

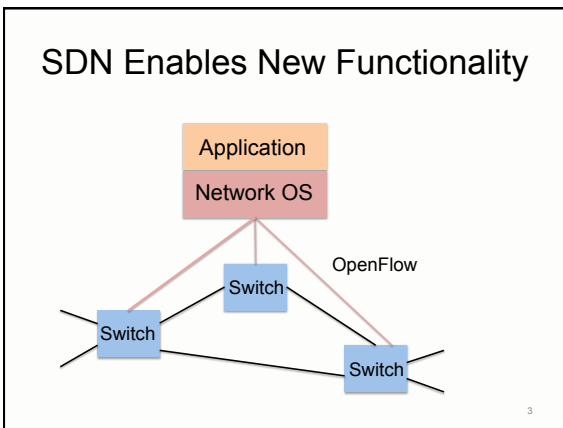
## Testing and Debugging

COS 597E: Software Defined Networking

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MW 11:00am-12:20pm

## Challenges for SDN Programmers

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### ... at the Risk of Bugs

**Network Operating System**

A fatal exception has occurred at 10.3.0.5/C0011E36 in OF(01) + 00010E36. The current OpenFlow application will be terminated.

- \* Press any key to terminate the current OpenFlow application
- \* Press CTRL+ALT+DEL again to restart your network. Your users will lose all network connectivity.

Press any key to continue

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### MAC-Learning Application

**Packet-In Event Handler**

```

mactable[srcmac] = inport
if (dstmac is broadcast address)
  flood packet
else if (dstmac is in mactable)
  outport = mactable[dstmac]
  install rule matching (inport, srcmac, dstmac)
  with action of forwarding packet to outport
else
  flood packet
    
```

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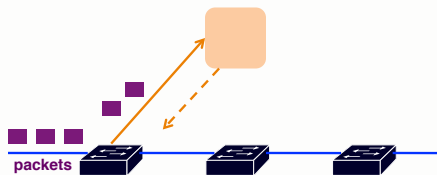
### Challenge #1: Two-Tiered Program

- Two-tiered application
  - Controller
  - Switches
- Rules in the switches
  - Crucial for performance
  - ... but limits visibility
- Example
  - MAC learning bug from Monday's class
  - Matching on dstmac, without inport and srcmac

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### Challenge #2: Control-Plane Delays

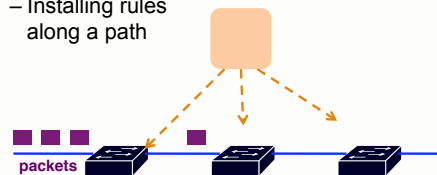
- Common programming idiom
  - First packet goes to the controller
  - Controller application installs rules



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### Challenge #3: Timing and Ordering

- Multiple switches
  - Different delays
- Example
  - Installing rules along a path



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### Challenge #4: Overlapping Rules

- Semantics of a rule depend on context
  - Overlapping patterns
  - Disambiguated by priorities
- Example
  - Initial rule matching `srcip==12.1.0.0/16`
  - Add a rule matching `srcip==12.0.0.0/8`
- Two scenarios
  - Overlap: `12.1.0.0/16` with higher priority
  - Shadowing: `12.0.0.0/8` with higher priority

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### Challenge #5: Conflicting Modules

- Modular programs
  - Multiple modules for different tasks
  - E.g., firewall and routing
- Routing
  - `Match(dstip=12.0.0.0/8) → forward(3)`
- Firewall
  - `Match(srcip=1.2.3.4, dstip=12.1.1.1) → drop`
- One rule may conflict with another

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### Challenge #6: Topologies

- Many different network topologies
  - Chain
  - Tree
  - Arbitrary graph
- Program should work for all topologies
- Example
  - Program that (implicitly) assumes the graph has no cycles

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### Challenge #7: End-to-End Protocols

- Internet applications are robust to errors
  - Retransmission of lost packets
  - Reordering of out-of-order packets
- This can mask some bugs
  - E.g., forgetting to handle the packet that triggered an event
  - E.g., forgetting to handle packets that arrive before you install rules in the switches

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## Discussing the Papers

NICE and ndb

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## Testing vs. Debugging

- Debugging
  - Fixing a known problem in your program
  - Locating and fixing bugs
  - E.g., using tools like gdb
- Testing
  - Convincing yourself that your program (probably) works
  - Systematically finding inputs that lead to incorrect outputs

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## Discussion

- Debugging
  - What debugging features are useful for SDN programmers?
  - How can we exploit OpenFlow capabilities to support debugging?
- Testing
  - How to overcome the scalability challenges?
  - How to detect performance bugs?
- Preventing bugs
  - How can we change the programming environment to prevent bugs?
  - How can we change the programming environment to make testing easier?

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## MAC-Learning Application

### Packet-In Event Handler

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