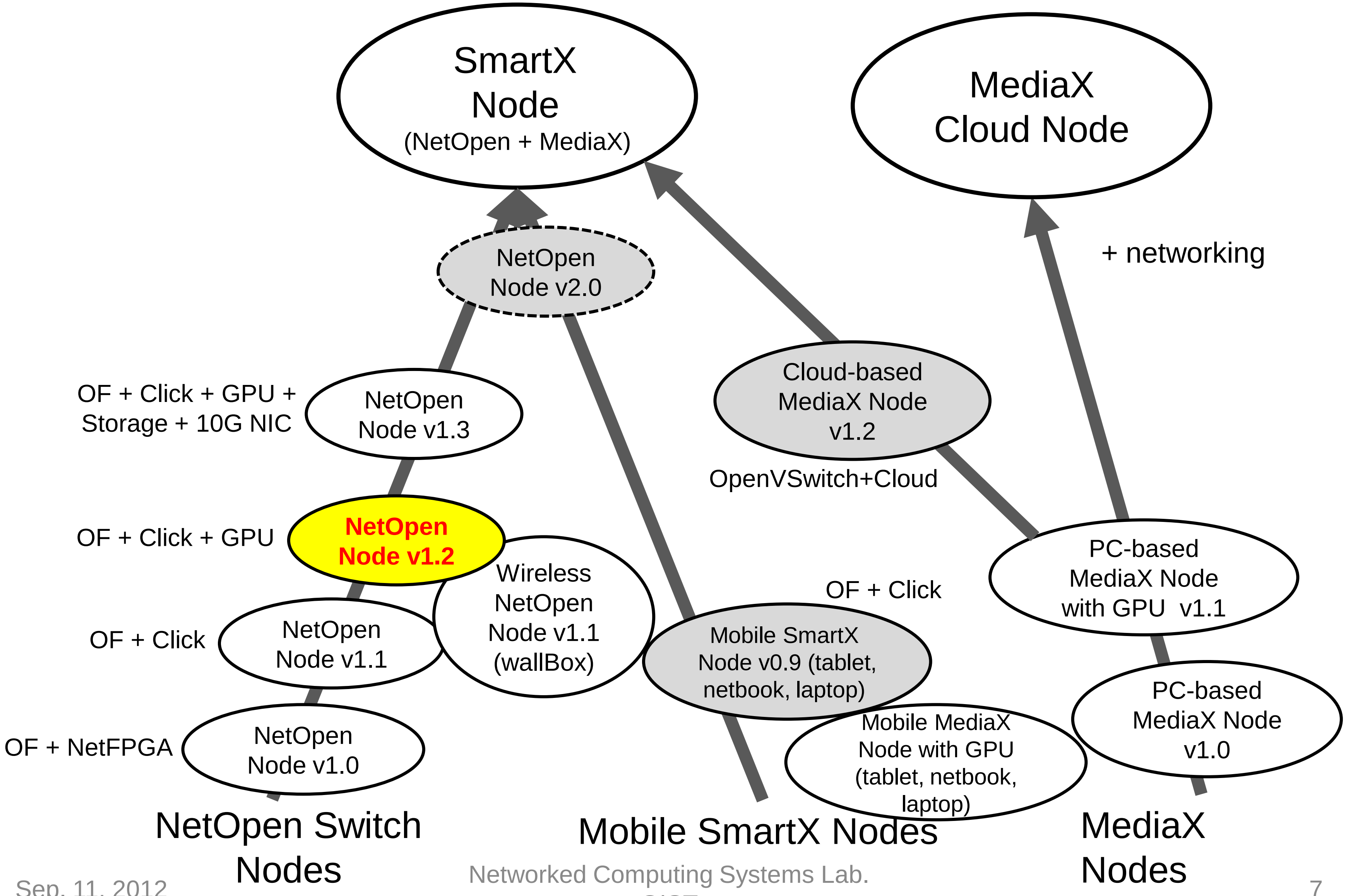


# Features of NetOpen Networking Service

- Extended flow-based networking:
  - An extension of flow-based networking to reinforce the balanced utilization of both networking and computing resources
- Primitive-based loosely coupled creation of services
  - ***Service primitives*** as linkage points between NetOpen networking services and programmable network substrates
  - Identify and then link the key features (from resource capabilities)
- Interactive service operation via intuitive UIs

