



**NYU**

**POLYTECHNIC SCHOOL  
OF ENGINEERING**

# **CAB: A Reactive Wildcard Rule Caching System for Software-Defined Networks**

**Bo Yan, Yang Xu, Hongya Xing  
Kang Xi, H. Jonathan Chao**

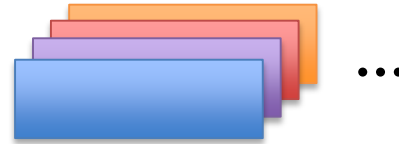
August 22, 2014





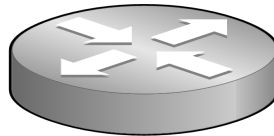
# Reactively Caching Rules on Demand

***Controller***

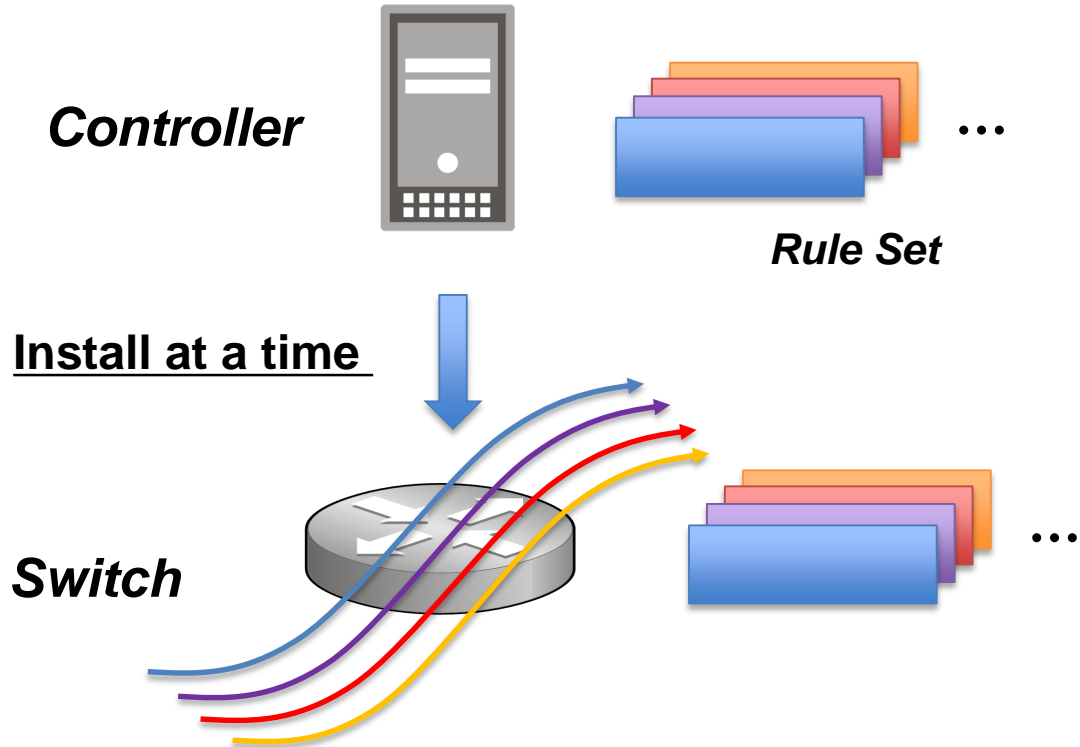


***Rule Set***

***Switch***

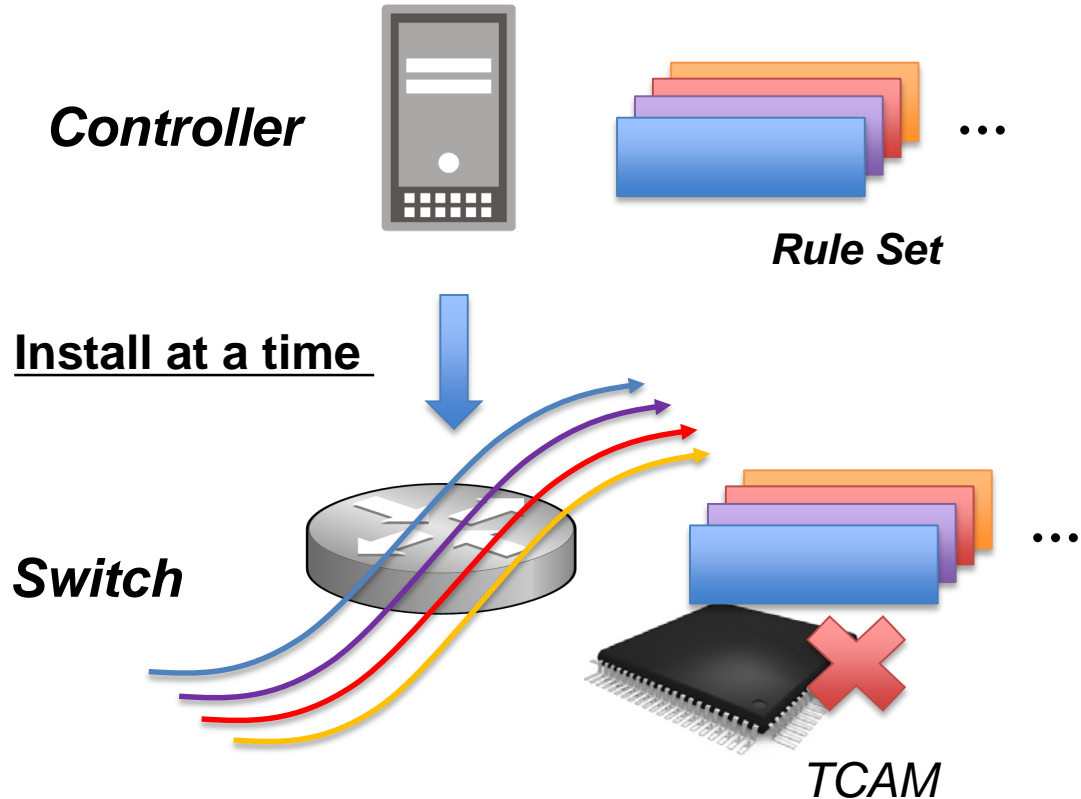


## Reactively Caching Rules on Demand



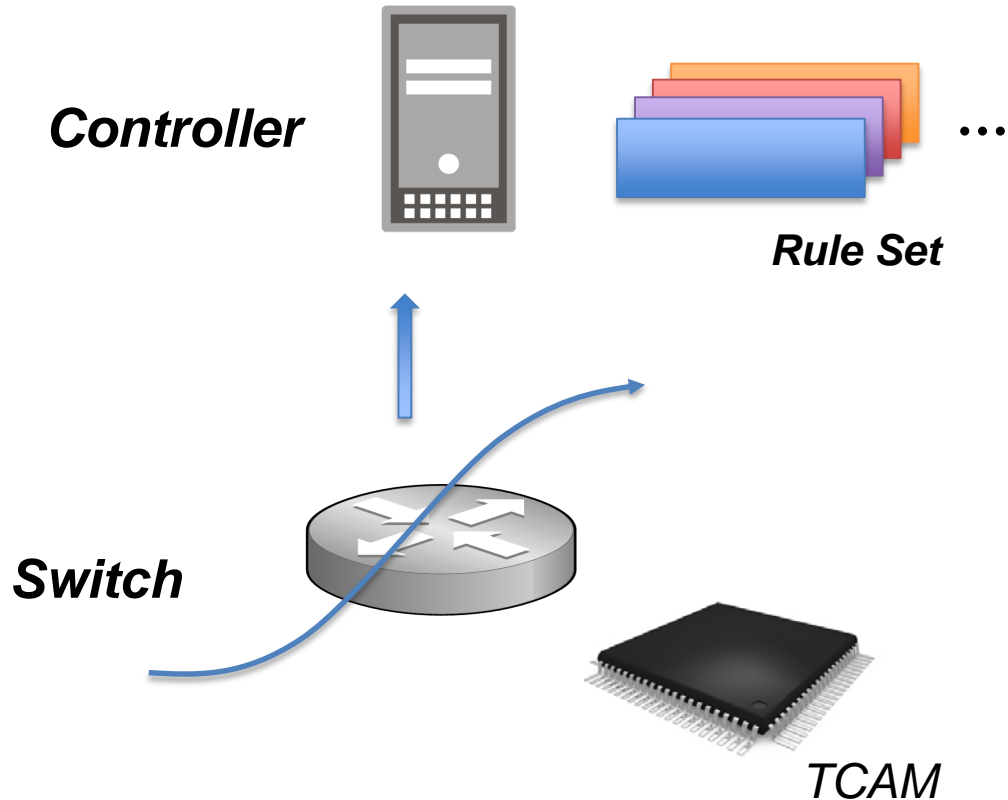


# Reactively Caching Rules on Demand



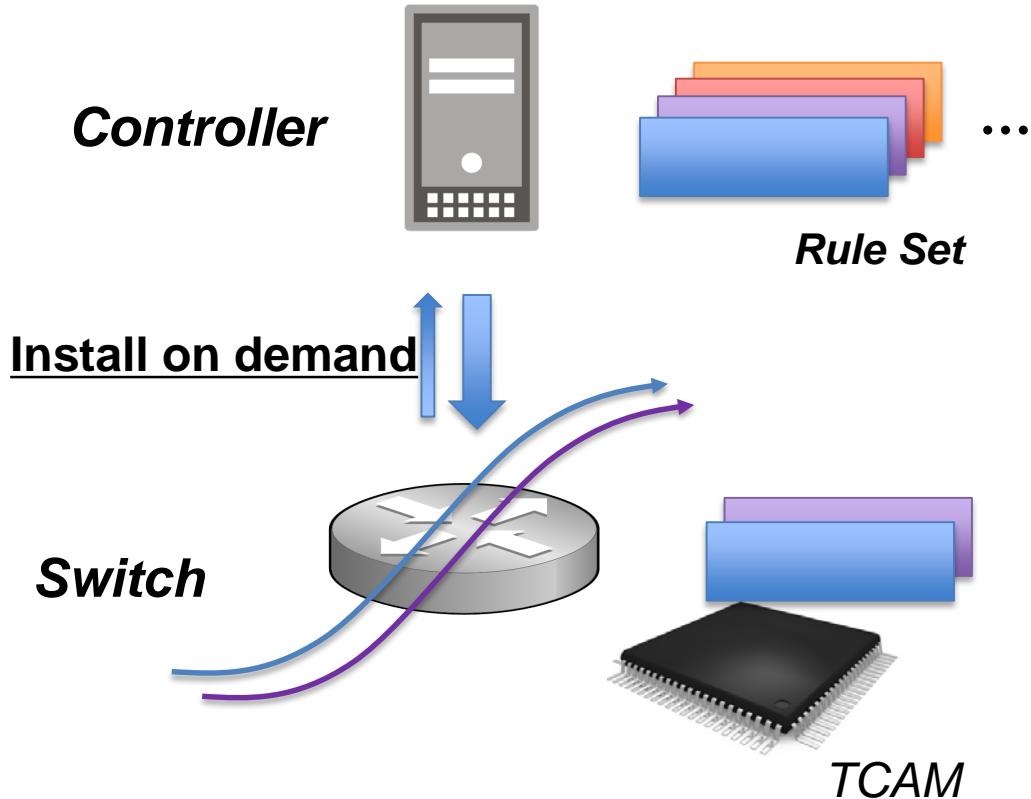


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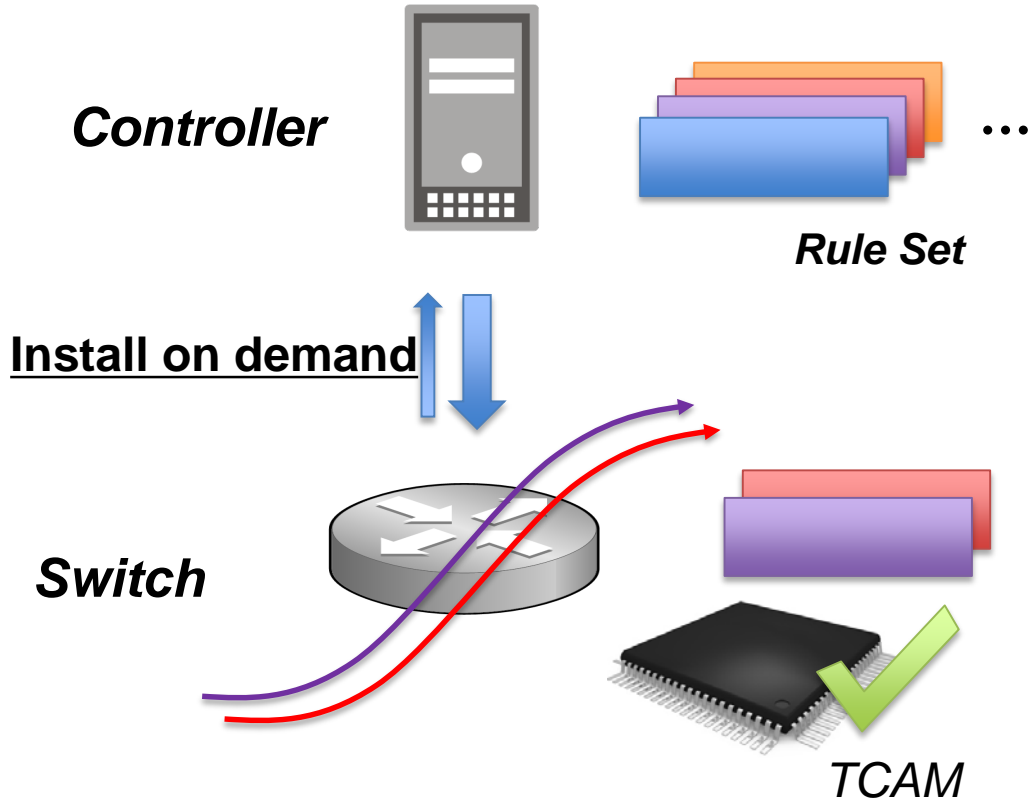


