

Split / Merge

System Support for Elastic Execution in Virtual Middleboxes



Shriram **RAJAGOPALAN** IBM Research & UBC

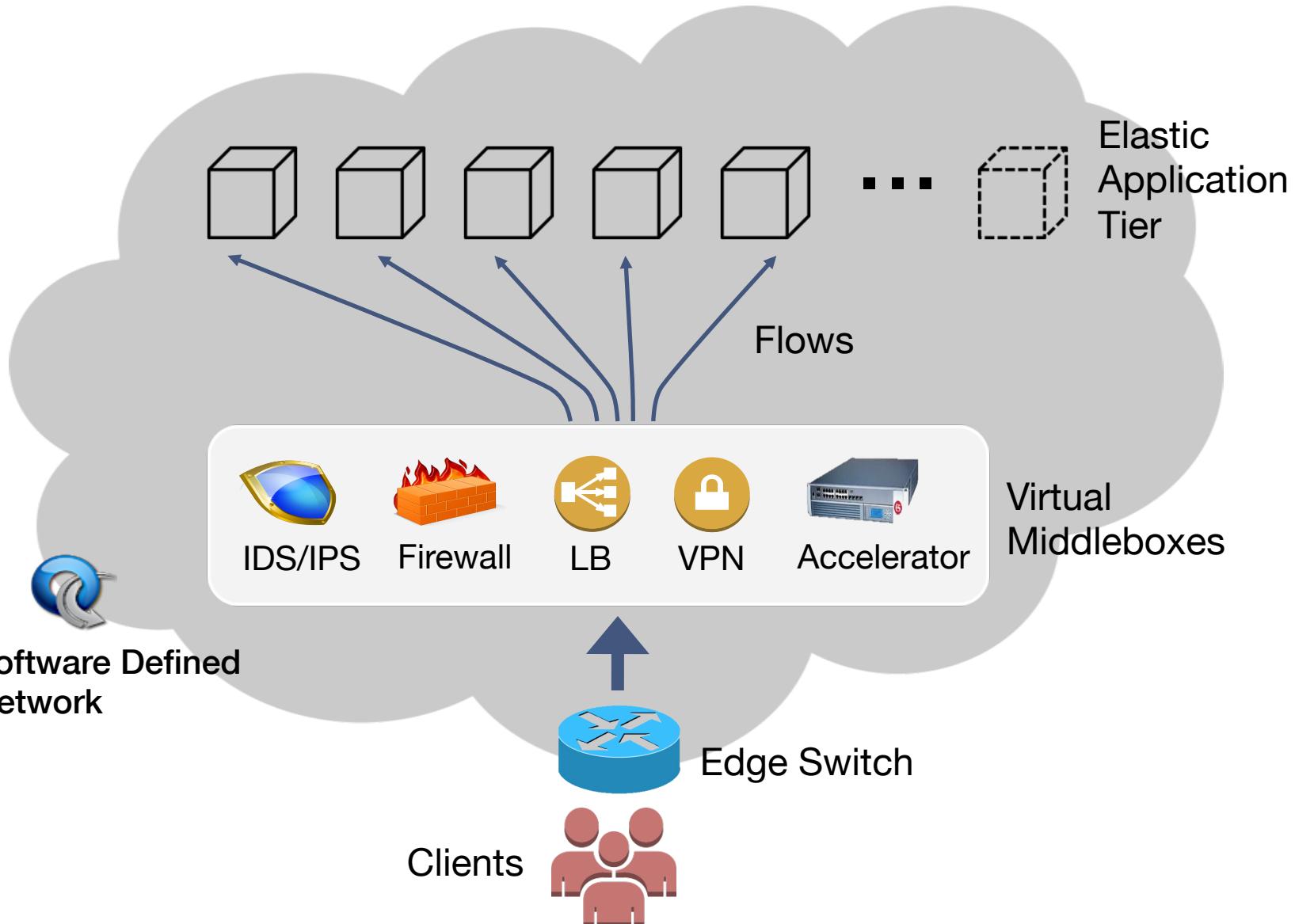
Dan **WILLIAMS** IBM Research

Hani **JAMJOOM** IBM Research

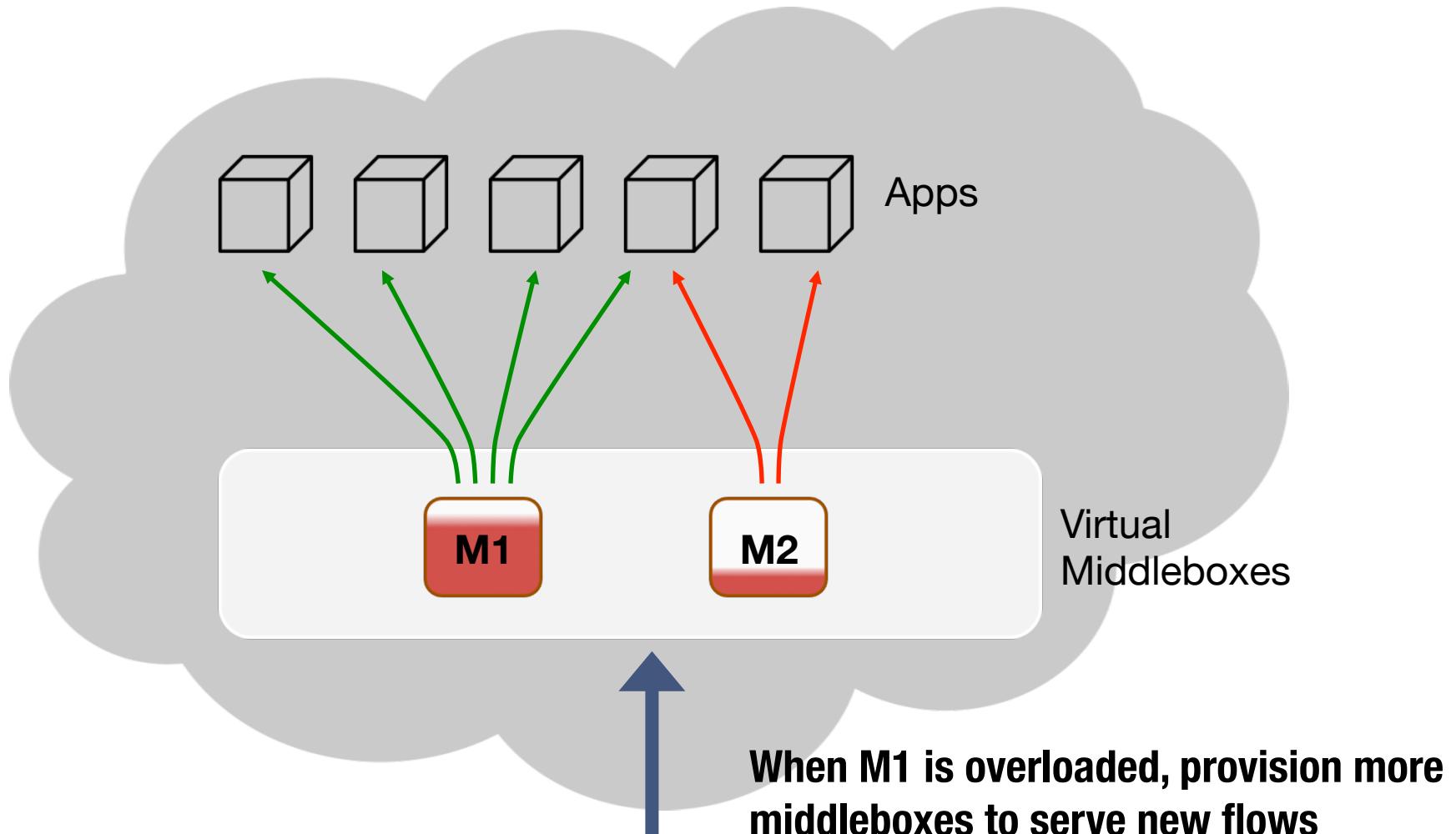
Andrew **WARFIELD** UBC

The Problem

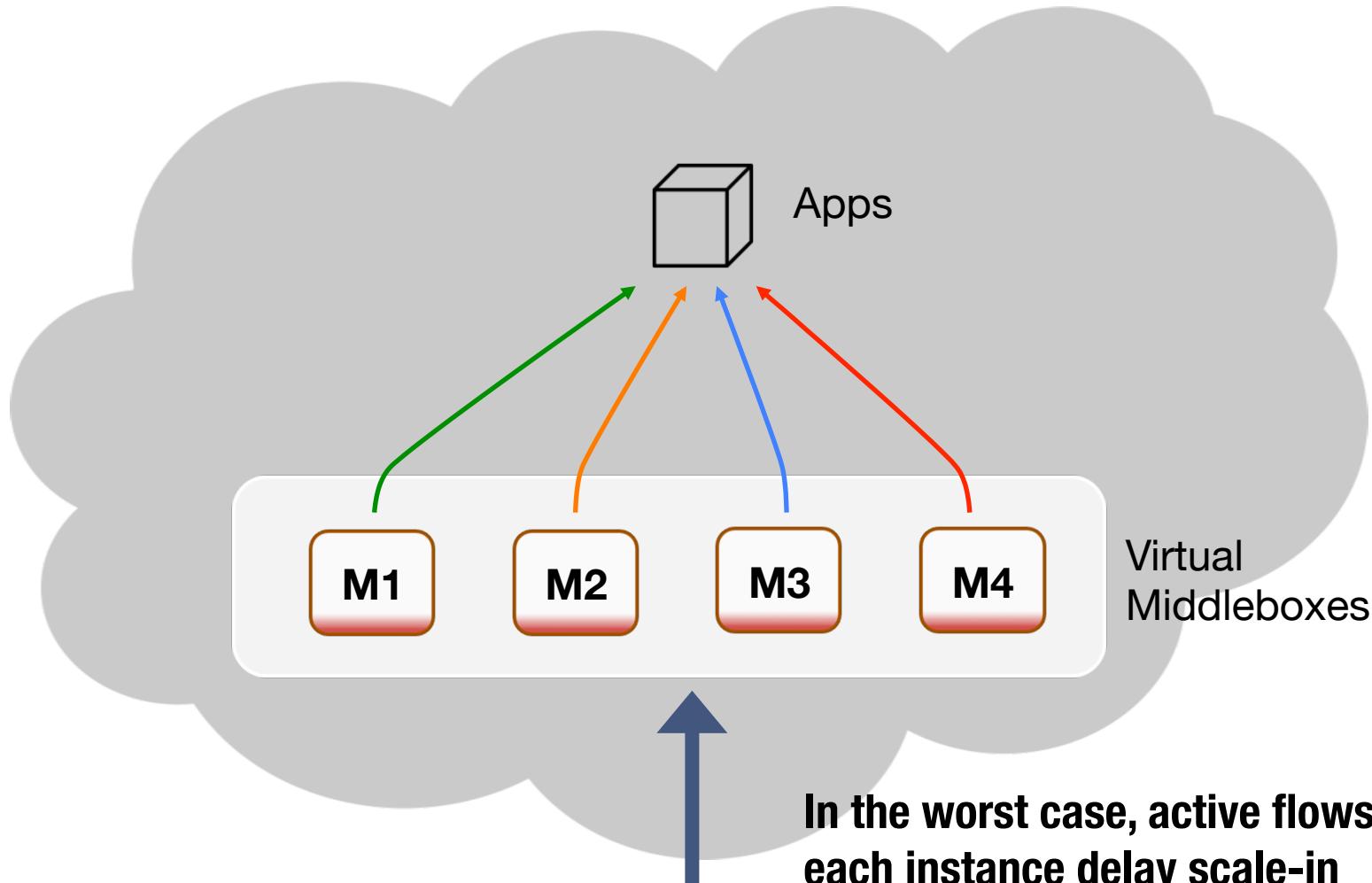
Elastic Applications Need Elastic Middleboxes