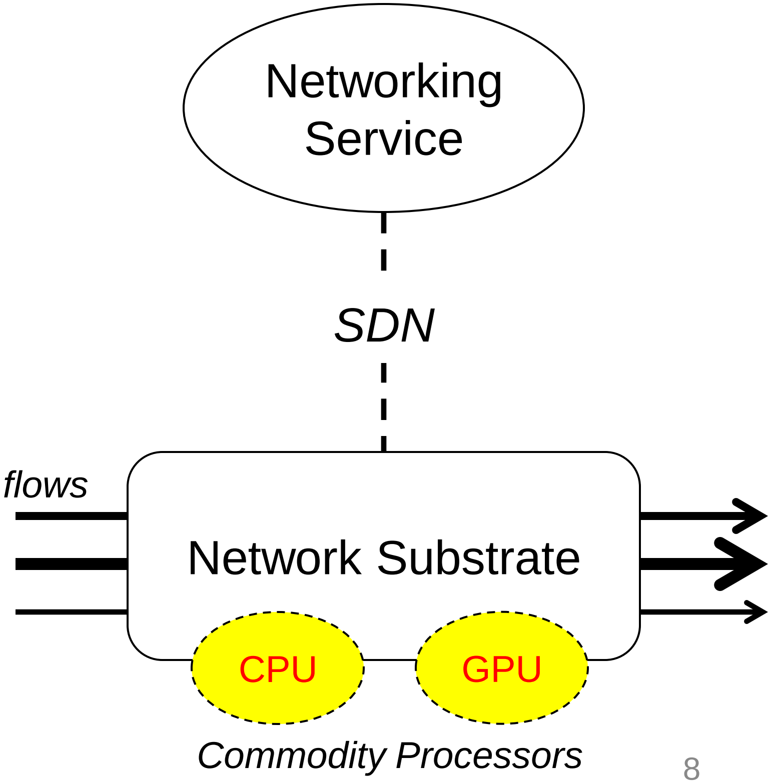


# A Road Map to Build SmartX nodes


SmartX Node (NetOpen + MediaX)
MediaX Cloud Node
+ networking
NetOpen Node v2.0
OF + Click + GPU + Storage + 10G NIC
NetOpen Node v1.3
Cloud-based MediaX Node v1.2
OpenVSwitch+Cloud
OF + Click + GPU
NetOpen Node v1.2
Wireless NetOpen Node v1.1 (wallBox)
OF + Click
PC-based MediaX Node with GPU v1.1
OF + Click
NetOpen Node v1.1
Mobile SmartX Node v0.9 (tablet, netbook, laptop)
PC-based MediaX Node v1.0
OF + NetFPGA
NetOpen Node v1.0
Mobile MediaX Node with GPU (tablet, netbook, laptop)
NetOpen Switch Nodes
Mobile SmartX Nodes
MediaX Nodes

# NetOpen Switch Node (v1.2)

- A Programmable Networking Switch Node with In-network Processing Support
- Design issues
  - Independent processing module for a service functionality
  - For each flow, a customized data plane can be built by selectively combining processing modules
  - This buildup can be controlled by a logically centralized controller

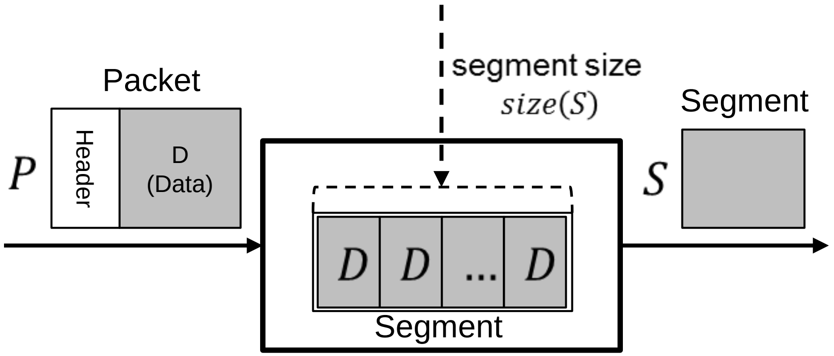


# In-network Processing leveraging Heterogeneous Computing

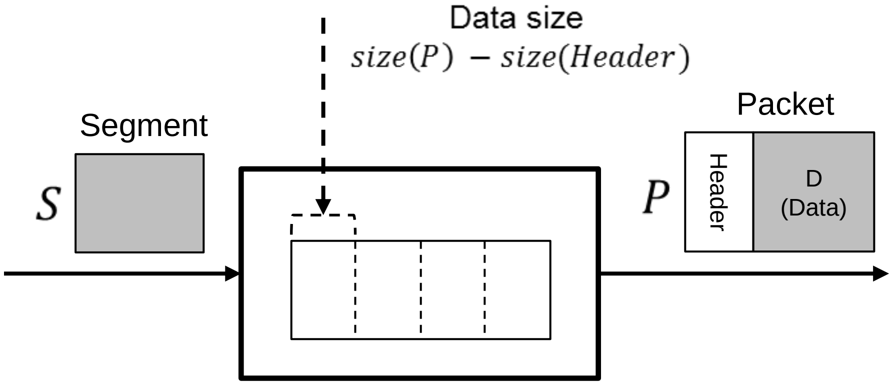
- In-network Processing
  - Additional processing on the packets before forwarding
  - Middle-boxes provide required processing functionalities, e.g., packet caching, transcoding, network coding
- Leverage Heterogeneous Computing (with CPU/GPU/…) for in-network processing
  - Powerful CPUs with multiple cores (e.g. Intel Xeon E7-2820, AMD FX-8150)
  - GPUs & GPGPUs (General Purpose Graphics Processing Units) with hundred cores (NVIDIA GTX580: 512 CUDA cores)

