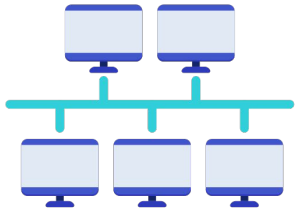
SDN - Network Slice Setup Optimization

Project Report - Networking II
Softwarized and Virtualized Mobile Networks
(prof. Fabrizio Granelli)

Samuele Pozzani

Project Goals



Simulate a network topology using Mininet

Develop a RYU-based SDN controller

Automatically optimize resources and provide QoS

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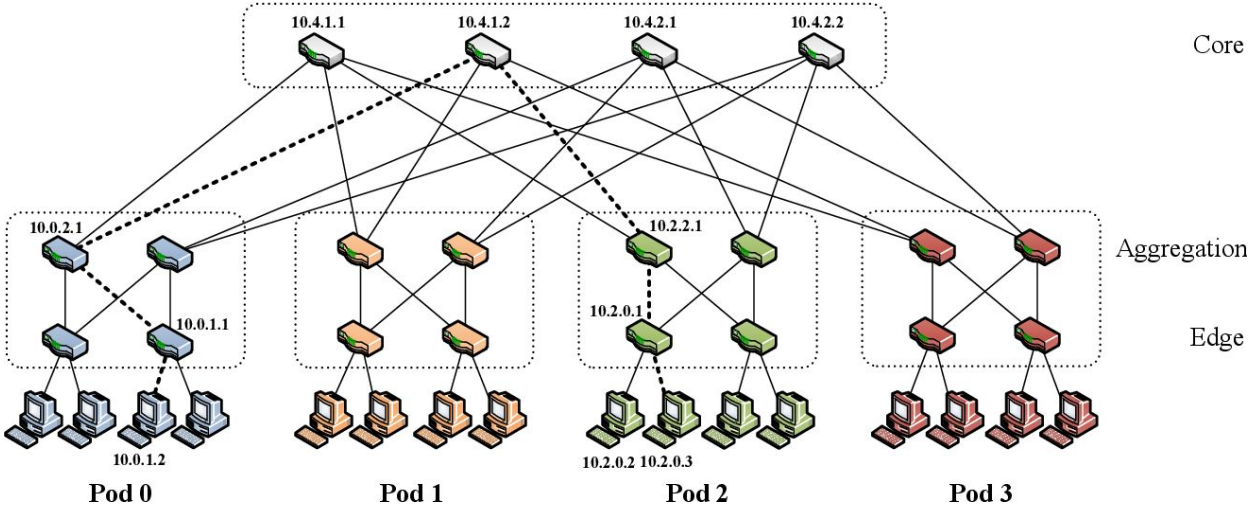
Fat-Tree DC Network Topology

$K = 4$



Mohammad Al-Fares, Alexander Loukissas, and Amin Vahdat, *"A scalable, commodity data center network architecture"*, SIGCOMM 2008.

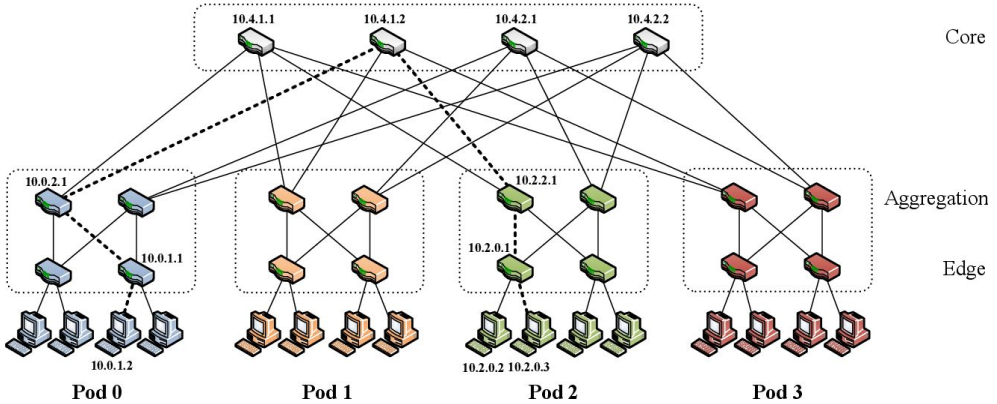
Two-Levels Routing

```
1  foreach pod x in [0, k − 1] do
2      foreach switch z in [(k/2), k − 1] do
3          foreach subnet i in [0, (k/2) − 1] do
4              addPrefix(10.x.z.1, 10.x.i.0/24, i);
5          end
6          addPrefix(10.x.z.1, 0.0.0.0/0, 0);
7          foreach host ID i in [2, (k/2) + 1] do
8              addSuffix(10.x.z.1, 0.0.0.i/8,
               (i − 2 + z)mod(k/2) + (k/2));
9          end
10     end
11 end
```

Algorithm 1: Generating aggregation switch routing tables. Assume Function signatures *addPrefix(switch, prefix, port)*, *addSuffix(switch, suffix, port)* and $addSuffix$ adds a second-level suffix to the last-added first-level prefix.

```
1  foreach j in [1, (k/2)] do
2      foreach i in [1, (k/2)] do
3          foreach destination pod x in [0, (k/2) − 1] do
4              addPrefix(10.k.j.i,10.x.0.0/16, x);
5          end
6      end
7  end
```

Algorithm 2: Generating core switch routing tables.



