SNF: Serverless Network Functions

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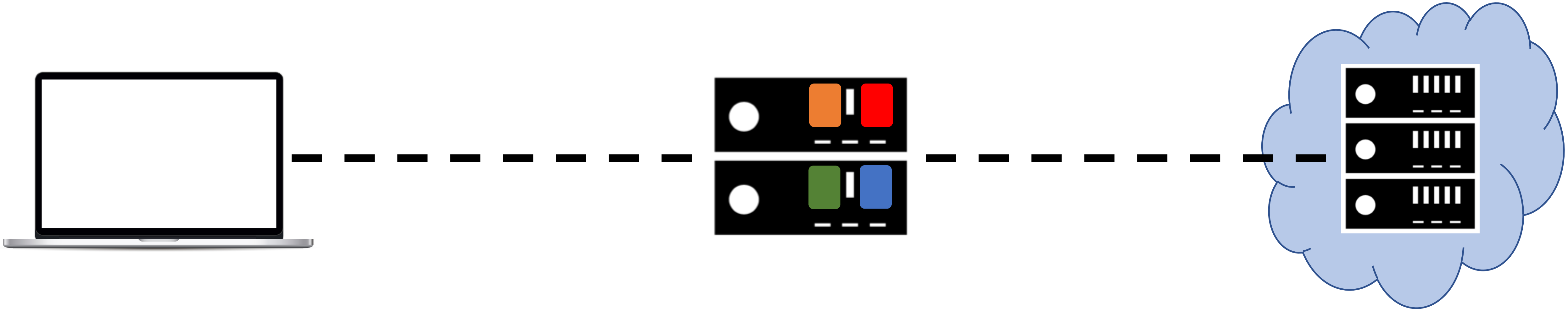
* This work does not have any affiliation with Google

Network Functions (NFs) 101



NFs are typically **stateful** and maintain **per-flow internal state**

- IDS: flow to automaton state mapping
- LB: flow to backend server mapping
- ....

How can one offer NFs as a Service (NFaaS)?

Intuitive programming model

Delivers low-latency processing requirements

Automatically scale up/down to meet the demand

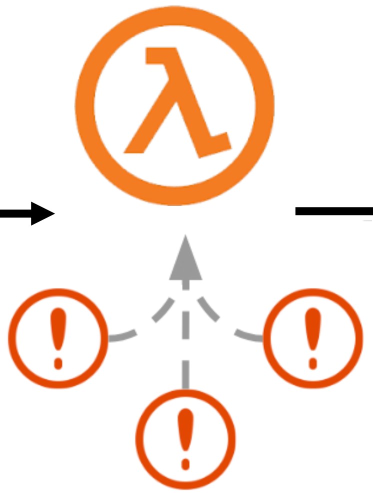
Usage-based billing

Serverless Computing for NFaaS?

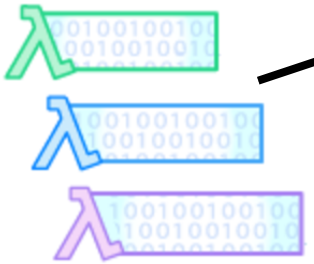
Seems to have the right building blocks

- Event-driven programming model
- Usage-based billing
- Automatic compute elasticity

Upload your function to the serverless computing platform and register for event-based triggers



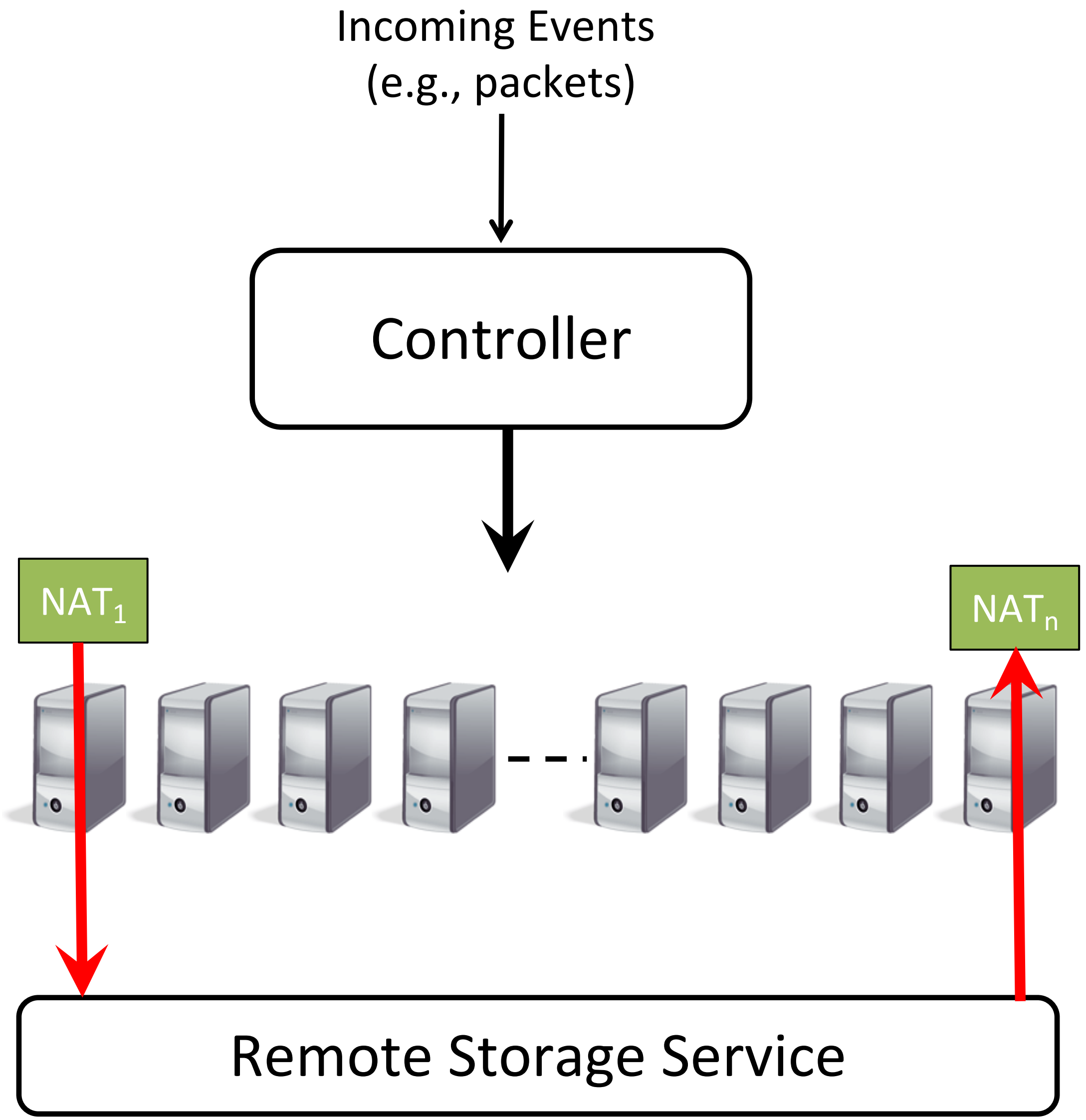
Execution is triggered when an event occurs



Platform runs your function only when triggered

Pay just for the computation time

Issue 1: Stateless Function Abstraction



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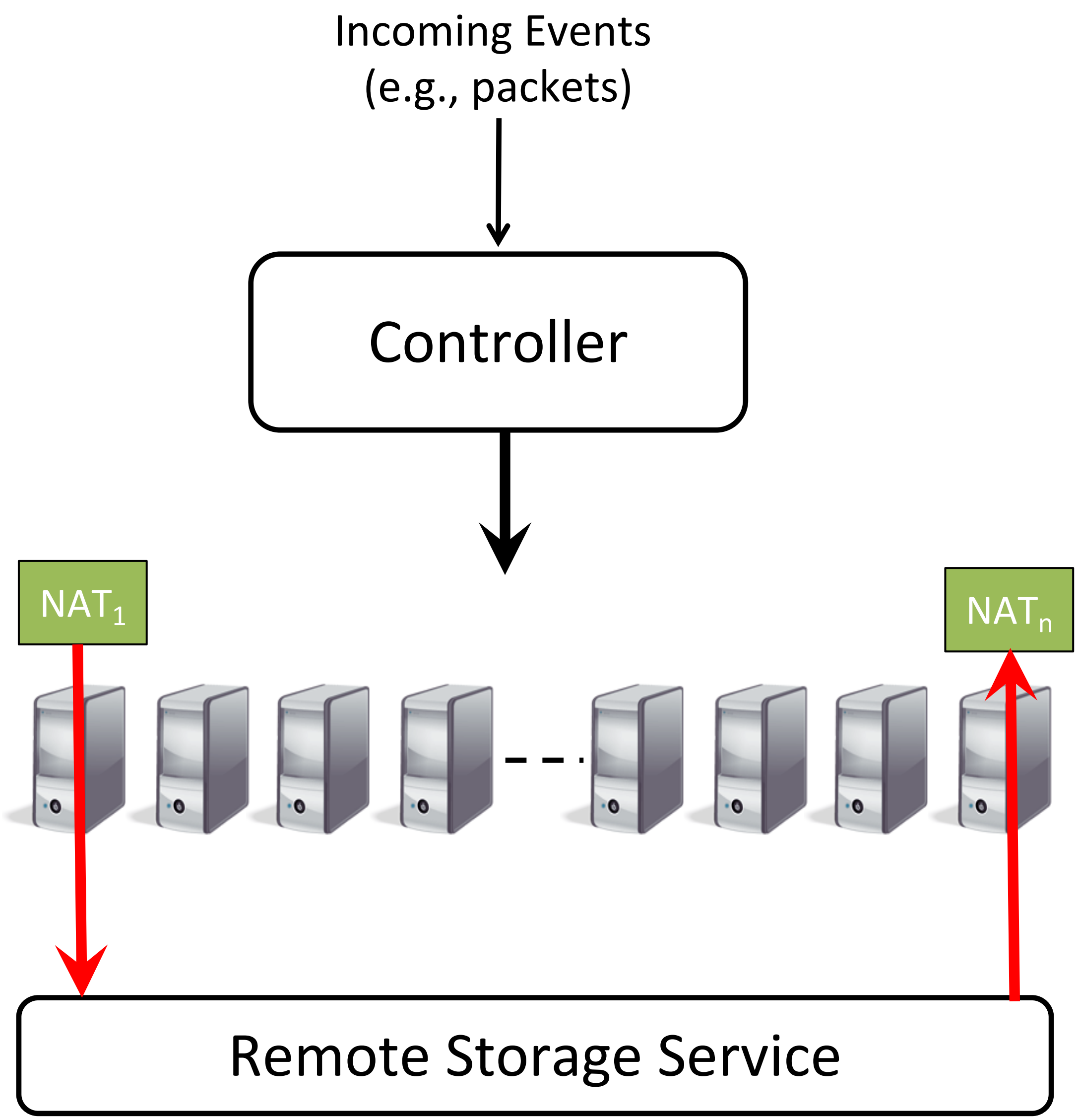

Functions are stateless by design – no (guaranteed) local state across events

State transfer via remote storage

- High per-packet processing latencies due to physical decoupling of compute and state