# How to handle In-network Processing

- In-network processing for a flow is explained by *a task,* defined as a set of actions (provided by processing modules) mapped to a flow
  - For example, a task for a video flow can be composed of decode, resize, and forward actions with segmentation and packetization
- Segmentation: Checks the application-layer packet header of each packet and batches the payload into *current segment* (Assuming the sequential transport of video frames)
- Packetization: Converts a segment back into packets

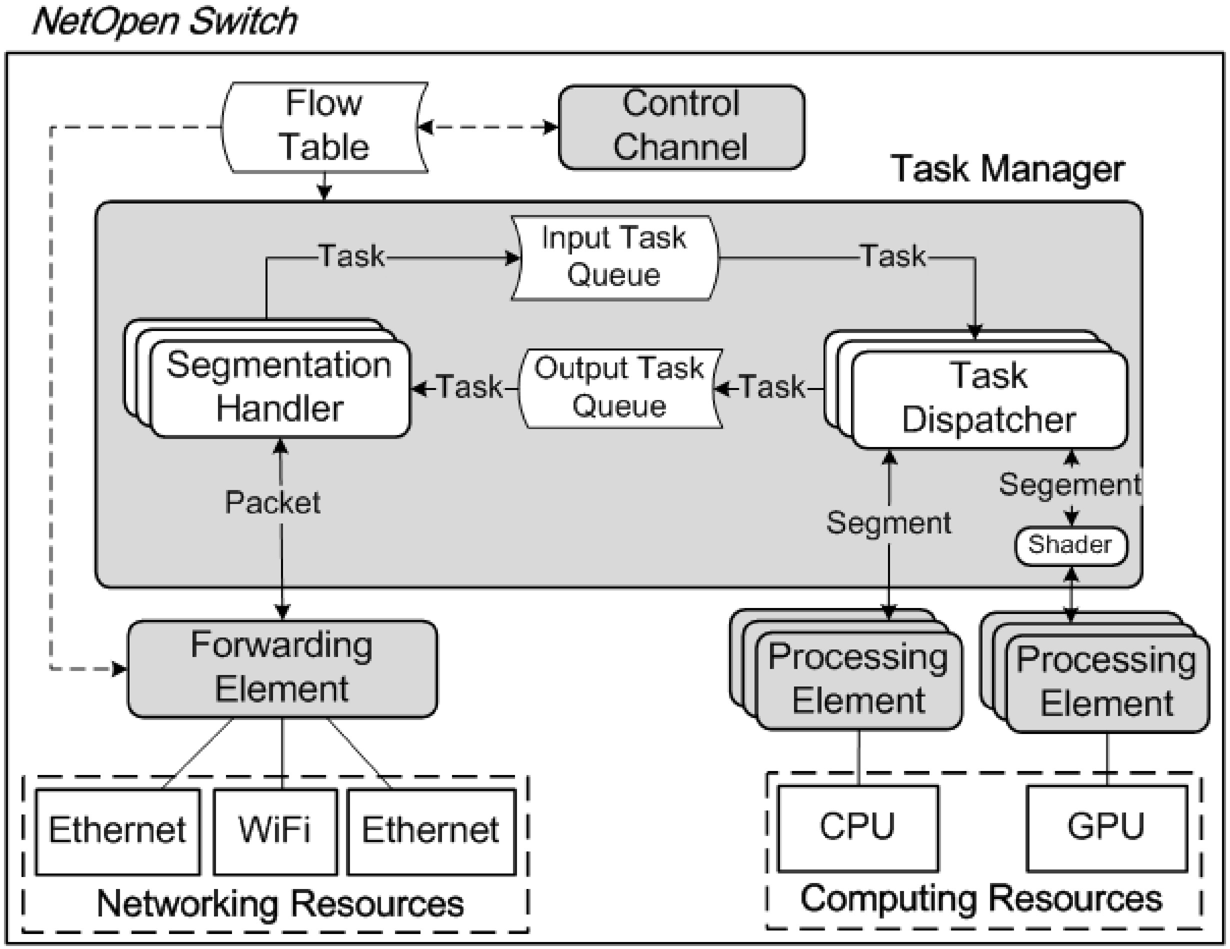


*<Segmentation>*



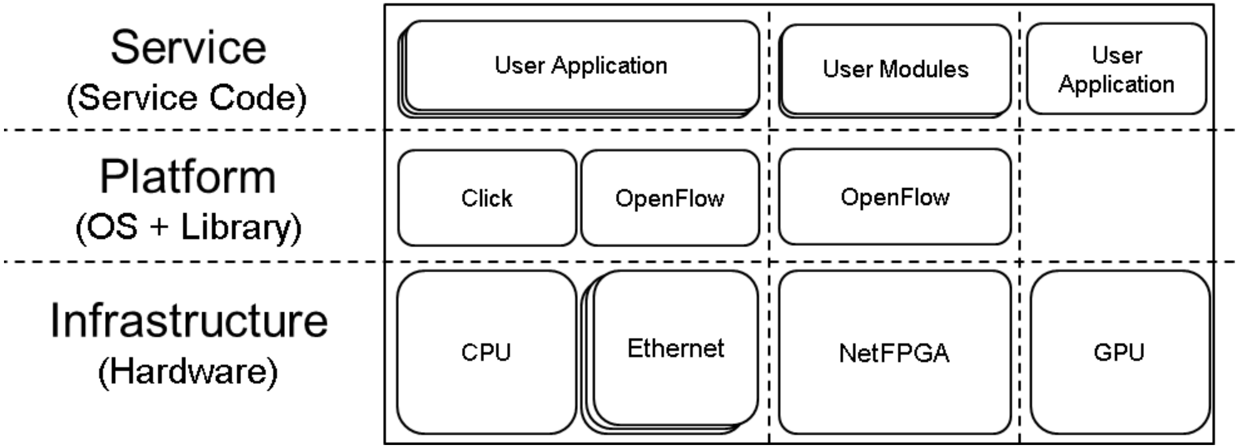
*<Packetization>*

# Early Design of NetOpen Switch Node for In-network Processing



We need a special purpose task dispatcher between task dispatchers and GPUs, *shader*, to avoid performance degradation due to multiple task dispatchers accessing GPU at the same time

