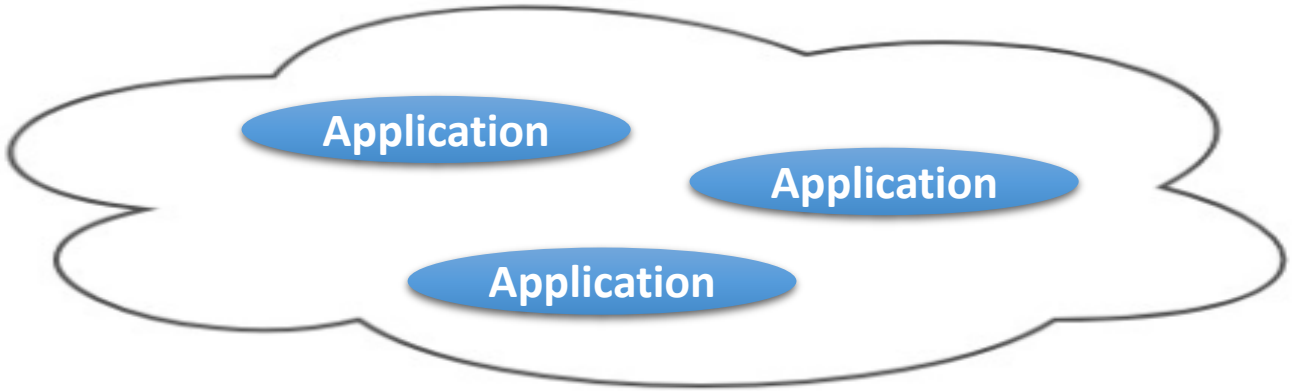
SDNKeeper: Lightweight Resource Protection and Management System for SDN-based Cloud

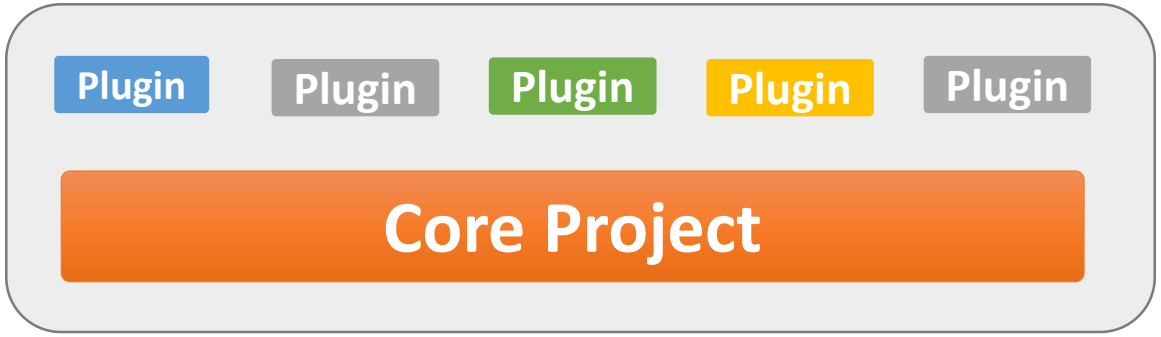
Xue Leng*

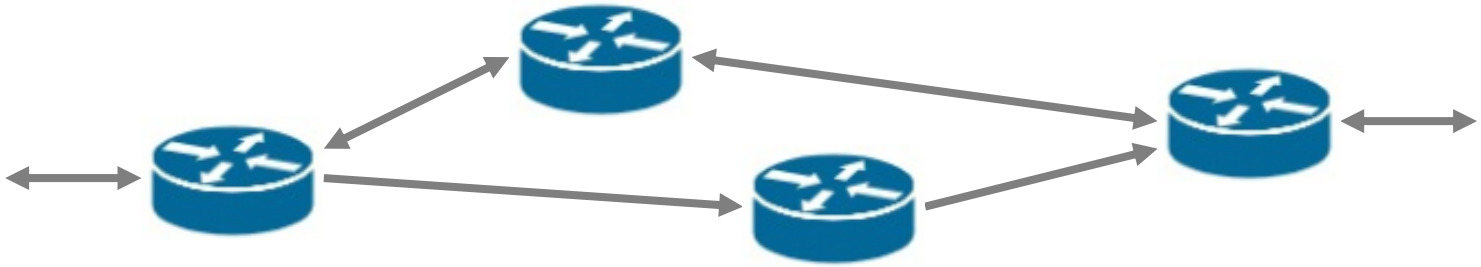
Kaiyu Hou#, Yan Chen*#, Kai Bu*, Libin Song#

*Zhejiang University** *Northwestern University#*

Background

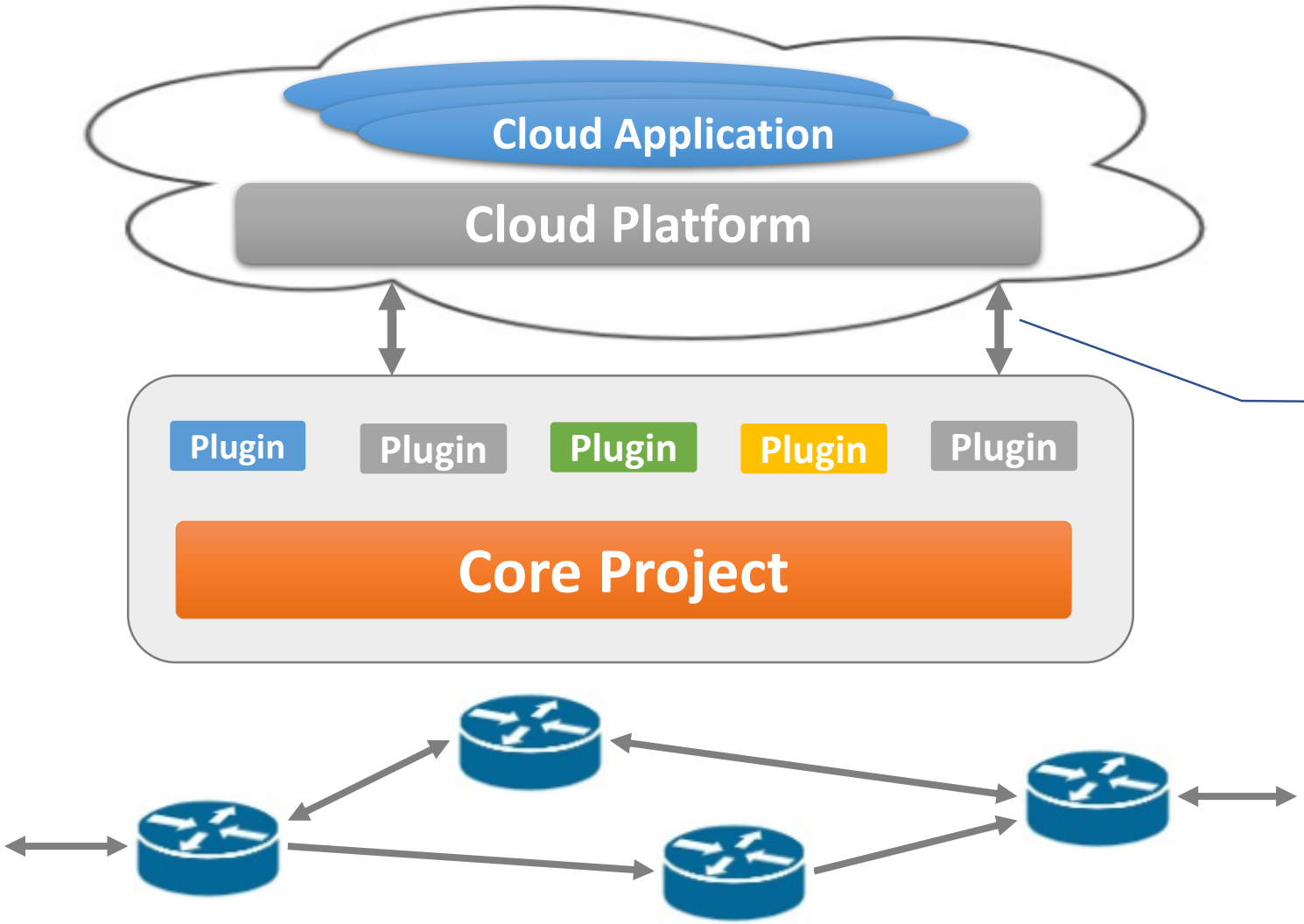






What is SDN ?
SDN-based Cloud ?

Background

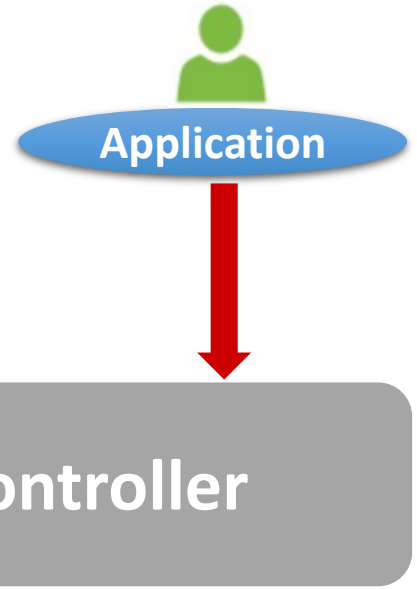


What is
SDN-based Cloud ?

