Integration of IEEE 802.16 with OpenFlow Software-Defined Networking

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Re:

For P802.16r Project, IEEE 802.16 Session #85

Base Contribution:

[none]

Purpose:

To stimulate and support discussion within the P802.16r project regarding Software-Defined Network control architecture.

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Integration of IEEE 802.16 with Software-Defined Network Control

This contribution is a followup to:

- IEEE 802.16-13-0049 (“Integration of IEEE 802.16 and Carrier Ethernet”)

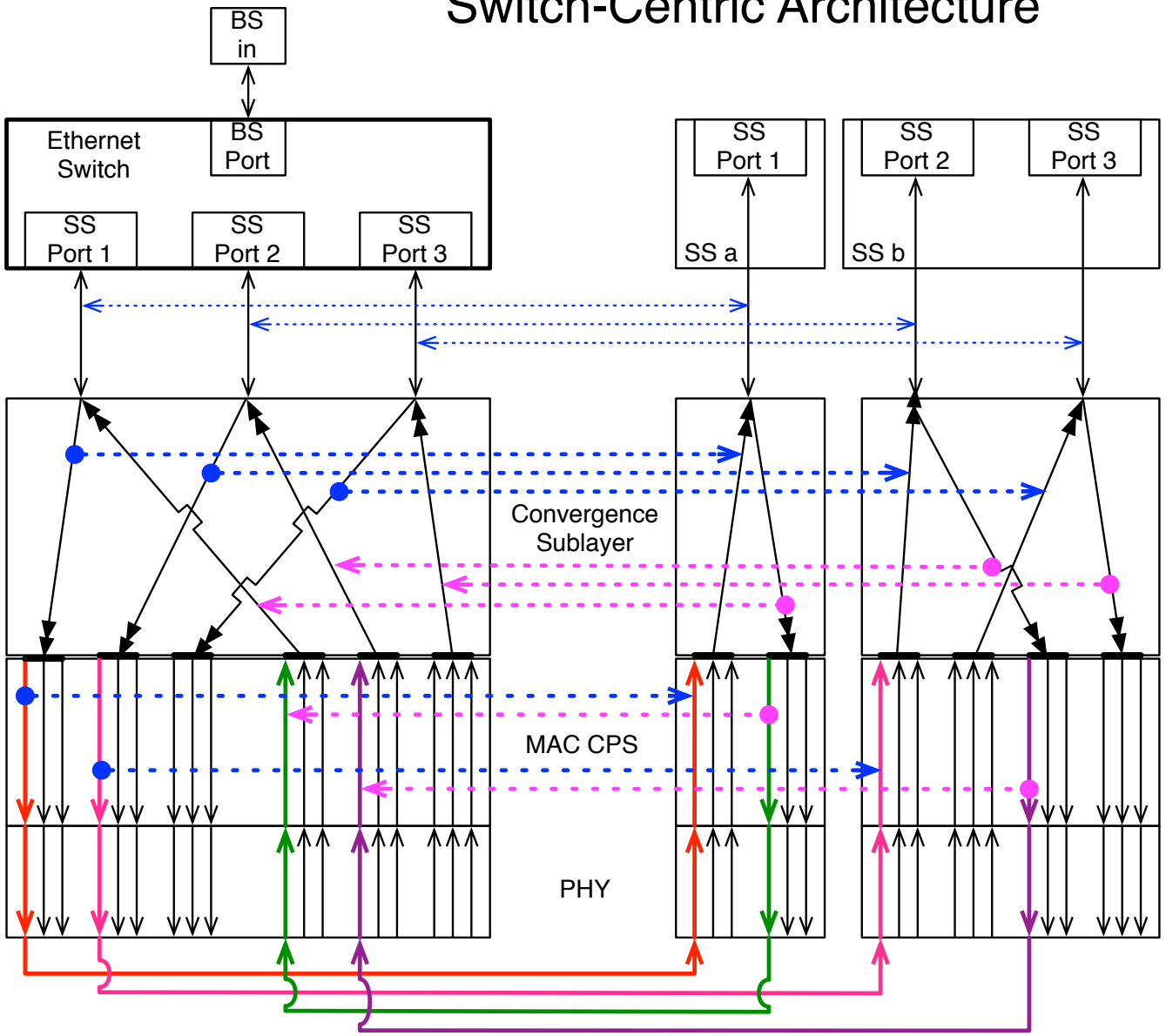
IEEE 802.16-13-0049 proposed a switch-centric architecture with a switch in the BS

Switch is presumably based on 802.1Q functionality (learning, spanning tree, etc.)

Enhancement: Use of SDN controller to program the switch, including QoS control, as an alternative to pure 802.1Q behavior.

See companion contribution IEEE 802.16-13-0098 for a more general overview of “Connection-Oriented Software-Defined Networking”

Switch-Centric Architecture



multiple SS Ports per SS
one SS per SS Port

One CS instance per SS
Port-aware CS

unidirectional
Connections

multiple Connections per SS Port
one SS Port per Connection
Connections labeled by SS Port

all Connections linked via PHY
[several examples highlighted]

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Switch Control

- Switching behavior per 802.1Q is required per IEEE 802.1Q
  - "The standard will comply with IEEE Std 802, IEEE Std 802.1D, and IEEE Std 802.1Q."
  - PAR P802.16r (IEEE 802.16-12-0587)
- It is also possible to allow other switch behavior.