# Reactively Caching Rules on Demand





# Reactively Caching Rules on Demand

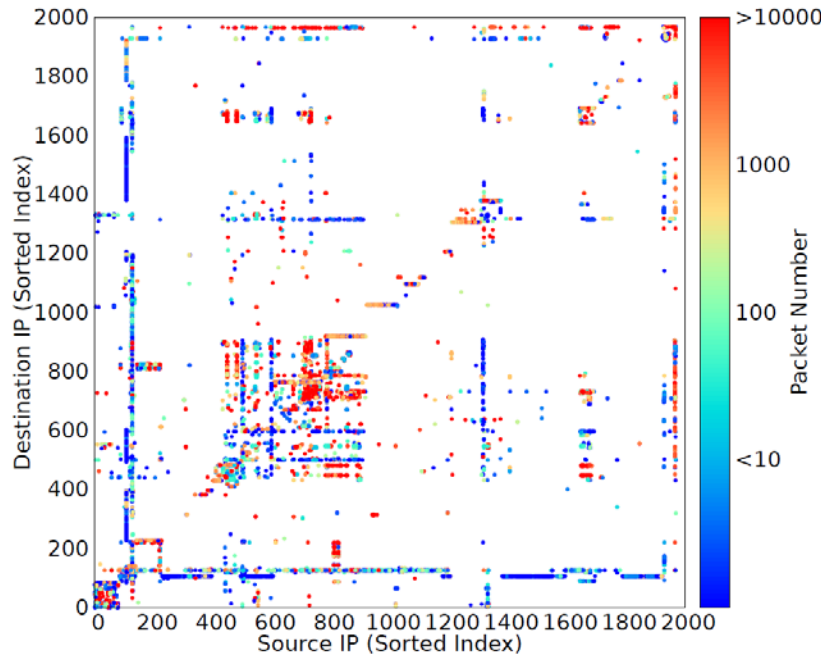




# Caching Wildcard Rules

Wildcard rules enables:

- Natural intention of managing flows aggregately
- Higher reusability for each rule
- Easy update of policies



*NYC Dept.Edu (DoE) Data Center Traces*



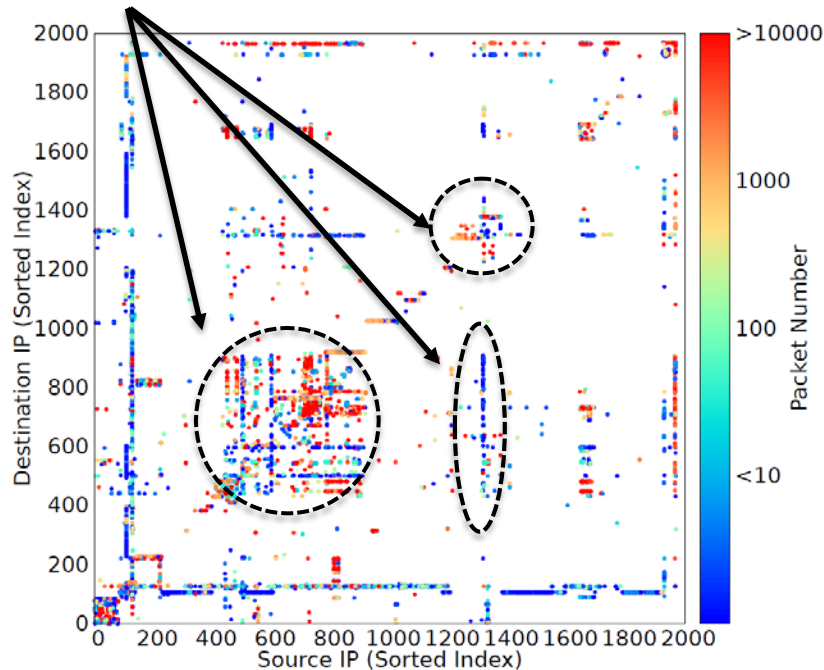


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## Locality of Traffic



*NYC Dept.Edu (DoE) Data Center Traces*

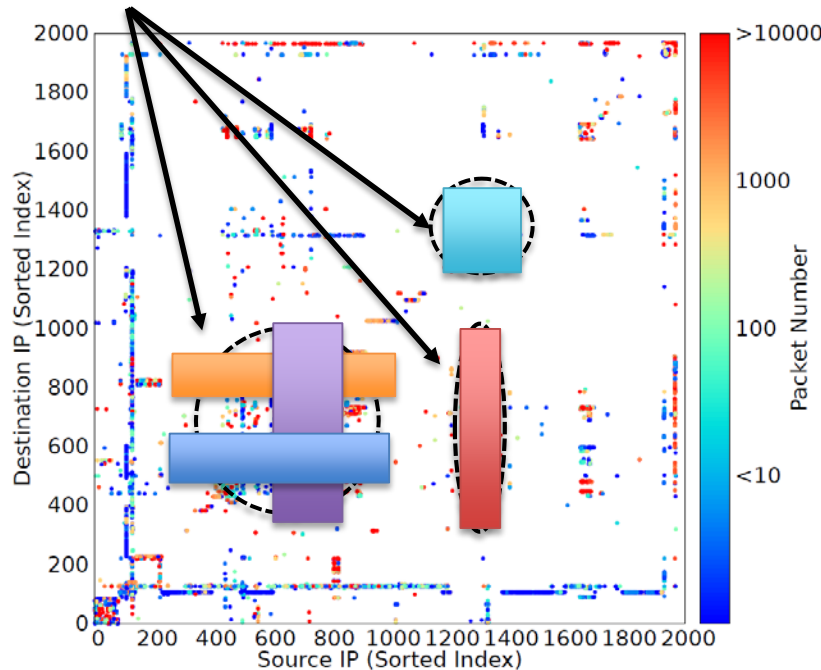


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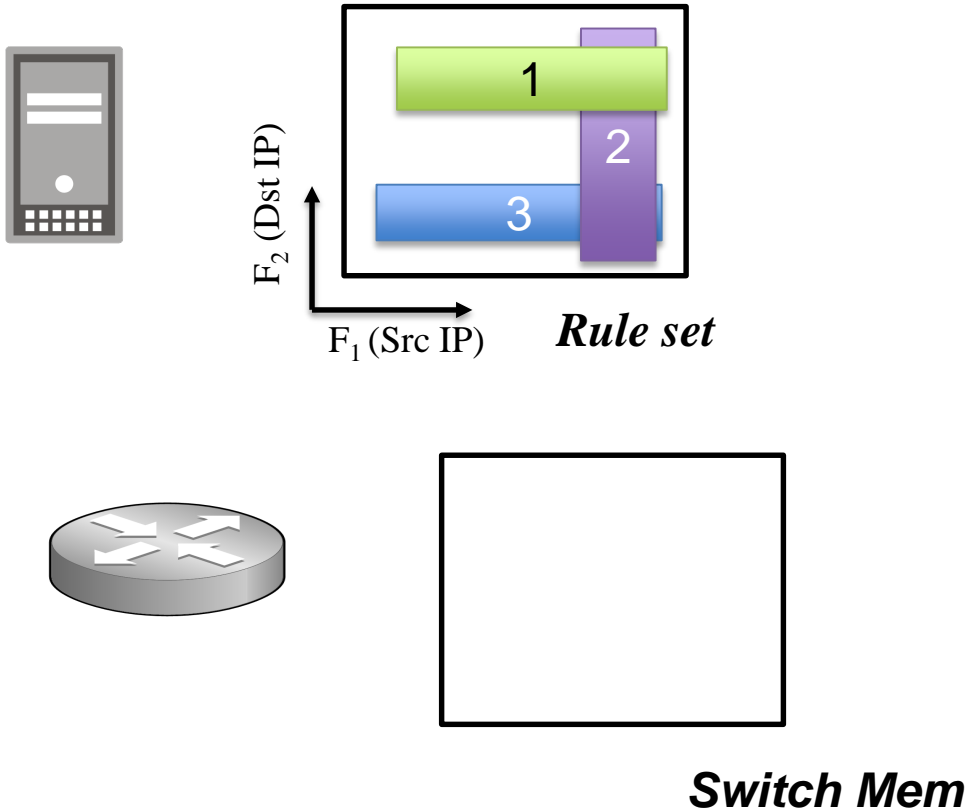
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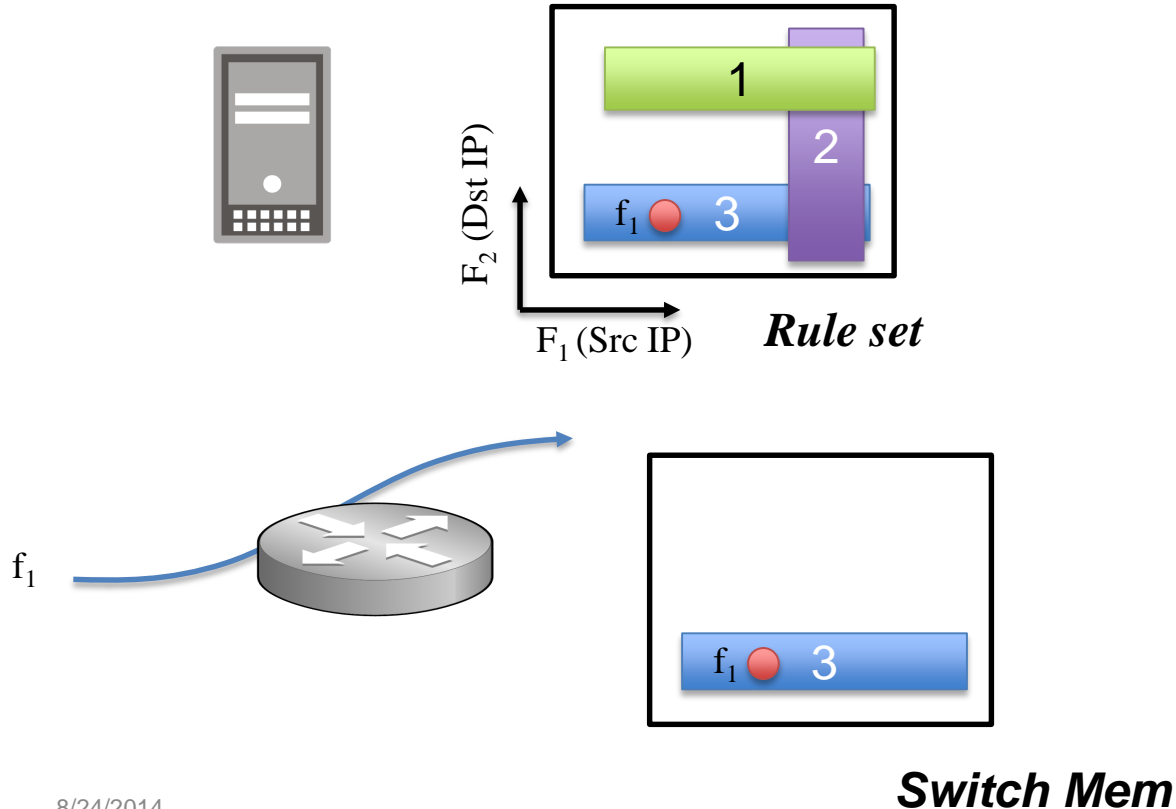