Northbound Interface (NBI)

Problem 1: Absence of Effective Access Control

- Inaccurate requests from applications
- Requests are tampered with in transit
- Malicious requests sent through NBI directly



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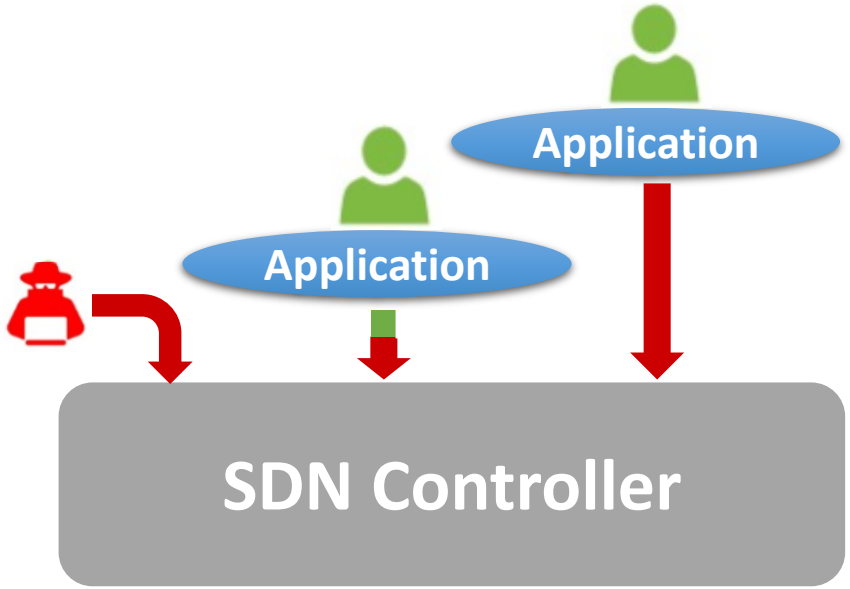
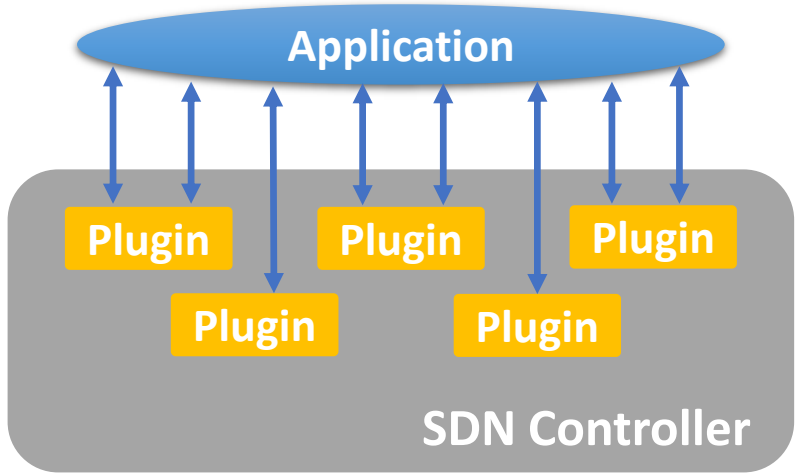
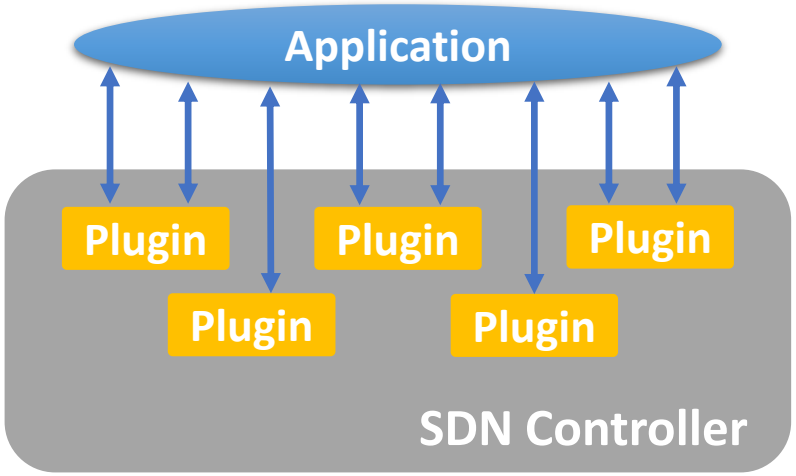


Problem 2: Absence of Unified Management



Problem 2: Absence of Unified Management

- **Inflexible control of resources[1]**
- **Error prone during network configuration**



[1] Resource is anything that can be utilized to provide services in response to client requests.

Current solutions

- **Access control on requests** **[JNSM'18], AAA Project in ODL**
  - Verify the legitimacy of user's identity

  Omit the legitimacy of user's operation, Coarse-grained
- **Reconciliating inside the plugin**
- **Redesigning API and controller architecture**

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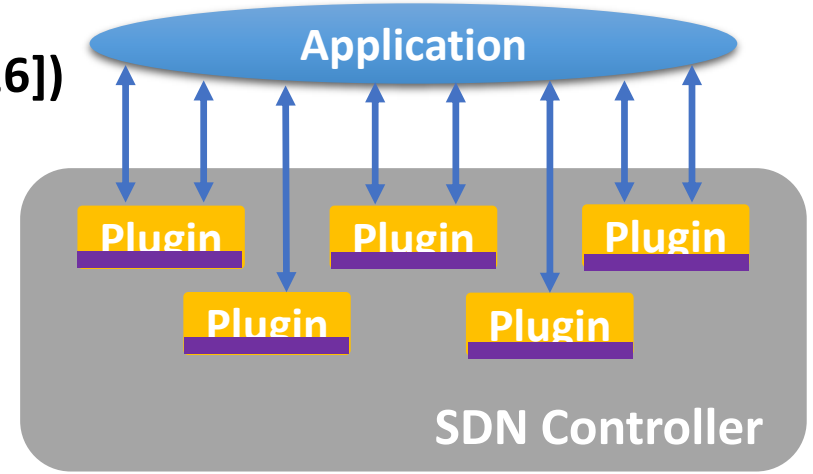
  Code modification, Inflexible

- Redesigning API and controller architecture



Current solutions

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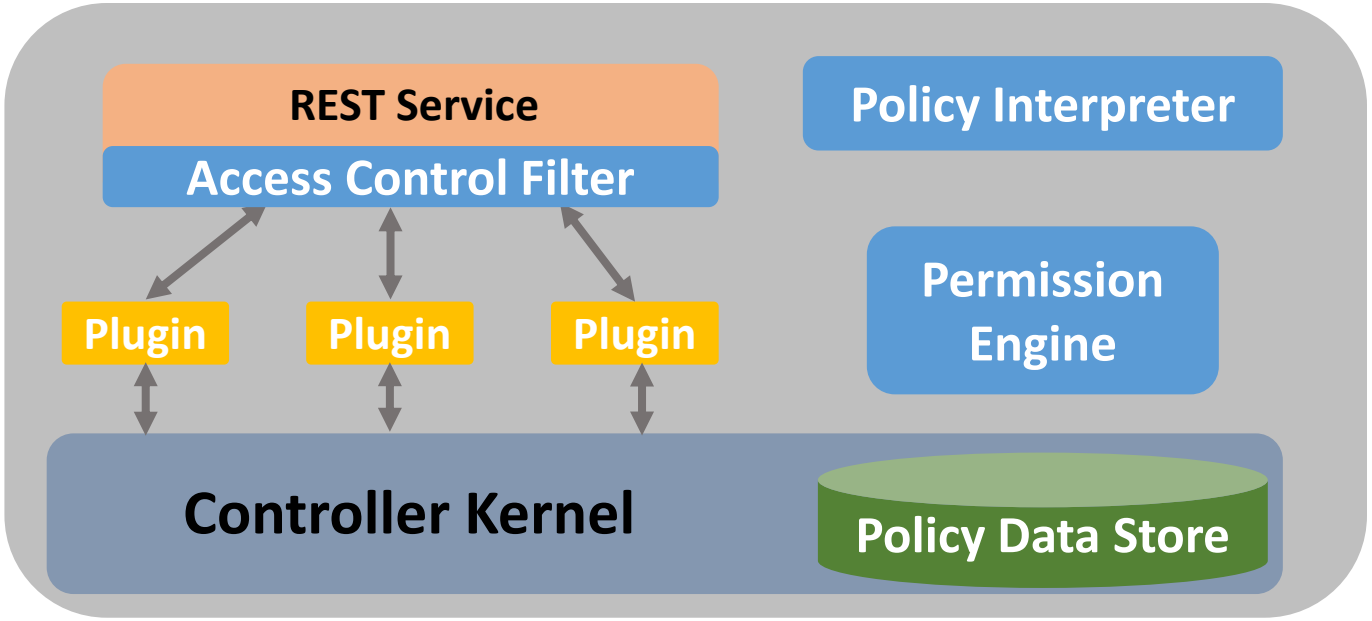
- **Reconciliating inside the plugin** (SDNShield[DSN'16])