OpenFlow

- *OpenFlow enables networks to evolve, by giving a remote controller the power to modify the behavior of network devices, through a well-defined "forwarding instruction set". The growing OpenFlow ecosystem now includes routers, switches, virtual switches, and access points from a range of vendors.*
- *The Open Networking Foundation (ONF) is now the home of the OpenFlow specification.*

  - <http://www.openflow.org>

Open Networking Foundation (ONF)

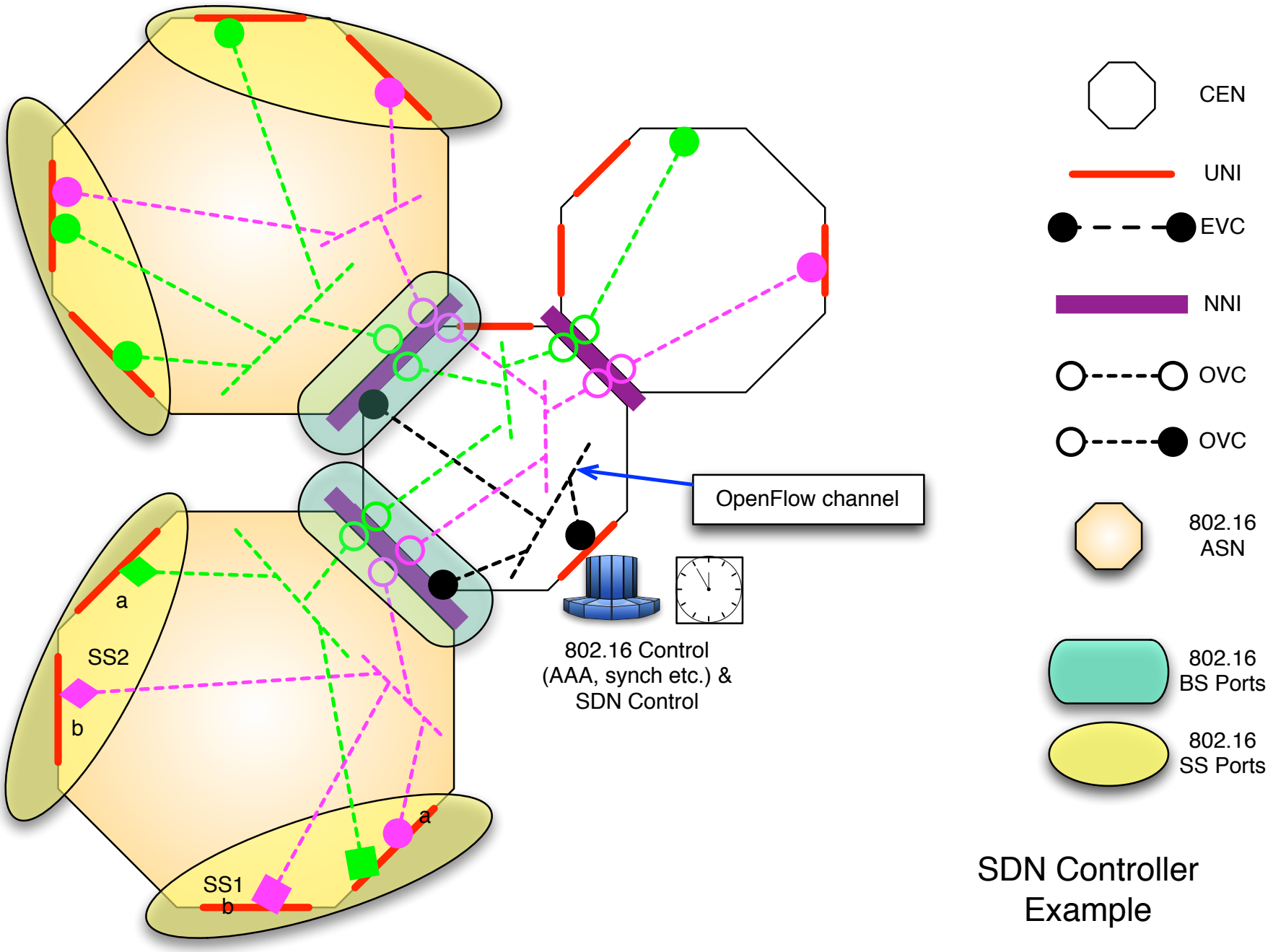
- *…a user-driven organization dedicated to the promotion and adoption of Software-Defined Networking (SDN) through open standards development.*
- *SDN is a new approach to networking in which network control is decoupled from the data forwarding function and is directly programmable*
- *Our signature accomplishment to date is introducing the OpenFlow™ Standard, which enables remote programming of the forwarding plane. The OpenFlow Standard is the first SDN standard and a vital element of an open software-defined network architecture.*

  - <https://www.opennetworking.org/about/onf-overview>

OpenFlow separates control and data path

- *In a classical router or switch, the fast packet forwarding (data path) and the high level routing decisions (control path) occur on the same device. An OpenFlow Switch separates these two functions. The data path portion still resides on the switch, while high-level routing decisions are moved to a separate controller, typically a standard server. The OpenFlow Switch and Controller communicate via the OpenFlow protocol...*

  - <http://www.openflow.org/wp/learnmore/>



SDN Controller
Example

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OpenFlow Hybrid Switch

OpenFlow-compliant switches come in two types: OpenFlow-only, and OpenFlow-hybrid.

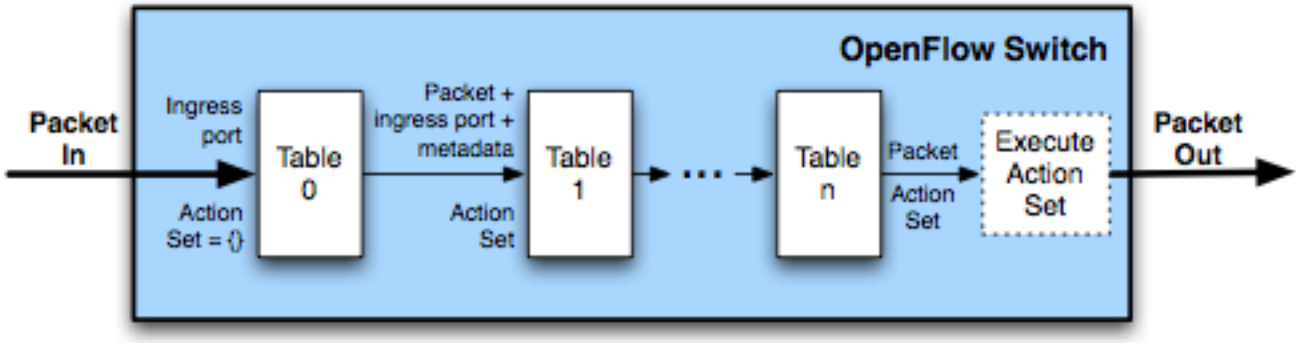
- *OpenFlow-only switches support only OpenFlow operation.*
- *OpenFlow-hybrid switches support both OpenFlow operation and normal Ethernet switching operation, i.e. traditional L2 Ethernet switching, VLAN isolation, L3 routing, ACL and QoS processing. Those switches should provide a classification mechanism outside of OpenFlow that routes traffic to either the OpenFlow pipeline or the normal pipeline. For example, a switch may use the VLAN tag or input port of the packet to decide whether to process the packet using one pipeline or the other, or it may direct all packets to the OpenFlow pipeline. This classification mechanism is outside the scope of this specification.*

