FlowGuard: Building Robust Firewalls for Software-Defined Networks

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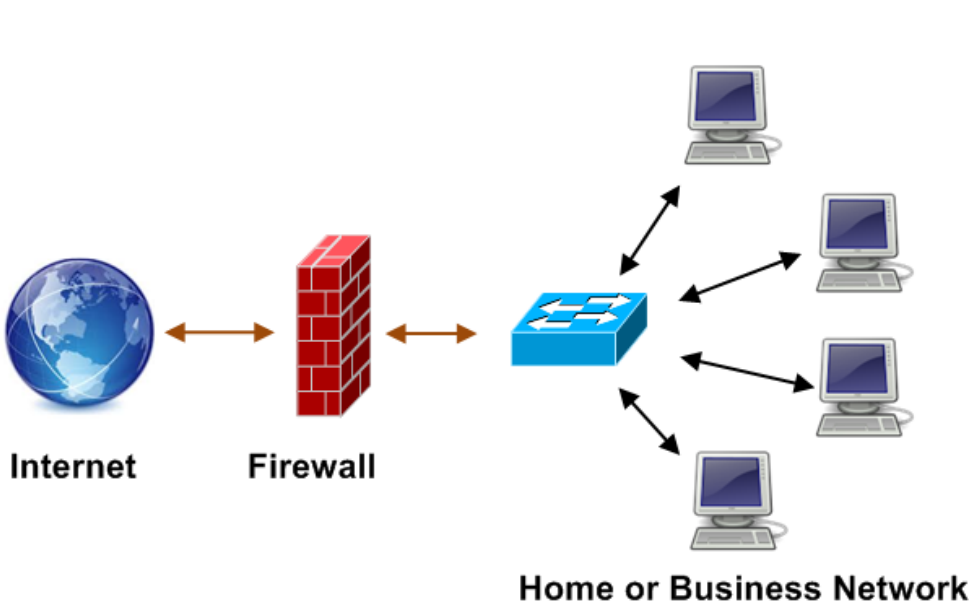
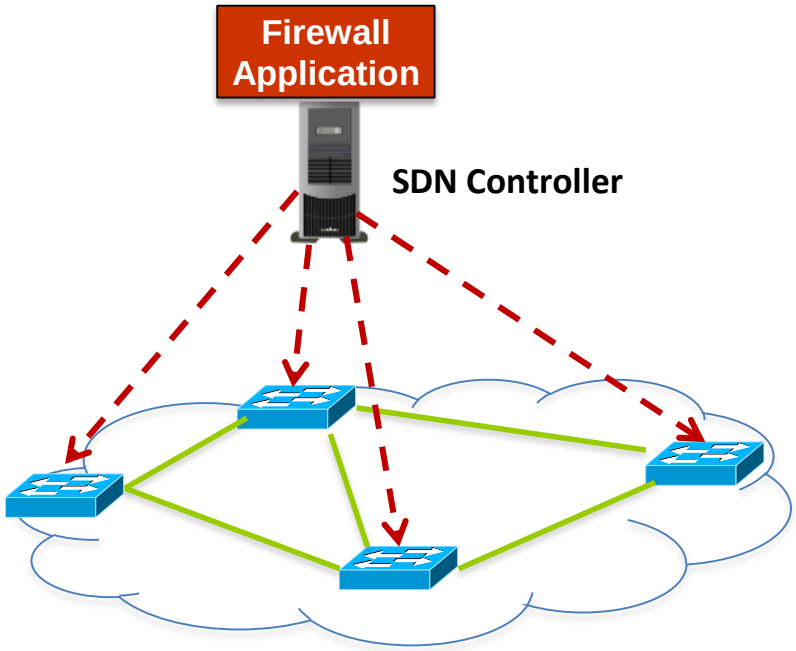
Outline

- Introduction
- Challenges for Building FW in SDN
- FlowGuard framework
  - Violation Detection Mechanism
  - Resolution Mechanism
- Conclusion

Traditional Firewalls Vs. SDN Firewalls

- Traditional FWs: all insiders are trusted
  - Internal traffic is not seen and cannot be filtered by the traditional firewall
- SDN FWs: monitoring all insiders