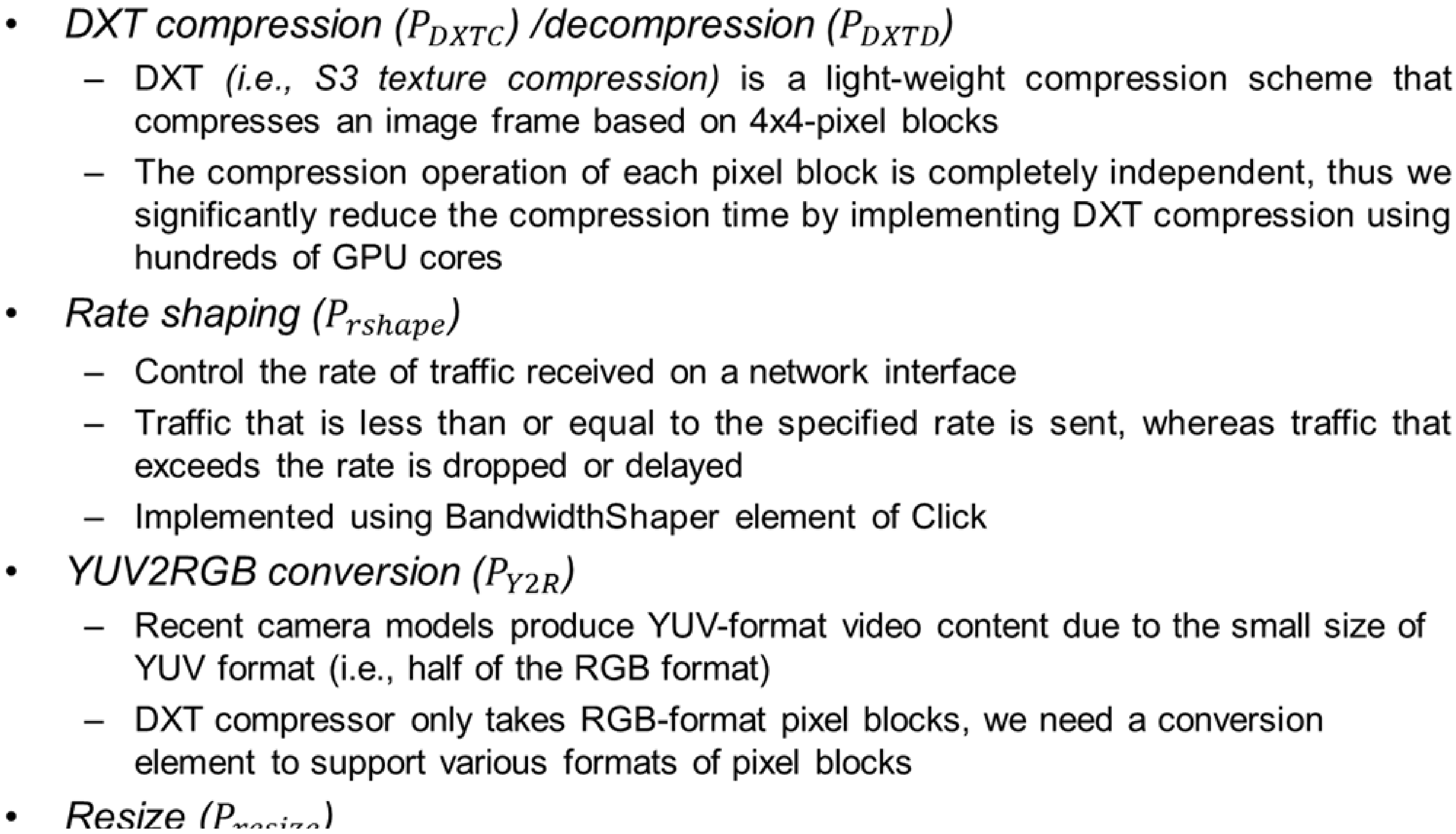
# Prototype Implementation



- Hardware
  - CPU: 2 Intel Xeon quad-core CPUs (1.6Ghz) with 12GB memory
  - GPU: NVIDIA GTX590 GPU
    - 2 stream processors (each has 512 cores)
    - 3GB GDDR5 memory
  - NIC: Six 1G NICs, two 2port 1G NICs, and two WiFi NICs