Hotspots Cannot be Alleviated Quickly

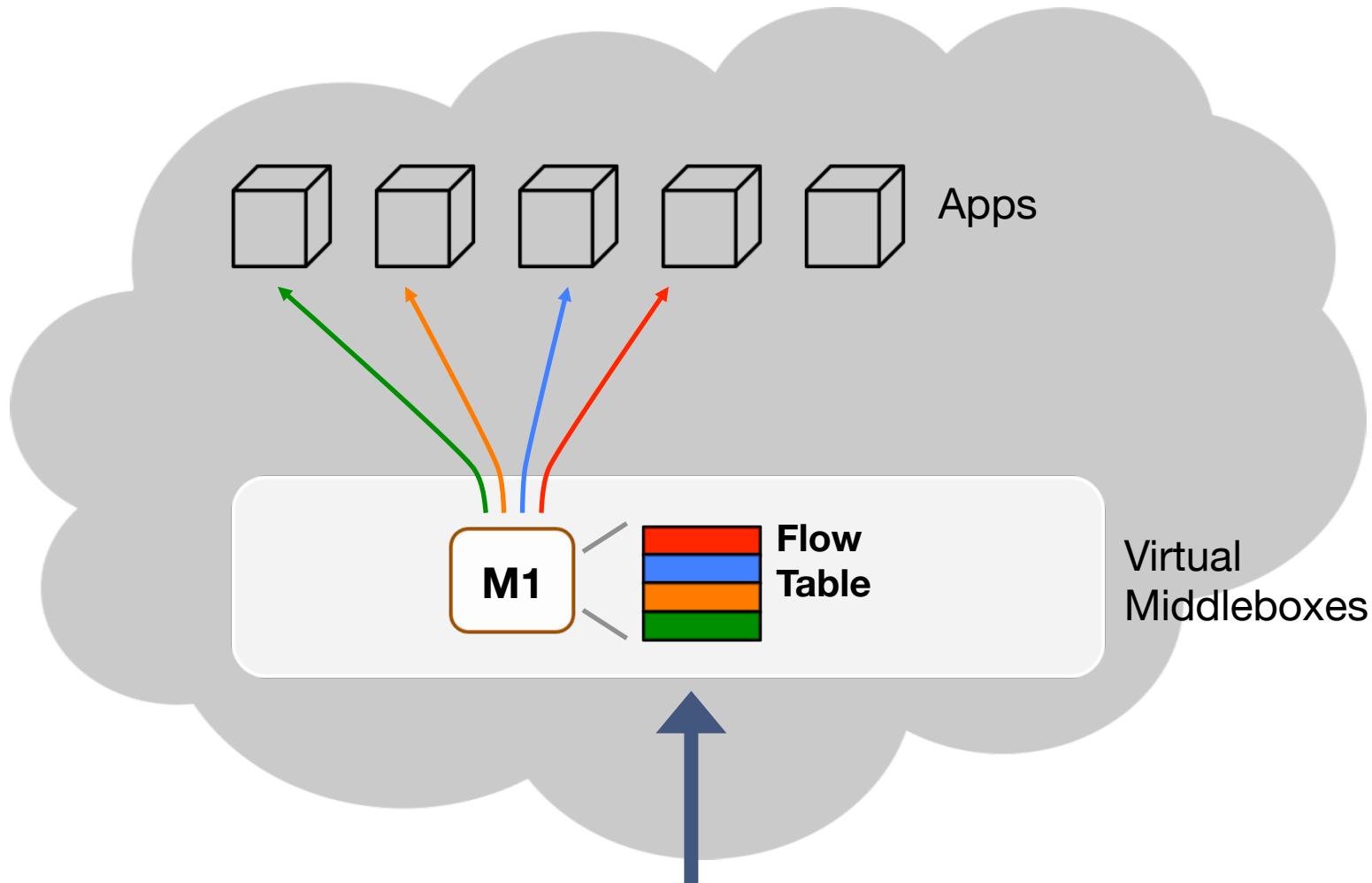


Scaling Inefficiencies Lead to Poor Utilization

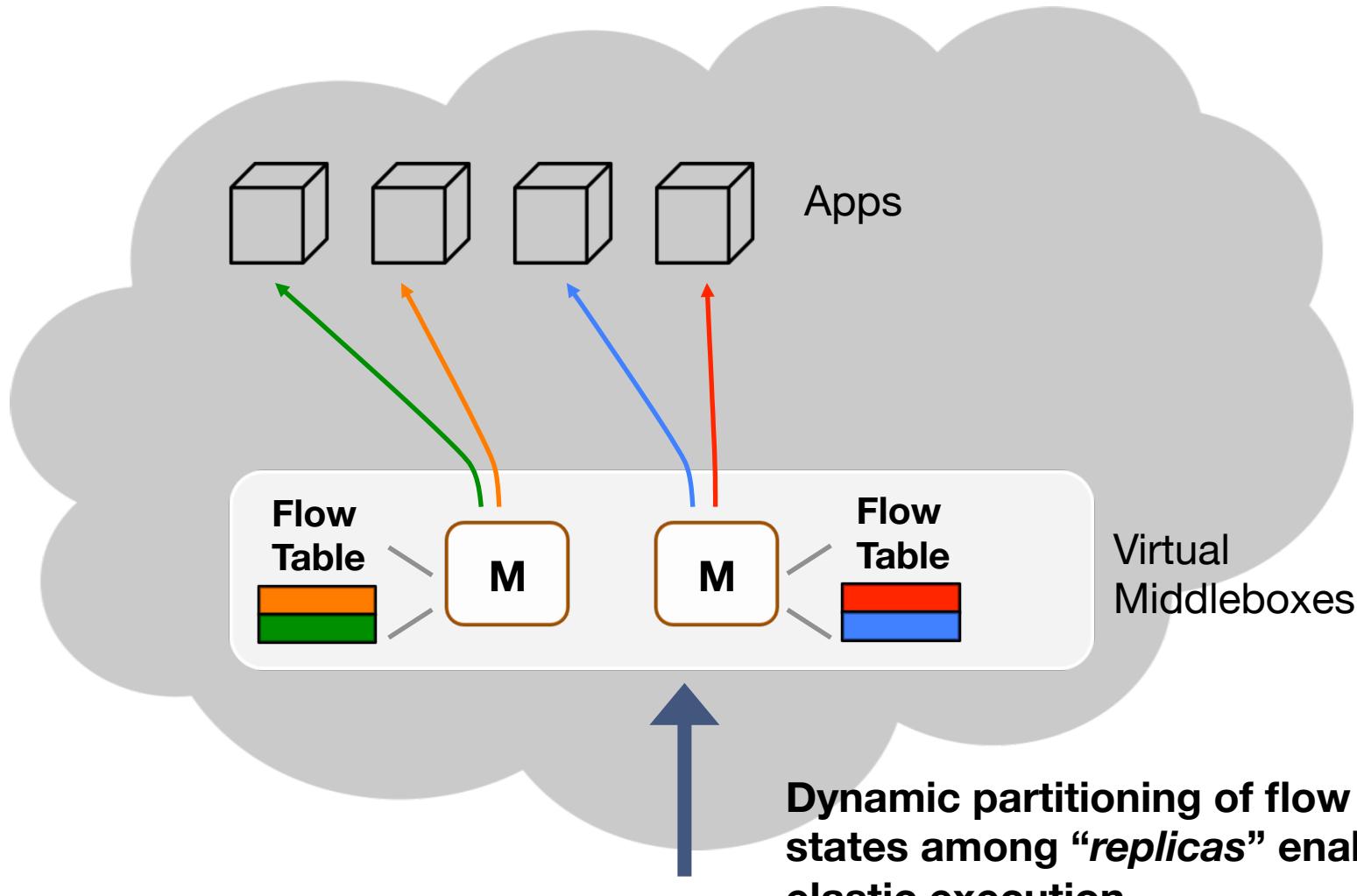


The Insight

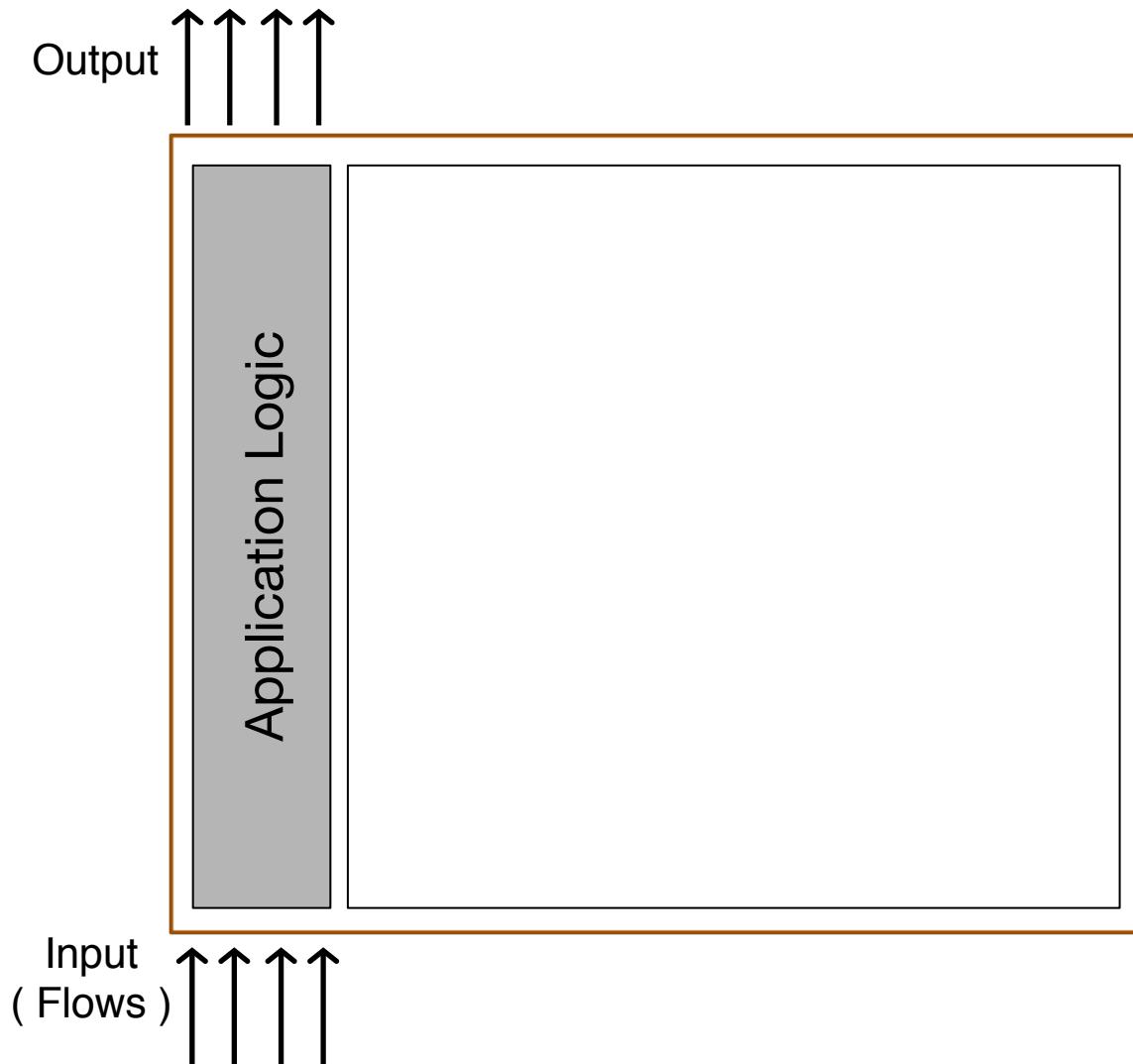
Flow State is Naturally Partitioned



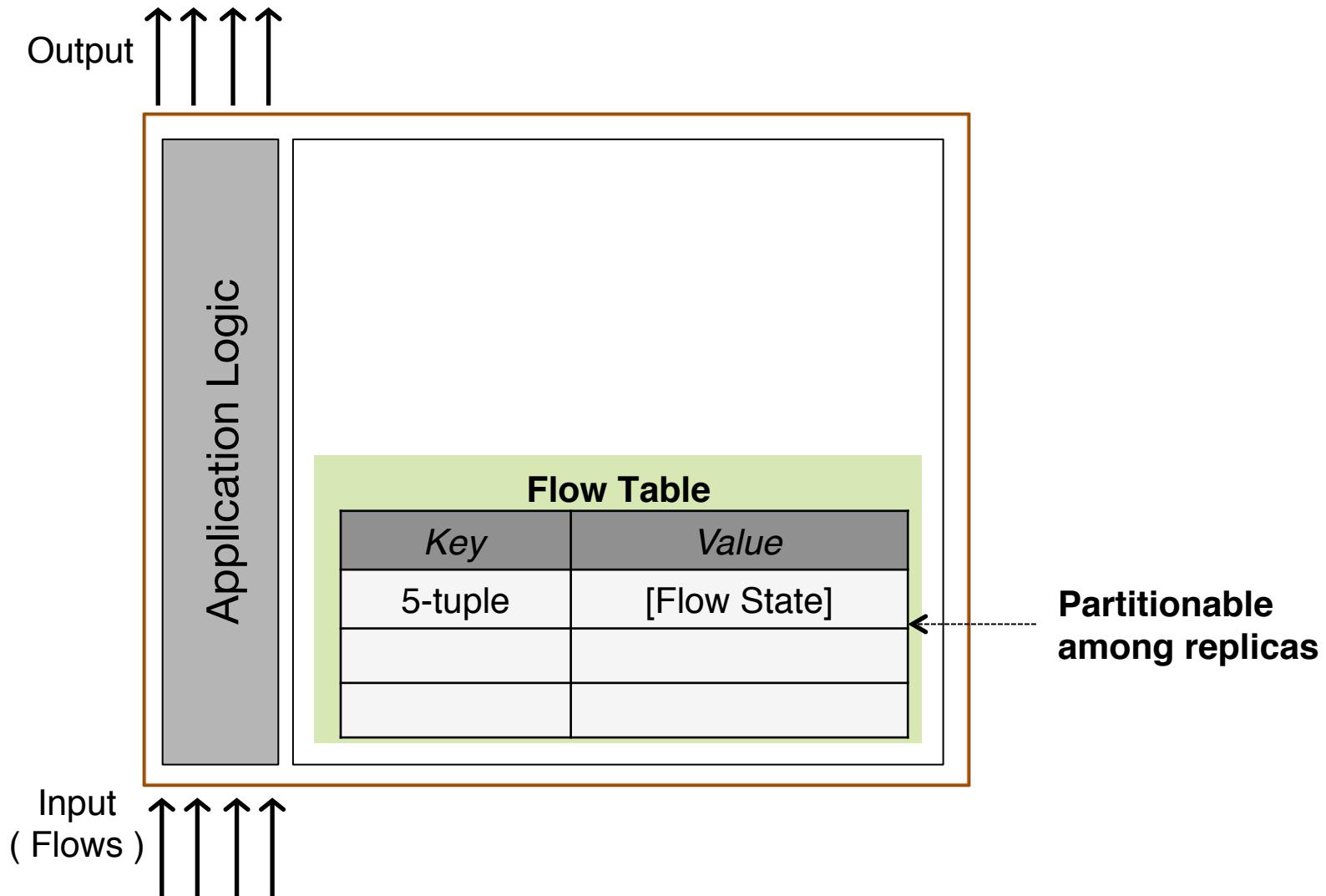
Enabling Elasticity in Virtual Middleboxes



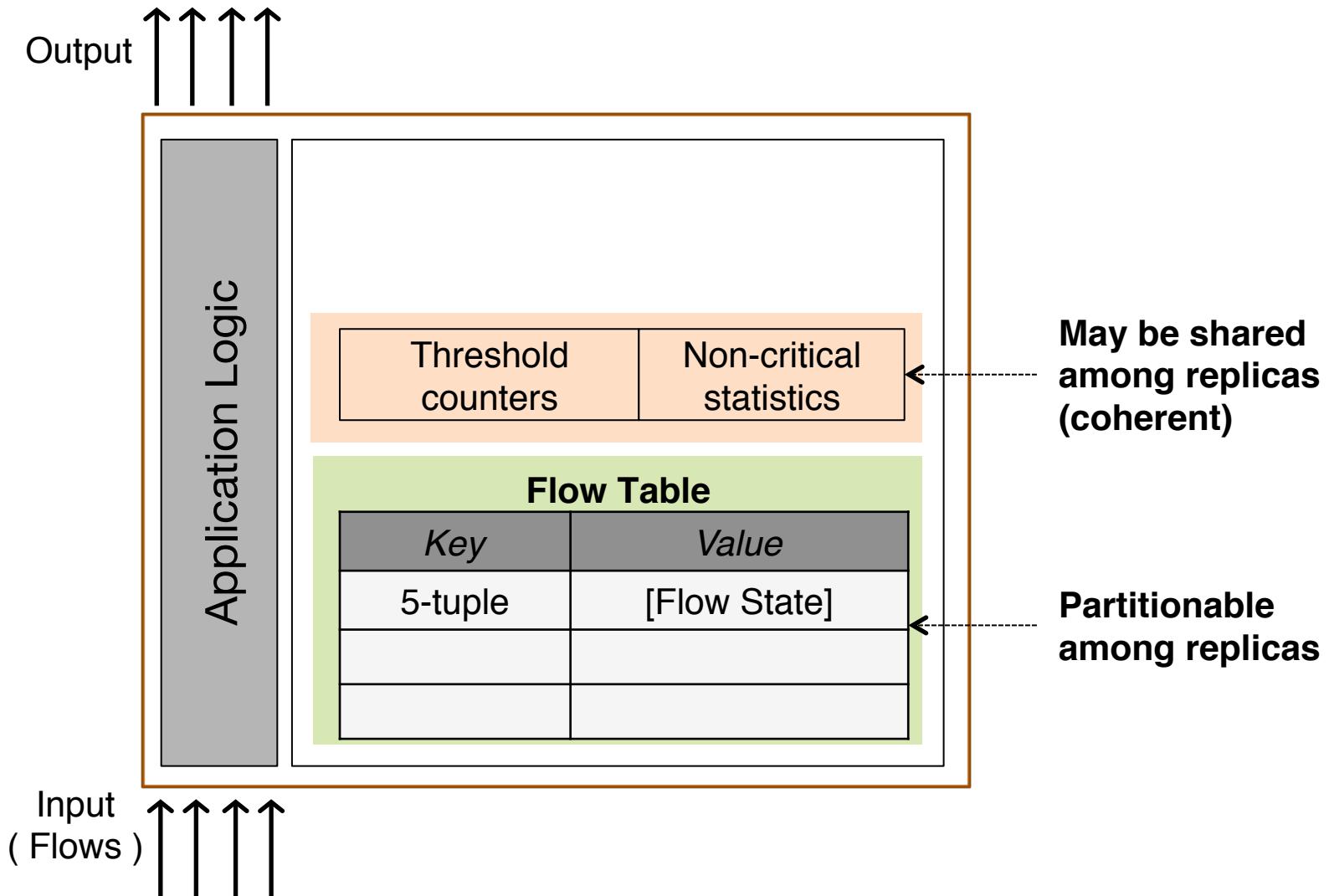
Understanding the State Inside a Middlebox



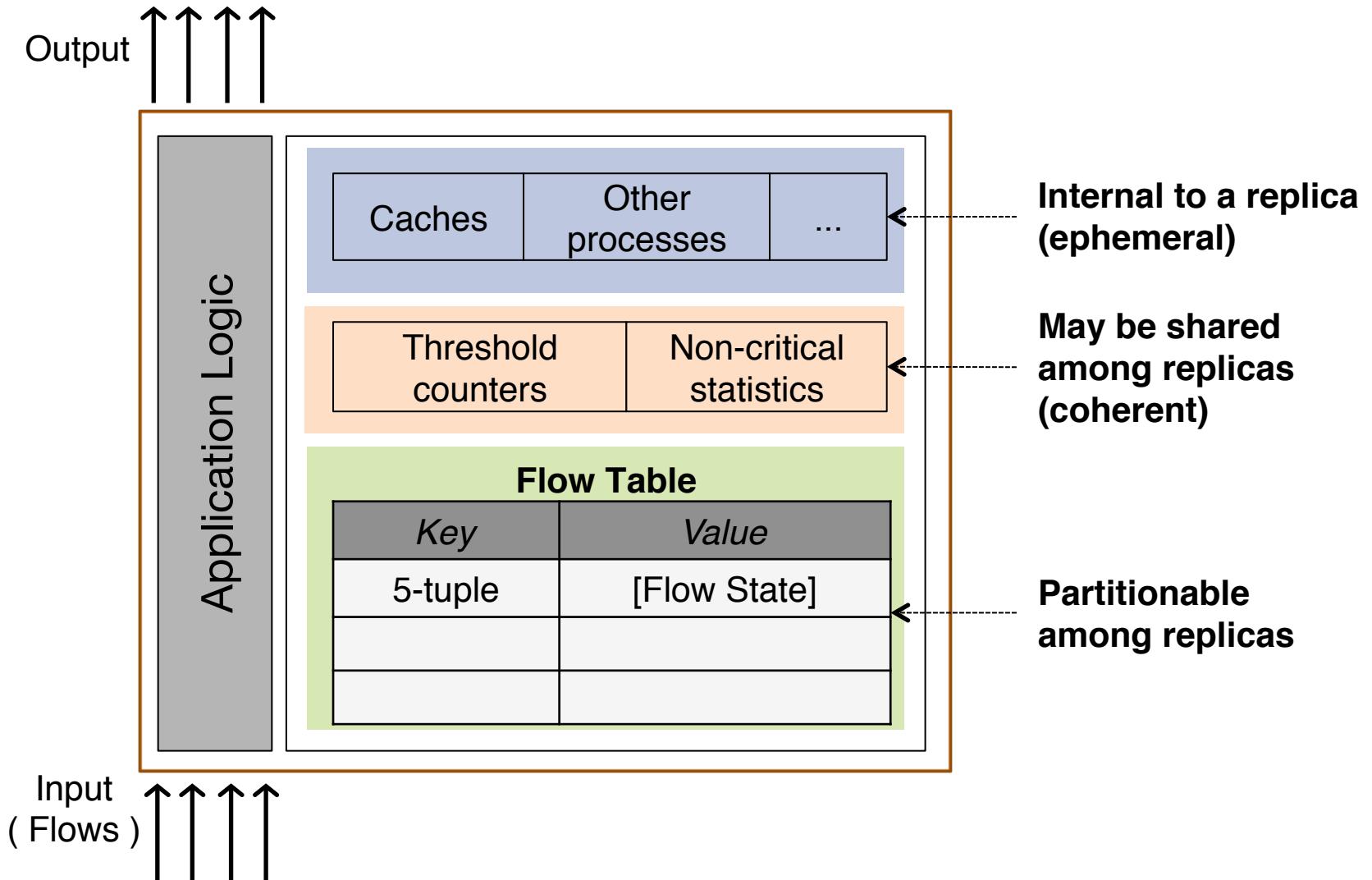
Understanding the State Inside a Middlebox



Understanding the State Inside a Middlebox

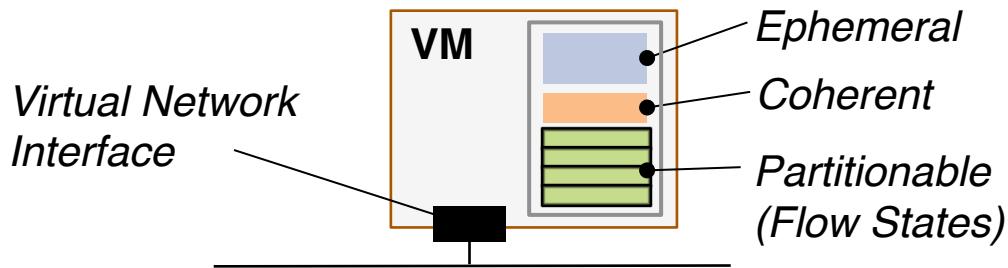


Understanding the State Inside a Middlebox

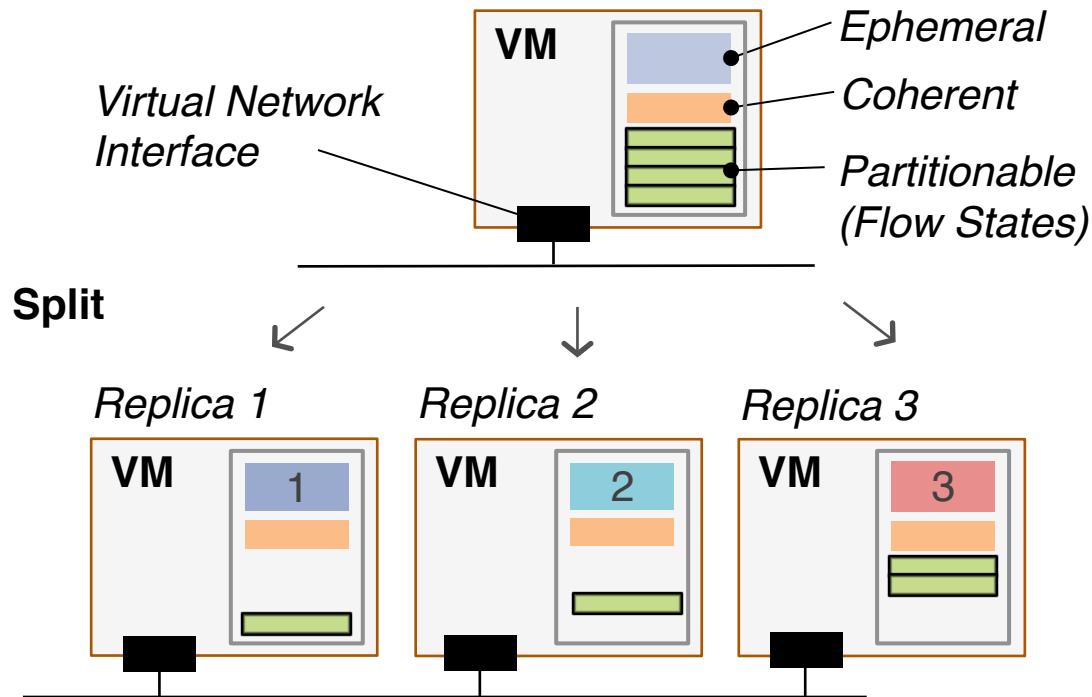


Our Contribution

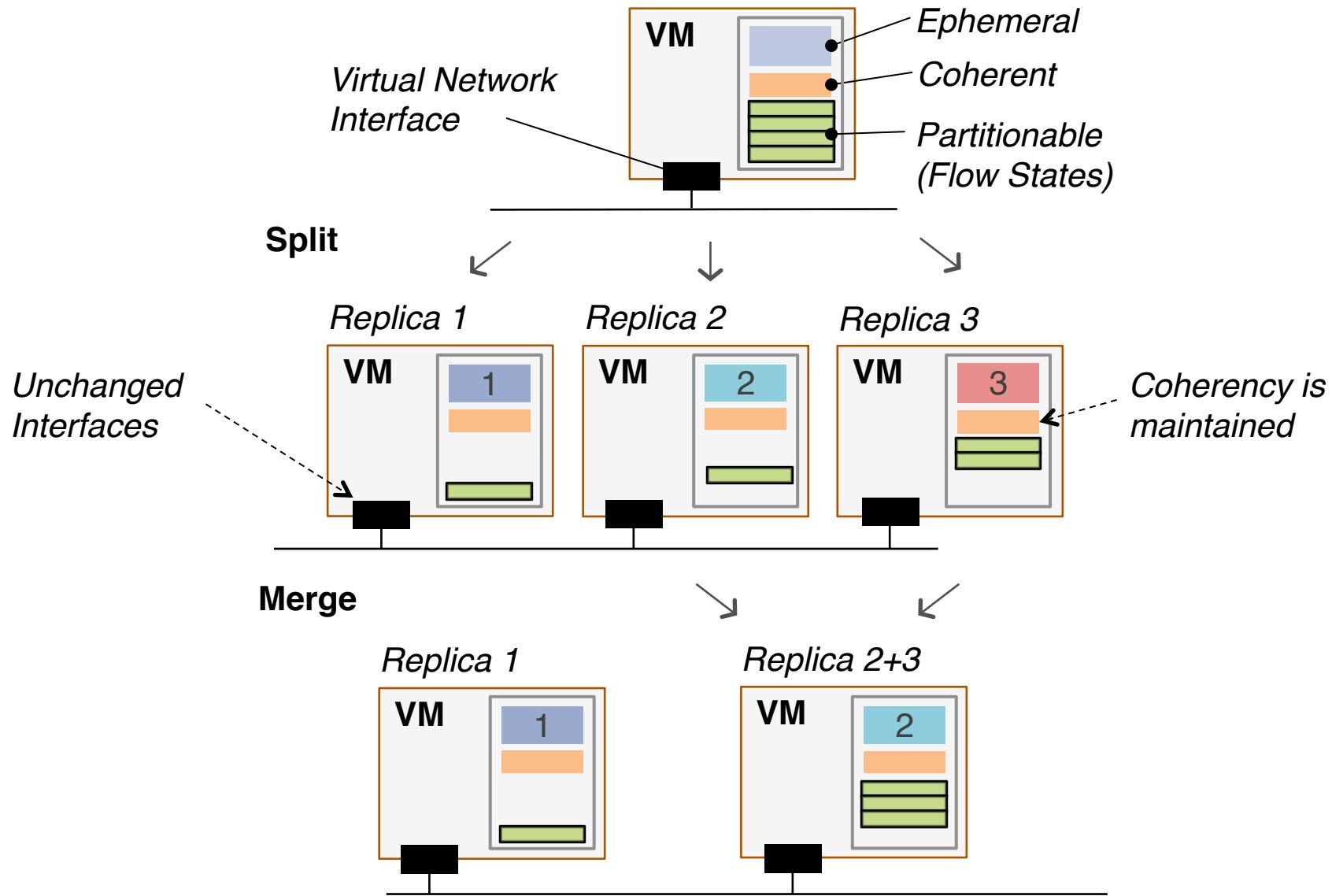
Split/Merge: A State-Centric Approach to Elasticity



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Split/Merge: A State-Centric Approach to Elasticity