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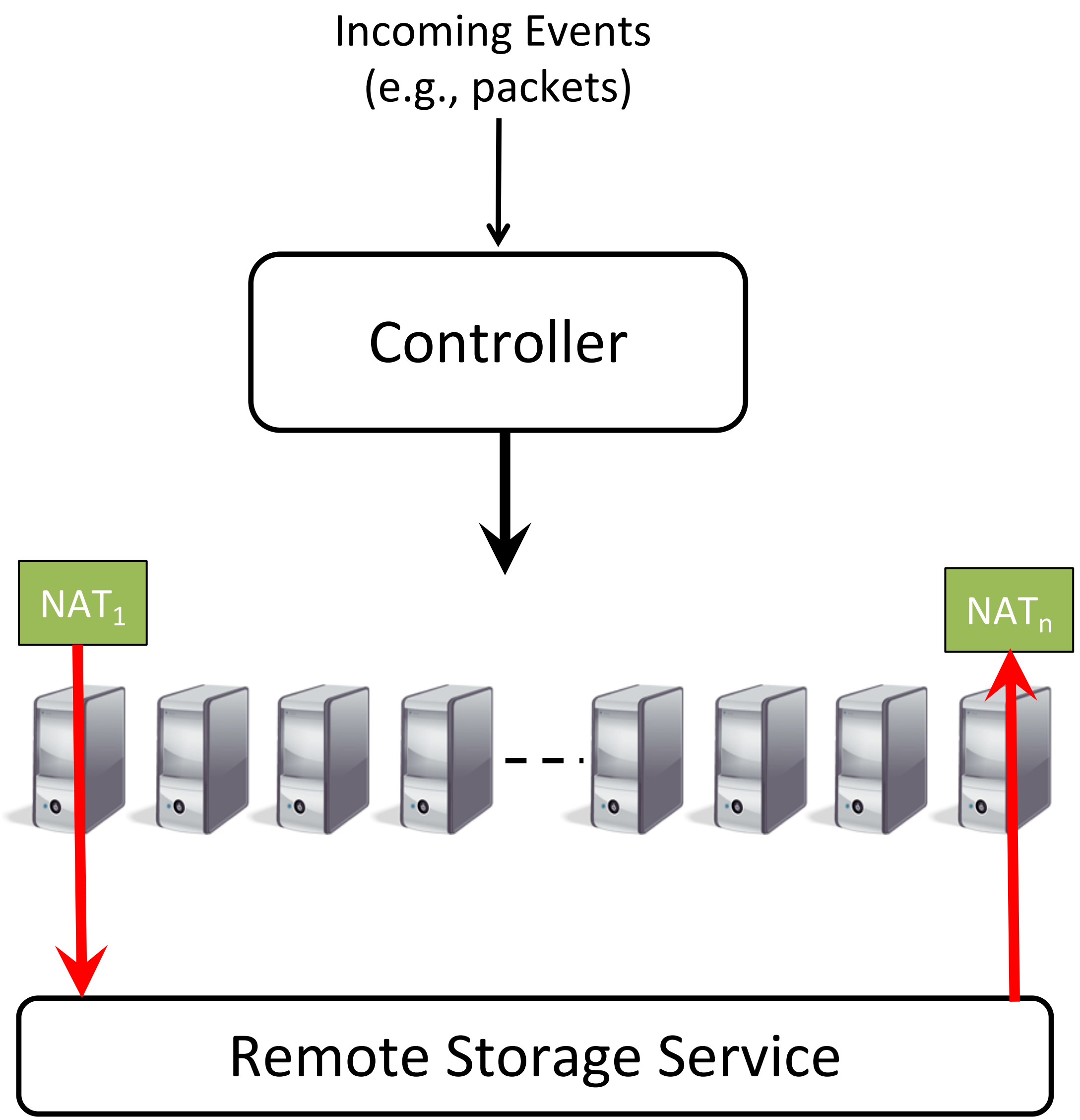


Functions are stateless by design – no (guaranteed) local state across events

State transfer via remote storage

- High per-packet processing latencies due to physical decoupling of compute and state

Why not opt for a “Server-full” NFaaS?

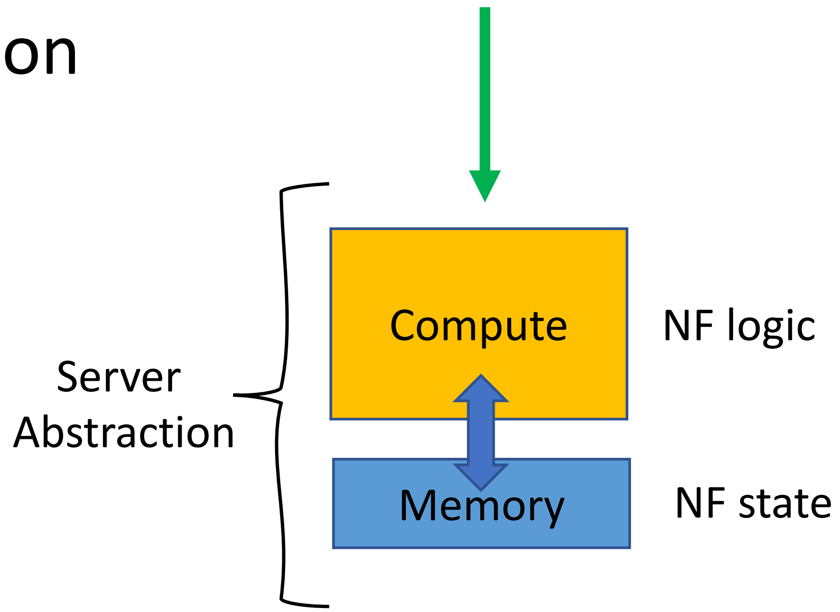
Compute and state are **physically coupled**

Leads to coarse-grained flow-level work allocation

- Commitment between a flow and compute unit

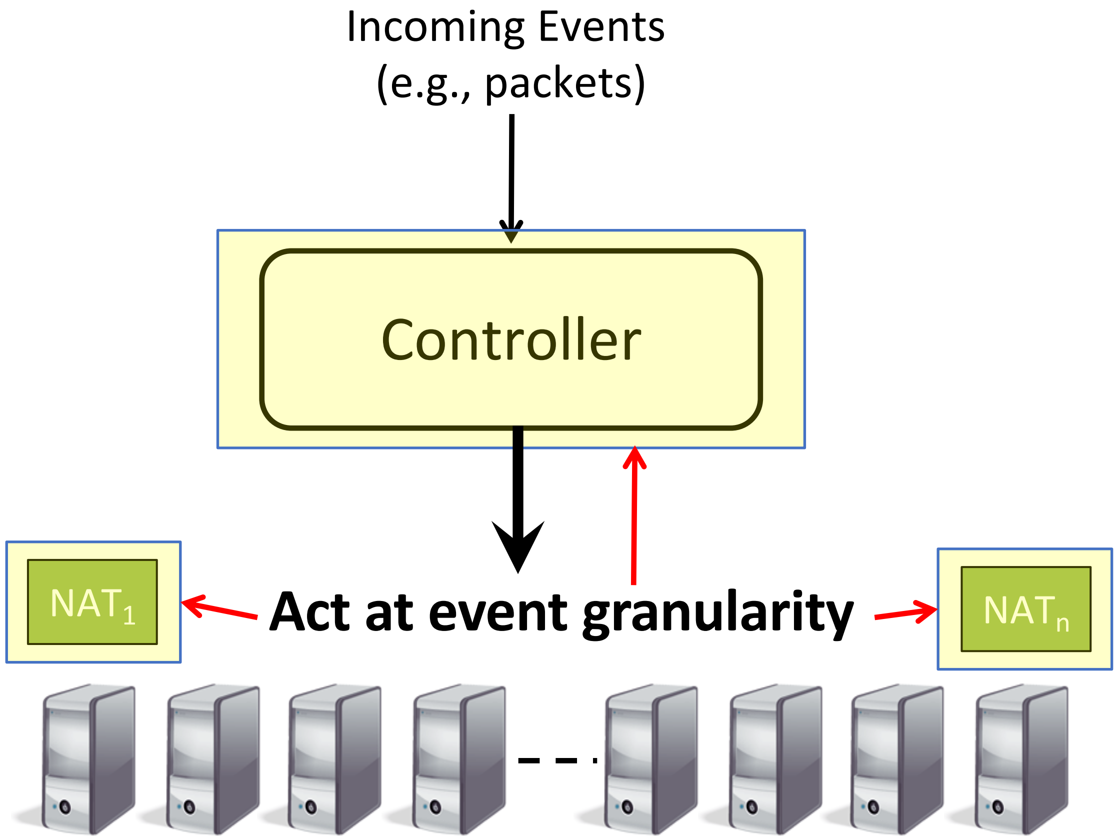
Trade-off between efficiency and performance

- Overload impacts performance
- Under utilization impacts efficiency



State migration during traffic redistribution has **high overheads**

Issue 2: Work Allocation at Billing Granularity



Coupling between units of controller work allocation and billing - events

- Leads to trade-off between resource efficiency, performance and usage-based billing.
  - Packet
    - Efficiency and ideal billing at the cost of performance
  - Flow
    - Performance at the cost of efficiency and ideal billing

Issue 2: Work Allocation at Billing Granularity

Incoming Events
(e.g., packets)

Controller

ing between units of controller
allocation and billing - events

– Leads to trade-off between resource

at

– Performance at the cost of
efficiency and ideal billing

SNF is a serverless platform that provides support to stateful NFs and allows offering NFaaS

SNF Design Overview: Key Ideas

Key Idea #1

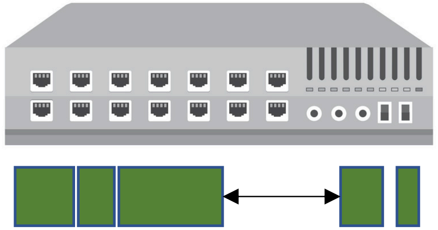
Decouple work allocation and billing granularity

Key Idea #2

Middleground for compute-state (de)-coupling

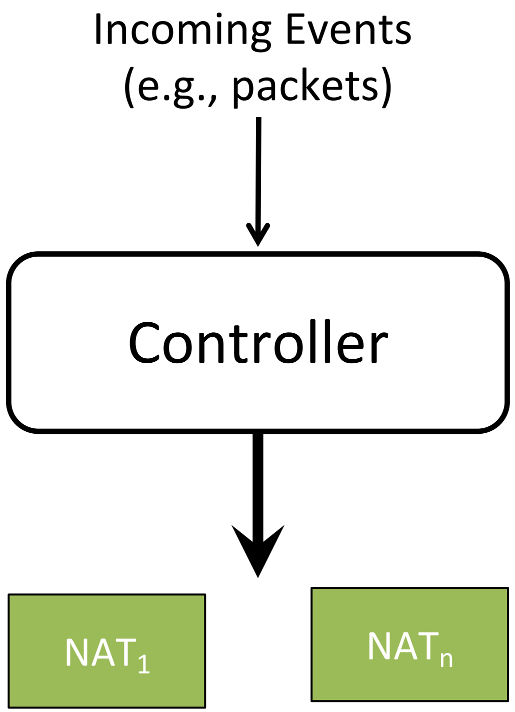
Key Idea #3

Leverage the existence of flowlets



Flowlets are **burst of packets** that is separated in time from other bursts by a sufficient gap — called **the flowlet timeout**

