Software-defined Network with Ravel

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Prerequisites

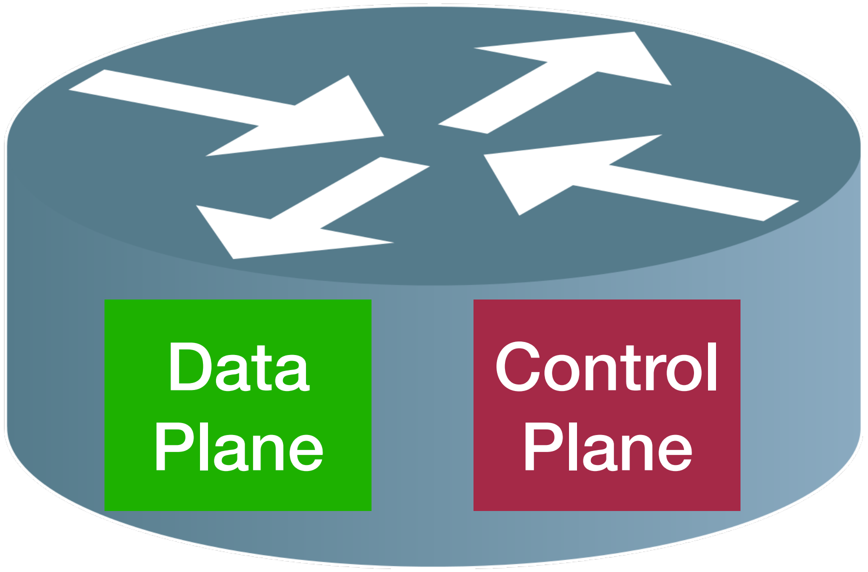
- PostgreSQL Database
- SQL Language
  - updates, views, triggers, rules, etc.
- Mininet

Our Goals

- What’s Software-defined network(SDN)?
- Principles and features of Ravel
- Architecture of Ravel
- Ravel examples

Control Plane and Data Plane

Network paradigm:

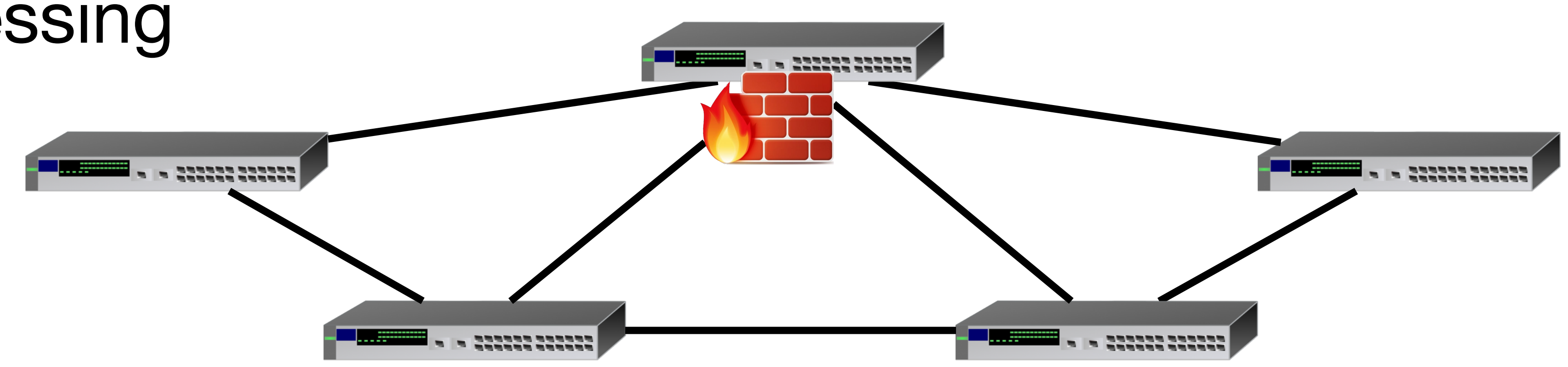


Data plane and control plane resides within the physical device

- Forwarding: Data plane
  - Directing a data packet to an out-going link
  - Individual router using a forwarding table
- Routing: Control plane
  - Computing paths the packets will follow
  - Individual router creating a forwarding table

Management Plane Challenges

- Indirect control
  - change weight instead of paths
  - complex optimization problem
- Uncoordinated control
  - cannot control which router updates first
- Interacting protocols and mechanisms
  - Routing and forwarding
  - Naming and addressing
  - Access control
  - Quality of service
  - …



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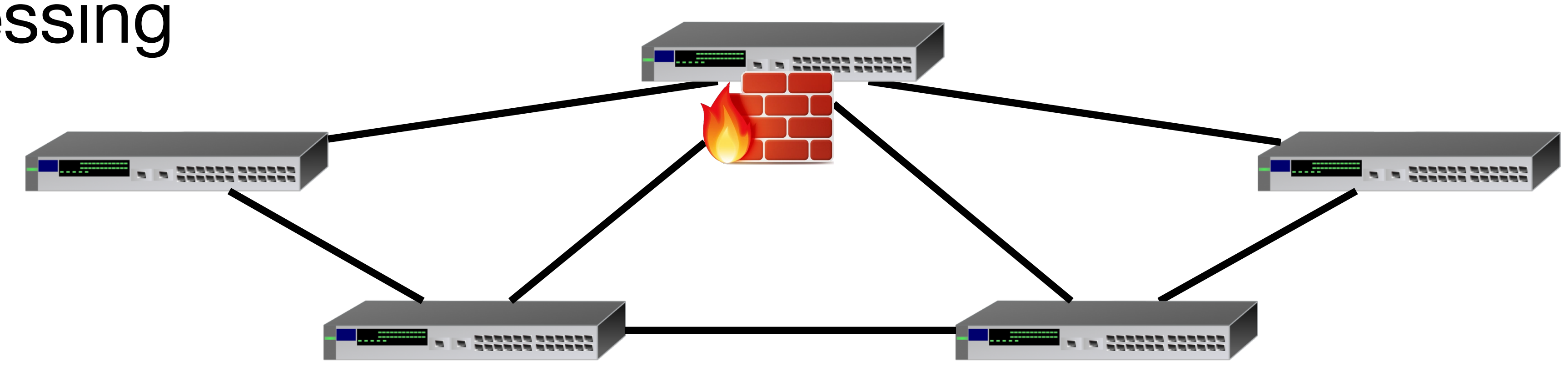
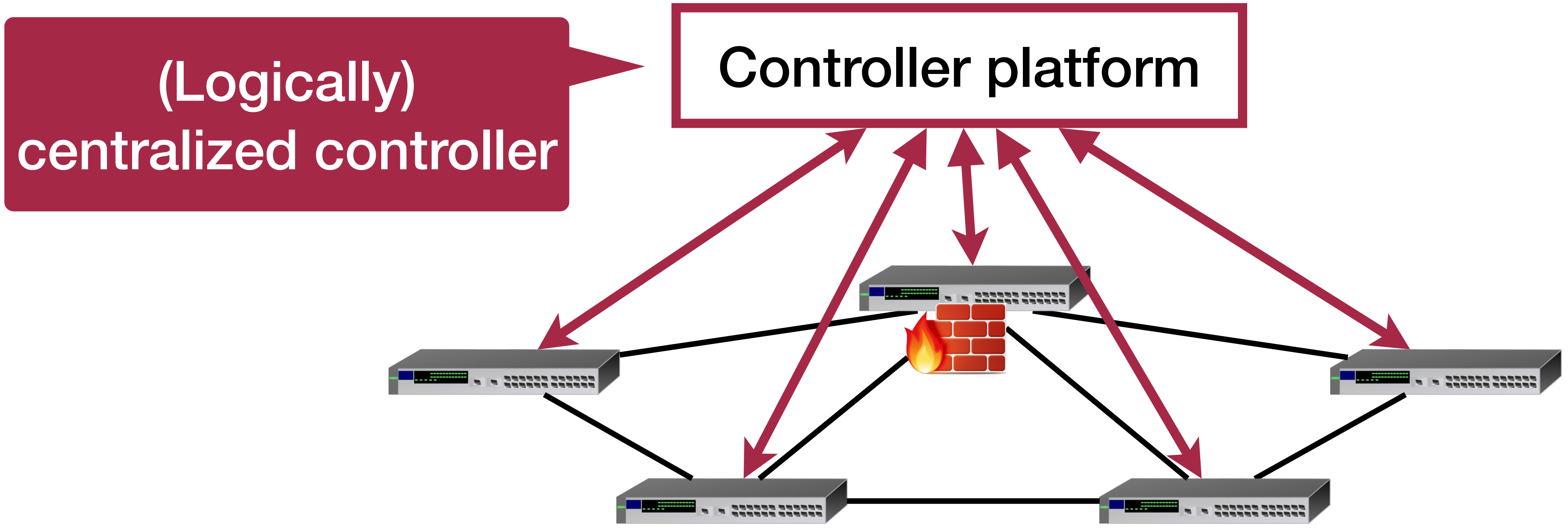


Software-defined network is to simplify management plane

Software-defined Network(SDN)

- Decouple control and data planes by providing open standard API



Software-defined Network(SDN)

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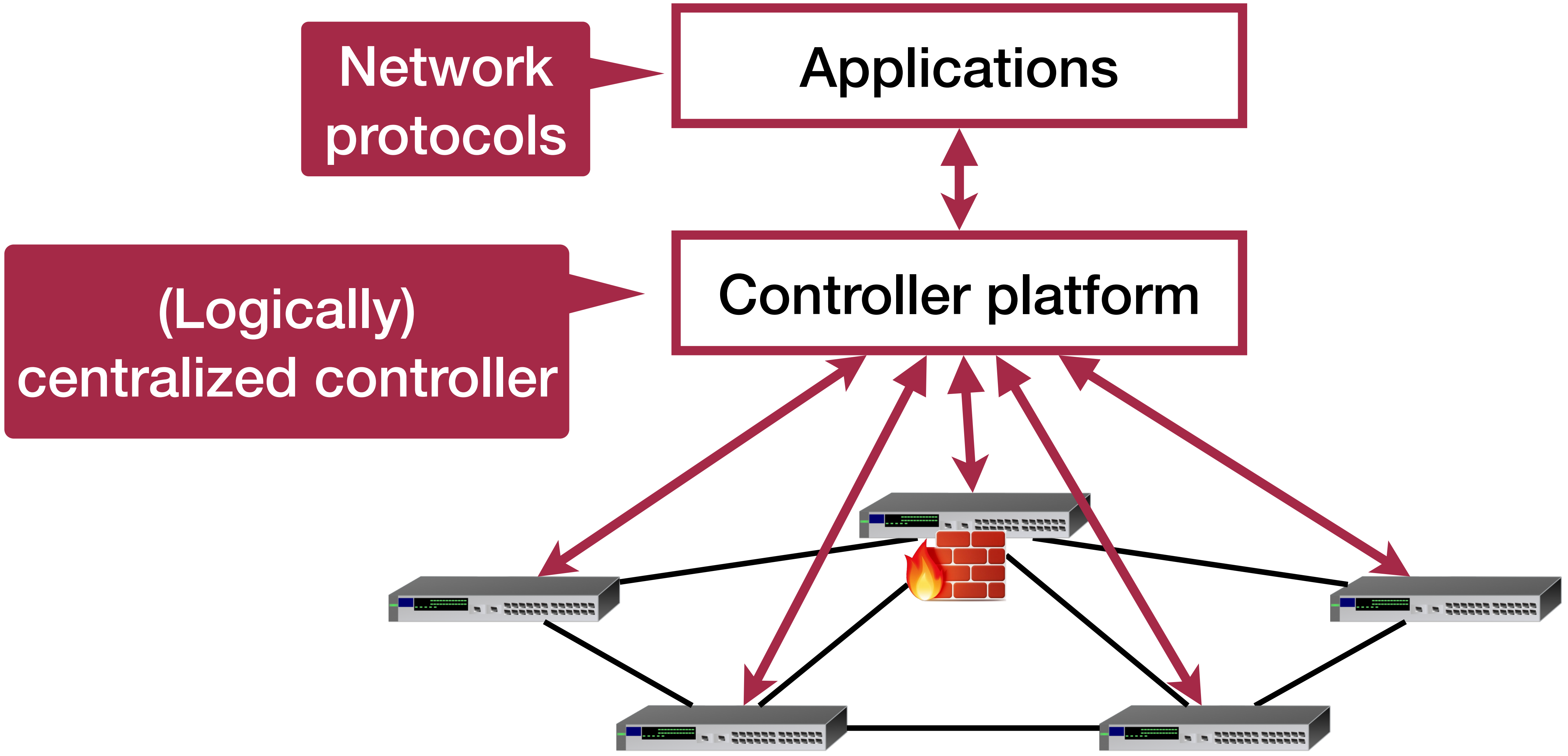

Software-defined Network(SDN)

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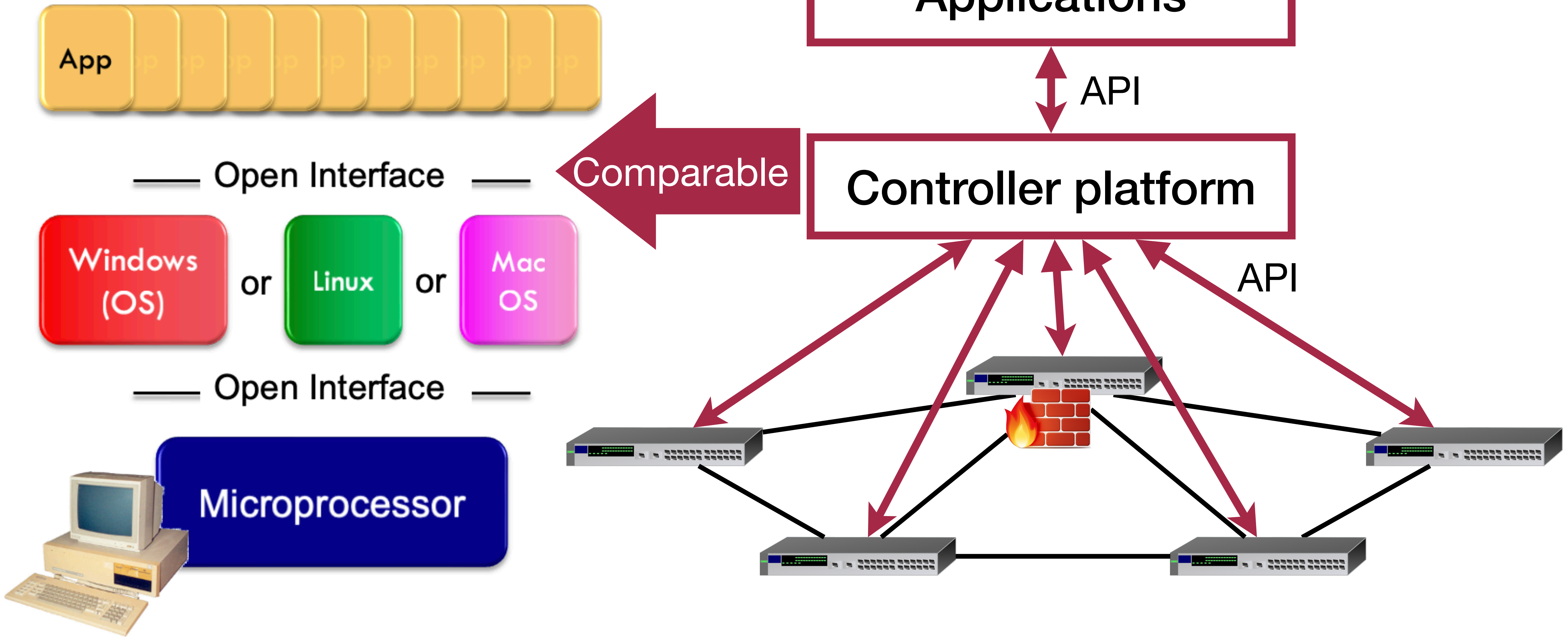

Software-defined Network(SDN)

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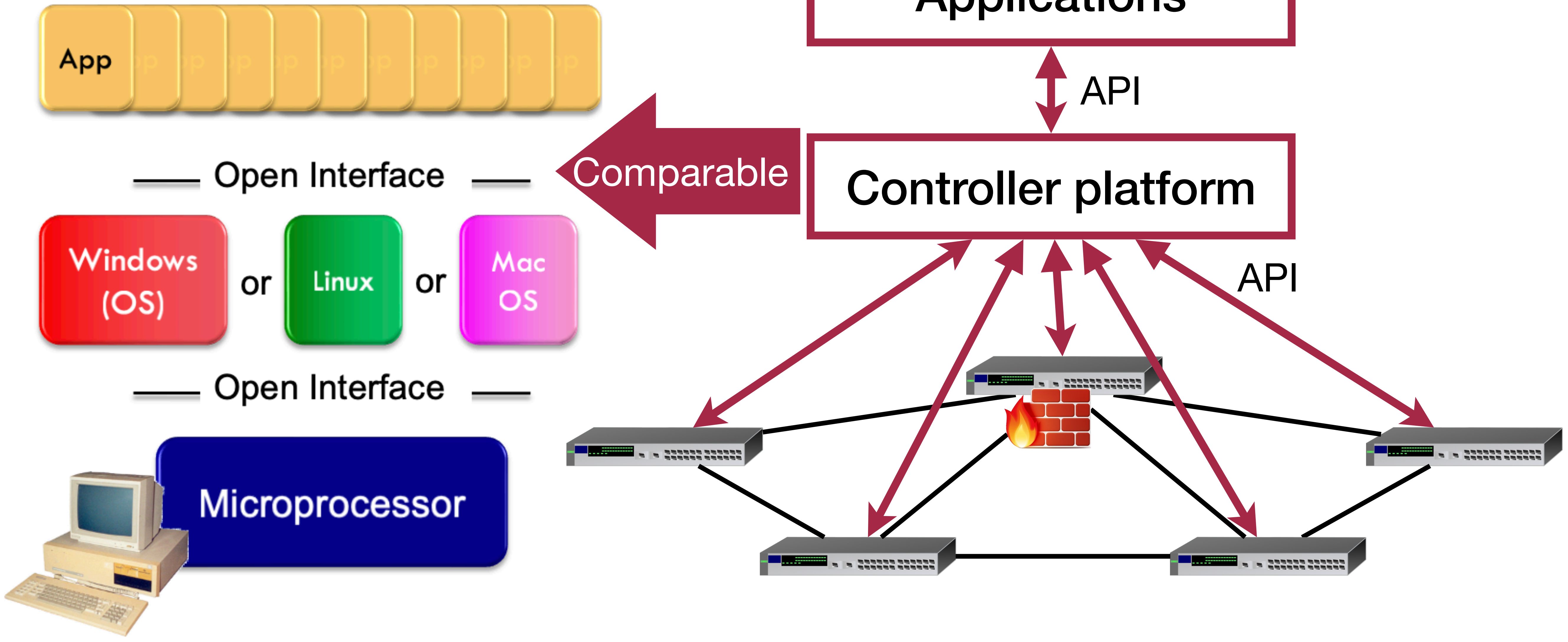
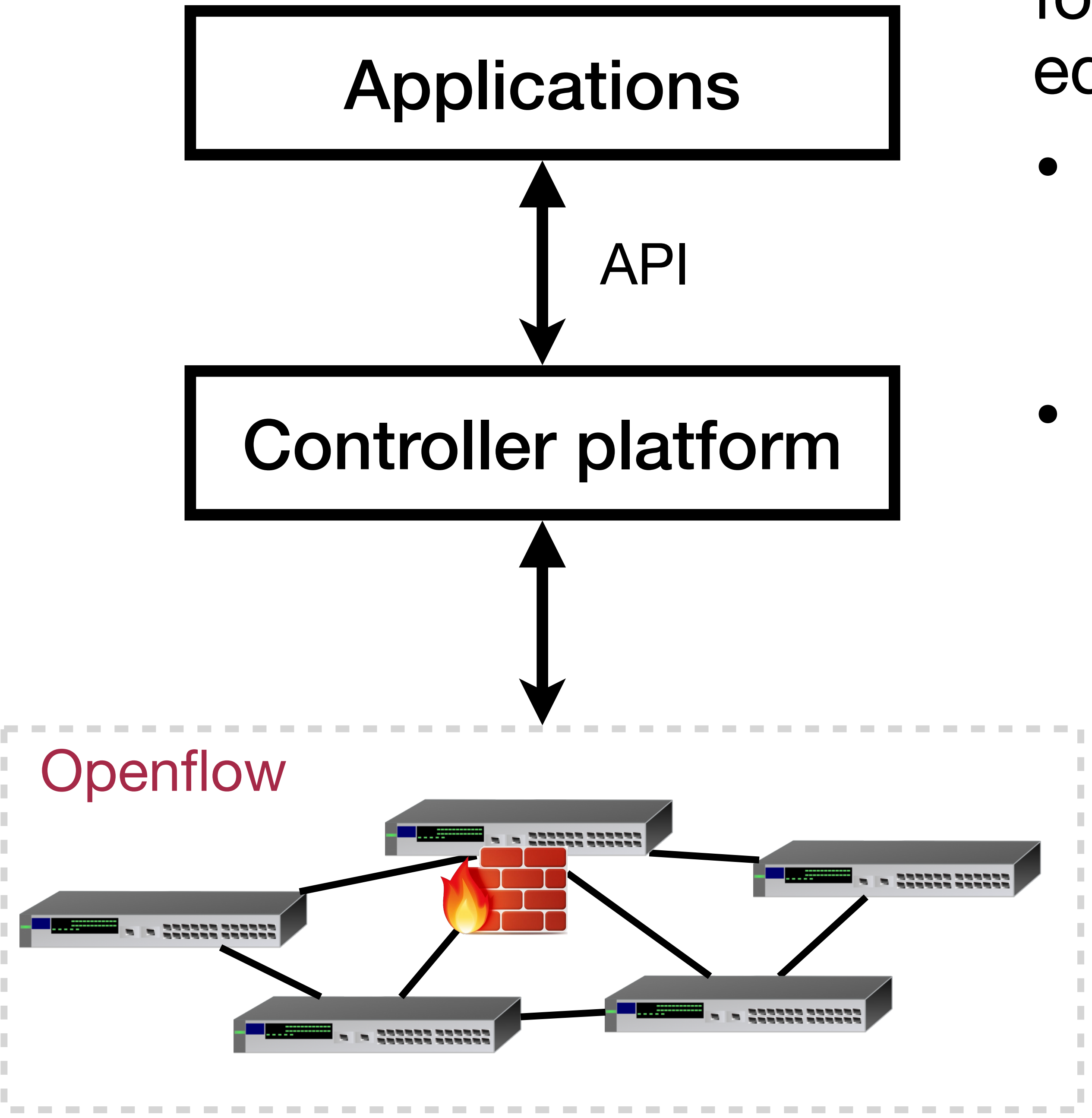