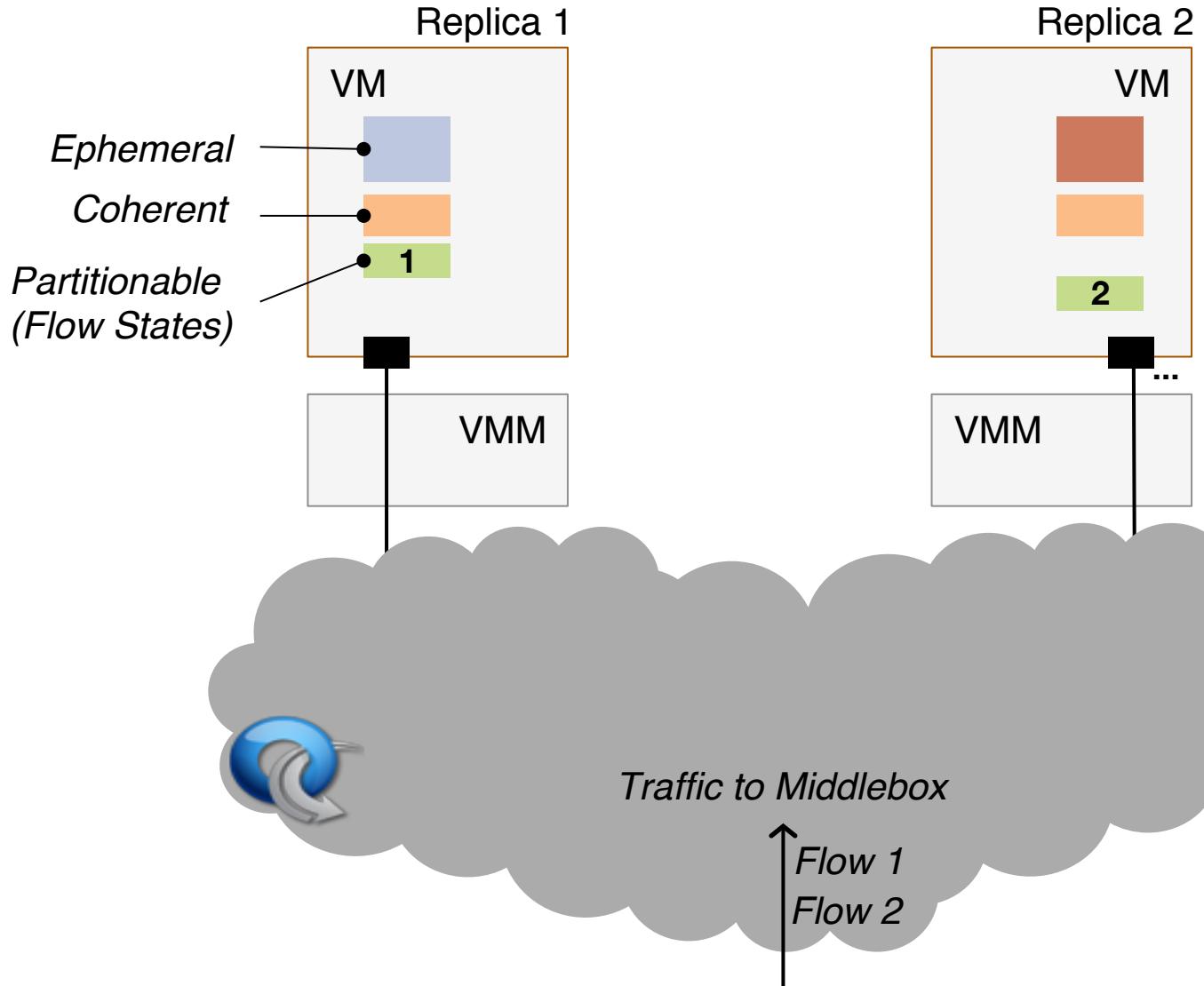


Implementation

FreeFlow

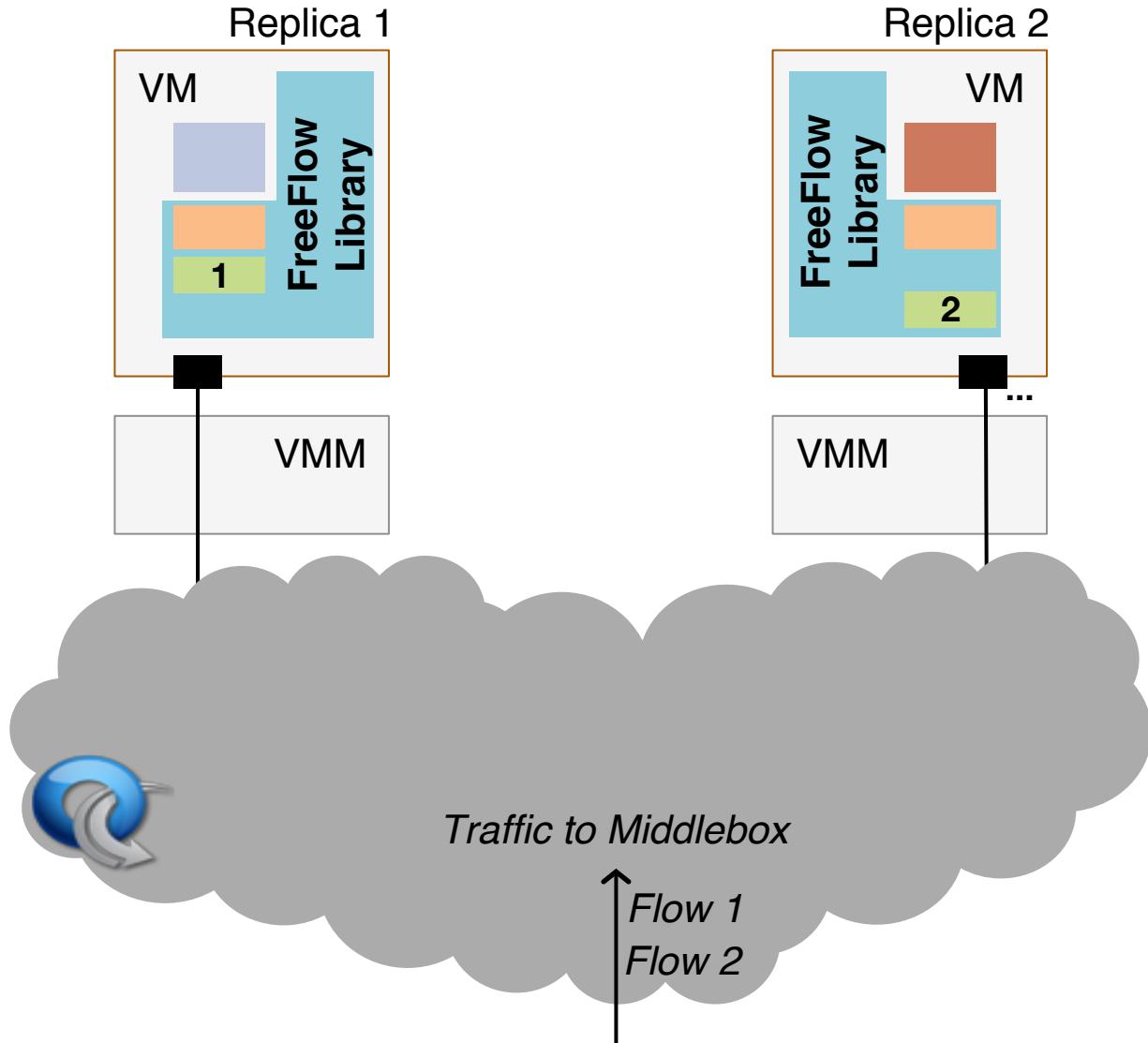
- A VMM based runtime that provides Split/Merge abstraction to applications
- Developers modify application code to annotate flow state
- FreeFlow takes care of the rest!

FreeFlow: A Split/Merge Implementation



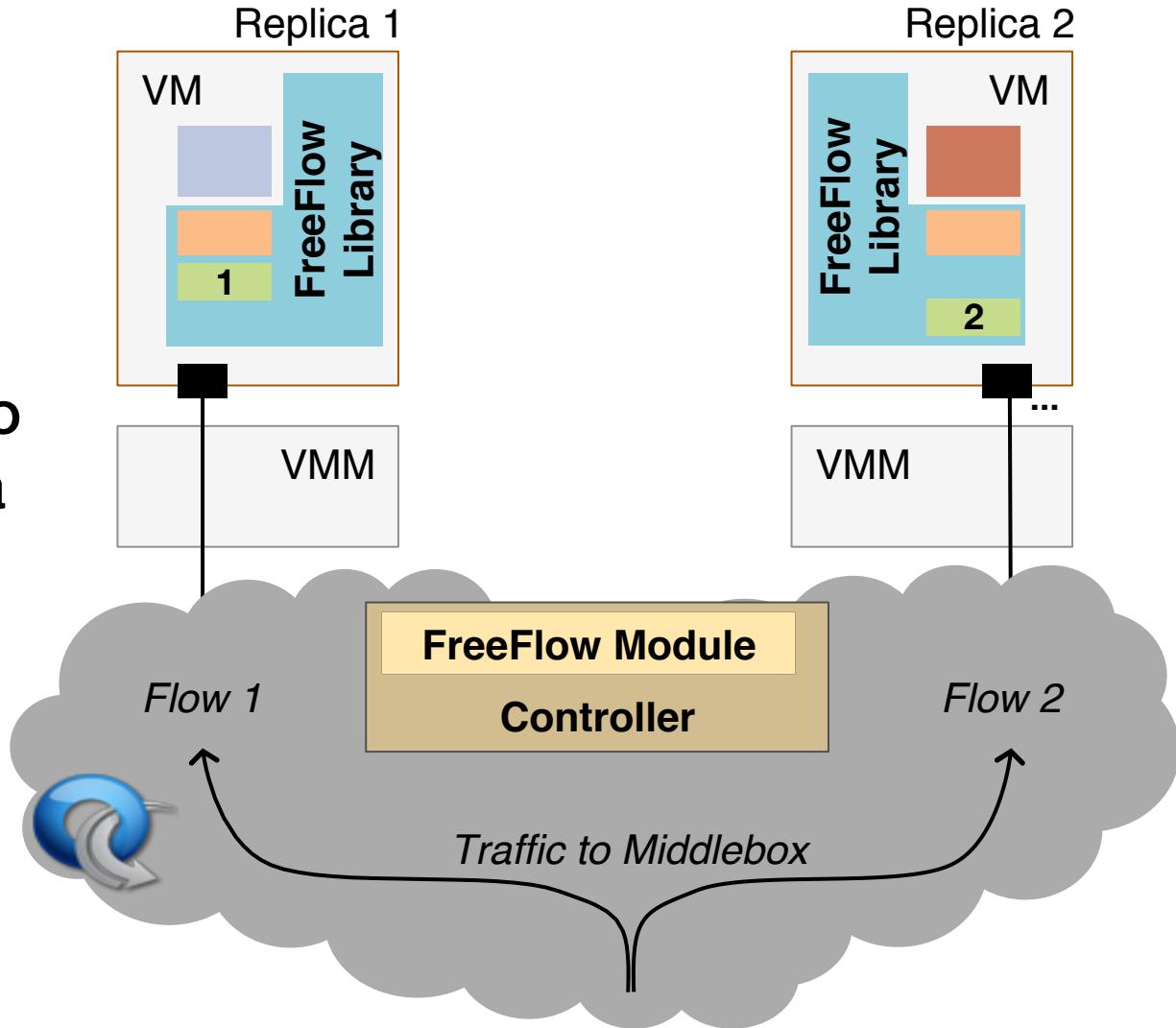
FreeFlow: A Split/Merge Implementation

- Need to manage application state



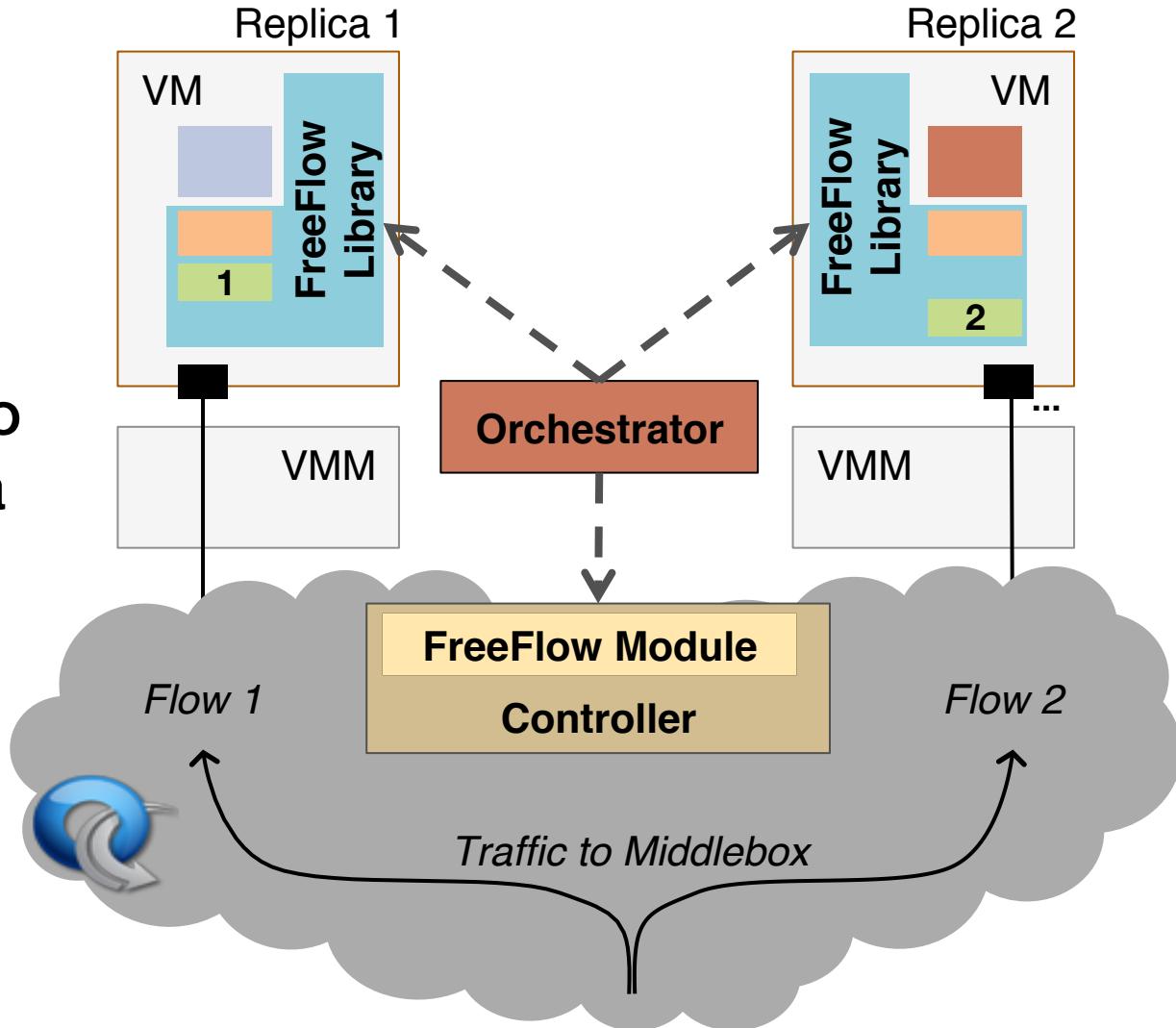
FreeFlow: A Split/Merge Implementation

- Need to manage application state
- Need to ensure flows are routed to the correct replica



FreeFlow: A Split/Merge Implementation

- Need to manage application state
- Need to ensure flows are routed to the correct replica
- Need to decide when to split or merge a replica



Annotating State using FreeFlow API

```
create_flow(flow_key, size)
delete_flow(flow_key)
flow_state get_flow(flow_key)
put_flow(flow_key)

flow_timer(flow_key, timeout, callback)
```

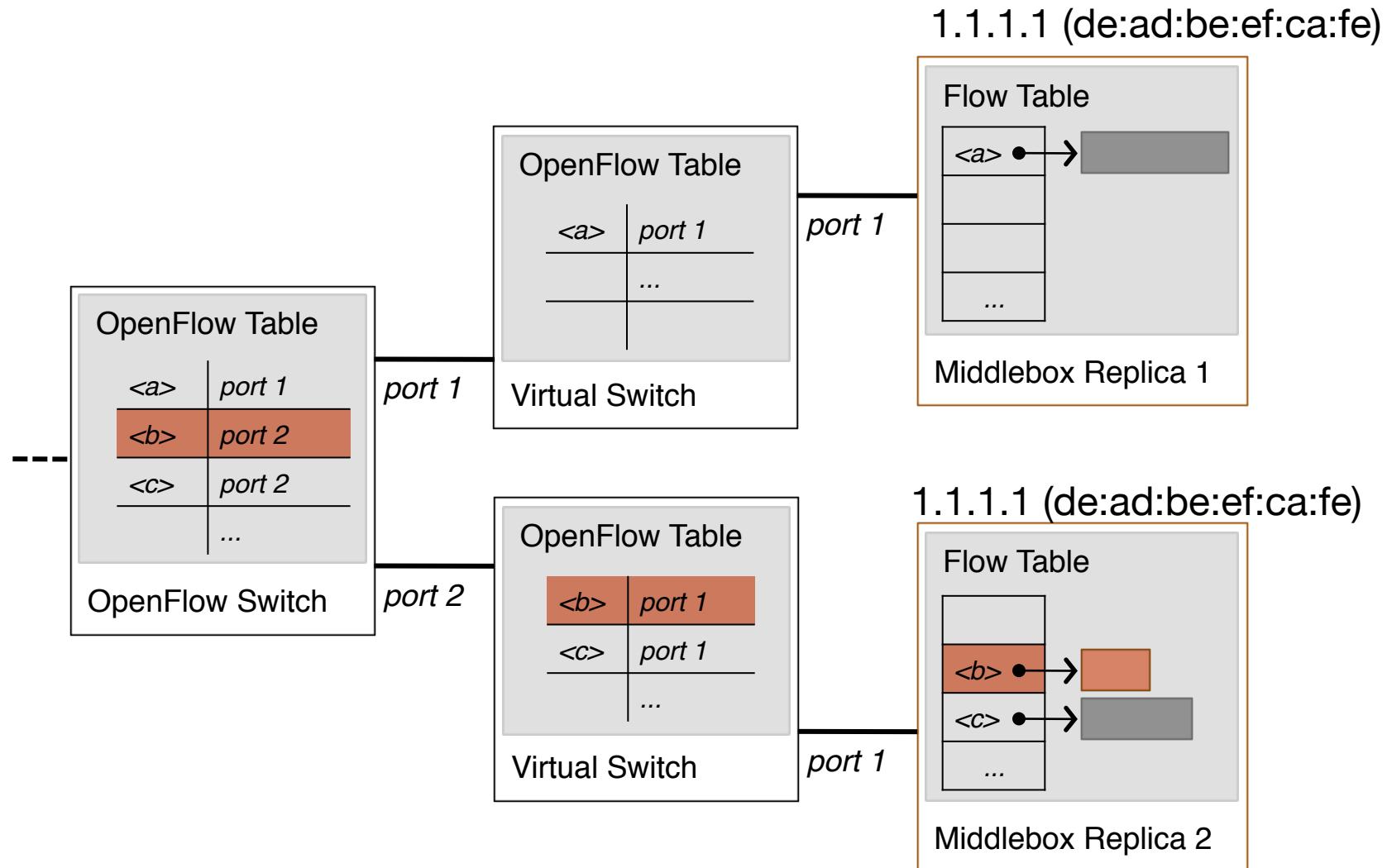
Partitioned State API

```
create_shared(key, size, cb)
delete_shared(key)
```

Coherent State API

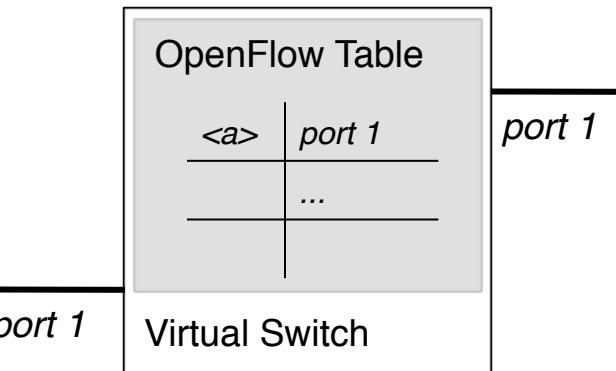
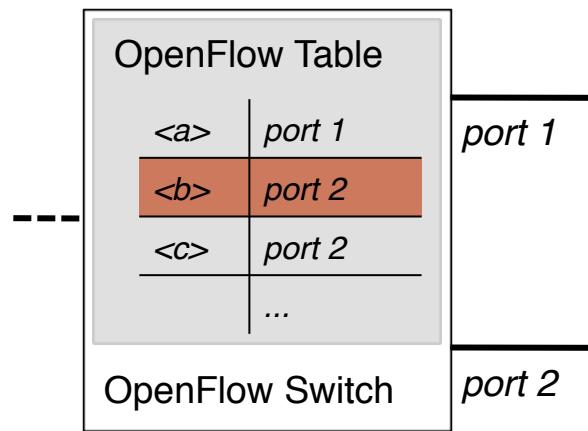
```
state get_shared(key, flags) // synch / pull / local
put_shared(key, flags)      // synch / push / local
```

Forwarding Flows Correctly using OpenFlow

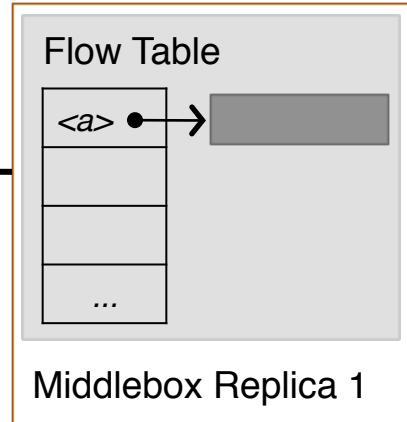


Flow Migration

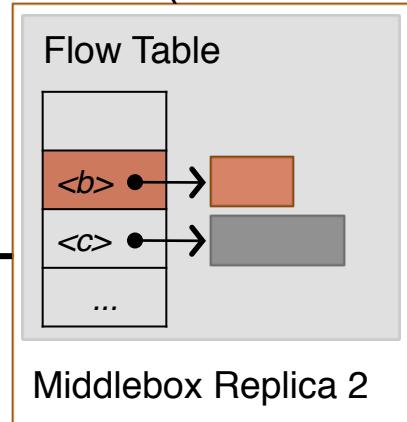
Migrating $\langle b \rangle$ from replica 2 to replica 1



1.1.1.1 (de:ad:be:ef:ca:fe)

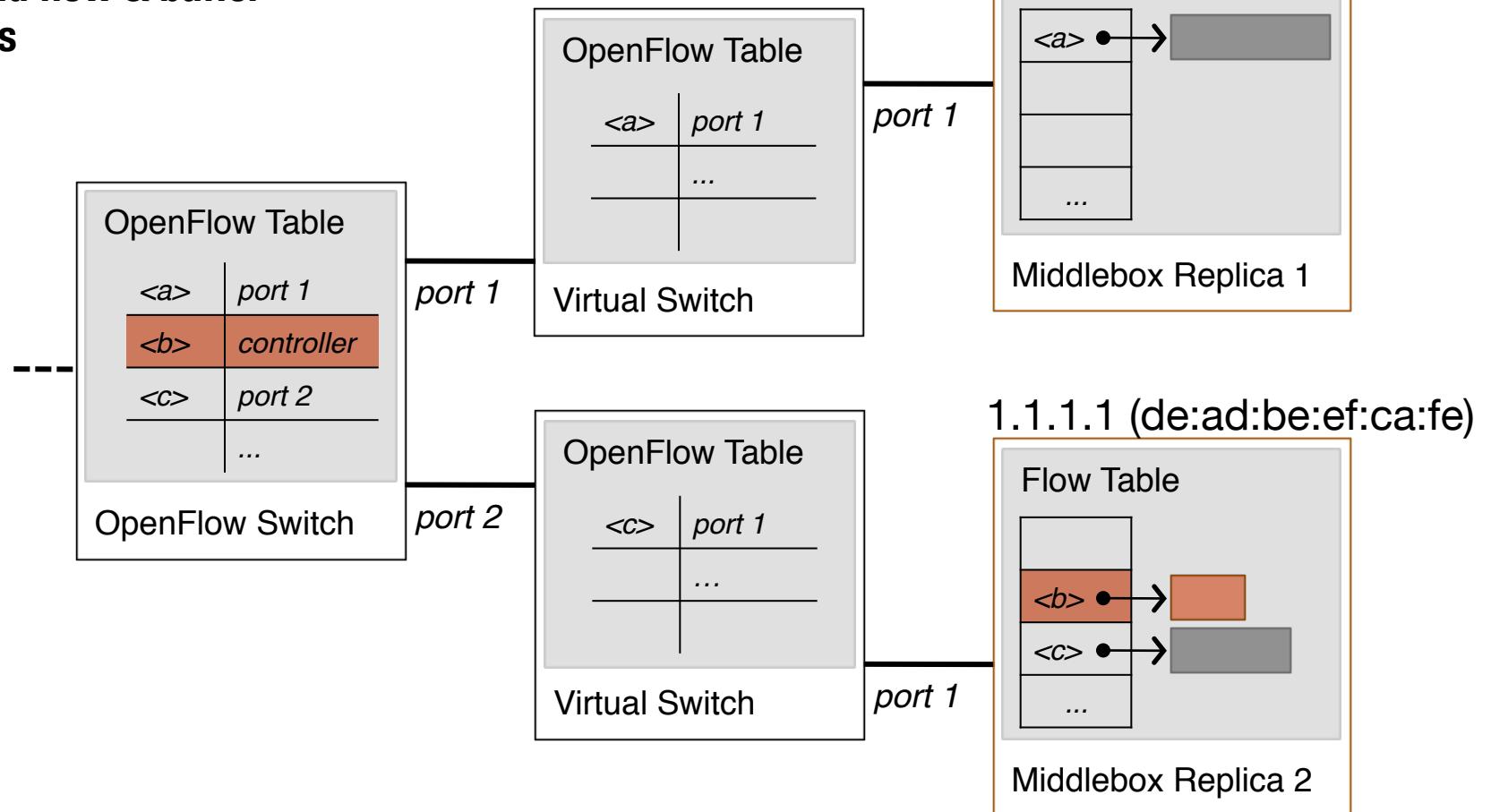


1.1.1.1 (de:ad:be:ef:ca:fe)