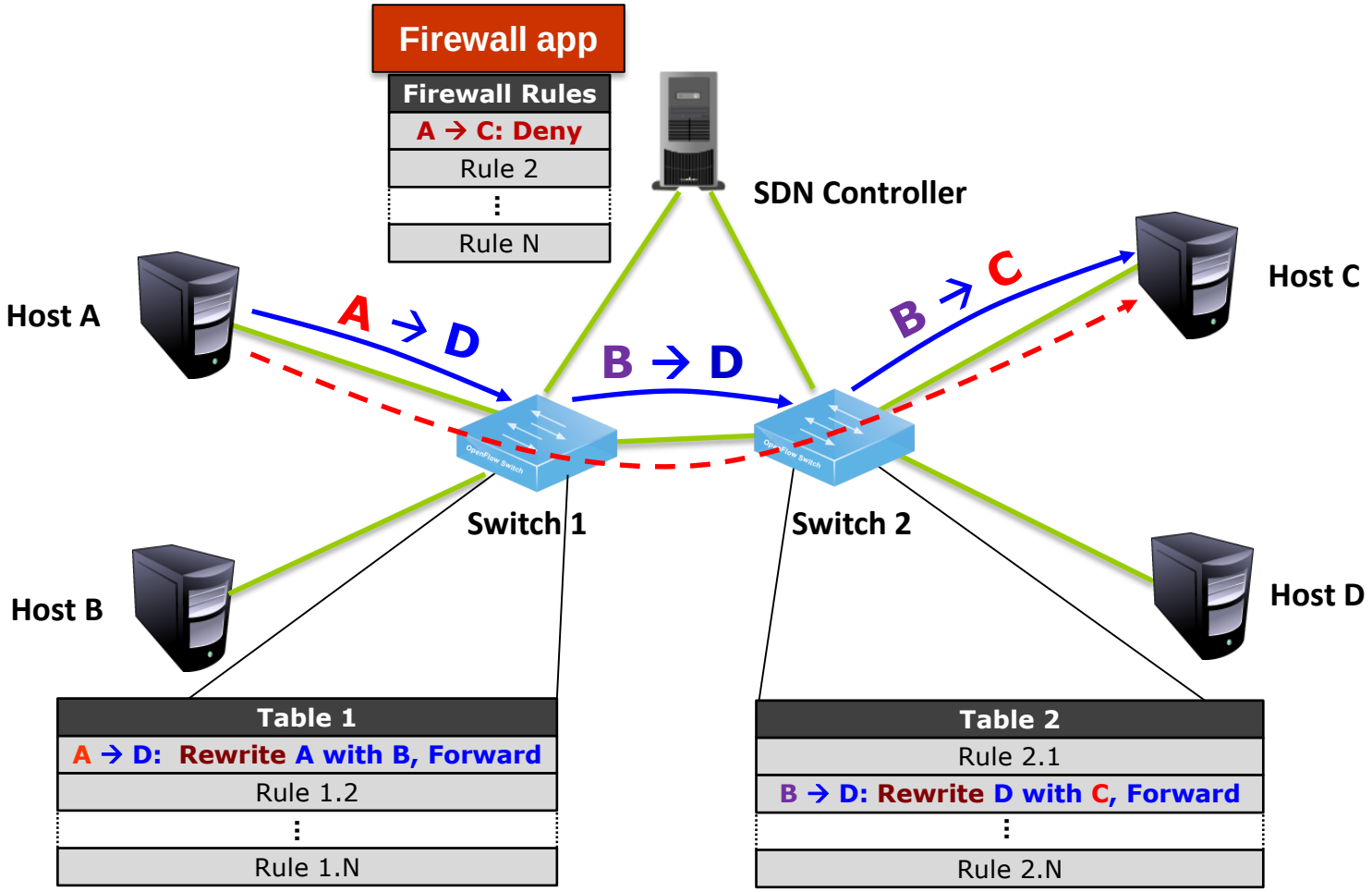


Challenges

- Examining **Dynamic** Network Policy Updates
  - A firewall in SDN is both
    - Packet Filter **+ Policy Checker**
      - The **first packet** goes through the controller and is filtered by firewall
      - The **subsequent** packets of the flow directly match the flow policy
- Checking Indirect Security Violations
  - **Indirect violation** caused by
    - Dynamic packet modification
      - OpenFlow allows an action, Set-Field, which can rewrite packet header
    - Rule dependency
      - Dependency relation depends on their priority
      - Rules may overlap partially / entirely each other (inter / intra table)

Challenges (cont'd)

- Indirect violation scenario



Challenges (cont'd)