# Challenge: Wildcard Rule Dependency



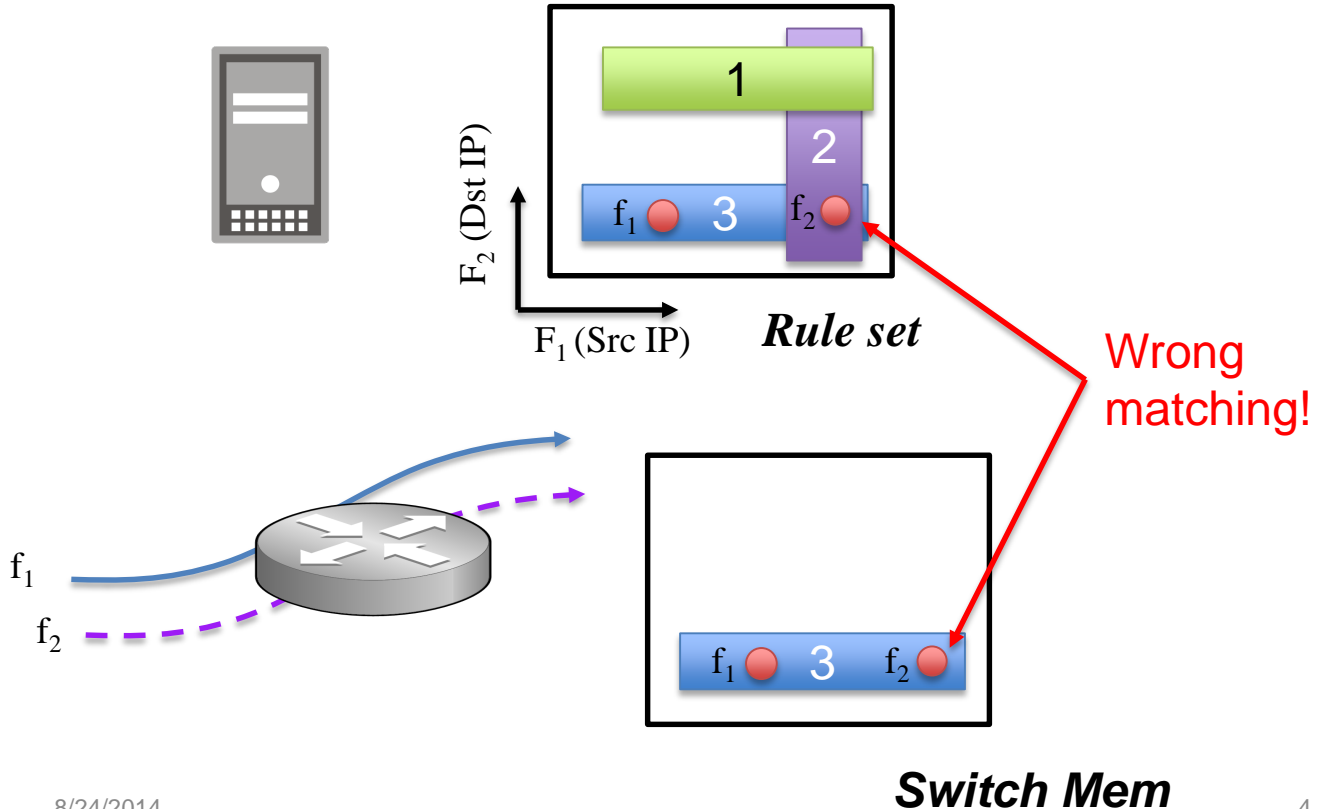


# Challenge: Wildcard Rule Dependency



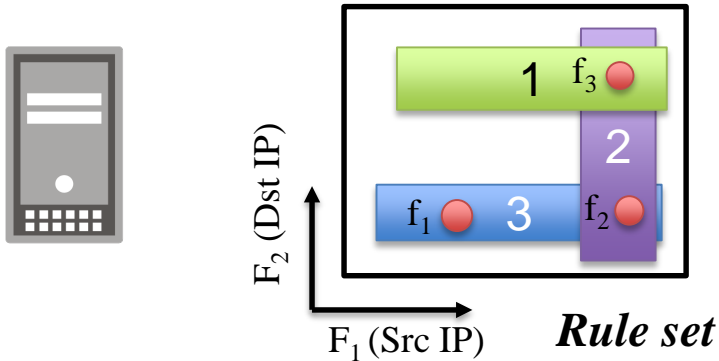


# Challenge: Wildcard Rule Dependency



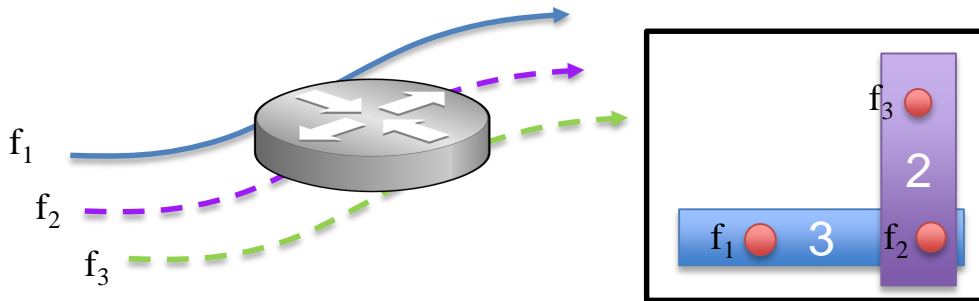


# Challenge: Wildcard Rule Dependency



Dependency  
has chain  
reaction

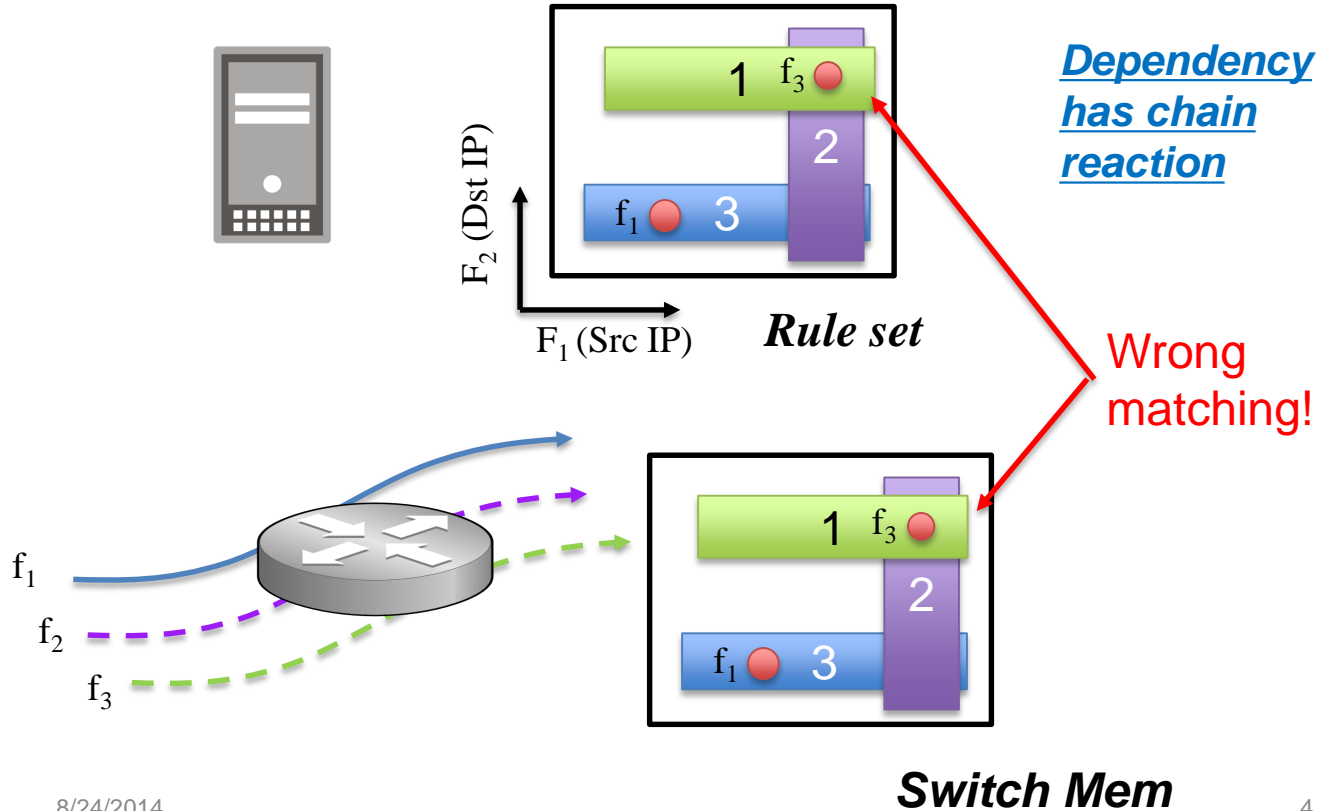
Wrong  
matching!