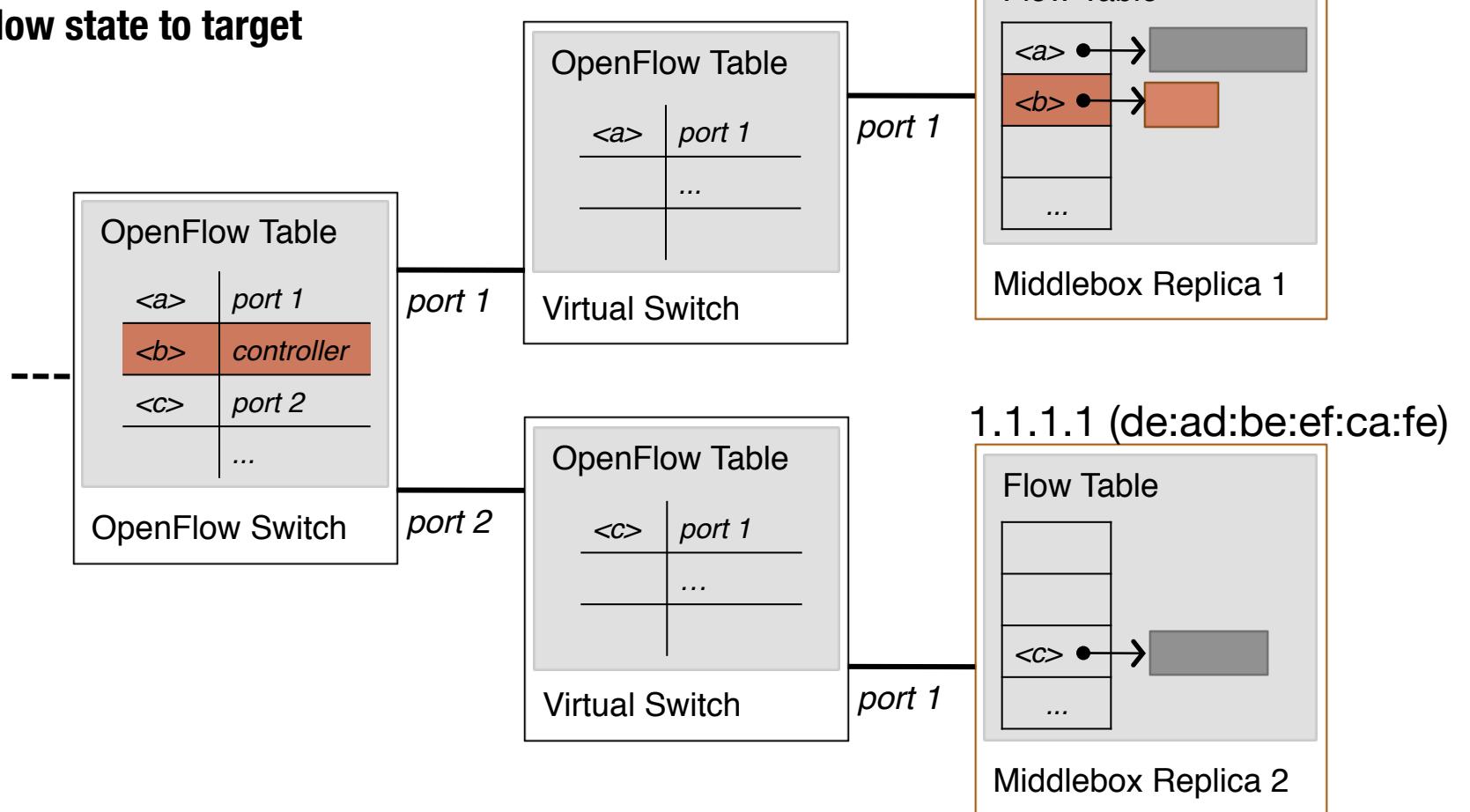
Flow Migration

Suspend flow & buffer packets



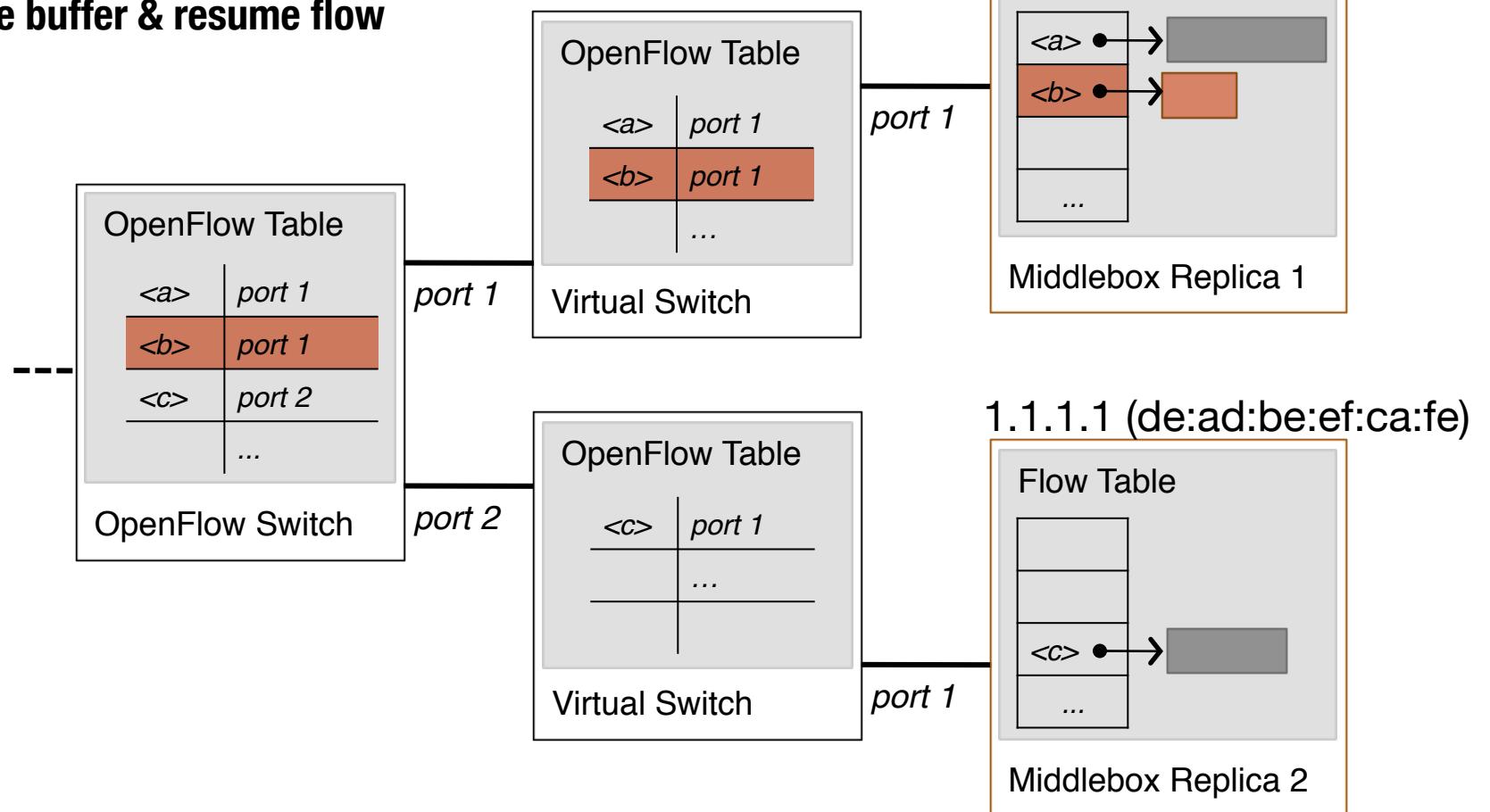
Flow Migration

Move flow state to target



Flow Migration

Release buffer & resume flow



Managing Coherent State

```
create_shared(key, size, cb)
```

```
delete_shared(key)
```

```
state get_shared(key, flags) // synch | pull | local
```

```
put_shared(key, flags)      // synch | push | local
```

Managing Coherent State

Strong Consistency

Distributed lock
for every update

```
create_shared("foo", 4, NULL)
while (1)
    process_packet()
    p_foo = get_shared("foo", synch)
    val = (*p_foo)++
    put_shared("foo", synch)
    if (val > threshold)
        bar()
```

Middlebox applications rarely need strong consistency!

Managing Coherent State

Eventual Consistency

```
create_shared("foo", 4, merge_fn)
while (1)
    process_packet()
    p_foo = get_shared("foo", local)
    val = (*p_foo)++
    put_shared("foo", local)
    if (val > threshold)
        bar()
    put_shared("foo", push)
```

Hi frequency
local updates

Periodic global
updates

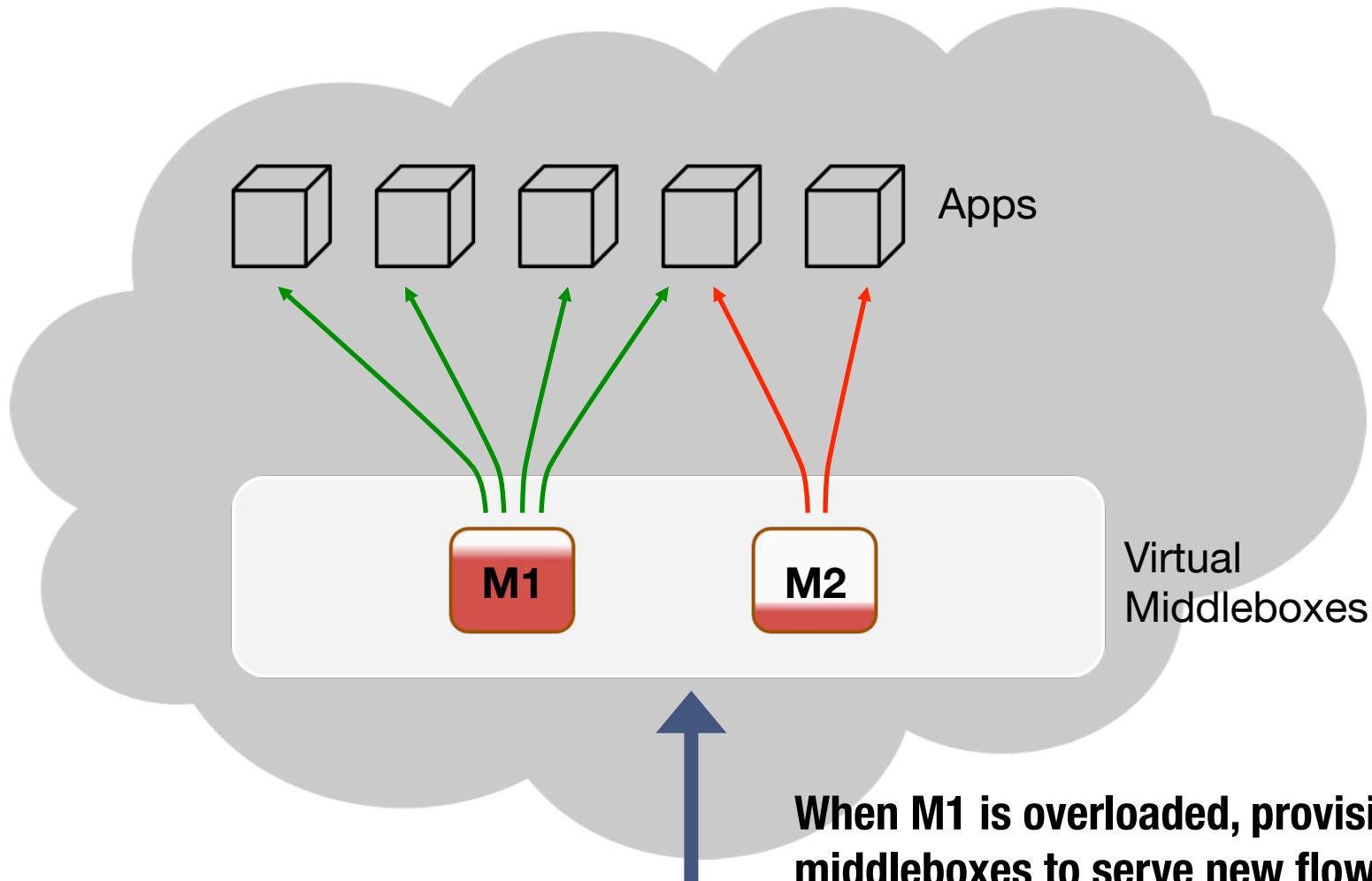


Evaluation

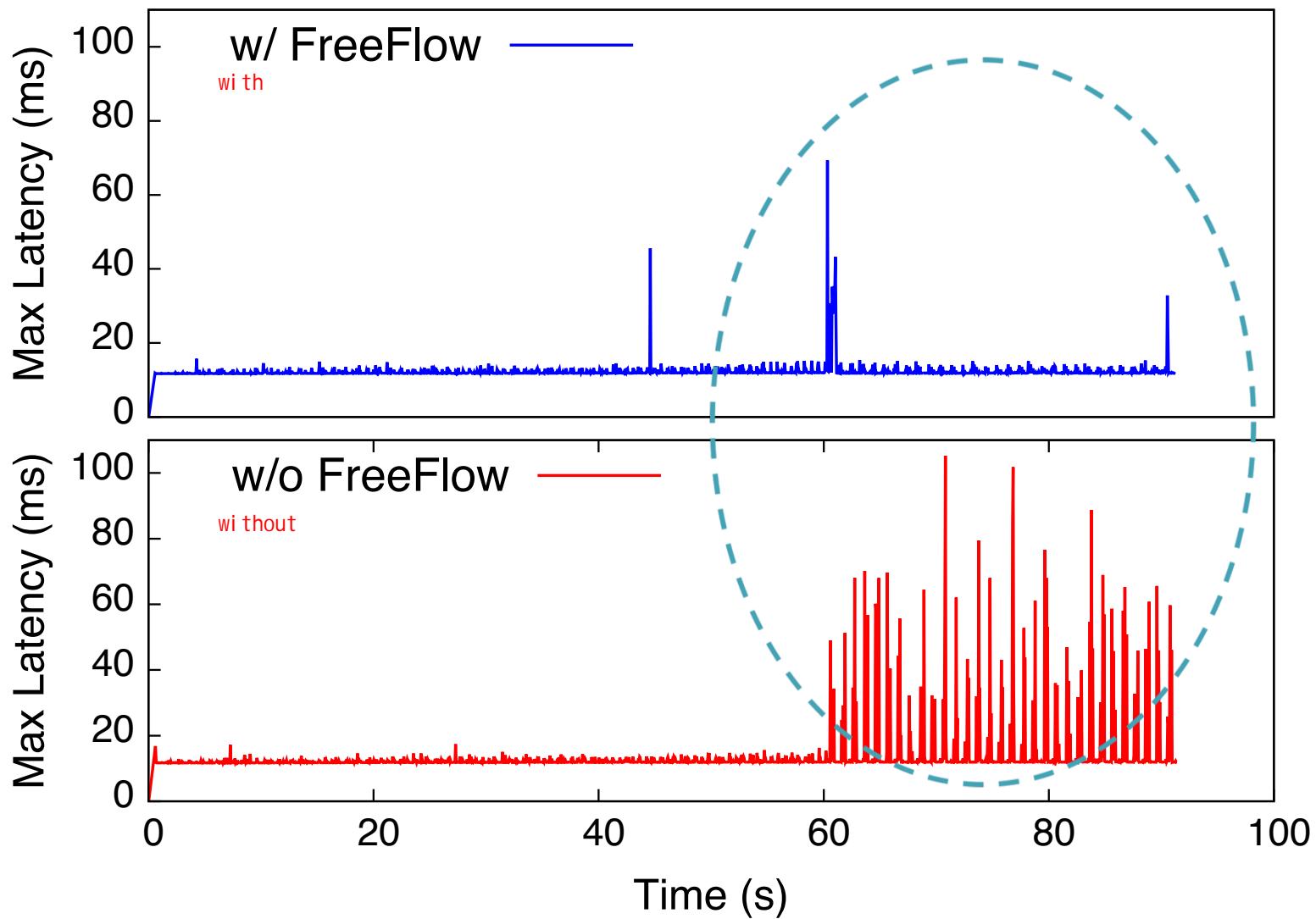
Evaluation Overview

- Eliminating hotspots during scale-out
- Fast and efficient scale-in
- Split/Merge Bro during a load burst