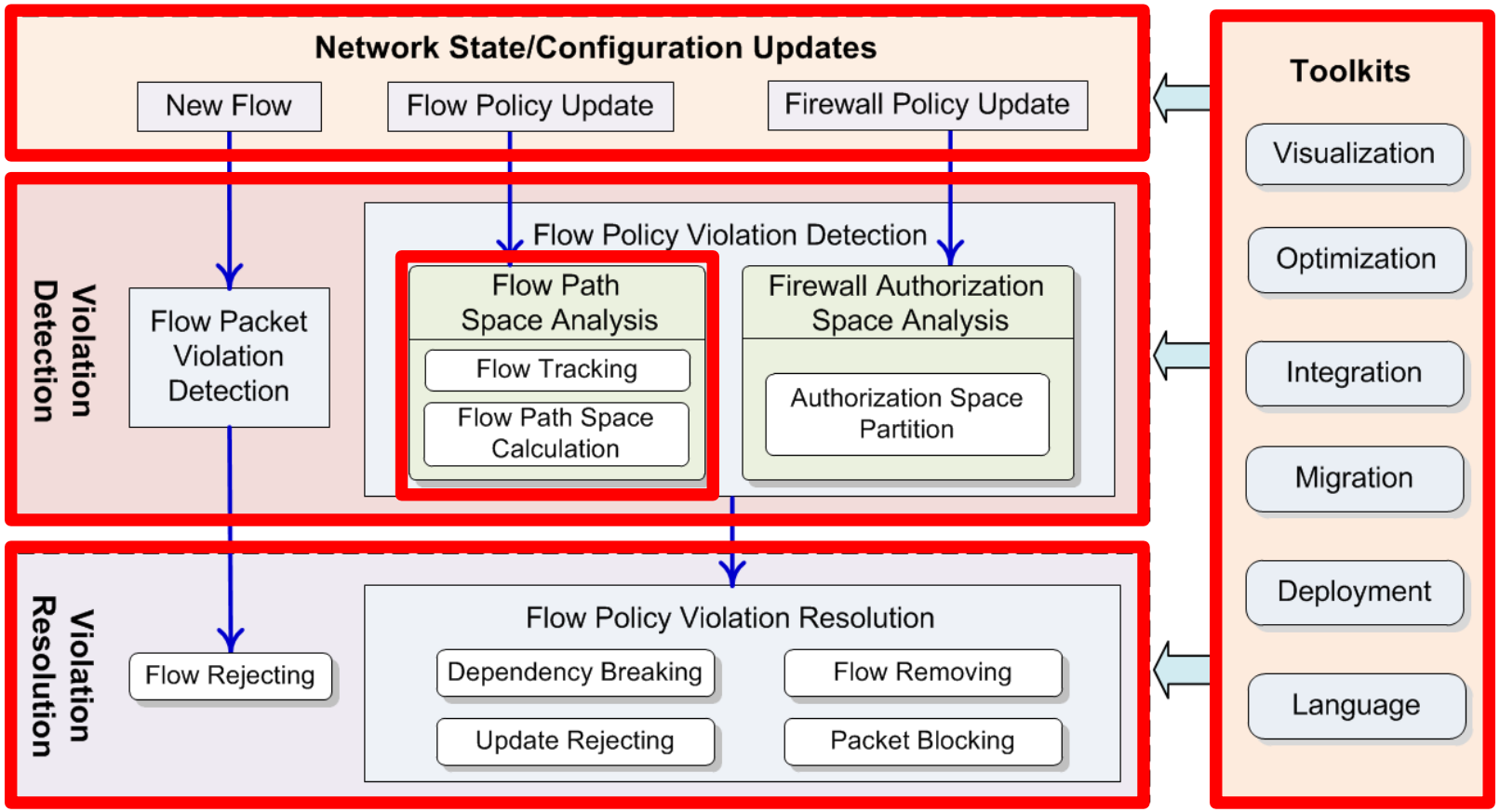
- Architecture Options
  - Centralized SDN firewall
    - Firewall policy is **centrally** defined and enforced at the controller
    - Limitation: cannot deal with partial policy violations
  - Distributed SDN firewall
    - Firewall policy is defined centrally, but propagated and enforced at each **individual** flow entry (ingress switch)
    - Limitation: needs a complicated revocation and repropagation mechanism to handle **dynamic** policy updates

State Of The Art

- SDN Firewall App
  - Built-in firewall application in Floodlight
    - Limited to check *flow packet* violations and unable to examine *flow policy* violations
- Policy Conflict Detection and Resolution
  - VeriFlow [Khurshid'13] and NetPlumber [Kazemian'13]
    - Lack of automatic, effective and *real-time* violation resolution
  - Pyretic [Monsanto'13]
    - Cannot discover and resolve *indirect* security violations
  - FortNOX [Porras'12]
    - Only conducts *pairwise* conflict analysis without considering *rule dependencies* in flow tables and firewall policies

