What P4 Can Learn From Linux Traffic Control Architecture

Jamal Hadi Salim
Mojatatu Networks

Intro To Linux TC

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We define Network Service as:
The treatment of selected network packets, as defined by a user policy, so as to achieve a defined goal on the selected packets.

The TC architecture is a ***Network Service Infrastructure***

- Has been around since late 90s

Functional Block Types are abstracted to allow composition of *policy graph(s)* to achieve a ***Network Service***

4 Functional Block Types

1. ***Qdiscs*** provide templating for queue algorithms (enqueuing and dequeuing packets)
2. ***Classifiers*** provide templates that define filtering algorithms (to discriminate/select packets)
3. ***Actions*** provide templating for arbitrary packet processing
4. ***Classes*** provide templating for encapsulating qdisc FBTs to allow service topology branching

Intro To Linux TC: Functional Block Types

Some *Qdisc* Kinds:

- ***Pfifo*** which implements a basic packet counting FIFO queueing algorithm.
- ***RED*** which implements the Random Early Detection(RED) algorithm.
- ***DRR*** which implements the Deficit Round Robin(DRR) algorithm.

Some *Classifier* Kinds:

- ***u32*** which implements a 32-bit key/mask (ternary, lpm and exact) matching algorithm.
- ***flower*** which implements a multi-tuple matching algorithm.
- ***fw*** which implements a (skbmark) metadata based matching algorithm.
- Others implementing string matching, ebpf etc etc

Some *Action* Kinds:

- ***gact*** which implements amongst other things dropping and accepting of packets.
- ***mirred*** which implements redirecting or mirroring packets.
- ***skbedit*** which implements metadata editing on a packet.
- ***pedit*** which implements arbitrary packet editing

Class Kinds

- Classes provide templating for encapsulating qdisc FBTs to allow service topology branching. On their own classes do not implement algorithms, so there is only one kind.

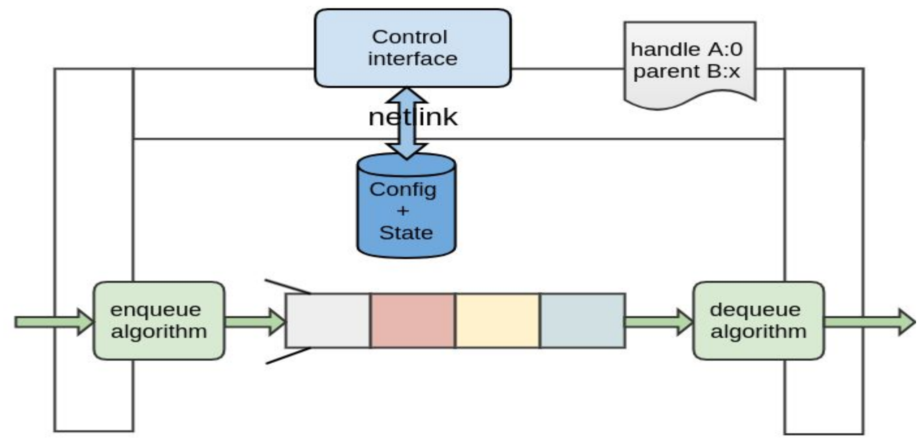
Intro To Linux TC: Policy Graphs

All FBT instances have:

- A <u>32 bit node id</u> used as graph vertex id
  - In a tree graph a parent id as well
- A control interface
  - Each node is configured individually