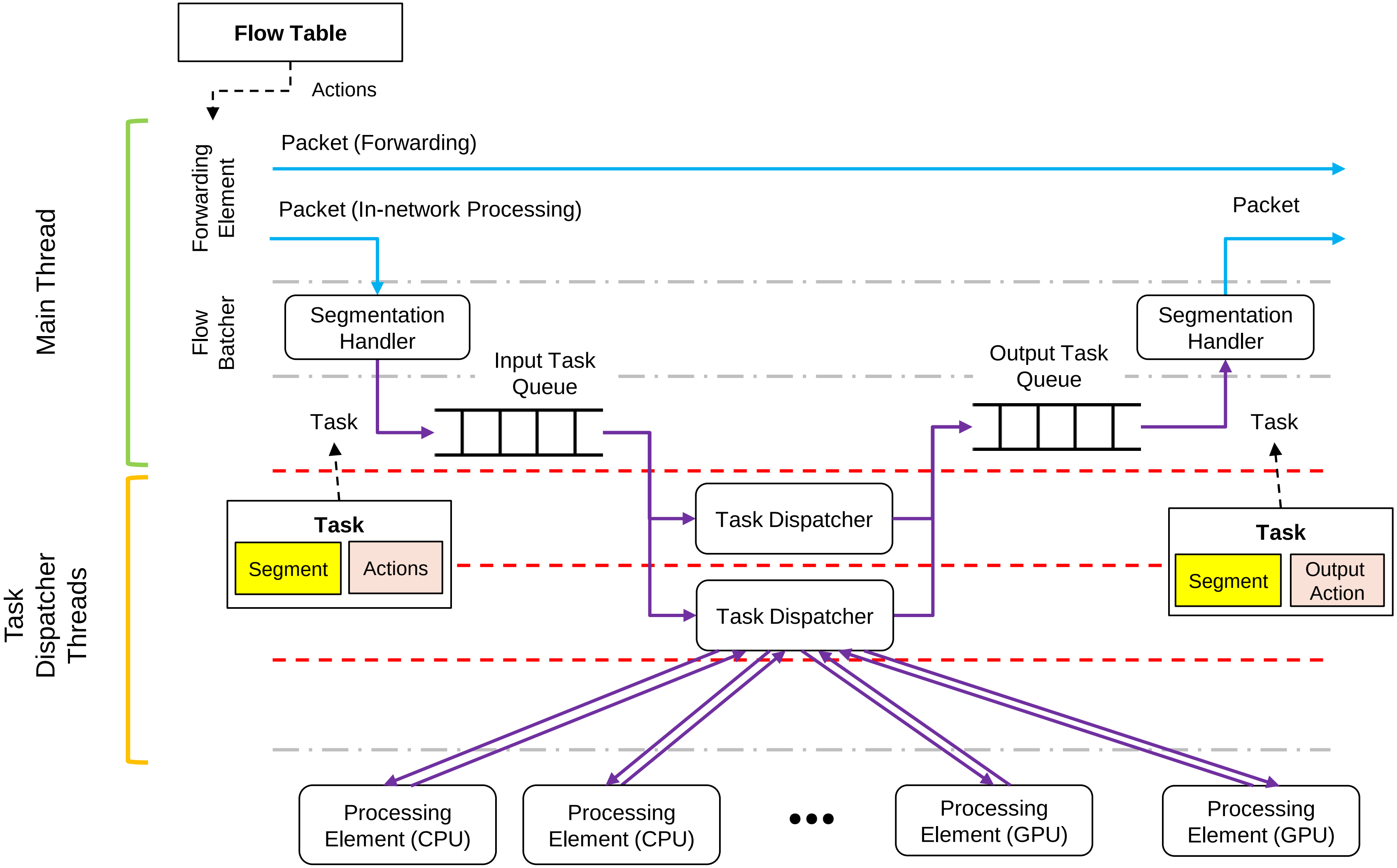
- Software (Click + OpenFlow)
  - Click: A toolkit for building a software modular router by combining Click elements (i.e., a small module that has a specific functionality)
  - Each service primitive is implemented as a Click element that is controlled based on OpenFlow