SNF Design Overview: Key Abstractions



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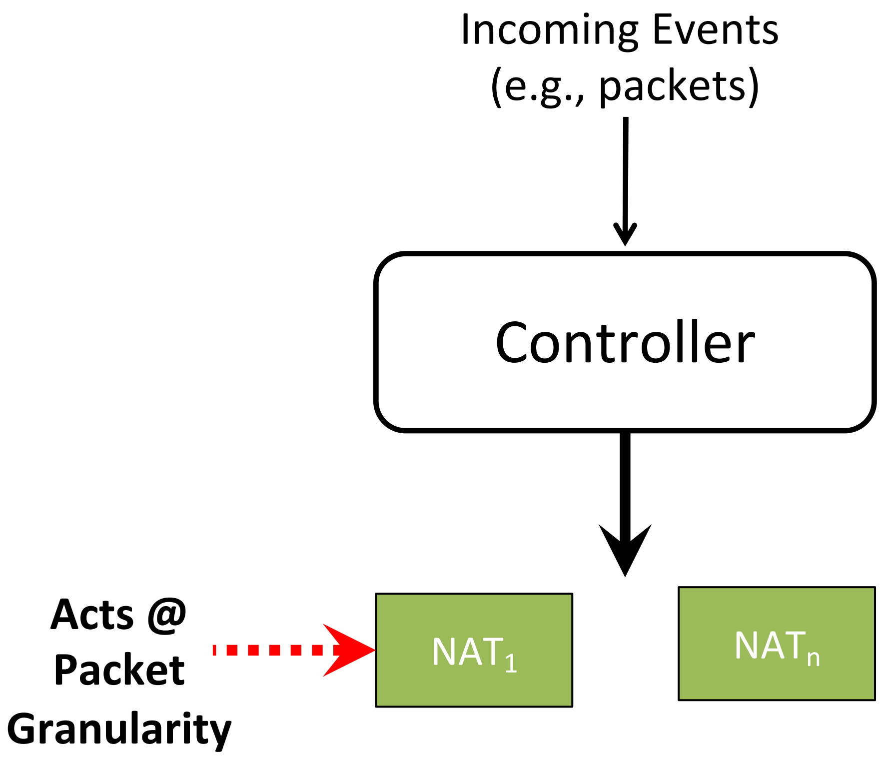

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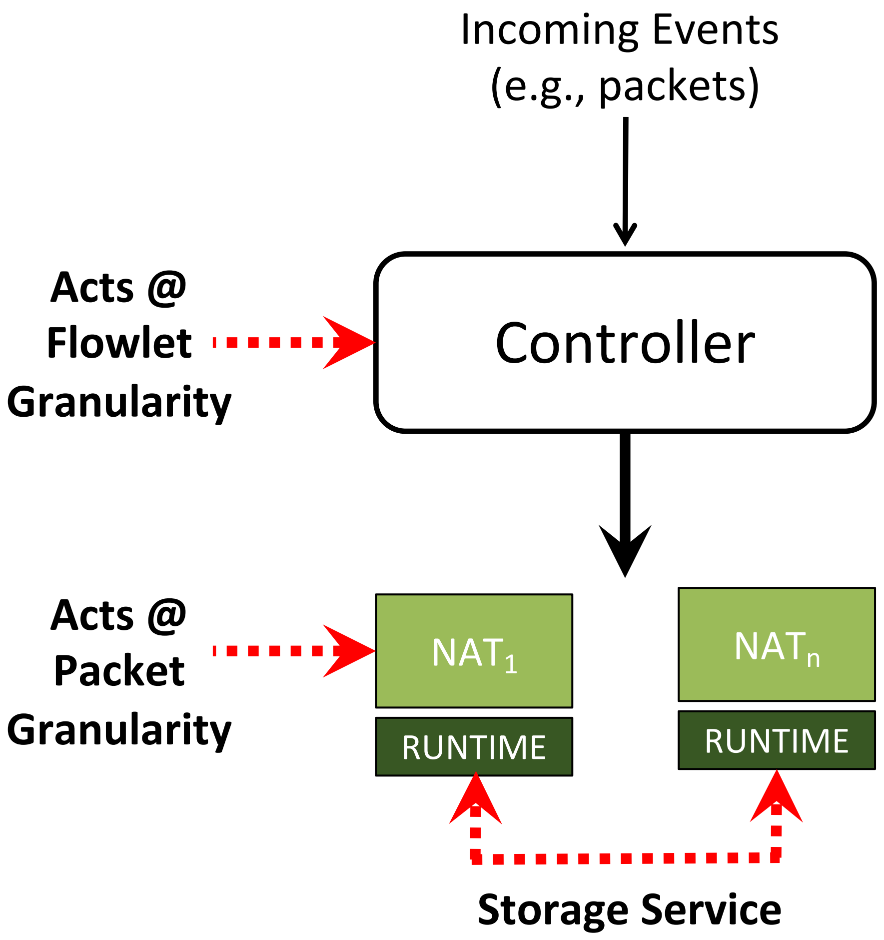

Ephemeral Stateful Functions

- **All events (packets) within a flowlet** are **sent to the same function** and state is maintained locally

Peer-Peer Distributed Storage

- NFs share state with each other in a peer-peer fashion
- Leverage the flowlet timeout to ***proactively*** replicate state

SNF Design: State Management - Why Proactive?

A flowlet $\boldsymbol{f_{i+1}}$ of flow F can be assigned to a different compute unit as compared to flowlet $\boldsymbol{f_i}$

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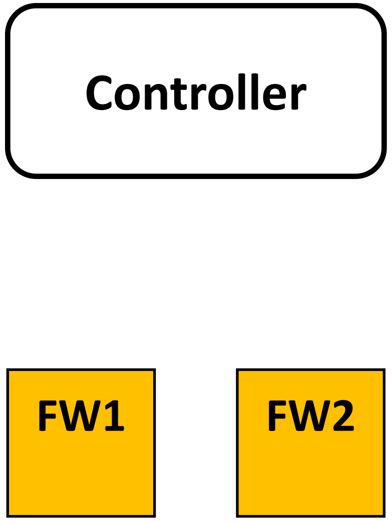

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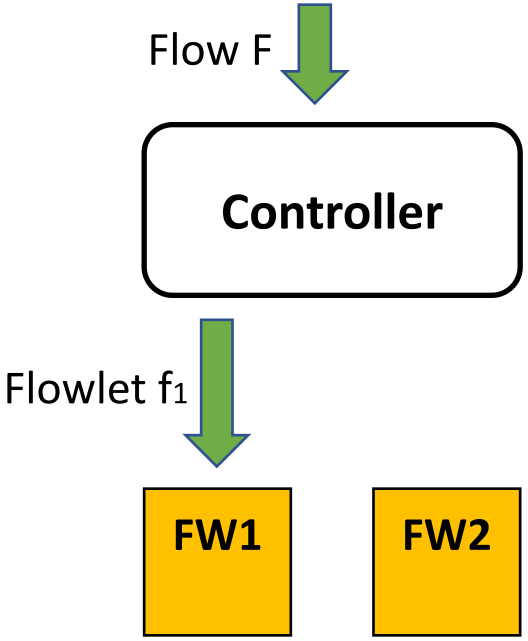

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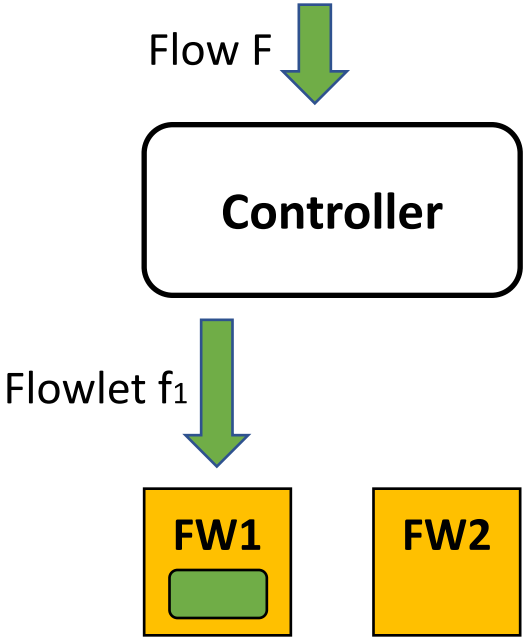

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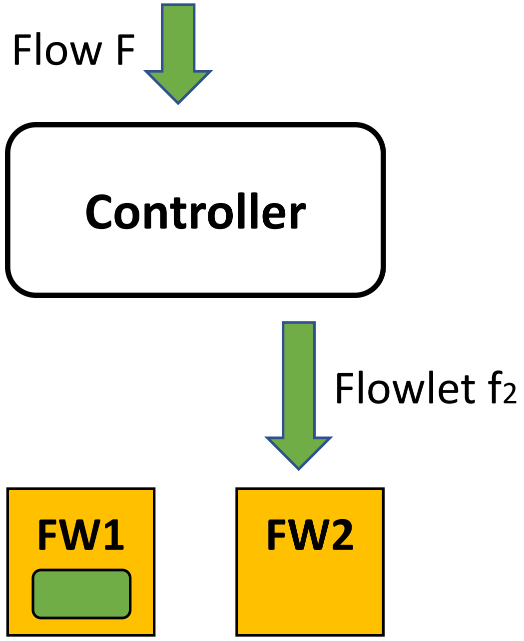

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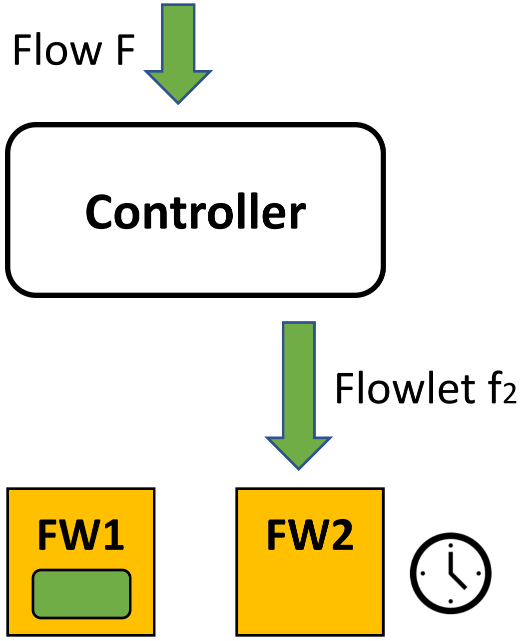

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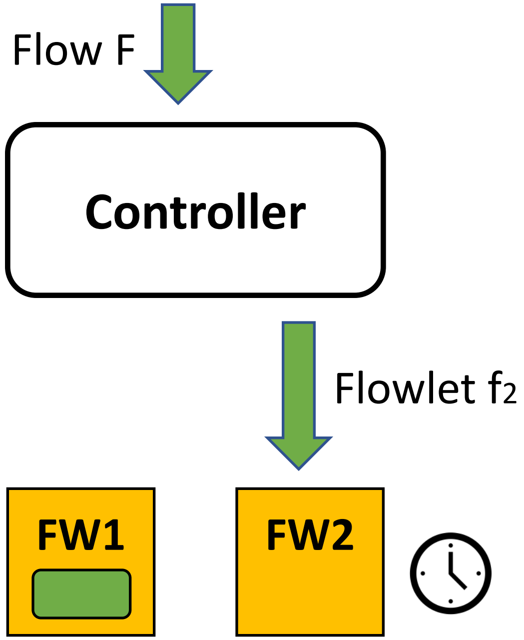

Such reactive approaches **degrade performance**!

SNF Design: State Management

Proactively replicate state before the next flowlet $\boldsymbol{f_{i+1}}$ arrives

When to proactively replicate?