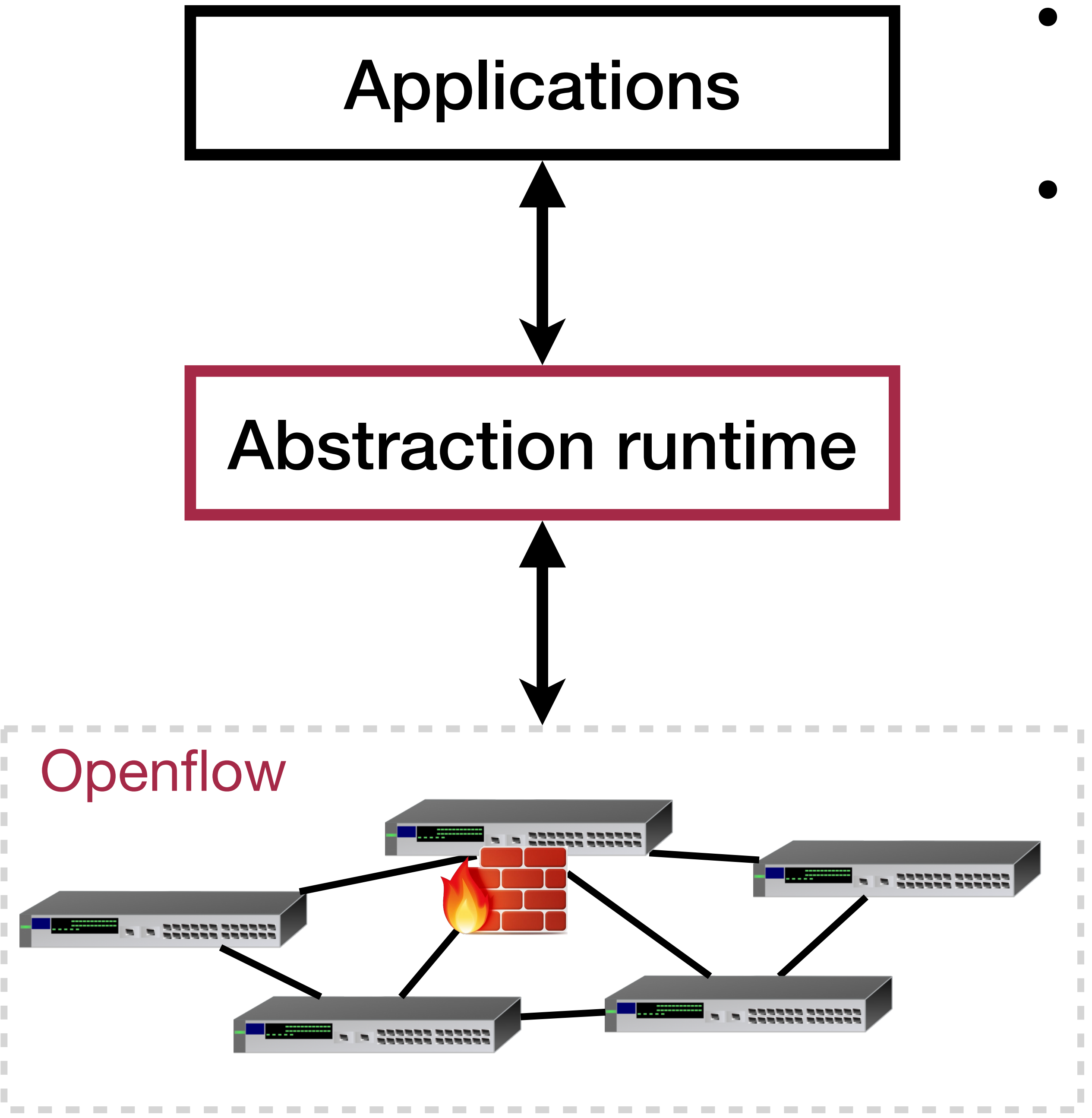
Software-defined network is an approach to building computer networks that separates and abstracts elements of networks

Software-defined Network(SDN)



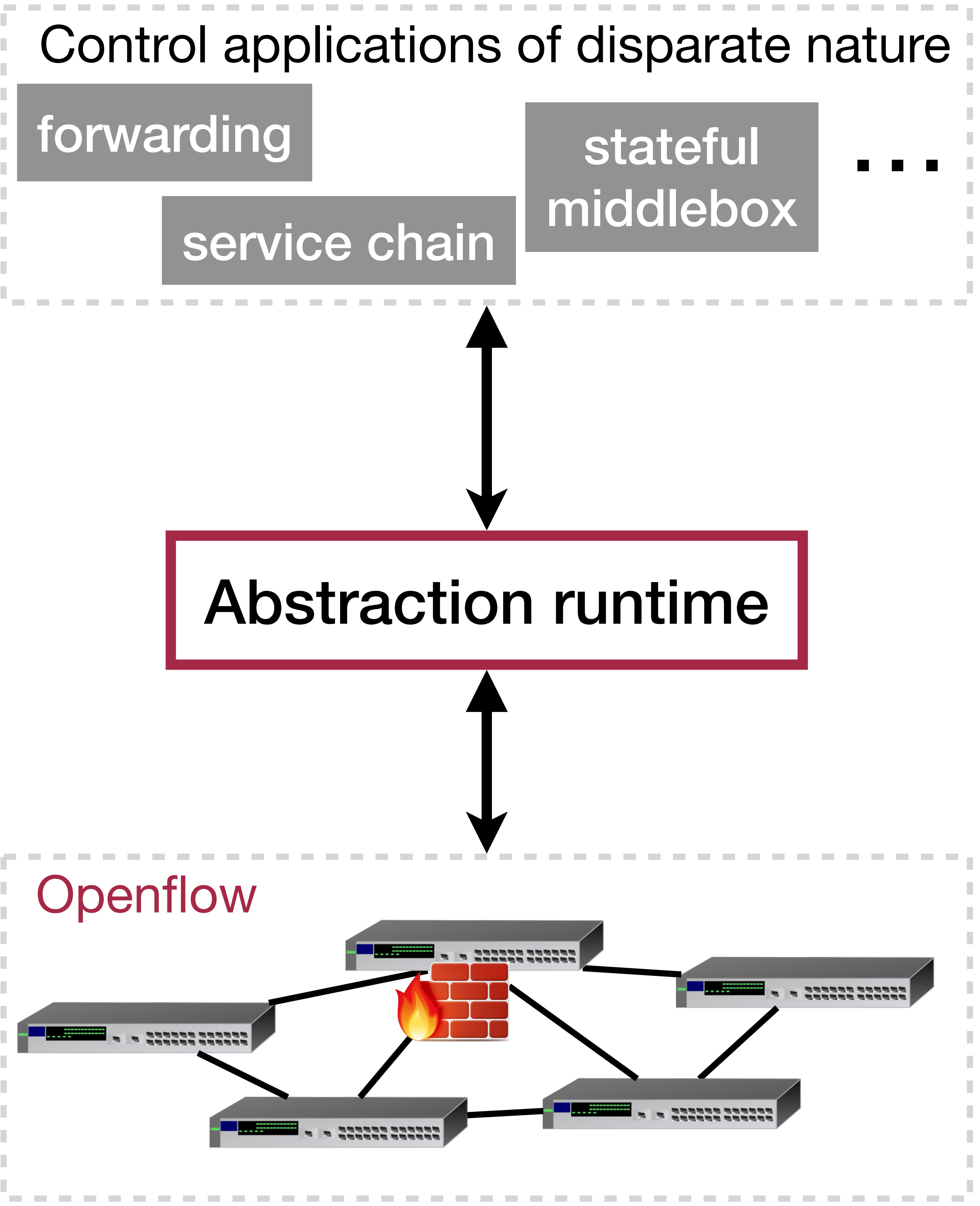
- Openflow is a multivendor standard defined by Open Network Foundations for implementing SDN in networking equipments
  - defines the communication between an SDN controller and network equipments.
  - to packet forwarding

Software-defined Network(SDN)

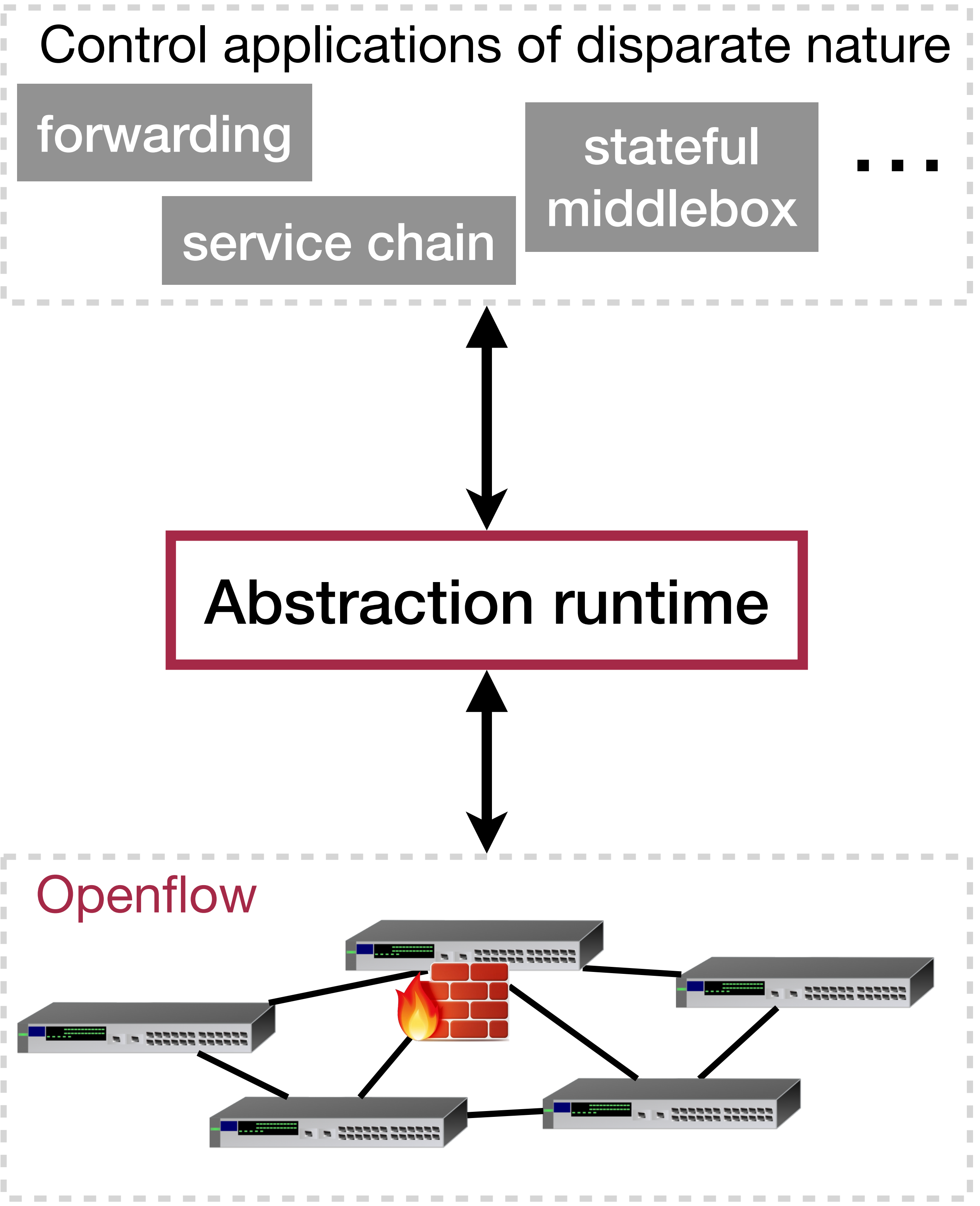


- Programming abstractions are crucial for the vision of SDN
  - high-level abstractions to make programming easy
  - what are "right" abstractions?

Software-defined Network(SDN)

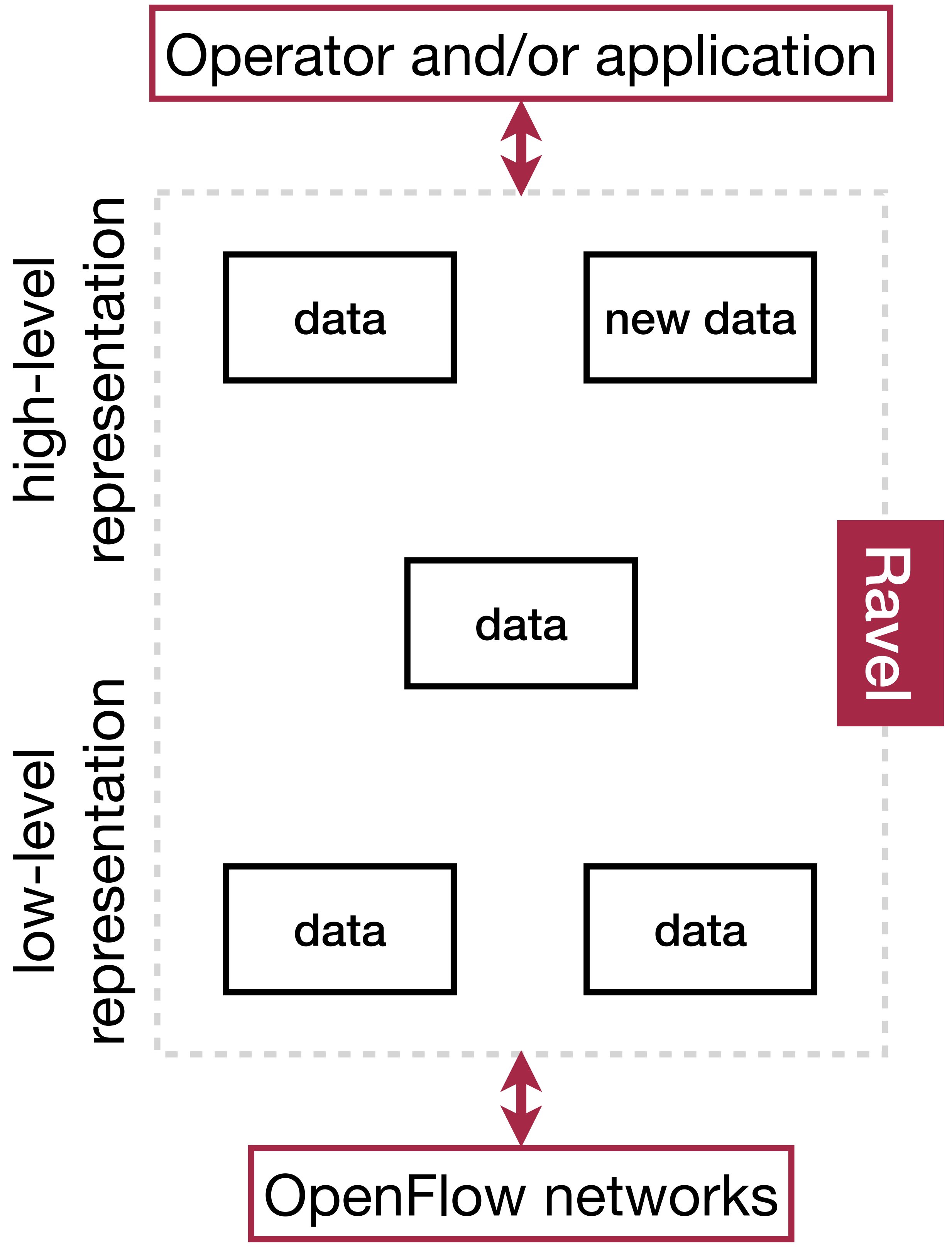


Network Keeps Evolving



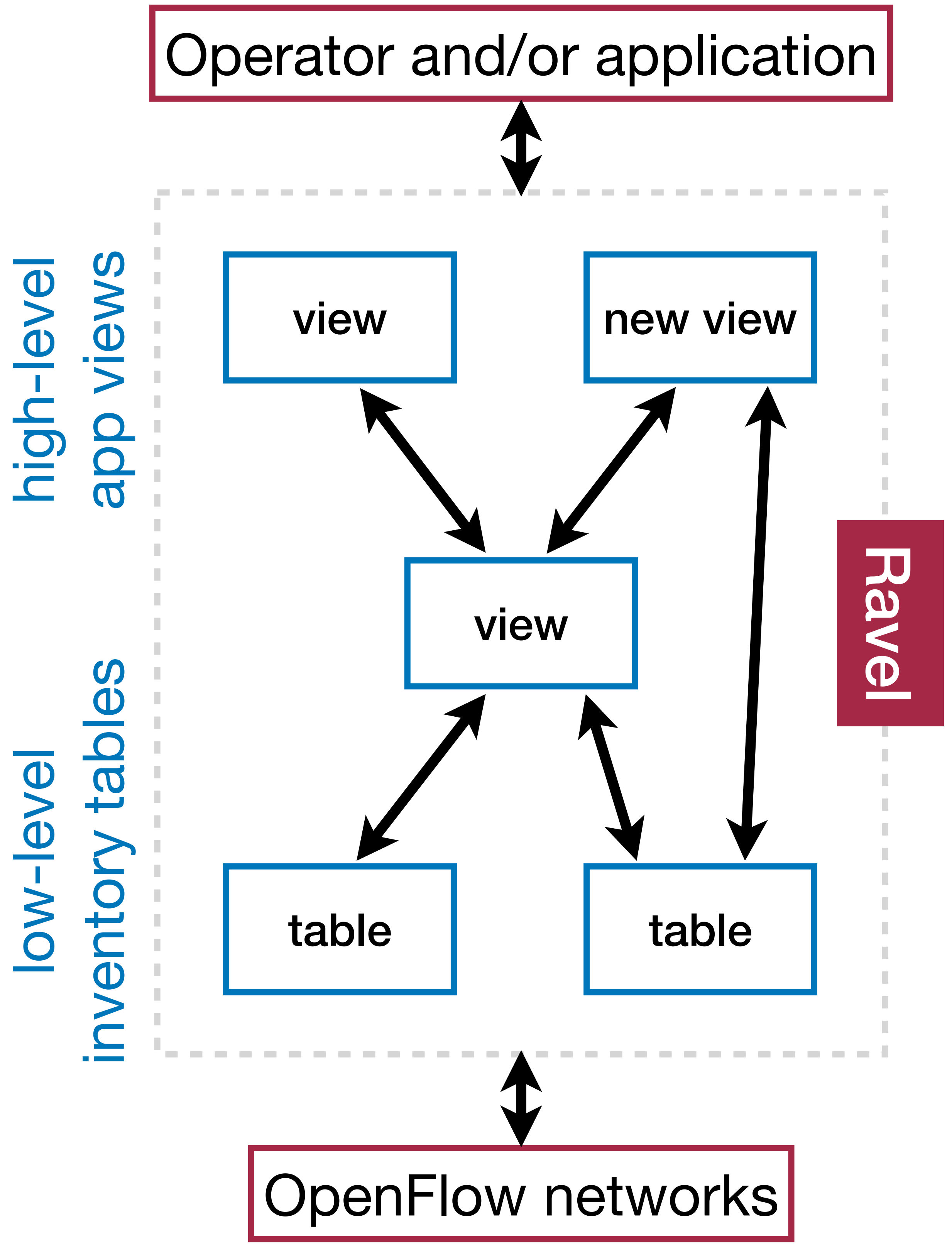
- New/changing requirements for abstractions
- Abstraction runtime needs re-engineering
- Orchestrate controls across abstractions

Ravel's Perspective



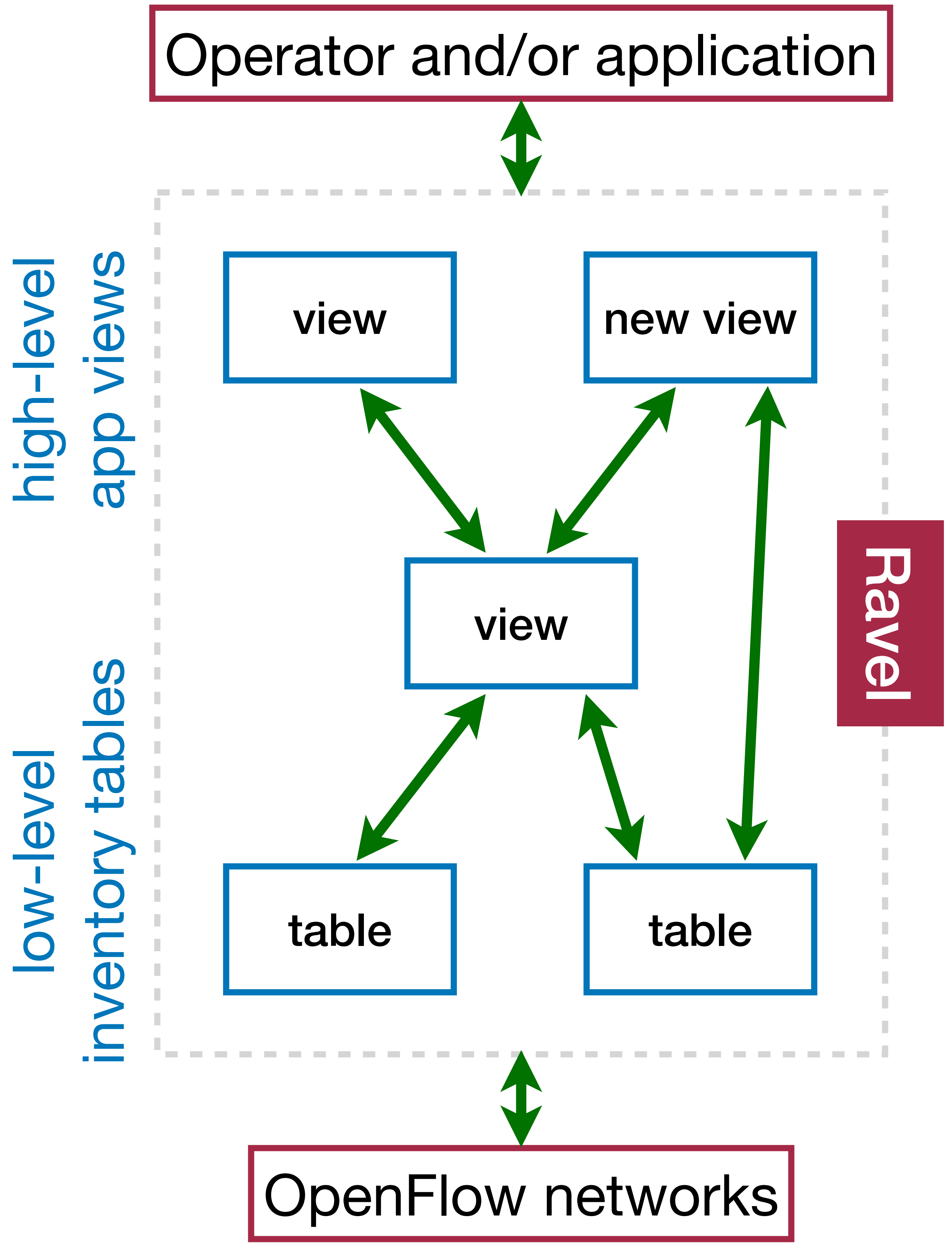
- SDN control revolves around data representation
- adopt a plain data representation
- use a universal data language