  Code modification, Inflexible

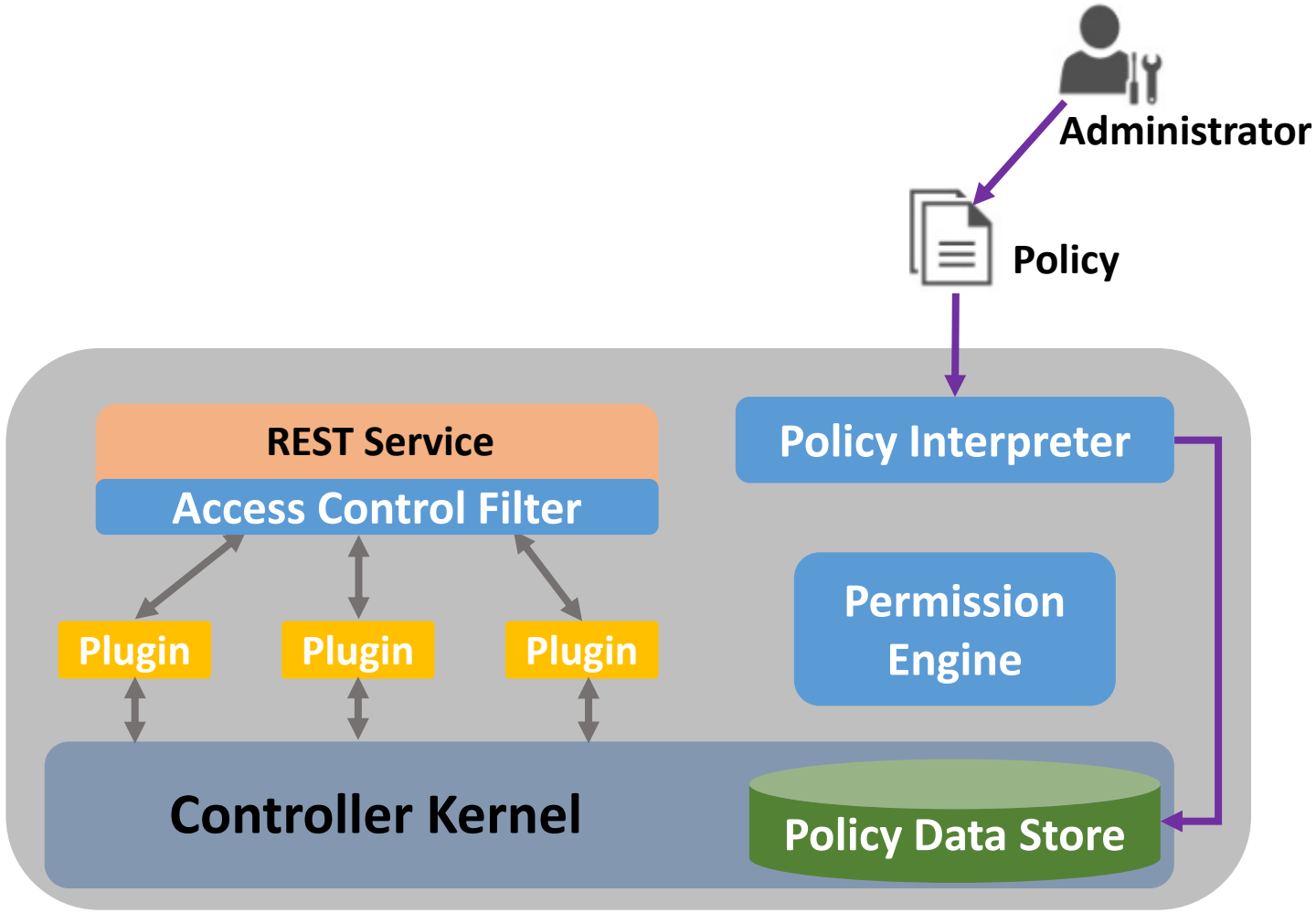
- **Redesigning API and controller architecture** [HotSDN'14, SIGCOMM CCR'13]

  Poor interoperability

SDNKeeper


REST Service
Access Control Filter
Policy Interpreter
Plugin
Plugin
Plugin
Permission Engine
Controller Kernel
Policy Data Store

SDNKeeper


Administrator
Policy
REST Service
Access Control Filter
Policy Interpreter
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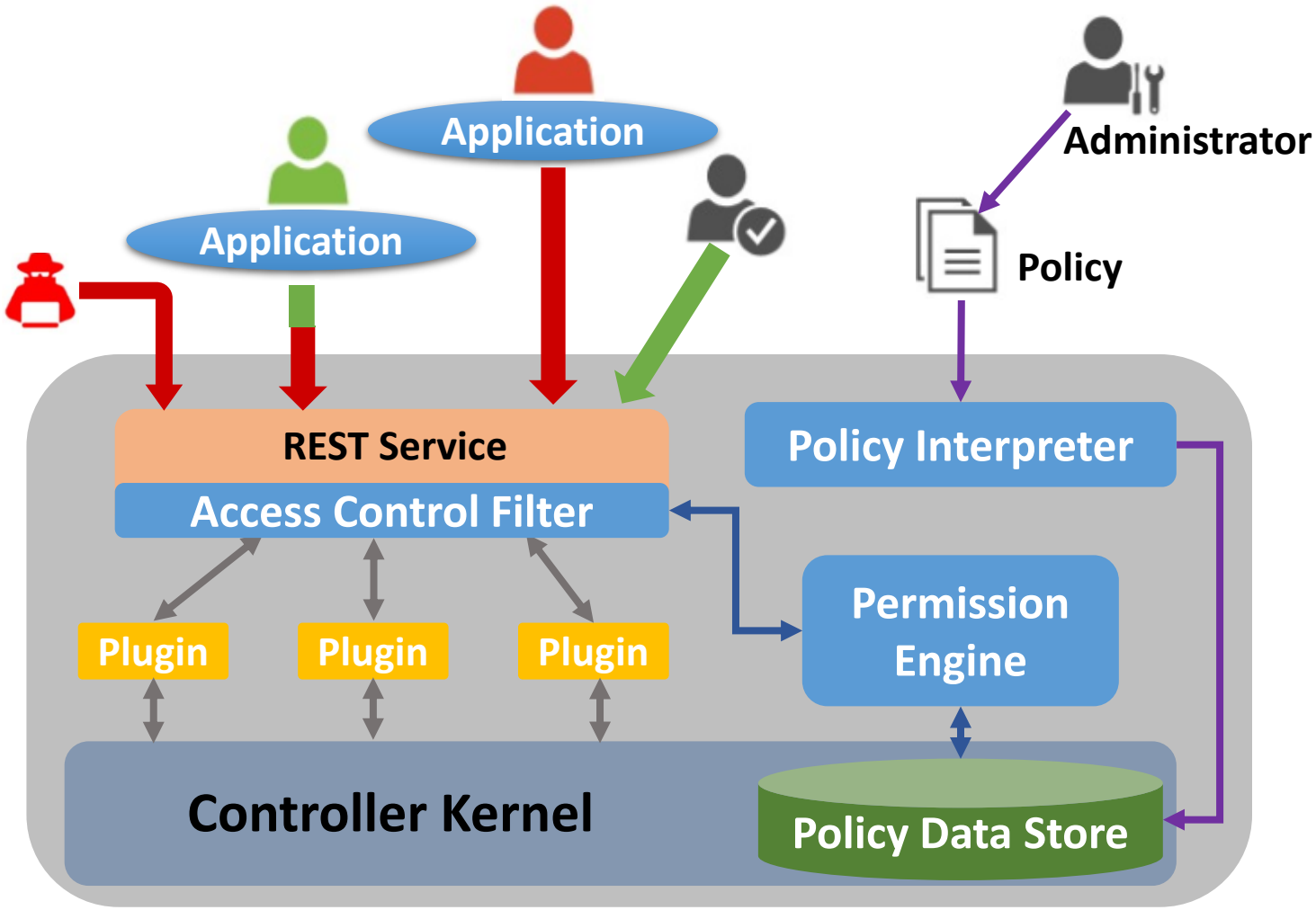
SDNKeeper