- OpenFlow Switch Specification Version 1.3.1

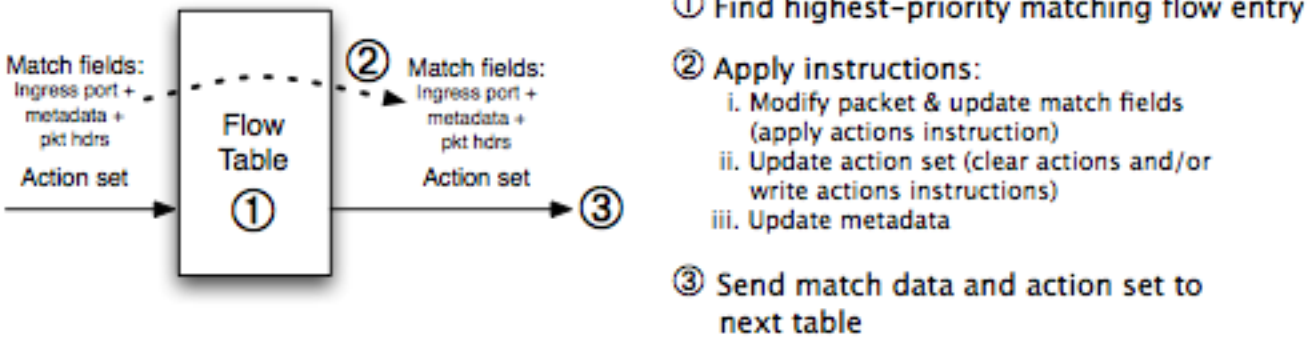
https://www.opennetworking.org/images/stories/downloads/sdn-resources/onf-specifications/openflow/openflow-spec-v1.3.1.pdf

OpenFlow Pipeline

- OpenFlow pipeline: multiple flow tables
  - at least one flow table per switch



(a) Packets are matched against multiple tables in the pipeline



(b) Per-table packet processing

Figure credit: OpenFlow Switch Specification Version 1.3.1

OpenFlow Pipeline Progress

- Actions per OpenFlow table

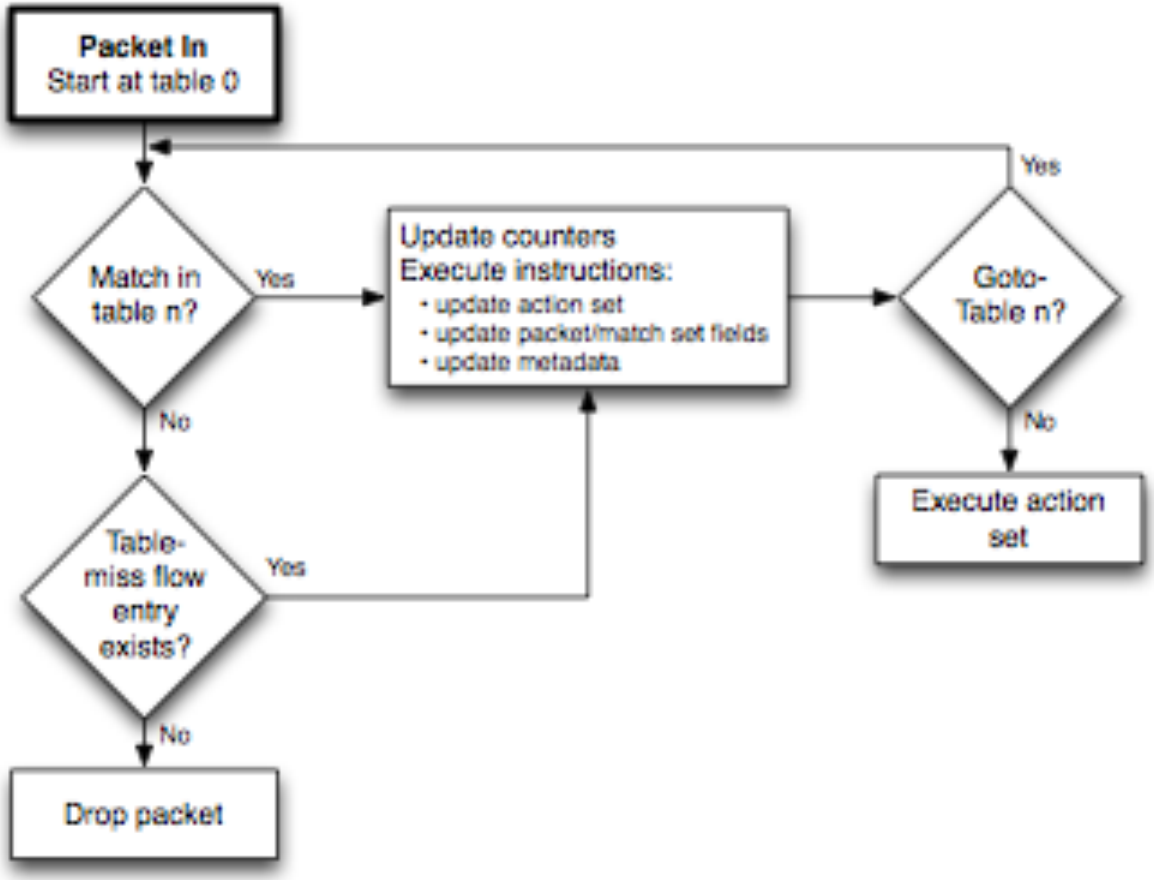


Figure credit: OpenFlow Switch Specification Version 1.3.1

802.16 Packet Classification

- *Classification is the process by which a MAC SDU is mapped onto a particular transport connection…*
- *A classification rule is a set of matching criteria applied to each packet entering... It consists of some protocol-specific packet matching criteria… , a classification rule priority, and a reference to a CID.*
- *It is possible for a packet to fail to match the set of defined classification rules. In this case, the CS shall discard the packet.*