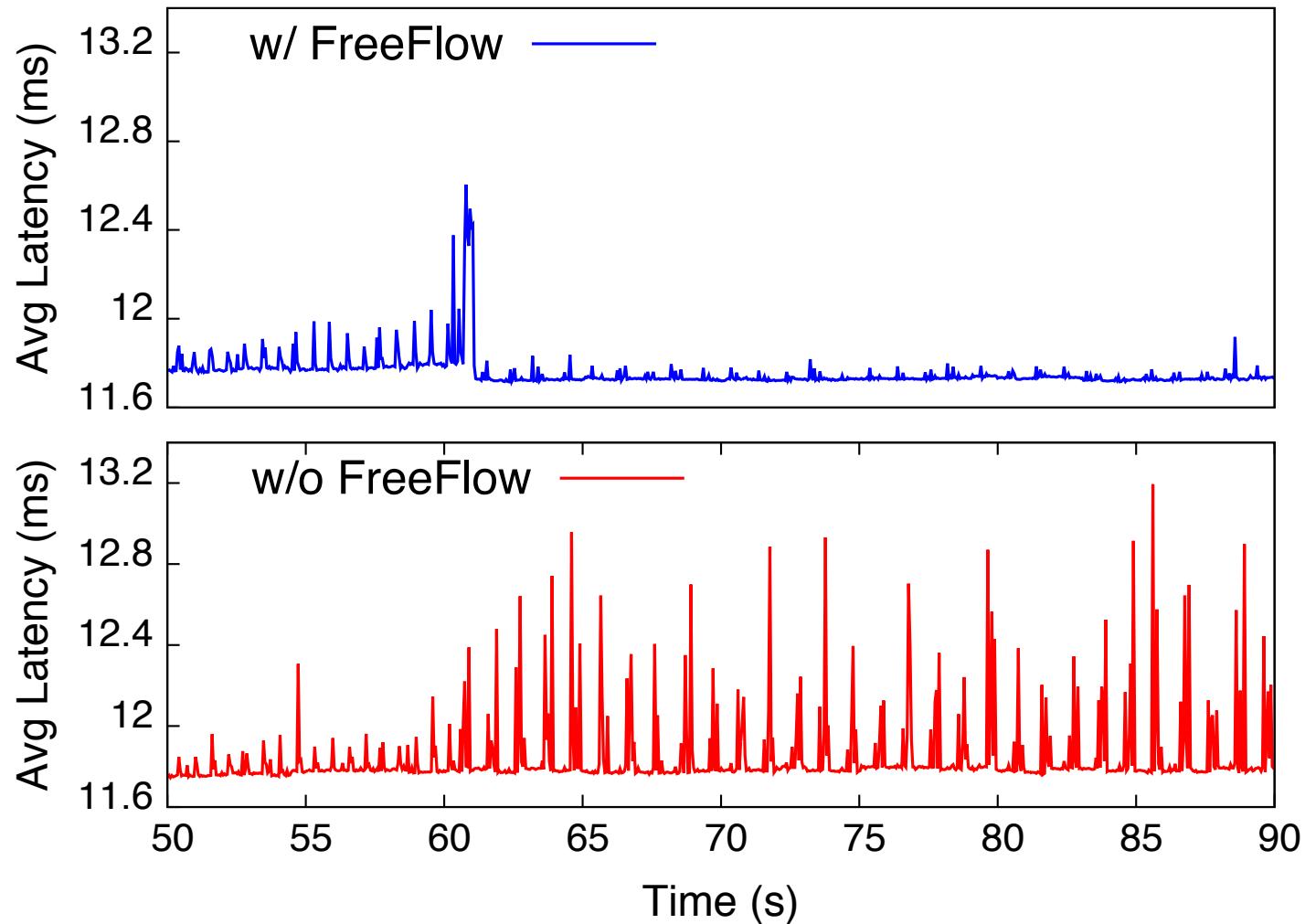
Hotspots Cannot be Alleviated Quickly



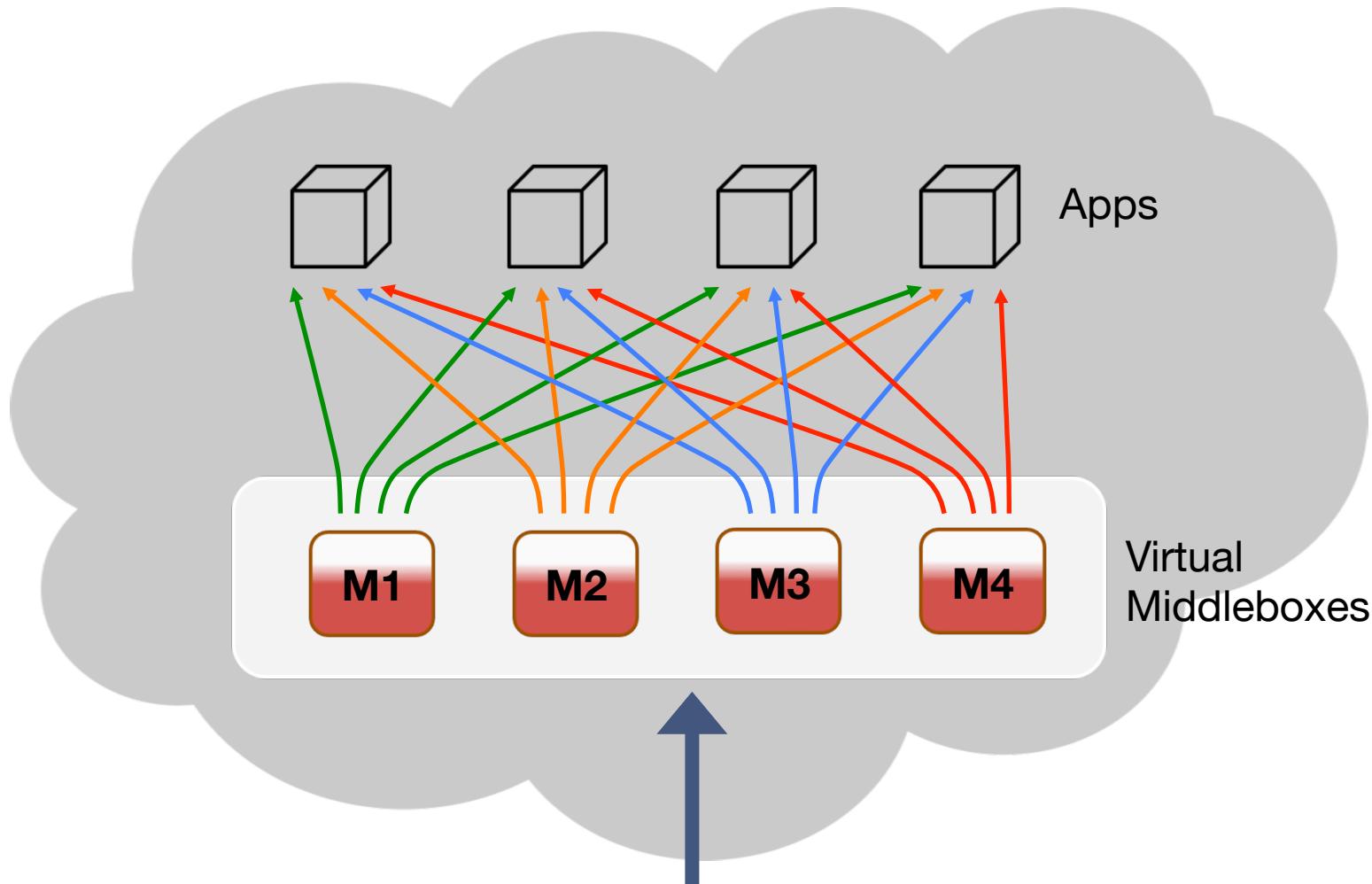
Eliminating Hotspots by Shedding Load



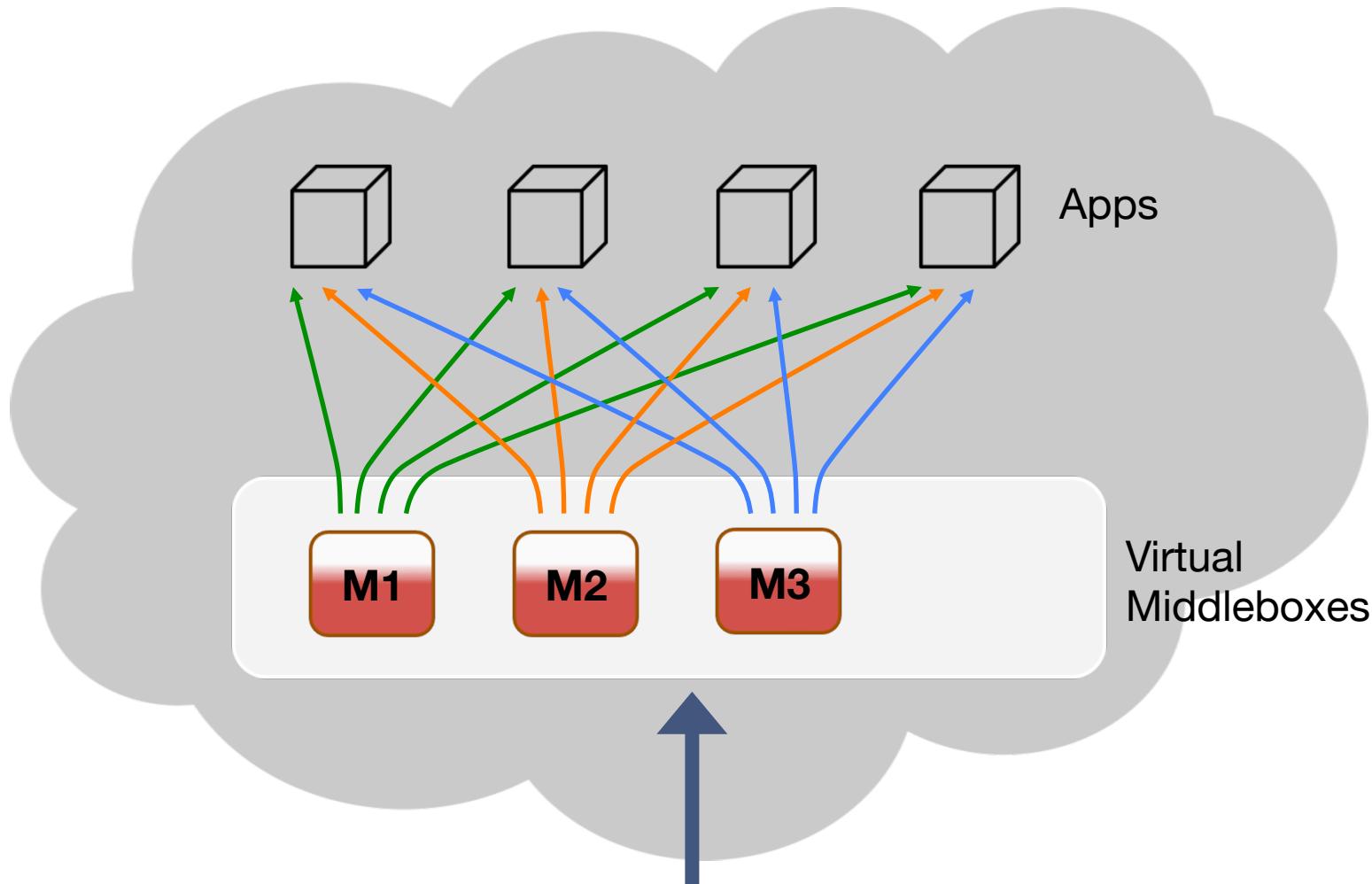
Eliminating Hotspots by Shedding Load



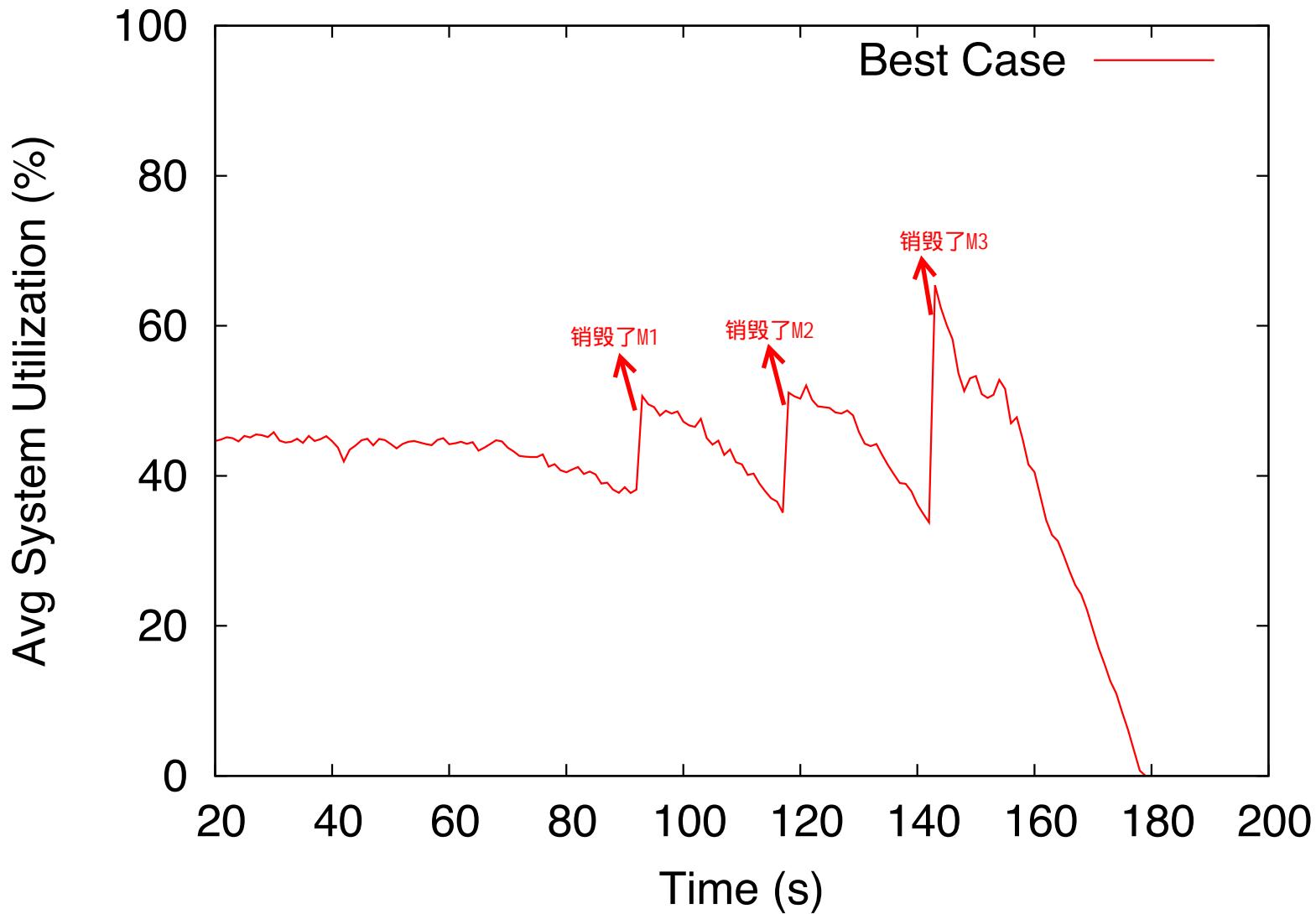
Scaling-In a Deployment : Best Case Scenario



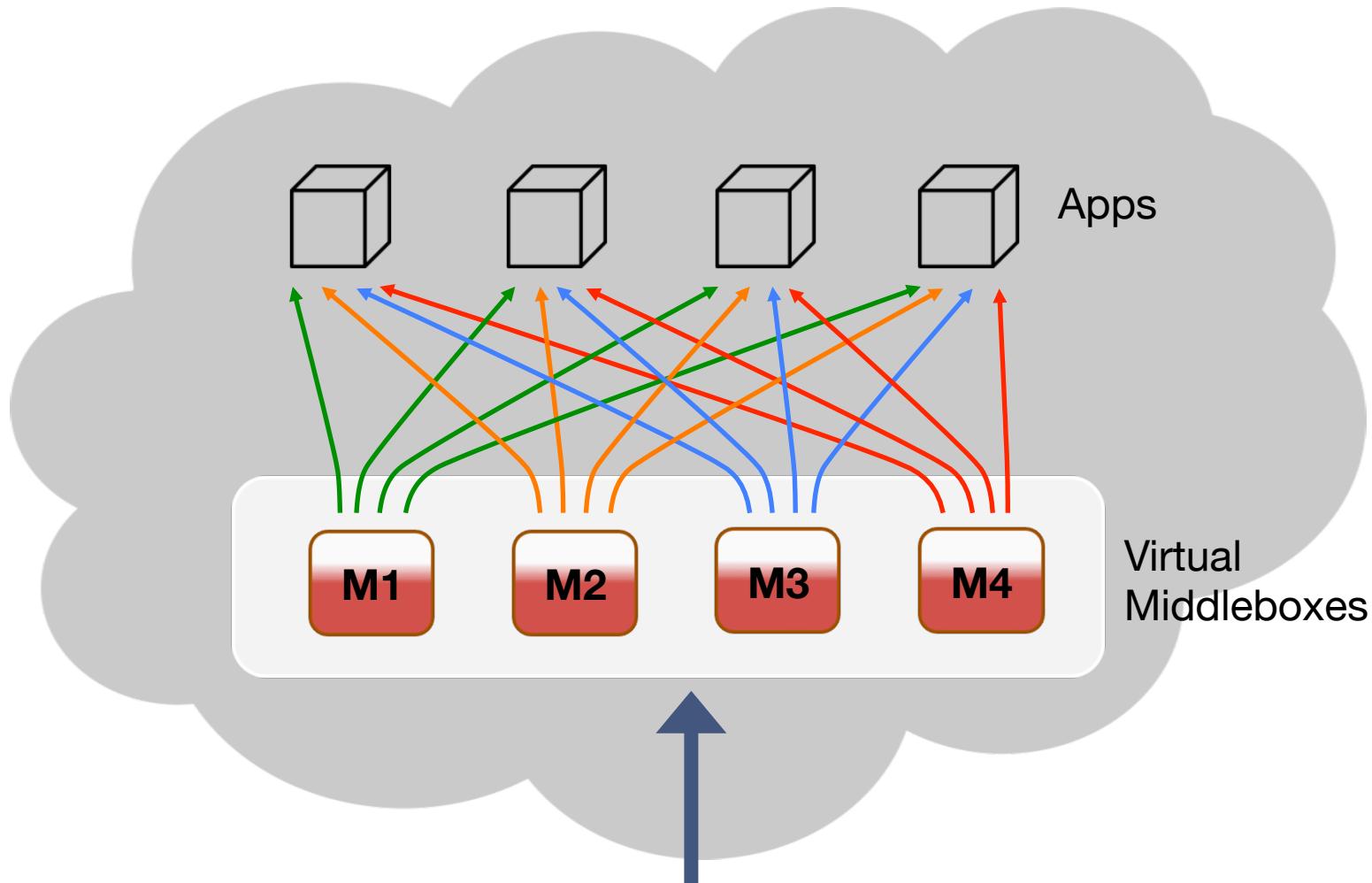
Scaling-In a Deployment : Best Case Scenario



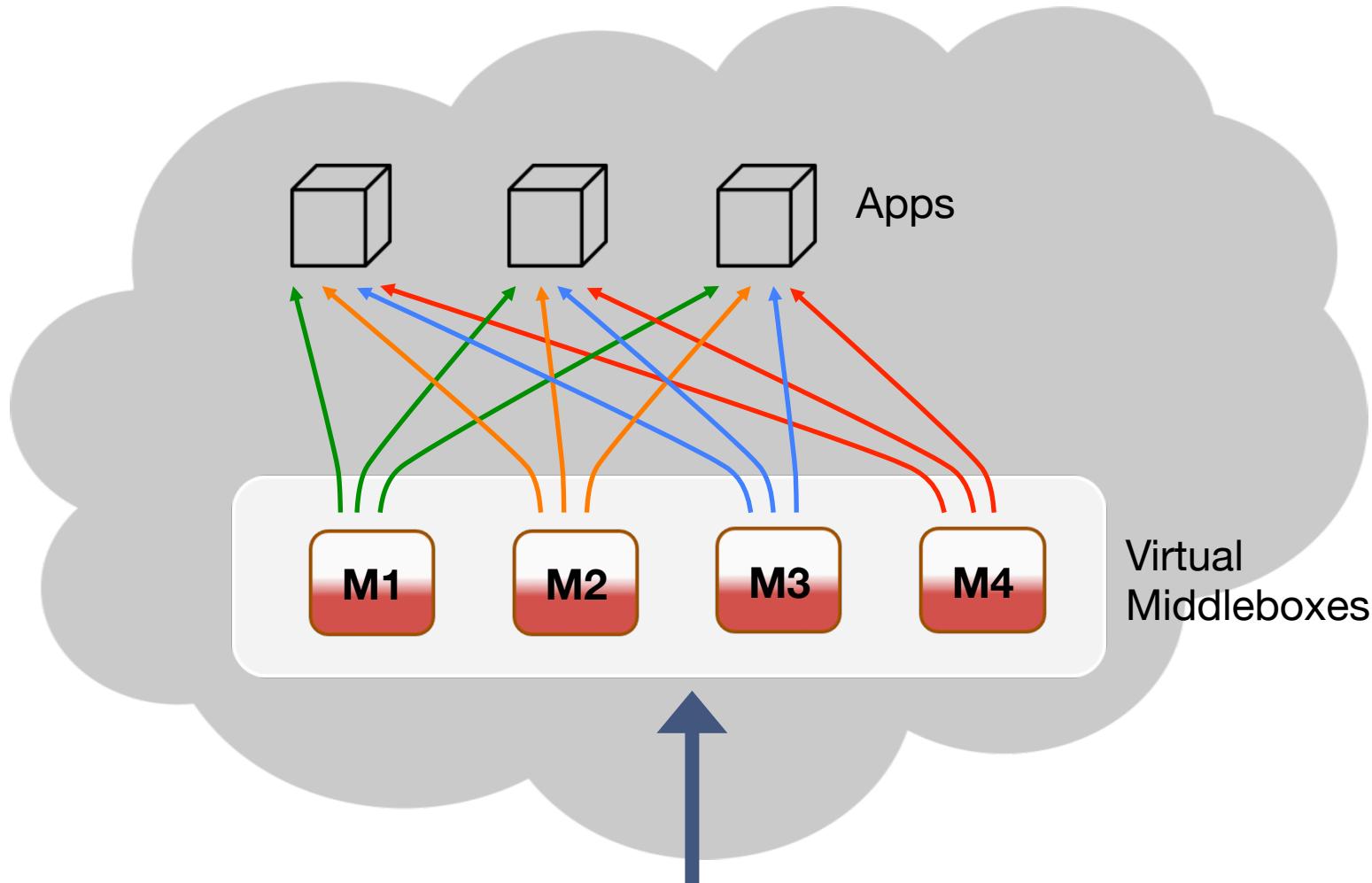
Scaling-In: Best Case Scenario



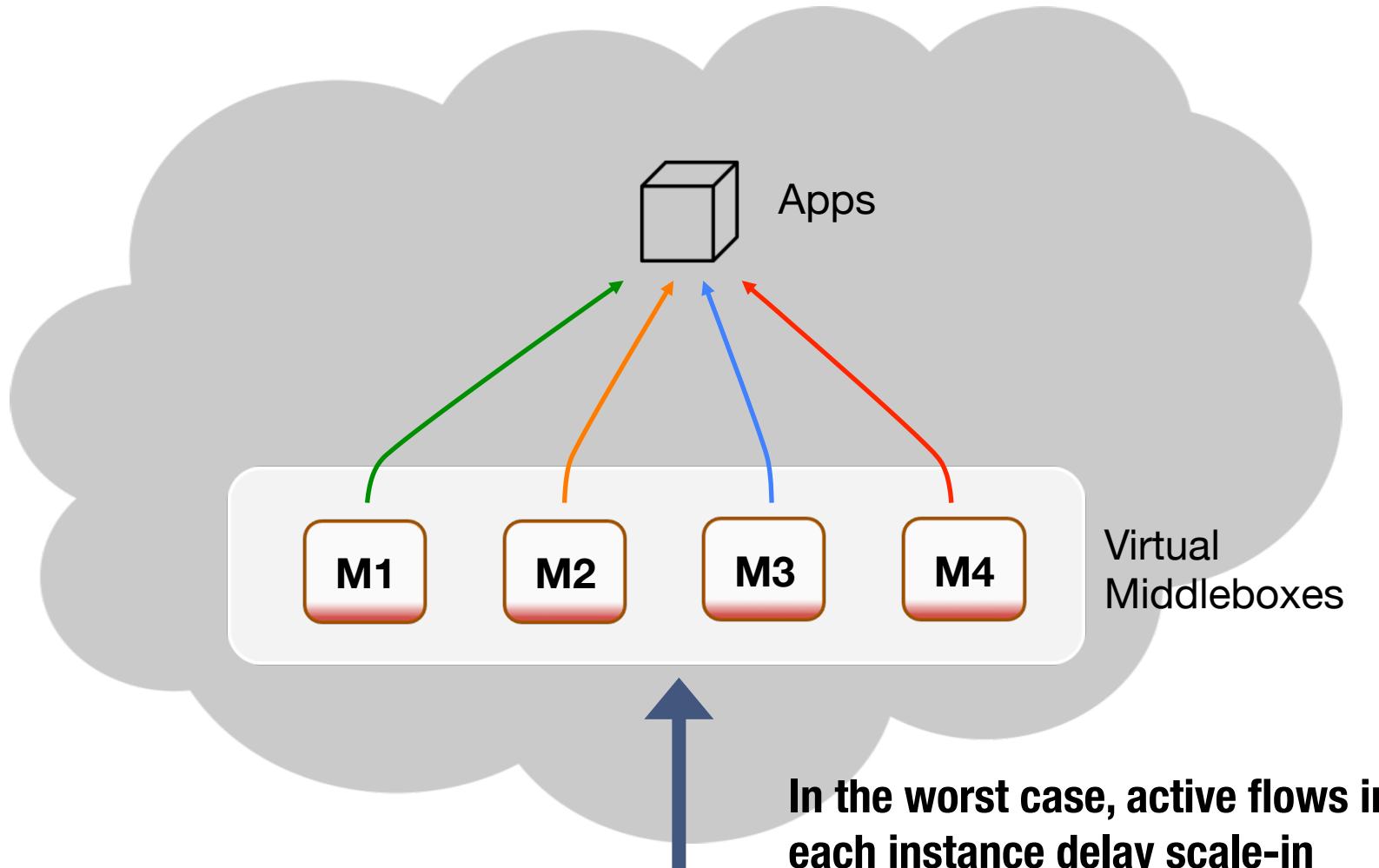
Scaling-In using *kill*: Worst Case Scenario