Application
Application
Administrator
Policy
REST Service
Access Control Filter
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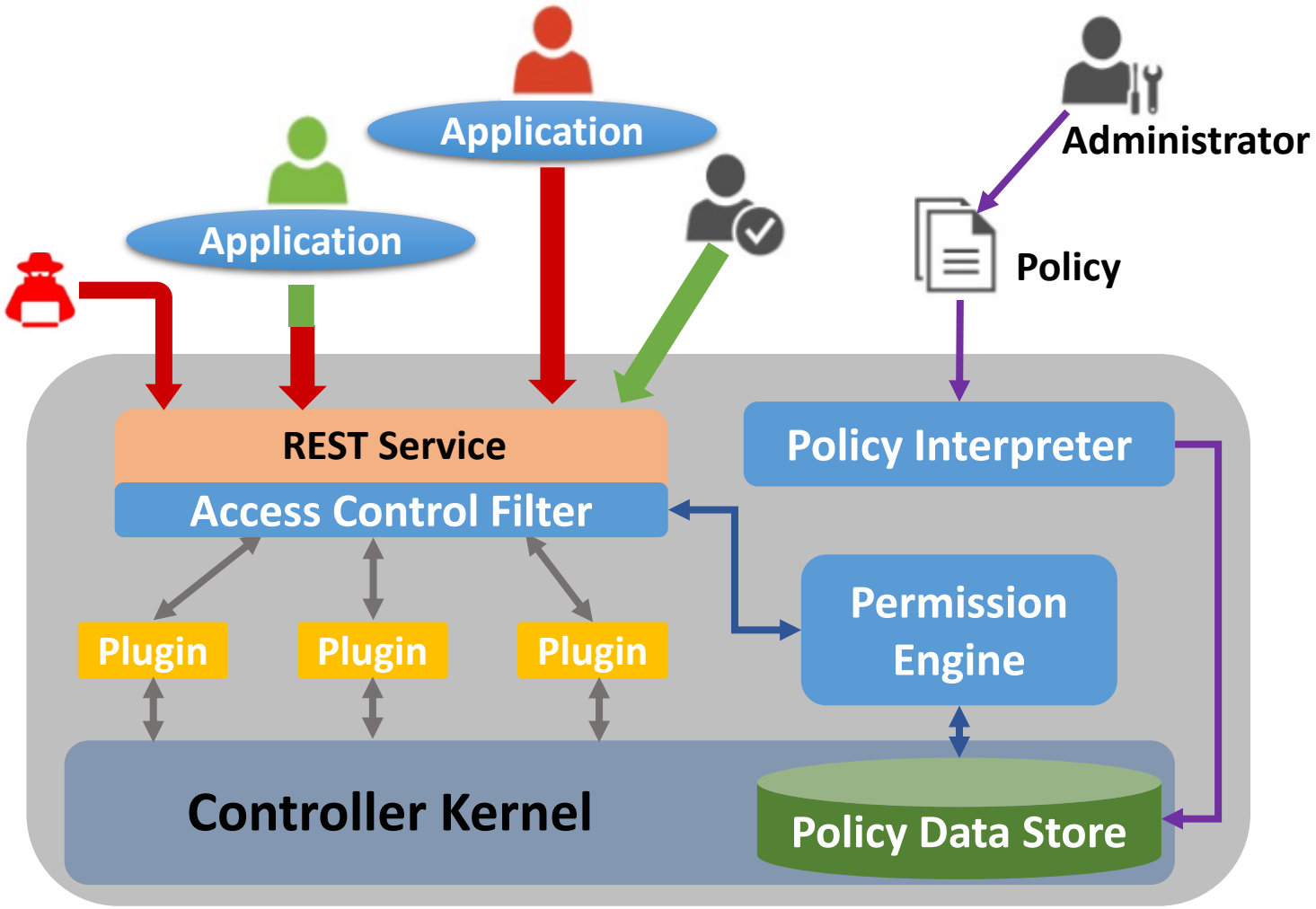
SDNKeeper



- Applicability
- Administrator Friendliness
- Centralized Management
- Hot Update

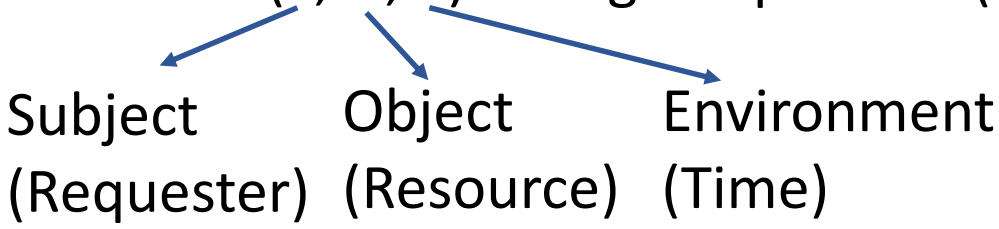
Detailed Designs

- **Policy Language – flexible permission abstractions**
- **Policy Interpreter – parsing semantic policies**
- **Permission Engine – performing access control on requests**

Policy Language

Attribute Based Access Control

P(S, O, E) <- Logic Expression(ATTR(S), ATTR(O), ATTR(E))



REST Request

```
1) Method: POST  (POST/GET/PUT/DELETE)
2) URI: https://<controller-ip>:<port>/networks/
3) Headers: {
     Content-Type : application/json,
     Authorization : {
        Username : Alice, Password : *** },
     ... }
4) Body (optional): {
     network : {
        name : alice-network,
        tenant_id : 9bacb3c5d39d41a7951...,
        subnets : [],
        network_type : vlan,
        ... }}
```

Policy Language

Attribute Based Access Control

P(S, O, E) <- Logic Expression(ATTR(S), ATTR(O), ATTR(E))

Policy: A set of assertion expressions
Composition: Iteration of *if-statements* and logical operators
Return: ACCEPT / REJECT

Policy

```
GLOBAL_POLICY {
  system_update {
    if (environment.time > 1am &&
        environment.time <  6am ) {
      REJECT }}}
LOCAL_POLICY {
  user {
    user_can_get_on_monday {
      if (action.method == 'GET') {
        if (environment.weekday == 'mon') {
          ACCEPT }}}}
  user.Alice {
    alice_cannot_delete_firewall {
      if (action.uri REG '/firewalls/') {
        if (action.method == 'DELETE') {
          REJECT }
        else {
          ACCEPT }}}
      ... }}
```

Global Policy

for ↳ all requests

Local Policy

for ↳ individual user group and user

Policy

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Global Policy

for → all requests

Local Policy

for → individual user group and user

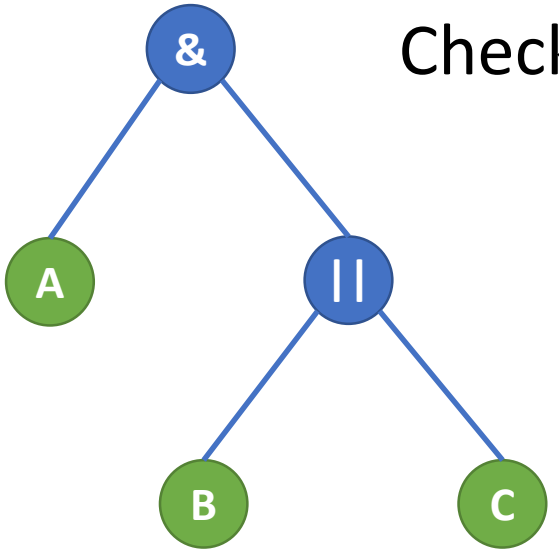
Performance

Expressiveness and simplicity

Detailed Designs

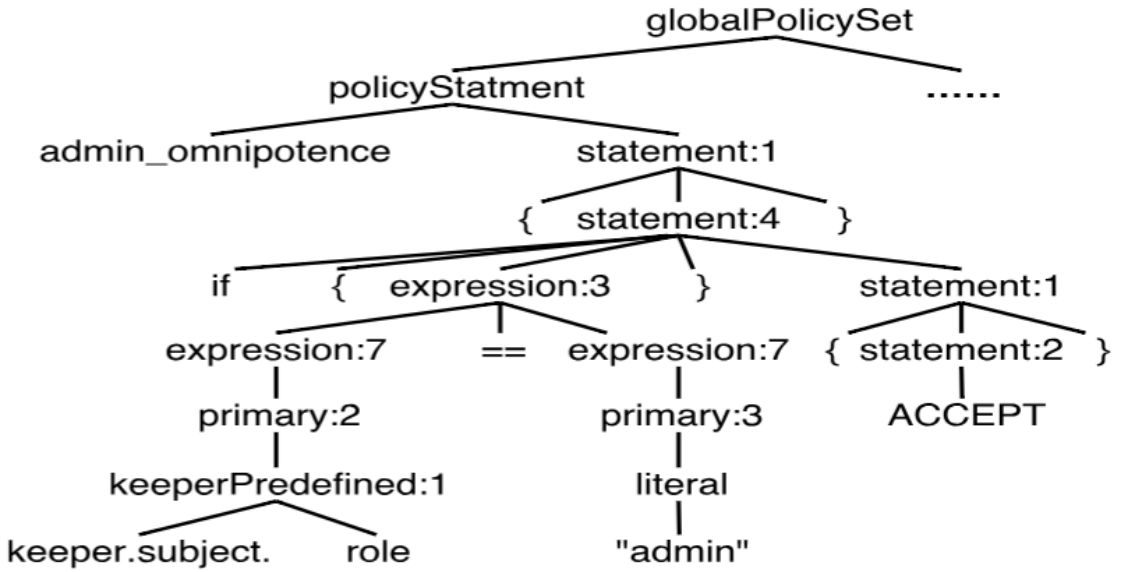
- **Policy Language – flexible permission abstractions**
- **Policy Interpreter – parsing semantic policies**
- **Permission Engine – performing access control on requests**

Policy Interpreter



Checking result

Logical operators



An attribute or a comparing value

(A && (B || C))

