Software Defined Networking

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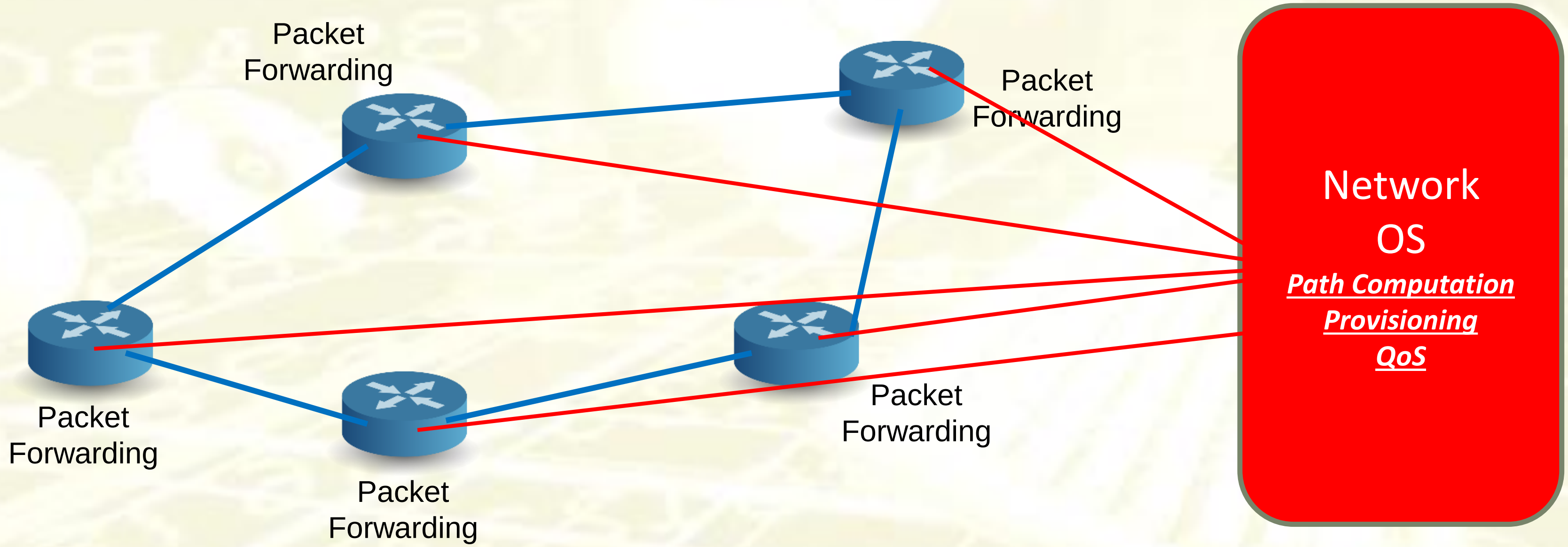
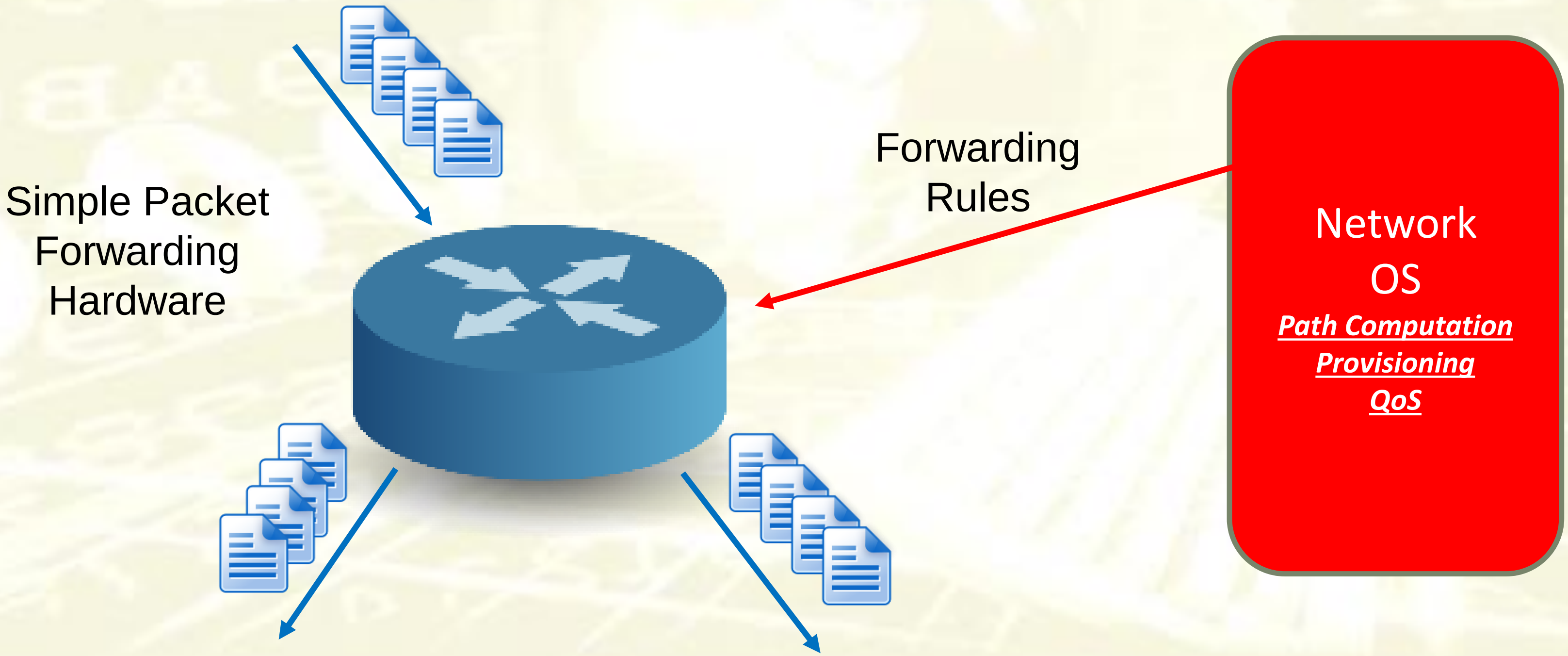
Concept

- ***Software defined networking***: Physical ***separation*** of the network **control** plane from the **forwarding** plane, where control plane controls several devices
- Centralization of control