Per IEEE Std 802.16-2012, subclause 5.2.2

802.16 Packet Classification (downlink)

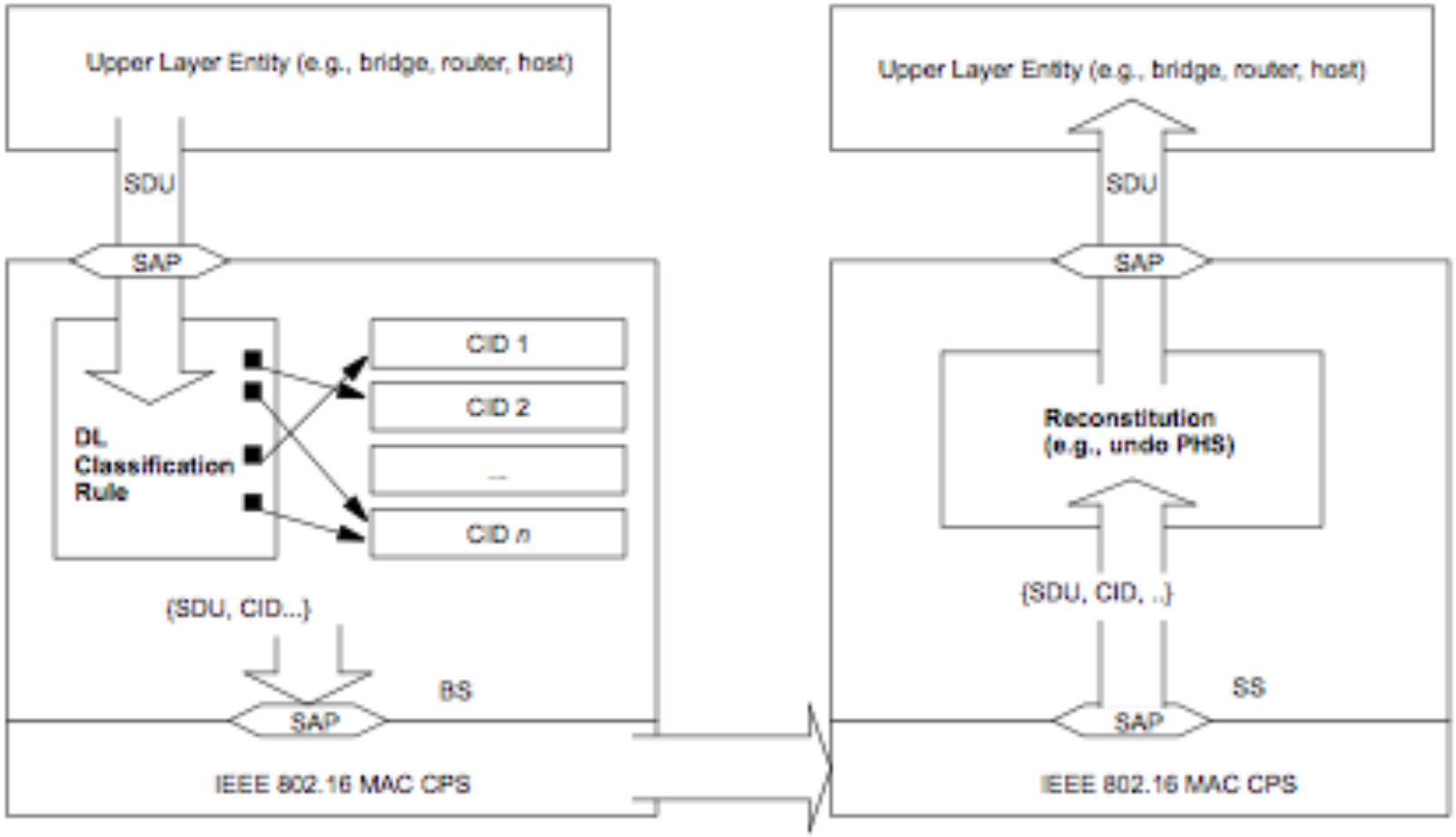


Figure 5-5—Classification and CID mapping (BS to SS)