Detailed Designs

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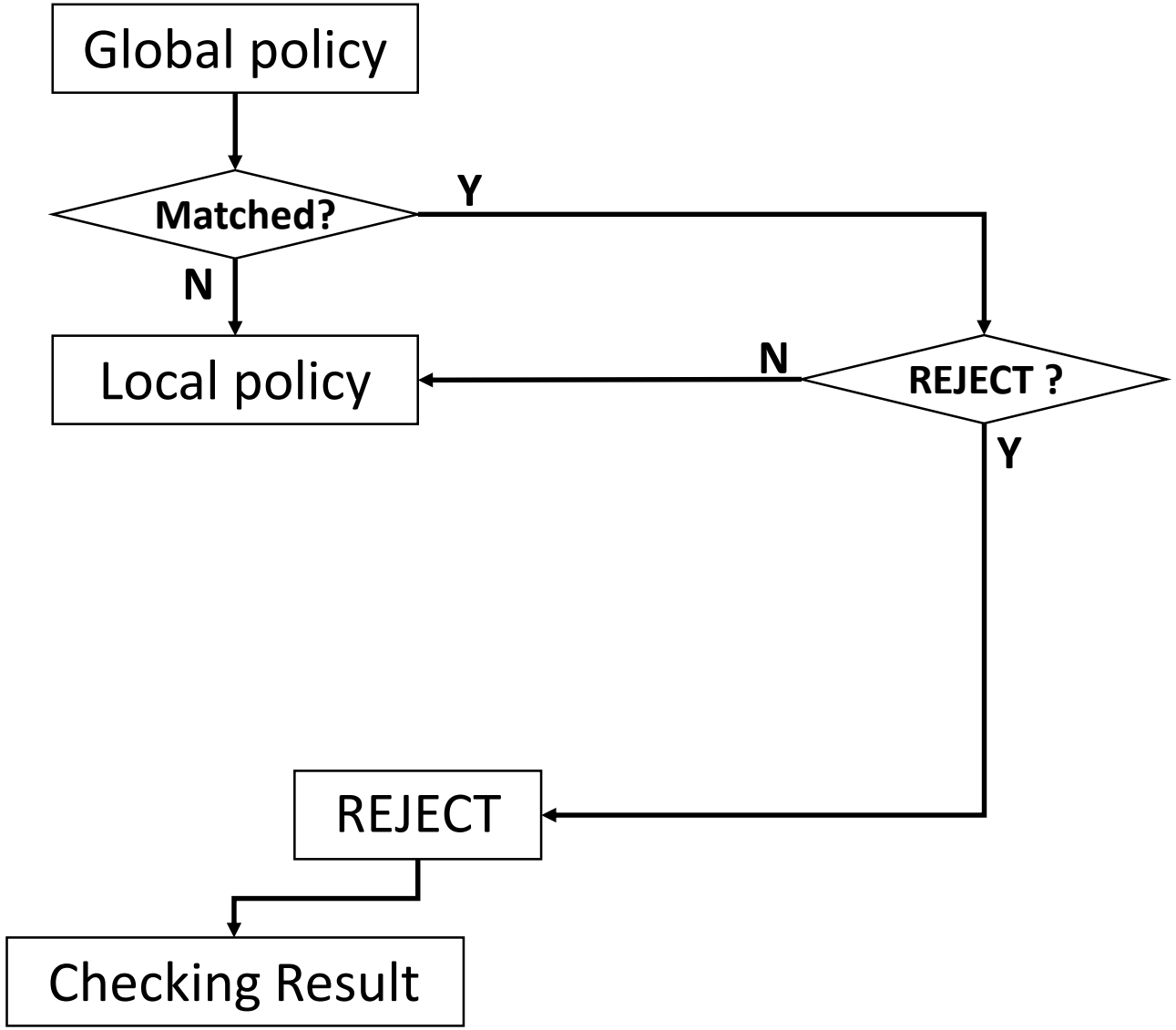
Permission Engine

Step 1: Checking with Global Policies

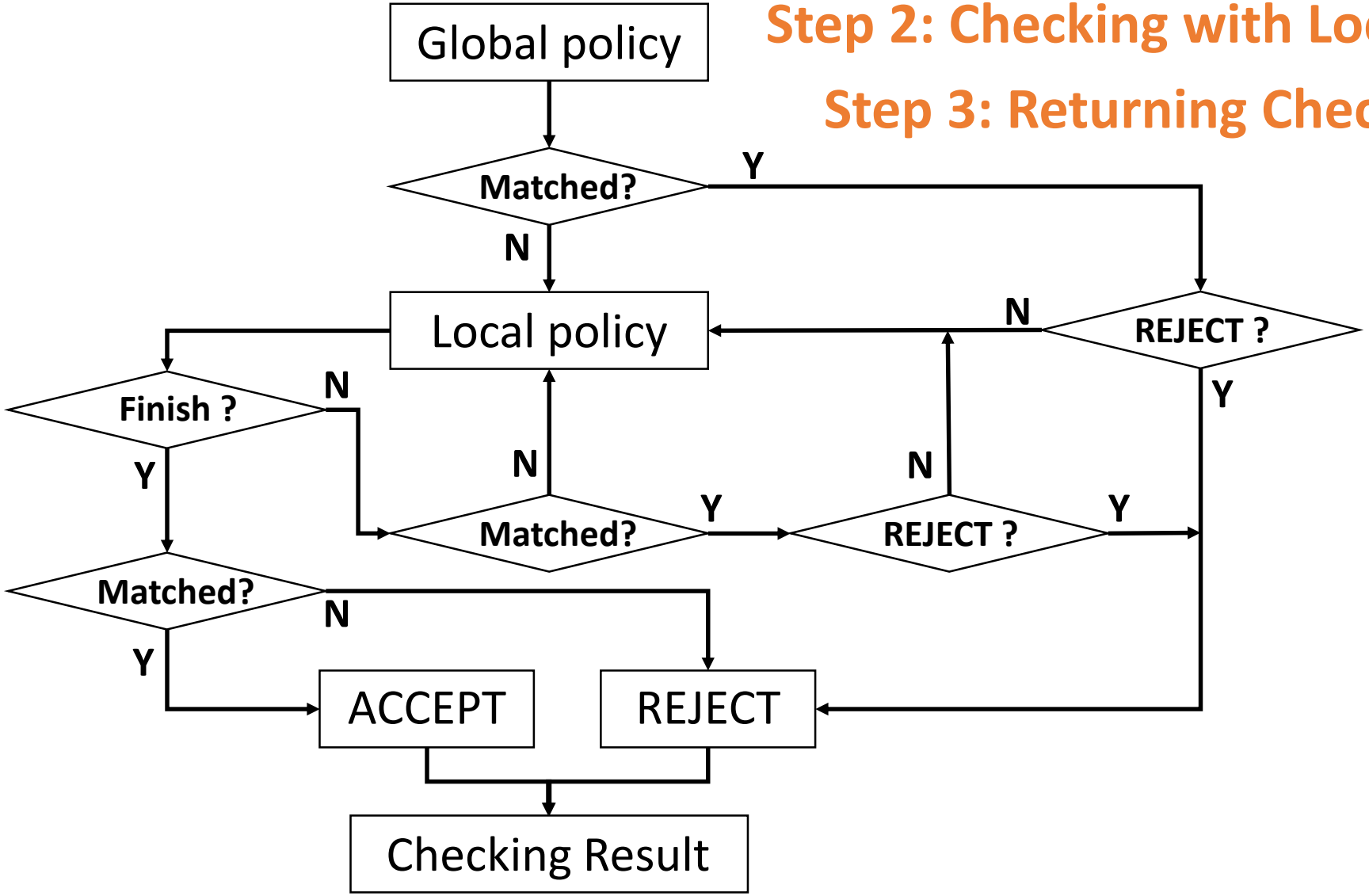


Permission Engine

Step 1: Checking with Global Policies

Step 2: Checking with Local Policies

Step 3: Returning Checking Result



Implementation

- **Filter-based, independent bundle**
  - Realizing the system on OpenDaylight controller
  - No modification is required to the controller and applications
- **Support for dynamic management**
  - CLI command: ***SDNKeeper: load/cache***

Effectiveness

Type	# API	# Attribute	Type	# API	# Attribute
Networking	6	220	Meter	2	13
Firewall	3	83	QoS	2	31
Security	2	24	Load Balance	2	81
VPN	4	104	BGP VPN	1	22
SFC	4	60	L2 Gateway	2	26

2789 policies

- **30 policies – all kinds of APIs**
- **185 policies – all kinds of actions in API**
- **664 policies – all kinds of attributes**
- **1910 policies – all possible combinations of two attributes**