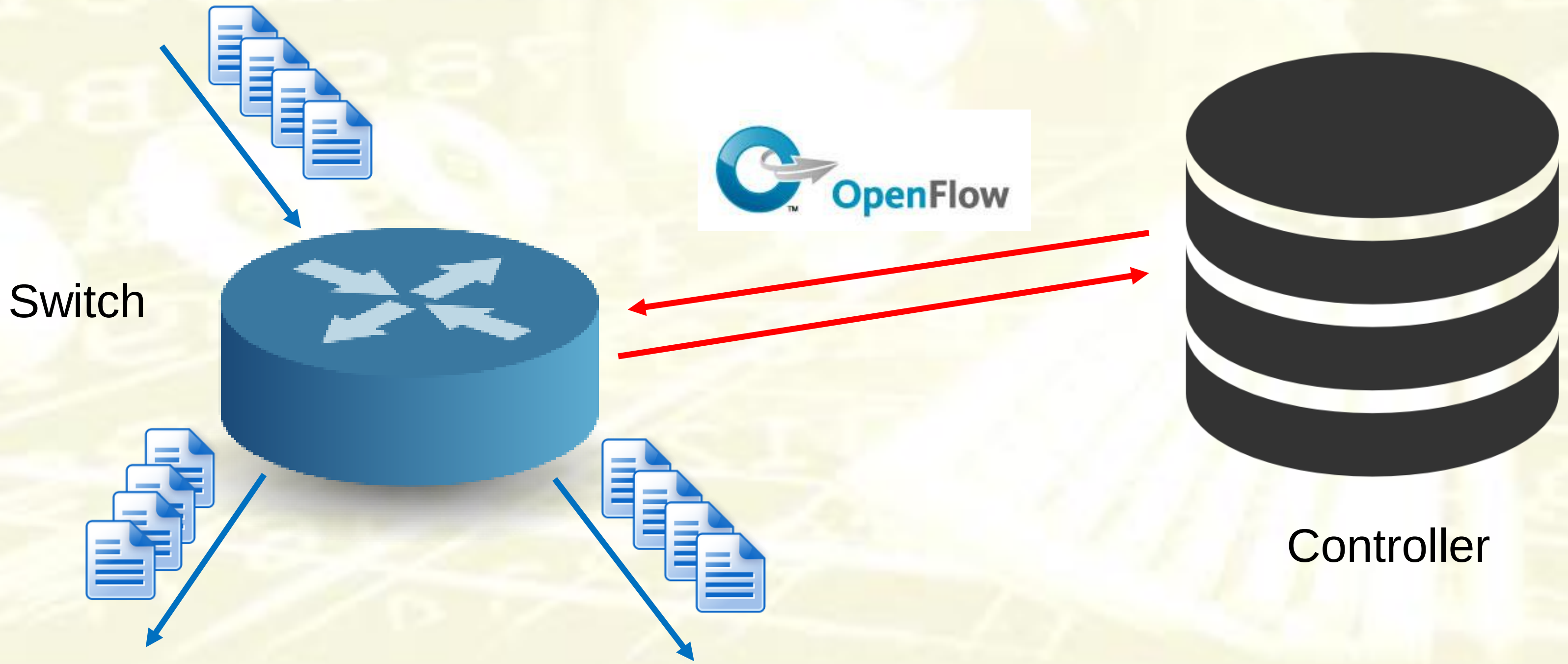
SDN Hardware

- Routers become ***simple hardware*** for packet forwarding (switch)
- A ***centralized controller*** is responsible for defining forwarding rules (controller)



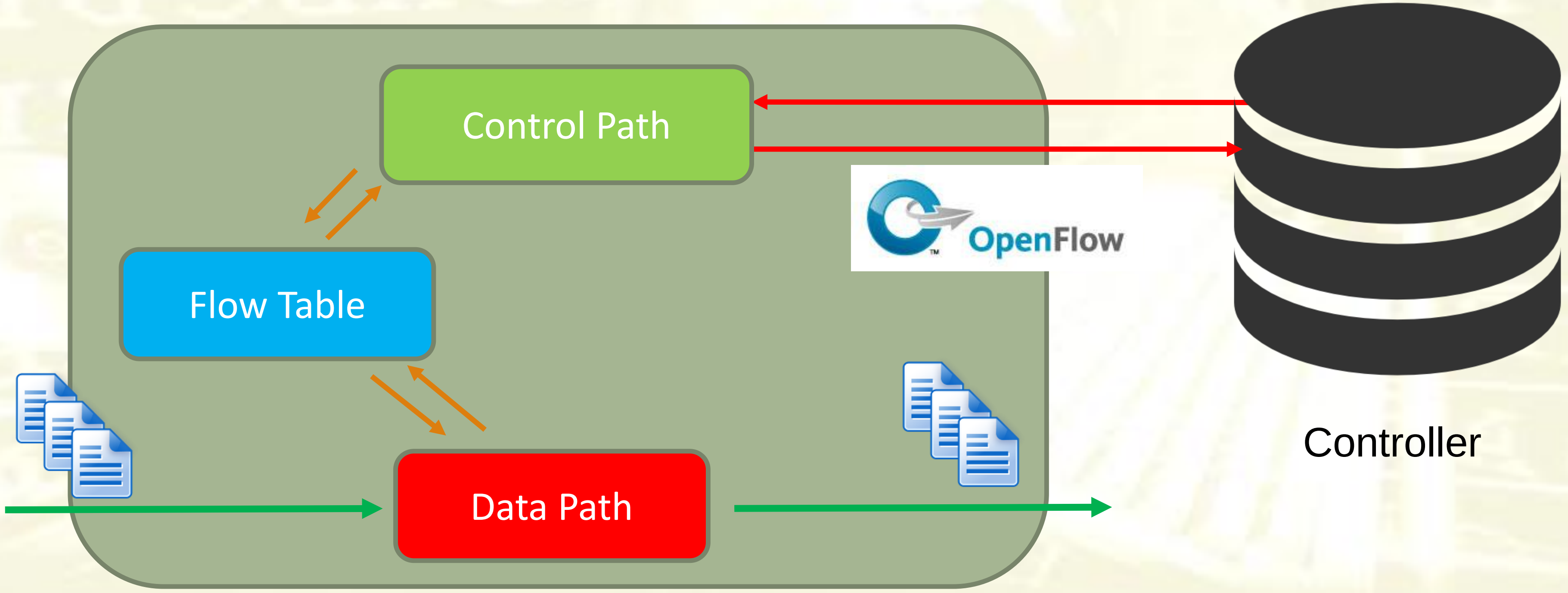
Open Flow

- Standard communication protocol that defines the interaction between switches and controllers
- It allows remote administration of packet forwarding table