**Switch Mem**

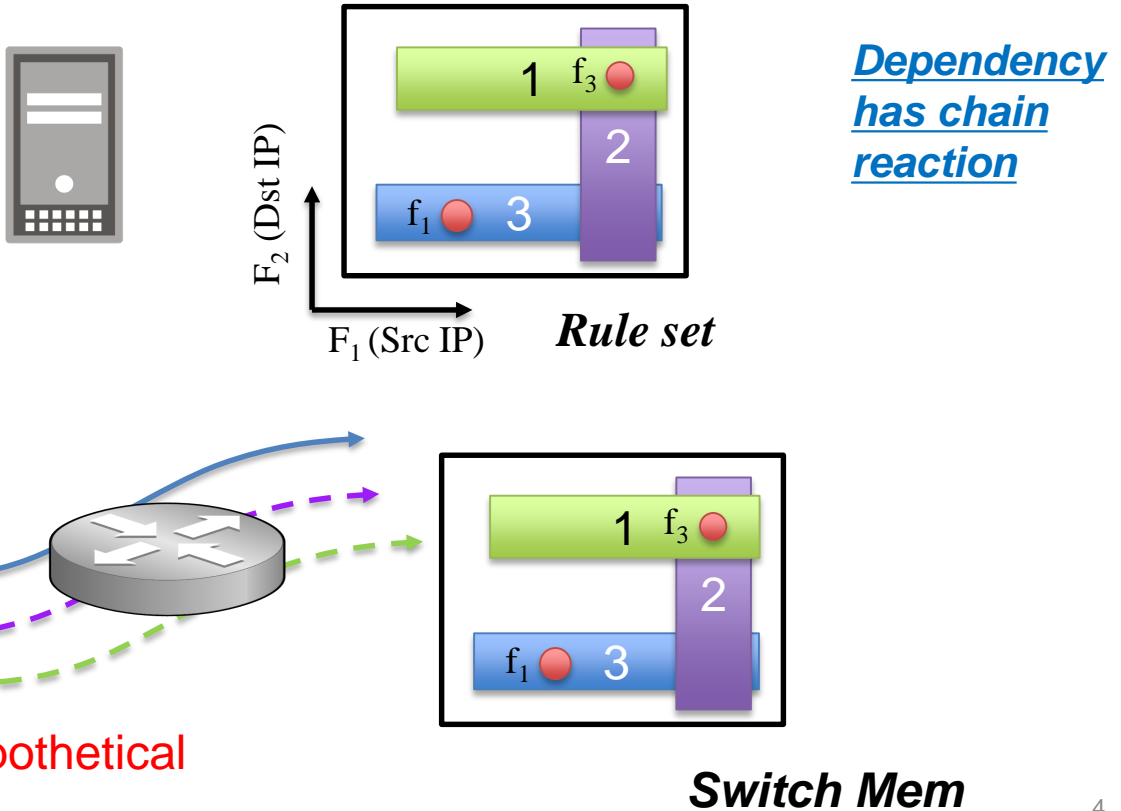


# Challenge: Wildcard Rule Dependency





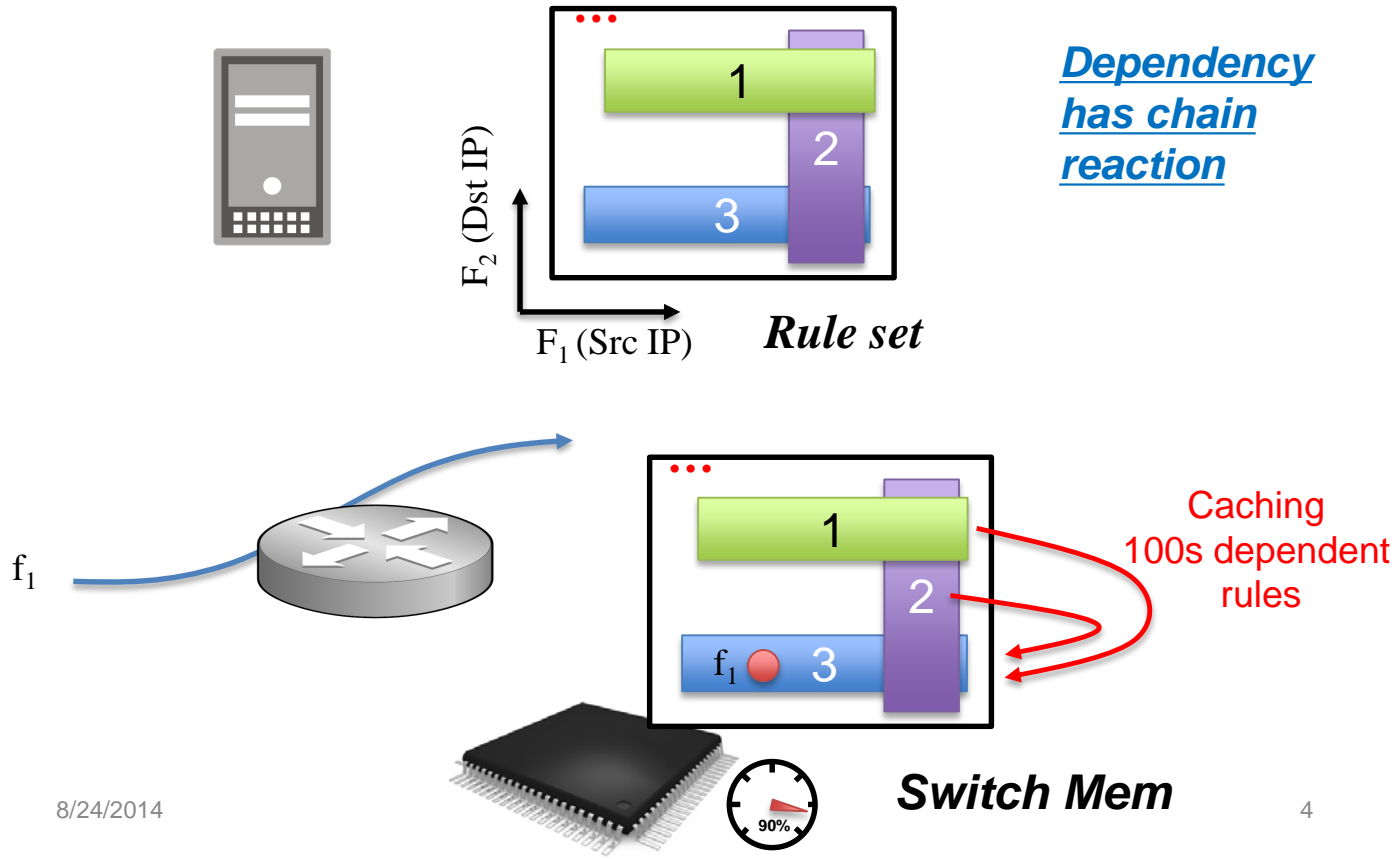
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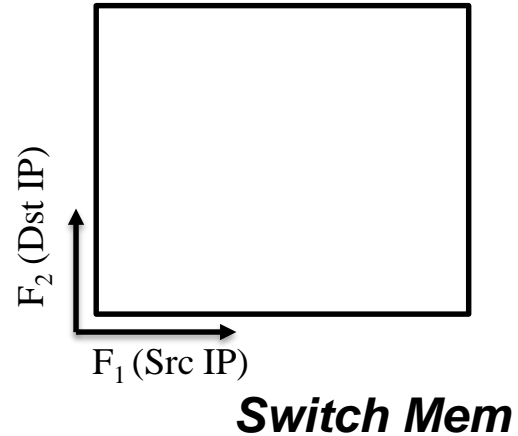
# Challenge: Wildcard Rule Dependency





Cache all dependent rules

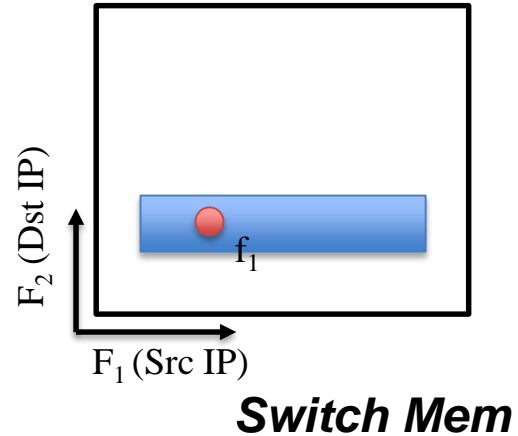
- Memory explosion





Cache all dependent rules

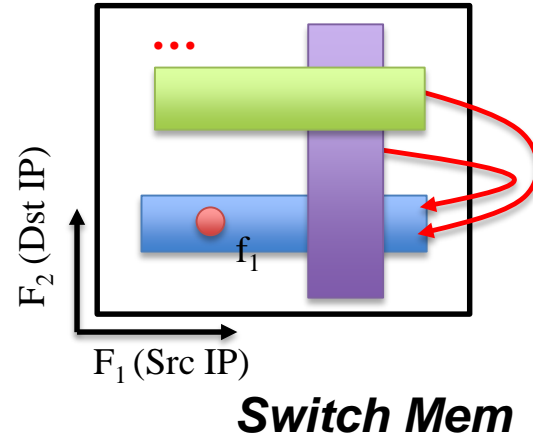
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Cache all dependent rules

- Memory explosion



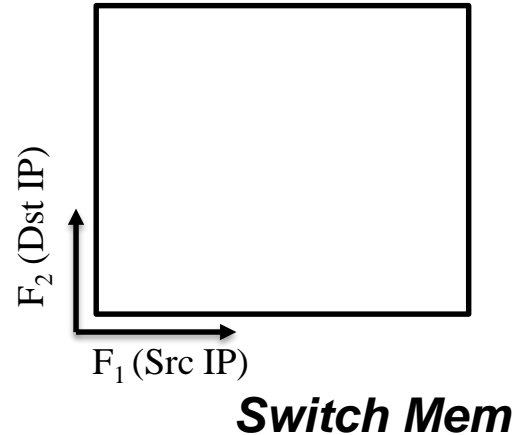


Cache all dependent rules

- Memory explosion

Cache exact match rules [DevoFlow][Ethane]

- Frequent rule installations



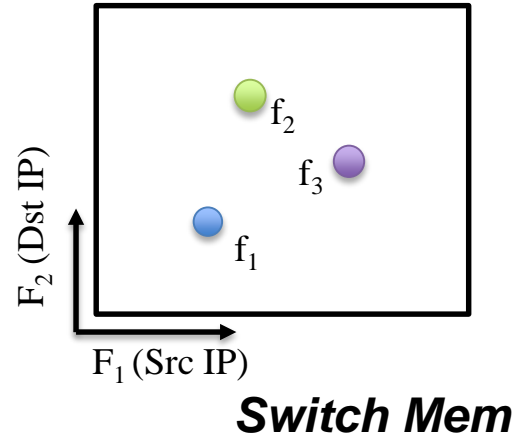


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Cache all dependent rules

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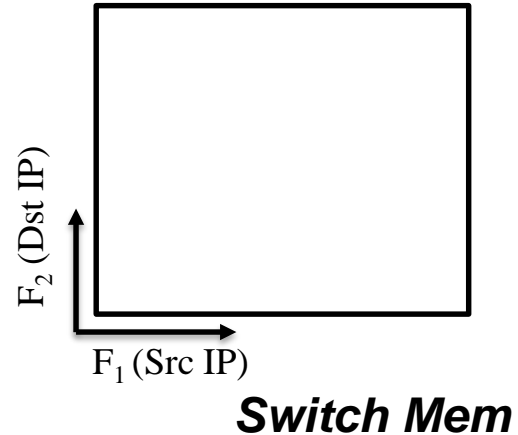
Cache exact match rules [DevoFlow][Ethane]

- Frequent rule installations

Split rule set and cache micro rules

[Smart Rule Cache][DIFANE]

- Significantly larger rule set





Cache all dependent rules

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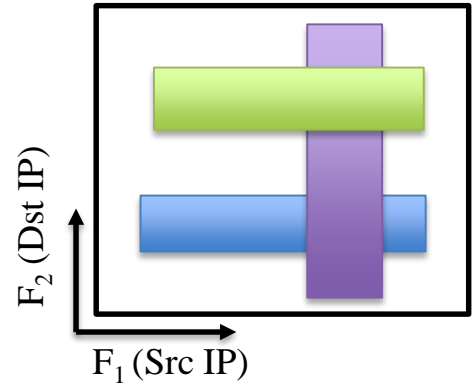
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**Switch Mem**





Cache all dependent rules

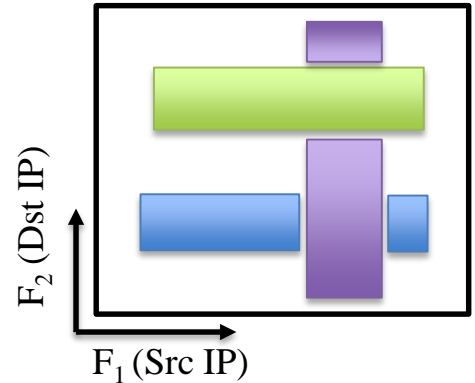
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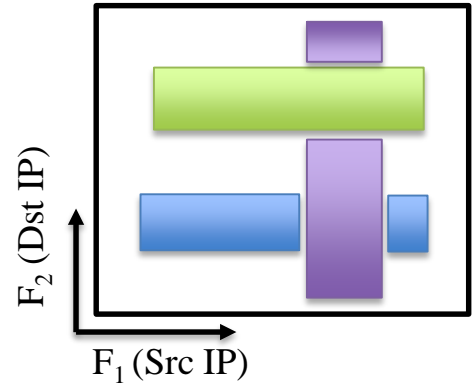
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**Switch Mem**

## Lack of efficiency in switch memory use

- more cache miss at switch
- higher controller load, control bandwidth
- longer flow setup delay



Cache all dependent rules

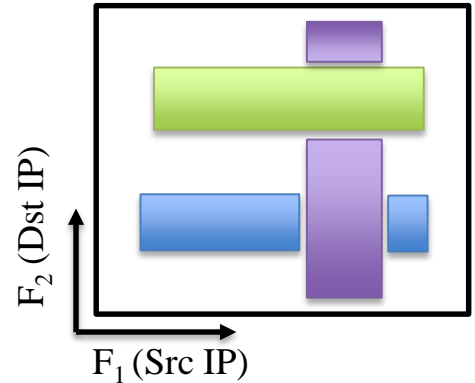
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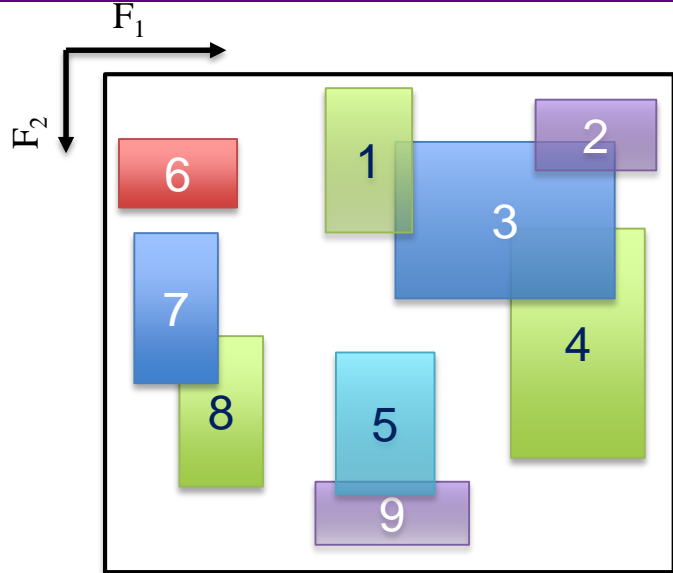
**Problem: how to accommodate rule dependency with efficient mem use?**