# Supported Primitives for In-networking Processing

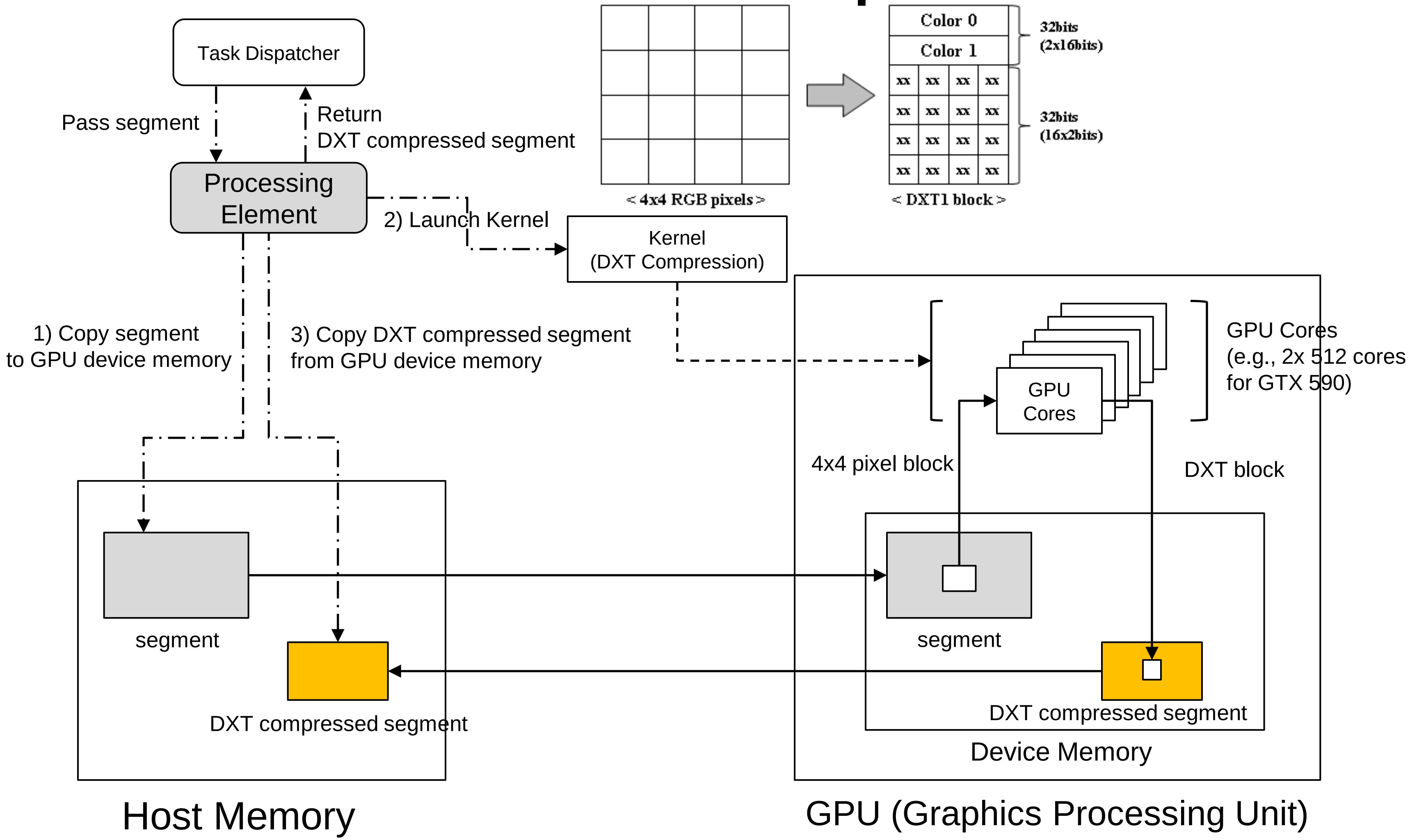


- *DXT compression ($P_{DXTC}$) /decompression ($P_{DXTD}$)*
  - DXT *(i.e., S3 texture compression)* is a light-weight compression scheme that compresses an image frame based on 4x4-pixel blocks
  - The compression operation of each pixel block is completely independent, thus we significantly reduce the compression time by implementing DXT compression using hundreds of GPU cores
- *Rate shaping ($P_{rshape}$)*
  - Control the rate of traffic received on a network interface
  - Traffic that is less than or equal to the specified rate is sent, whereas traffic that exceeds the rate is dropped or delayed
  - Implemented using BandwidthShaper element of Click
- *YUV2RGB conversion ($P_{Y2R}$)*
  - Recent camera models produce YUV-format video content due to the small size of YUV format (i.e., half of the RGB format)
  - DXT compressor only takes RGB-format pixel blocks, we need a conversion element to support various formats of pixel blocks
- *Resize ($P_{resize}$)*