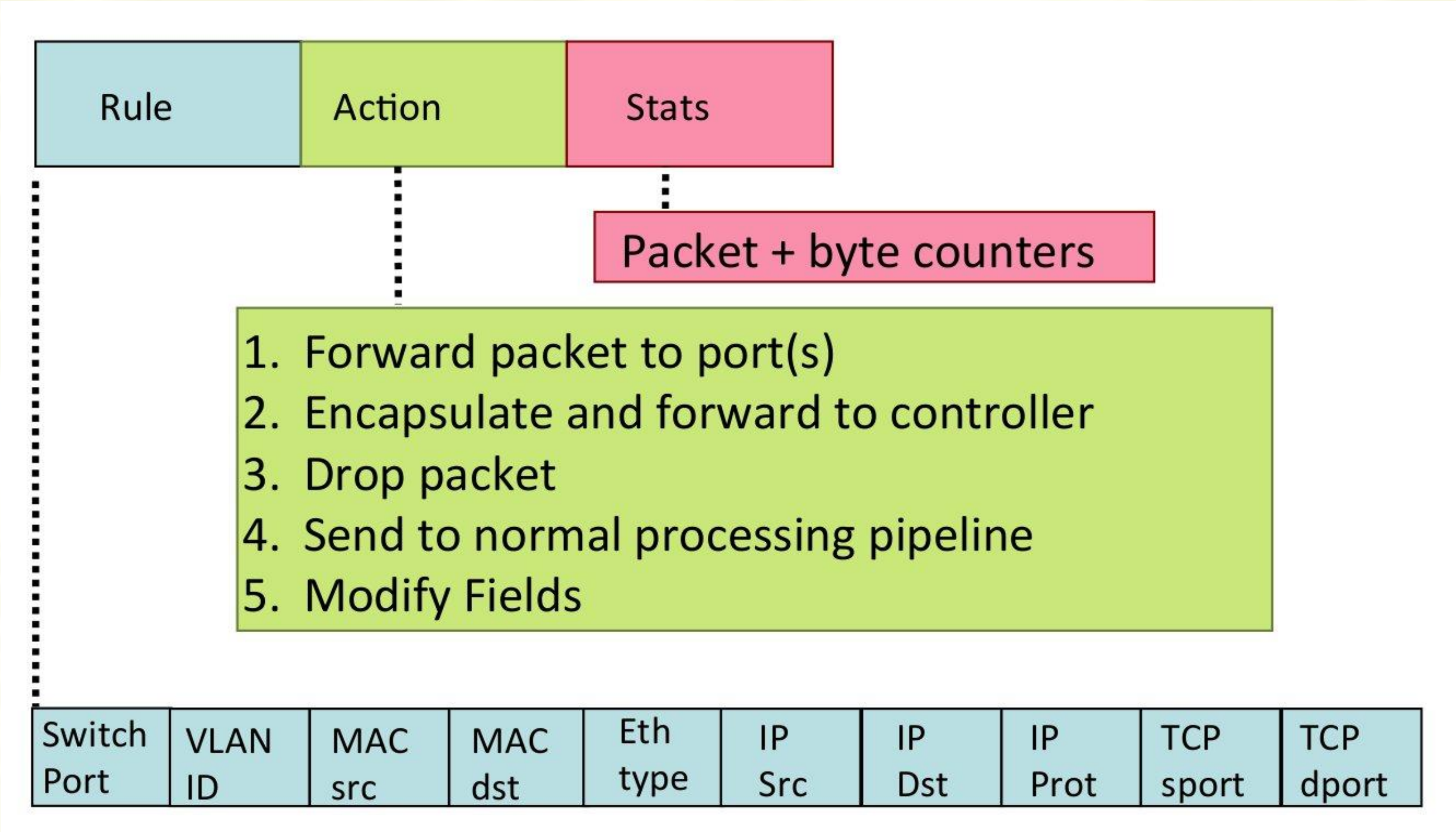
Open Flow Switch

- Packets are forwarded according to a simple ***flow table***
- Controller uses the Open Flow protocol to populate the Flow Table



Flow Table

- Set of rules (similar to cisco ACL) that determines the action to be performed for each packet



Rules Examples

- ***Cross-layer rules*** for packet classification
- Different ***functionalities*** can be implemented:
  - *Switching*
  - *Routing*
  - *Firewall*

Switching

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	00:1f:..	*	*	*	*	*	*	*	port6

Flow Switching

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
port3	00:20..	00:1f..	0800	vlan1	1.2.3.4	5.6.7.8	4	17264	80	port6

Firewall

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Forward
*	*	*	*	*	*	*	*	*	22	drop