A Database-defined Network



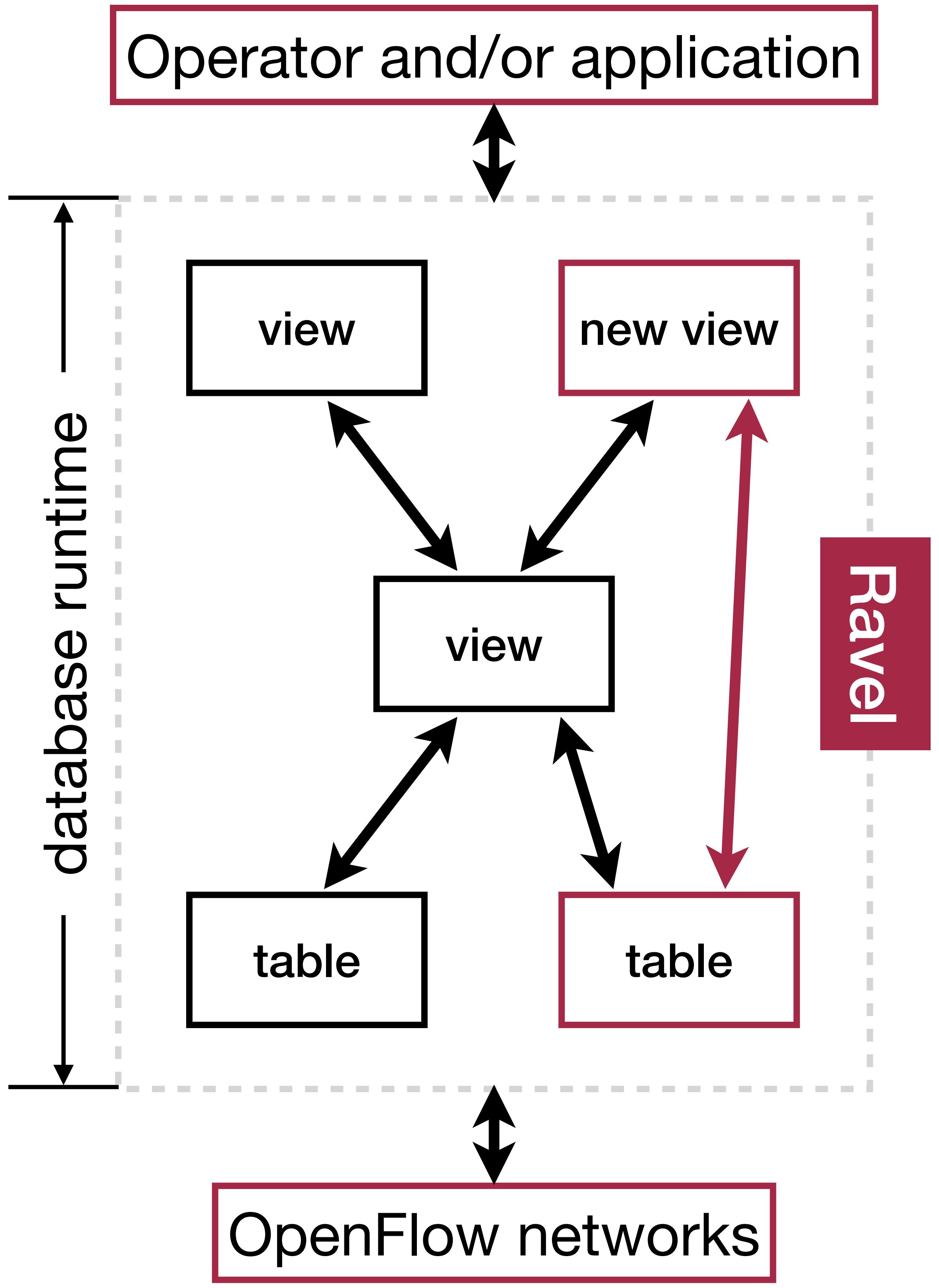
- Relation — the plain data representation
  - Table — stored relation
  - View — virtual relation

A Database-defined Network



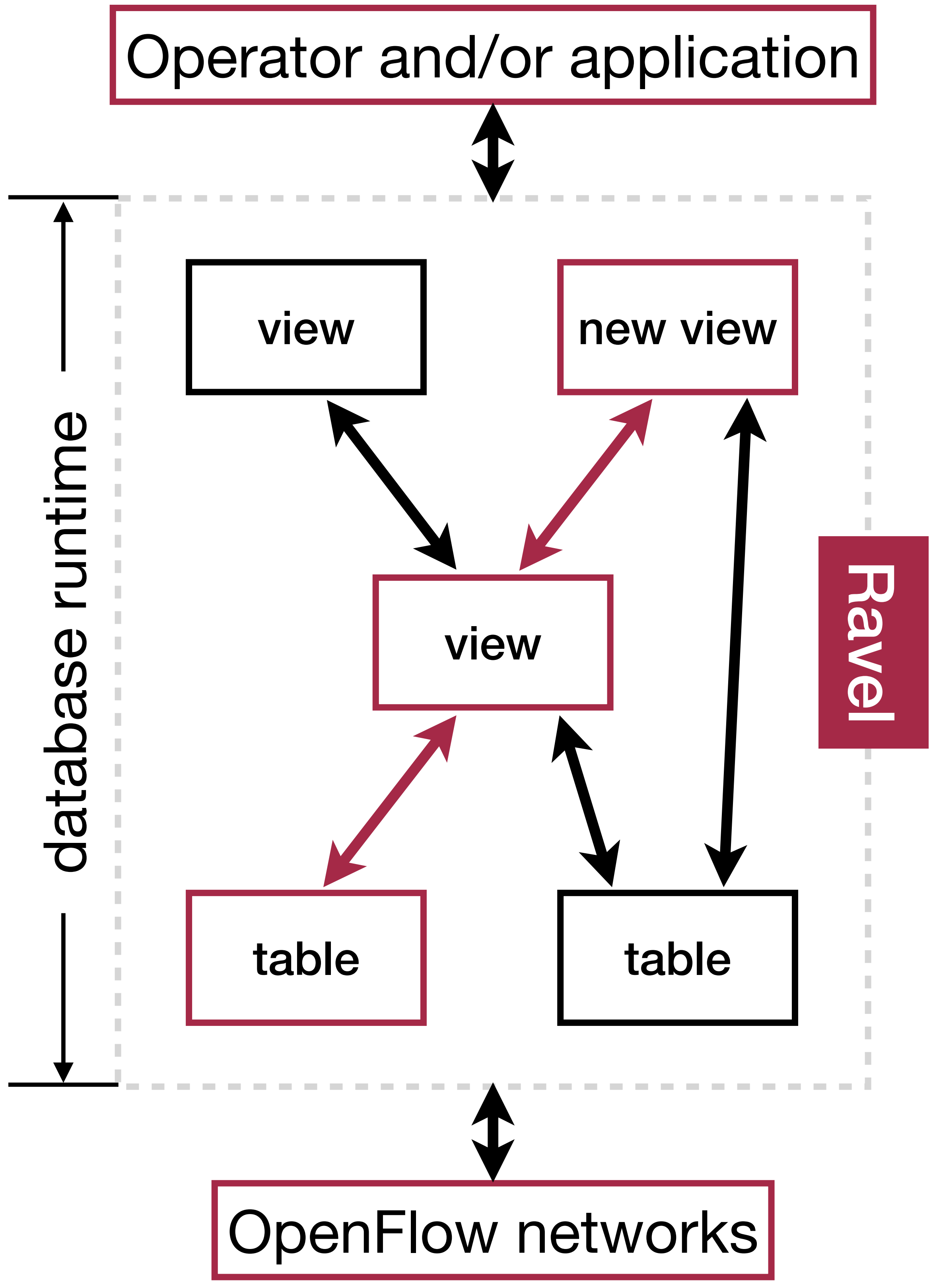
- Relation — the plain data representation
  - Table — stored relation
  - View — virtual relation
- SQL — the universal language
  - Query, update, trigger, rule

Ravel: A realization with SQL database



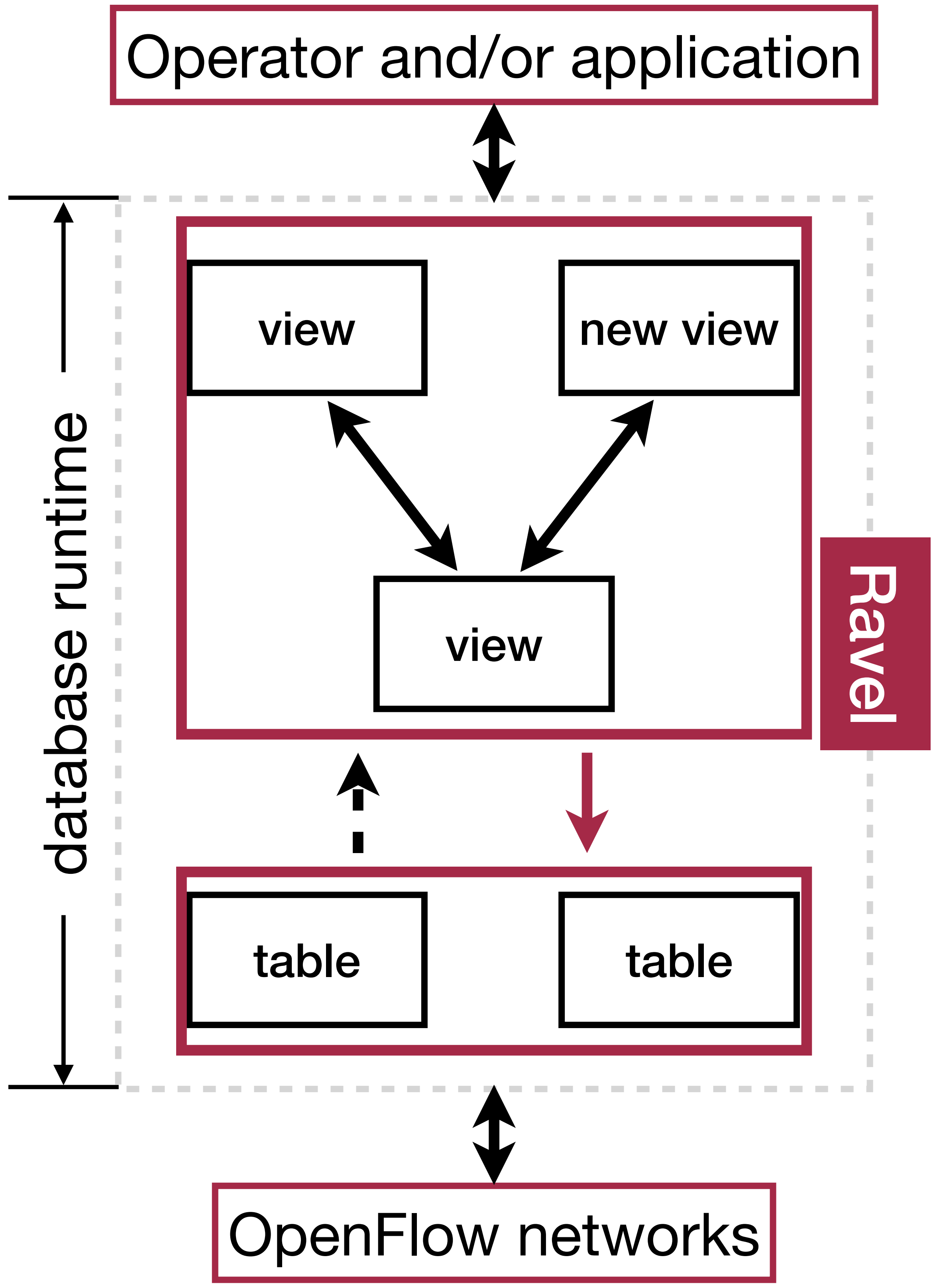
- Ad-hoc programmable abstraction via views

Ravel: A realization with SQL database



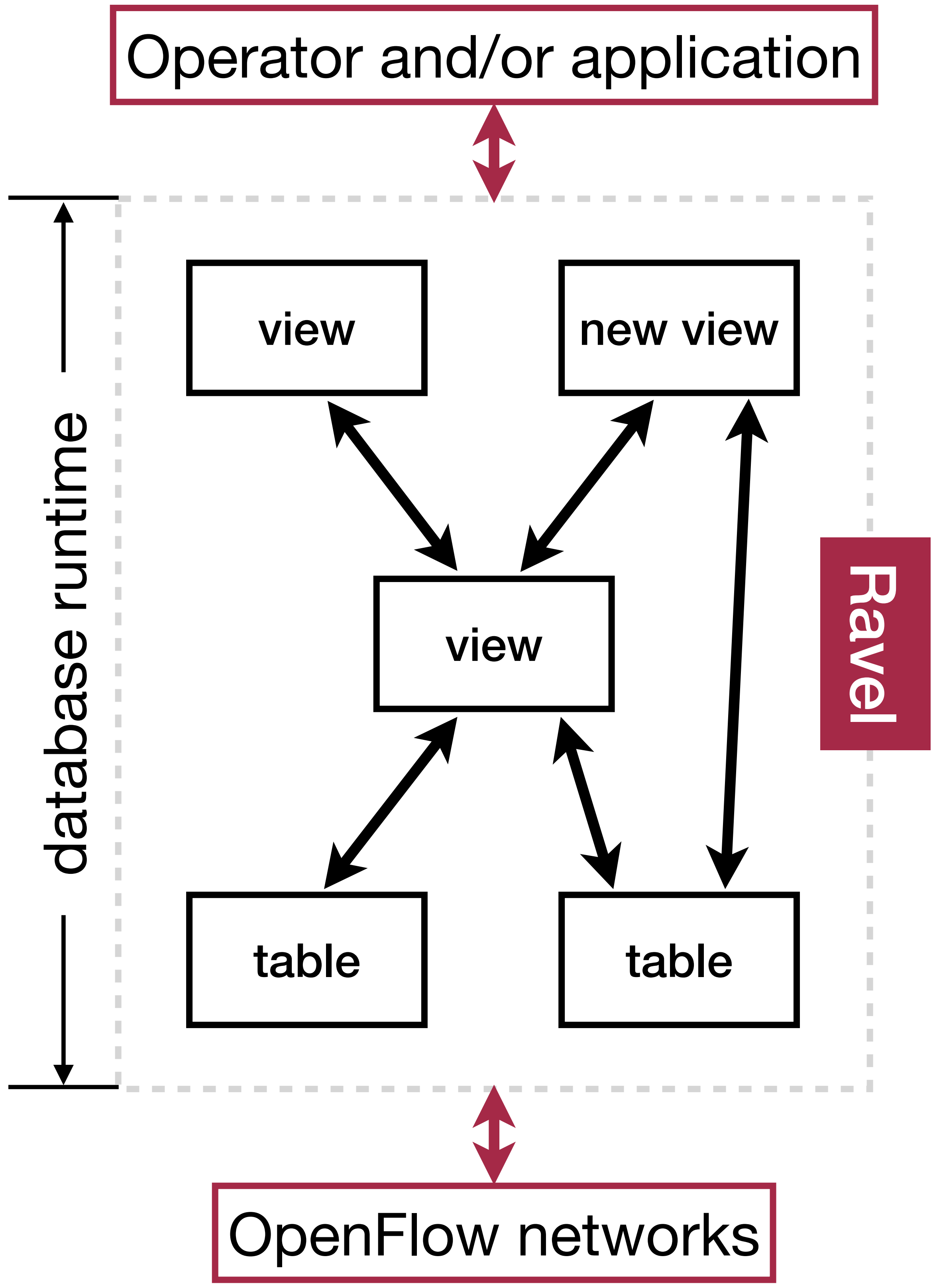
- Ad-hoc programmable abstraction via views
- Orchestration across abstractions via view mechanism

Ravel: A realization with SQL database



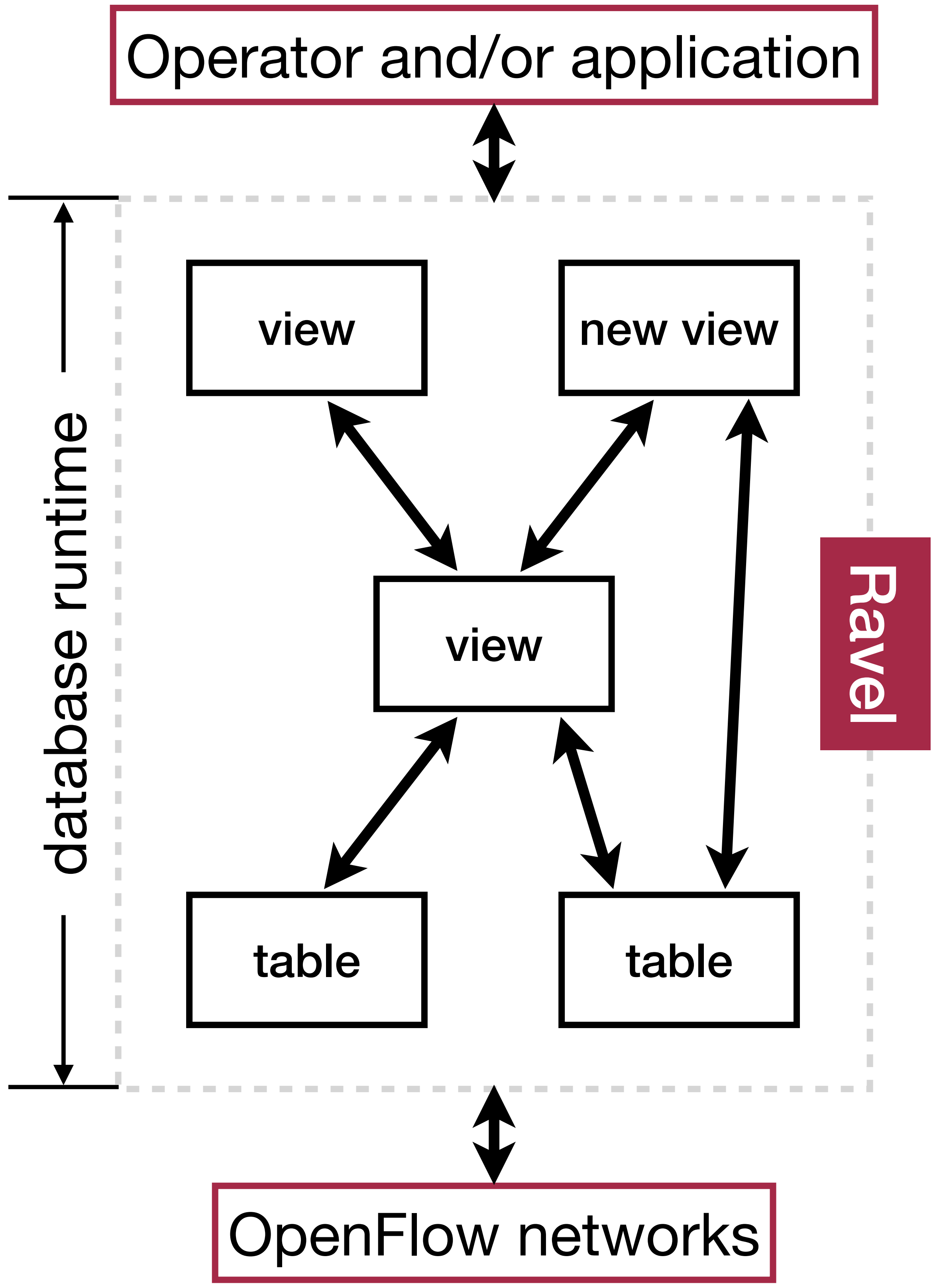
- Ad-hoc programmable abstraction via views
- Orchestration across abstractions via view mechanism
- Orchestration across applications via data mediation

Ravel: A realization with SQL database



- Ad-hoc programmable abstraction via views
- Orchestration across abstractions via view mechanism
- Orchestration across applications via data mediation
- Network control via SQL