Mohammad Al-Fares, Alexander Loukissas, and Amin Vahdat, *"A scalable, commodity data center network architecture"*, SIGCOMM 2008.

Network Slicing

```
1  foreach pod x in [0, k − 1] do
2      foreach switch z in [(k/2), k − 1] do
3          foreach subnet i in [0, (k/2) − 1] do
4              addPrefix(10.x.z.1, 10.x.i.0/24, i);
5          end
6          addPrefix(10.x.z.1, 0.0.0.0/0, 0);
7          foreach host ID i in [2, (k/2) + 1] do
8              addSuffix(10.x.z.1, 0.0.0.i/8,
               (i − 2 + z)mod(k/2) + (k/2));
9          end
10     end
11 end
```

Algorithm 1: Generating aggregation switch routing tables. Assume Function signatures *addPrefix(switch, prefix, port)*, *addSuffix(switch, suffix, port)* and $addSuffix$ adds a second-level suffix to the last-added first-level prefix.

```
slices = {
    0: ['10.0.0.2', '10.3.0.2', '10.2.0.2',],
    1: ['10.0.1.2', '10.2.1.3',],
    2: ['10.0.1.3', '10.2.0.3', '10.2.1.2',],
}

# Check whether src host is in the same slice as dst host
if any( src in slice and dst in slice
    for slice in slices.values() ):

    # Compute target port number
    port = (dst.hostid - 2 + switch.number) % (K / 2) + (K / 2)

    # Add FlowTable entry to the switch identified by datapath
    add_two_level_flow (
        switch = switch.datapath ,
        ip = dst,
        mask = 0xFFFFFFFF,
        port = port + 1,
        timeout = 30
    )
```

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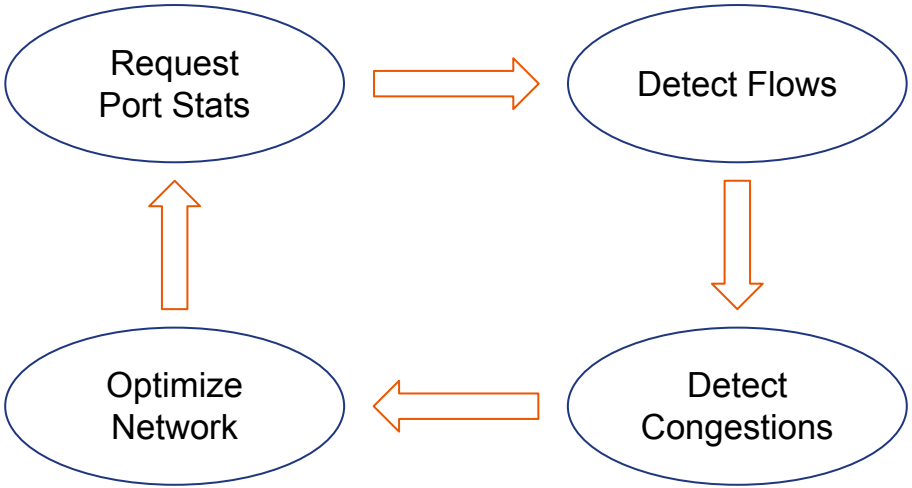
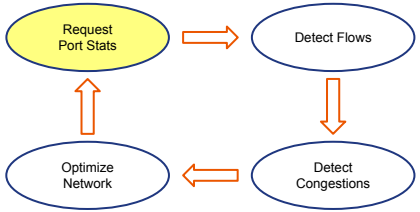
Flow Scheduler - Loop




```python
from threading import Thread

class SDNController(app_manager.RyuApp):
    def __init__(self):
        self.scheduler = FlowScheduler()
        self.scheduler.start()

class FlowScheduler(Thread):
    def run(self):
        self.__main_loop()
```

