OpenFlow 1.3: Protocol, Use Cases, And Building a Fault Tolerant Application

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Game Plan

- Pre-work for hands on demo
- OpenFlow 1.3
  - Motivation (vs. 1.0)
  - Popular features
  - Community support
  - Other details
- GENI Cinema OpenFlow 1.3 use case
- Hands-on with OpenFlow 1.3 groups

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Before We Get Started…

1. Login to GENI @ http://portal.geni.net and select the GRWBU2016 project (which you should be a member of already)
2. Create a new slice using the GENI RSPEC file located @ http://tinyurl.com/fast-failover-rspec
3. Bind your resources to an InstaGENI rack
4. Reserve your resources
5. Go grab some lunch
6. Login to your resources

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Evolution of the OpenFlow Protocol

- OpenFlow 1.0
  - What you know and love!
- OpenFlow 1.1
  - Multiple tables and group tables
  - Some more matches and actions
- OpenFlow 1.2
  - The OpenFlow Extensible Match (OXM)
- OpenFlow 1.3
  - Meters
  - Table features

Evolution of the OpenFlow Protocol

- OpenFlow 1.4
  - + Bundles
  - + Flow table synchronization
  - + Flow monitoring
- OpenFlow 1.5
  - + More fine-grained matches and actions
  - + Egress tables
  - + Packet type aware pipeline & pipeline registers
  - + Group/meter table improvements
- …But we struggle to keep up…

Why OpenFlow 1.3?

- OF 1.0 primary complaint = too rigid
- OF 1.3 gains
  - ✓ Greater match and action support
  - ✓ Instructions add flexibility and capability
  - ✓ Groups facilitate advanced actions
  - ✓ Meters provide advanced counters
  - ✓ Per-table features
  - ✓ Custom table-miss behavior
  - ✓ …and more!

Note…

OpenFlow 1.1 and 1.2 *introduced* some of the features we will discuss.

However, due to the relative lack in adoption of OpenFlow 1.1 and 1.2, we will consider such features as *OpenFlow 1.3 features*.

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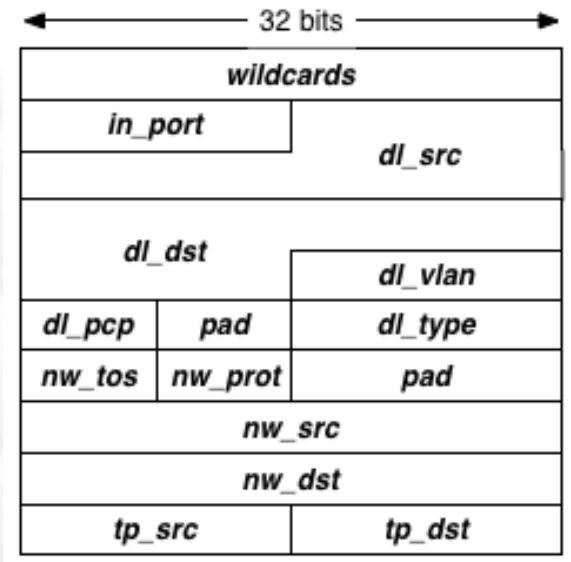
OpenFlow 1.3 Matches

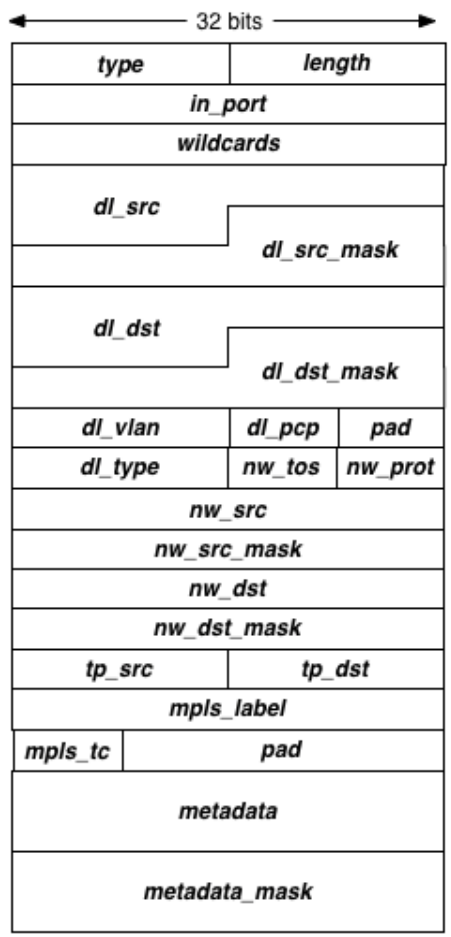
- OXM = OpenFlow Extensible Match
  - *Variable-length* list of matches, in *any order*
  - Contrast to rigid match structure of OF1.1-