A <u>Service graph anchored at a location</u>

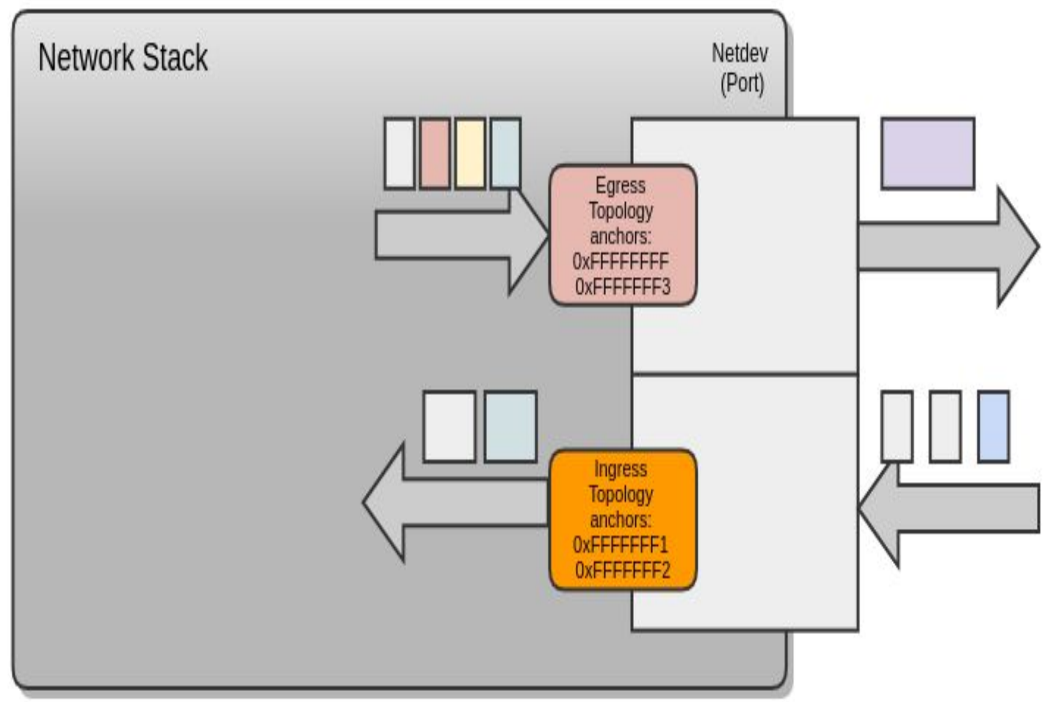
- FBT node instances are composed to form a service using node IDs



Intro To Linux TC: Policy Graph Anchors

To build a TC policy topology we need a root/start node ID (associated with a port/netdev)

- An ID of *0xFFFFFFFF* is reserved for use as a handle for the anchor point of the *EGRESS* topology.
- An ID of *0xFFFFFFF3* is reserved for use as a handle on the egress anchor point for the *EGRESSCLSACT* topology.
- An ID of *0xFFFFFFF1* is reserved for use as a handle for the anchor point of the *INGRESS* topology.
- An ID of *0xFFFFFFF2* is reserved for use as a handle for the *INGRESSCLSACT* topology.
- More could be added at different stack points

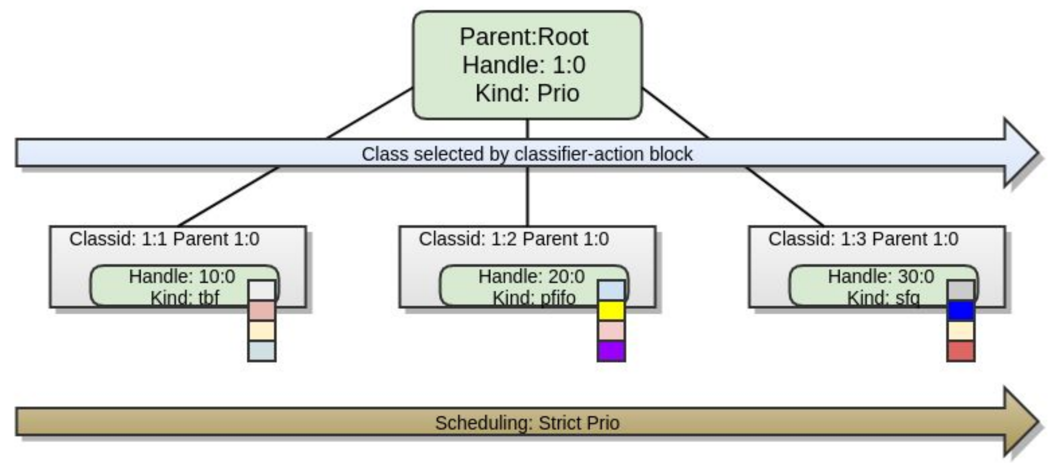


Intro To Linux TC Qdisc Subsystem

EGRESS Service Topology

Policy graph nodes composed of:

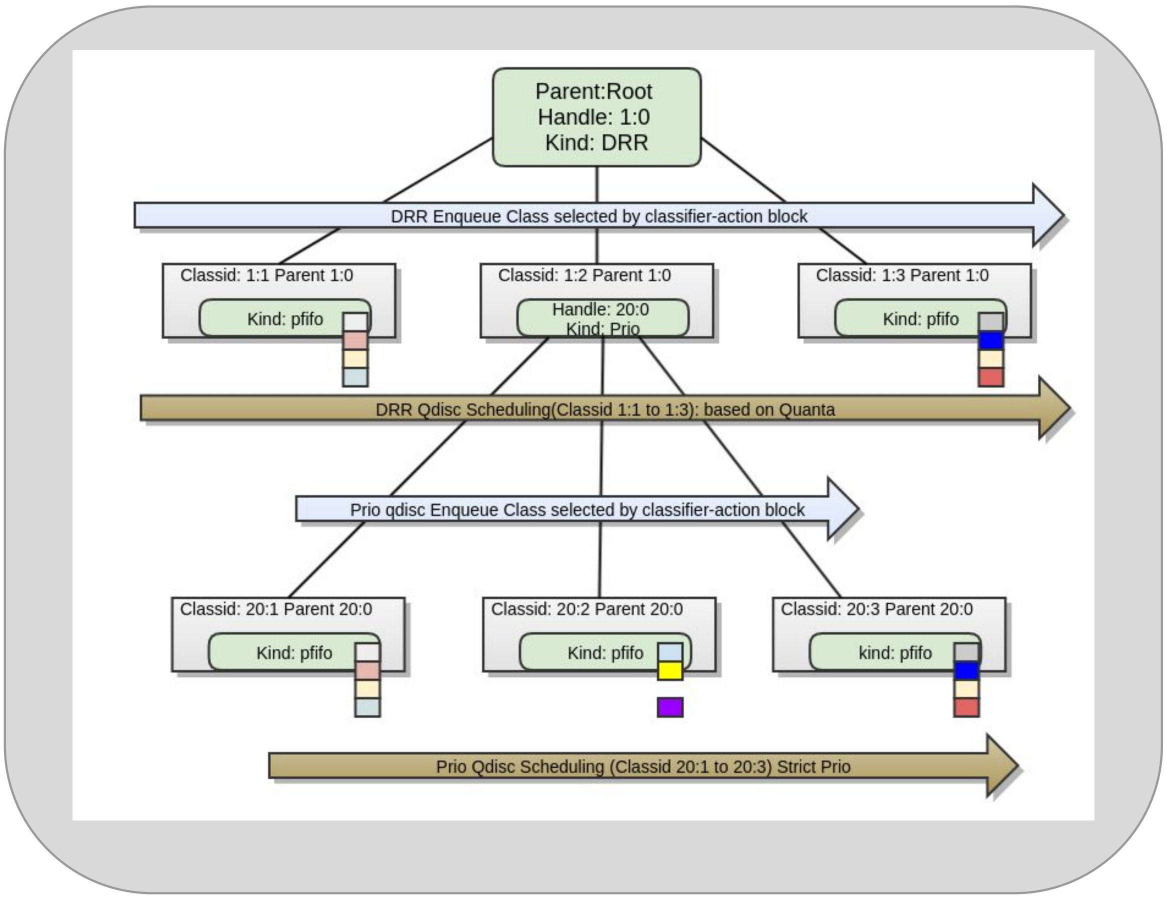
- Classifiers
- Actions
- Queueing algorithms
- Scheduling algorithms