Ravel: A realization with SQL database



- Attractive features:
    - Abstraction
    - Orchestration
    - SQL

Abstraction: Network Tables

Reachability Matrix

fid	src	dst	vol	…
1	h_1	h_4	5	
2	h_2	h_3	9	

…

Topology

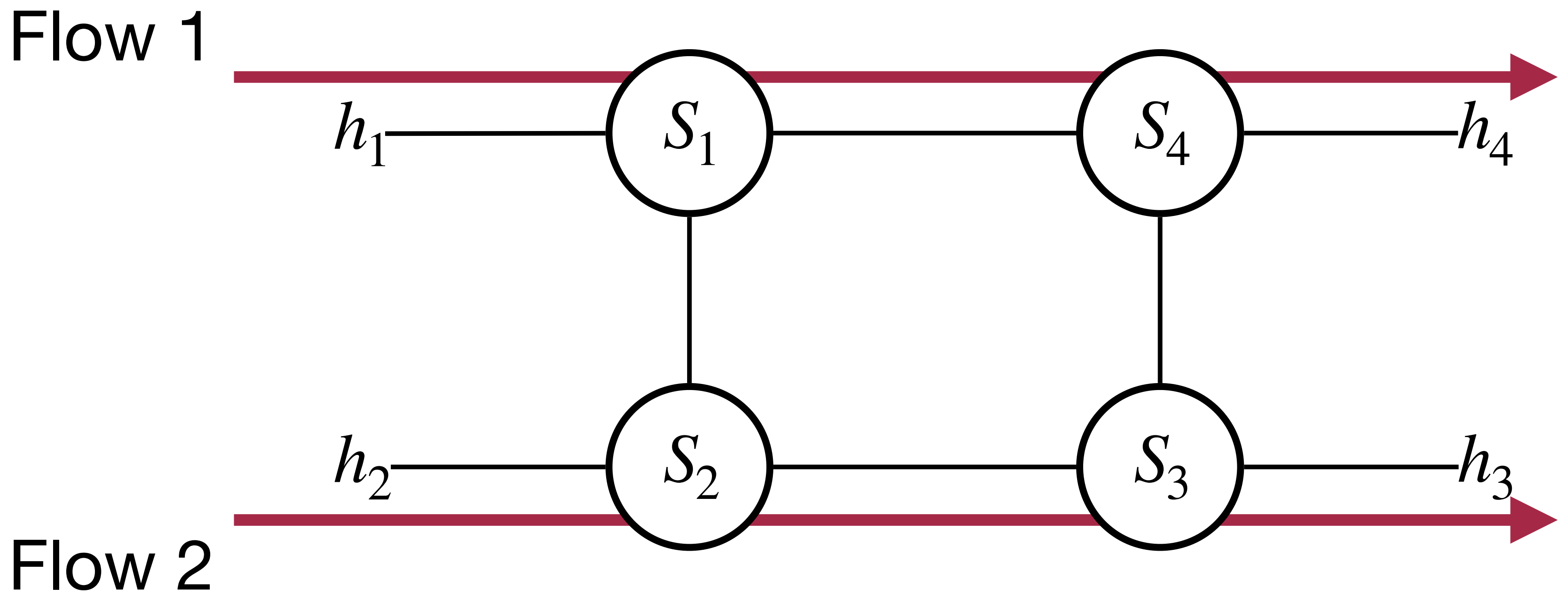
sid	nid
S_1	S_2
S_1	S_4
S_1	h_1

…

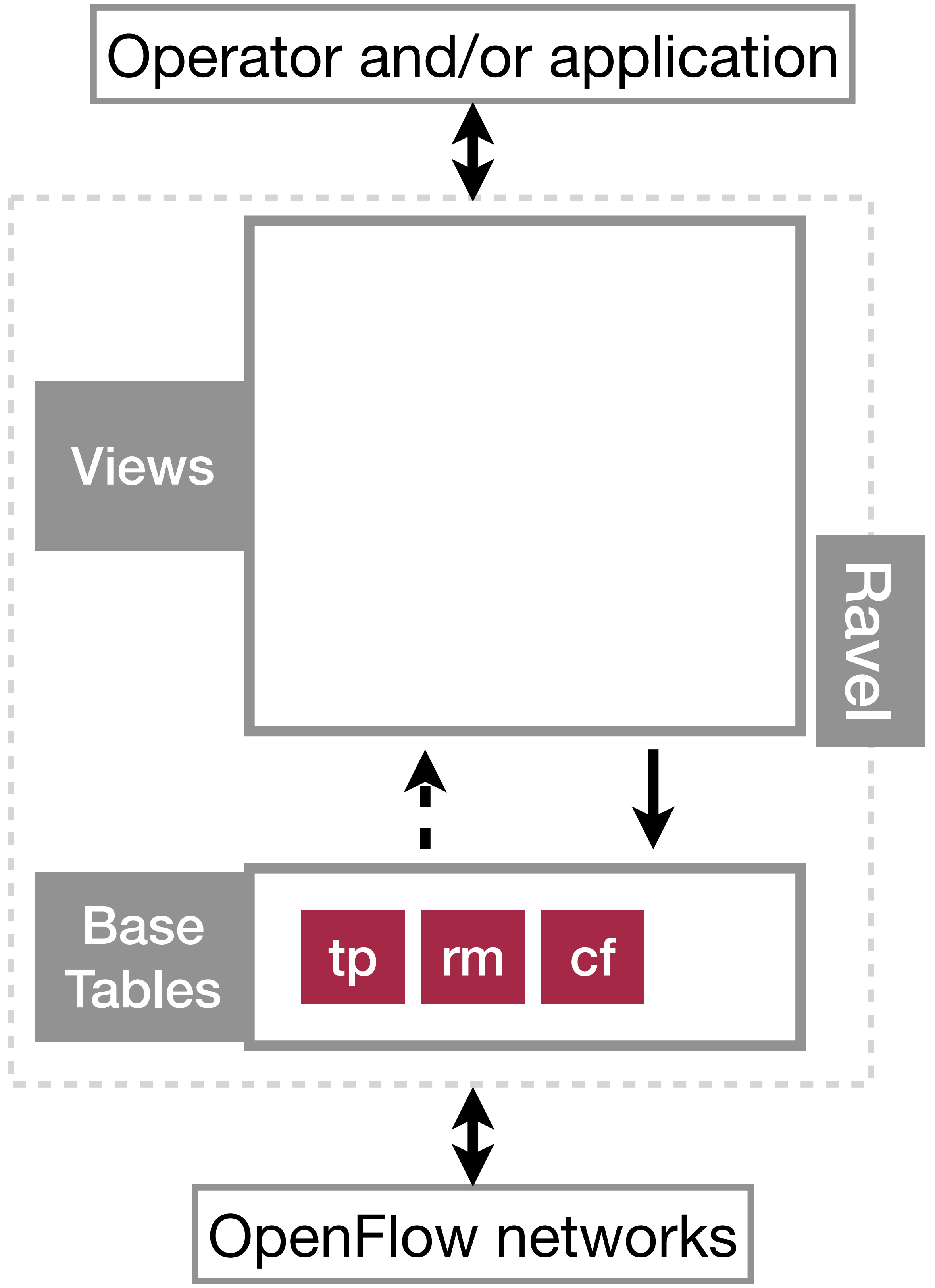
Configuration

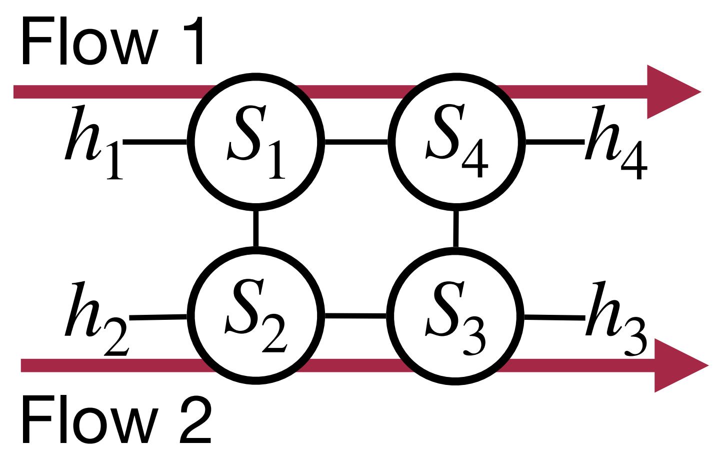
fid	sid	nid
1	S_1	S_4
1	S_4	h_4

…



Abstraction: Application View





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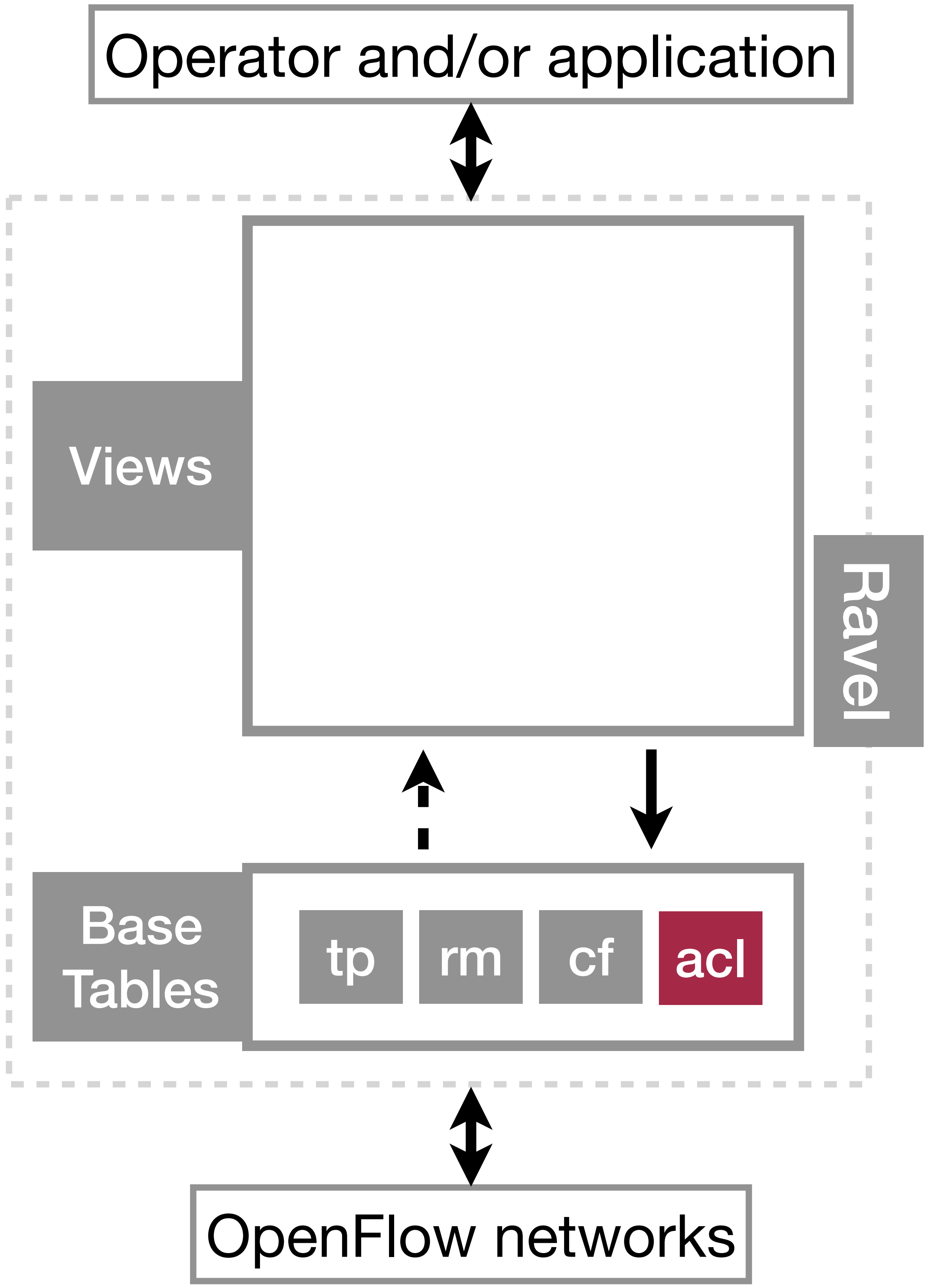
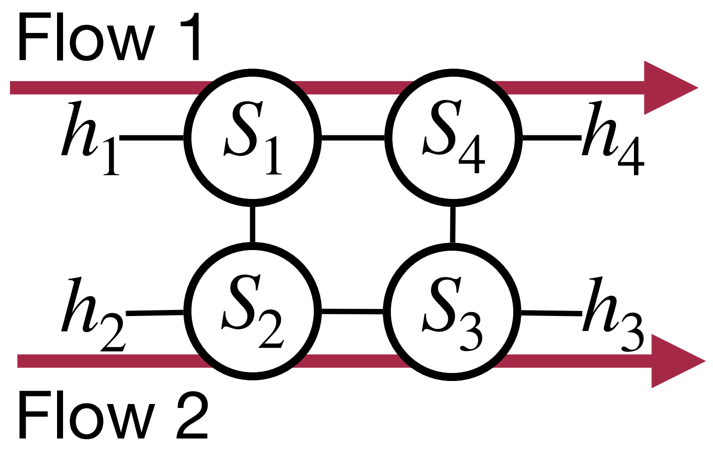


- Firewall view
  - monitoring unsafe flows violating access control(ACL) policy

Access Control

end1	end2	allow
h_1	h_4	0
h_2	h_3	1

…



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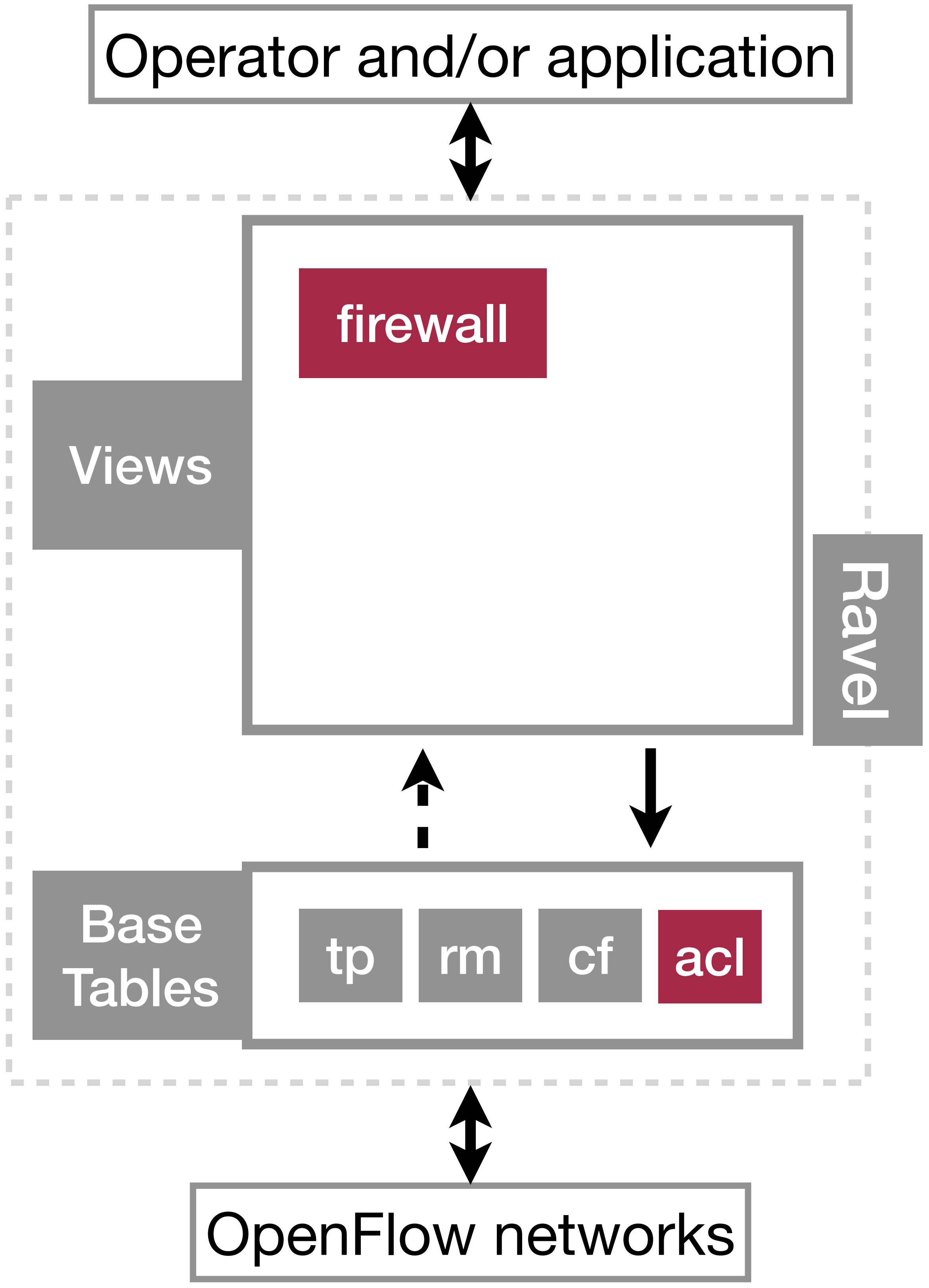
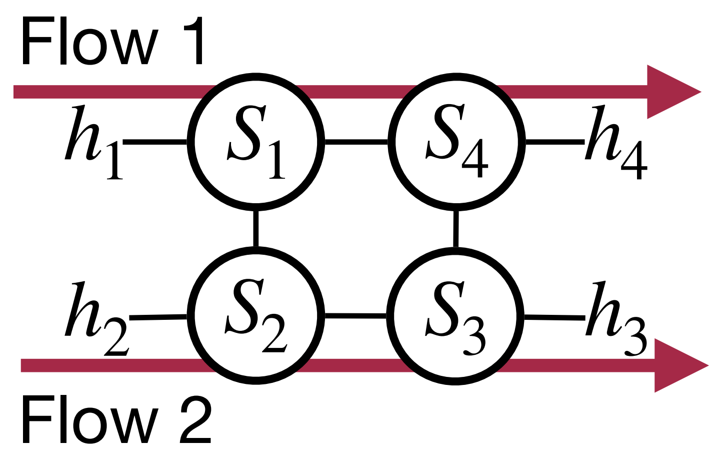


- Firewall view
  - monitoring unsafe flows violating access control(ACL) policy

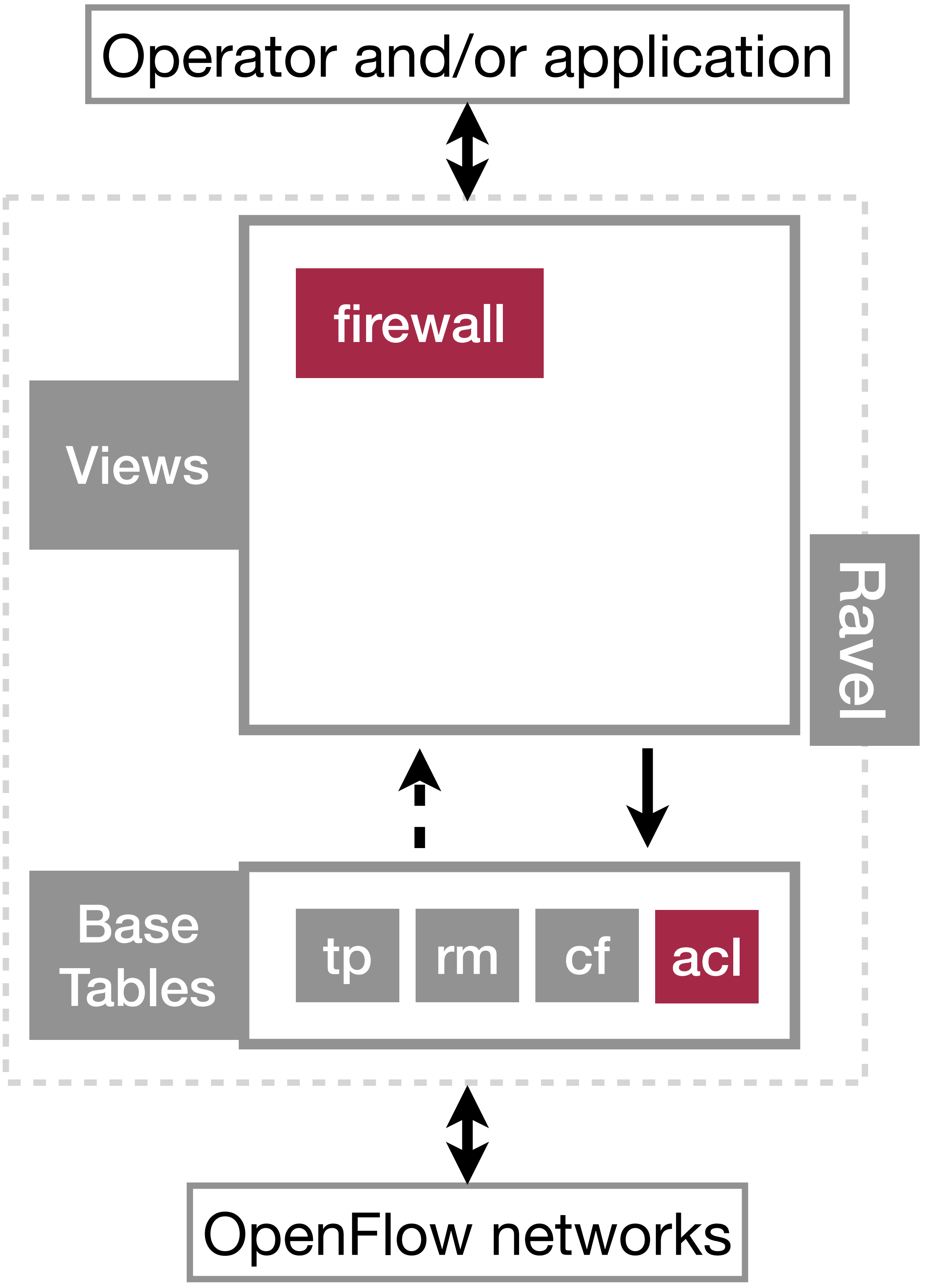
```
CREATE VIEW acl_violation(
   SELECT fid FROM rm
   WHERE (src, dst)
   IN (
      SELECT end1, end2 FROM acl
      WHERE allow = 0
   )
)
```

Access Control

end1	end2	allow
h_1	h_4	0
h_2	h_3	1
	…	



Abstraction: Application View

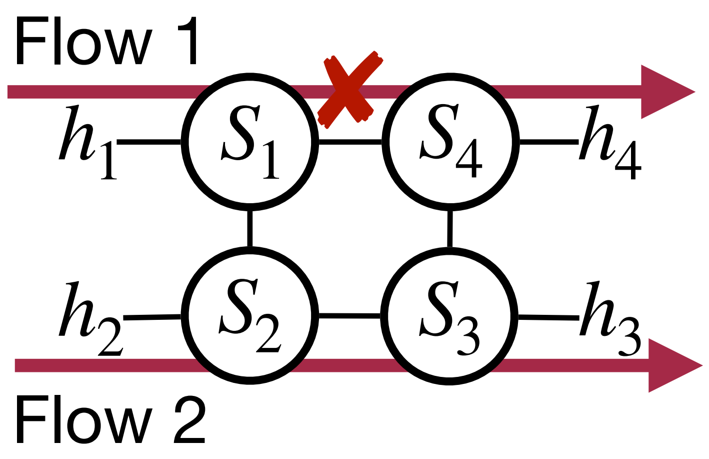


- Firewall view
  - monitoring unsafe flows violating access control(ACL) policy
- Firewall control
  - repairing violation