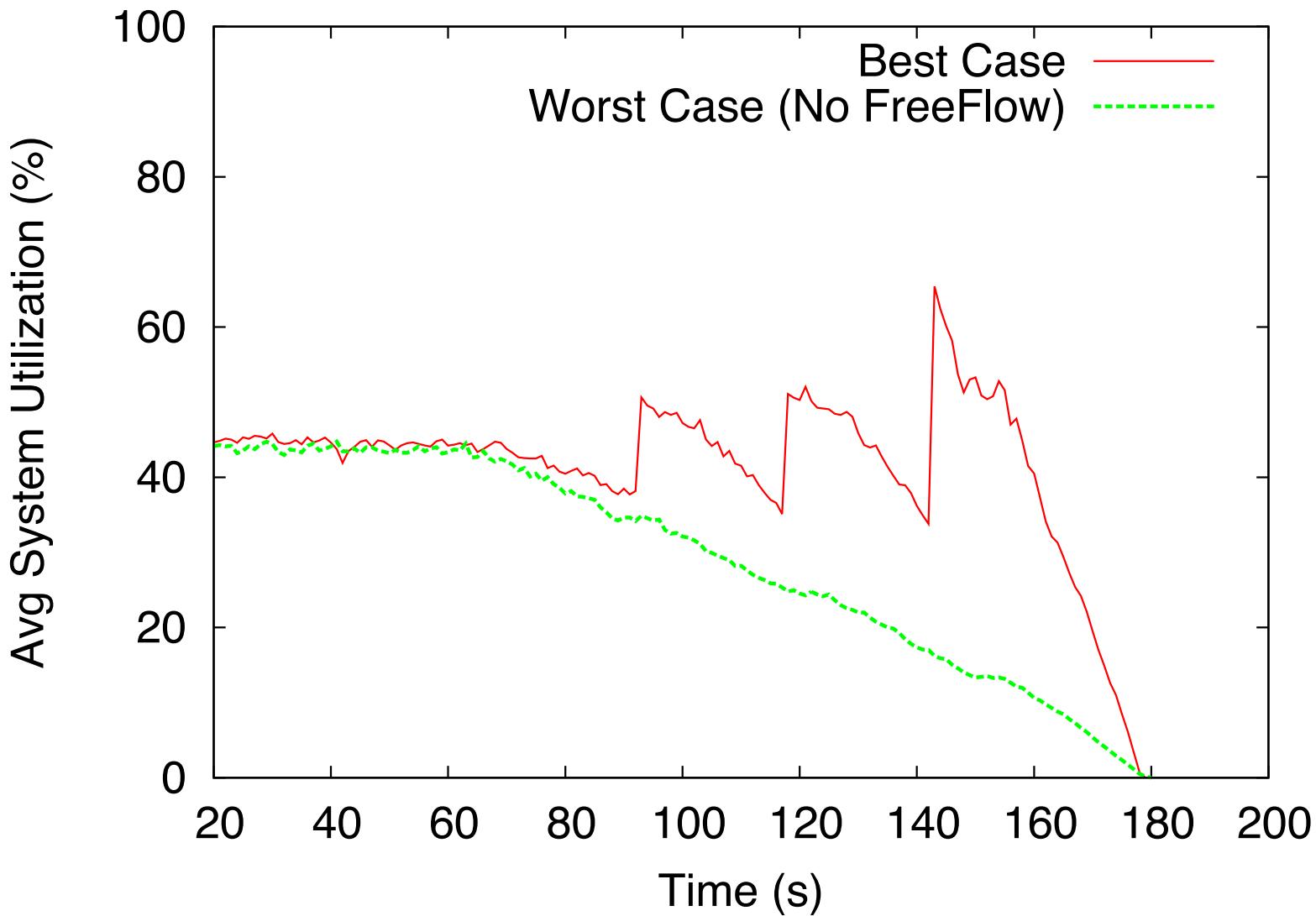
Scaling-In using *kill*: Worst Case Scenario



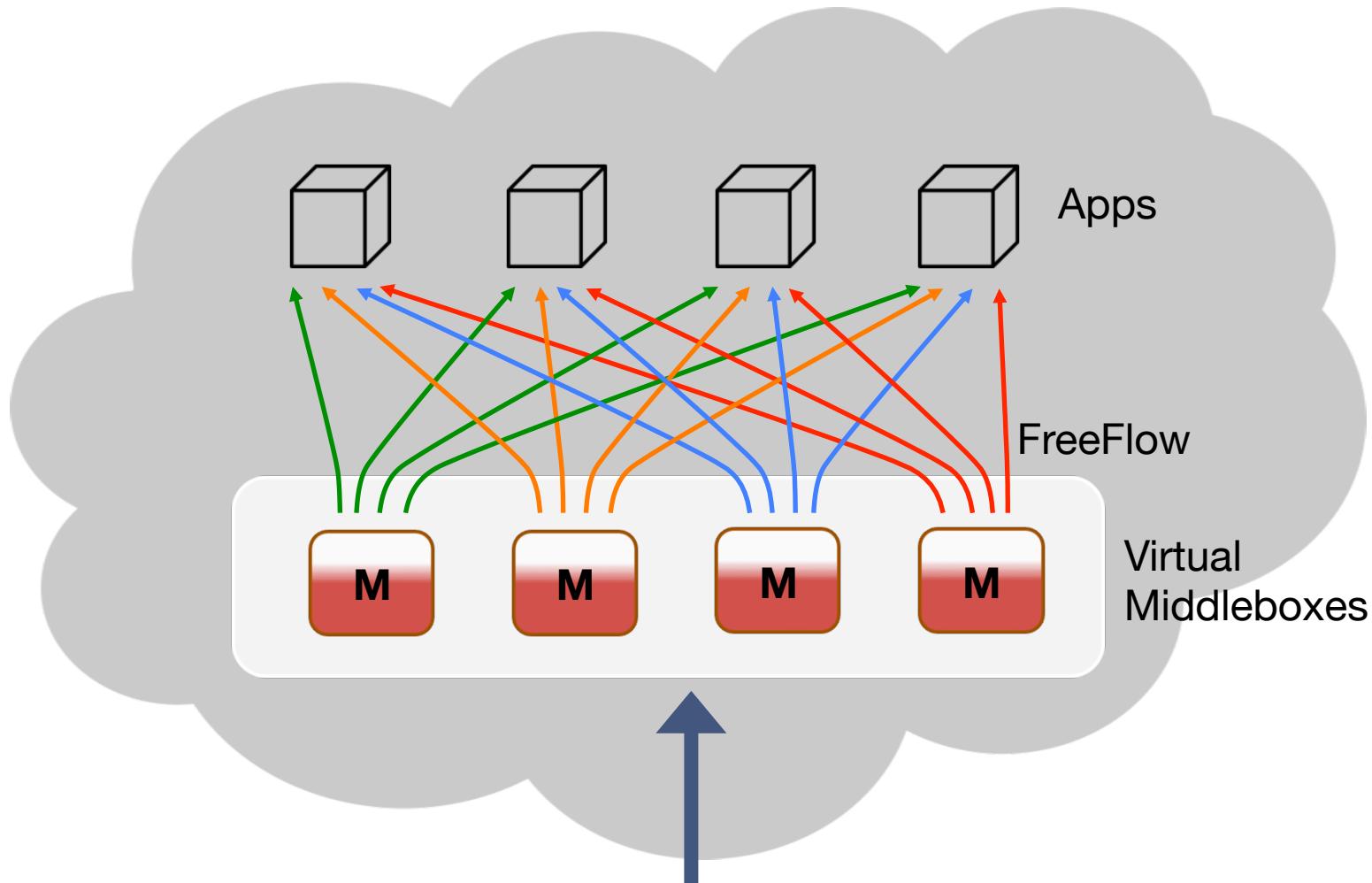
Scaling-In using *kill*: Worst Case Scenario



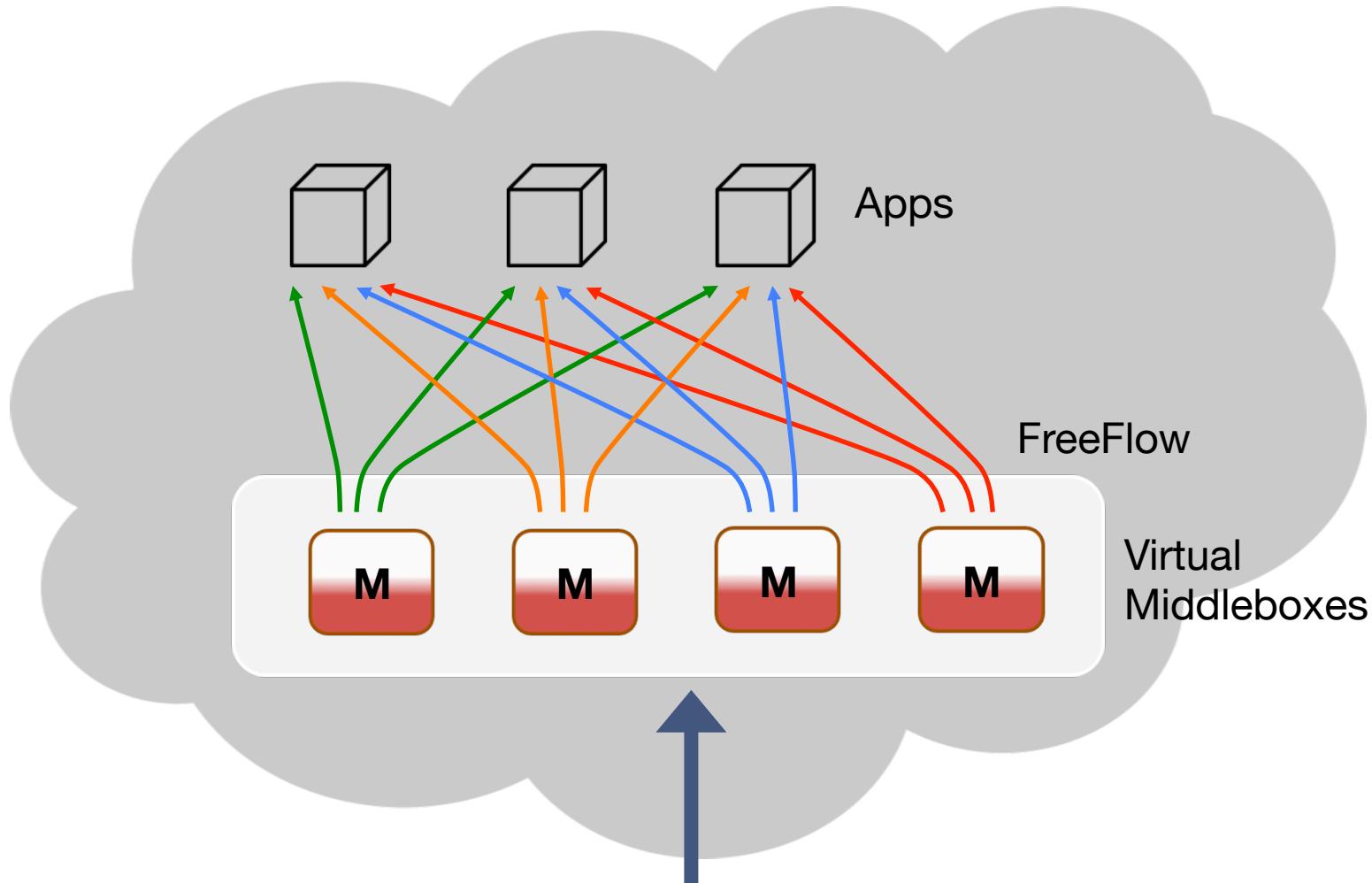
Scaling-In using *kill*: Slow & Inefficient



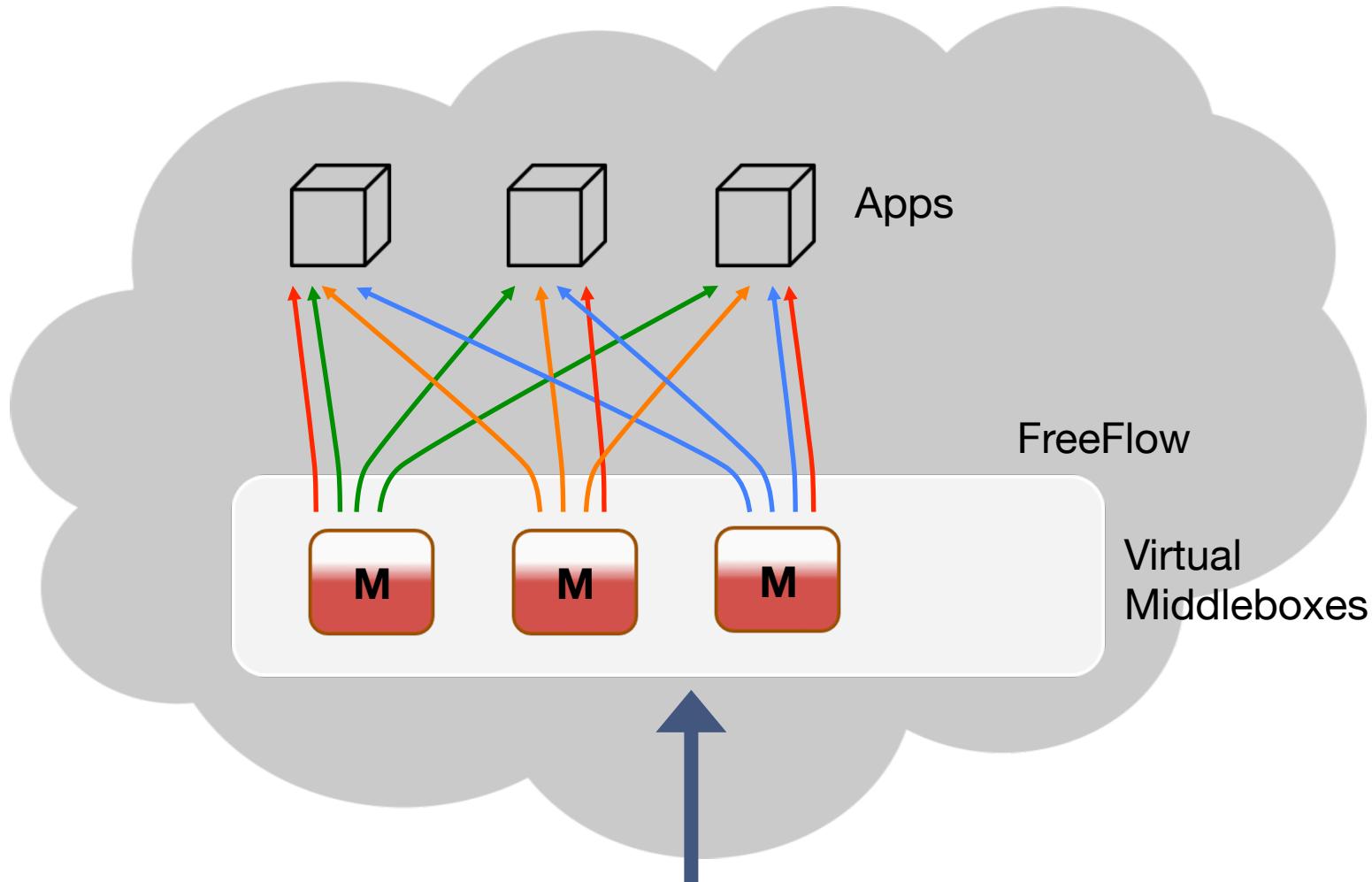
Scaling-In using *merge* : Worst Case Scenario



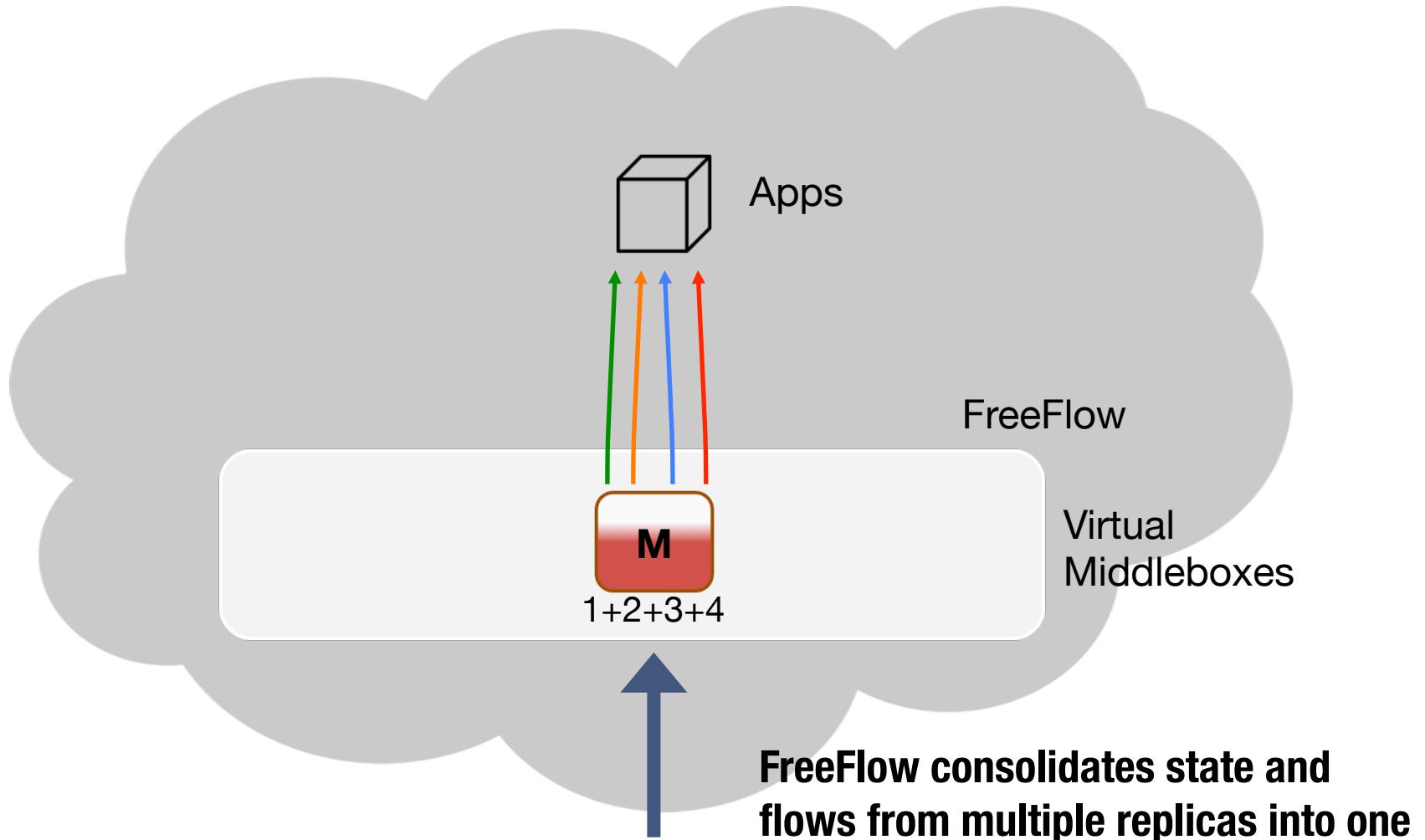
Scaling-In using *merge* : Worst Case Scenario



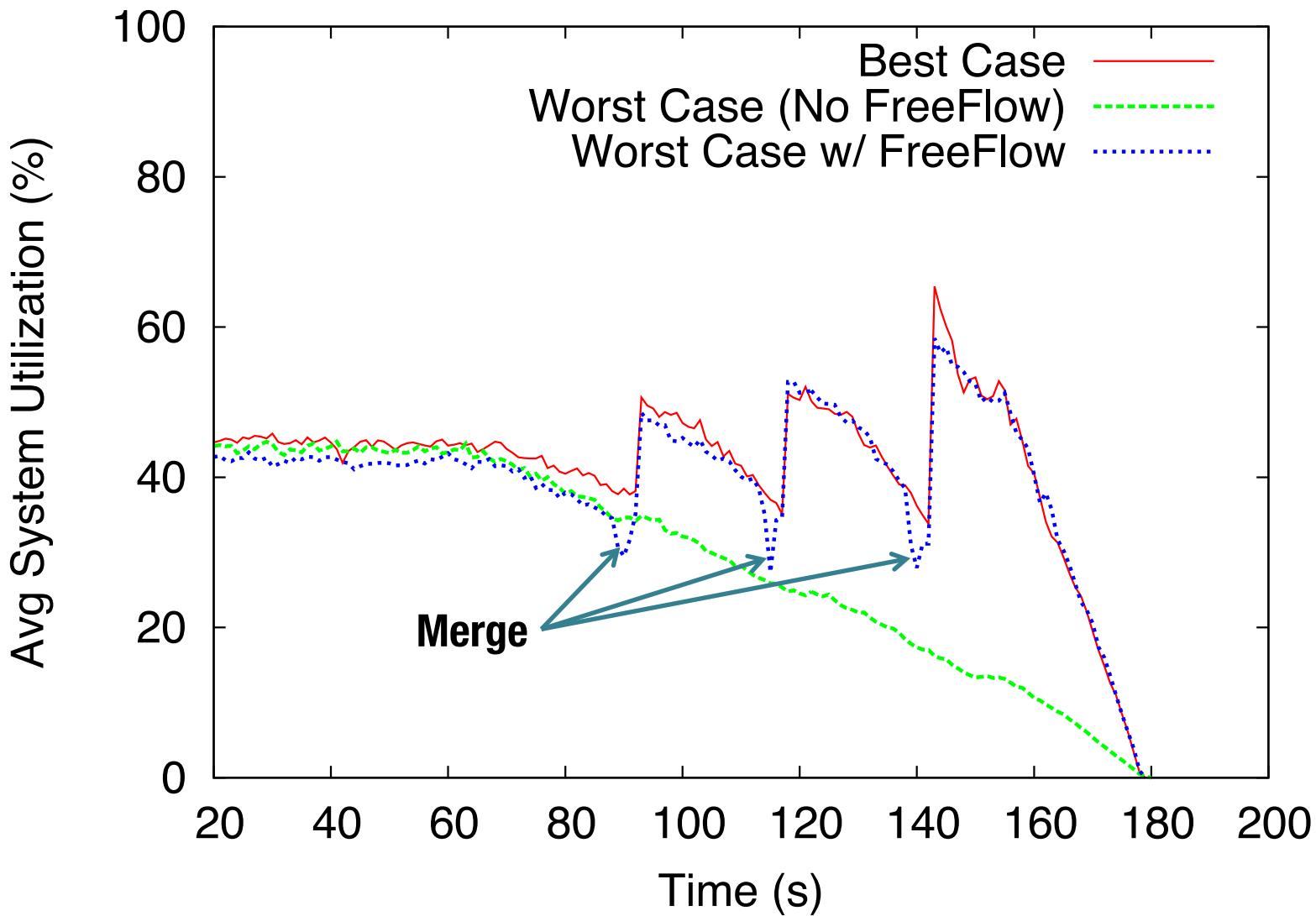
Scaling-In using *merge* : Worst Case Scenario