Reason for the OXM

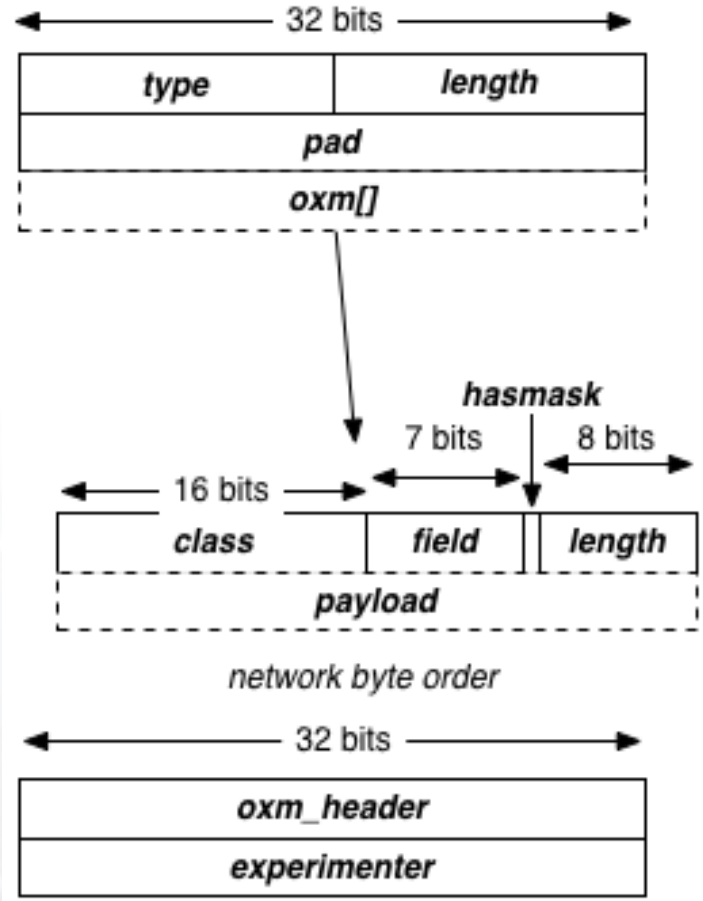
OpenFlow 1.0



OpenFlow 1.1



OpenFlow 1.2+



http://flowgrammable.org/sdn/openflow/message-layer/

OpenFlow 1.3 Matches

- Increased match support w/OXM
  - Ingress port
  - Ethernet
  - VLAN
  - IPv4
  - TCP
  - UDP
  - ARP
  - MPLS
  - PBB
  - ICMPv4
  - ICMPv6
  - IPv6
  - Tunnel
  - SCTP
  - Metadata
  - Custom/Experimenter

OpenFlow 1.3 Actions

- Set field
  - Any OXM
- Push/Pop
  - VLAN
  - MPLS
  - PBB
- Set queue
- Goto group
- Output
- TTL
  - Set
  - Decrement
- Custom/Experimenter

OpenFlow 1.3 Instructions

- Apply actions
  - List of actions to perform *immediately*

- Write actions

  List of actions to perform *later*

- Clear actions
  - Clear list of accumulated "write actions"

- Meter
  - Send to an installed meter

- Goto table
  - Send to another table in the switch

- Write metadata
  - Store some "data" associated with the packet as it traverses table(s)