Routing

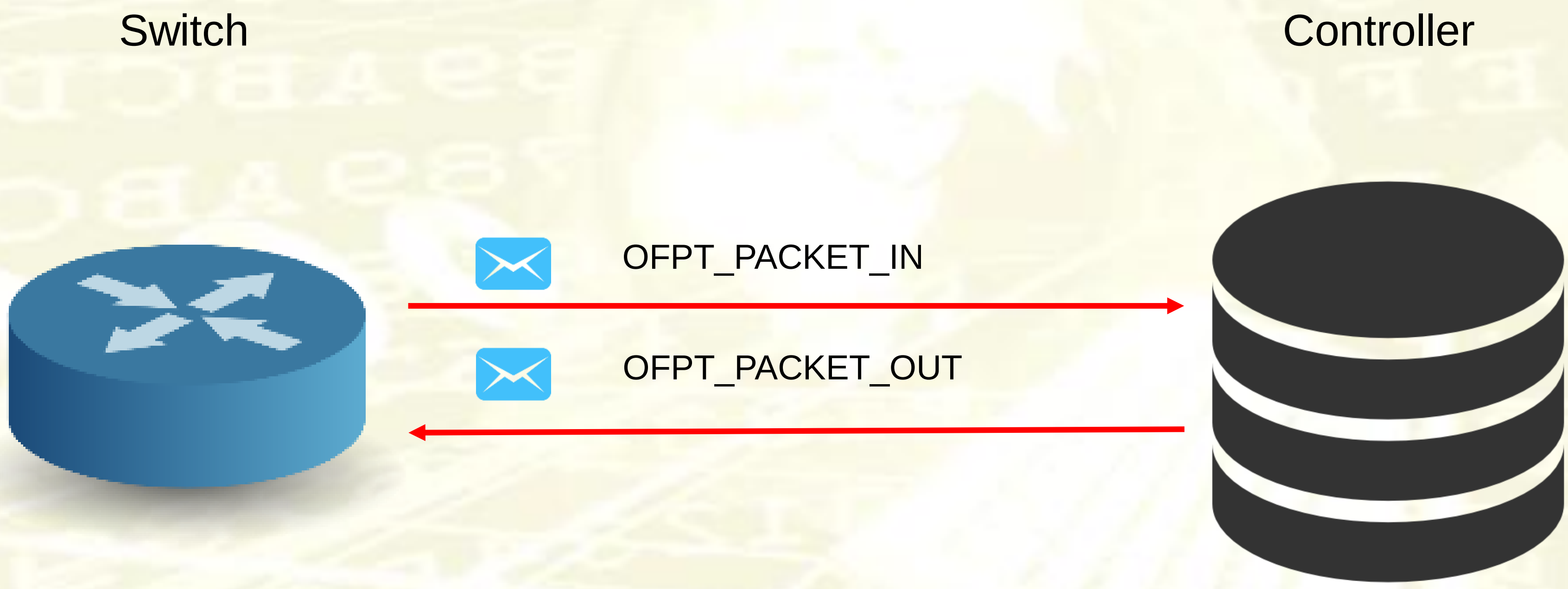
Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	*	*	*	*	5.6.7.8	*	*	*	port6

OF Messages - Startup

- At startup a set of startup messages is sent to allow the controller to discover the capabilities of the switch

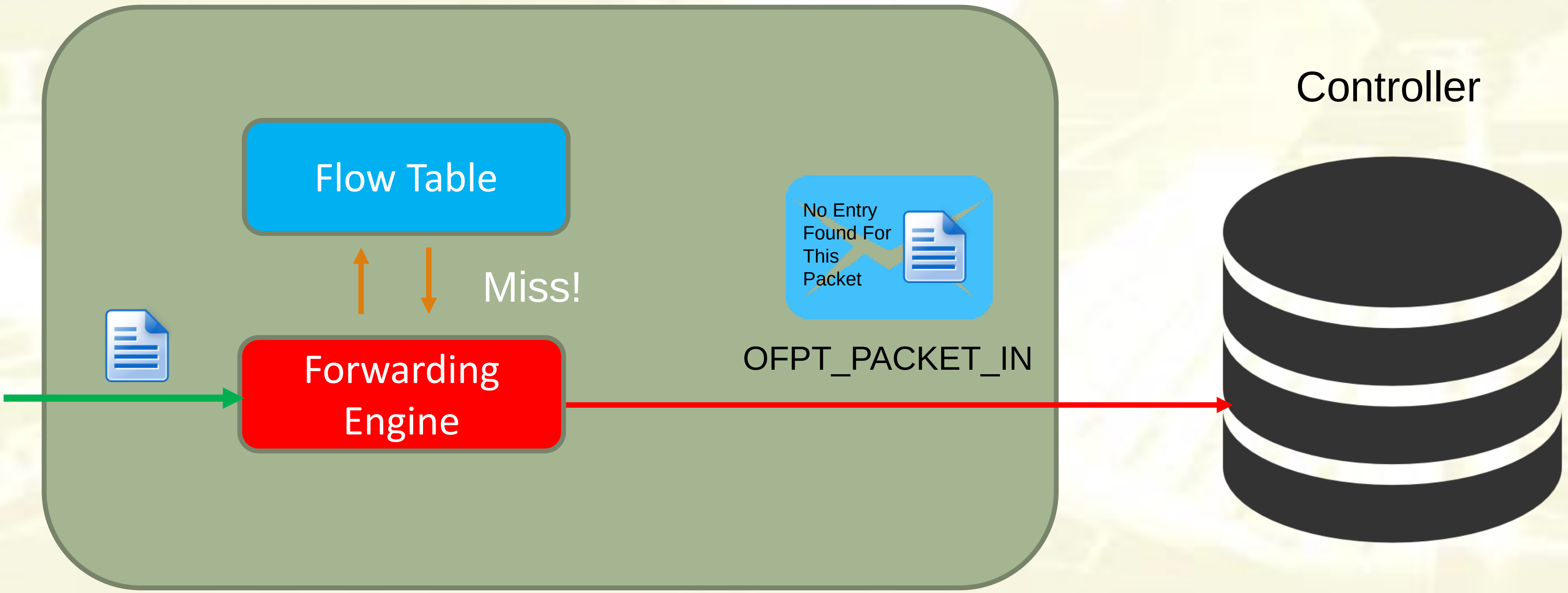
OF Messages – Normal Operations

- During normal operations switch and controller interacts with IN and OUT packets