Figure credit: IEEE Std 802.16-2012

802.16 Packet CS compared to OpenFlow

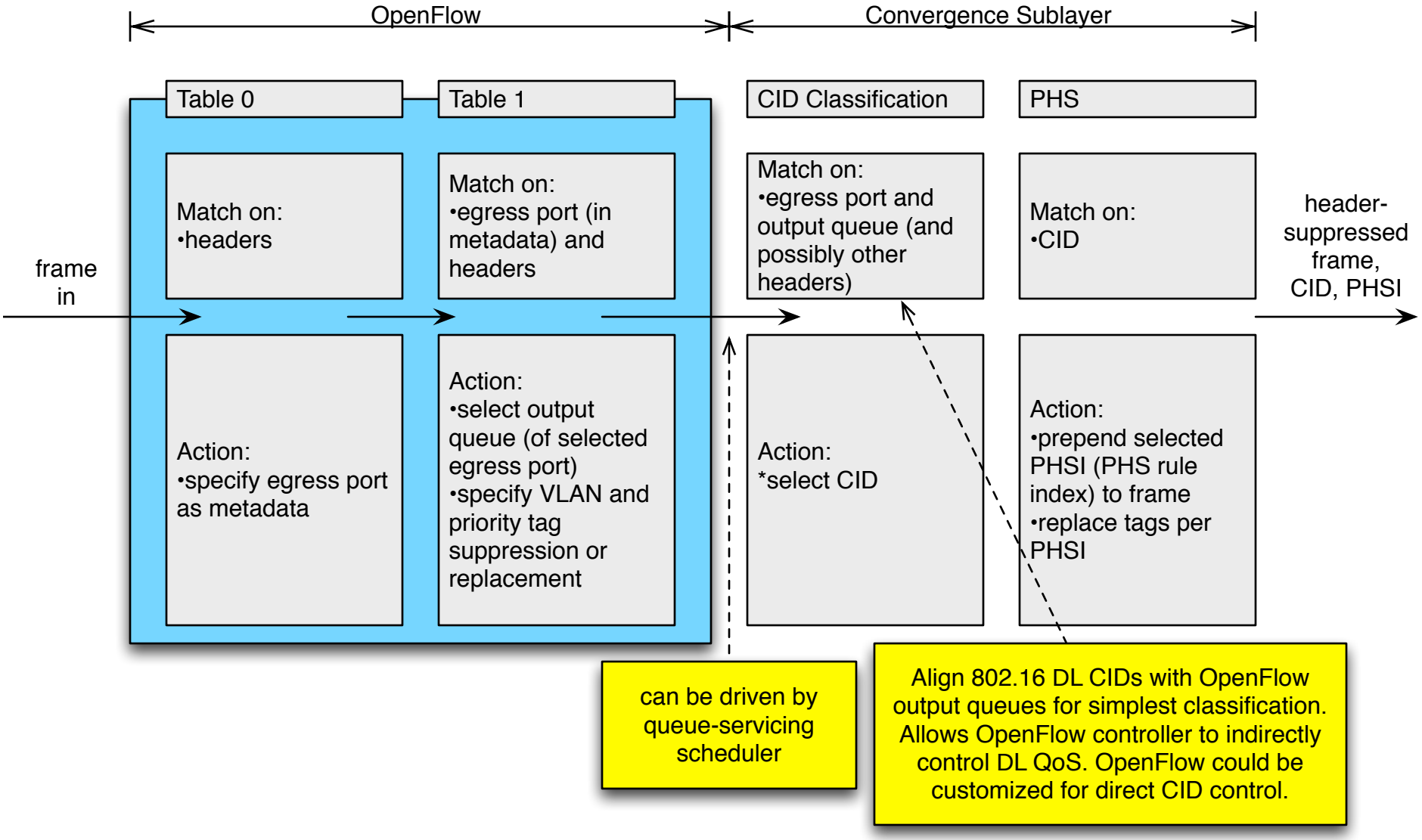
	802.16-2012 Packet CS	OpenFlow
Destination	CID	Port
Table Pipeline	No; one table, plus PHS	Pipeline sequence
Match on	Headers, with masks	Headers, with masks
Match Priority	Prioritized rules	Prioritized rules
Action without match	Drop	Specified by Table Miss entry; can send to controller for learning, etc.
Match actions & Match instructions	Forward; Drop [PHS]	Forward; Drop; Group; <Set Queue>; <Push/Pop Tag>; <Set Field>; <Change TTL>; <Write Metadata>
Counters & Timers	No	Yes
Meter Tables	No	Yes
Automatic Rule Deletion	No	Timeouts (hard and idle)

OpenFlow Queues

- *limited QoS through a simple queuing mechanism*
- *queues can attach to a port and be used to map flow entries on it*
- *Flow entries mapped to a specific queue will be treated according to that queue's configuration (e.g. min rate).*
- *queue properties*
  - *Minimum rate*
  - *Maximum rate*
  - *Experimenter defined property*

- OpenFlow Switch Specification Version 1.3.1

Downlink Pipeline



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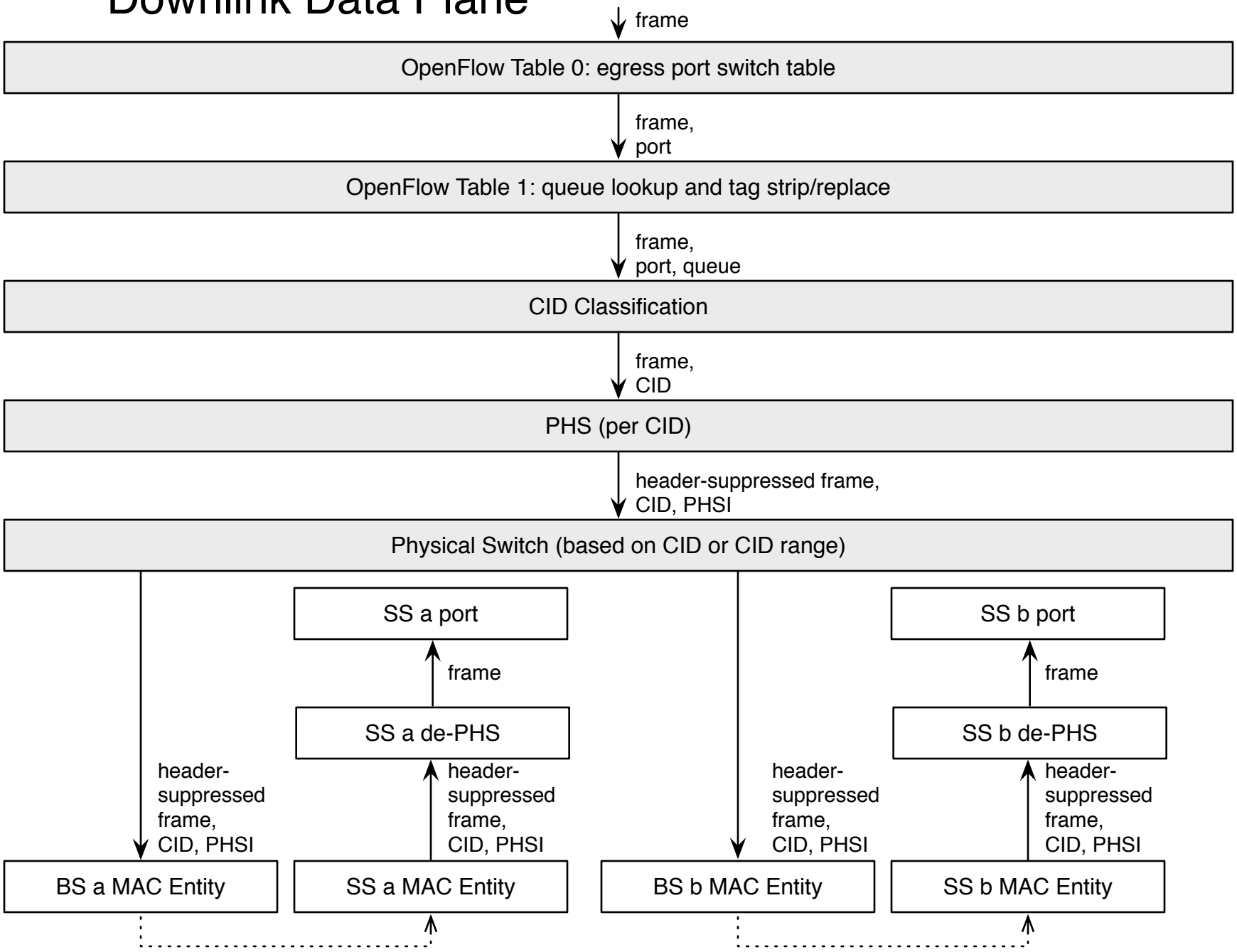
Downlink Data Plane