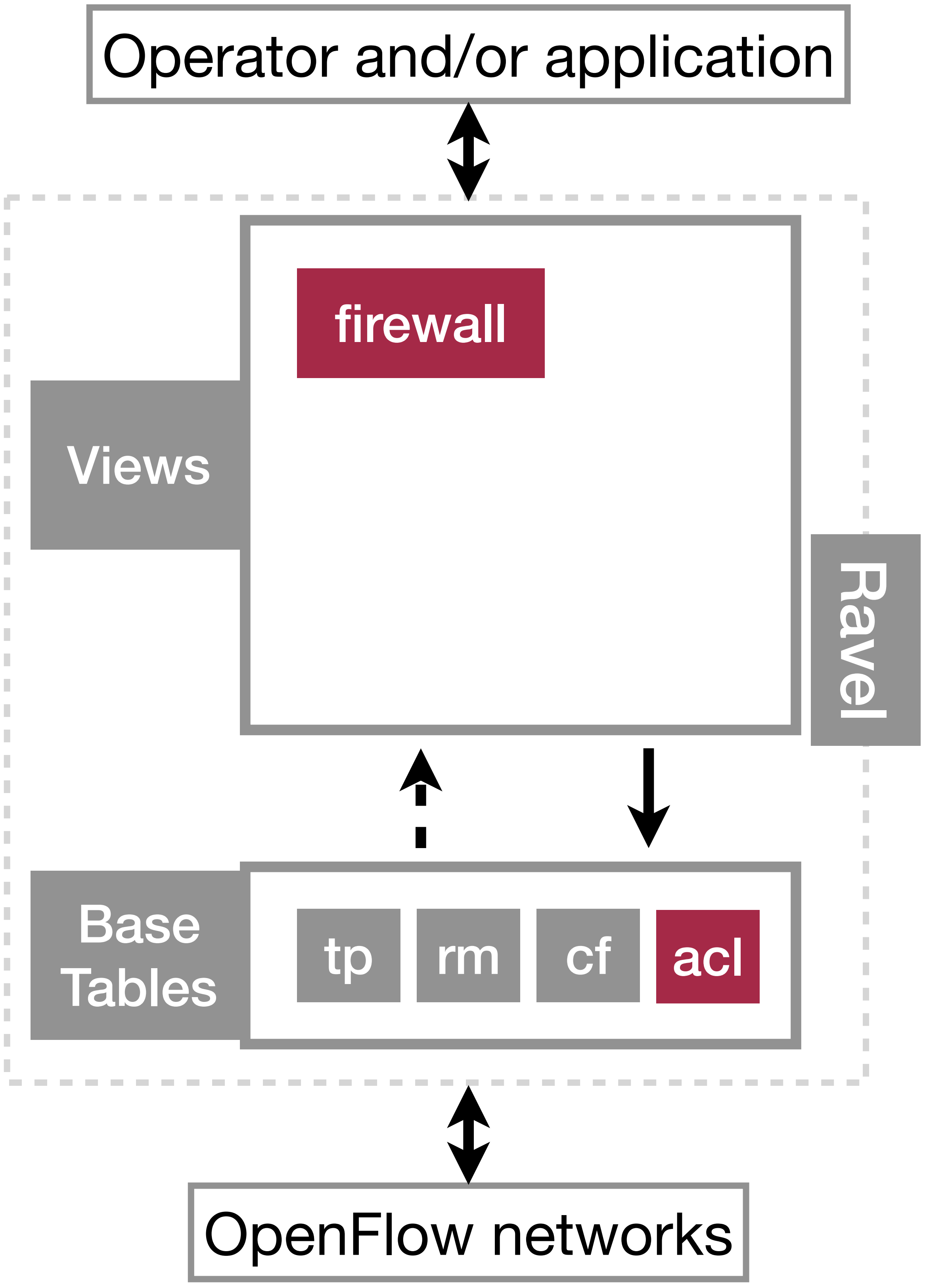
```
CREATE RULE acl_repair AS
ON DELETE TO acl_violation
DO INSTEAD
DELETE FROM rm WHERE fid = OLD.fid
```

Access Control

end1	end2	allow
h_1	h_4	0
h_2	h_3	1
…		



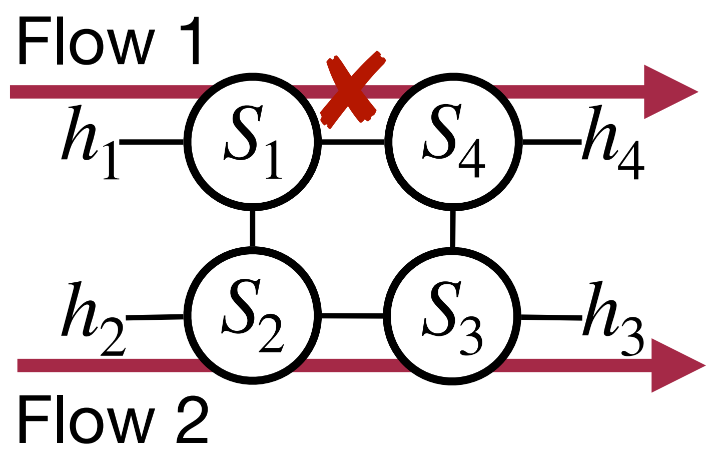
Abstraction: Application View



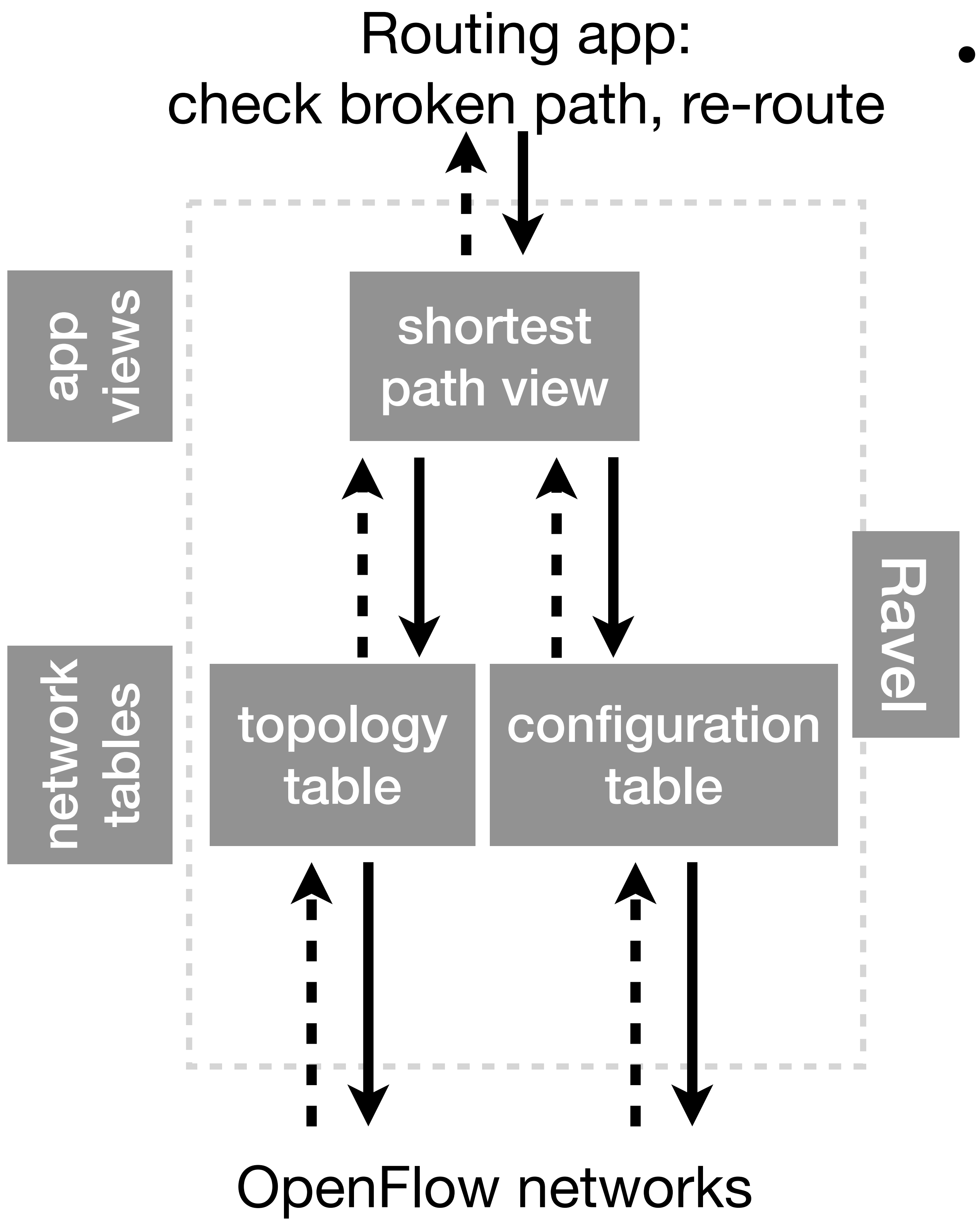
- Firewall view
  - monitoring unsafe flows violating access control(ACL) policy
- Firewall control
  - repairing violation
- More…
  - routing, stateful firewall, load balancer, etc.

Access Control

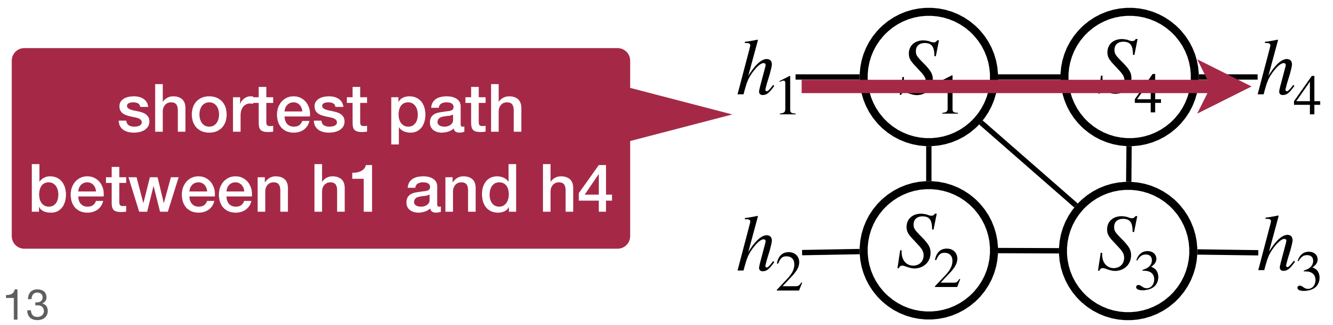
end1	end2	allow
h_1	h_4	0
h_2	h_3	1
…		



Orchestration across Representations



- Routing
  - a process of path selection in any networks



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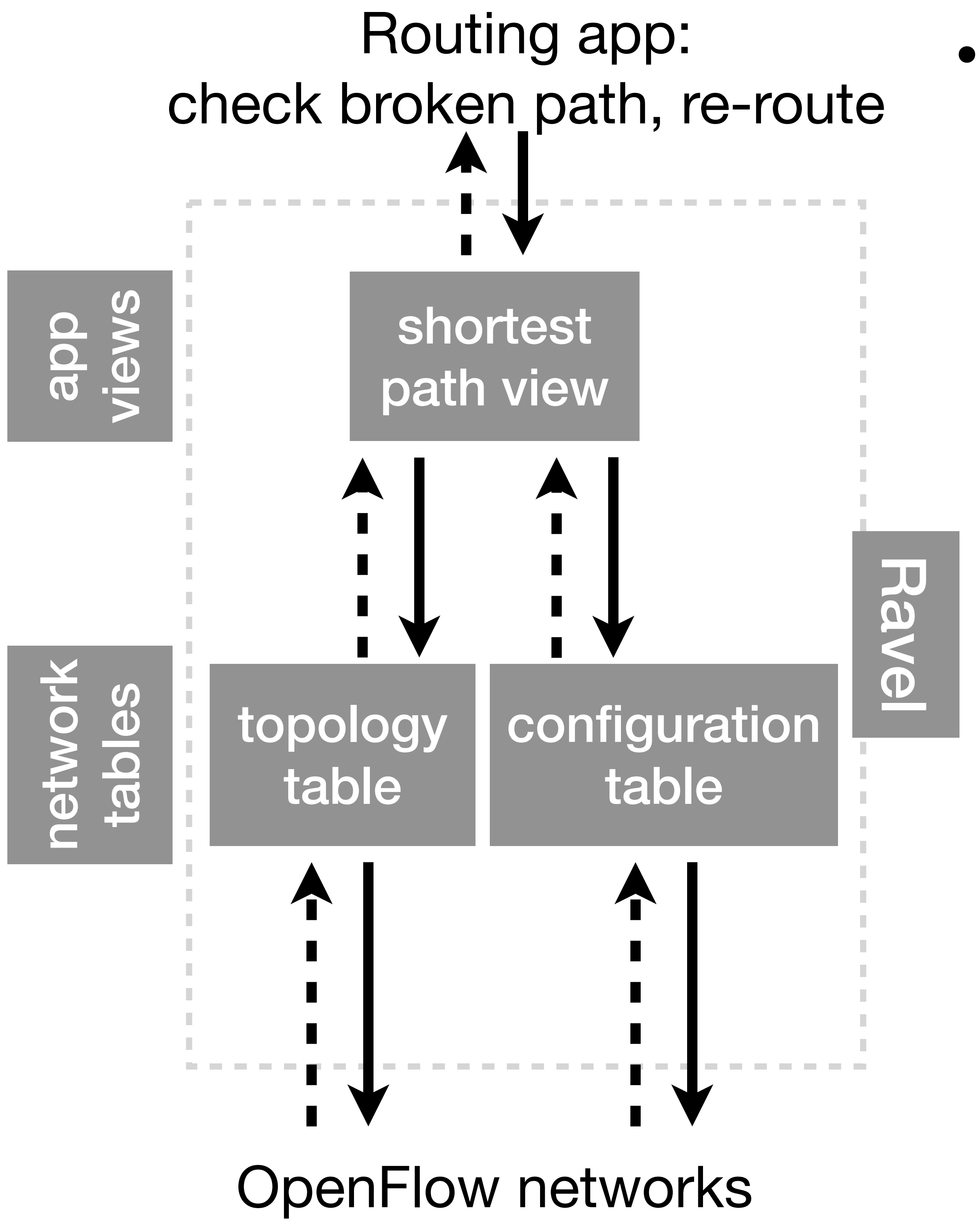


- Routing
  - a process of path selection in any networks

Shortest path view

fid	...	path
1		…, S_1, S_4, …

…

Topology

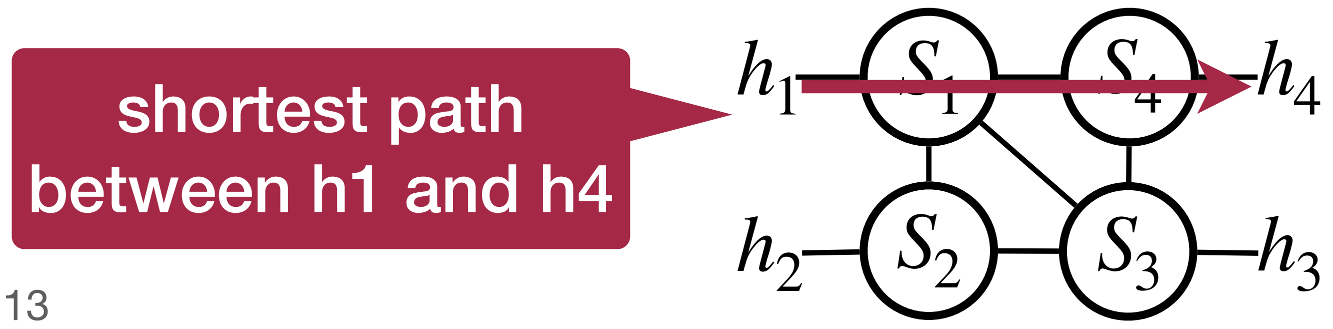
sid	nid	active
S_1	S_4	1
S_1	S_3	1
S_1	h_1	1

…

Configuration

fid	sid	nid
1	S_1	S_4
1	S_4	h_4

…



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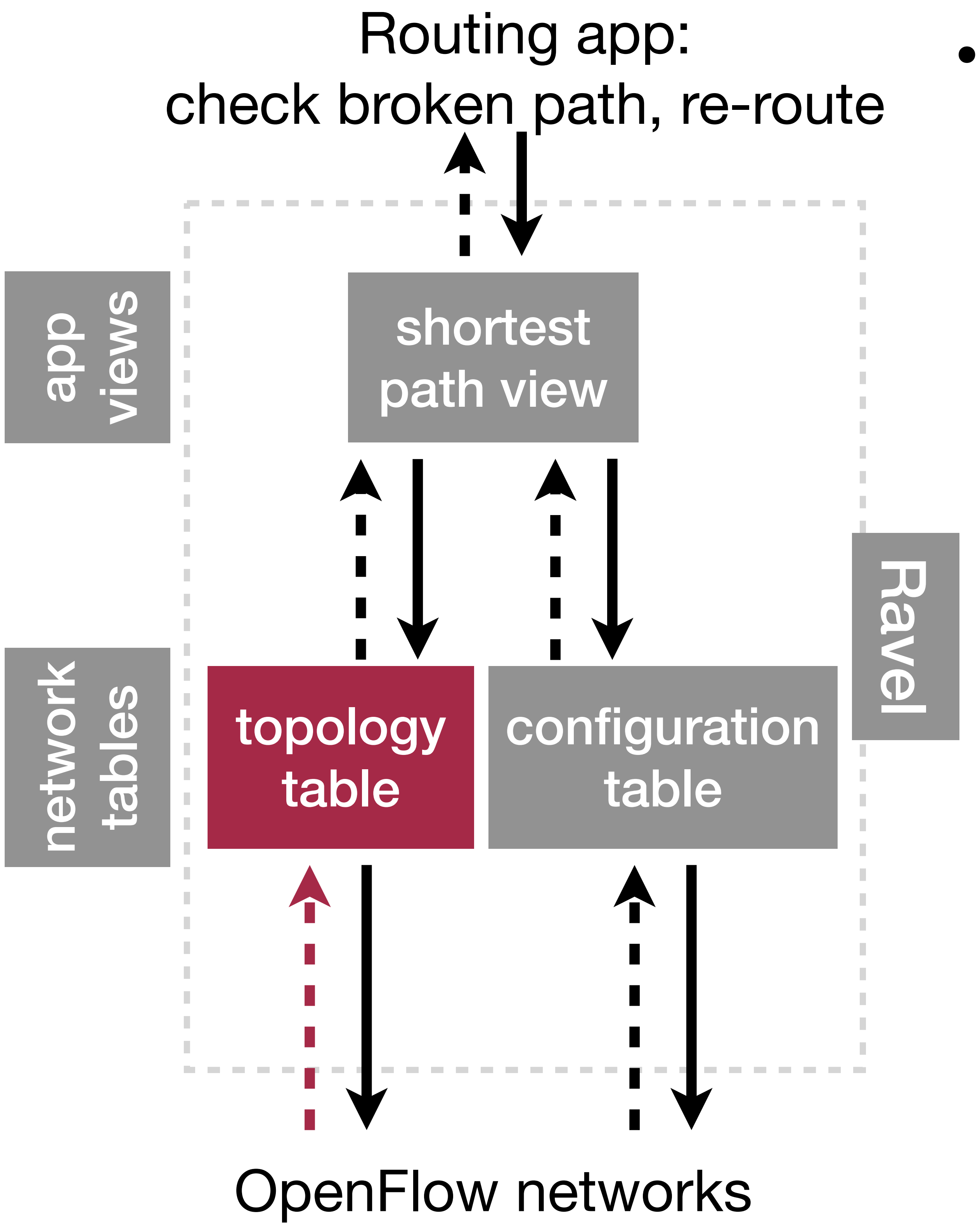


- Routing
  - a process of path selection in any networks

Shortest path view

fid	…	path
1		…, S_1, S_4, …

…

Topology

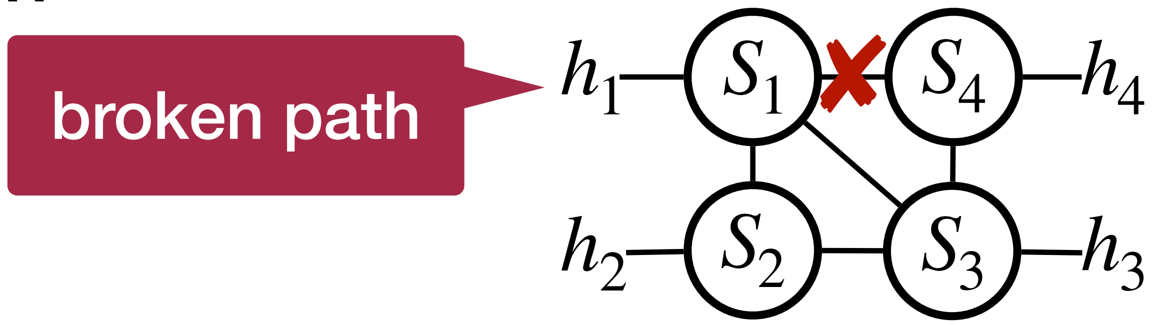
sid	nid	active
S_1	S_4	0
S_1	S_3	1
S_1	h_1	1