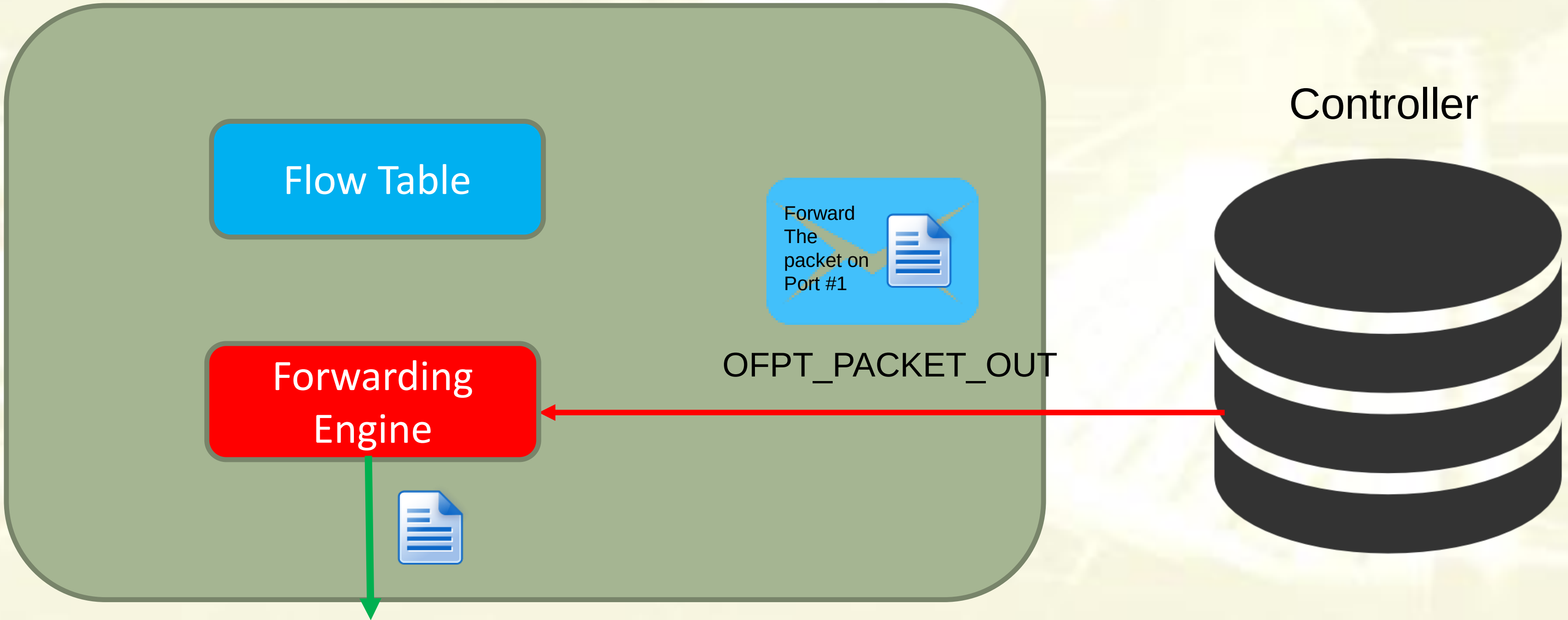
Switch Operations

- For each received packet the Flow Table is looked up
- If a match is ***found*** the action is executed, otherwise the ***packet (or a reference) is forwarded to the controller encapsulated into a Packet-In***



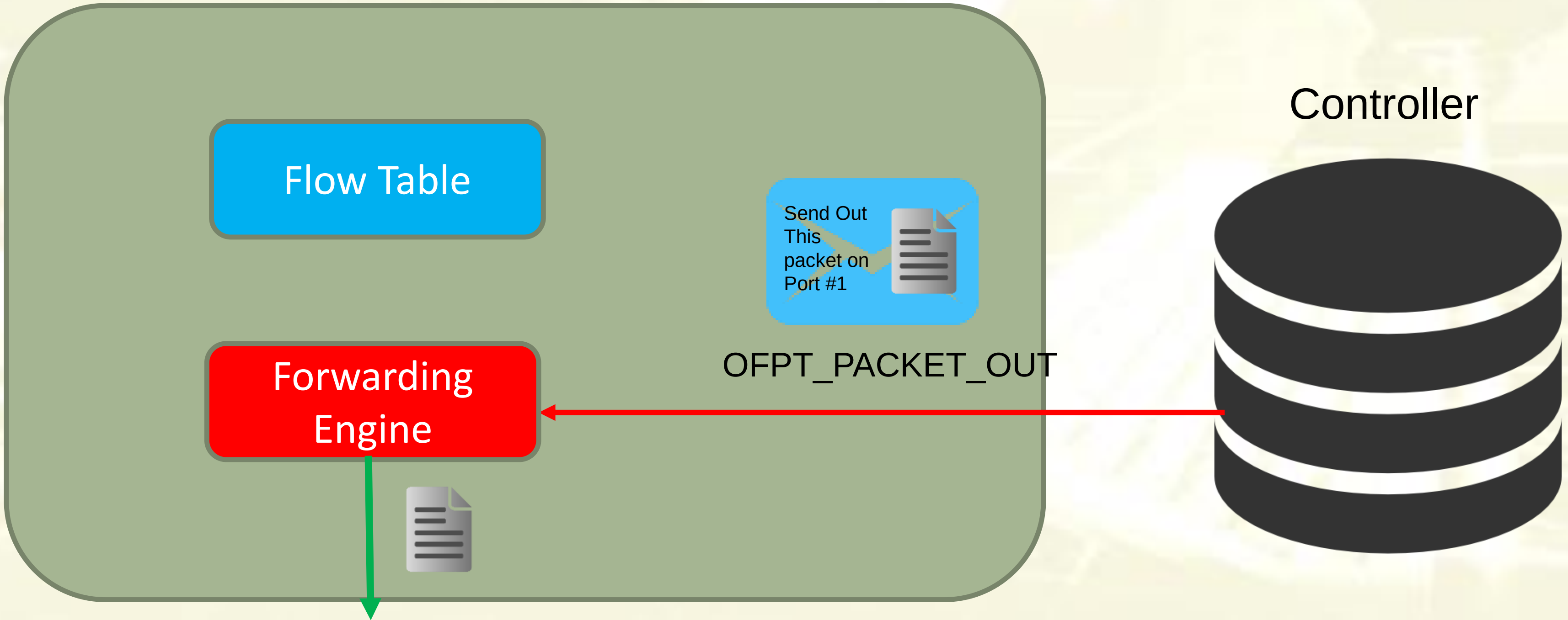
Switch Operations

- The controller can reply with a Packet-Out specifying the action to be performed (e.g. forward the packet on port #1)
- It will be executed only once (no modifications to the Flow Table)