- Balance between making unnecessary transfers and wait times
- Replicate at half the flowlet inactivity timeout

Where to proactively replicate?

- Future flowlet to compute unit assignment not known
- **Top K** compute units in a weighted randomized manner
    - weights correspond to how controller prioritizes allocation to a particular compute unit

SNF Design: Compute Management

Weighted greedy bin-packing algorithm

- Maximally pack flowlets into few compute units
- Prefers units to which have been proactively replicated

Score = Utilization + α x StateExists

α balances **utilization against proactive benefits**

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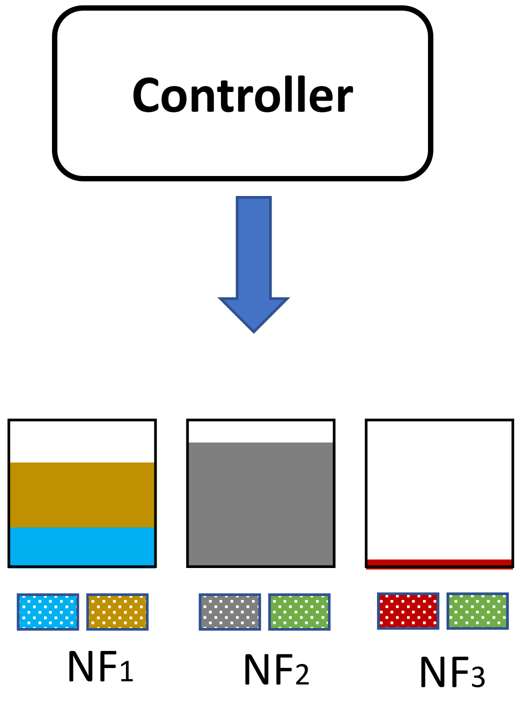

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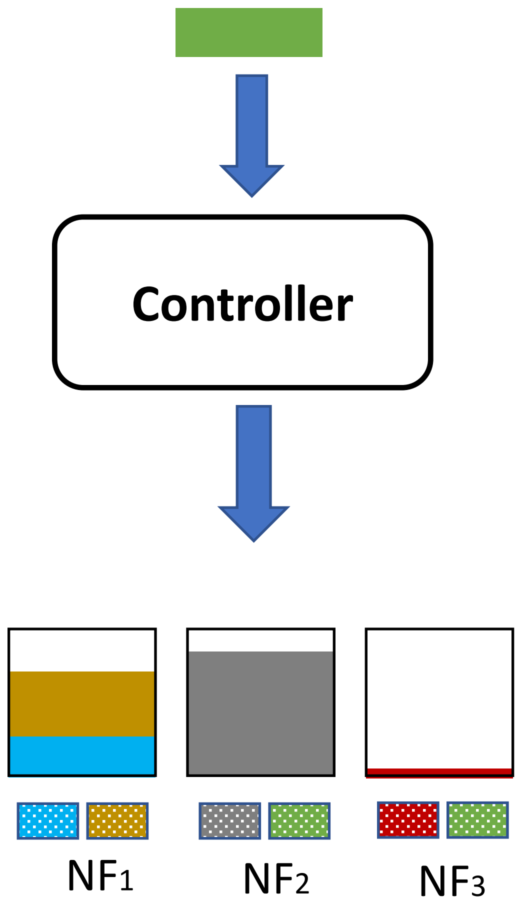

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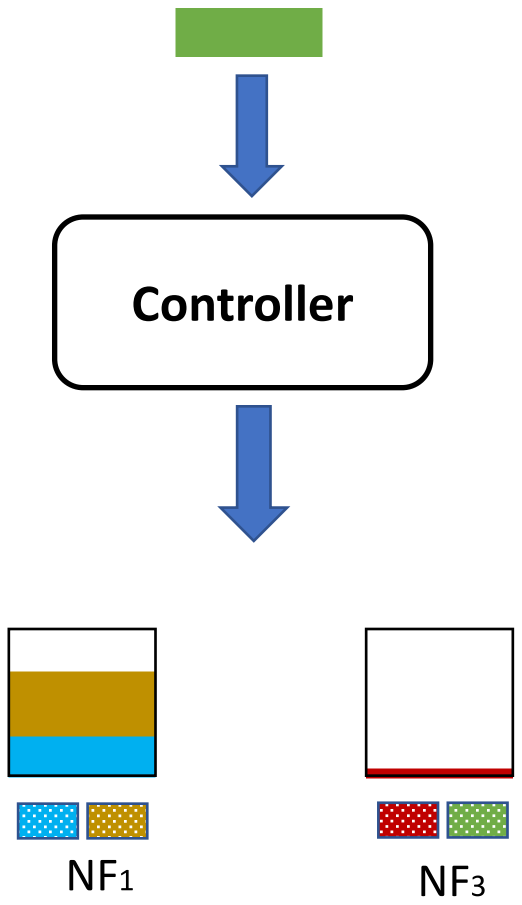


SNF Evaluation: Implementation and Testbed

Prototype – built from scratch

Workload – replay previously captured packet traces (3.8 M packets with 1.7K connections)

NFs – NAT, LB, IDS, UDP Whitelister, QoS Traffic Policer

Compute units **configured to handle 1Gbps** incoming workload

SNF Evaluation: Compute Management

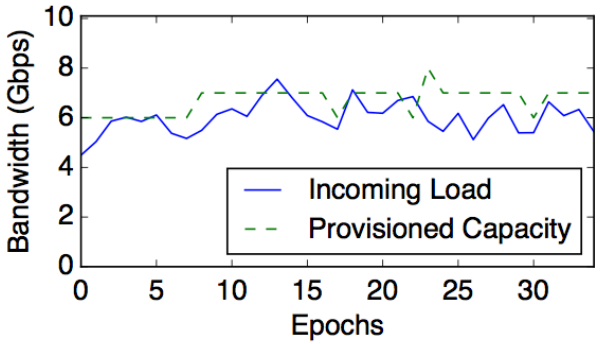
Can SNF provision compute as per the incoming traffic demand at fine time scales?

Baselines:

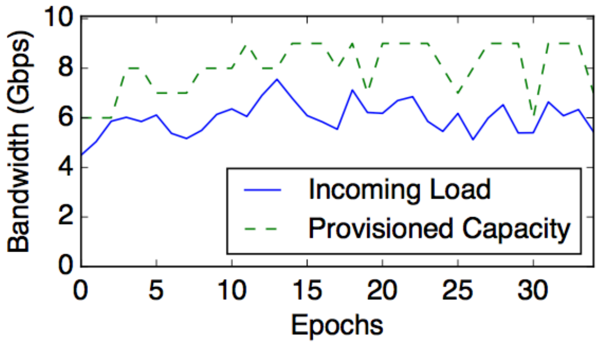
Vanilla Flow Allocation	**Smart Flow Allocation (Xms)**
Allocate when new flow arrives (associated with compute unit for entire lifetime)	Allocate when new flow arrives and every X ms
Adopted by generic server-full alternatives	Adopted by NF specific solutions

SNF Evaluation: Compute Management

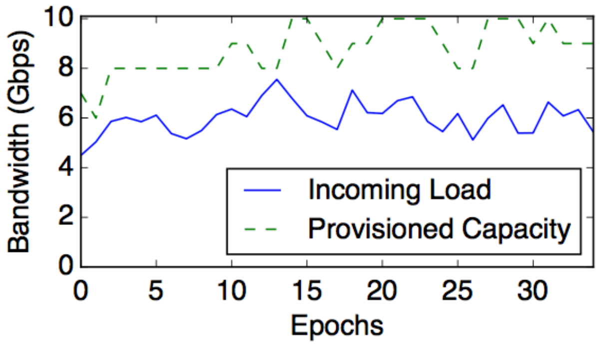
Vanilla Flow



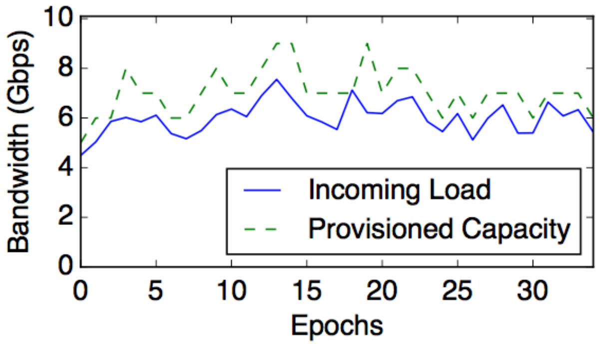
Smart Flow (100ms)



Smart Flow (50ms)



Flowlet



SNF Evaluation: Compute Management

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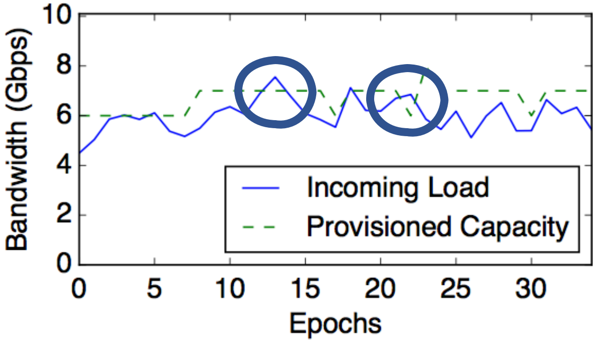

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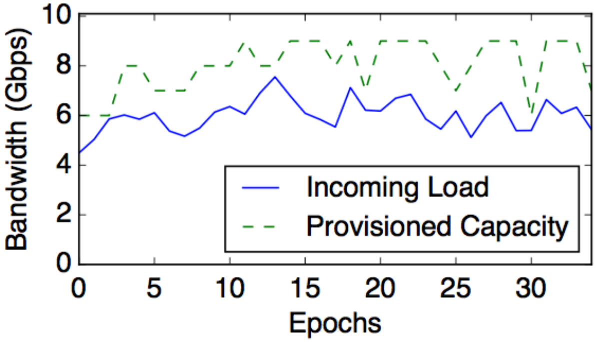

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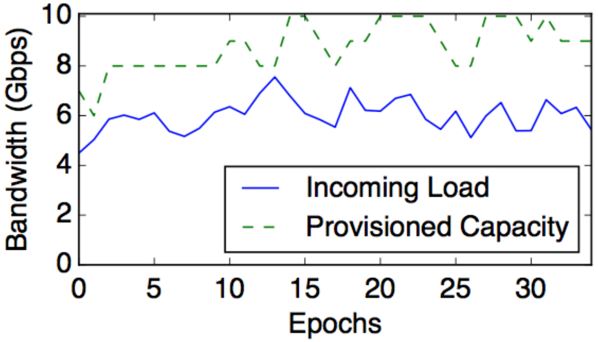

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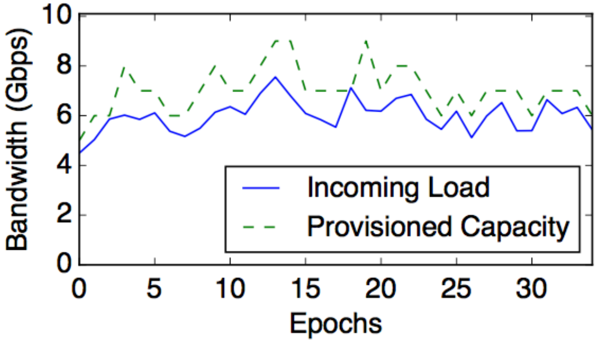