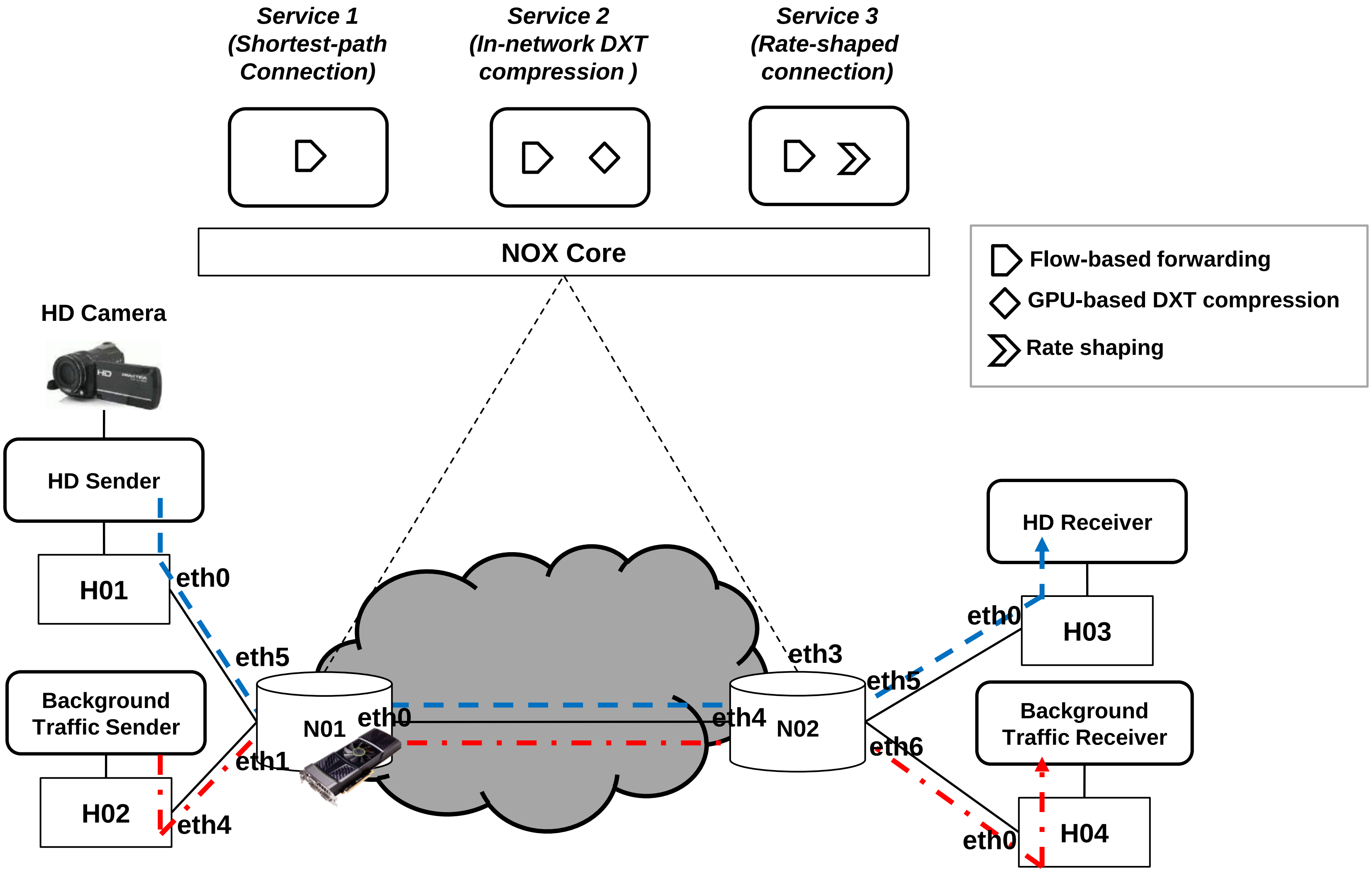
# Per-flow Customized Data Plane



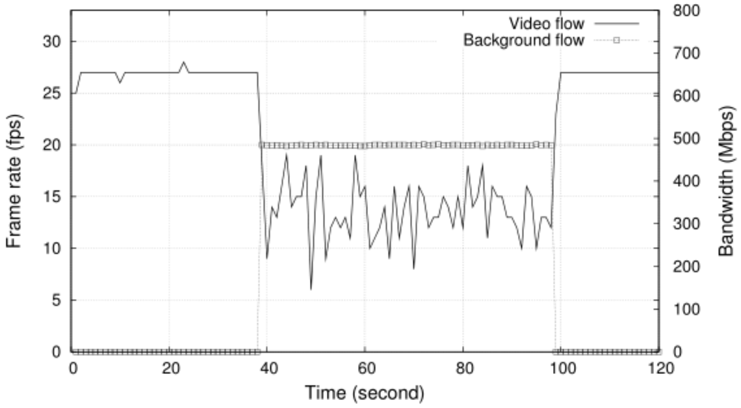
# A Processing Element for GPU-based DXT Compression