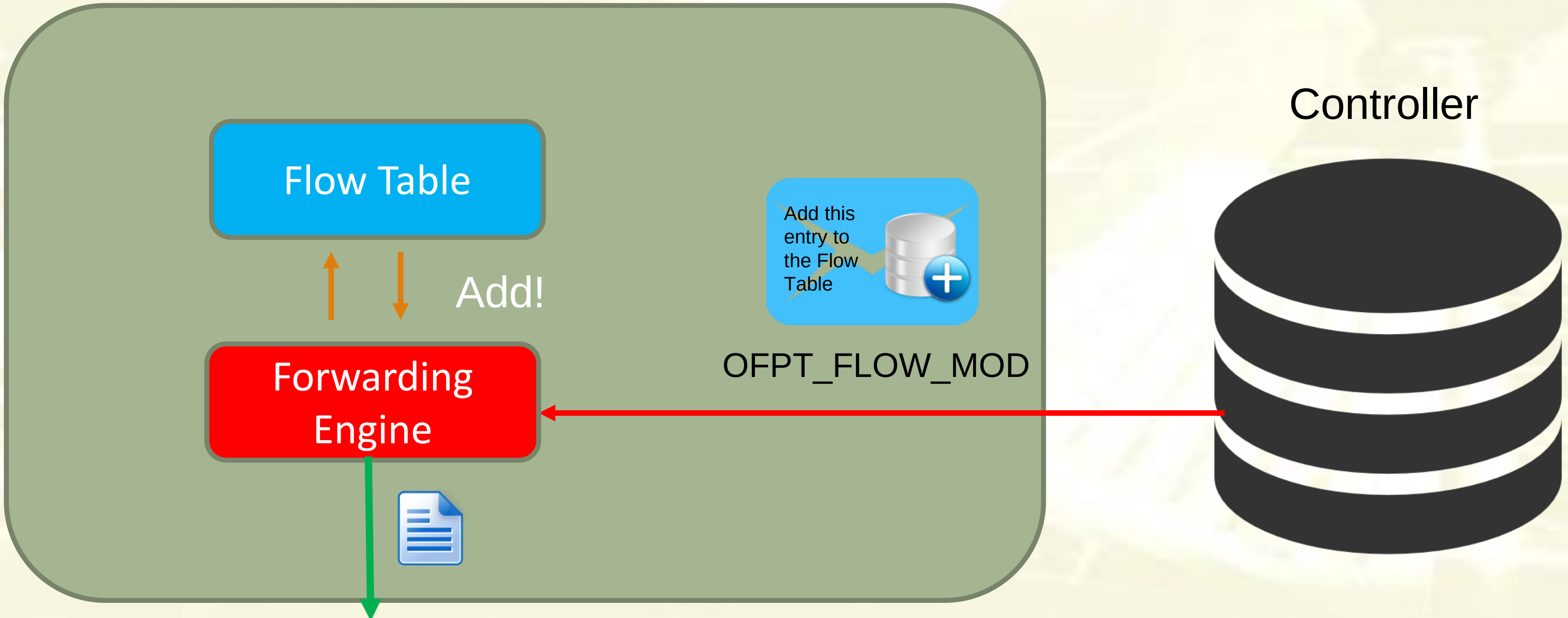
Switch Operations

- The controller can reply with a Packet-Out specifying a new packet to be sent out
- It will be executed only once (no modifications to the Flow Table)



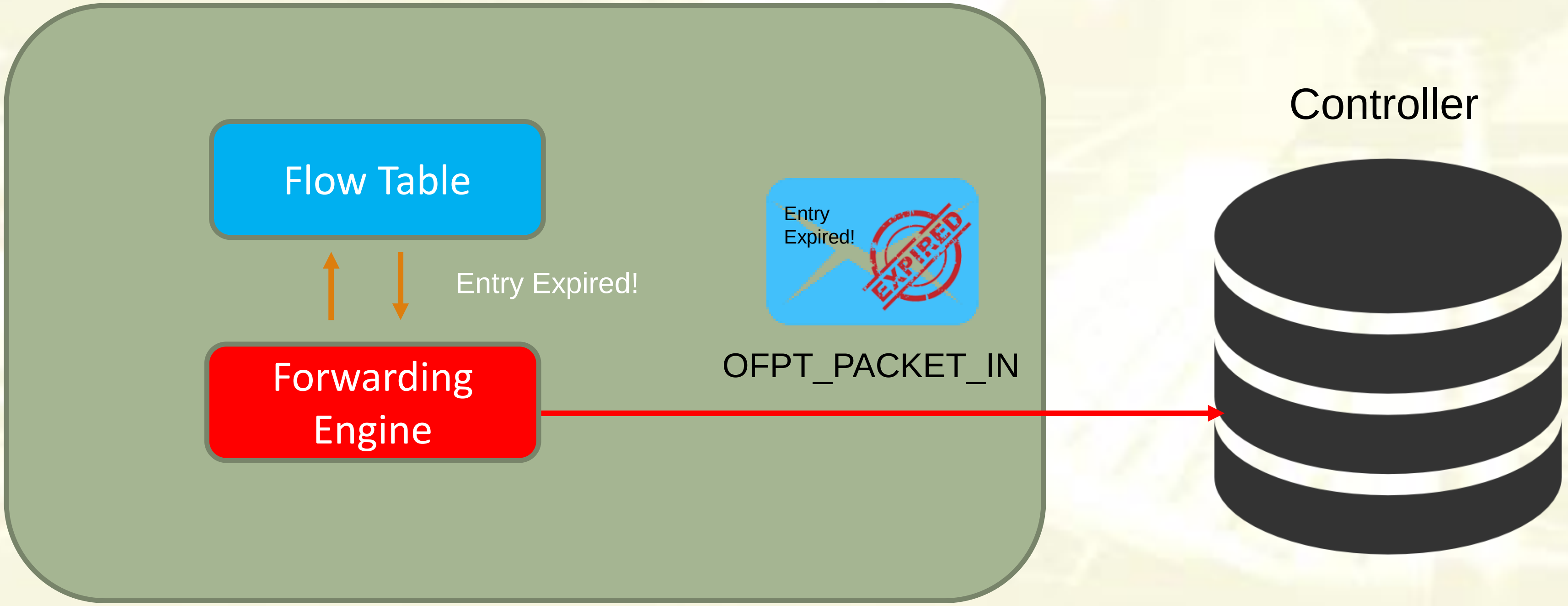
Switch Operations

- The controller can reply with a ***Flow-Mod*** message that instructs the switch to add a new entry to its table
- The new entry will instruct the switch to perform a certain operation without contacting the controller
- The operation associated with the new entry is then executed