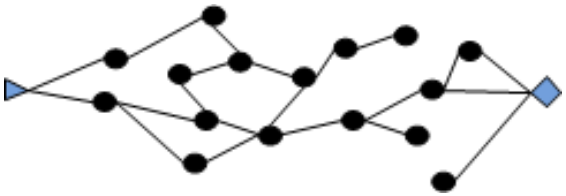
Our Approach

- **FlowGuard**: a comprehensive framework for building robust SDN firewalls

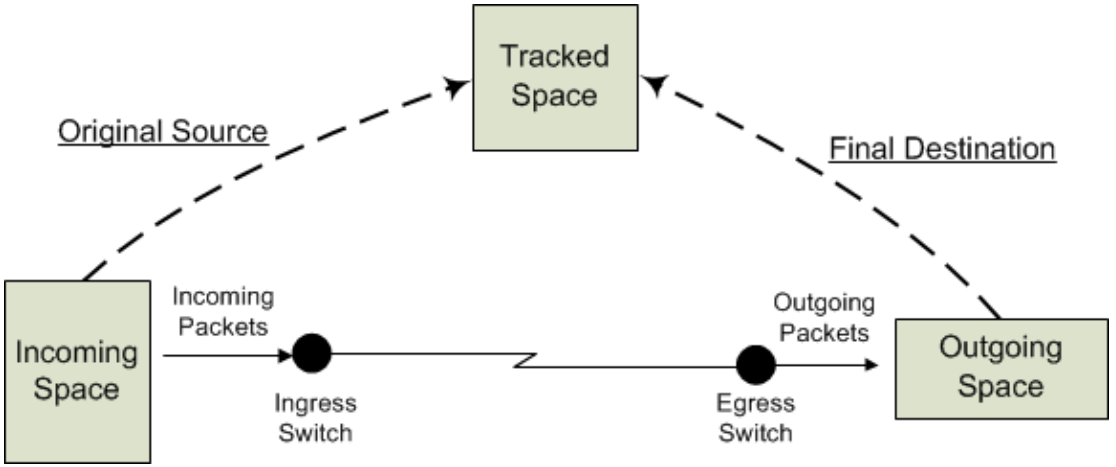


Space Analysis

- Flow Path Space Analysis
  - Flow tracking graph(NetPlumber [Kazemian'13])
    - Dynamic packet modification
    - Rule dependency



  - Flow path space calculation
    - Incoming space
    - Outgoing space
    - Tracked space



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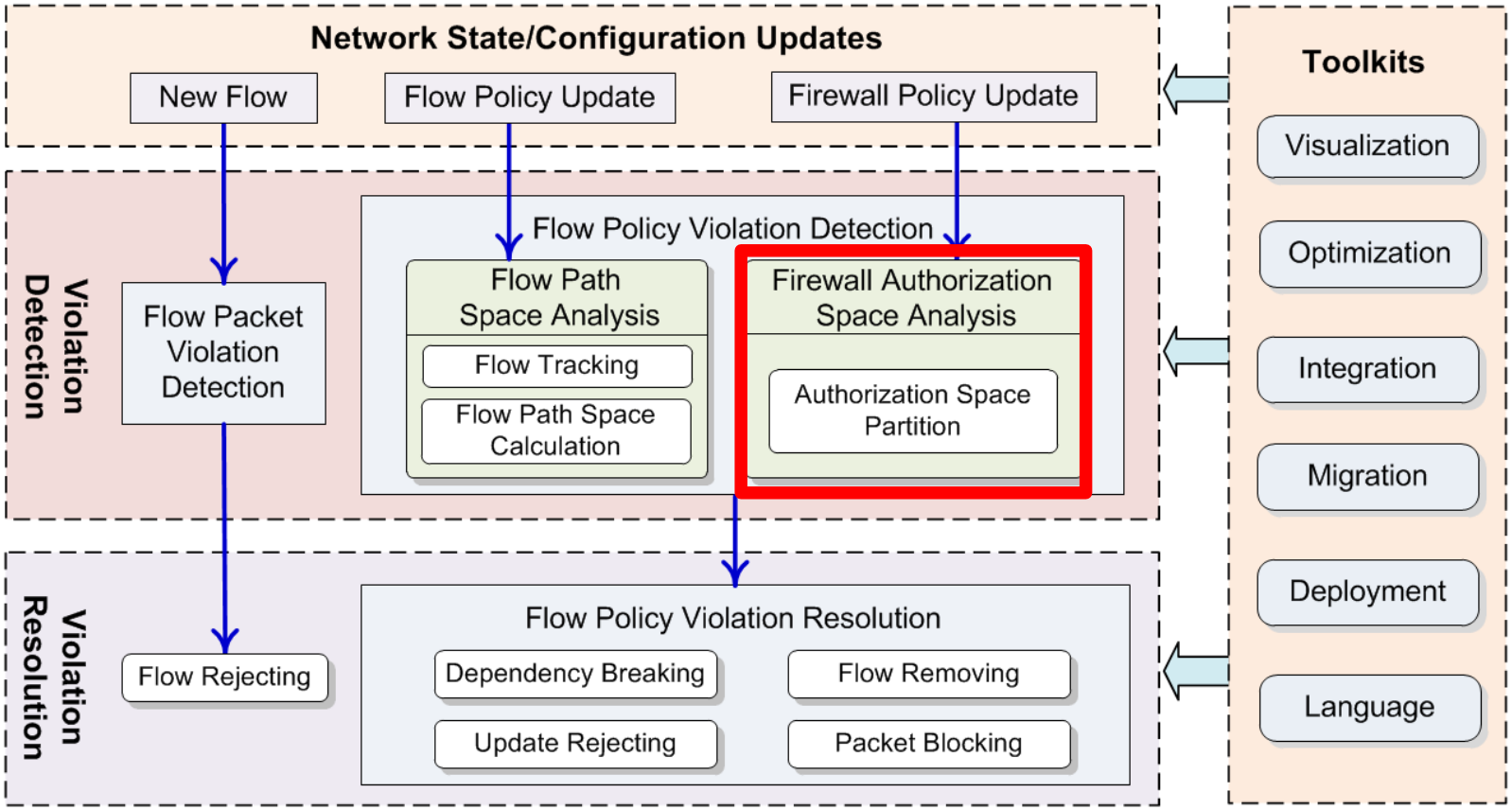
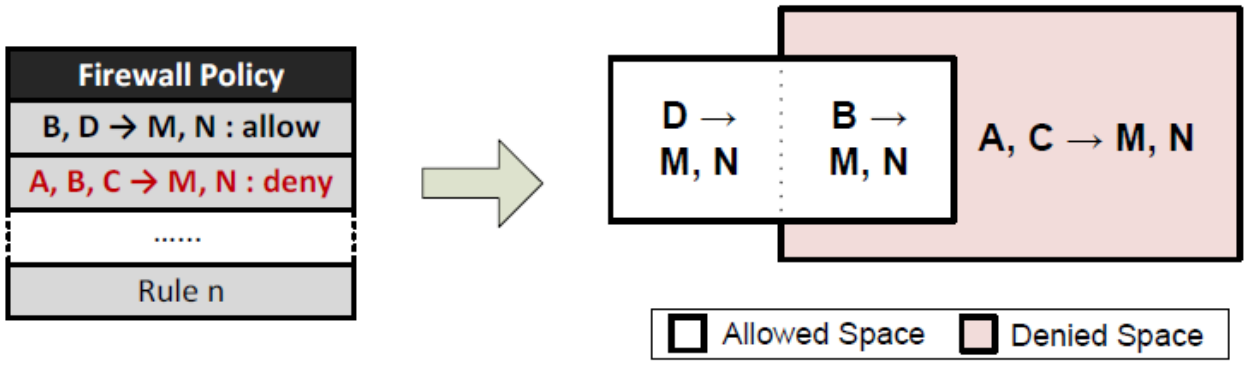