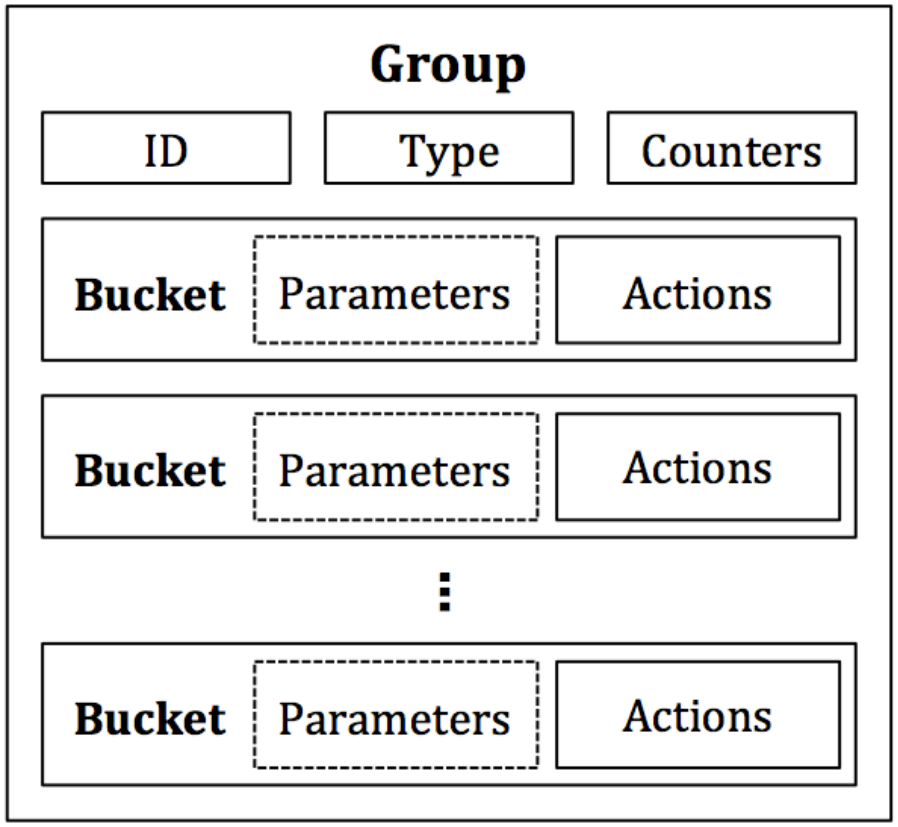
OpenFlow 1.3 Meters

- Monitor and rate-limit packets
- Multiple meter "bands" define different *rate thresholds*

```
if (rate > t1) do_this;
else if (rate > t2) do_that;
else if (rate > t3) drop_it;
else do_nothing;
```

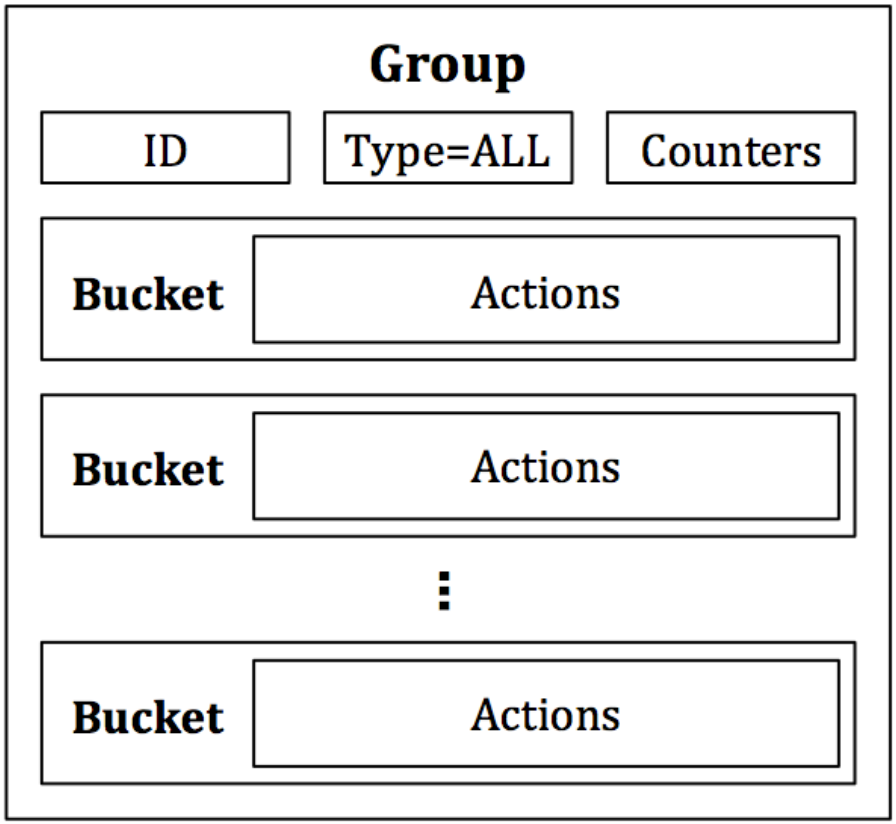
OpenFlow 1.3 Groups

- Allow more complex actions
- Bucket = (list of actions) + (optional params)
- Actions can be unique per bucket