# Solution: CAching rules in Buckets (CAB)

**CAB Controller**

**Rules**



***Rule set (Controller)***

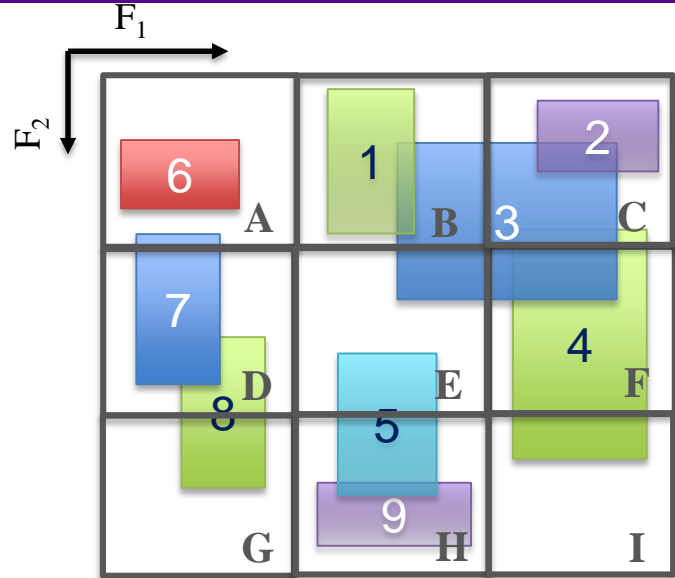


# Solution: CAching rules in Buckets (CAB)

## CAB Controller

Buckets

Rules



*Rule set (Controller)*



# Solution: CAching rules in Buckets (CAB)

## CAB Controller

Buckets

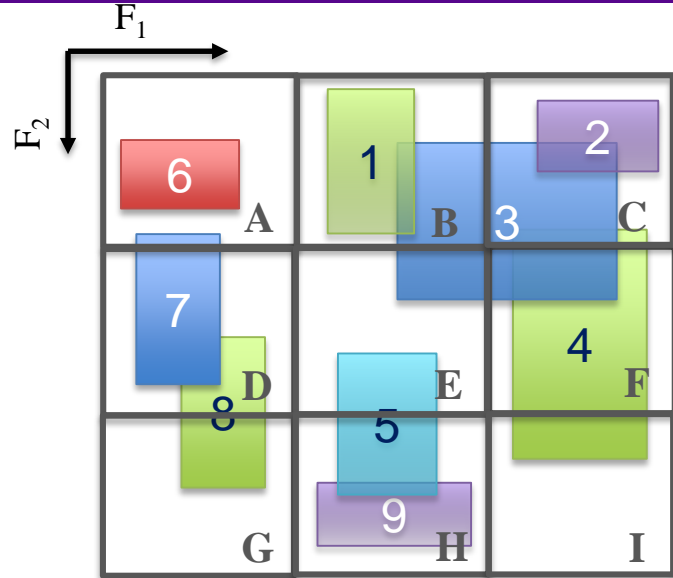
Rules



Bucket Filter

Flow Table

OpenFlow Switch



*Rule set (Controller)*



# Solution: CAching rules in Buckets (CAB)

## CAB Controller

Buckets

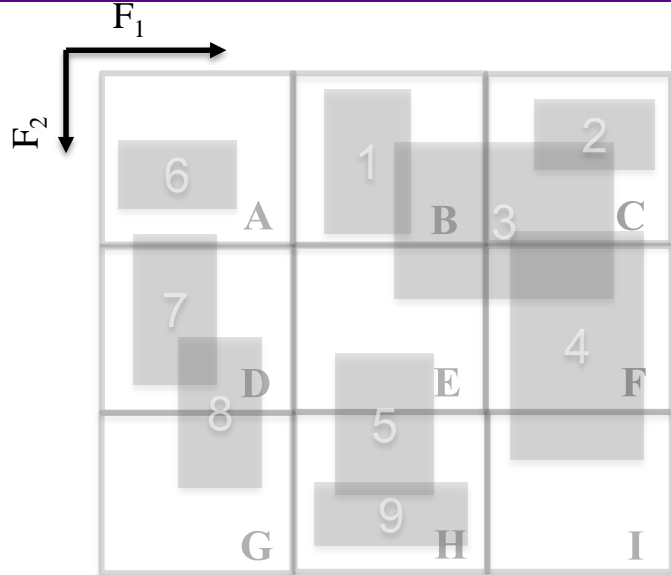
Rules



Bucket Filter

Flow Table

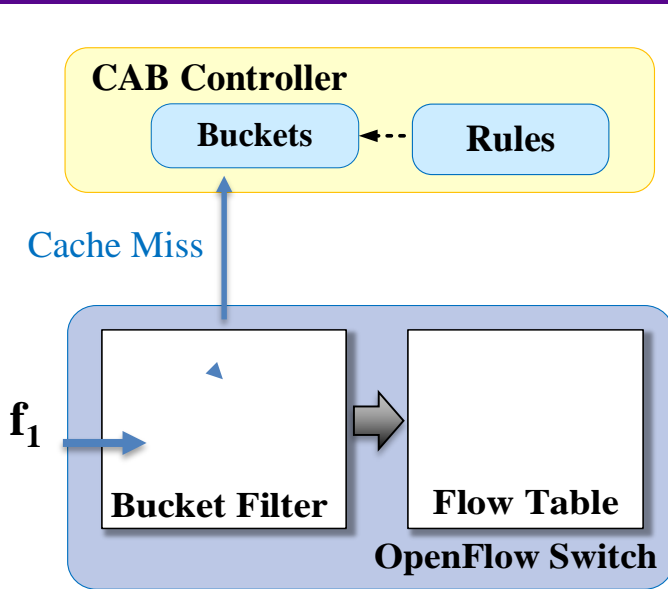
OpenFlow Switch



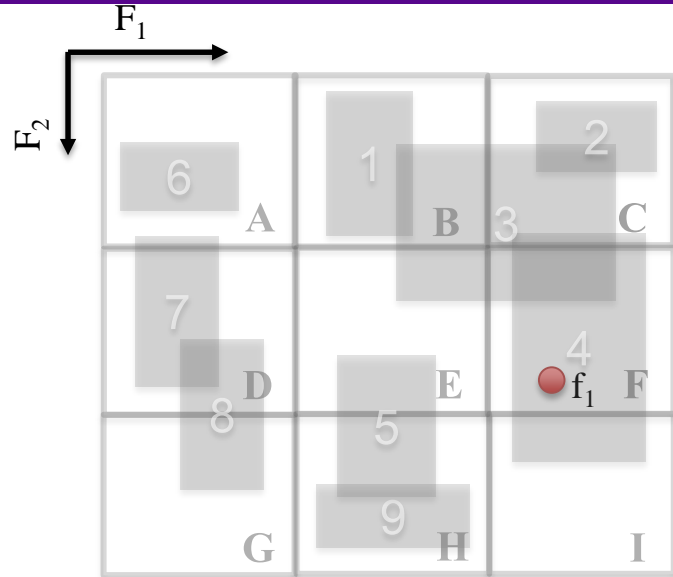
**Switch Mem**



# Solution: CAching rules in Buckets (CAB)



Cache Miss at Bucket Filter

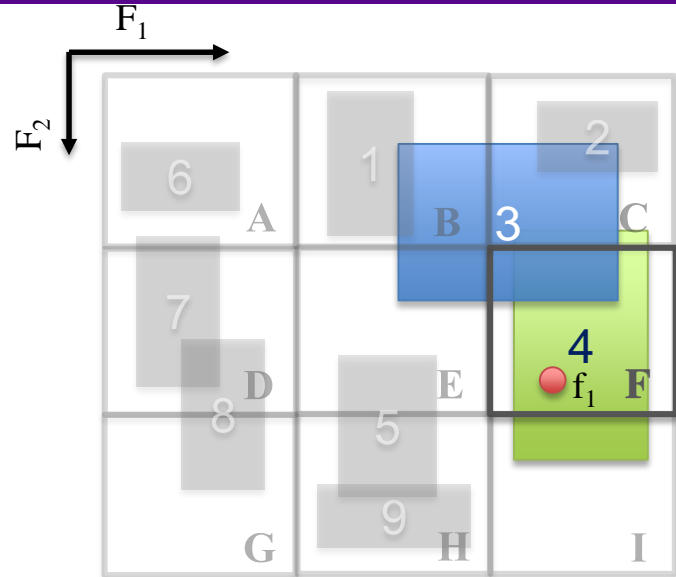
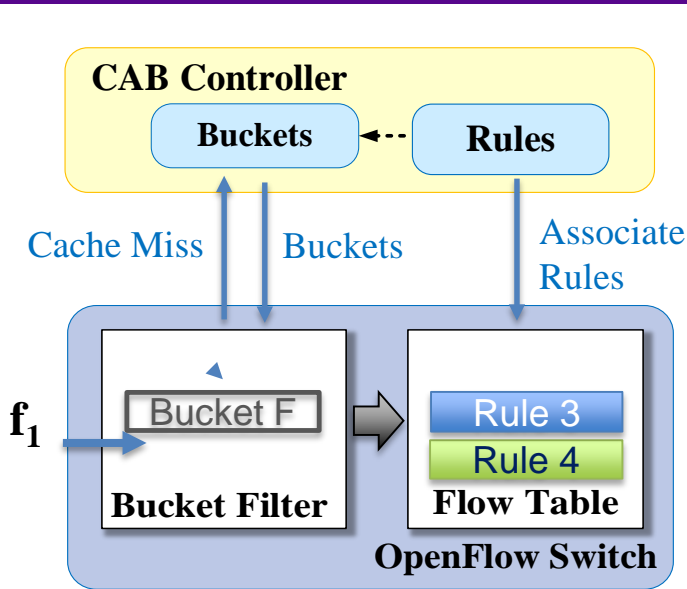


**Switch Mem**





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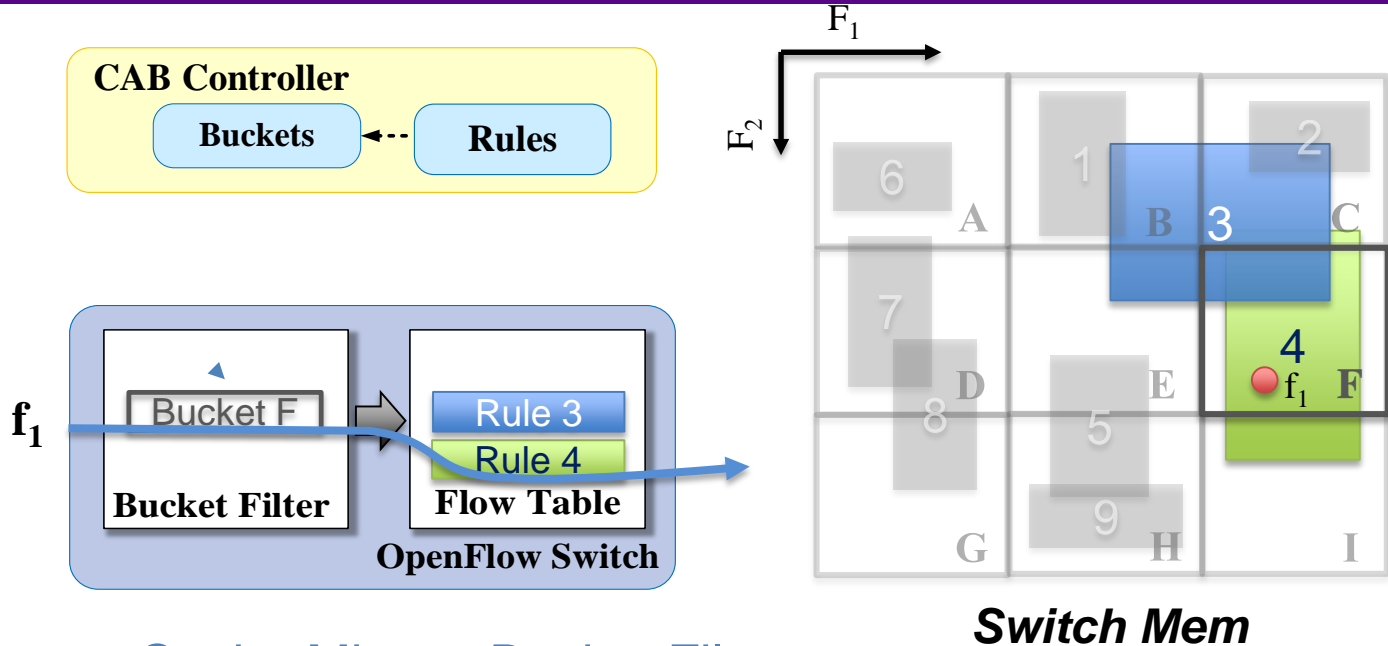