Space Analysis (cont'd)

- Firewall Authorization Space
  - Decouple dependency relations between "allow" rules and "deny" rules in the firewall policy
    - Denied authorization space
    - Allowed authorization space



(a) Example firewall policy

(b) Authorization space partition

Our Approach

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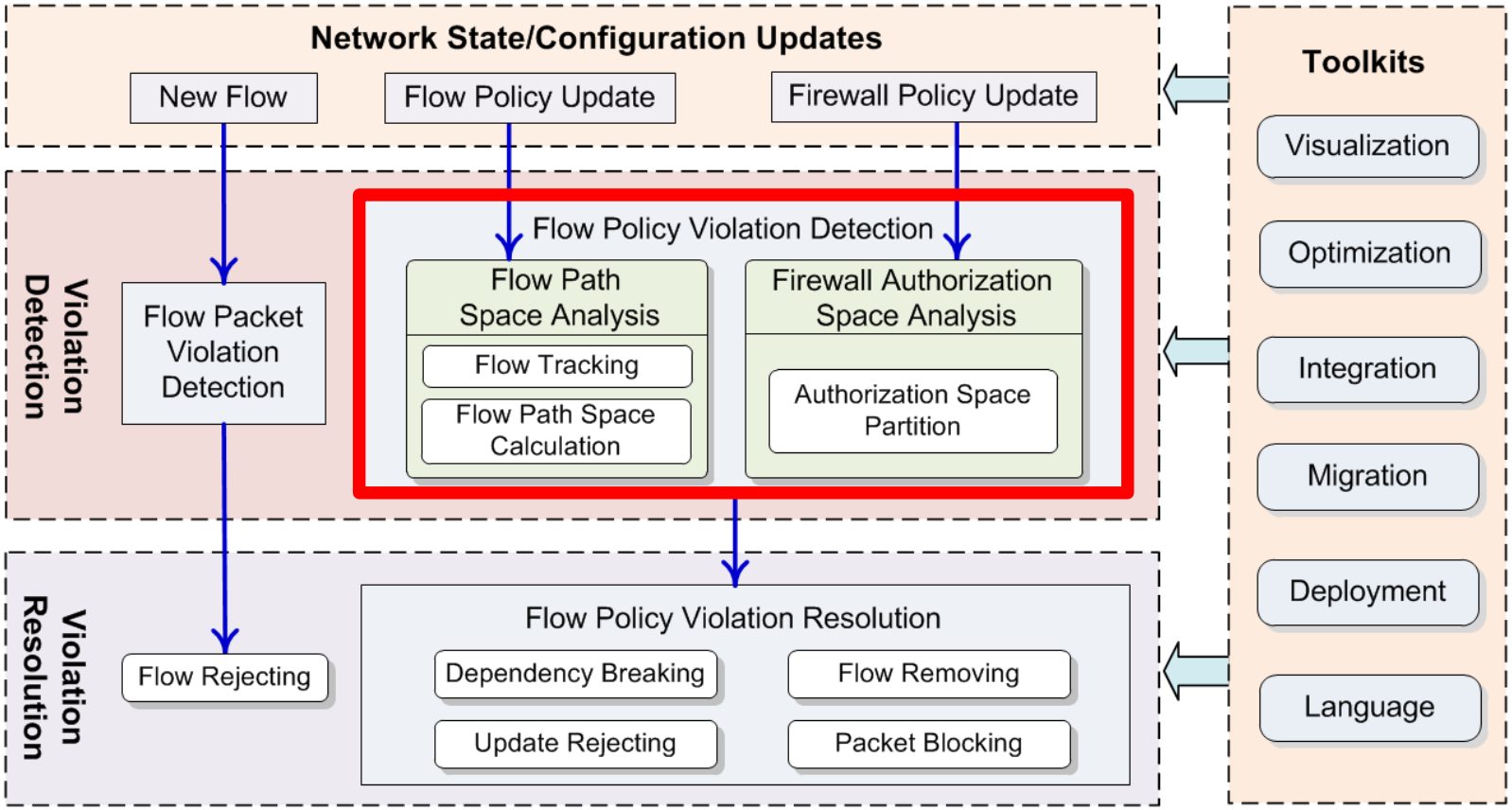
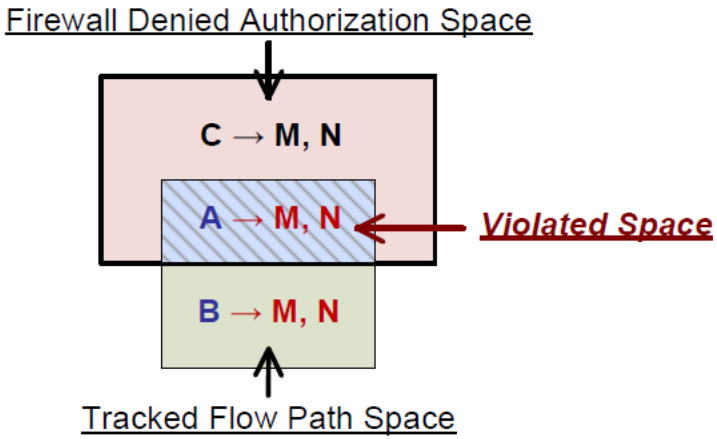