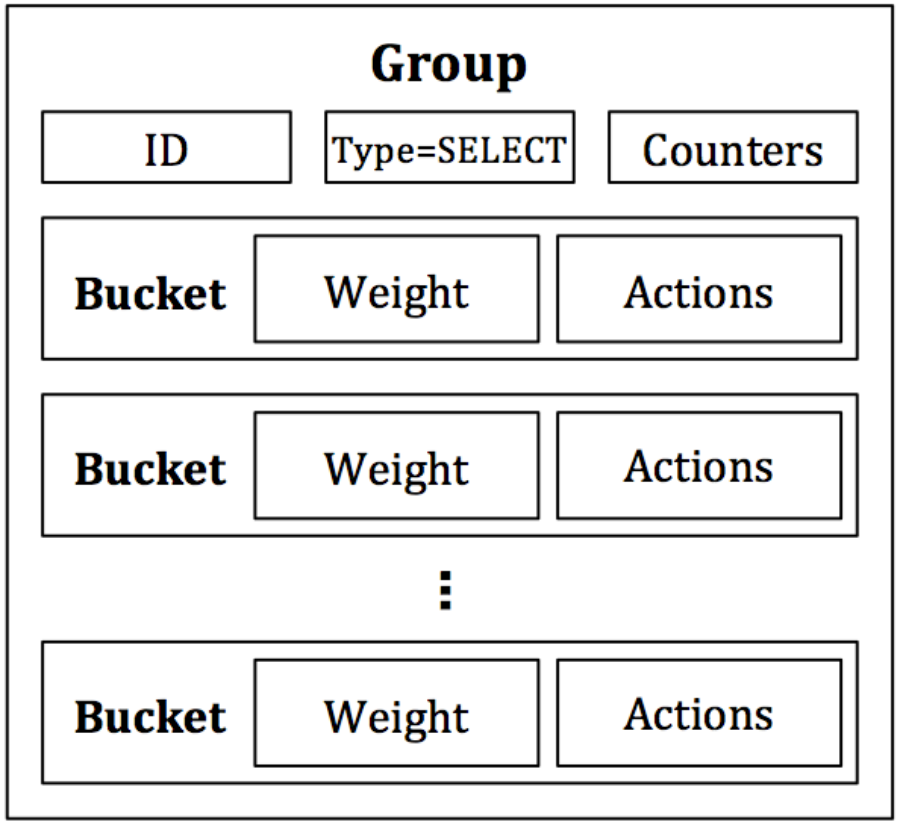
ALL Group

- Copy packet to *all buckets*
- No special parameters
- Use case: GENI Cinema uses ALL groups



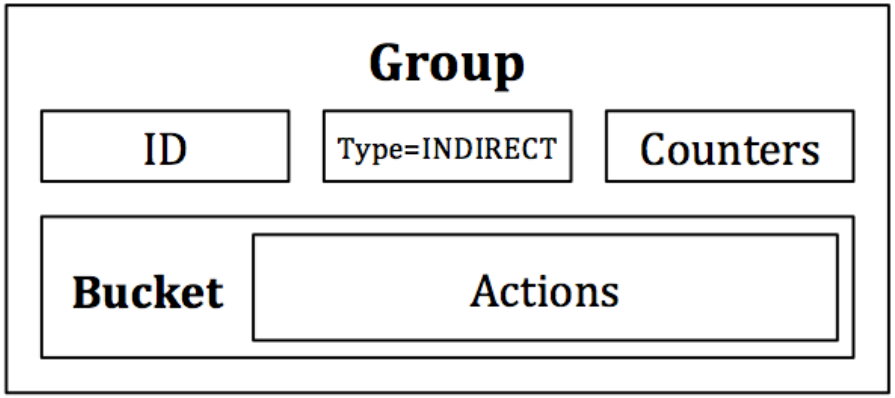
SELECT Group

- Distribute packet to a *single bucket*
- Weight assigned to each bucket
- Distribution algorithm is switch-dependent
  - Weighted round-robin?