Flow Scheduler - Port Stats Request

```
/* Body of reply to OFPMP_PORT_STATS request. If a counter is unsupported,
 * set the field to all ones. */
struct ofp_port_stats {
    uint16_t length;         /* Length of this entry. */
    uint8_t pad[2];          /* Align to 64 bits. */
    uint32_t port_no;
    uint32_t duration_sec;   /* Time port has been alive in seconds. */
    uint32_t duration_nsec;  /* Time port has been alive in nanoseconds beyond
                                duration_sec. */
    uint64_t rx_packets;     /* Number of received packets. */
    uint64_t tx_packets;     /* Number of transmitted packets. */
    uint64_t rx_bytes;       /* Number of received bytes. */
    uint64_t tx_bytes;       /* Number of transmitted bytes. */

    uint64_t rx_dropped;     /* Number of packets dropped by RX. */
    uint64_t tx_dropped;     /* Number of packets dropped by TX. */
    uint64_t rx_errors;      /* Number of receive errors.  This is a super-set
                                of more specific receive errors and should be
                                greater than or equal to the sum of all
                                rx_*_err values in properties. */
    uint64_t tx_errors;      /* Number of transmit errors.  This is a super-set
                                of more specific transmit errors and should be
                                greater than or equal to the sum of all
                                tx_*_err values (none currently defined.) */

    /* Port description property list - 0 or more properties */
    struct ofp_port_stats_prop_header properties[0];
};
OFP_ASSERT(sizeof(struct ofp_port_stats) == 80);
```




```
class Switch():
    def __init__(self):
        self.port_stats = {
            i : PortStats()
            for i in range(1, FAT_TREE_K + 1)
        }

class PortStats():
    def update_stats(self, tx_bytes, rx_bytes):
        # tx/rx bytes since latest update
        self.dtx_bytes = tx_bytes - self.tx_bytes
        self.drx_bytes = rx_bytes - self.rx_bytes
        # Total amount of tx/rx bytes
        self.tx_bytes = tx_bytes
        self.rx_bytes = rx_bytes
```

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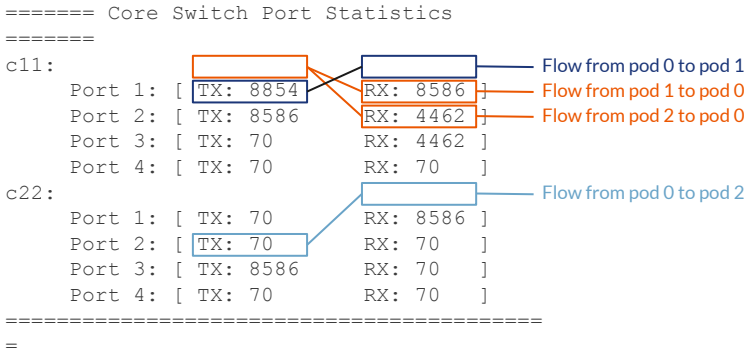
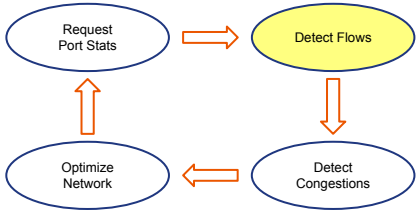
Flow Scheduler - Detect Flows



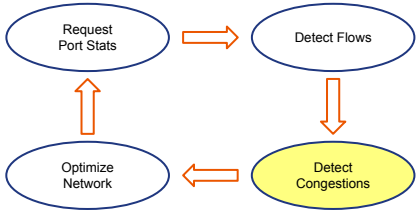



```
class Flow():

    def __init__(self, switch_id, in_pod, out_pod, ttl):
        self.switch = Switch(switch_id)
        self.in_pod = in_pod
        self.out_pod = out_pod
        self.ttl = ttl

    def update_ttl(self):
        """ Decrease flow Time To Live counter """
        self.ttl -= 1
```

For more advanced techniques, refer to:

Mohammad Al-Fares, *"Hedera: Dynamic Flow Scheduling for Data Center Networks"*, NSDI 2010

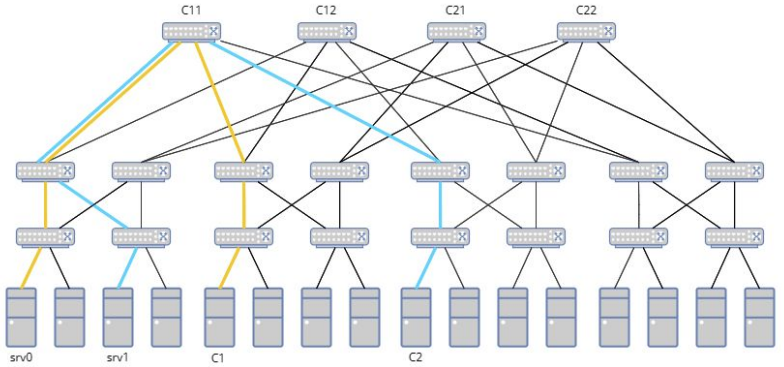
Flow Scheduler - Detect Congestions




```
======= Core Switch Port Statistics
=======
c11:
      Port 1: [ TX: 8854      RX: 8586 ]
      Port 2: [ TX: 8586      RX: 4462 ]
      Port 3: [ TX: 70        RX: 4462 ]
      Port 4: [ TX: 70        RX: 70   ]
c22:
      Port 1: [ TX: 70        RX: 8586 ]
      Port 2: [ TX: 70        RX: 70   ]
      Port 3: [ TX: 8586      RX: 70   ]
      Port 4: [ TX: 70        RX: 70   ]
=========================================
```