Violation Detection

- Space Comparison
  - Compare Tracked Flow Space against Firewall Denied Authorization Space
    - Entire Violation
      - Denied authorization space includes whole tracked space
    - Partial Violation
      - Denied authorization space partially includes tracked space



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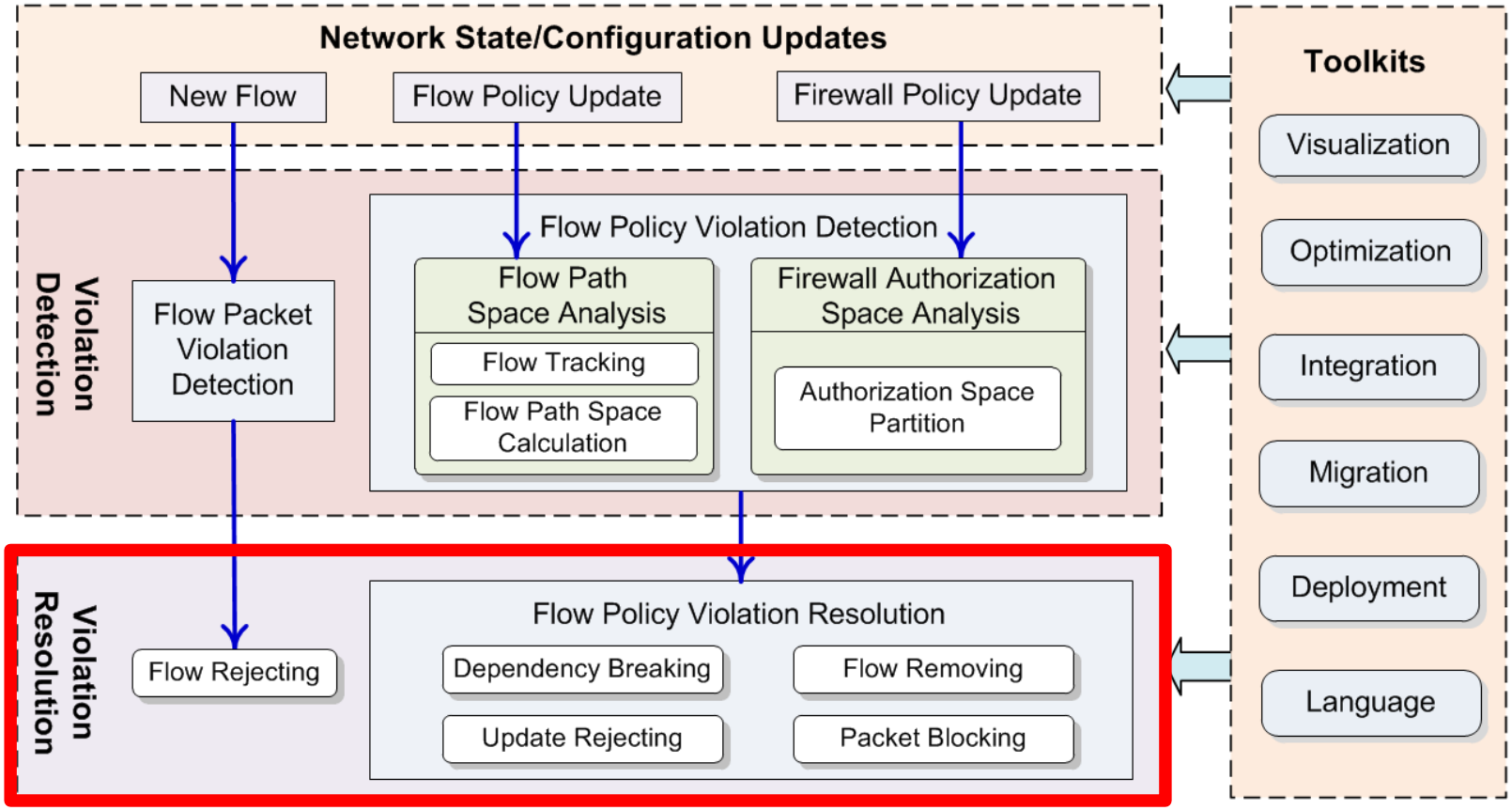
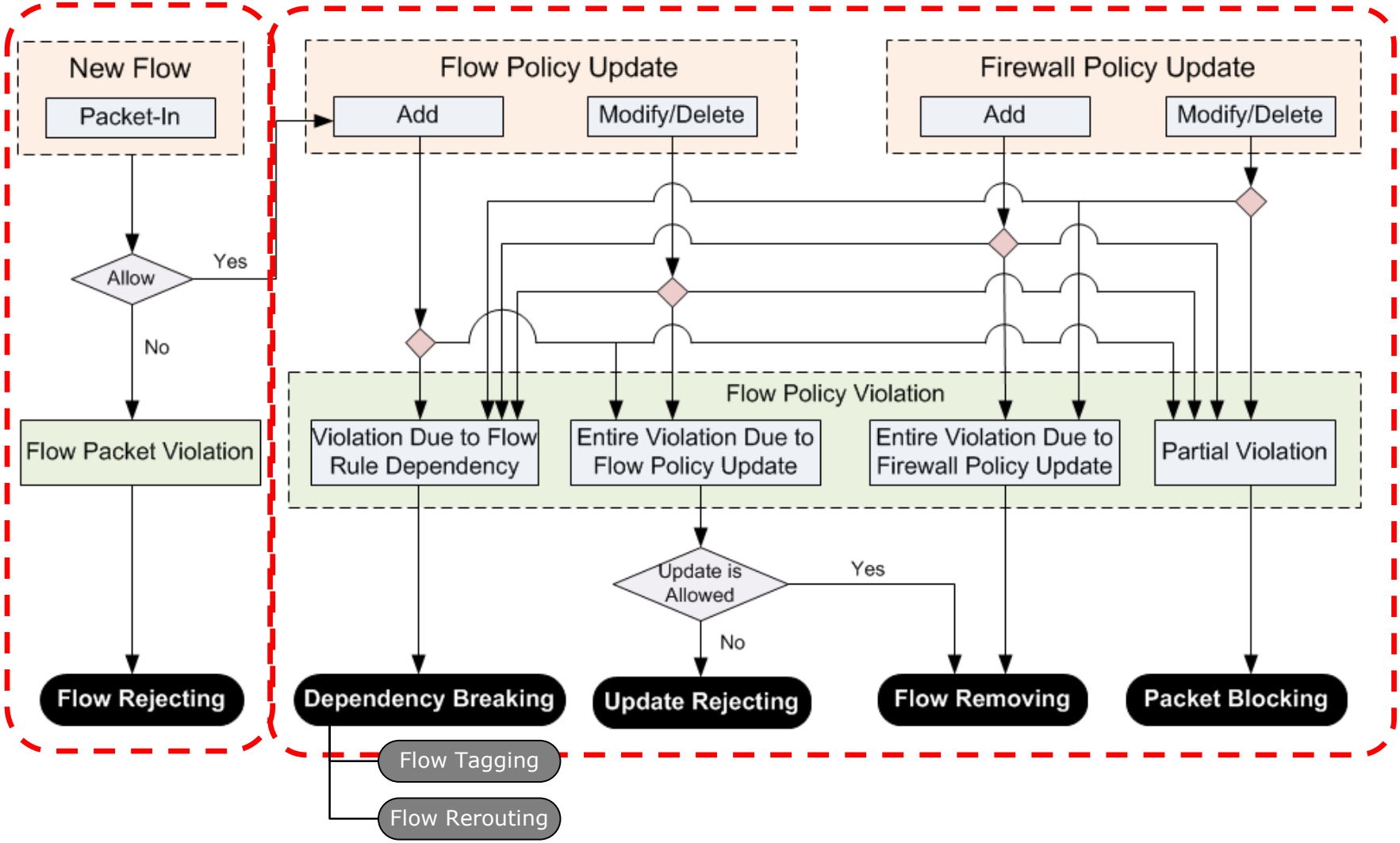