**Switch Mem**

Cache Miss at Bucket Filter  
Install bucket F and rule 3 & 4



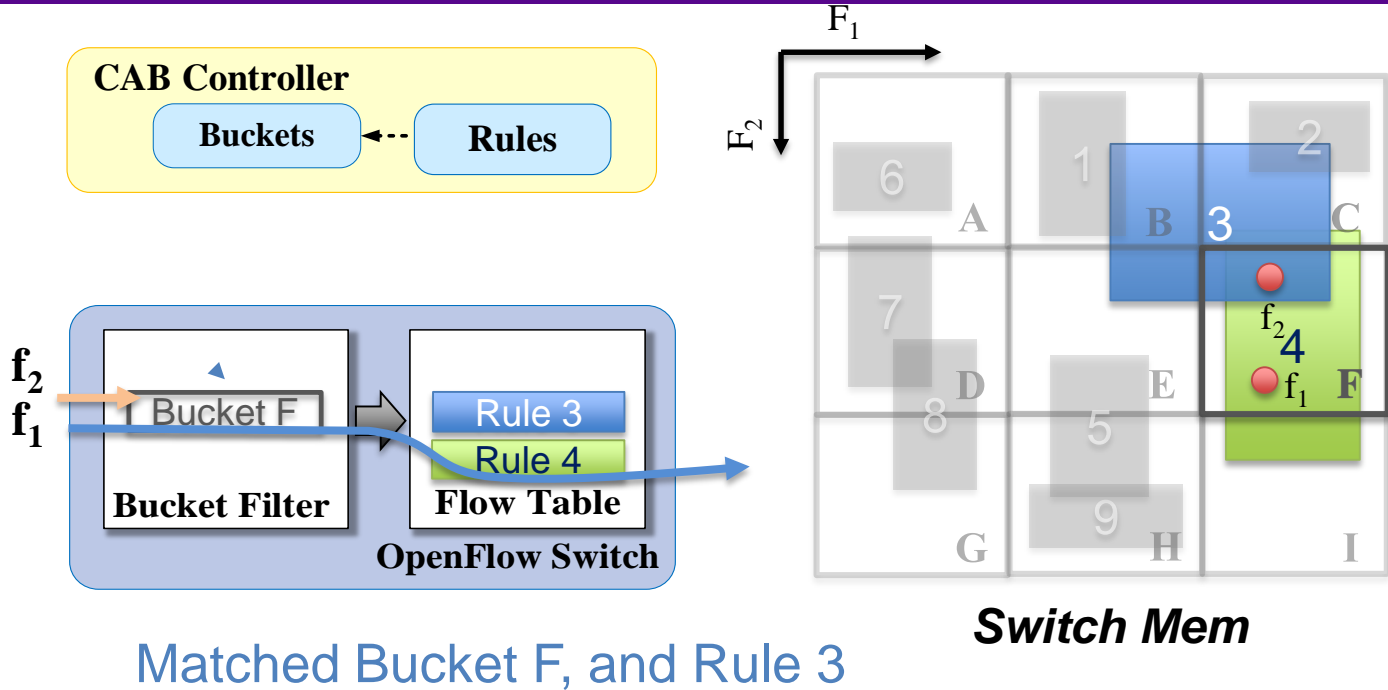
# Solution: CAching rules in Buckets (CAB)



Cache Miss at Bucket Filter  
Install bucket F and rule 3 & 4  
 $f_1$  is set up

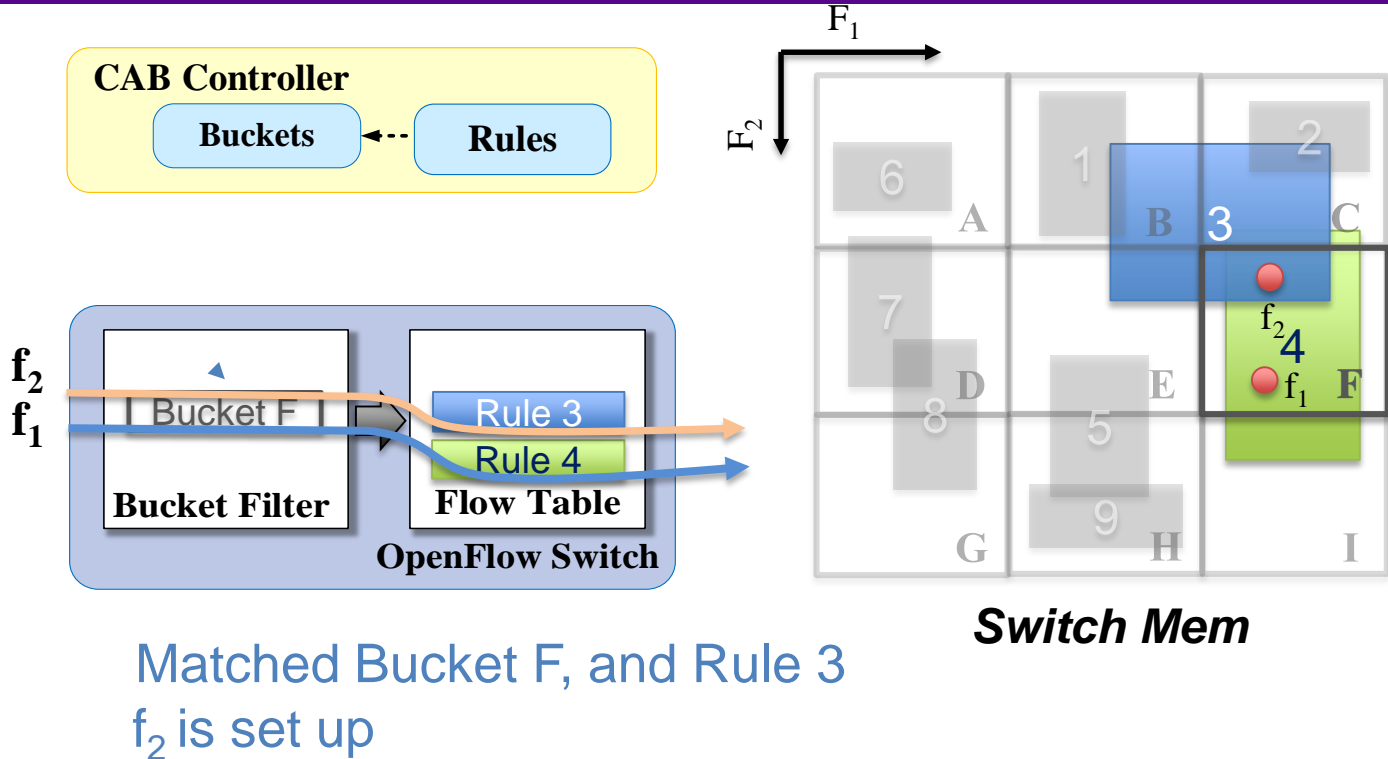


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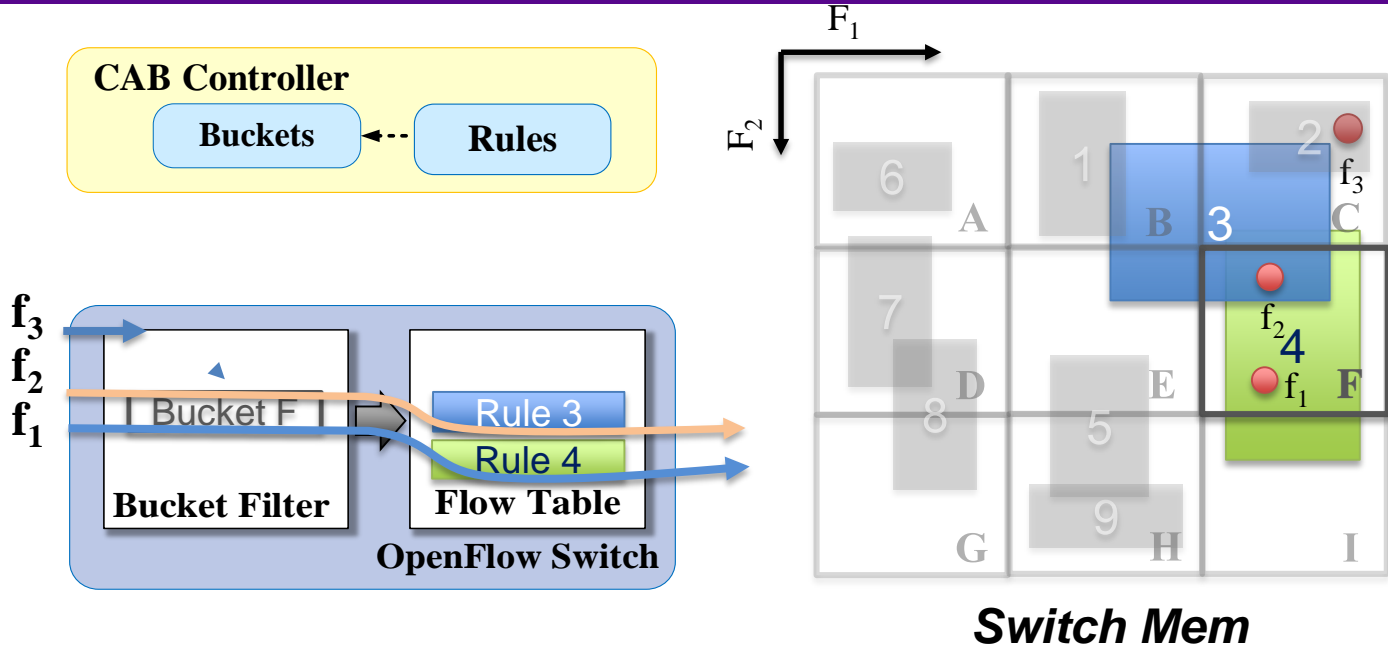