…

Configuration

fid	sid	nid
1	S_1	S_4
1	S_4	h_4

…



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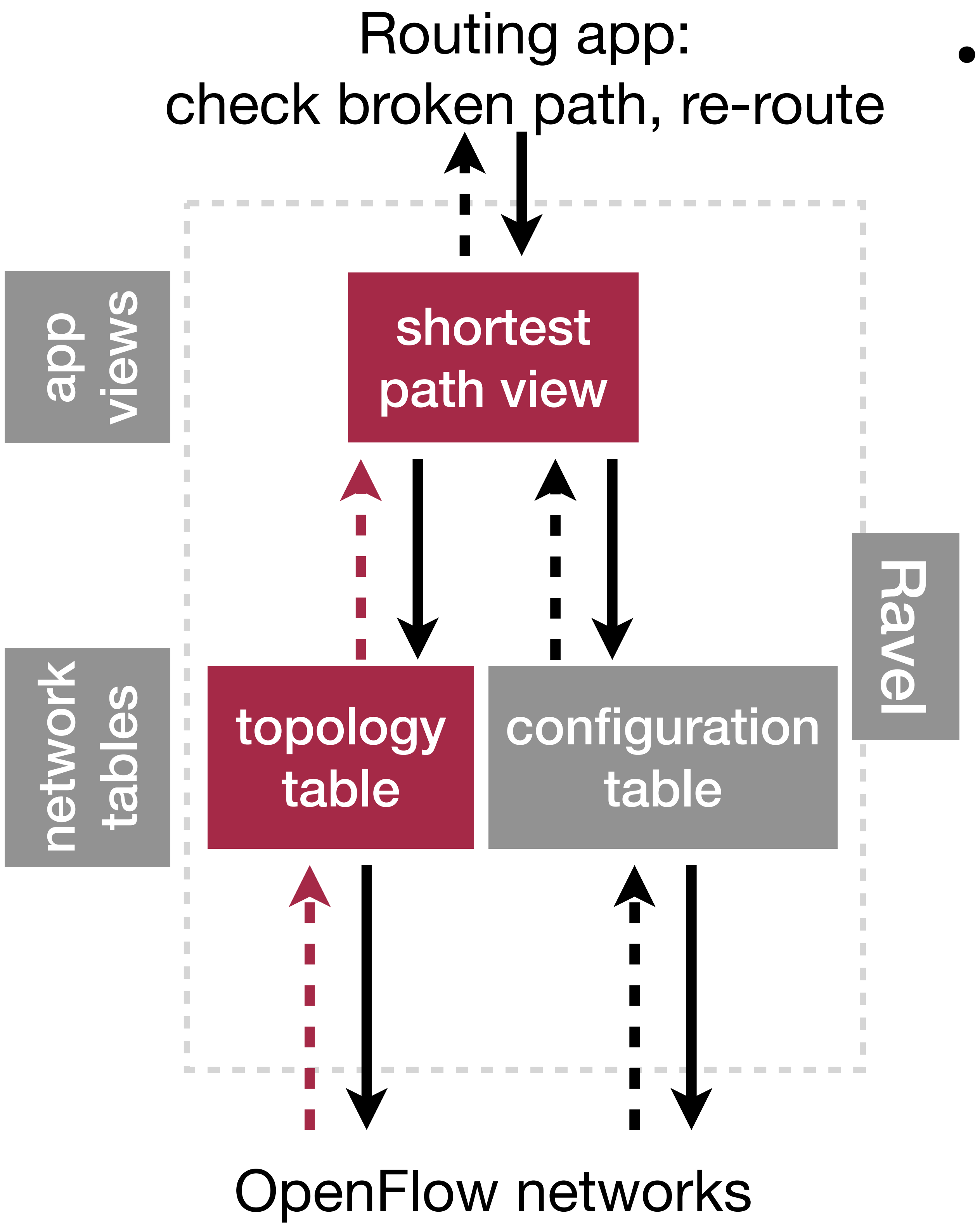


- Routing
  - a process of path selection in any networks

Shortest path view

fid	…	path
1		…, S_1, S_4, …

…

Topology

sid	nid	active
S_1	S_4	0
S_1	S_3	1
S_1	h_1	1

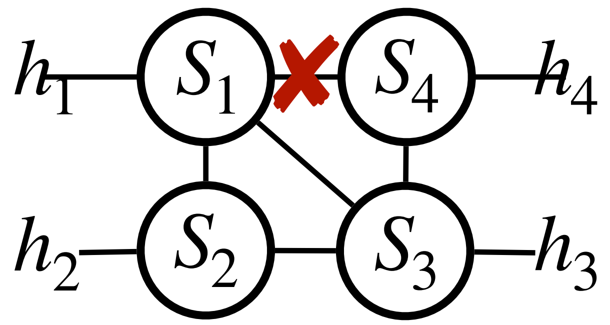
…

Configuration

fid	sid	nid
1	S_1	S_4
1	S_4	h_4

…

broken path



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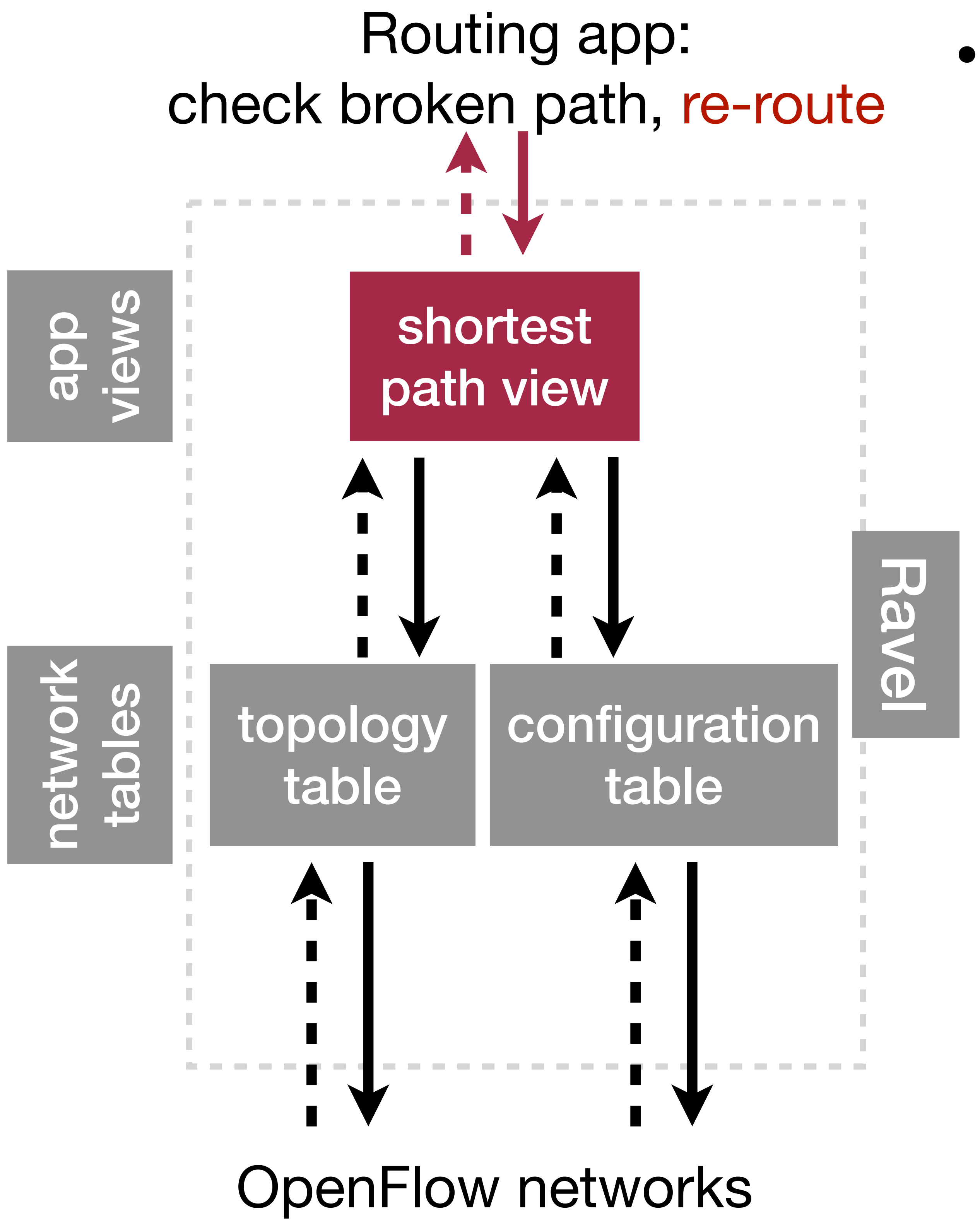


- Routing
  - a process of path selection in any networks

Shortest path view

fid	…	path
1		…, S_1, S_3, S_4, …

…

Topology

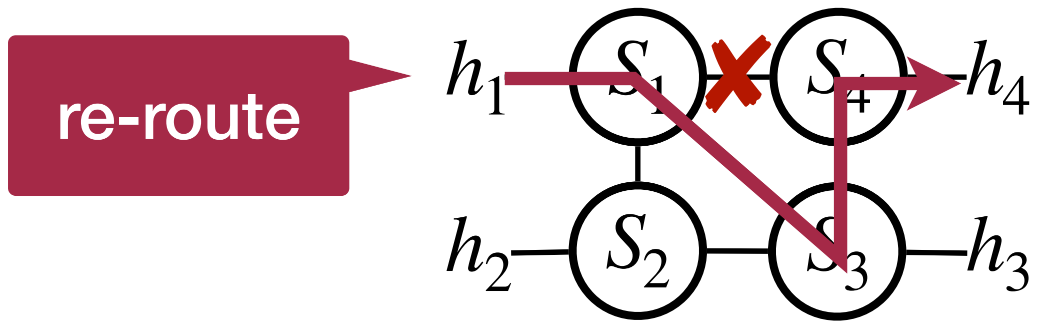
sid	nid	active
S_1	S_4	0
S_1	S_3	1
S_1	h_1	1

…

Configuration

fid	sid	nid
1	S_1	S_4
1	S_4	h_4

…



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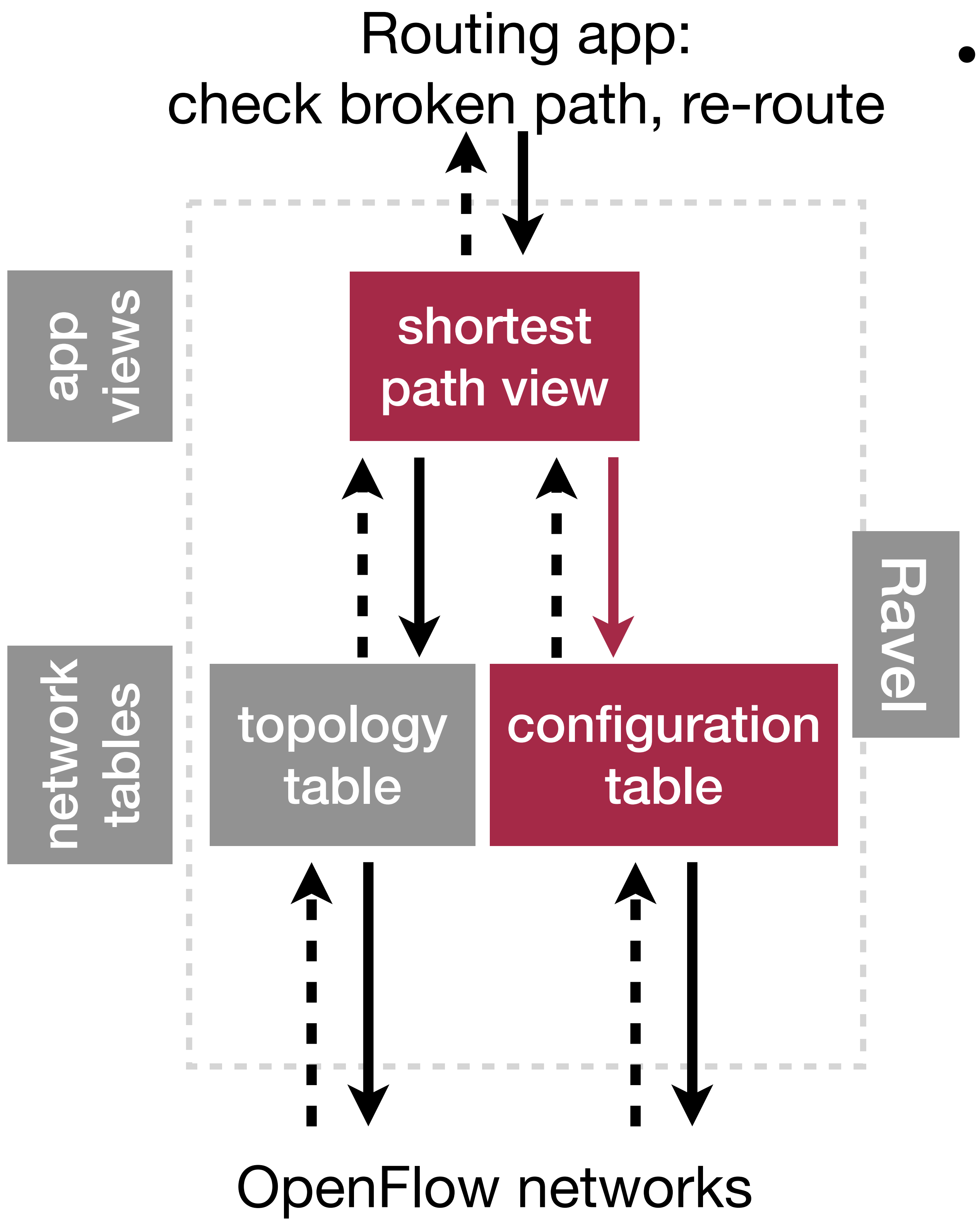


- Routing
  - a process of path selection in any networks

Shortest path view

fid	…	path
1		…, S_1, S_3, S_4, …

…

Topology

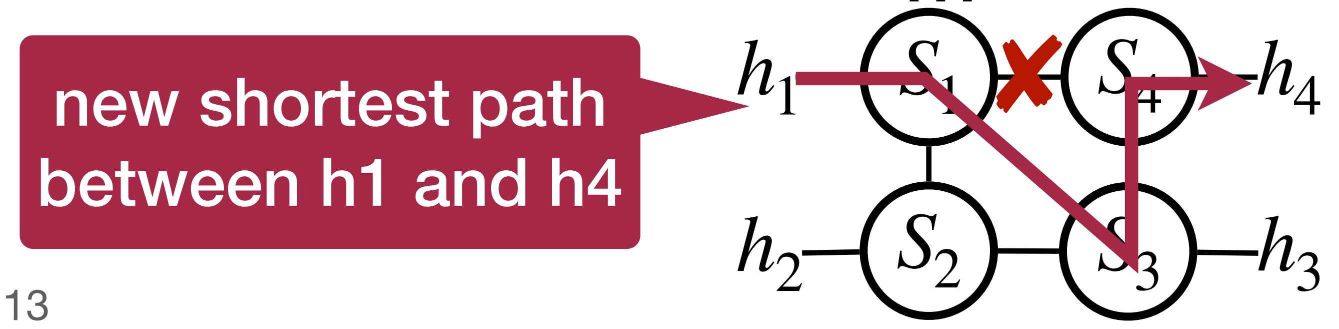
sid	nid	active
S_1	S_4	0
S_1	S_3	1
S_1	h_1	1

…

Configuration

fid	sid	nid
1	S_1	S_3
1	S_3	S_4
1	S_4	h_4

…



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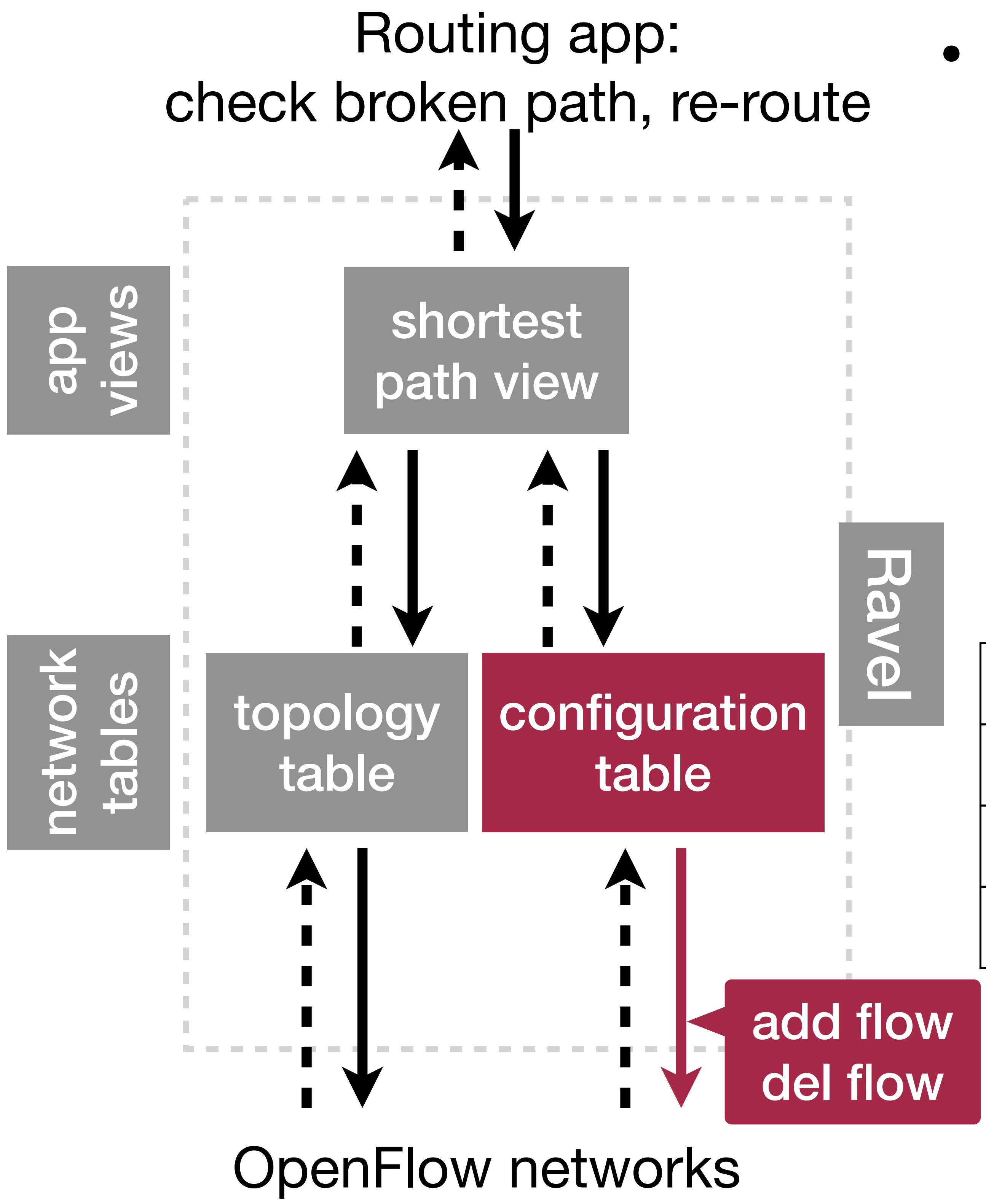


- Routing
  - a process of path selection in any networks

Shortest path view

fid	…	path
1		…, S_1, S_3, S_4, …

…

Topology

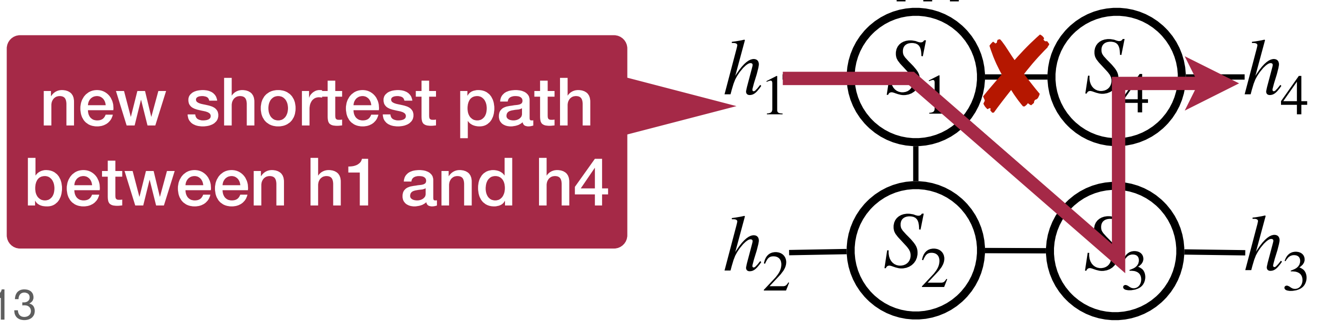
sid	nid	active
S_1	S_4	0
S_1	S_3	1
S_1	h_1	1

…

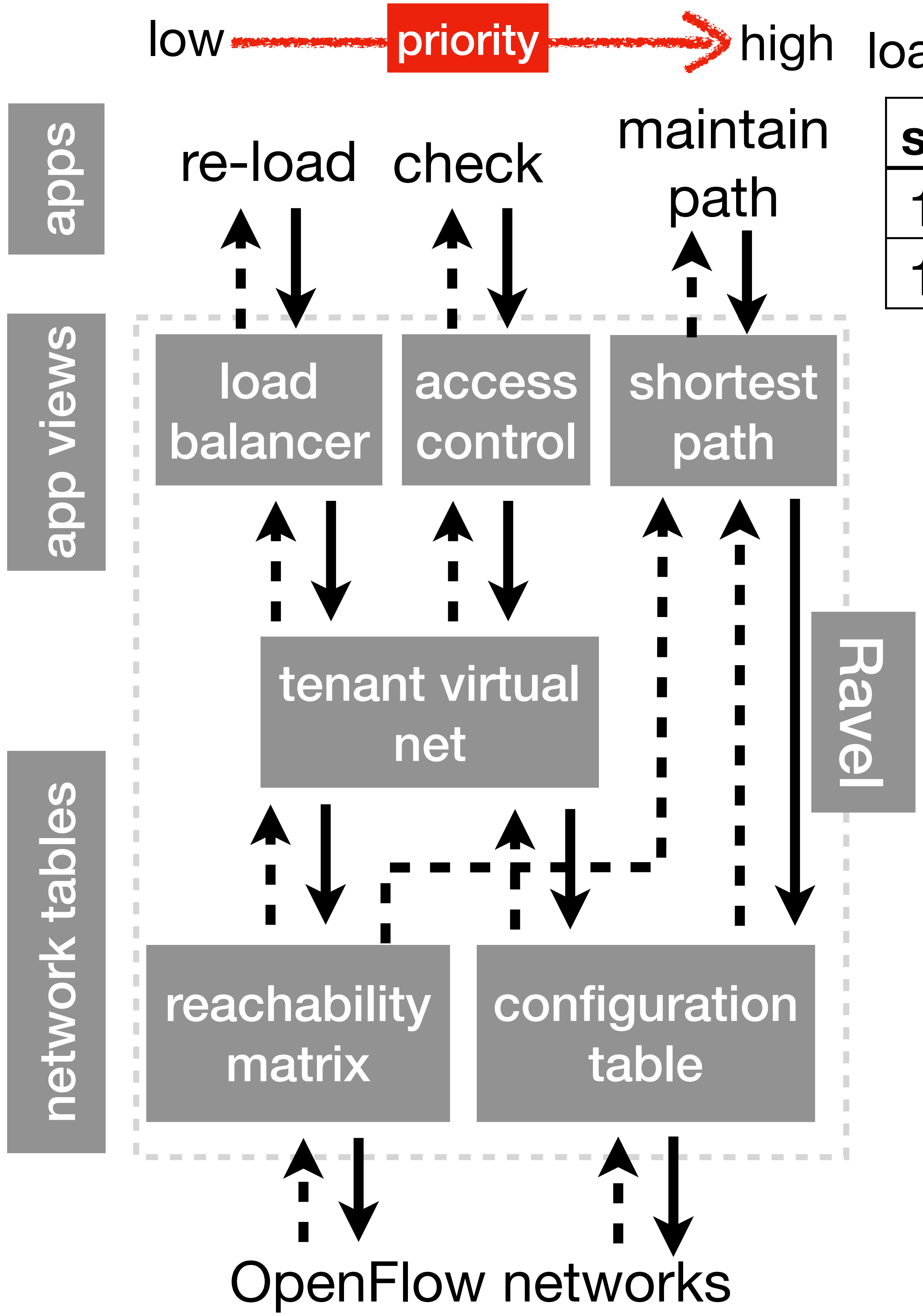
Configuration

fid	sid	nid
1	S_1	S_3
1	S_3	S_4
1	S_4	h_4

…



Orchestration across Applications



load balancer

sid	load
10	3
11	1

access control

src	dst	allow
1	10	0
1	11	1

shortest path

...	path

...