2789 illegal requests

Effectiveness

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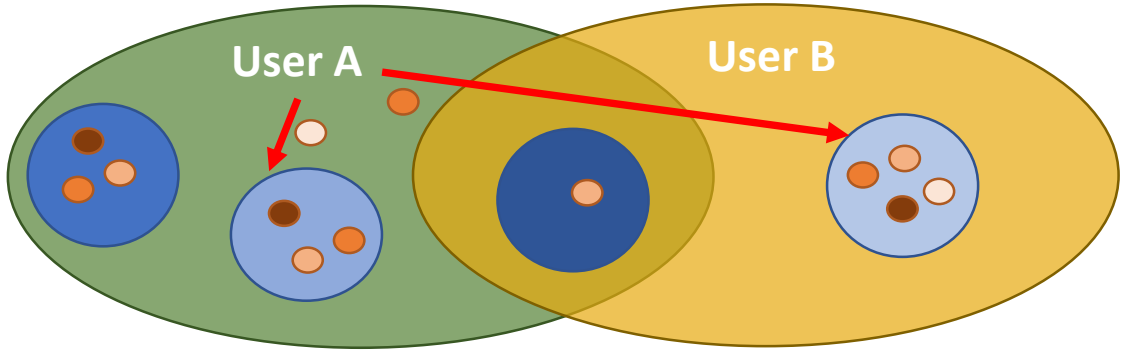
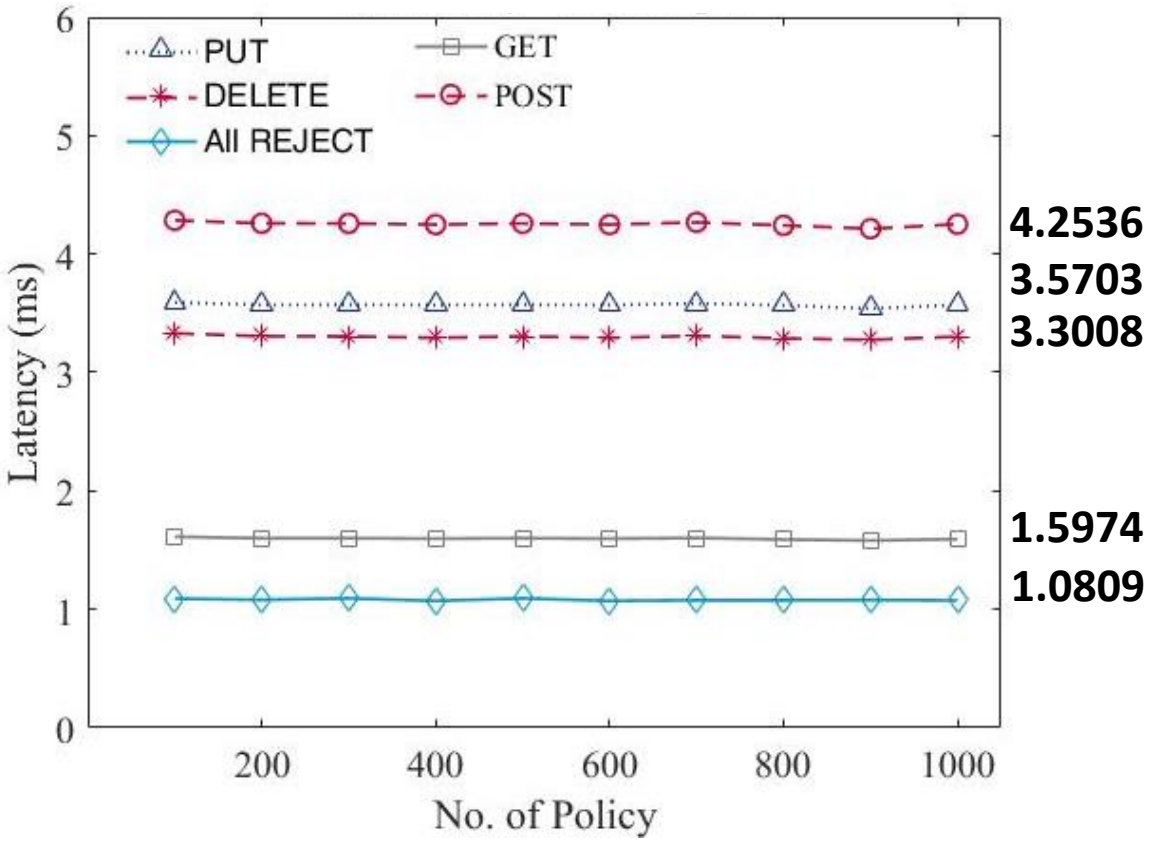
2789 illegal requests

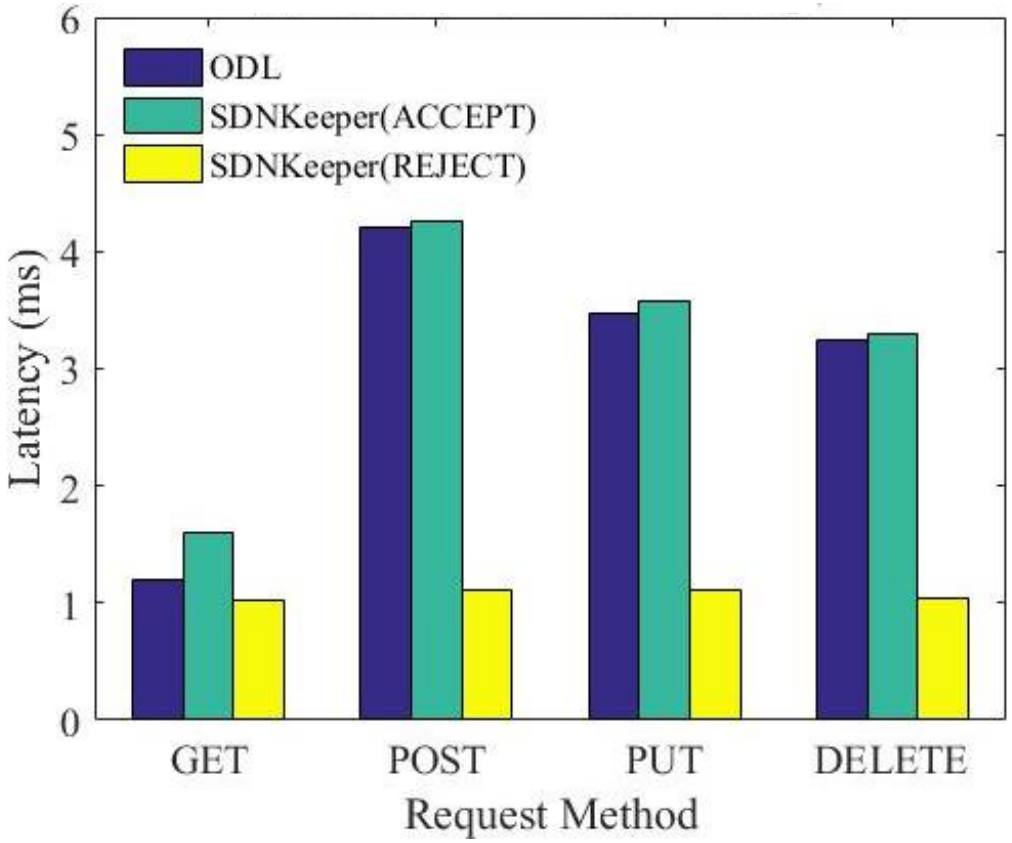


Processing Delay

Latency - SDNKeeper



Latency – SDNKeeper VS OpenDaylight



No significant increase in latency

Processing Delay

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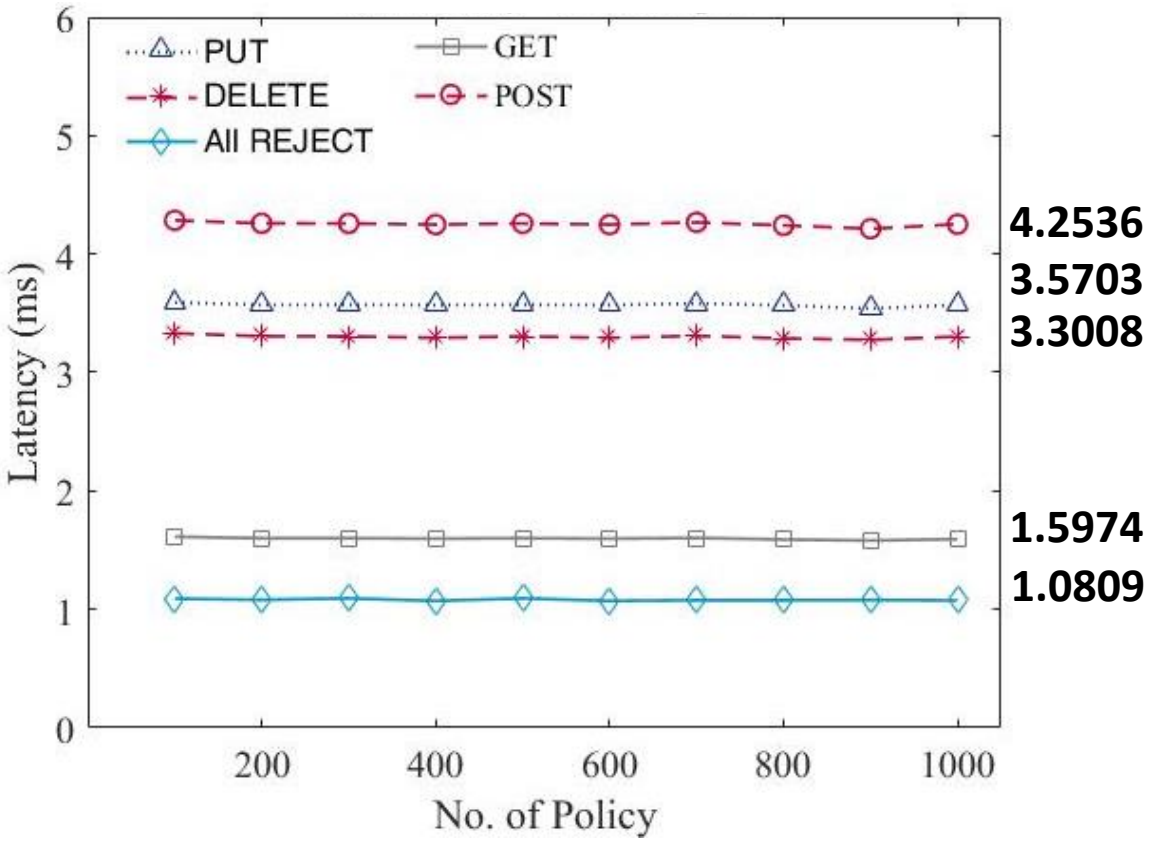