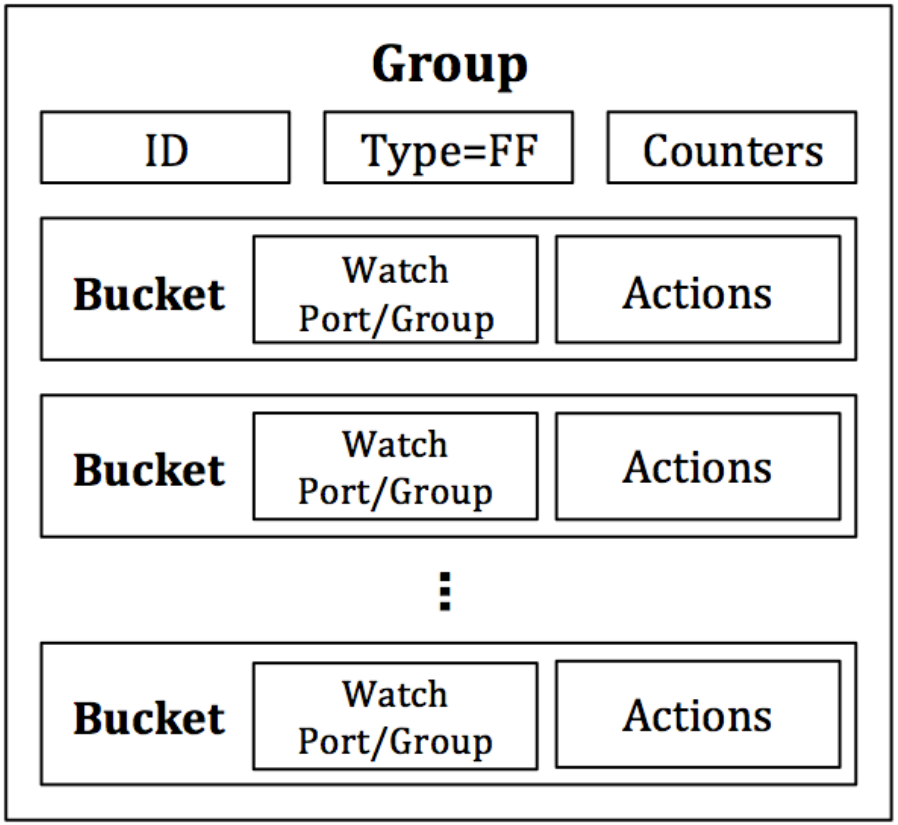
INDIRECT Group

- All packets go to a single bucket
- No special parameters
- Consolidate common actions amongst a set of flows
  - Reduce complexity
  - Reduce memory footprint



FAST-FAILOVER Group

- Use a *single bucket* for all packets
- Watch port/group as parameters
  - Determines "liveness" of bucket
  - If port/group is up, bucket can be used
  - If port/group is down, bucket cannot be used



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Community Support

- Great software switch support
  - OVS supports everything* *except meters*
    - Present *protocol* support for meters
    - Table features supported in 2.4.0
    - Groups *fully* supported in 2.3.1
  - ofsoftswitch *supports* meters but does not support all other OpenFlow 1.3 features
- Hit-and-miss support with HW vendors
  - Some vendors technically do, *but* can be buggy
- Wide controller support

*to my knowledge

Floodlight Controller

- Java-based OpenFlow controller
  - OpenFlow 1.0 and 1.3 support
  - Experimental OpenFlow 1.1, 1.2, 1.4
  - Lots of included modules
- Home
  - http://projectfloodlight.net
- Documentation and tutorials
  - http://floodlight.atlassian.net/wiki
- Large, **active** community
  - floodlight-dev@openflowhub.org
  - Google Group

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Multi-Version OpenFlow Handshake

- Handshake
  - Message-exchanging process to establish an OpenFlow channel between a controller and a switch
  - Need to negotiate common OpenFlow version
- Algorithm
  - Switch says "Hello version_X" with OF version X
  - Controller says "Hello version_Y" with OF version Y
  - Switch and controller each pick *lower version of X and Y*
    - (theirs < mine) ? theirs : mine; e.g. (X < Y) ? X : Y;
- **Caveat…**