Flow from pod 0 to pod 1
Flow from pod 1 to pod 0
Flow from pod 2 to pod 0
Flow from pod 0 to pod 2

Discovered congested downlink from core switch c11 to pod 0




```
class DownLink():

    def __init__(self, switch, dst_pod):
        self.switch: Switch = switch
        self.dst_pod: int = dst_pod
```

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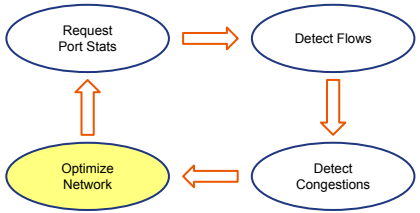
Flow Scheduler - Optimize Network

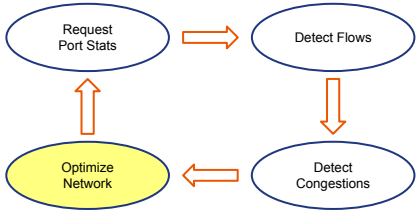


Foreach **congested downlink**:

1. **Find a service** inside the pod connected to the downlink
2. Search for a new **non-conflicting path**
3. If a path was found:
   a. **Re-route traffic** through the new path

   Otherwise:
   b. **Migrate the service** to a new pod which is the destination of an available path
   c. **Re-route traffic** through the new path

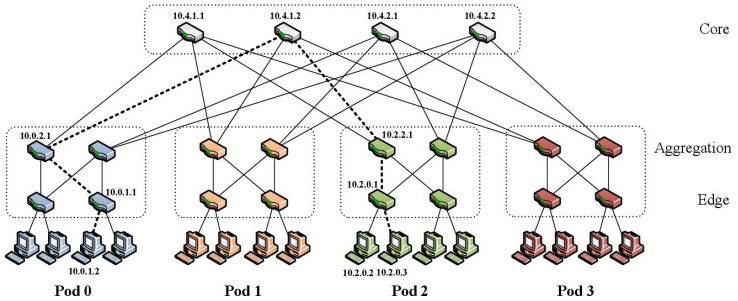
Optimize Network - Create Path




```
def create_path(dst_service, via_switch):
    for switch in switches:
        if switch.is_core or switch.pod == dst_service.pod:
        # Do not update core switches and
        # switches in the same pod of the dst host
            continue

        if switch.is_edge:
            port = (K / 2) + via_switch.j      # Edge
        if not switch.is_edge:
            port = (K / 2) + via_switch.i      # Aggregate

        add_two_level_flow(
            datapath = switch.datapath,
            ip = dst_service.ip,
            mask = 0xFFFFFFFF,
            port = port,
            timeout = 30,
            priority = int(time()) & 0xFFFF    # High priority
        )
```



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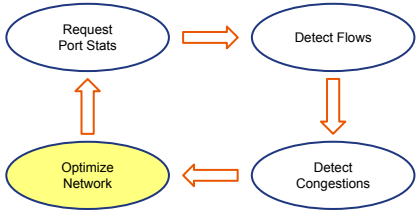
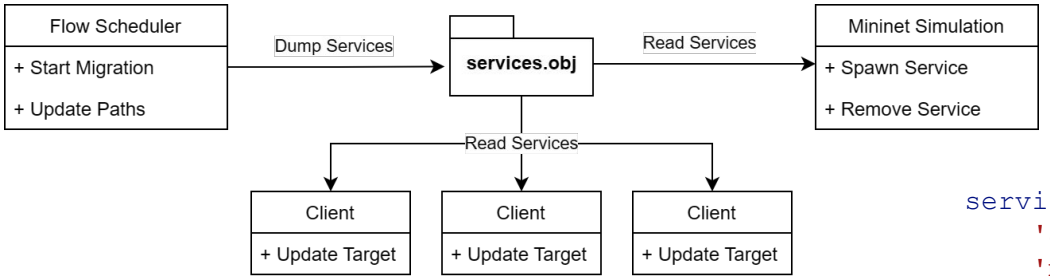
Optimize Network - Migrate Service



Enable **communication** between the simulation loop and the Flow Scheduler **dumping** the services list on the **FileSystem**




```
services = {
    'apache_srv'    : '10.0.0.2',
    'mysql_srv'     : '10.0.1.2',
    'dotnet_be_srv' : '10.2.1.3',
}
```

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Thank You

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