Vanilla Flow Allocation does not adapt well to incoming workload

Smart Flow (Xms) Allocation leads to most overprovisioning of compute units

Flowlet Allocation closely matches the incoming load

SNF Evaluation: Compute Management

Vanilla Flow

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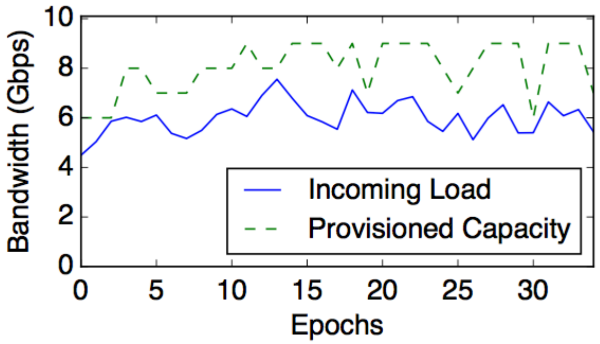

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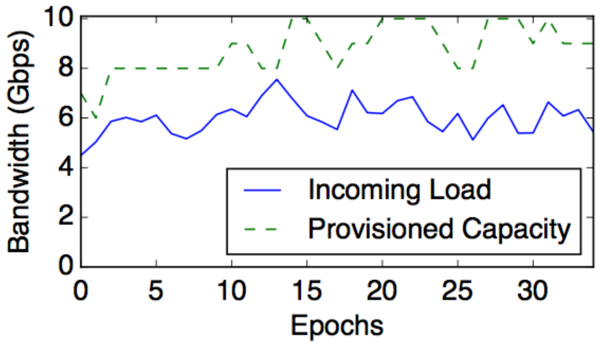

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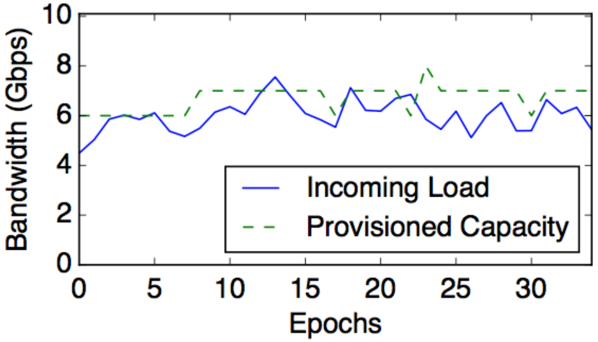

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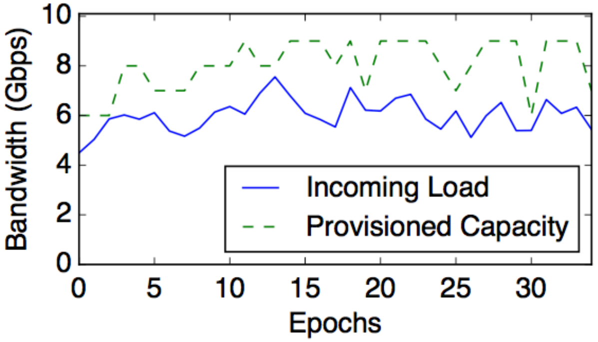

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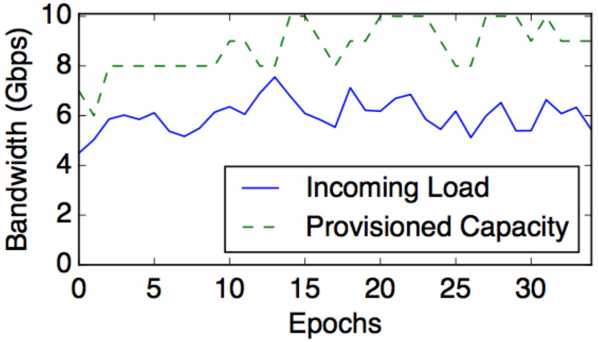

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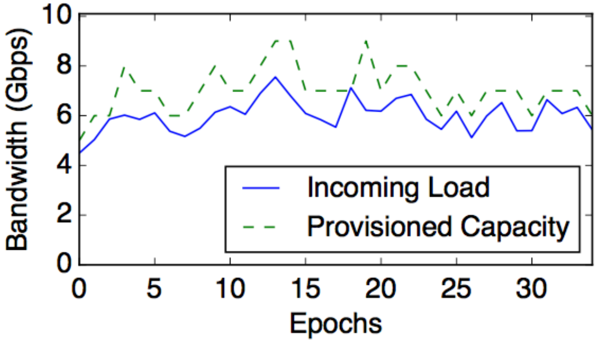

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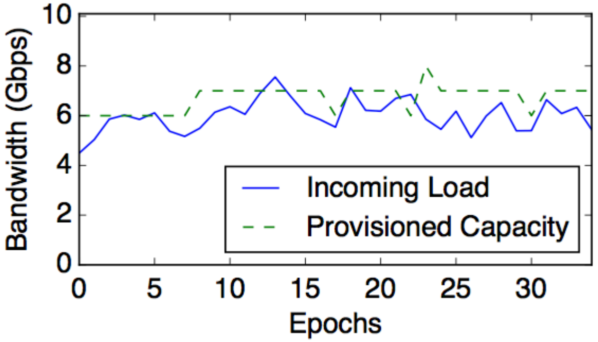

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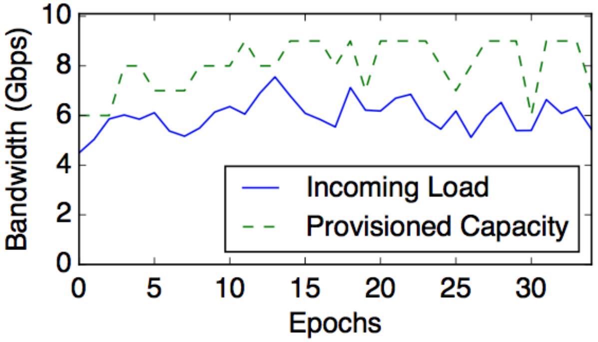

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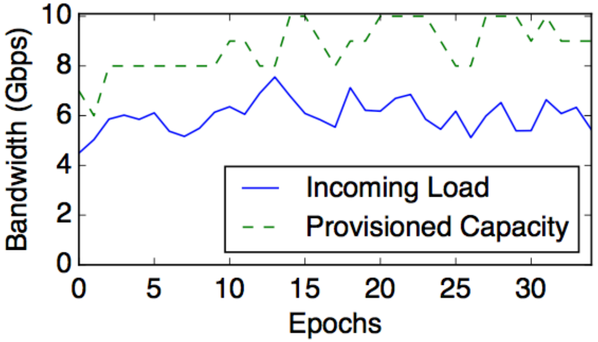

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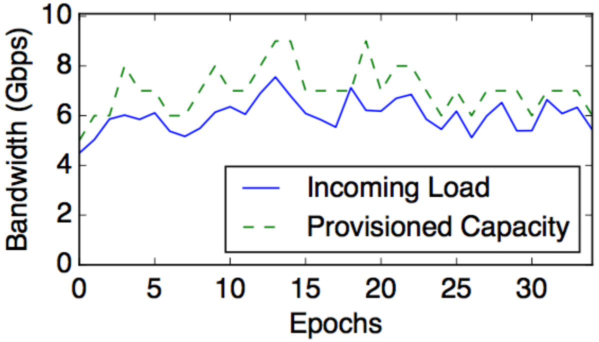

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Flowlet Allocation gets **3.36x** more opportunities to assign work

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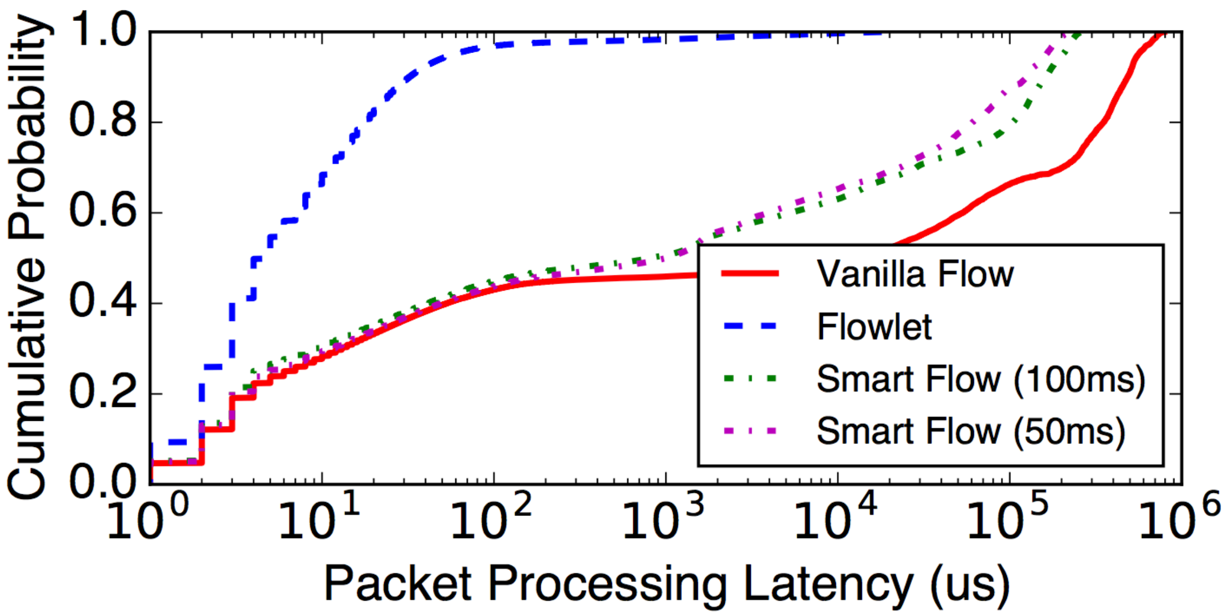