Entry Management

- Entries in the flow table expire
- As the entry is expired a Packet-In is sent to the Controller containing a ***Flow-Expired*** message
- Entries expire after a hard timeout (always) or after an idle timeout (if packets matching with the entry are not received)



Mininet

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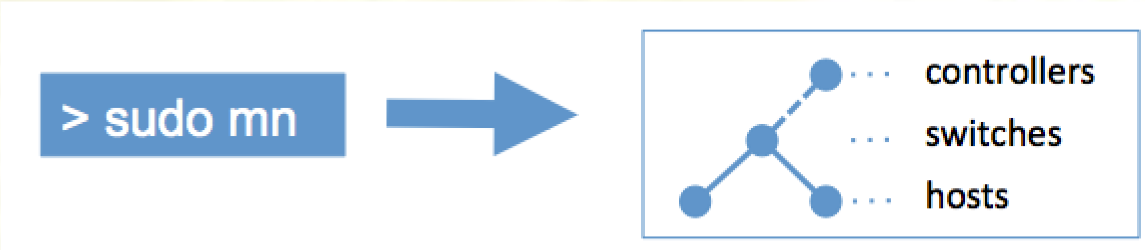
Mininet

- Mininet is a virtual network emulator for testing of SDN deployments
- It allows in one program to emulate a network composed of OpenFlow switches and hosts which can generate traffic
- The network of OpenFlow switches can be connected to a real controller



Mininet

Type of the topology, topology with one single switch and three hosts

- Launch the simulator:

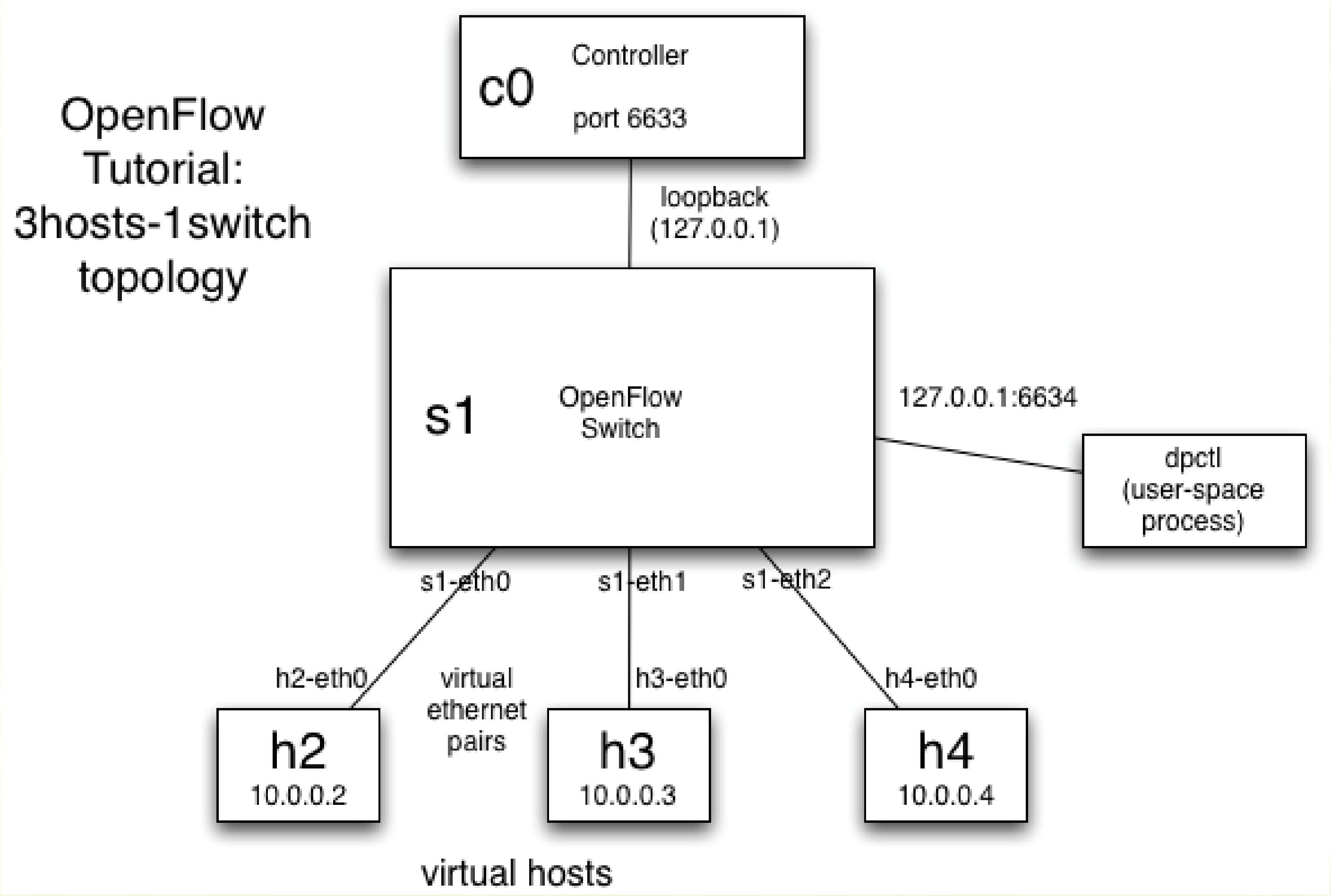
```
sudo mn --topo single,3
--ipbase=10.0.0.0
```

Without a controller the simulated switches behave as normal swtiches bridging the different networks

IP network subnet for simulated hosts

Simulated Architecture

- The basic topology has the following architecture



Mininet Basics

- Run a program on a host
  - `host_name command`
    - `h1 ping 10.0.0.2`
    - `h1 ifconfig -a`
    - `h1 ifconfig h1-eth0 10.0.0.1`
- Open a separate terminal on a host
  - `xterm host_name`
    - `xterm h1`
    - `From the terminal for example you can run wireshark!`

Floodlight

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Floodlight

- Floodlight is a java framework that allows the implementation of OpenFlow controllers
- It not only provides an implementation of the OpenFlow protocol but also an implementation of some basic operations implemented by controllers

External Controller

<u>How to connect mininet to an external controller</u>

- Launch the simulator:

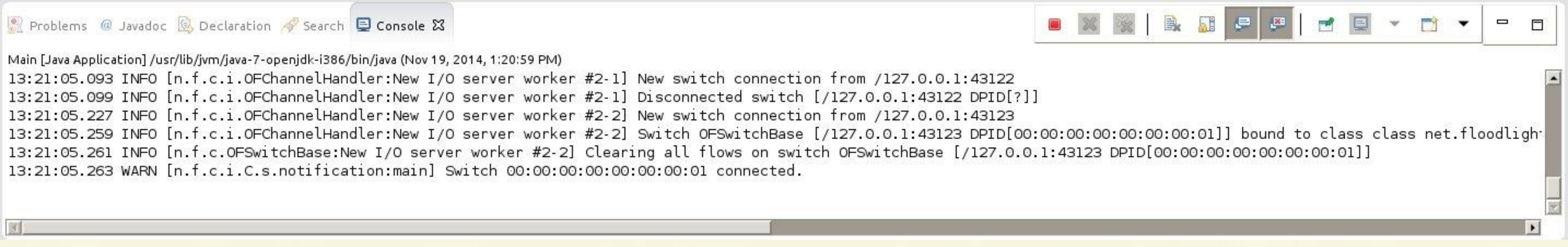
```
sudo mn --topo single,3
--mac --switch ovsk
--controller remote,
ip=127.0.0.1,port=6653,protocols=OpenFlow13
--ipbase=10.0.0.0
```

The version of the OpenFlow protocol the switch will use to communicate with the controller, 1.3 in this case

IP and port of the real OpenFlow controller (in this case it runs on localhost listening on port 6653

Controller

- If you launch the controller now you obtain the following message from the emulator:
  - `Unable to contact the remote controller at 127.0.0.1:6633`
- For our test we use ***Floodlight***, a framework to implement OpenFlow controller
- Compile and Execute the controller using the "*ant run*" command
- Or open eclipse to run floodlight directly into eclipse
- Wireshark can be executed on the loopback interface to capture OpenFlow messages between controller and switch



Floodlight

- Floodlight has a modular structure, each module implements one functionality
- Inbound packets are processed in cascade by each module, each module can interrupt the pipeline
- The modules included in the pipeline and their order are specified inside the file
  - `src/main/resources/floodlightdefault.properties`

```
floodlight.modules=\
net.floodlightcontroller.jython.JythonDebugInterface,\
net.floodlightcontroller.counter.CounterStore,\
net.floodlightcontroller.storage.memory.MemoryStorageSource,\
net.floodlightcontroller.core.internal.FloodlightProvider,\
net.floodlightcontroller.threadpool.ThreadPool,\
net.floodlightcontroller.devicemanager.internal.DeviceManagerImpl,\
net.floodlightcontroller.devicemanager.internal.DefaultEntityClassifier,\
net.floodlightcontroller.staticflowentry.StaticFlowEntryPusher,\
net.floodlightcontroller.firewall.Firewall,\
net.floodlightcontroller.hub.Hub,\
net.floodlightcontroller.forwarding.Forwarding,\
net.floodlightcontroller.linkdiscovery.internal.LinkDiscoveryManager,\
net.floodlightcontroller.topology.TopologyManager,\
net.floodlightcontroller.flowcache.FlowReconcileManager,\
net.floodlightcontroller.debugcounter.DebugCounter,\
```

New Module

- To create a new module and add it to the pipeline you need to create a new Java class implementing the ***IOFMessageListener*** and ***IFloodlightModule*** interfaces
- Eclipse tools can be used to generate a skeleton:

Add Class In Eclipse

1. Expand the "floodlight" item in the Package Explorer and find the "src/main/java" folder.
2. Right-click on the "src/main/java" folder and choose "New/Class".
3. Enter "net.floodlightcontroller.mactracker" in the "Package" box.
4. Enter "MACTracker" in the "Name" box.
5. Next to the "Interfaces" box, choose "Add…".
6. Add the "IOFMessageListener" and the "IFloodlightModule", click "OK".
7. Click "Finish" in the dialog.

Initialization and dependences

- Each module that wants to process OF packets need to connect with the ***FloodlightProvider*** which dispatches the messages
- Explicit dependency on its creation needs to be declared
- At initialization a reference to it needs to be gathered

```
protected IFloodlightProviderService floodlightProvider; // Reference to the provider

// Called at initialization time. Retrieve reference to the provider
@Override
public void init(FloodlightModuleContext context) throws FloodlightModuleException {
    floodlightProvider = context.getServiceImpl(IFloodlightProviderService.class);
}

// Called to specify the dependences. Add dependency on the provider
@Override
public Collection<Class<? extends IFloodlightService>> getModuleDependencies() {
    Collection<Class<? extends IFloodlightService>> l =
        new ArrayList<Class<? extends IFloodlightService>>();
    l.add(IFloodlightProviderService.class);
    return l;
}
```

Handle Packet-In Messages

- Each module that wants to process Packet-In messages needs to register and define a ***receive*** function

```
// Set module name
@Override
public String getName() {
    return ModuleExample.class.getSimpleName();
}

// Called at startup time (after all the modules have been initialized)
@Override
public void startUp(FloodlightModuleContext context) {
    floodlightProvider.addOFMessageListener(OFType.PACKET_IN, this);
}

// Called every time a Packet-In is received
@Override
public net.floodlightcontroller.core.IListener.Command receive(IOFSwitch sw,
           OFMessage msg, FloodlightContext cntx) {

    Ethernet eth = IFloodlightProviderService.bcStore.get(cntx,
           IFloodlightProviderService.CONTEXT_PI_PAYLOAD);
    // Print the source MAC address
    Long sourceMACHash = Ethernet.toLong(eth.getSourceMACAddress().getBytes());
    System.out.printf("MAC Address: {%s} seen on switch: {%s}\n",
           HexString.toHexString(sourceMACHash),
           sw.getId());
    // Let other modules process the packet
    return Command.CONTINUE;
}
```

Register the new module

- Each needs to be registered in the pipeline

```
Append the name of the class in the file
src/main/resources/META-INF/services/net.floodlight.core.module.IFloodlightModule
net.floodlightcontroller.unipi.ModuleExample

Add the module into the pipeline
src/main/resources/floodlightdefault.properties
floodlight.modules = <leave the default list of modules in place>,
net.floodlightcontroller.unipi.ModuleExample
```

- Test it!