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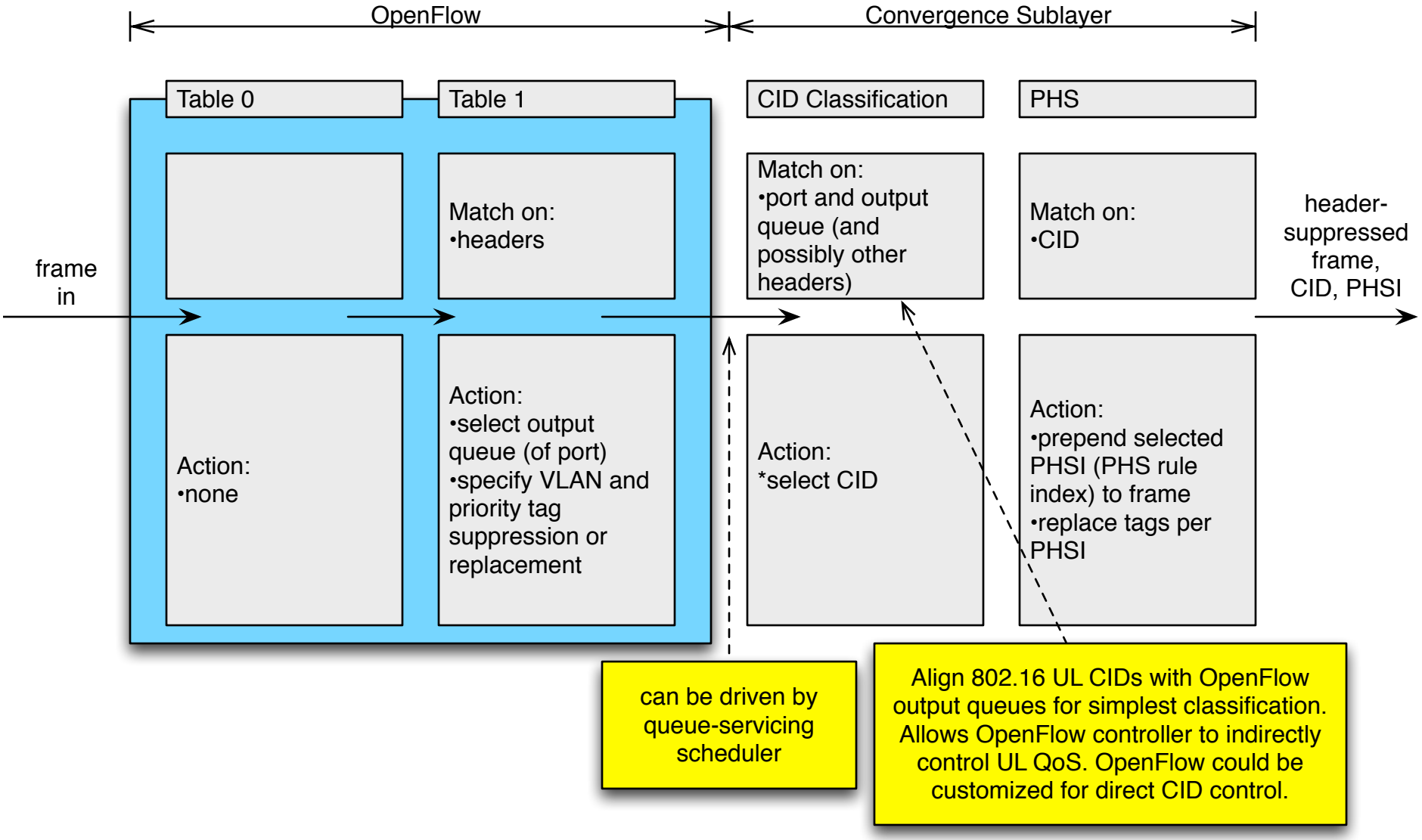
Uplink Pipeline