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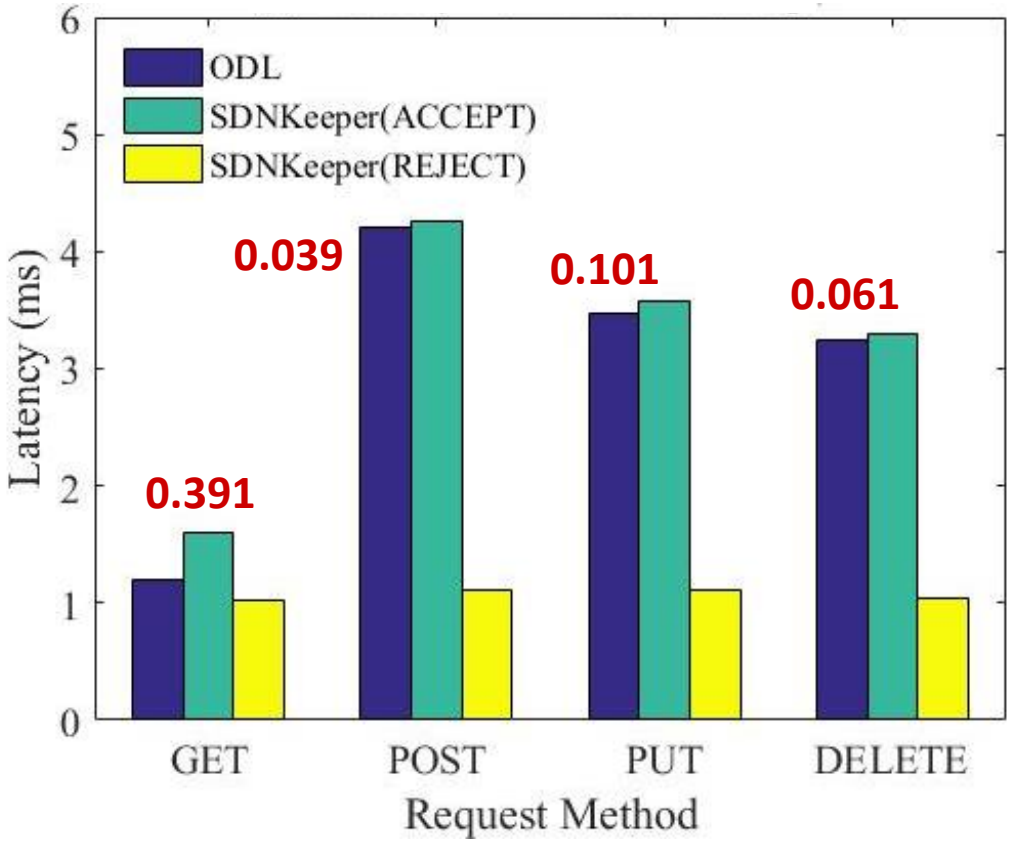
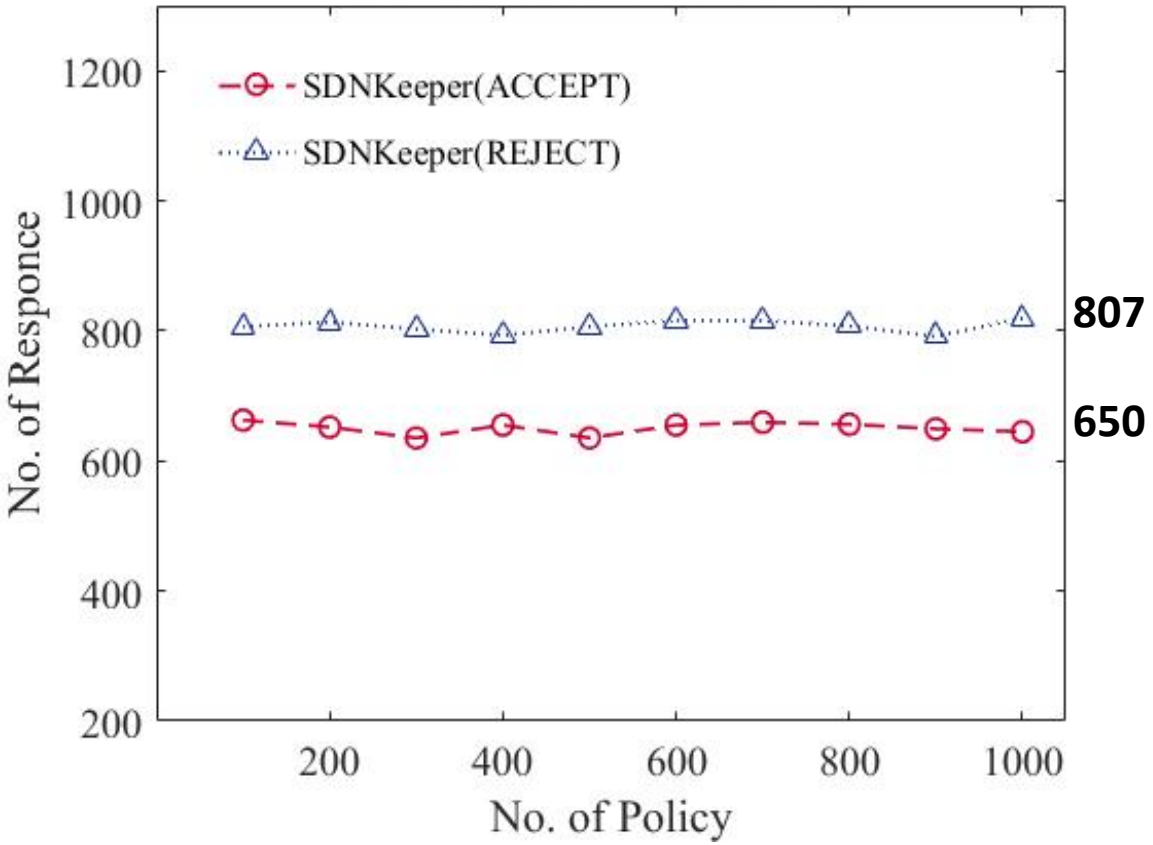