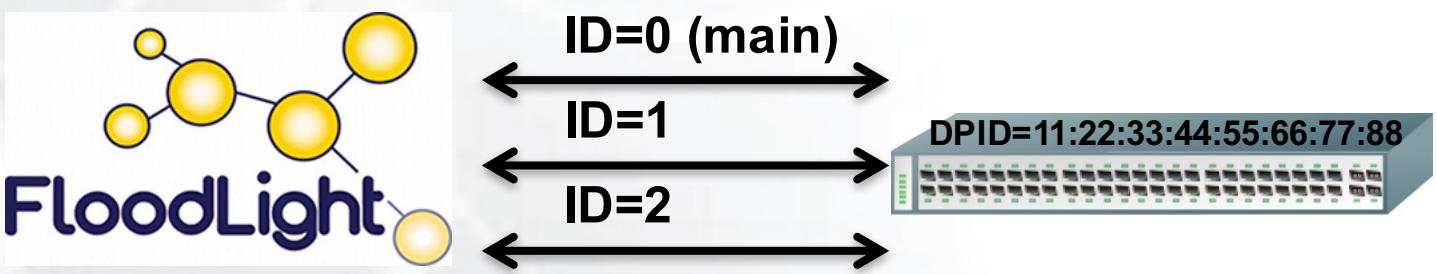
  Algorithm requires support for each OF version up to and including the "Hello" version advertised

  Not the case in implementation/practice
- **Fix** for (controller >= OF1.3) && (switch >= OF1.3)

  Hello advertises highest version + version bitmap for negotiation

OpenFlow Auxiliary Connections

- Multiple control connections per switch
  - Parallelize some operations
  - Negotiated on a per-switch basis
  - Aux ID 0 = main; Aux ID > 0 = other
- Controller chooses which connection to use
  - Main
  - Aux 1
  - Aux 2
  - …etc.



OpenFlow 1.3 Controller Roles

- OpenFlow 1.3 integrates roles in protocol
  - Role = controller read/write permissions for *each switch*
  - MASTER + SLAVE
    - Exactly one master controller per switch
    - Zero or more slaves per switch
    - Only the master controller can write
    - All (other) slave controllers can read
  - EQUAL
    - All controllers can read and write
    - Likely requires synchronization between controllers (e.g. HA)
- But, doesn't Nicira has role extension for OF 1.0?
  - Same idea for MASTER and SLAVE
  - Nicira's OTHER role = OpenFlow 1.3's EQUAL role

OpenFlow Multipart Messages

- Steady-state controller-to-switch "queries"
- Efficiently process large requests
- Flow stats, port stats, group stats, meter stats, table features…
- Request and reply pairs with same XID
- OFPMPF_REQ_MORE flag for more messages

```
45 9.947447000 127.0.0.1 127.0.0.1 OFP 1.3 84 Multipart request (CSM) - OFPT_MULTIPART_
▶ Frame 45: 84 bytes on wire (672 bits), 84 bytes captured (672 bits) on int
▶ Linux cooked capture
▶ Internet Protocol Version 4, Src: 127.0.0.1 (127.0.0.1), Dst: 127.0.0.1 (1
▶ Transmission Control Protocol, Src Port: 6633 (6633), Dst Port: 59610 (596
▼ Openflow Protocol
  ▼ Header
      Version: 0x04
      Type: Multipart request (CSM) - OFPT_MULTIPART_REQUEST (18)
      Length: 16
      Transaction ID: 745755502
  ▼ Multipart request
      Type: Port description - OFPMP_PORT_DESC (13)
    ▼ Flags: 0x0000
        .... .... .... ...0 = More requests to follow: Not set
      Padding
      Body: <MISSING>
```

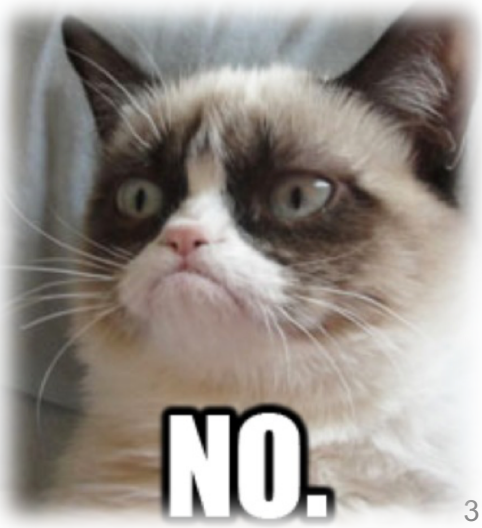
Table Miss Behavior

What to do if a packet matches no flows?

- Previously, a *property of the flow table*
  - Typically, send to the controller
- In OpenFlow 1.3, *defined by a flow*
  - Zero-priority and fully-wildcarded match
  - User-defined actions and instructions
  - Can send to controller/drop (most common)
  - Or, can do what YOU want

Table Features

- Many OpenFlow features *are optional, not required*
- **Problem:** How to determine switch features?
- **Solution:** Table Features specify capabilities of each table
  - Matches, actions, instructions, etc.
- Do table features indicate match *co-dependencies* or *hardware* vs. *software* support?



