Georgia Institute of Technology

**Dr. Nick Feamster**
Associate Professor

# Software Defined Networking


*In this course, you will learn about software defined networking and how it is changing the way communications networks are managed, maintained, and secured.*

School of Computer Science

# Module 6.4: Programming SDNs

- Four Lessons
  - Motivation for Programming SDNs
  - Programming Languages for SDNs
  - **Composing SDN Control**
    - **Pyretic**
  - Event-Driven SDN
- Programming Assignment
- Quiz

# What is Pyretic?

- SDN Language and Runtime
  - **Language:** Way of expressing high-level policies
  - **Runtime:** Way of "compiling" those policies to OpenFlow rules

- Allows programmers to specify policies on "located packets" (packet + location)

Monsanto, Christopher, et al. "Composing software defined networks." *NSDI, Apr* (2013).

# Features

- **Network policy as function:** Take as input a packet, return packets at different locations
- **Boolean predicates:** In contrast to OpenFlow “exceptions”
- **Virtual packet header fields:** Can refer to locations, tags on packets, etc.
- **Parallel and sequential composition:** Compose policies

# Network Policies

- In OpenFlow, policies are bit patterns (tough to reason about)
- In Pyretic, policies are functions that map packets to other packets

| Syntax | Summary |
|---|---|
| `identity` | returns original packet |
| `none` | returns empty set |
| `match(f=v)` | `identity` if field `f` matches `v`, `none` otherwise |
| `mod(f=v)` | returns packet with field `f` set to `v` |
| `fwd(a)` | `mod(outport=a)` |
| `flood()` | returns one packet for each port on the network spanning tree |

# Boolean Predicates

- In OpenFlow, packets either match on a rule, or they "fall through" to the next rule
  - Simple "or", "not", etc. is tough to reason about

- Pyretic's match function outputs the packet or nothing depending on the predicate

```
match(dstip=10.0.0.3) | match(dstip=10.0.0.4)
```

# Virtual Packet Header Fields

- Unified way of representing packet metadata
- Packet is a dictionary that maps a field name to a value
  - `match`(inport=a)
  - `match`(switch=T)
  - `match`(dstmac=b)
- The `mod` function can also modify packet metadata

# Policy Composition

- **Sequential composition:** Perform one operation, then the next (e.g., firewall then switch)

```
match(dstip=2.2.2.8) >> fwd(1)
```

- **Parallel composition:** Perform both operations simultaneously (e.g., counting, forwarding)

```
(match(dstip=2.2.2.8) >> fwd(1)) +
(match(dstip=2.2.2.9) >> fwd(2))
```

# Traffic Monitoring

- Can create a query to see packet streams

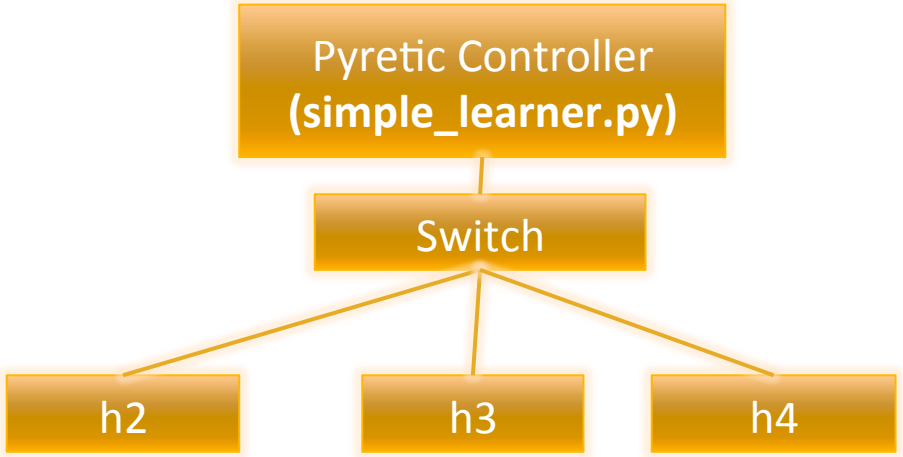
```
self.query = packets(1,['srcmac','switch'])
self.query.register_callback(learn_new_MAC)
```

- Callbacks are invoked to handle each new packet that arrives for the query

# Dynamic Policies

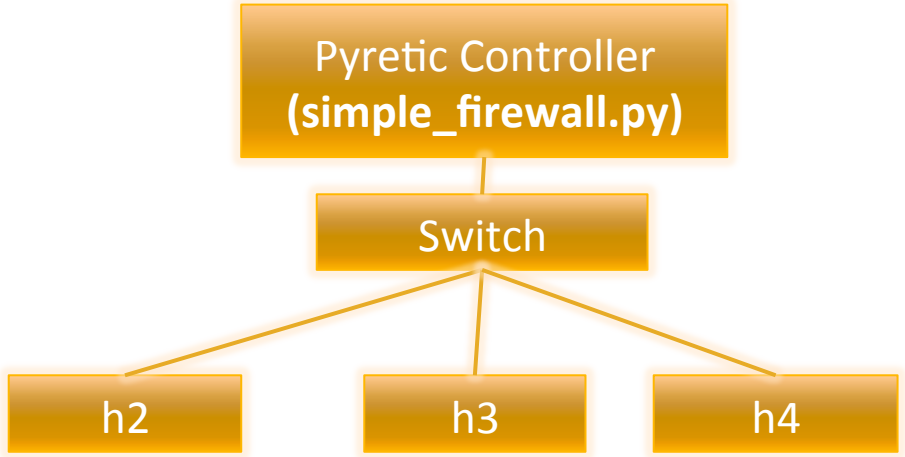
- Policies whose forwarding behavior changes
- Represented as timeseries of static policies
- Current value is `self.policy`
- Common idiom
  - Set a default policy
  - Register callback that updates policy
- Two examples: switch, firewall

# Example: Pyretic Switch




- `$ sudo mn --topo single,3 --mac -arp`
- Every first packet with new source MAC at the switch is read by a query
- Policy is updated with new predicate

# Example: Pyretic Firewall




- Create dynamic firewall policy
- Register a callback to check rules
- Sequentially compose with learning switch

# Summary

- Pyretic makes writing complex policies easy
  - Network policy as function
  - Predicates on packets
  - Virtual packet headers
  - Policy composition
- Composition makes it easy for policies to build on one another
- Next: Events