No significant increase in latency

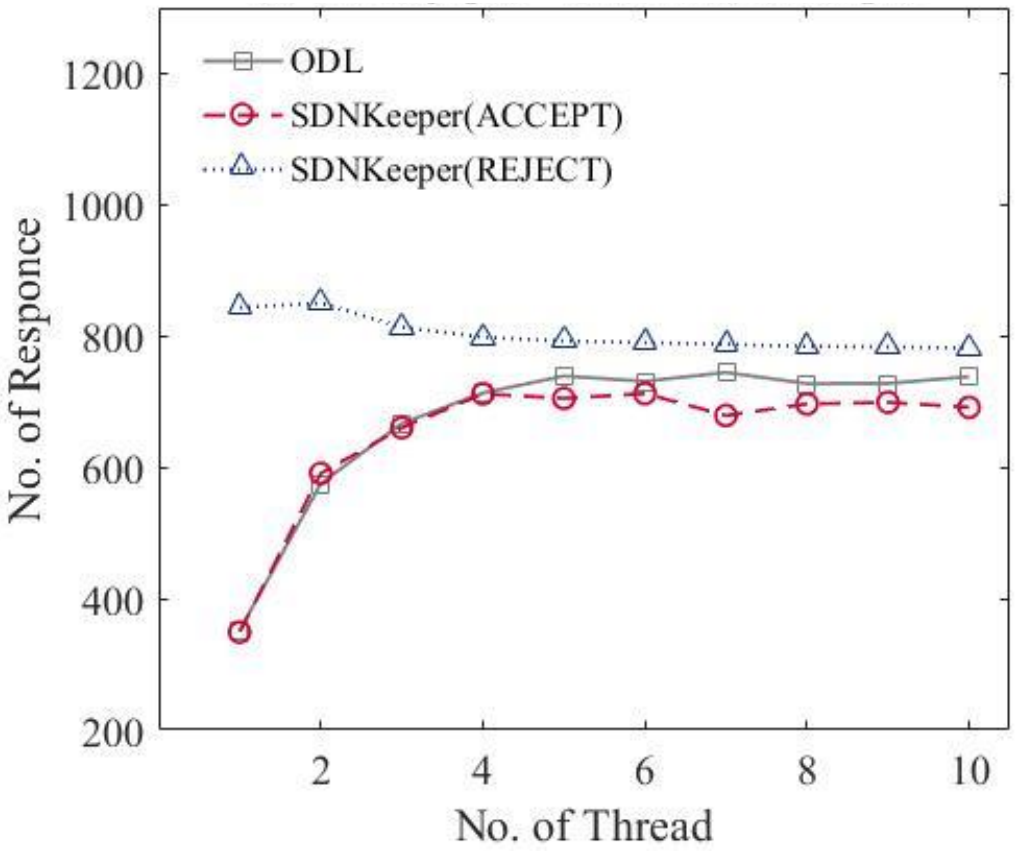
An average delay of 0.15ms

Throughput

Throughput - SDNKeeper



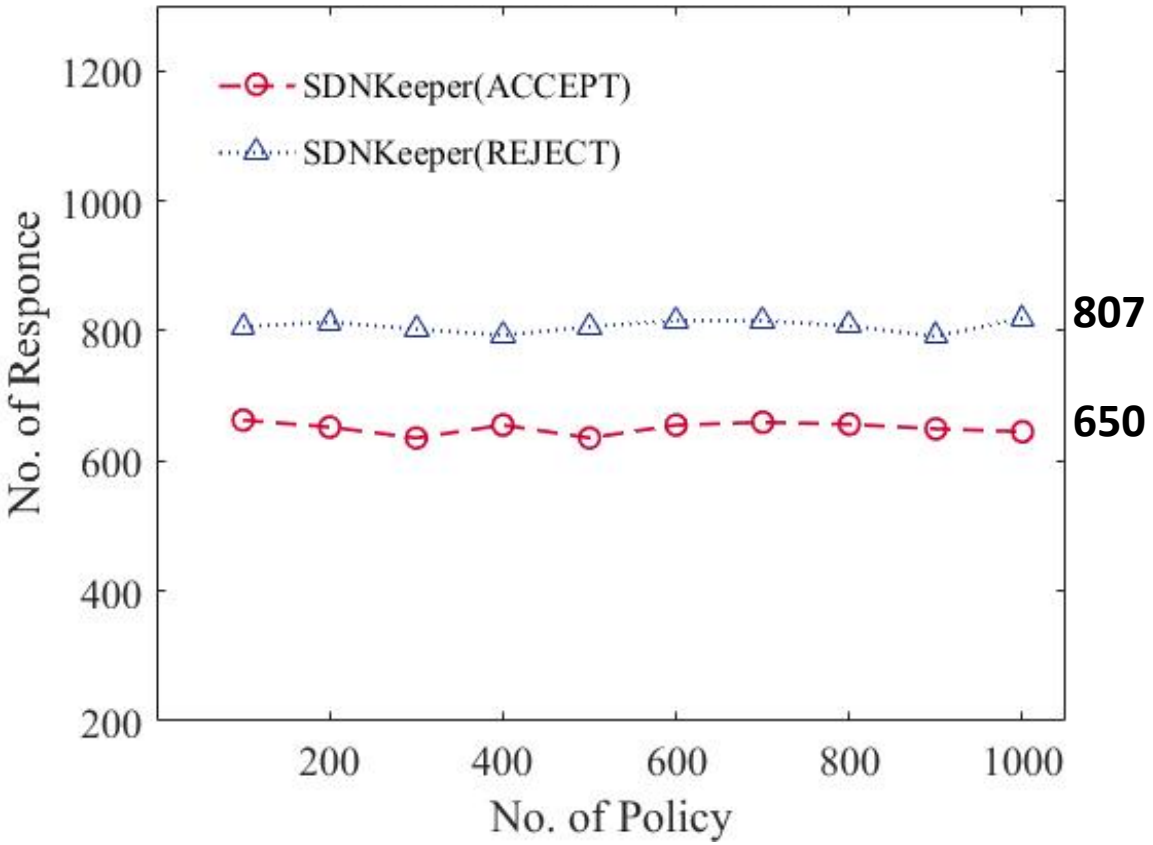
Throughput – SDNKeeper VS OpenDaylight



No significant effect in throughput

Throughput

Throughput - SDNKeeper



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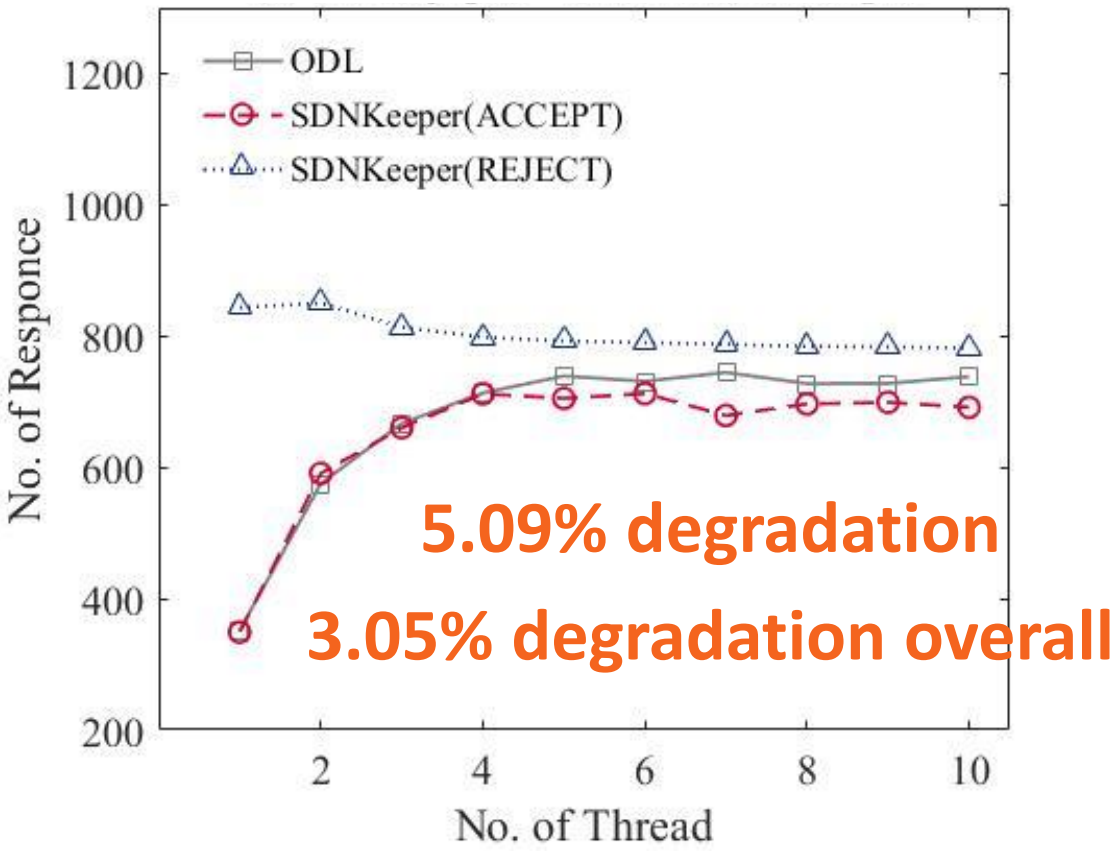

No significant effect in throughput

Conclusions

- **SDNKeeper: a lightweight access control system**
  - Defending against malicious requests
  - Assisting in managing resources
  - Real-time protection and policy hot-update
- **Reliable enforcement with good performance**

Thank you

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Back Up Page

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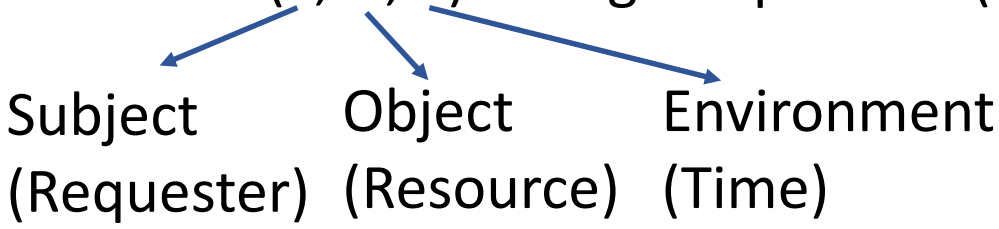

Predefined Data Structure

REST Request

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1) Method: POST   (POST/GET/PUT/DELETE)
2) URI: https://<controller-ip>:<port>/networks/
3) Headers: {
     Content-Type : application/json,
     Authorization : {
        Username : Alice, Password : *** },
     ... }
4) Body (optional): {
     network : {
        name : alice-network,
        tenant_id : 9bacb3c5d39d41a7951...,
        subnets : [],
        network_type : vlan,
        ... }}
```

Policy Language

Attribute Based Access Control

P(S, O, E) <- Logic Expression(ATTR(S), ATTR(O), ATTR(E))

Subject (Requester)

Object (Resource)

Environment (Time)

Predefined Data Structure

subject.role *subject.user*

action.uri *action.method*

$.{object_name}.attribute

$.network.network_type

REST Request

```
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3) Headers: {
     Content-Type : application/json,
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        tenant_id : 9bacb3c5d39d41a7951...,
        subnets : [],
        network_type : vlan,
        ... }}
```

Policy

```
policy    : policy_name '{' statement '}'
statement : 'ACCEPT' |  'REJECT' | if_state
if_state  : 'if (' expr ')' statement
            ('else' statement)?
```

Policy: A set of assertion expressions

Composition: Iteration of *if-statements* and logical operators

Return: ACCEPT / REJECT

```
alice_cannot_delete_firewall {
  if (action.uri REG '/firewalls/') {
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    else {
      ACCEPT }}}
```

```
system_update {
  if (environment.time > 1am &&
      environment.time <  6am ) {
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```