Shadow Configurations: A Network Management Primitive

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Configuration is Complex

“80% of IT budgets is used to maintain the status quo.”

“... human error is blamed for 50-80% of network outages.”

Source: The Yankee Group, 2004

Source: Juniper Networks, 2008
Configuration is Complex

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Why is configuration hard today?

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Source: Juniper Networks, 2008

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Configuration Management

Today

Simulation & Analysis

- Depend on simplified models
  - Network structure
  - Hardware and software
- Limited scalability
- Hard to access real traffic
Configuration Management

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Test networks

- Can be prohibitively expensive
Configuration Management Today

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Test networks
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Why are these not enough?
Analogy with Programming

Programming

Program → Target System
Analogy with Programming

**Programming**

- Program
- Target System

**Network Management**

- Configs
- Target Network
Analogy with Databases

Databases

STATE A
- INSERT ...
- UPDATE ...
- DELETE ...

STATE B
- INSERT ...
- UPDATE ...
- DELETE ...
Analogy with Databases

Databases

STATE A
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STATE B
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Network Management

STATE A
- ip route ...

STATE B
- ip addr ...

STATE C
- router bgp ...

STATE D
- router ospf ...

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Yale LANS / SIGCOMM 2008
Enter, Shadow Configurations

**Key ideas**

- Allow additional (shadow) config on each router
- In-network, interactive shadow environment
- “Shadow” term from computer graphics
Enter, Shadow Configurations

Key ideas

- Allow additional (shadow) config on each router
- In-network, interactive shadow environment
- “Shadow” term from computer graphics

Key Benefits

- Realistic (no model)
- Access to real traffic
- Scalable
- Transactional
Roadmap

Motivation and Overview

System Basics and Usage

System Components
- Design and Architecture
- Performance Testing
- Transaction Support

Implementation and Evaluation
System Basics

What's in the shadow configuration?

- Routing parameters
- ACLs
- Interface parameters
- VPNs
- QoS parameters
What's in the shadow configuration?

- Routing parameters
- ACLs
- Interface parameters
- VPNs
- QoS parameters
Example Usage Scenario: Backup Path Verification
Example Usage Scenario: Backup Path Verification

Send test packets in shadow
Example Usage Scenario: Backup Path Verification

Disable shadow link

X X
Example Usage Scenario: Backup Path Verification
Example Usage Scenario: Configuration Evaluation
Example Usage Scenario: Configuration Evaluation
Example Usage Scenario: Configuration Evaluation

Video Server

Duplicate packets to shadow
Roadmap

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Implementation and Evaluation
Design and Architecture

Management
  Configuration UI

Control Plane
  BGP
  OSPF
  IS-IS

Forwarding Engine
  FIB
  Interface0
  Interface1
  Interface2
  Interface3
Design and Architecture

Management
- Configuration UI

Control Plane
- BGP
- OSPF
- IS-IS

Forwarding Engine
- Shadow-enabled FIB
- Shadow Bandwidth Control
- Interface0
- Interface1
- Interface2
- Interface3
Design and Architecture

Management
  Configuration UI

Control Plane
  BGP
  OSPF
  IS-IS
  Shadow Management
  OSPF
  IS-IS
  BGP

Forwarding Engine
  Shadow-enabled FIB
  Shadow Bandwidth Control
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  Interface1
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Design and Architecture

Management
- Configuration UI

Control Plane
- BGP
- OSPF
- IS-IS
- Shadow Management
  - Commitment
- OSPF
- IS-IS
- BGP

Forwarding Engine
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Design and Architecture

Management
- Configuration UI
- Debugging Tools
- Shadow Traffic Control
- FIB Analysis

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Design and Architecture

- **Management**
  - Configuration UI
  - Debugging Tools
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  - FIB Analysis

- **Control Plane**
  - BGP
  - OSPF
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  - Shadow Management
    - Commitment

- **Forwarding Engine**
  - Shadow-enabled FIB
  - Shadow Bandwidth Control
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Shadow Bandwidth Control

Requirements

- Minimal impact on real traffic
- Accurate performance measurements of shadow configuration
Shadow Bandwidth Control

Requirements
- Minimal impact on real traffic
- Accurate performance measurements of shadow configuration

Supported Modes
- Priority
- Bandwidth Partitioning
- Packet Cancellation
Packet Cancellation

Observation
- Content of payload may not be important in many network performance testing scenarios
- Only payload size may matter
Observation

- Content of payload may not important in many network performance testing scenarios
- Only payload size may matter

Idea: only need headers for shadow traffic

Piggyback shadow headers on real packets
Packet Cancellation Details

Output interface maintains real and shadow queues

Packet cancellation scheduling

- If real queue non-empty
  - Grab real packet
  - Piggyback shadow header(s) if available

- Else if shadow queue non-empty
  - Send full shadow packet
Commitment

Objectives

- Smoothly swap real and shadow across network
  - Eliminate effects of transient states due to config changes
- Easy to swap back
Commitment

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- Smoothly swap real and shadow across network
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Issue
- Packet marked with *shadow* bit
  - 0 = Real, 1 = Shadow
- Shadow bit determines which FIB to use
- Routers swap FIBs asynchronously
- Inconsistent FIBs applied on the path
Commitment Protocol

Idea: Use tags to achieve consistency
- Temporary identifiers

Basic algorithm has 4 phases
Commitment Protocol

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Basic algorithm has 4 phases
- Distribute tags for each config
  - **C-old** for current real config
  - **C-new** for current shadow config
Commitment Protocol

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- Swap configs (tags still valid)
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- Remove tags from packets
  - Resume use of shadow bit
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  - Resume use of shadow bit
- For more details, see paper
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Implementation and Evaluation
Implementation

Kernel-level (based on Linux 2.6.22.9)
- TCP/IP stack support
- FIB management
- Commitment hooks
- Packet cancellation

Tools
- Transparent software router support (Quagga + XORP)
- Full commitment protocol
- Configuration UI (command-line based)

Evaluated on Emulab (3Ghz HT CPUs)
Evaluation: CPU Overhead

Static FIB
- 300B pkts
- No route caching

With FIB updates
- 300B pkts @ 100Mbps
- 1-100 updates/sec
- No route caching
Evaluation: Memory Overhead

FIB storage overhead for US Tier-1 ISP

<table>
<thead>
<tr>
<th>Memory Increase (%)</th>
<th>Single Router Removed</th>
<th>Multiple Routers Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
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<td>80</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Normalized Router ID (Sorted) % Routers Removed

35%
Evaluation: Packet Cancellation

Accurate streaming throughput measurement
- Abilene topology
- Real transit traffic duplicated to shadow
- Video streaming traffic in shadow
Limited interaction of real and shadow

- Intersecting real and shadow flows
  - CAIDA traces
- Vary flow utilizations
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- Intersecting real and shadow flows
  - CAIDA traces
- Vary flow utilizations
Evaluation: Commitment

Applying OSPF link-weight changes

- Abilene topology with 3 external peers
  - Configs translated to Quagga syntax
  - Abilene BGP dumps
Evaluation: Commitment

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Conclusion and Future Work

Shadow configurations is new management primitive
- Realistic in-network evaluation
- Network-wide transactional support for configuration

Future work
- Evaluate on carrier-grade installations
- Automated proactive testing
- Automated reactive debugging
Thank you!
Backup Slides
Evaluation: Router Maintenance

Setup

- Abilene topology with 3 external peers
  - Configs translated to Quagga syntax
  - Abilene BGP dumps