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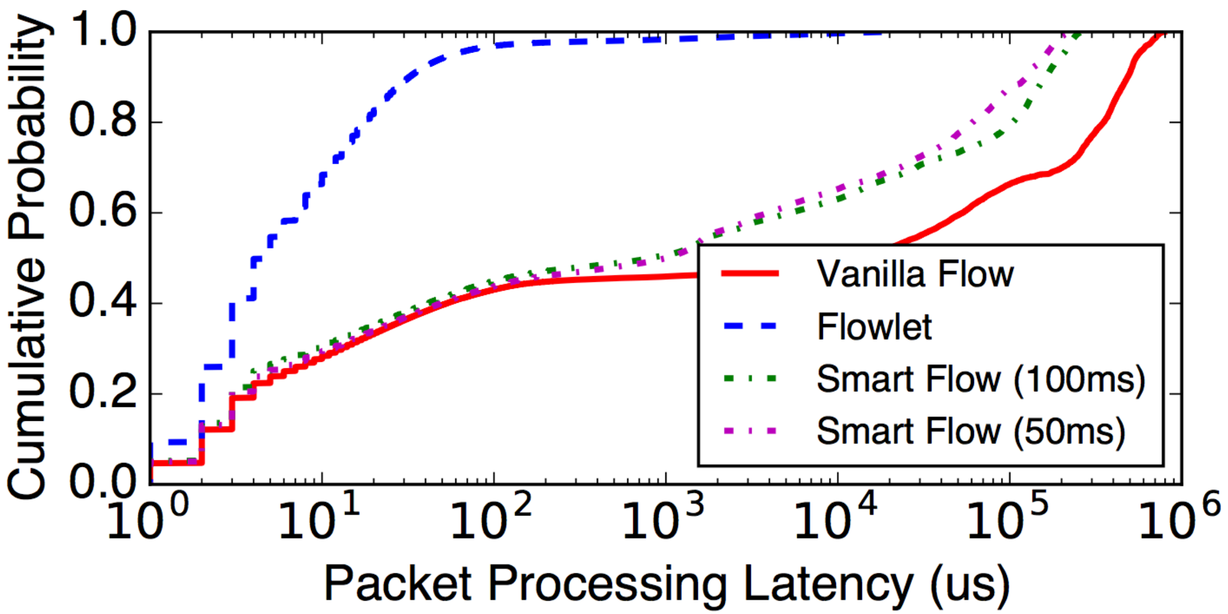
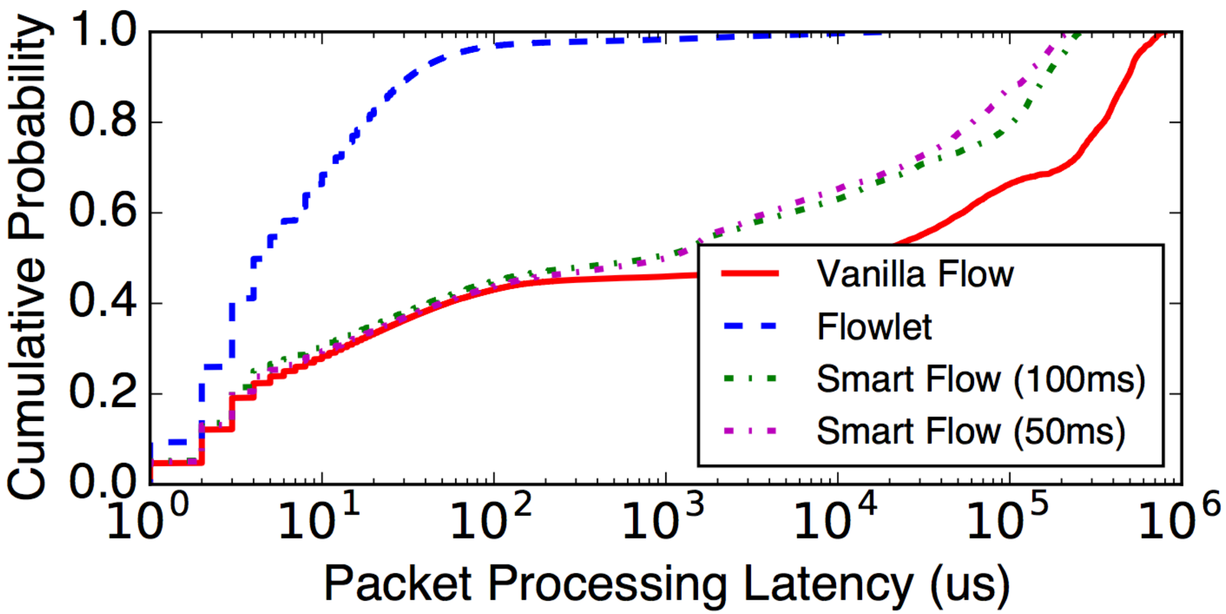


Vanilla Mode

High Latencies

SNF Evaluation: Compute Management

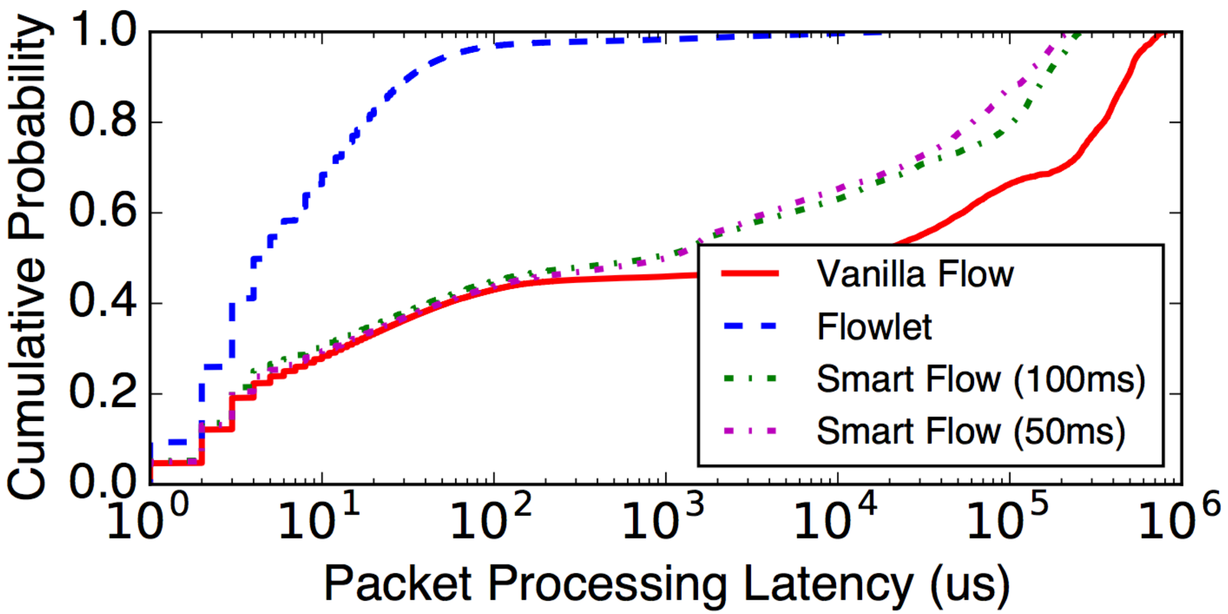


Vanilla Mode

High Latencies

Pinning of flows to compute

SNF Evaluation: Compute Management



Vanilla Mode

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↓

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Smart Flow Mode

Moderately High Latencies

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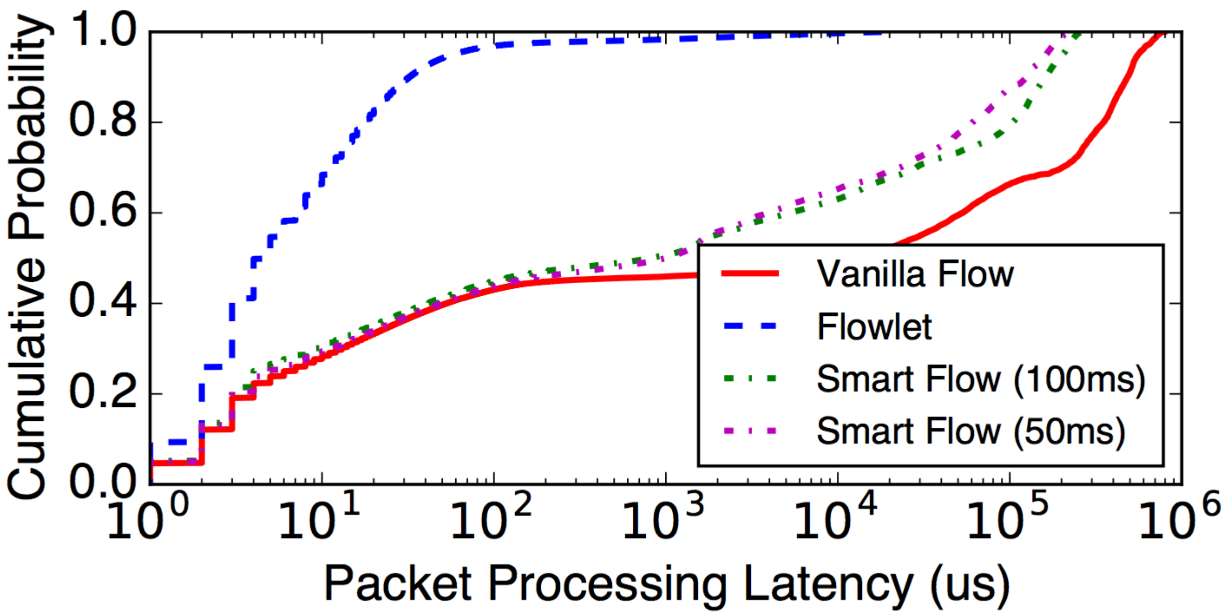

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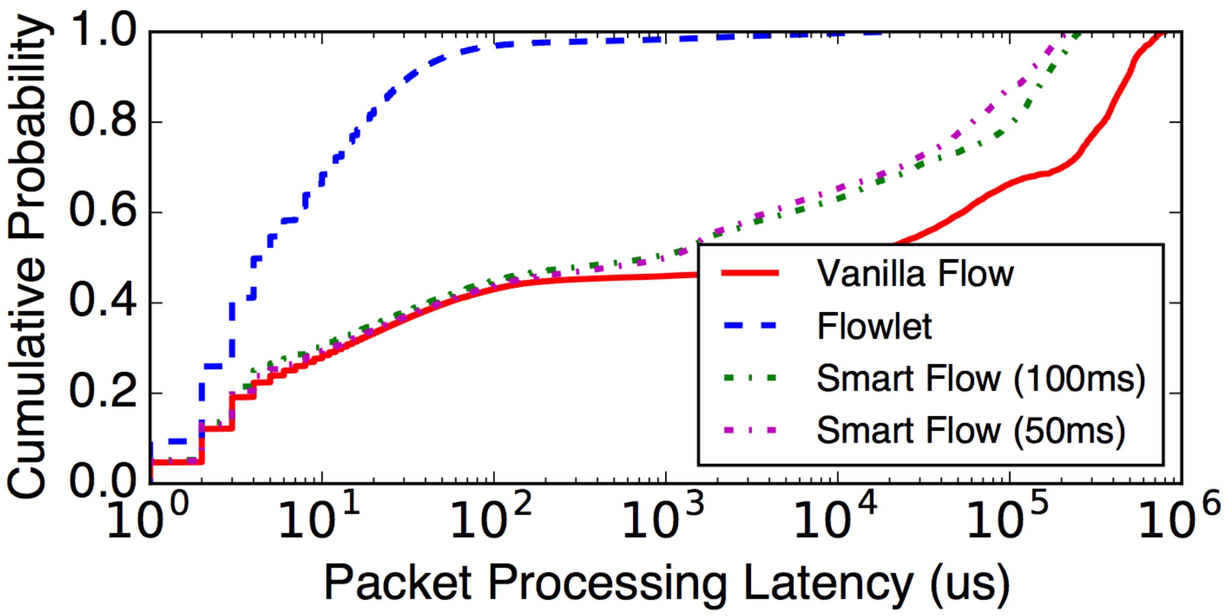
Smart Flow Mode