Scaling-In using *merge* : Worst Case Scenario

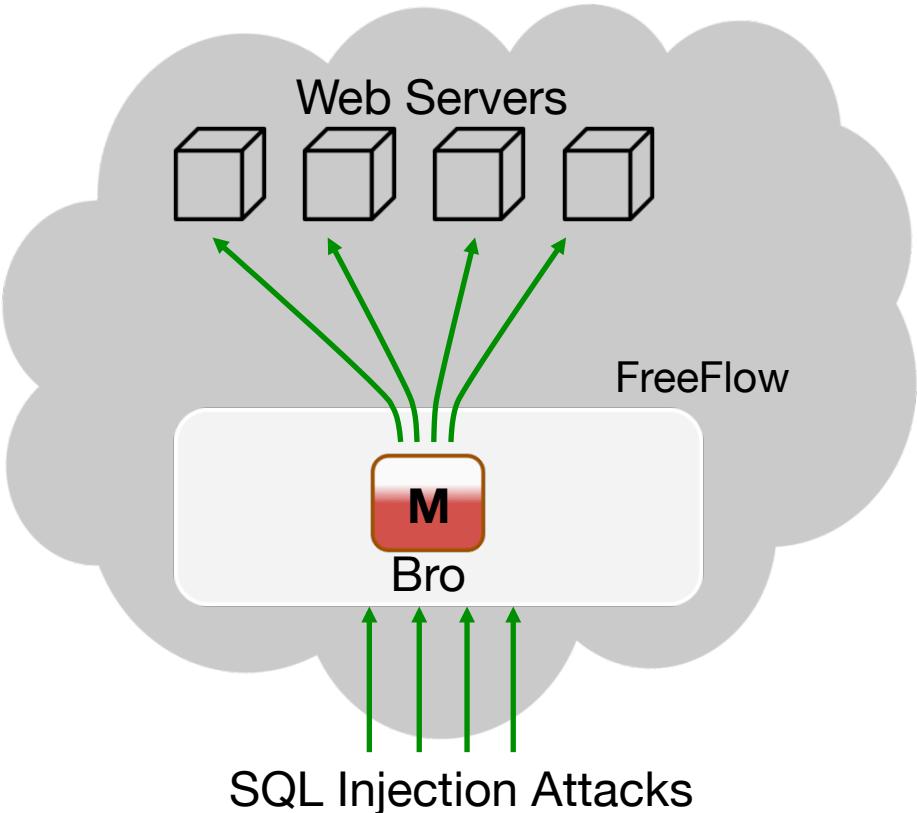


Scaling-In using *merge*: Fast & Efficient

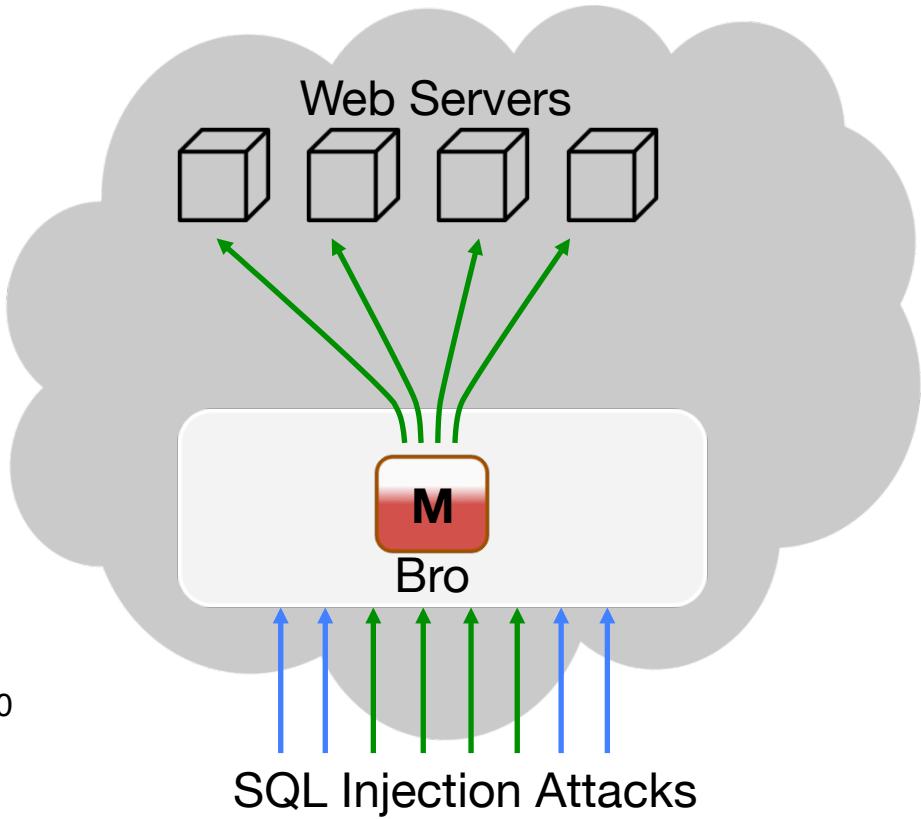
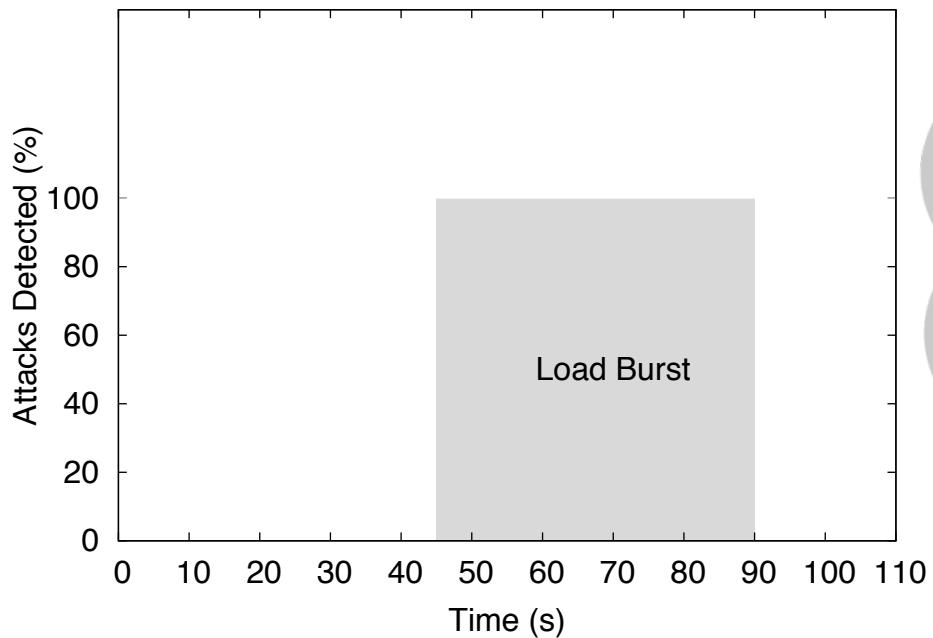


Splitting & Merging Bro IDS

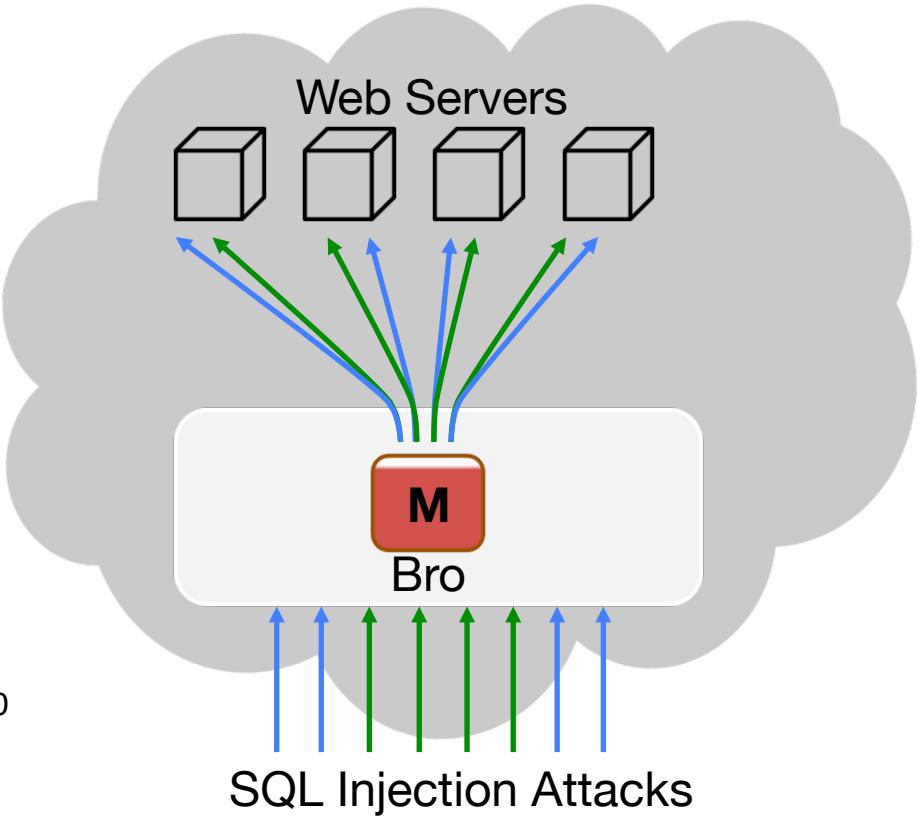
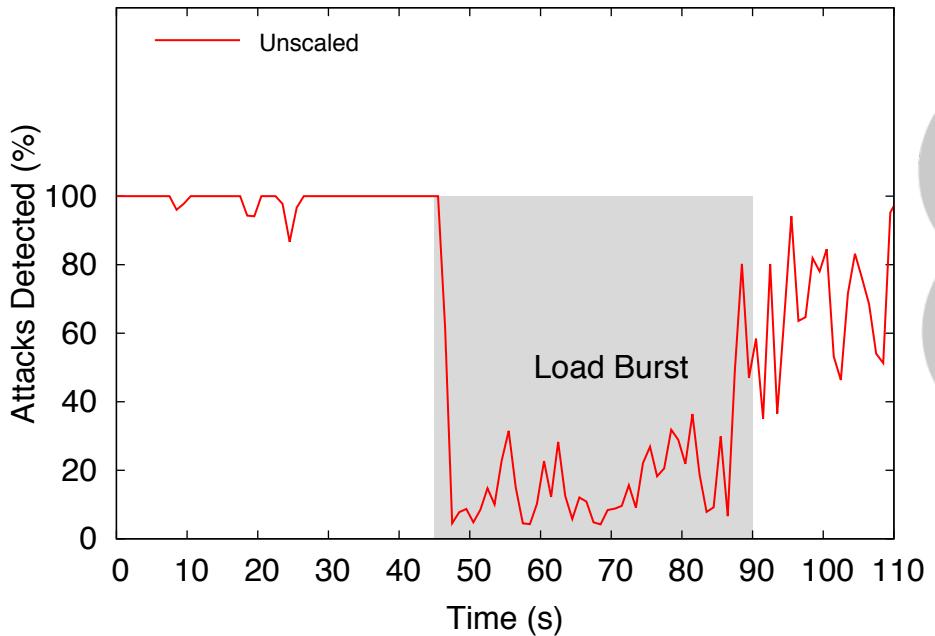
- Ported the Event Engine to FreeFlow
- Support for UDP, TCP/HTTP protocols
- SQL Injection Detection plugin



Handling a Load Burst

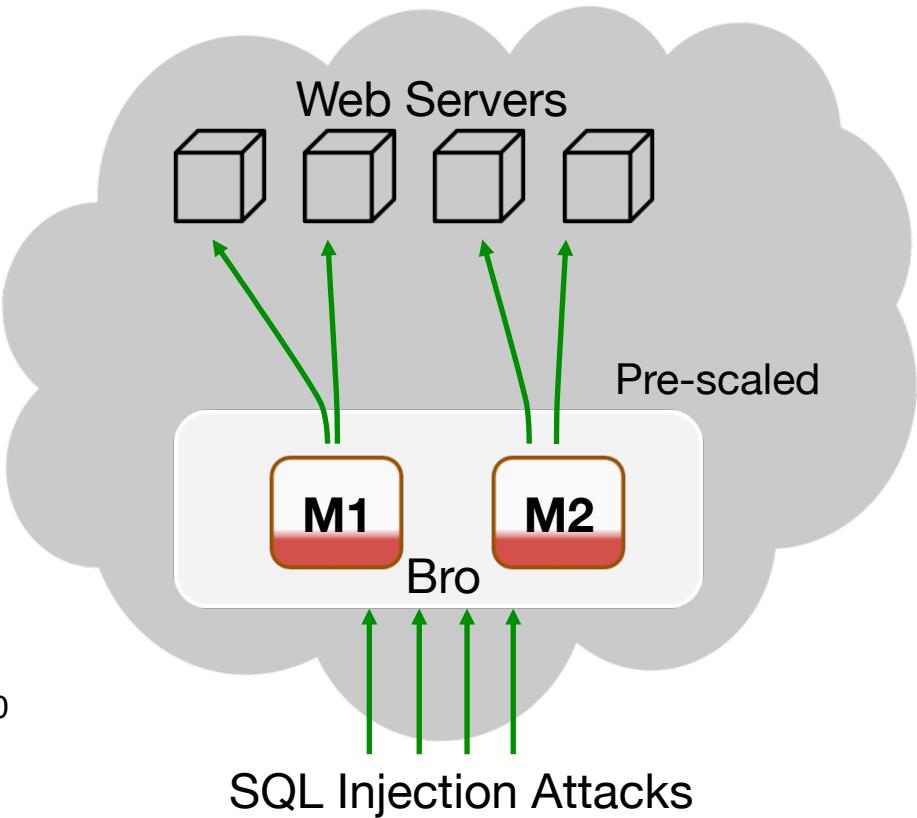
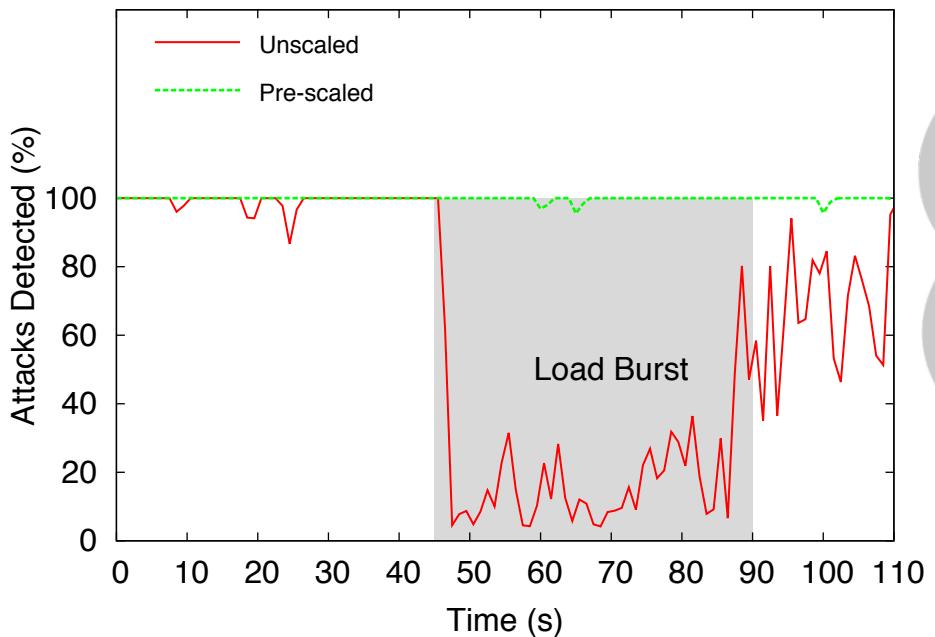


Handling a Load Burst : No Scaling



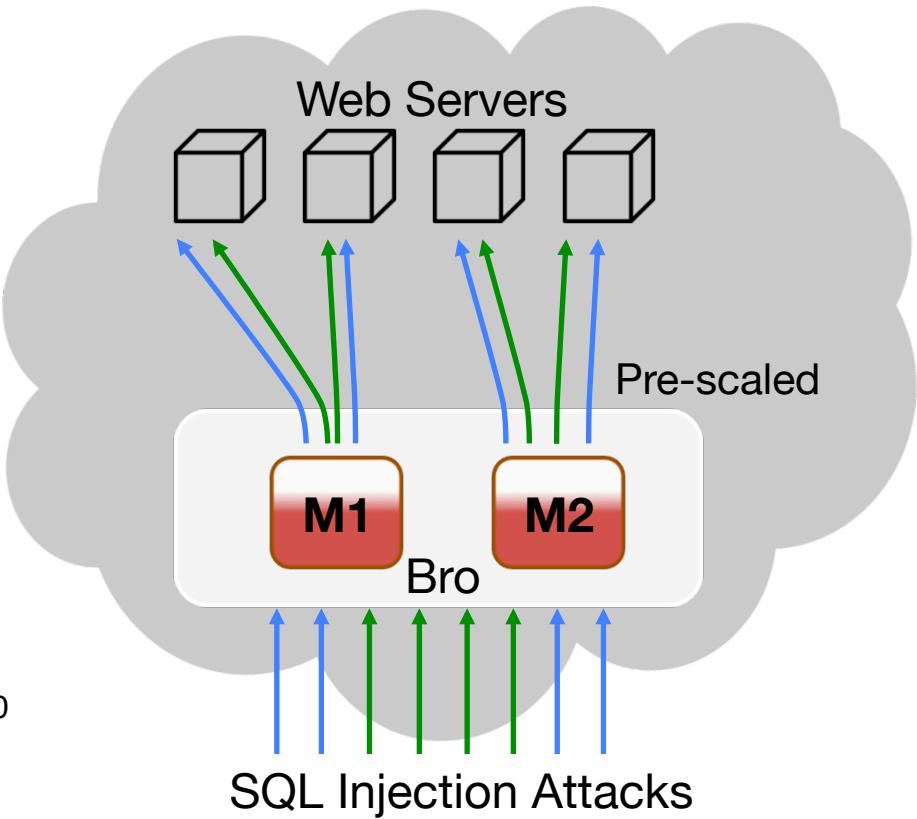
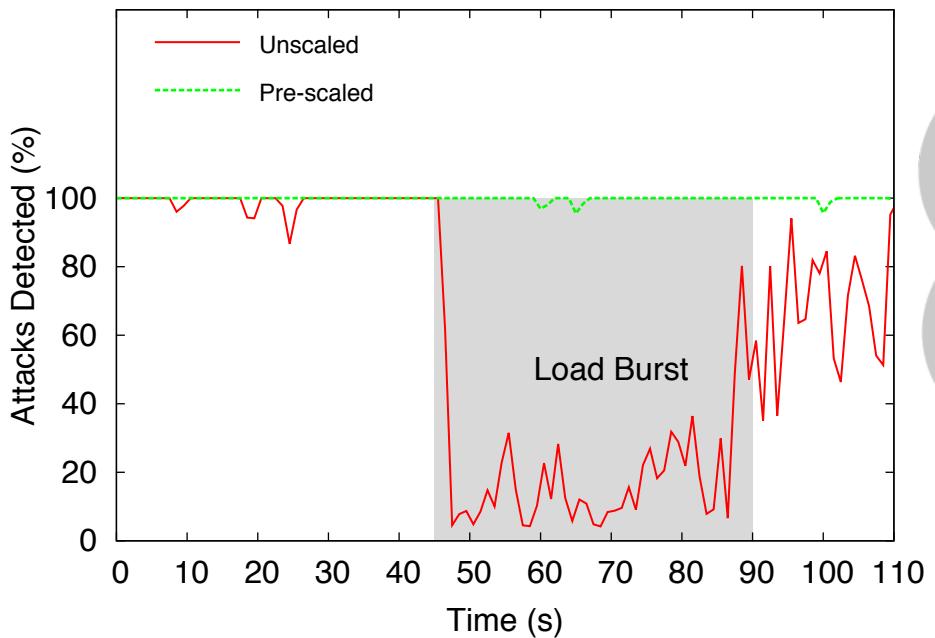
Without enough capacity to handle the load burst, the system performance degrades severely

Handling a Load Burst : Pre-Scaled



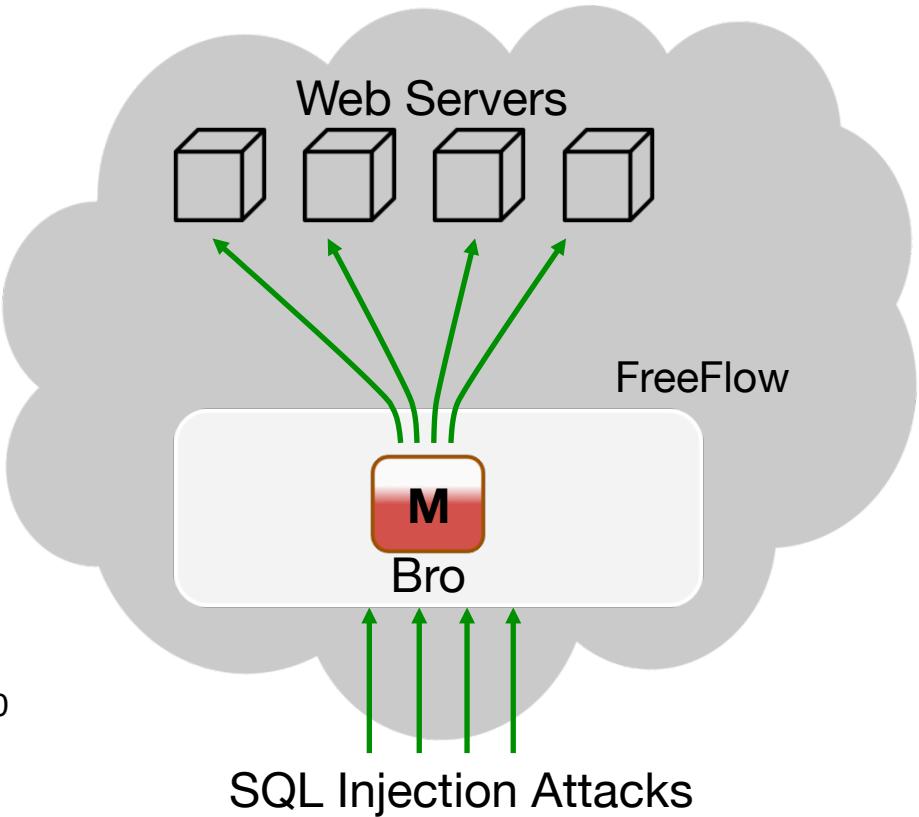
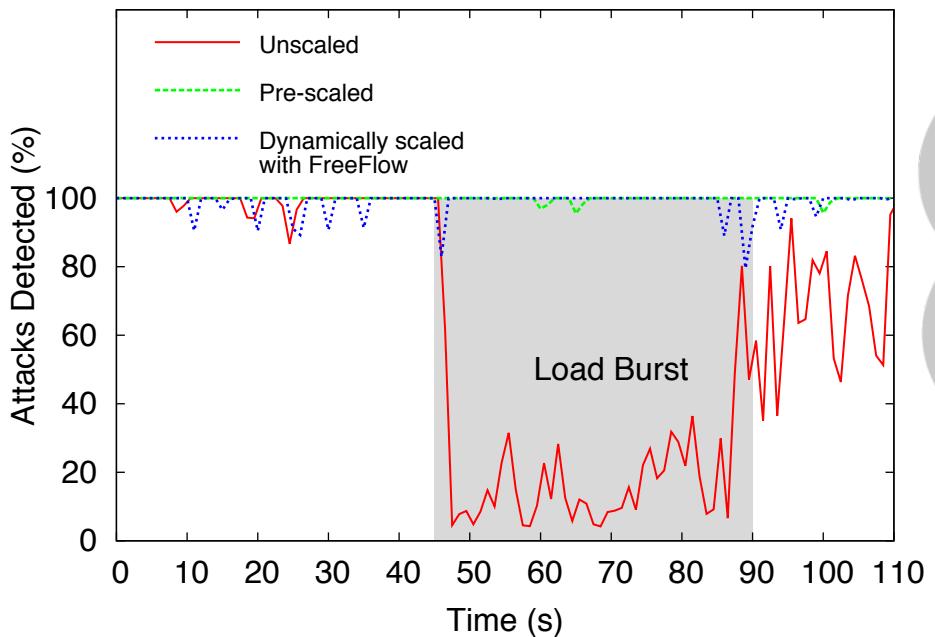
Two instances are provisioned apriori,
enough to handle a load burst, if any