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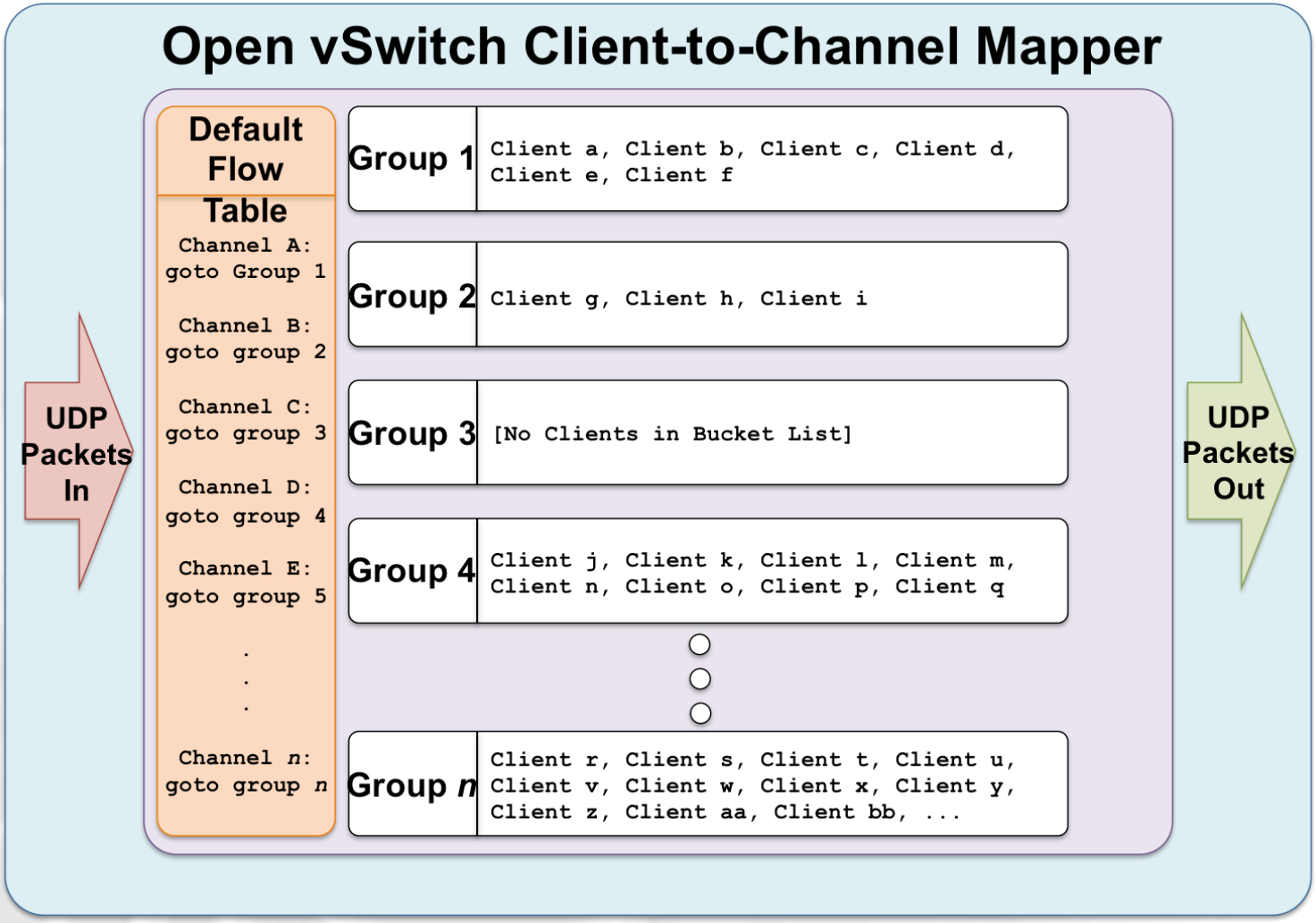
What is GENI Cinema?

- Live video streaming service
  - Operates entirely over GENI
  - OpenFlow 1.0 and 1.3 based solution
- Offers channel changing abilities
- Scalable and efficient

What's special about GENI Cinema?