Moderately High Latencies

Unable to handle low-time scale overloads

SNF Evaluation: Compute Management



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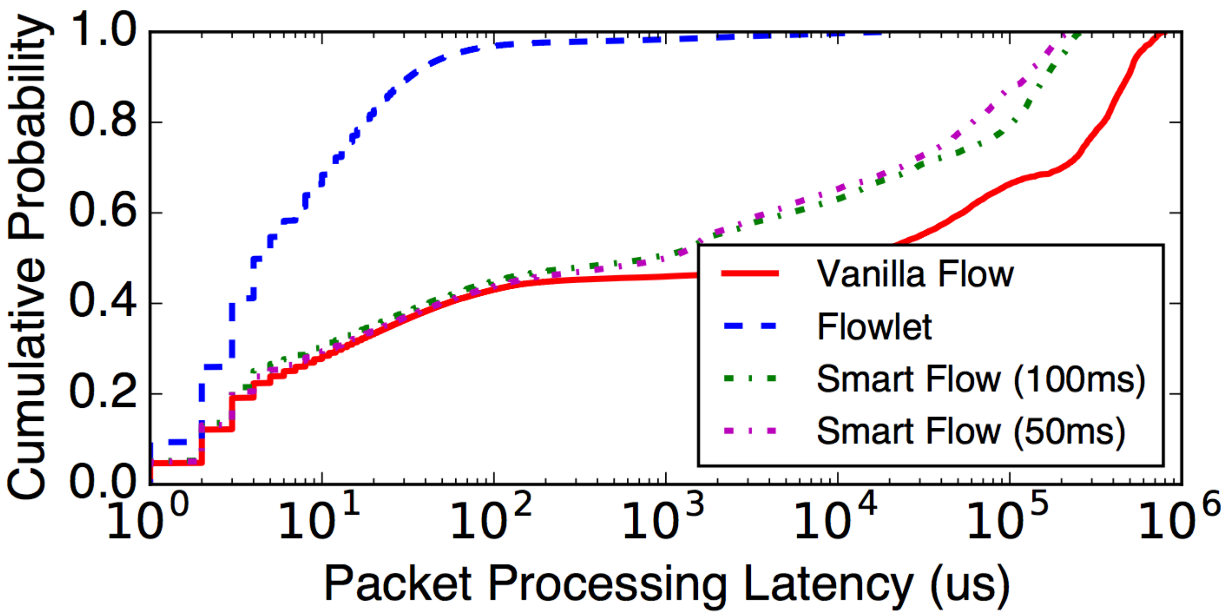
Reactive State Transfers

SNF Evaluation: Compute Management



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Flowlet Mode

Low Latencies

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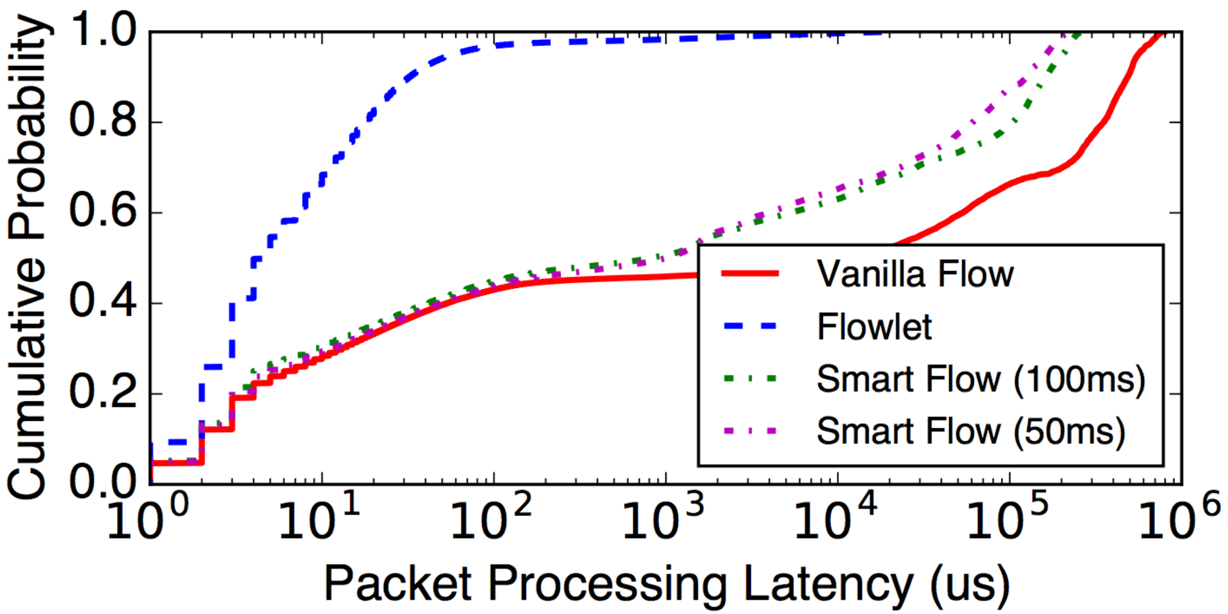

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Proactive State Transfers

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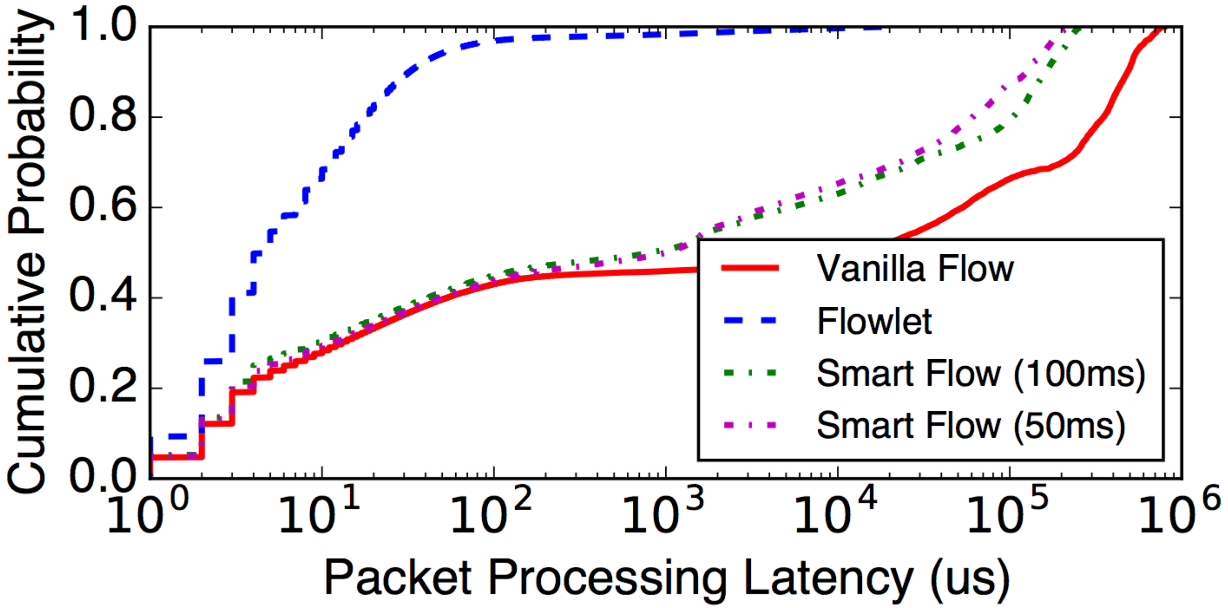

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Smart Flow Mode

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Reactive State Transfers

Flowlet Mode

Low Latencies

Proactive State Transfers

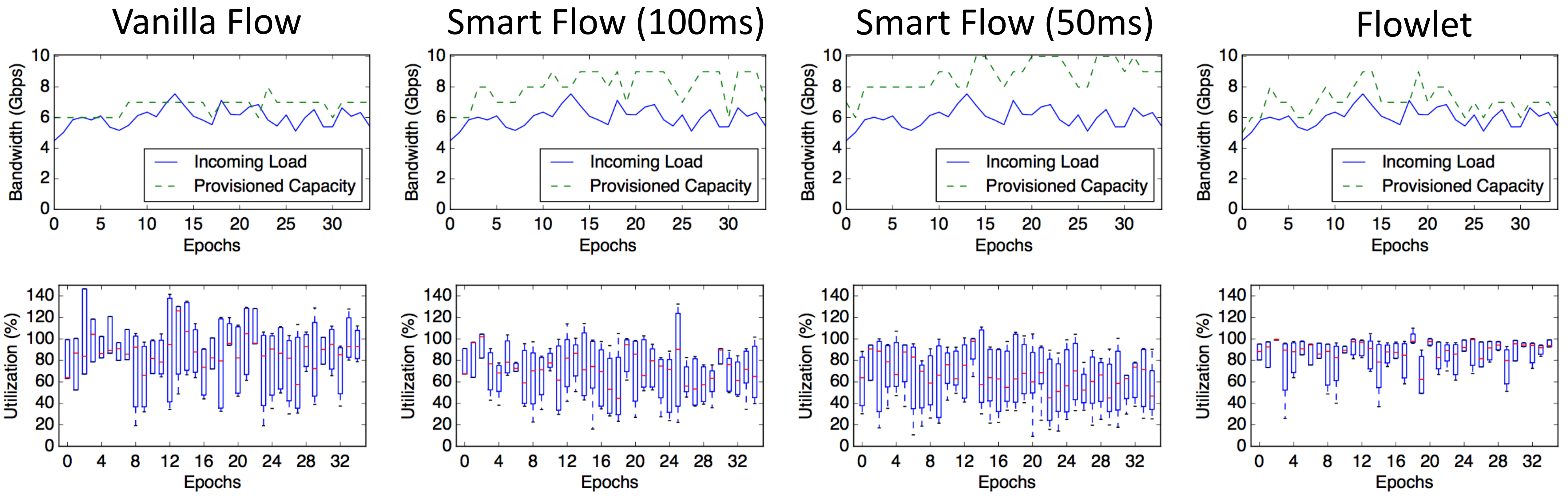
Frequent Work Allocation

SNF Evaluation: Compute Management

Can SNF provision compute as per the incoming traffic demand at fine time scales?

Does SNF provide its performance while not sacrificing utilization?

SNF Evaluation: Compute Management



Flowlet allocation mode ensures that there is rare overload and lesser under utilization

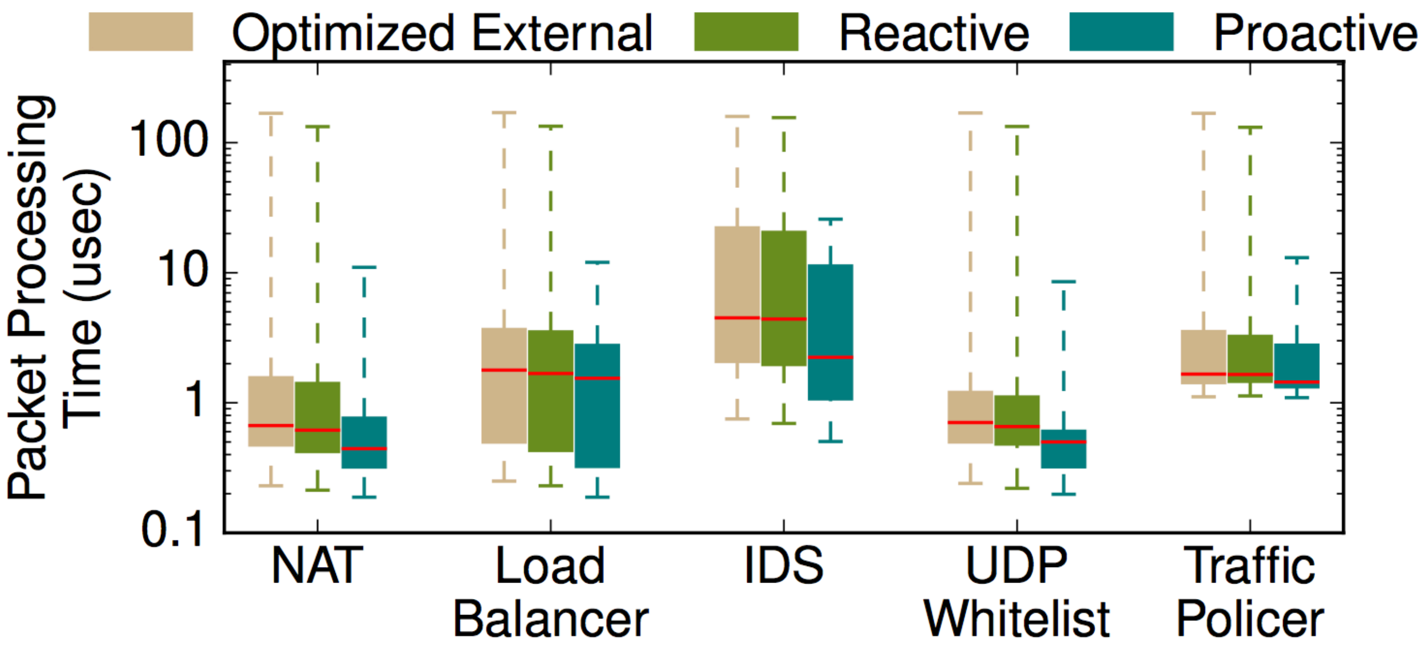
SNF Evaluation: State Management

Does proactive state replication help curtail tail latencies?