# Solution: CAching rules in Buckets (CAB)



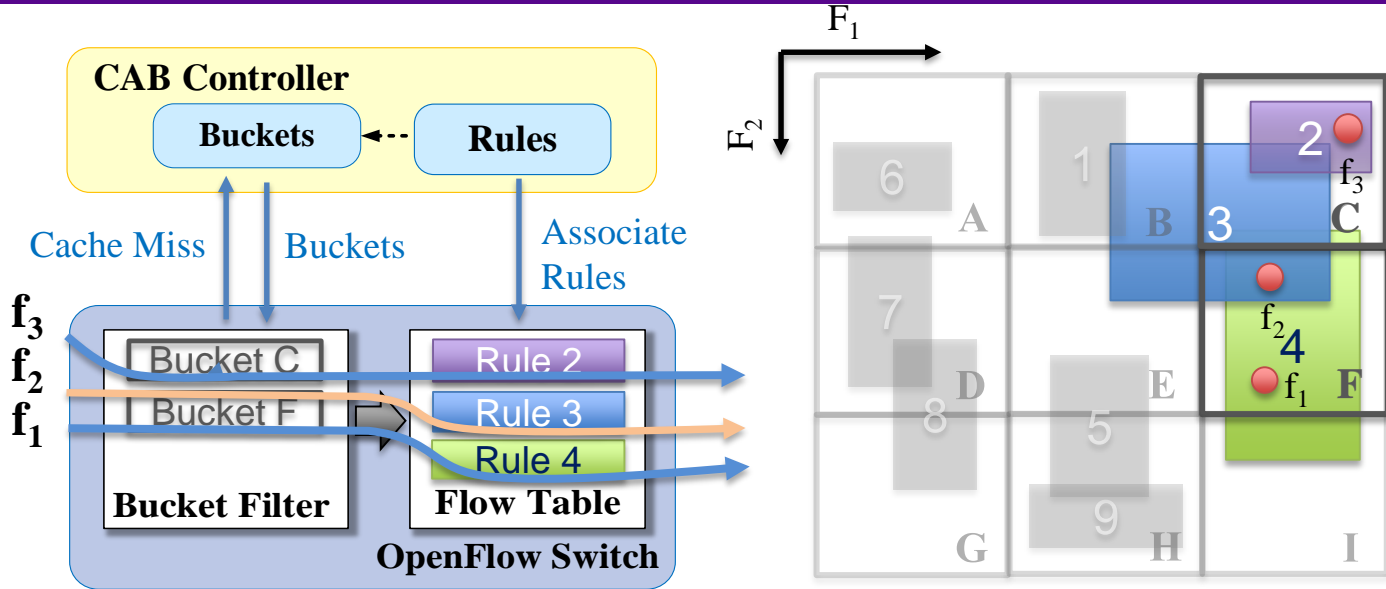


# Solution: CAching rules in Buckets (CAB)





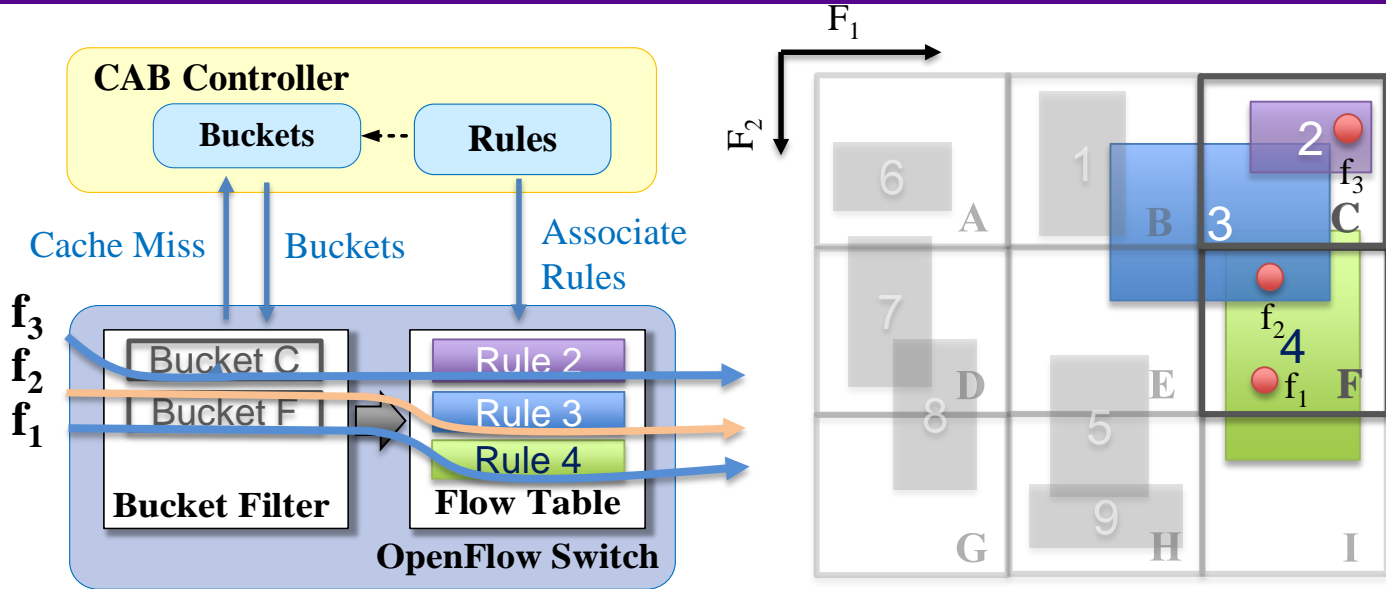
# Solution: CAching rules in Buckets (CAB)



Cache Miss at Bucket Filter  
Install bucket C and rule 2 (&3)  
 $f_3$  is set up



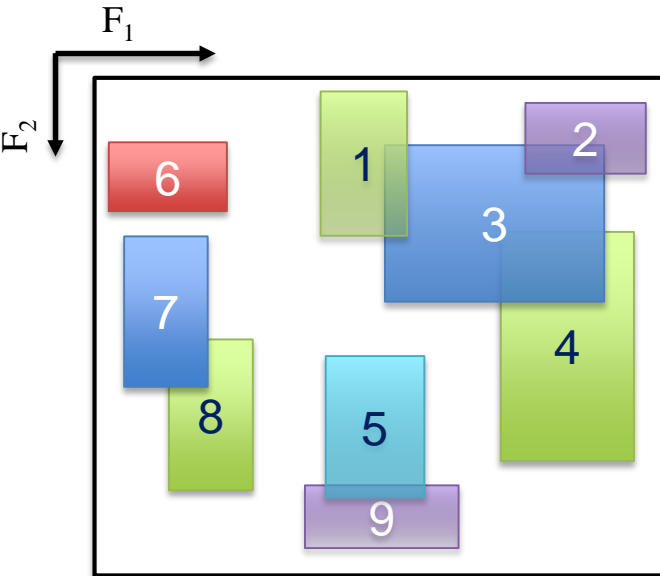
# Solution: CAching rules in Buckets (CAB)



**Now no more 100s dependent rules**  
**Only rules within requested bucket**



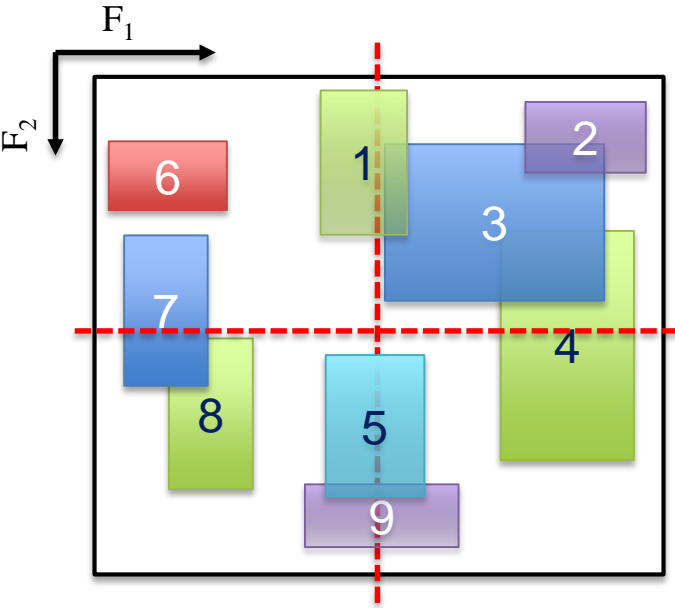
# Bucket size affects memory efficiency







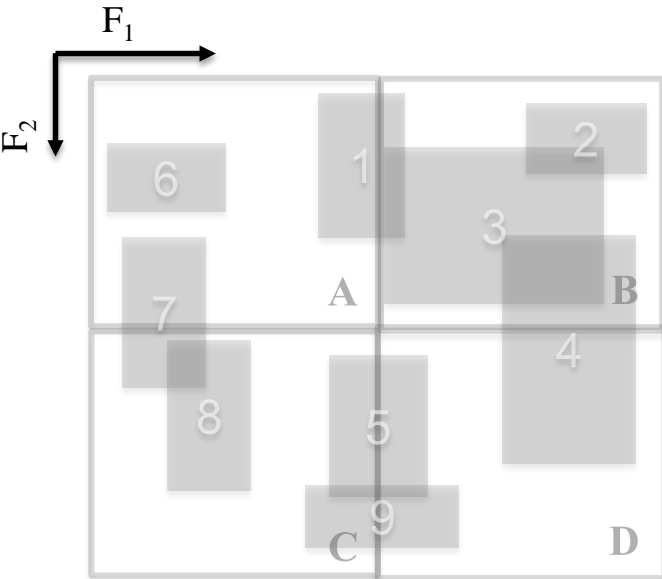
# Bucket size affects memory efficiency



Larger buckets (2x2)



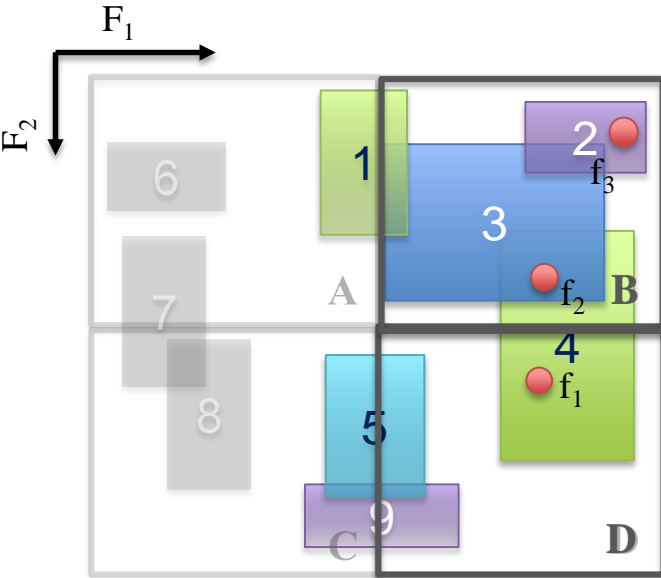
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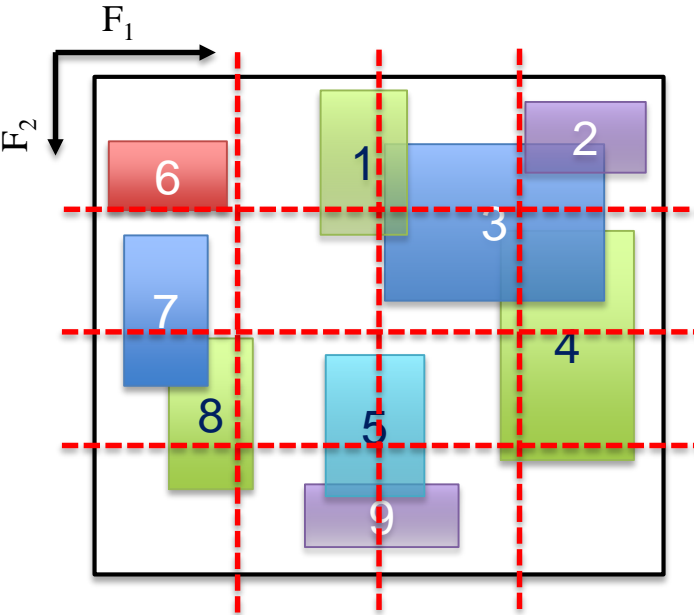


Larger buckets (2x2)

- More rules cached each time
- Unmatched rules cached



# Bucket size affects memory efficiency



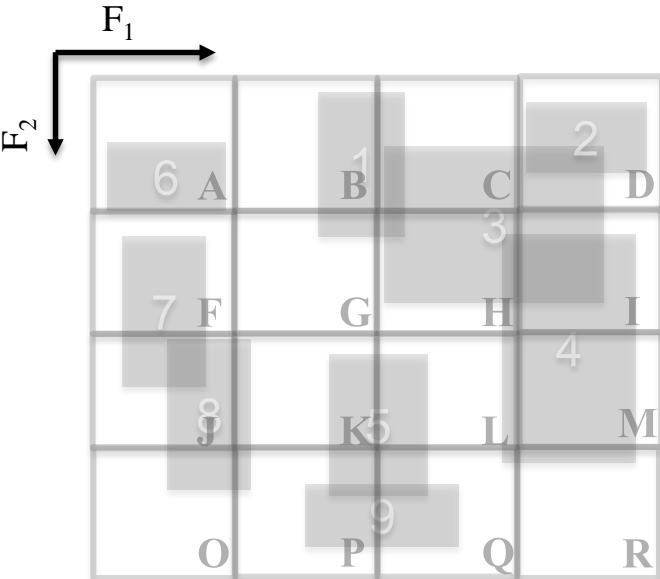
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Smaller buckets (4x4)



# Bucket size affects memory efficiency



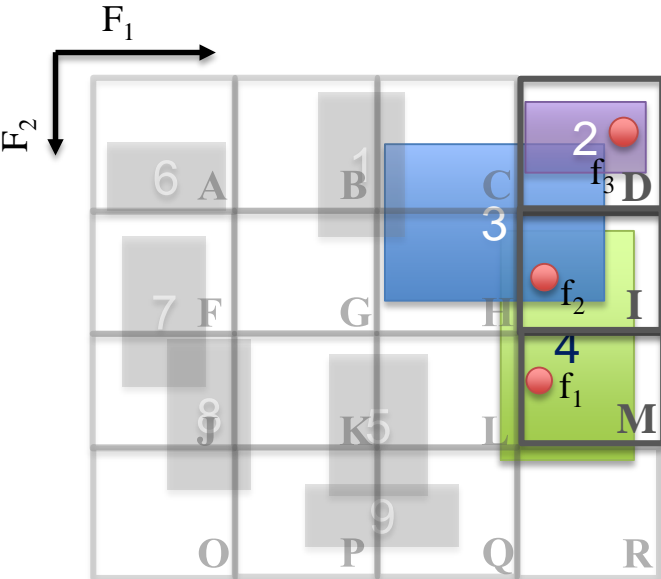
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## Larger buckets (2x2)

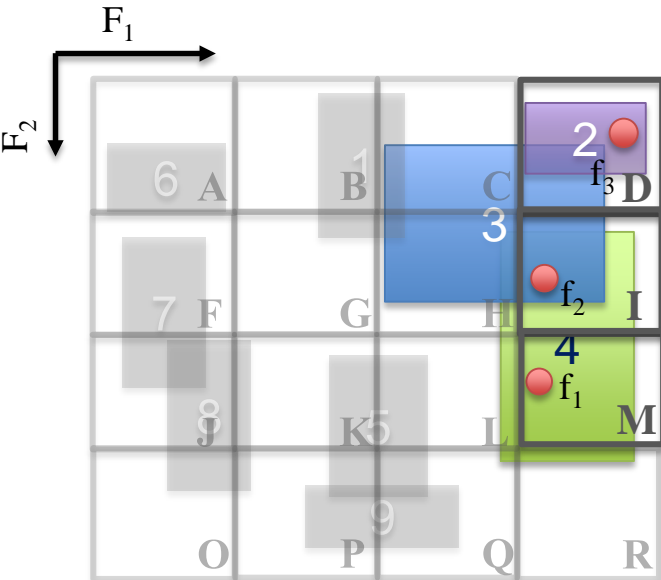
- More rules cached each time
- Unmatched rules cached