- Software defined networking based
  - Heavy use of OpenFlow 1.3 ALL groups
- "Fast" channel changing
  - GENI Cinema = ~2s average
  - YouTube live = ~5s average
  - Digital cable TV = ~3s average
  - Satellite TV = …
- Event *perspective* in hands of user
  - Multiple cameras available to select

GENI Cinema ALL Groups



Quick Demonstration

https://cinema.smartfuture2015.net

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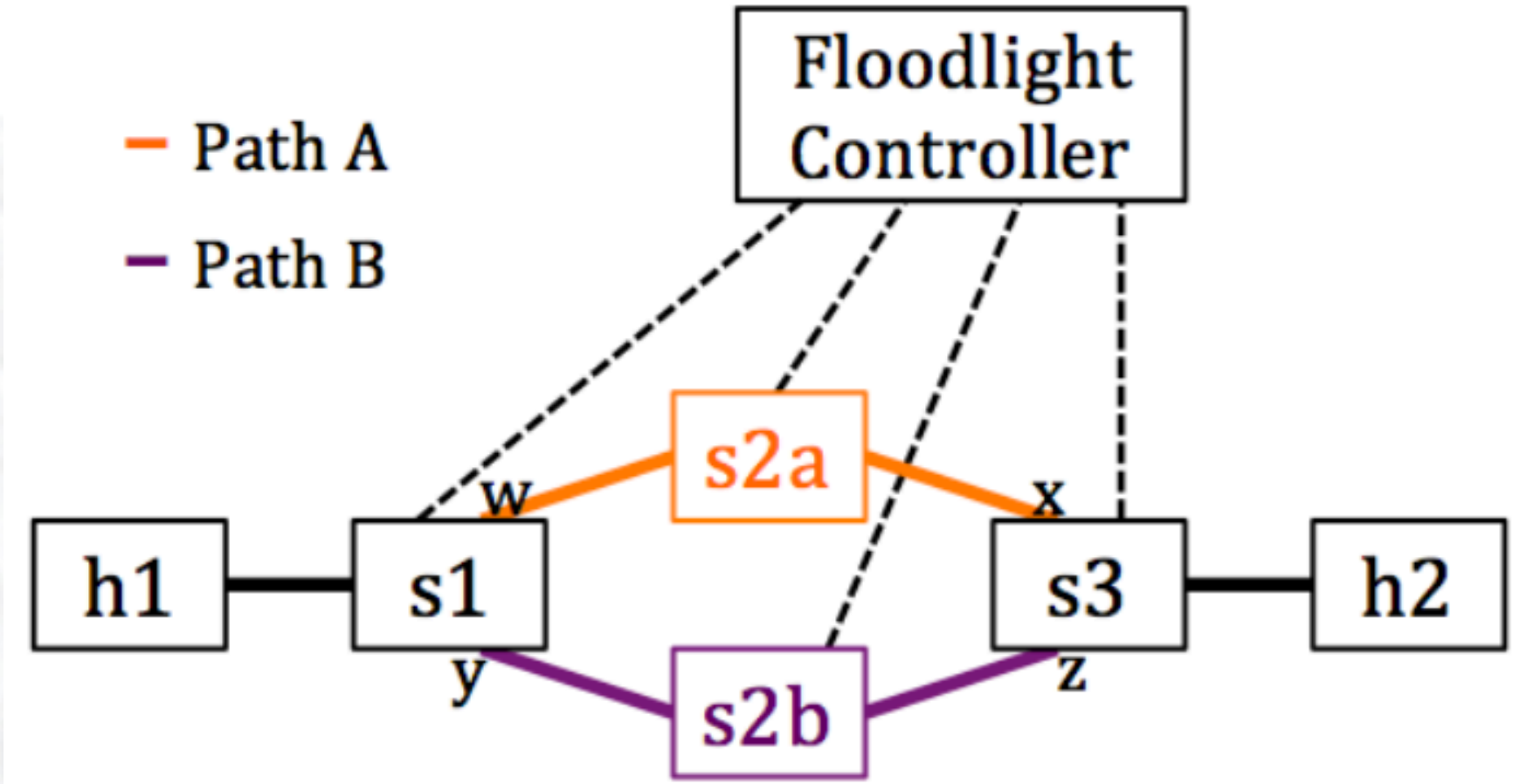
Your Turn!

- Problem
  - A single path from point A to point B leaves a single point of failure in any topology. Upon link failure, end-to-end communication is impossible.
- Solution
  - Use redundant links to allow end-to-end connections to persist in the event of a link failure.

Tutorial Topology



Hands-on Tutorial

https://floodlight.atlassian.net/wiki/display/floodlightcontroller/How+to+Work+with+Fast-Failover+OpenFlow+Groups

Or…

http://tinyurl.com/fast-failover-demo