Handling a Load Burst : Pre-Scaled



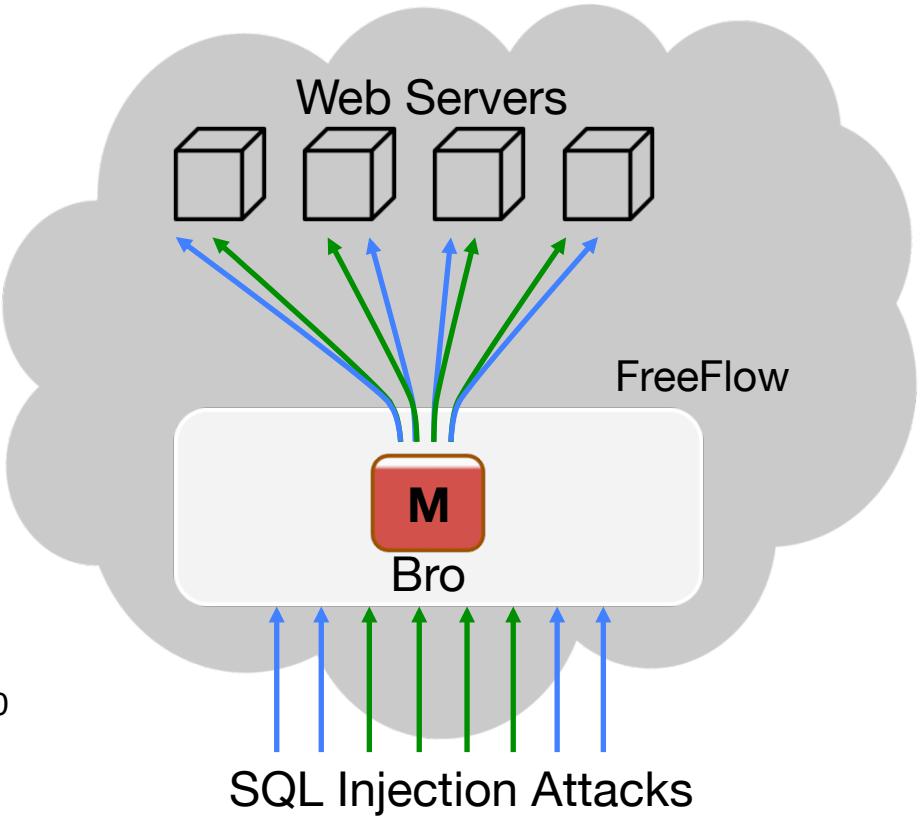
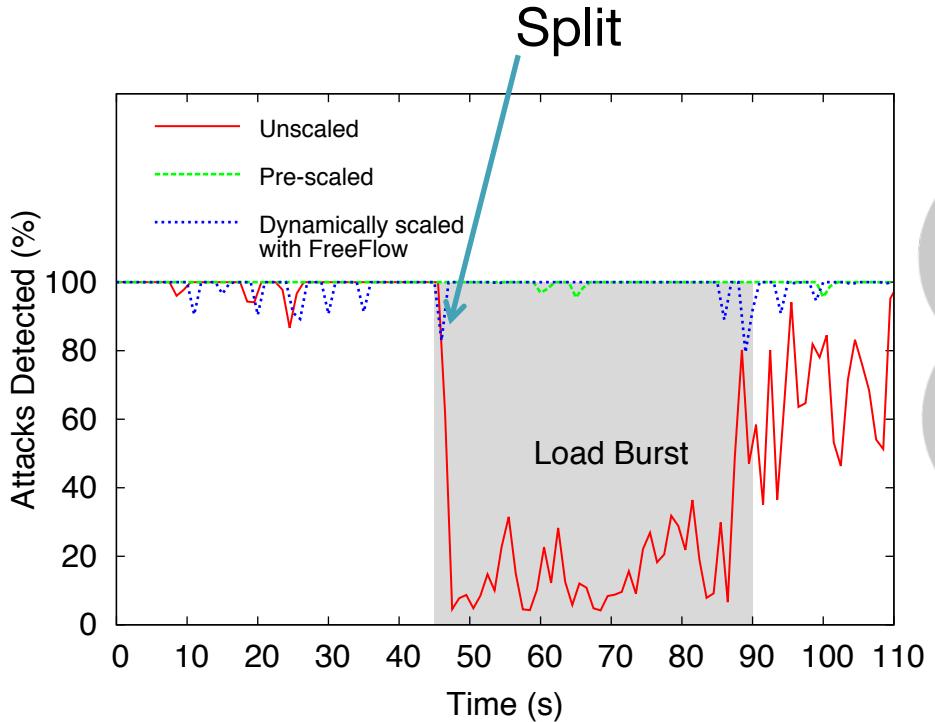
Load burst has no impact on system performance, as there is enough capacity to handle the load

Handling a Load Burst : Split/Merge



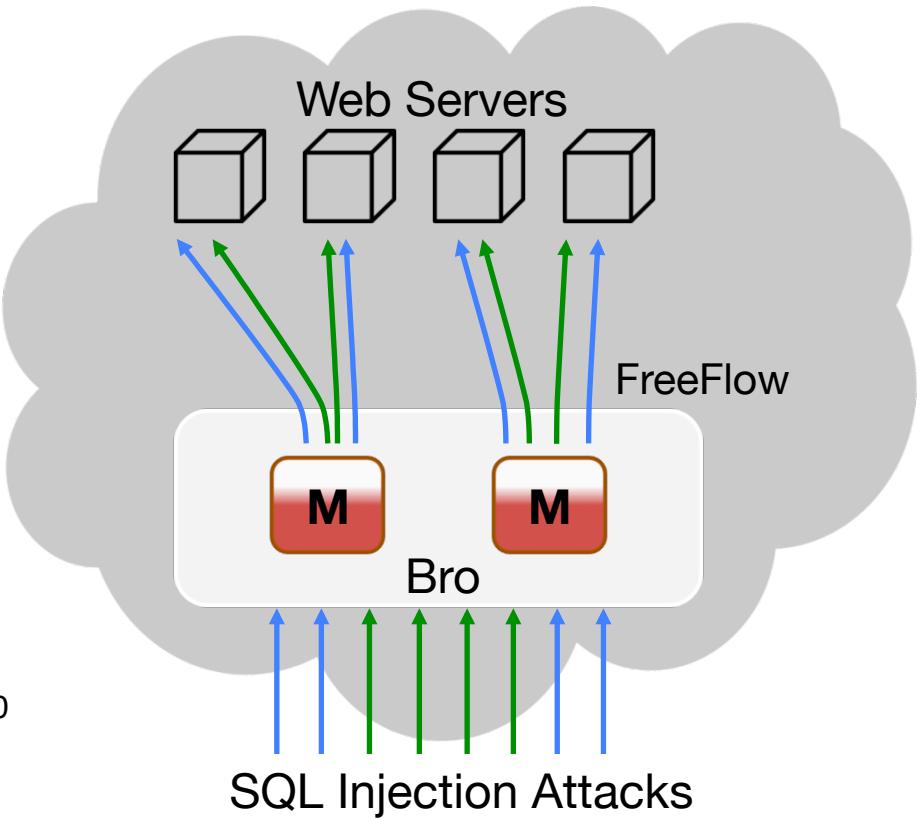
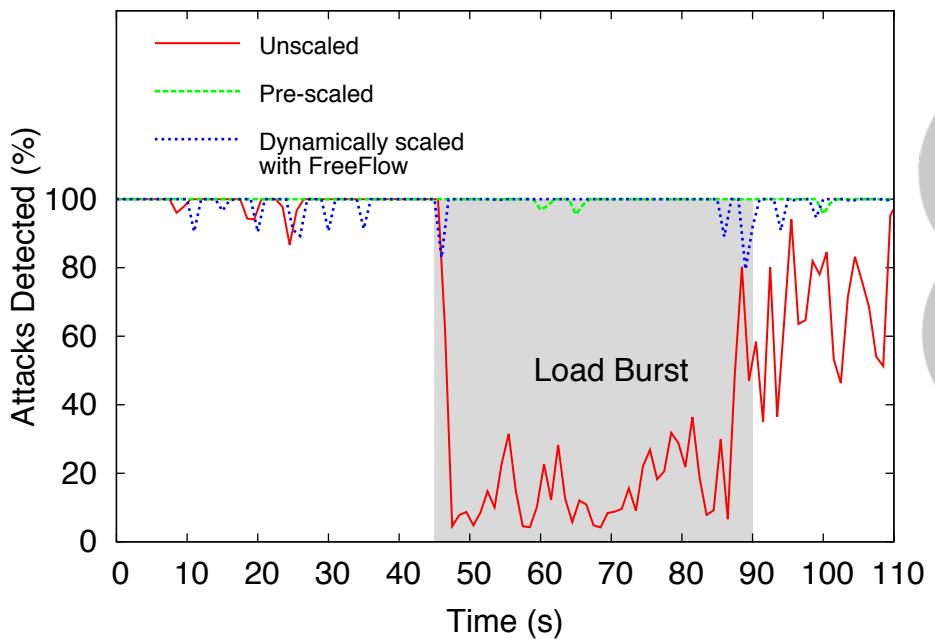
One replica handles the load well,
before the load burst

Handling a Load Burst : Split/Merge



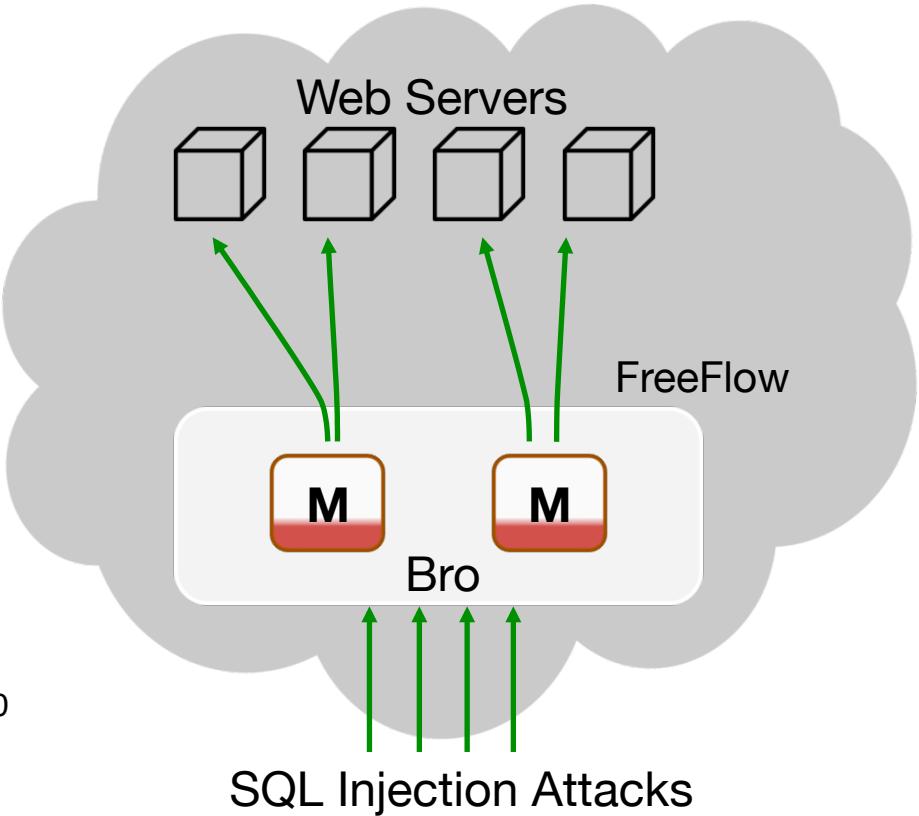
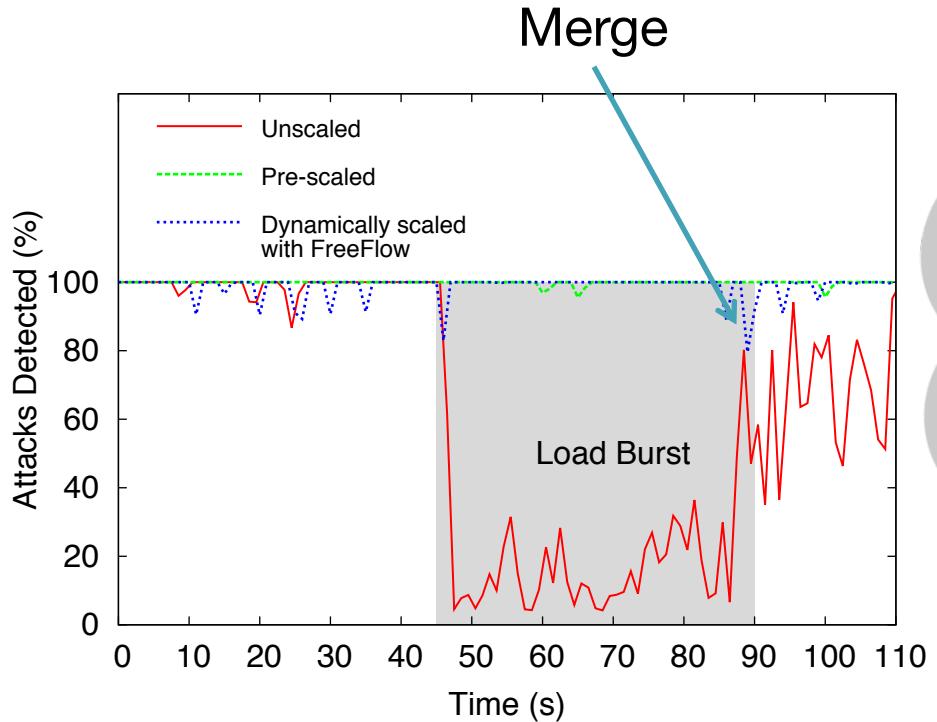
When load burst starts, the Orchestrator *splits* the replica and rebalances the load

Handling a Load Burst : Split/Merge



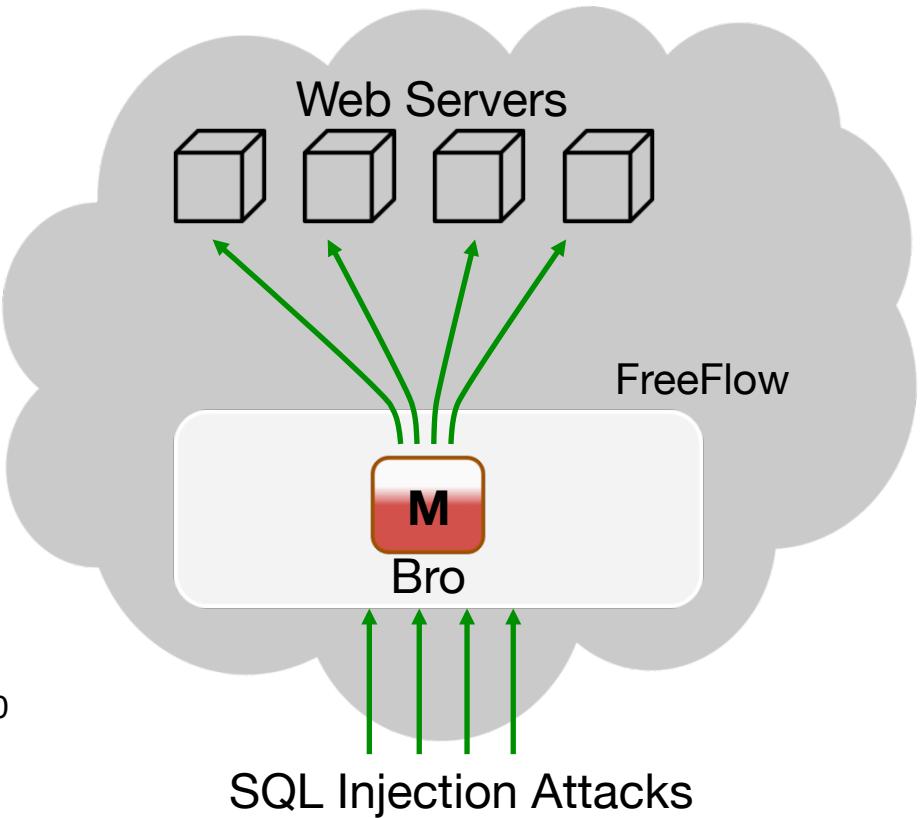
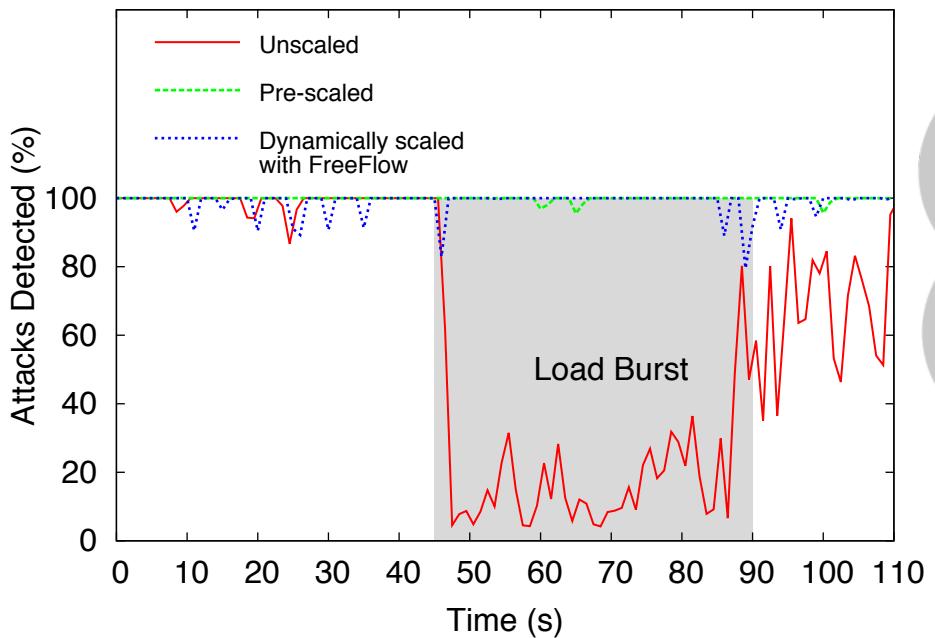
With the load rebalanced,
performance returns to normal

Handling a Load Burst : Split/Merge



When system utilization drops after the load burst, the Orchestrator *merges* the two replicas

Handling a Load Burst : Split/Merge



Summary

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 **FreeFlow**
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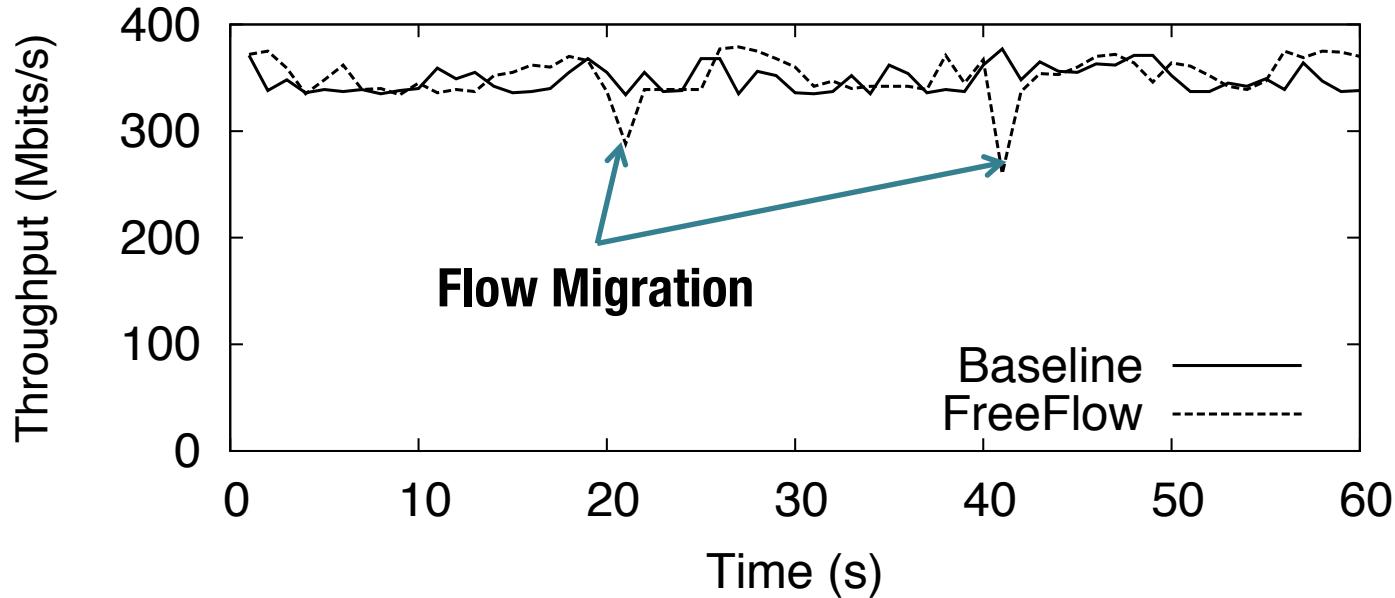
Tweets

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Split/Merge enables balanced elasticity in virtual middleboxes thru dynamic partitioning & consolidation of state and flows among replicas

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Flow Migration Overhead - TCP



Flow Migration Overhead - UDP