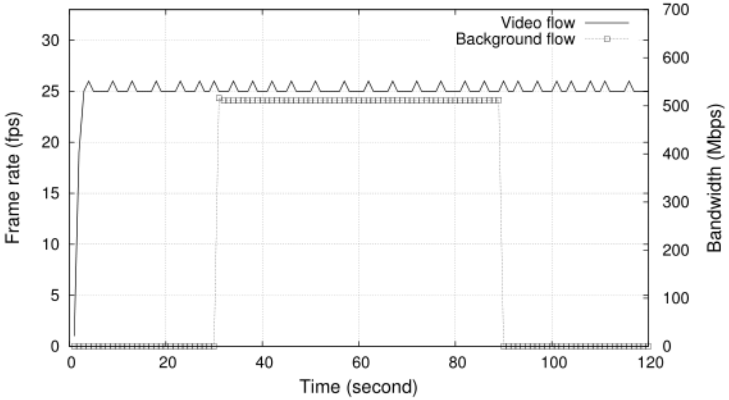
# Experimental Verification


*Service 1 (Shortest-path Connection)*
*Service 2 (In-network DXT compression )*
*Service 3 (Rate-shaped connection)*
NOX Core
Flow-based forwarding
GPU-based DXT compression
Rate shaping
HD Camera
HD Sender
H01
eth0
eth5
Background Traffic Sender
H02
eth1
eth4
N01
eth0
eth4
N02
eth3
eth5
eth6
HD Receiver
eth0
H03
Background Traffic Receiver
eth0
H04

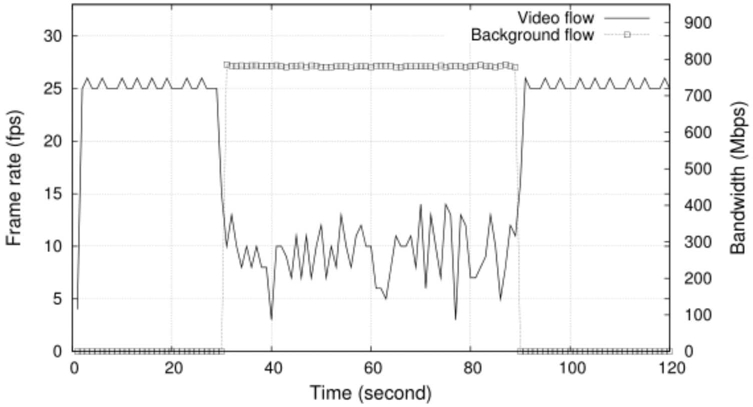
# Verification Results (Functionality)



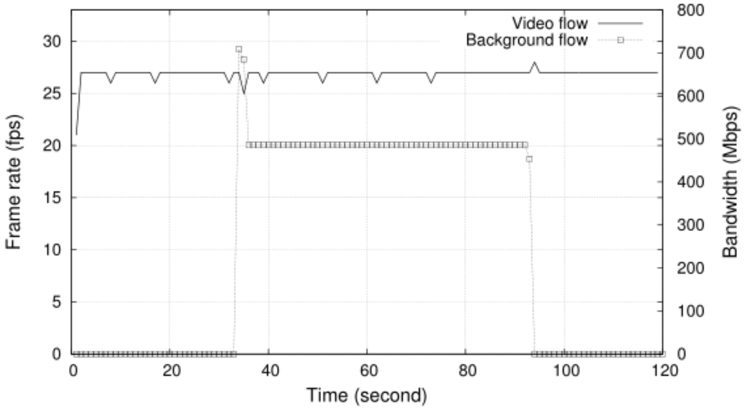
Frames rates in H03 with a 800Mbps background flow injection



Frames rates in H03 with in-network DXT compression (Background: 500Mbps)



Frames rates in H03 with in-network DXT compression (Background: 800Mbps).



Frames rates in H03 with in-network DXT compression (Background traffic in-network rate-shaped from 800Mbps to 500Mbps).

# Conclusion

- The NetOpen switch node
  - A programmable network substrate supporting the concept of NetOpen networking service
- Design and prototype a NetOpen switch node providing in-network processing
  - Provides service functionalities as programmable processing modules that can be enabled independently
  - For each flow, a customized data plane can be built by selectively combining service functionalities (under the logically centralized control)
- Future work
  - Enhancing the performance of in-network processing
  - Continue the next versions of NetOpen switch node

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# Thank you!

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