tenant virtual net

...	host	server
...	1	10

Reachability Matrix

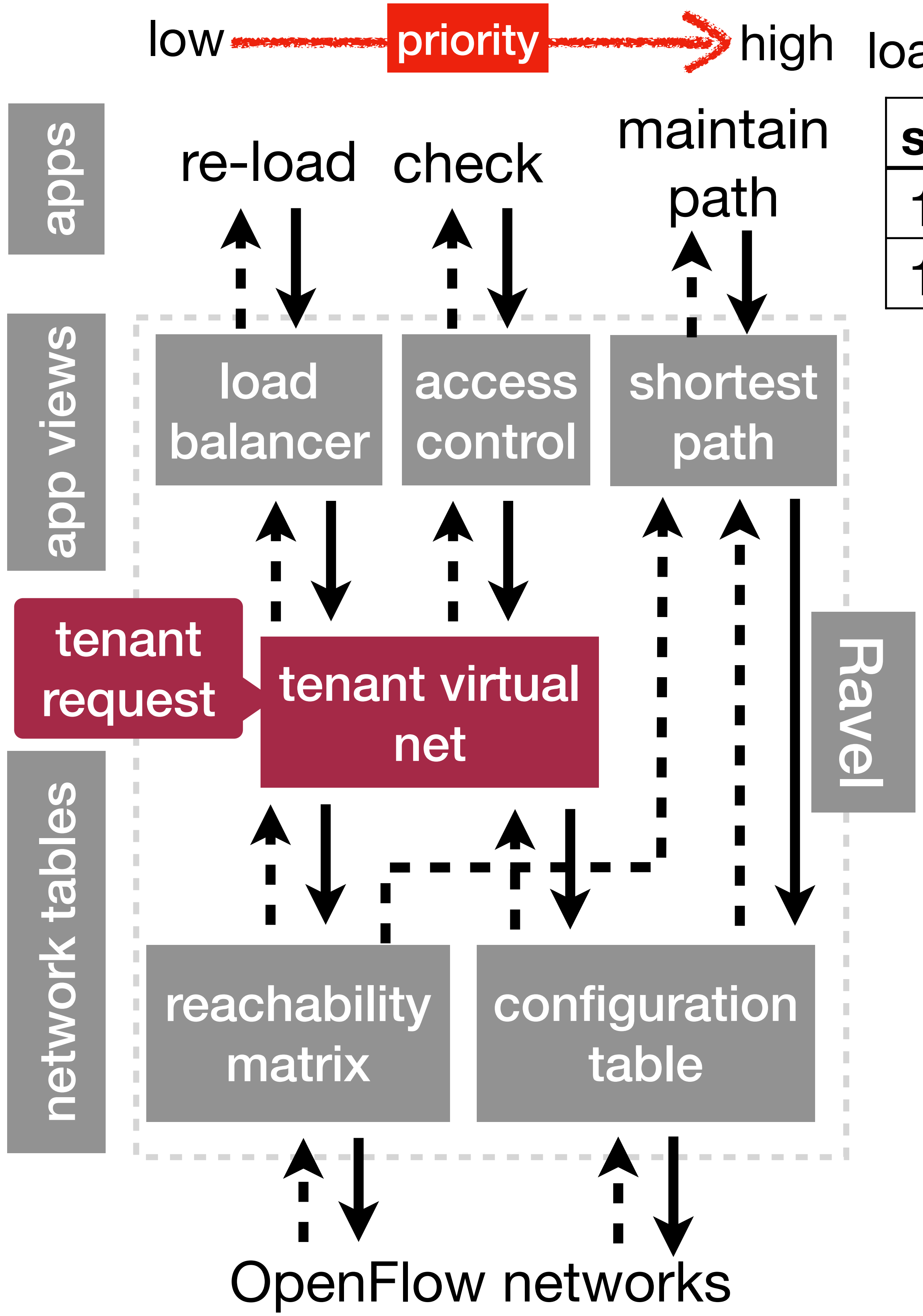
fid	sid	nid

Configuration

fid	sid	nid

...

Orchestration across Applications



load balancer

sid	load
10	3
11	1

…

access control

src	dst	allow
1	10	0
1	11	1

shortest path

…	path

tenant request host 1 to server 10

tenant virtual net

…	host	server
…	1	10

Reachability Matrix

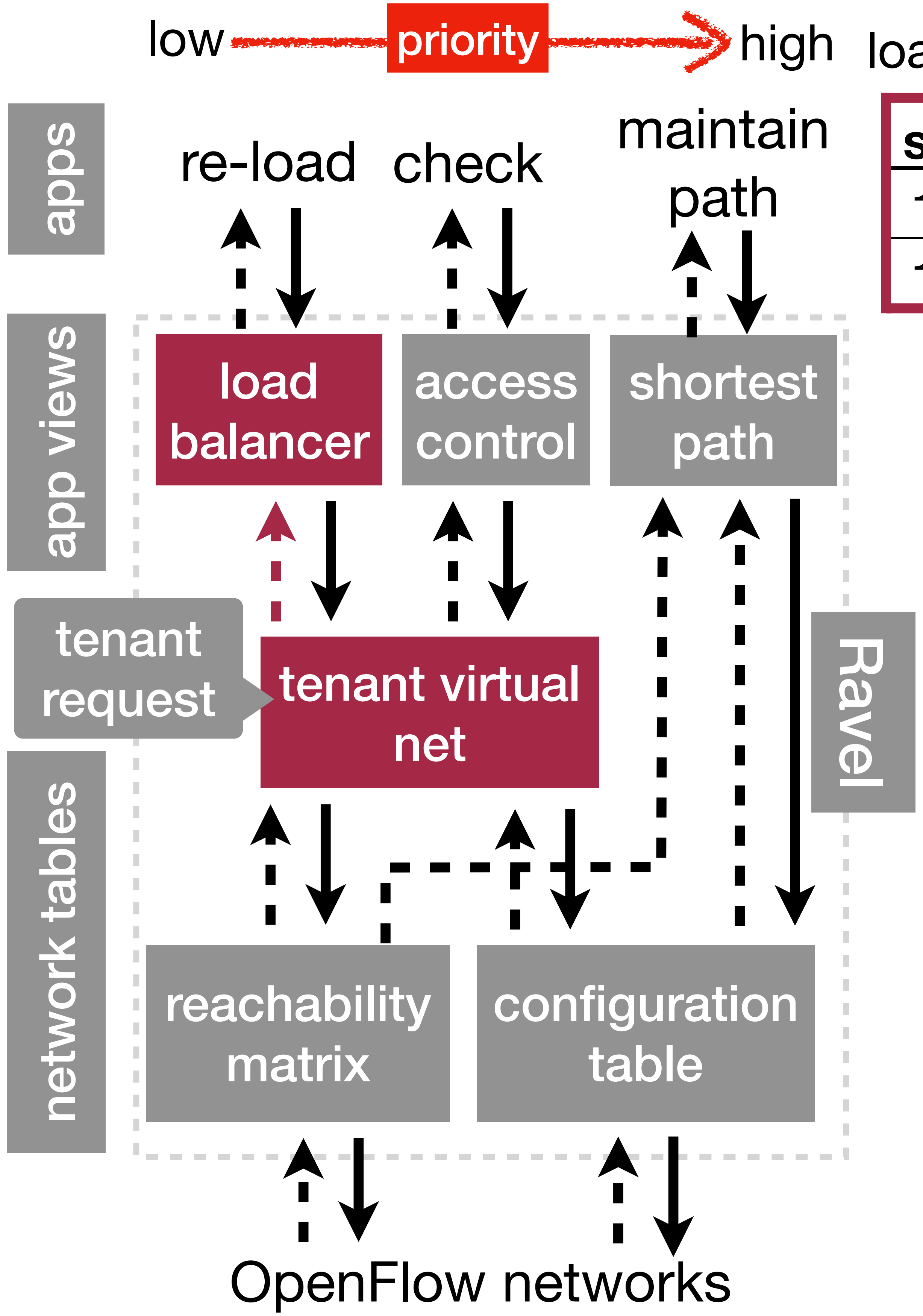
fid	sid	nid

Configuration

fid	sid	nid

…

Orchestration across Applications



load balancer

sid	load
10	4
11	1

access control

src	dst	allow
1	10	0
1	11	1

shortest path

…	path

…

tenant request host 1 to server 10

tenant virtual net

…	host	server
…	1	10

Reachability Matrix

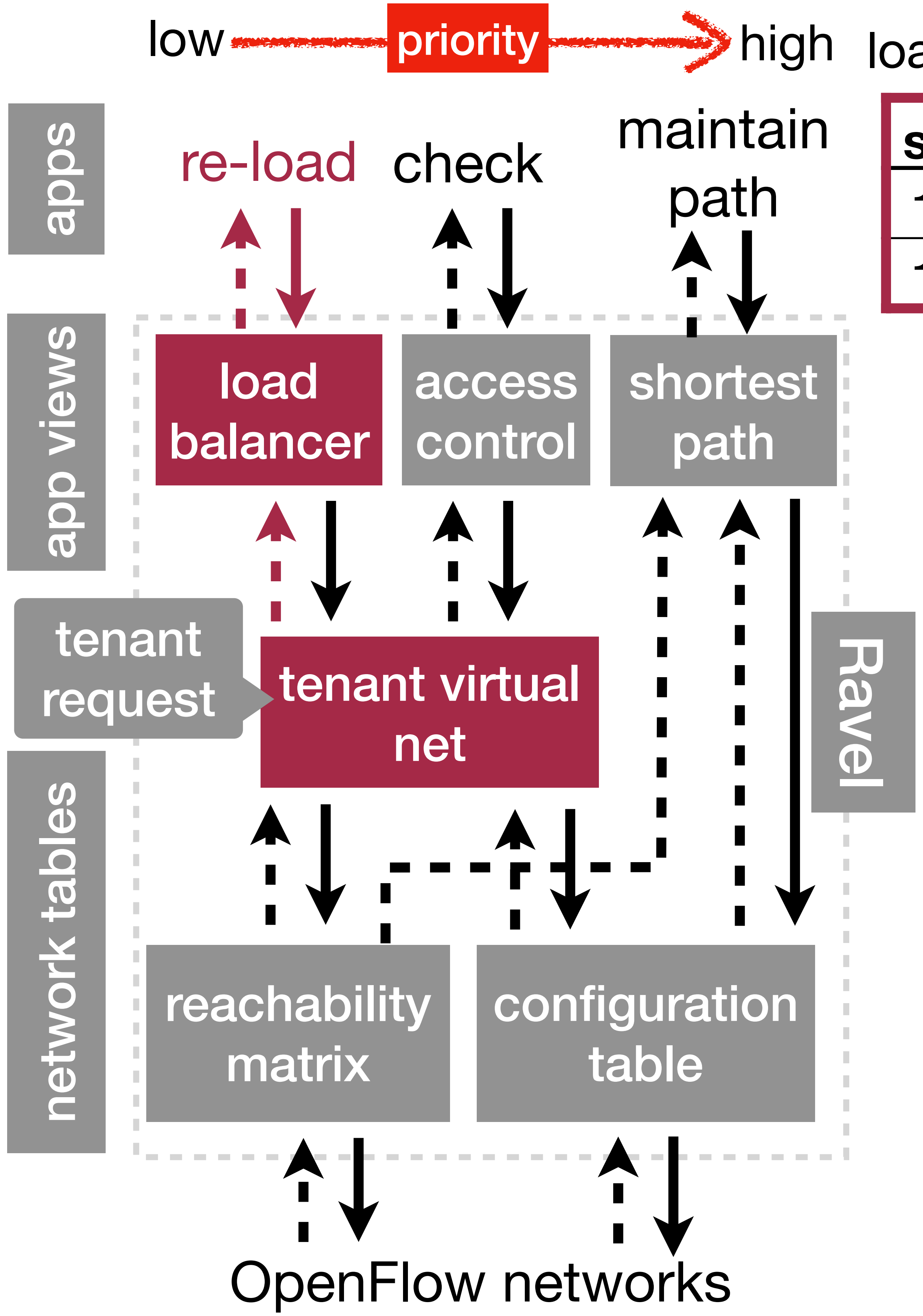
fid	sid	nid

Configuration

fid	sid	nid

…

Orchestration across Applications



load balancer

sid	load
10	3
11	2

access control

src	dst	allow
1	10	0
1	11	1

shortest path

...	path

…

tenant request host 1 to server 10

tenant virtual net

...	host	server
…	1	10

Reachability Matrix

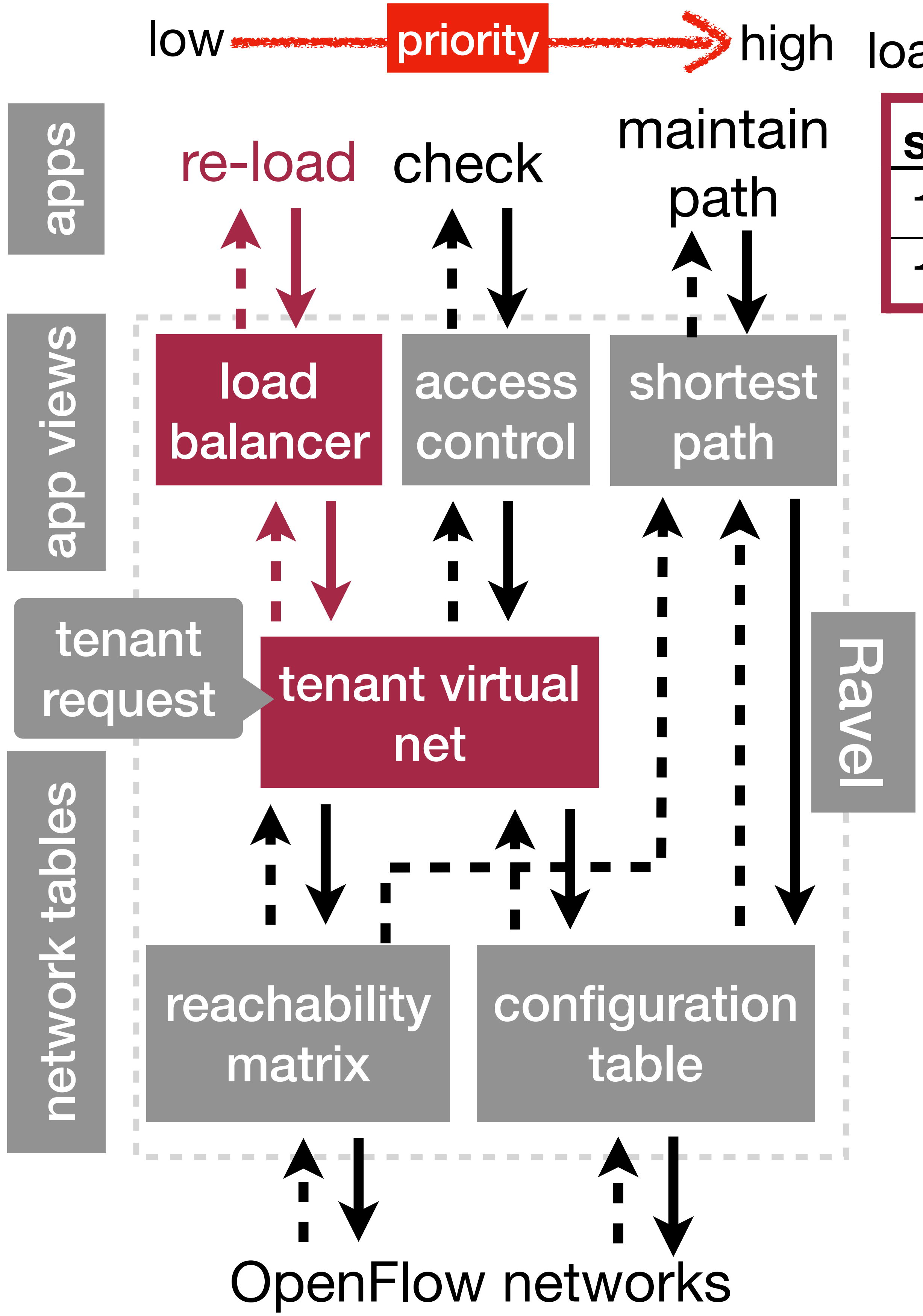
fid	sid	nid

Configuration

fid	sid	nid

…

Orchestration across Applications



load balancer

sid	load
10	3
11	2

access control

src	dst	allow
1	10	0
1	11	1

shortest path

…	path

…

tenant request host 1 to server 10

tenant virtual net

…	host	server
…	1	11

Reachability Matrix

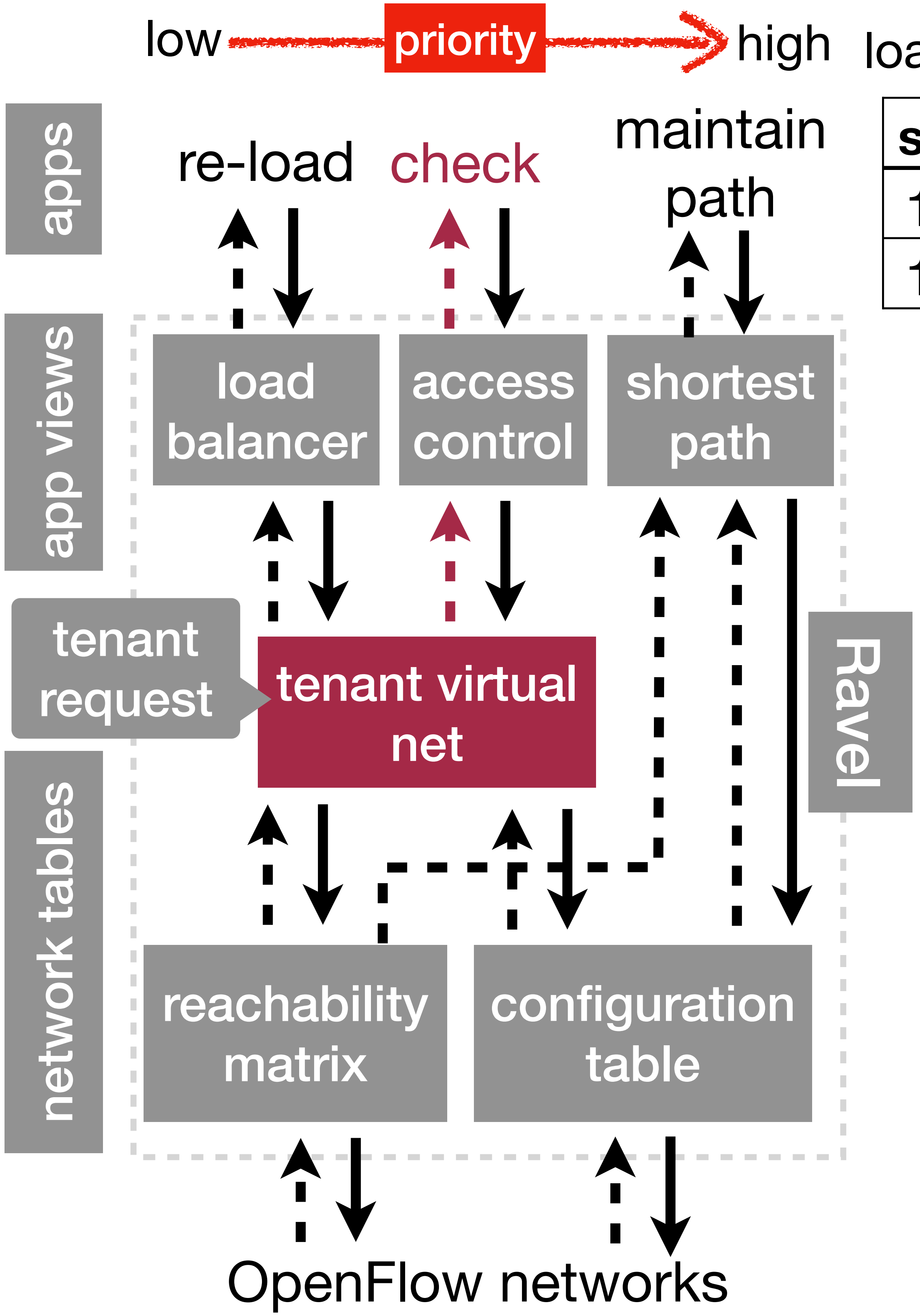
fid	sid	nid

Configuration

fid	sid	nid

…

Orchestration across Applications



load balancer

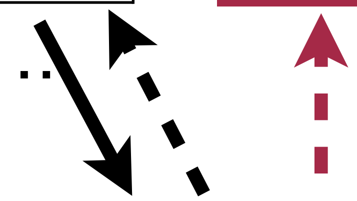
sid	load
10	3
11	2

access control

src	dst	allow
1	10	0
1	11	1

shortest path

...	path



tenant request host 1 to server 10

tenant virtual net

...	host	server
...	1	11

Reachability Matrix

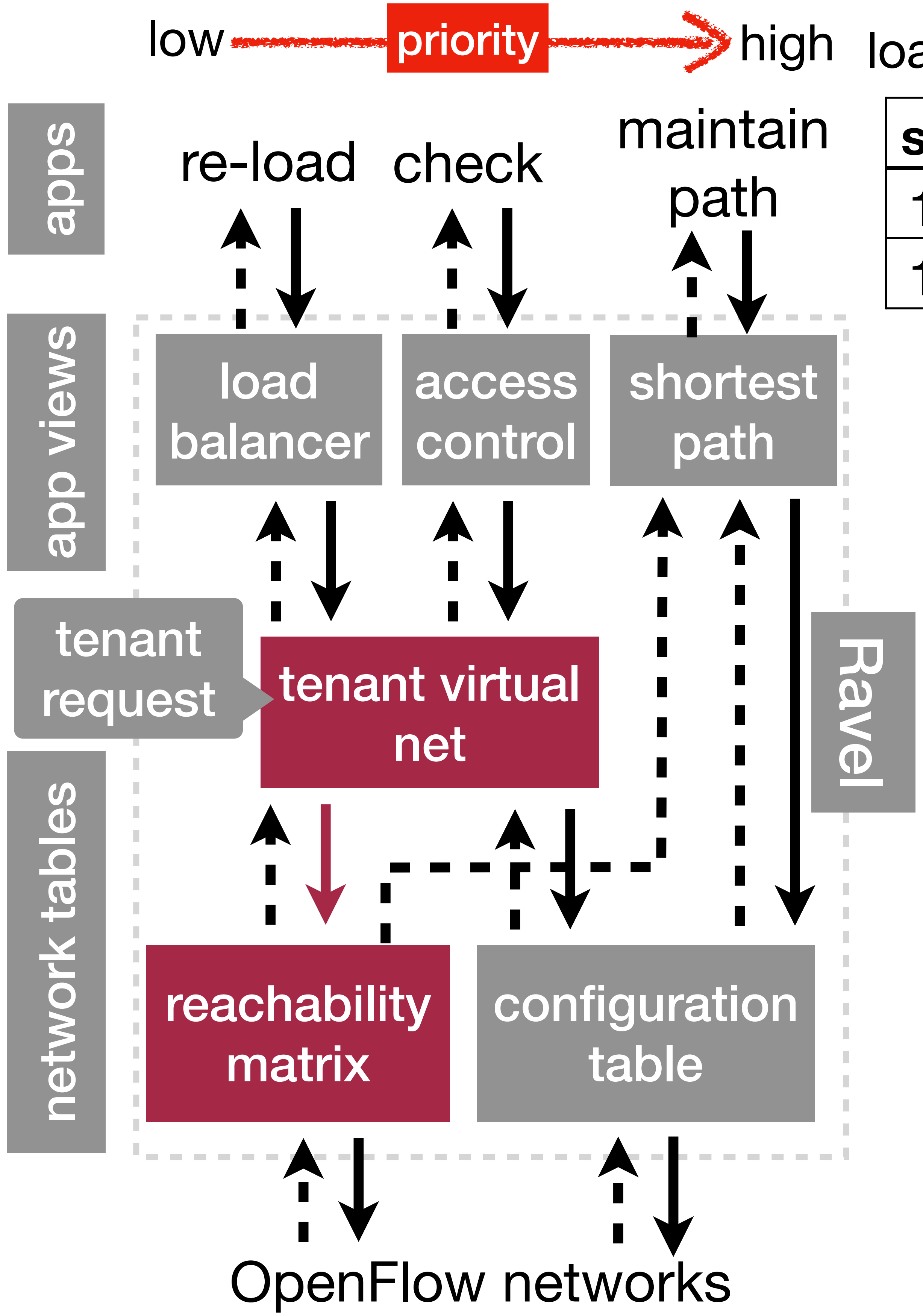
fid	sid	nid

Configuration

fid	sid	nid

...