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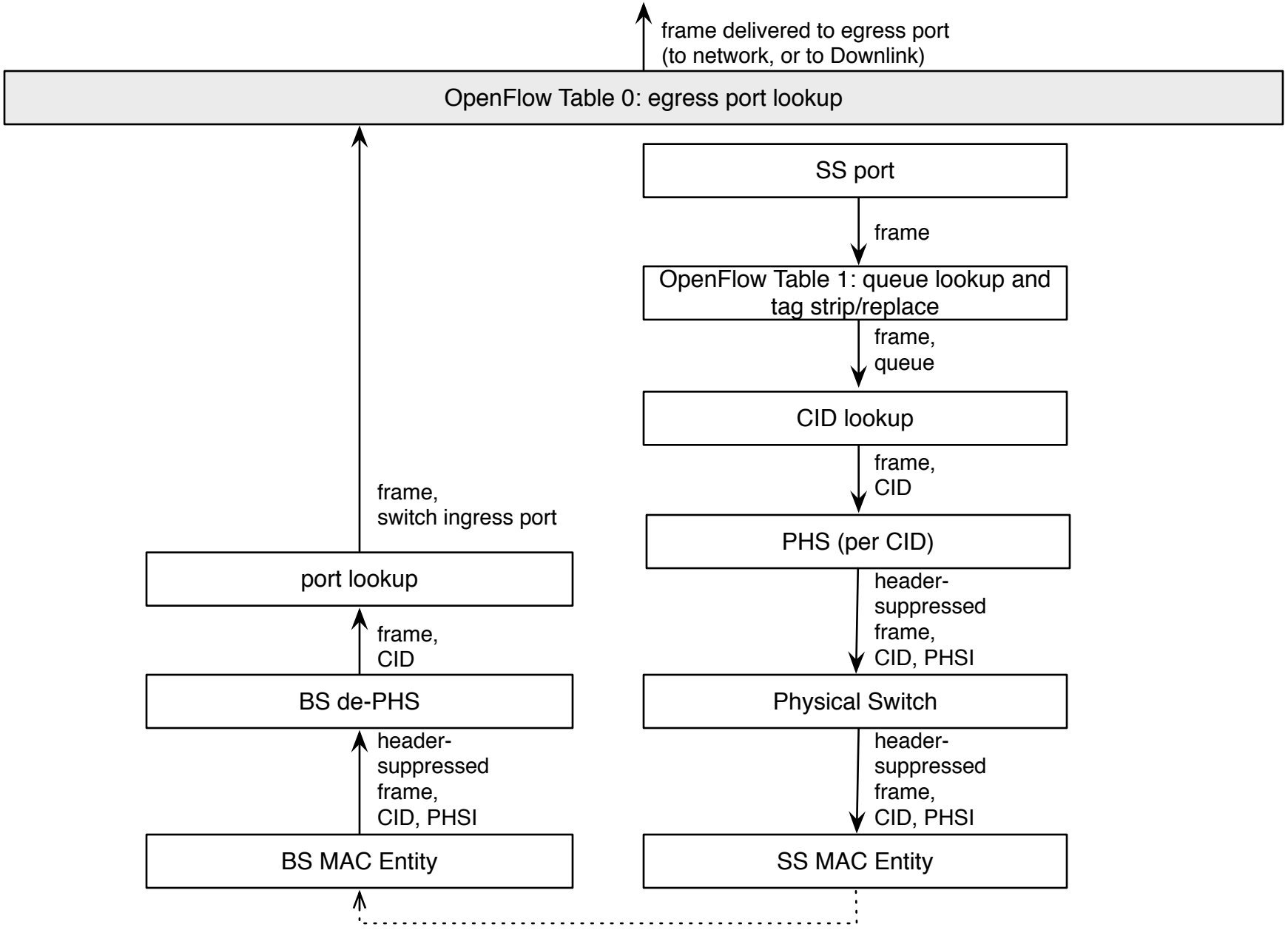
Uplink Data Plane



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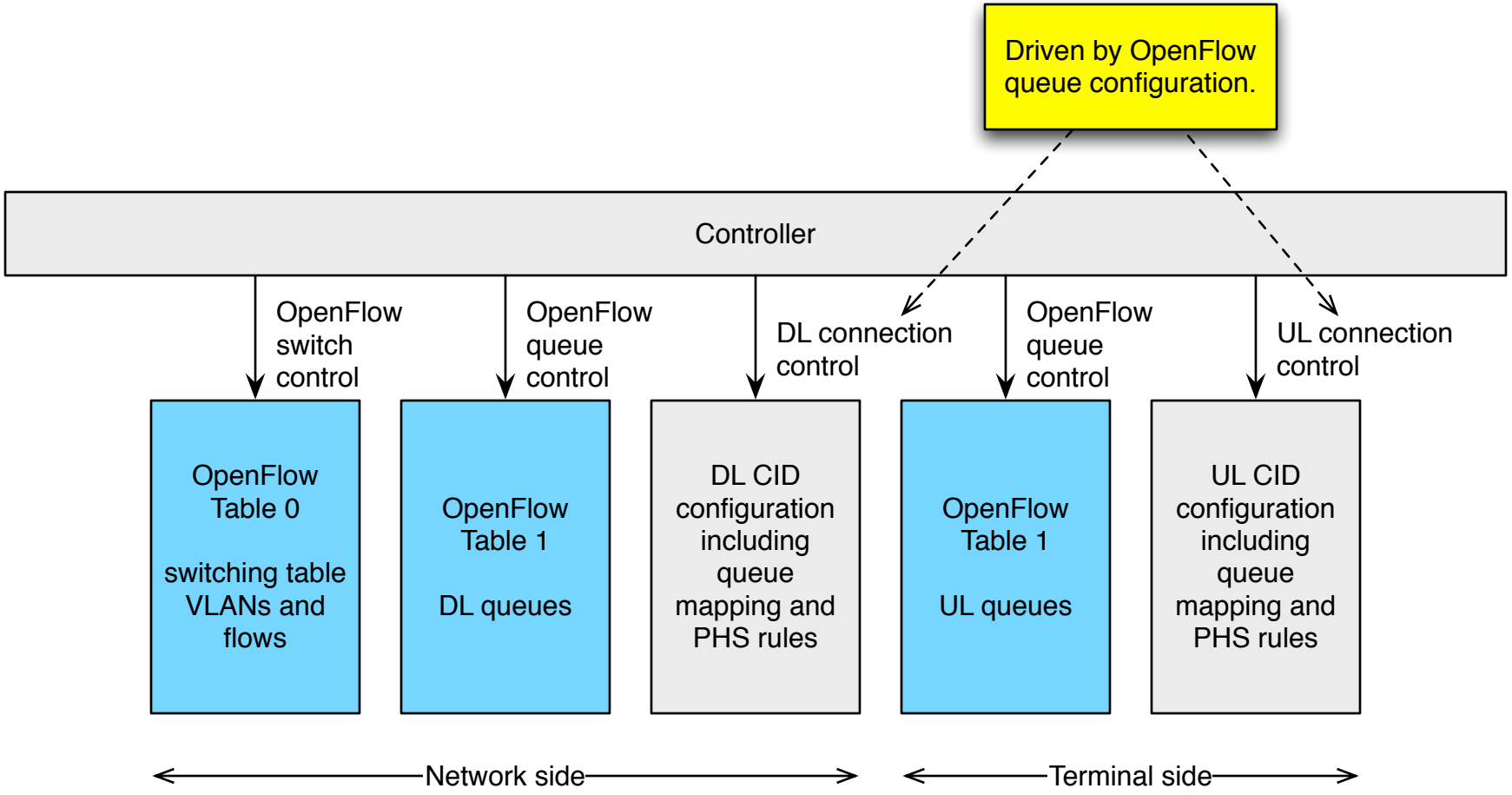
Control Plane