Violation Resolution

- **Automatic** Violation Resolution Mechanism



Implementation & Evaluation

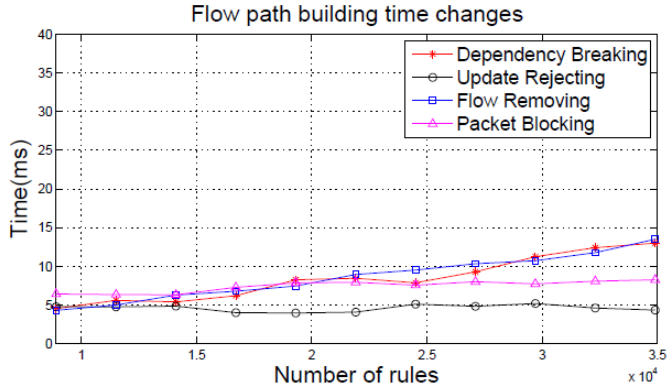
- Prototype of FlowGuard
  - Floodlight V 0.90
- Evaluation Environment
  - Real-world network topology
    - Stanford backbone network [kazemian'13]
  - Mininet 2.0
- Flow Tracking, Violation Detection and Resolution

	Flow Rejecting	Dependency Breaking		Update Rejecting	Flow Removing	Packet Blocking
		Tagging	Rerouting			
Tracking	-	4.54		4.78	4.32	6.42
Detection	0.03	0.04		0.05	0.07	0.06
Resolution	0.03	4.34	1.88	3.73	3.71	2.53

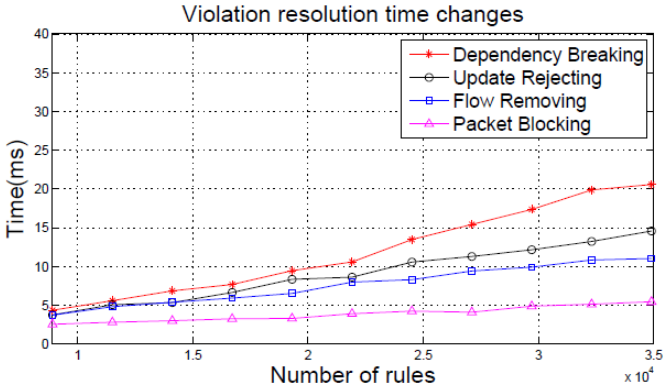
Table 1: Tracking, Detection and resolution time (ms) for different resolution strategies

Evaluation (cont'd)

- Scalability and Performance Analysis

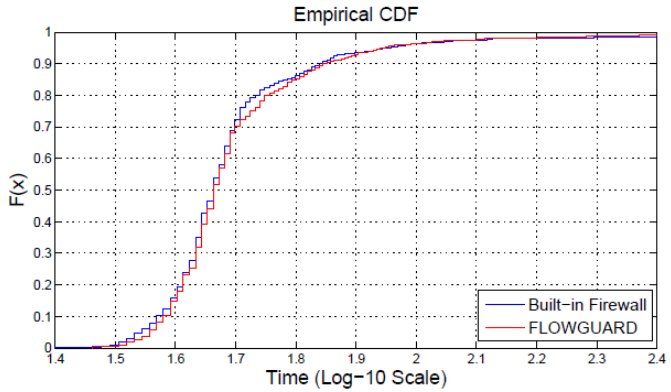


(a) Flow path building time changes.

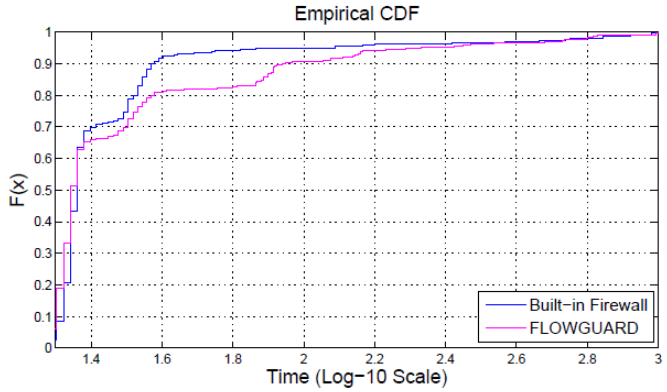


(b) Violation resolution time changes.

Figure 3: Scalability analysis.



(a) Firewall rule update time in microsecond.



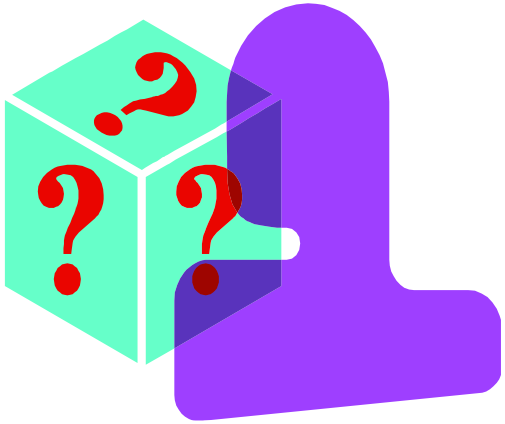
(b) Per packet inspection time in microsecond.

Figure 4: Performance comparison.

Concluding Remarks

- Identifying essential challenges for building robust firewall in SDN
- Proposing a comprehensive framework, ***FlowGuard***, to address identified challenges
- Future Work
  - Developing ***Stateful*** SDN Firewall
  - Firewall ***virtualization*** using Network Function Virtualization (NFV)
  - Robust ***security enforcement kernels*** for SDN controllers

Q & A



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