## Smaller buckets (4x4)

- More buckets cached



# Bucket size affects memory efficiency



Larger buckets (2x2)

- More rules cached each time
- Unmatched rules cached

Smaller buckets (4x4)

- More buckets cached

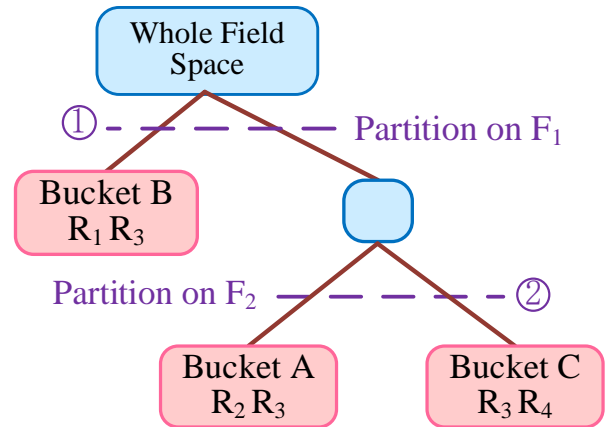
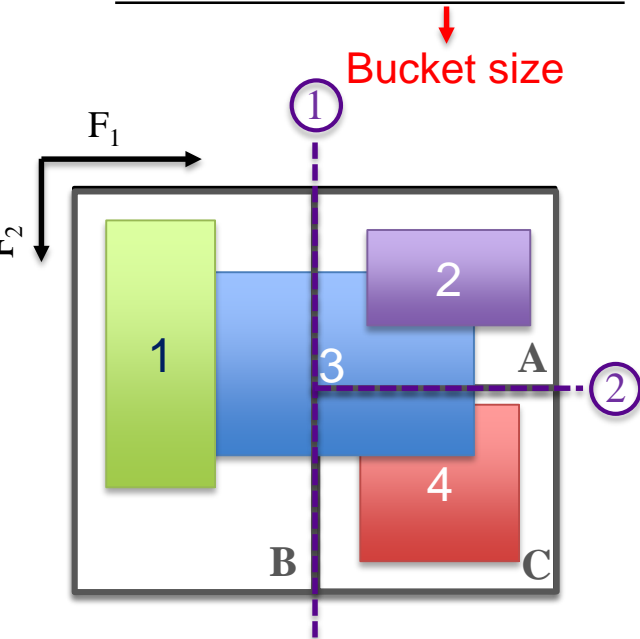
**Choosing bucket size affects switch memory efficiency**



# Bucket Generation Decision Tree

Decision tree based generation algorithm [HyperCut]

**No. of associate rules** in each bucket is bounded



Technical problems:

How to select the fields to partition?  
[see paper]





## Performance Evaluation

- Cache miss rate
- Bandwidth Consumption
- Flow setup latency (see paper)

## Parameter Setting

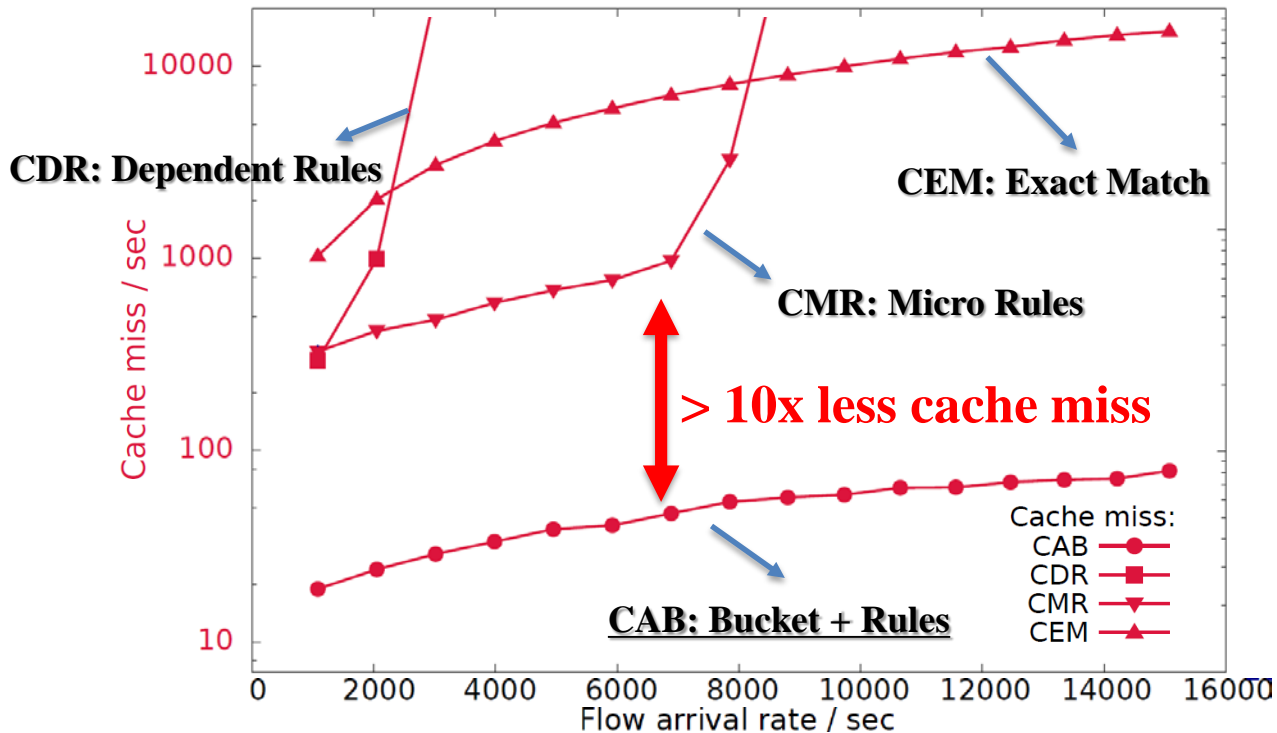
- Effects of Tuning bucket size

## Comparison

- **CAching rules in Buckets (**CAB**)**
- Caching exact match rules (CEM)
- Caching micro rules (CMR)
- Caching dependent rules (CDR)

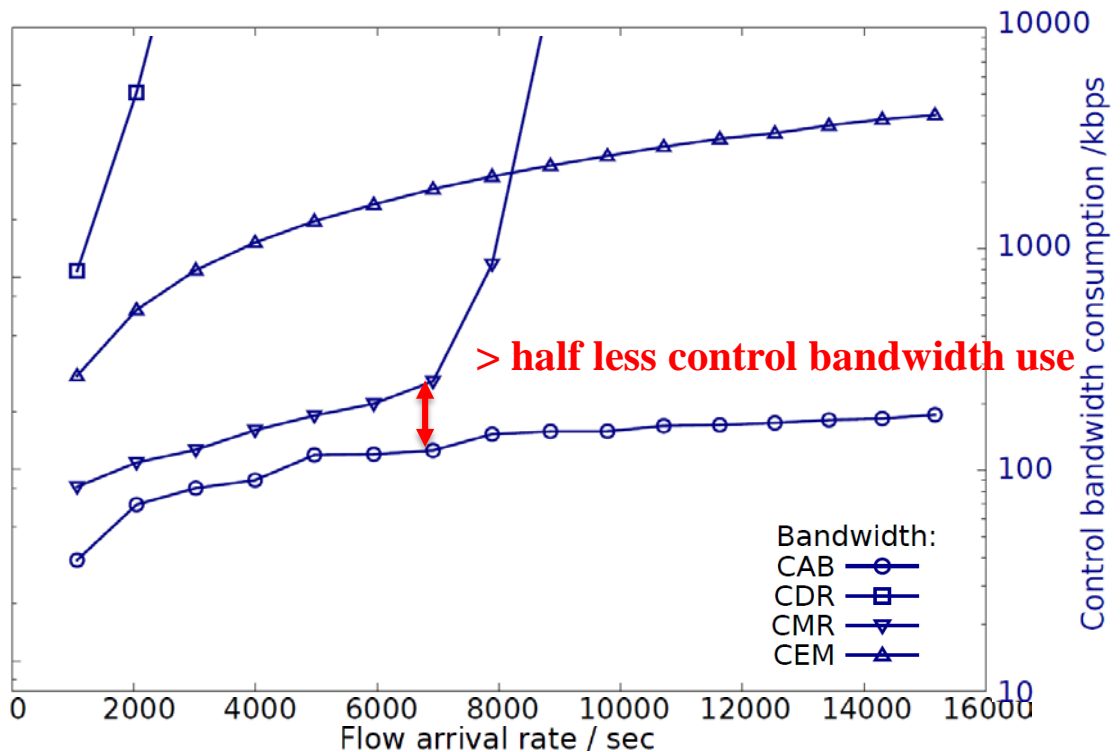


# Cache Miss and Control Bandwidth Performance



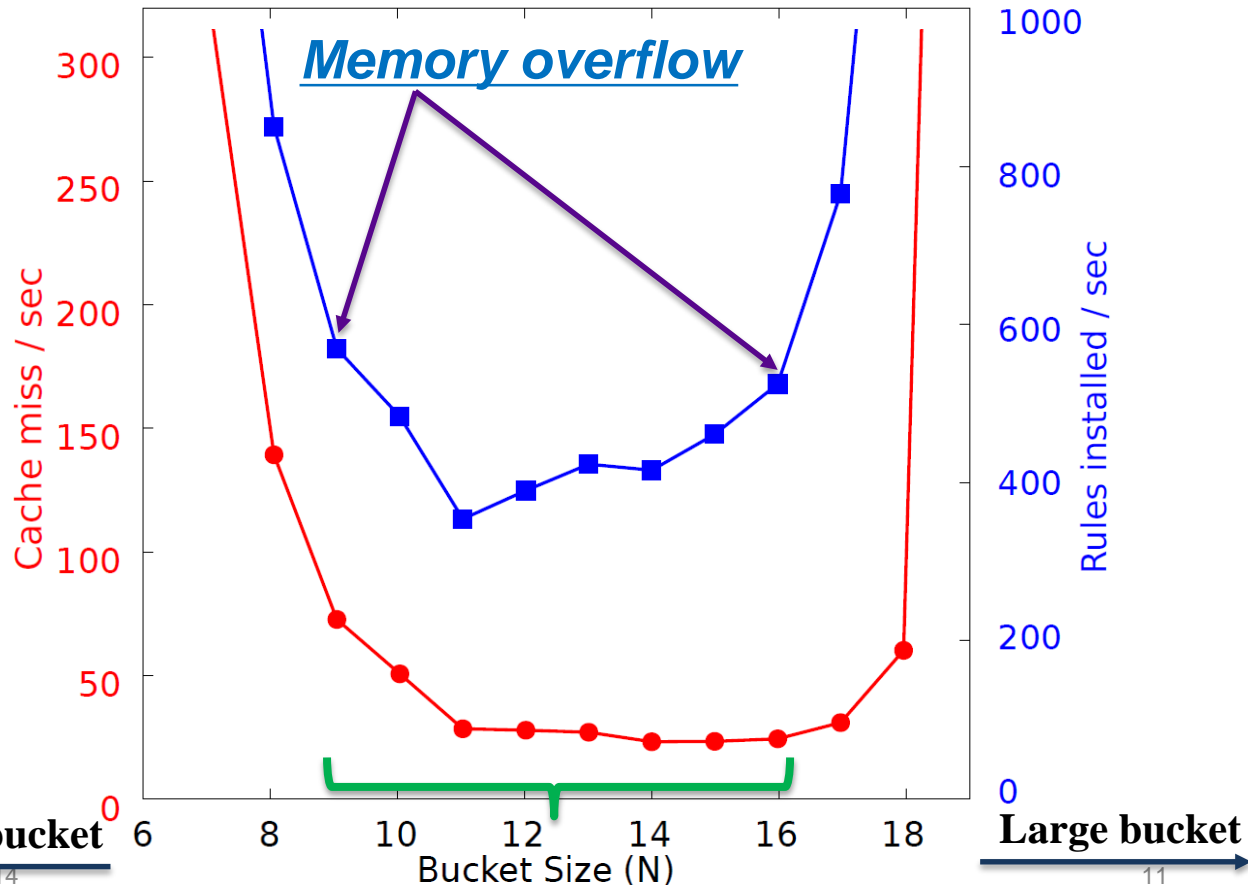


# Cache Miss and Control Bandwidth Performance





# Effect of tuning bucket size





CAB is a novel wildcard rule caching system which

Resolves **rule dependency** in wildcard rule caching

Achieves **efficient switch memory use** helps reducing  
control network bandwidth  
flow setup latency  
controller load

Is **fully compatible** with the latest OpenFlow standards



# Thank you!

## Q&A