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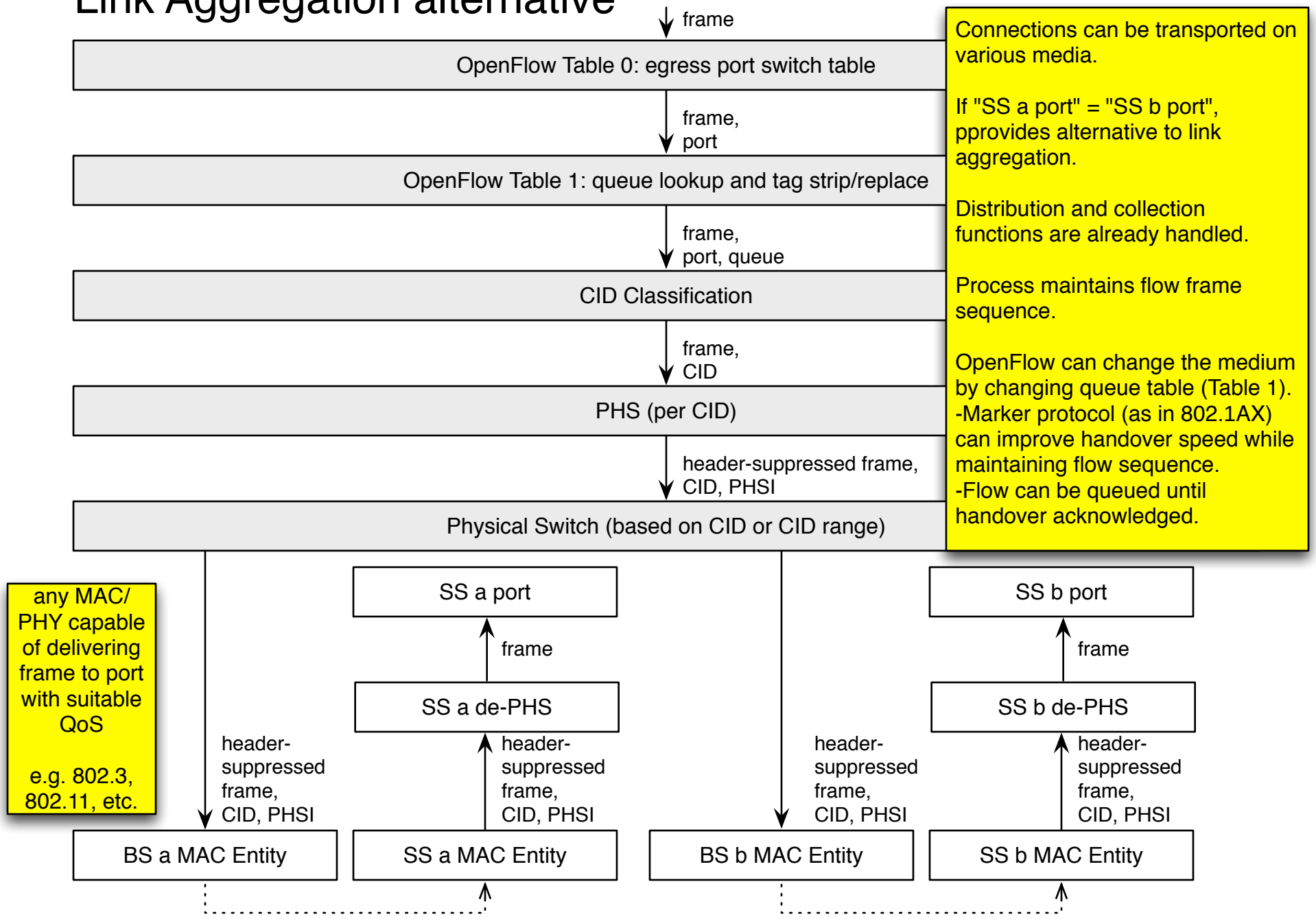
Link Aggregation alternative



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Conclusions

- OpenFlow Switch Specification specifies a programmable switch with simple Class of Service (CoS) control.
- OpenFlow switching involves packet header inspection and prioritized rules, similar to 802.16 Packet CS
  - Actions are more comprehensive than the 802.16 Packet CS
  - Control system is far more comprehensive than specified in 802.16.
- Feasible to integrate OpenFlow Hybrid Switch with switch-centric architecture of 802.16-13-0049.
- If OpenFlow CoS control and flows are mapped to 802.16 CIDs, OpenFlow controller can indirectly drive 802.16 QoS.
- OpenFlow could be modified for direct 802.16 QoS control.
- Process can support various MACs, not only 802.16.
- Process allows multi-MAC aggregation and handover.