Orchestration across Applications



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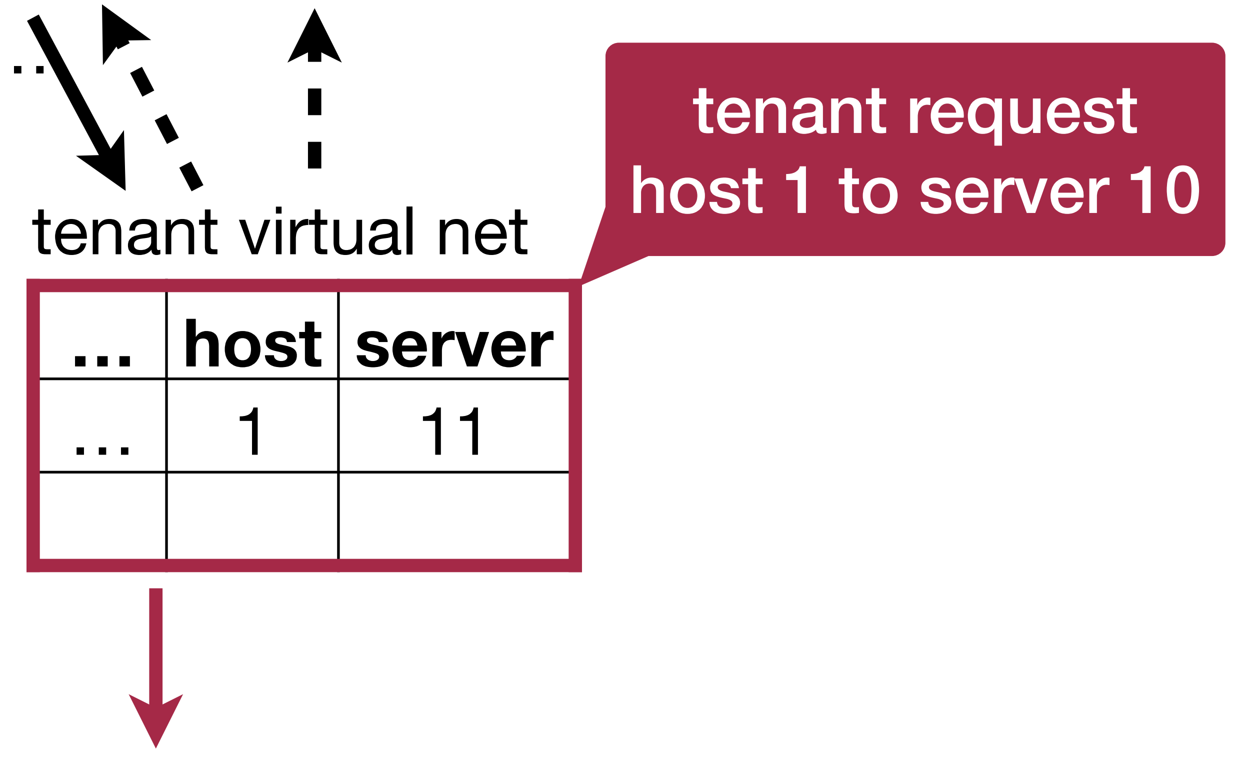

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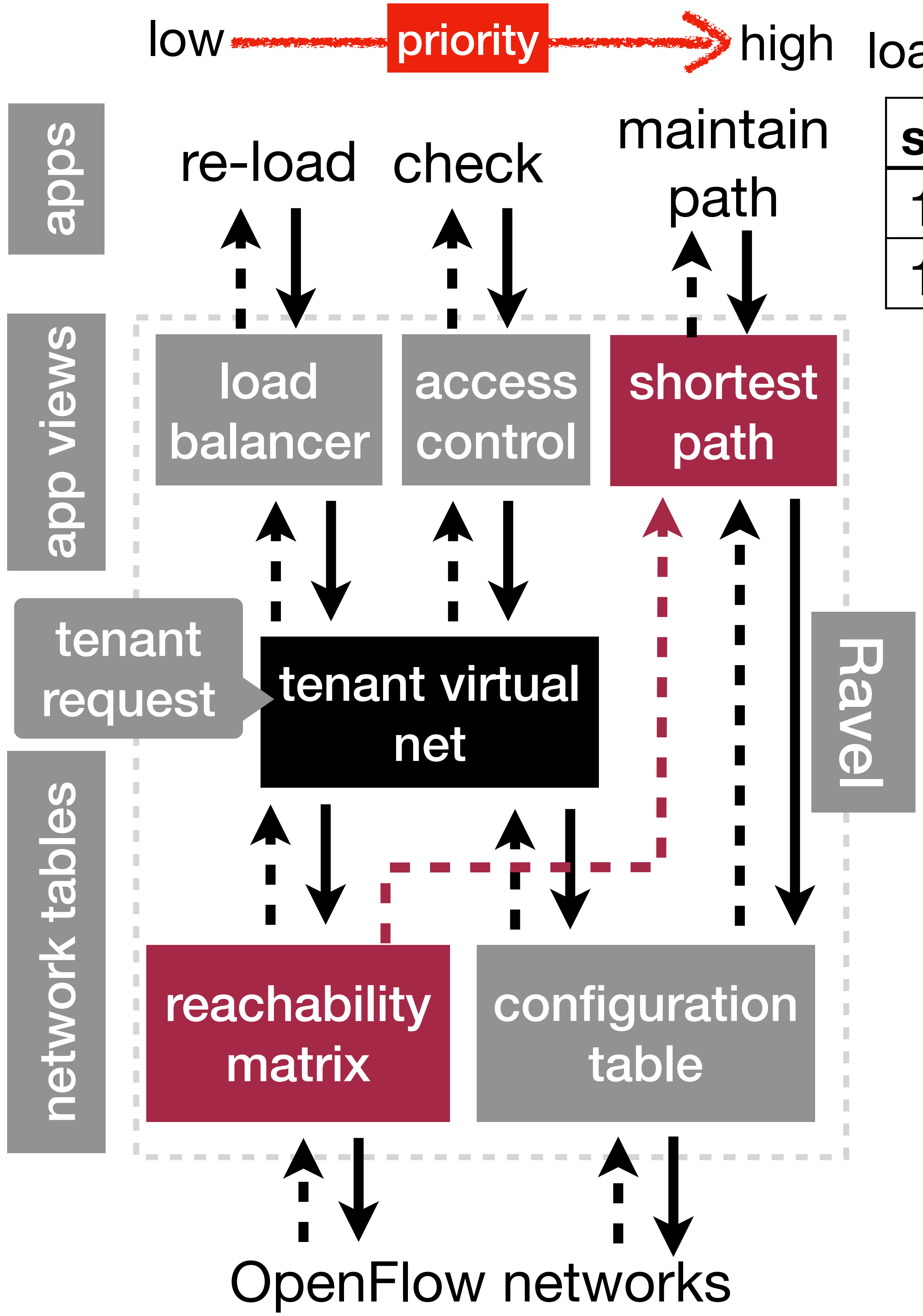
Orchestration across Applications



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	1, …, 11

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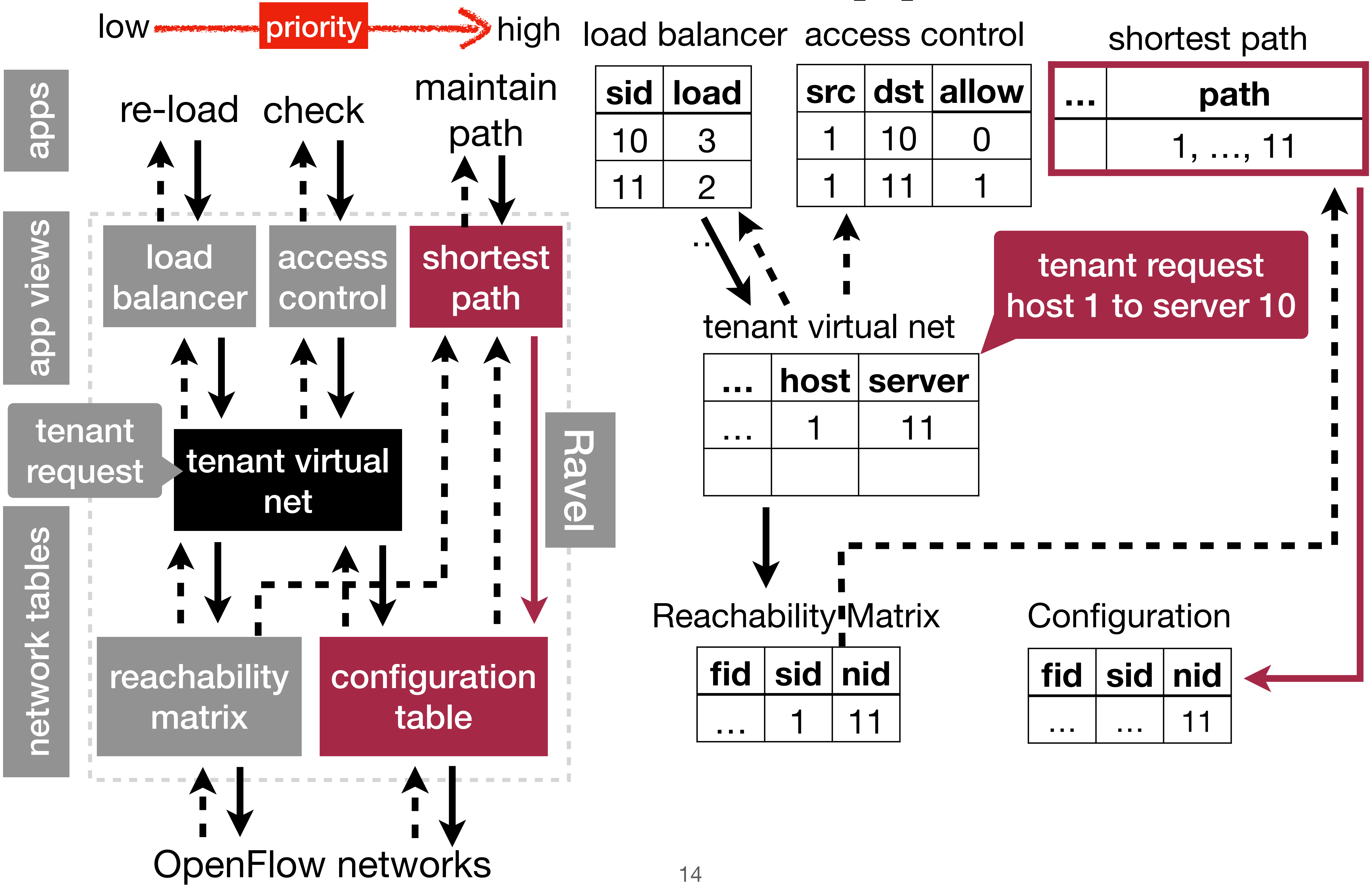

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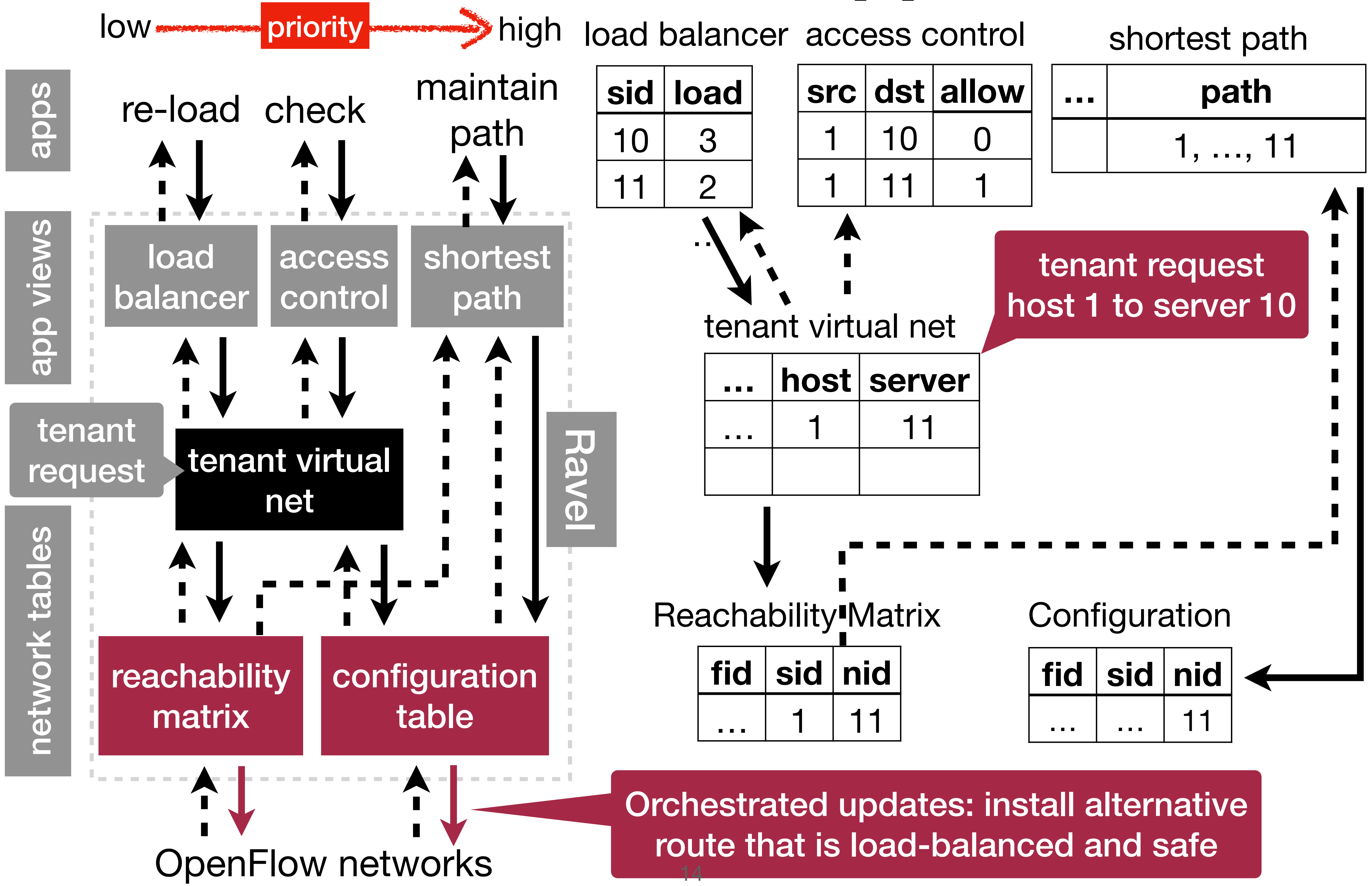
Orchestration across Applications



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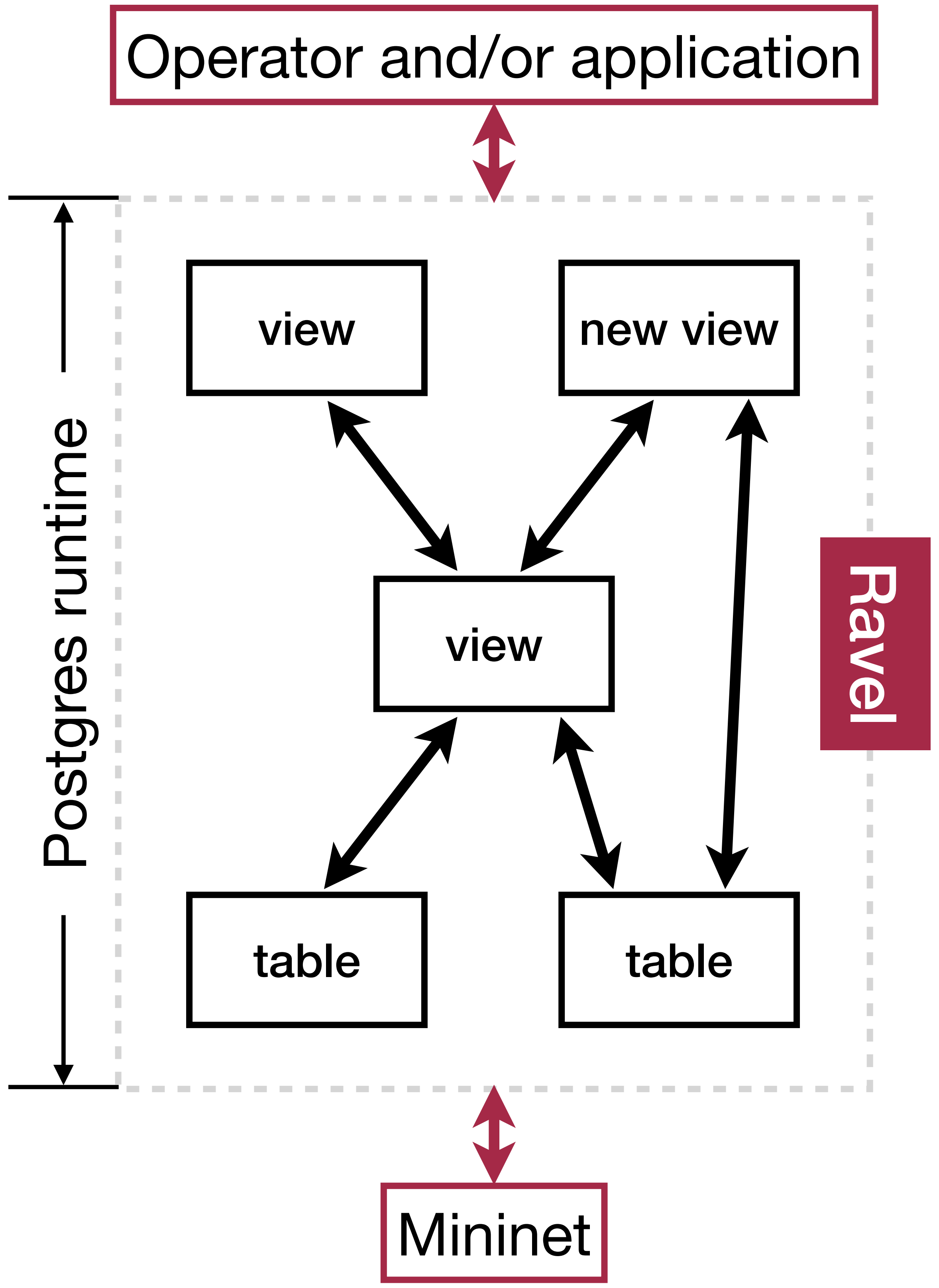
Orchestrated updates: install alternative route that is load-balanced and safe

Ravel Review



- Ad-hoc programmable abstraction via views
- Orchestration across abstractions via view mechanism
- Orchestration across applications via data mediation
- Network control via SQL

Demo

- Ravel website
    - http://ravel-net.org
    - Download Ravel: http://ravel-net.org/download
    - Walkthrough video: http://ravel-net.org/videos/walkthrough.mp4
    - Tutorial: http://ravel-net.org/manual
- Paper: Ravel: A Database-Defined Network
    - http://anduowang.github.io/docs/sosr16.pdf
- Github
    - https://github.com/ravel-net/ravel

Project Task

- Download and Play with Ravel v0.2.1
- Task 1: Create an load balancer application
- Task 2: Orchestrate load balancer, fw, routing applications with an ascending priority
- You can use any interesting topology with Mininet
- Show your results in a pdf.

Thanks

Questions?