Baselines:

Reactive	**Optimized State External**
On arrival of new flowlet, state pulled from compute unit where previous flowlet was processed	State proactively pushed to external store and pulled on arrival of new flowlet
↓	↓
NF State Management Solutions	State Management in Serverless Platforms Today

SNF Evaluation: State Management



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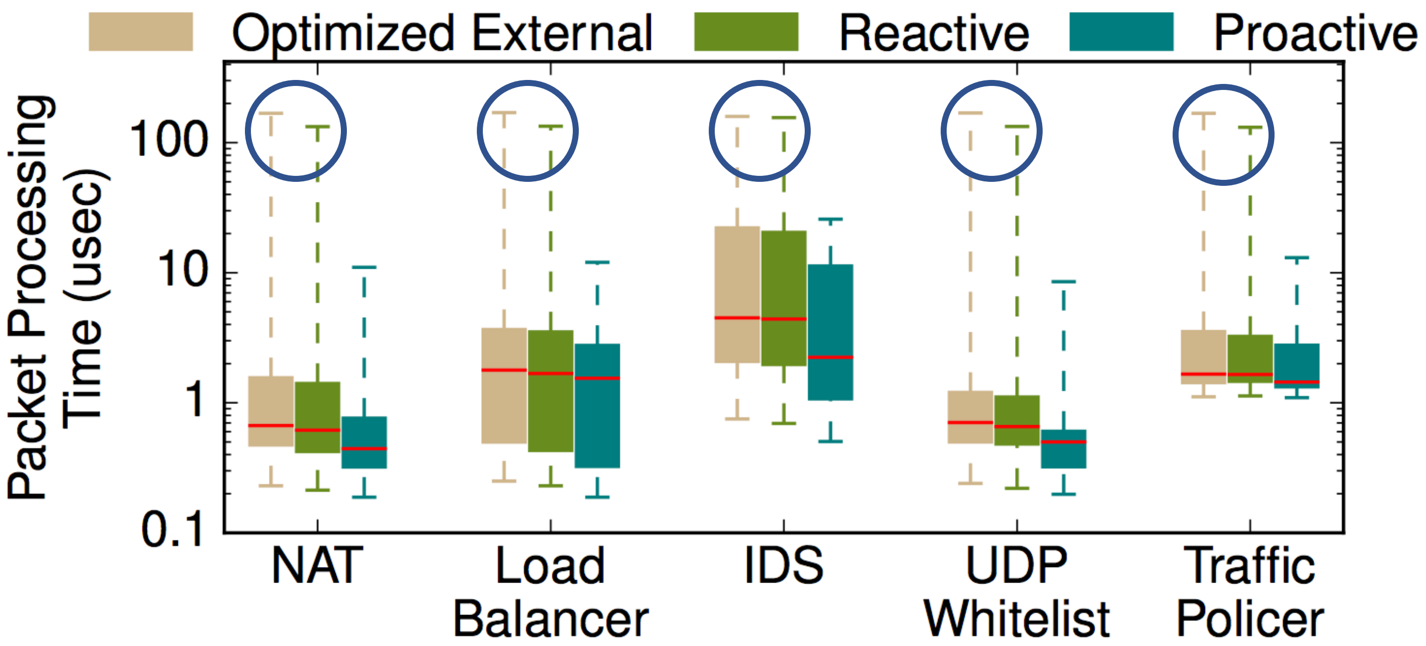
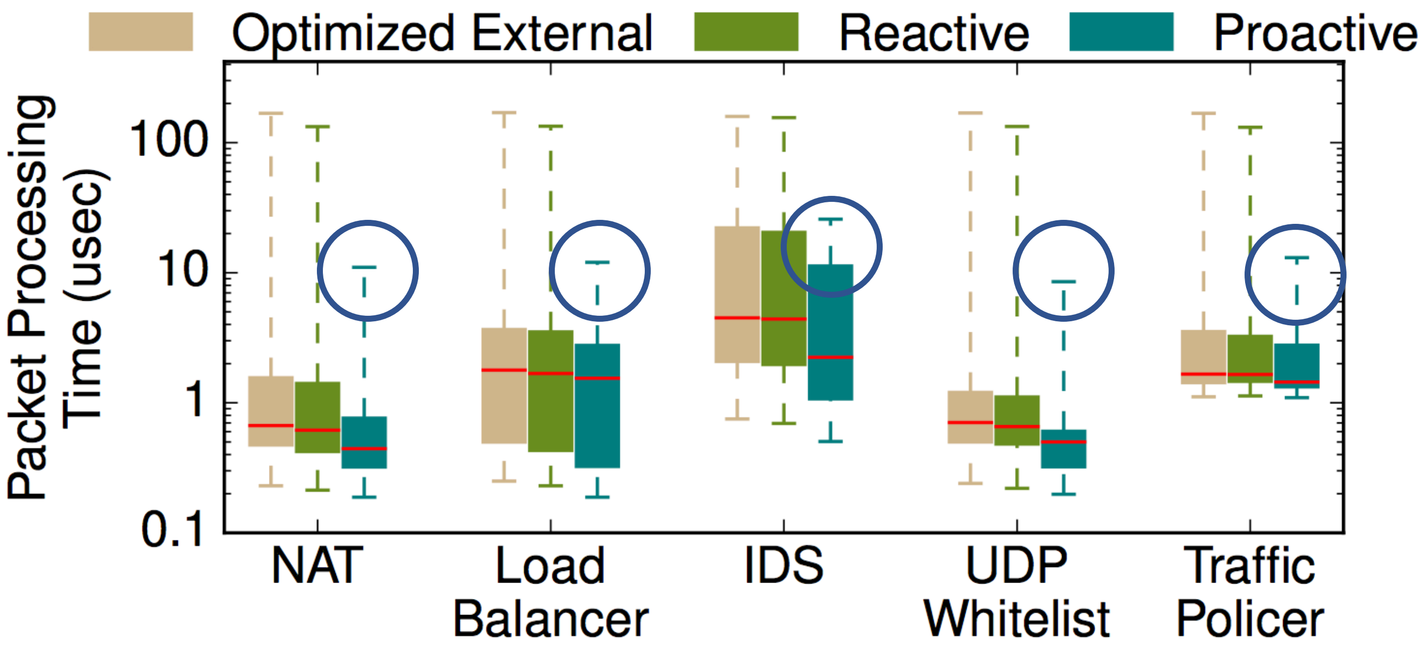


Baselines

Tail latencies dominated by RTT

SNF Evaluation: State Management



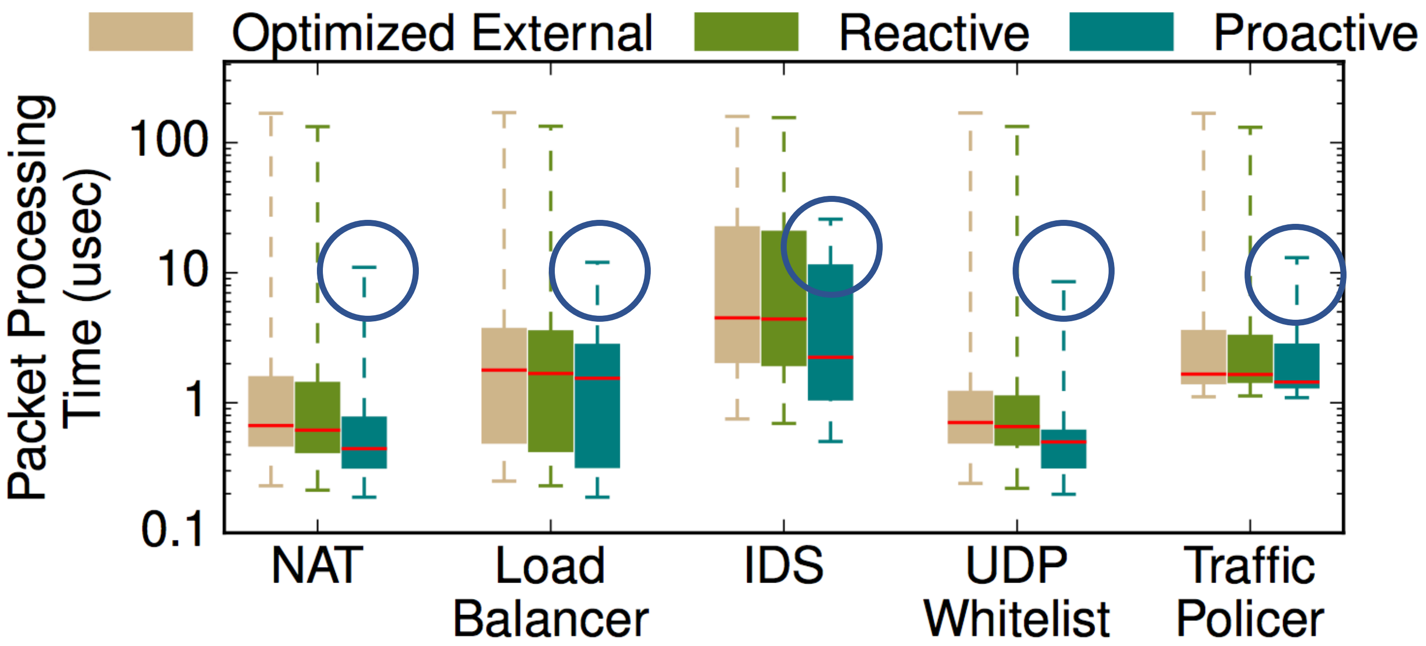
Baselines

Tail latencies dominated by RTT

Proactive (SNF)

Low tail latencies due to proactive state transfers

SNF Evaluation: State Management



Baselines

Tail latencies dominated by RTT

Proactive (SNF)

Low tail latencies due to proactive state transfers

12-15x

improvement in tail latencies

SNF Summary

Performant and efficient serverless platform that offers NFaaS

Decouple work allocation granularity (flowlet) from billing (packet) granularity

Realize the notion of ephemeral stateful functions

SNF Summary

Performant and efficient serverless platform that offers NFaaS

Decouple work allocation granularity (flowlet) from billing (packet) granularity

Realize the notion of ephemeral stateful functions

More details in paper

How to ensure state fault tolerance?	How to deal with adversarial flowlets?	……..

Thank you!

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SNF: Serverless Network Functions

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