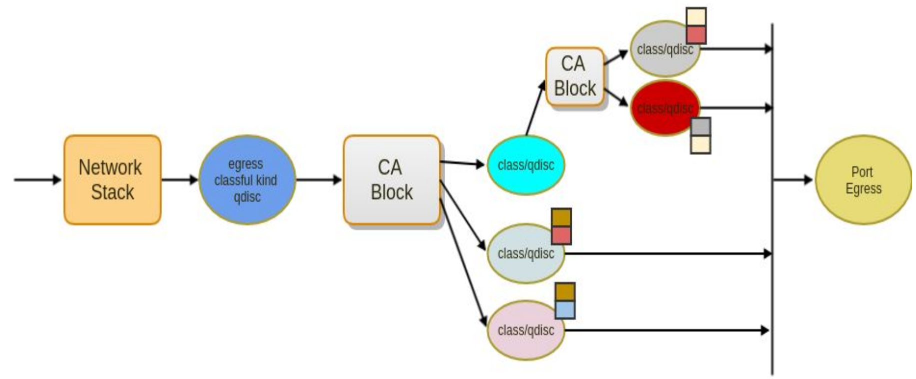


Policy scripting BNF grammar via the tc utility

- It is possible to describe more than match-action
- Policy not part of datapath program (*apply()*)
  - Graph composition of different nodes done in the control plane

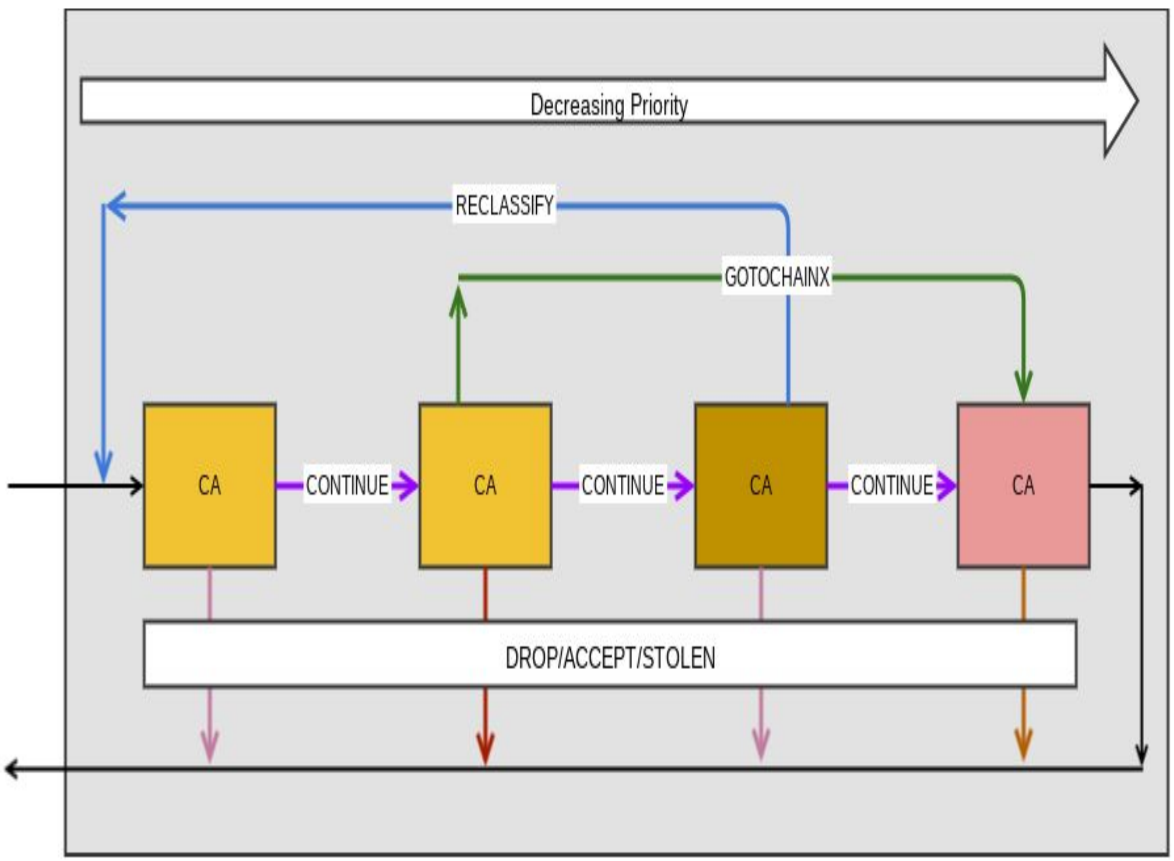
Sample EGRESS Service Topology





Intro To Linux TC Classifier Action Subsystem

Basic Classifier Action Chain/Pipeline

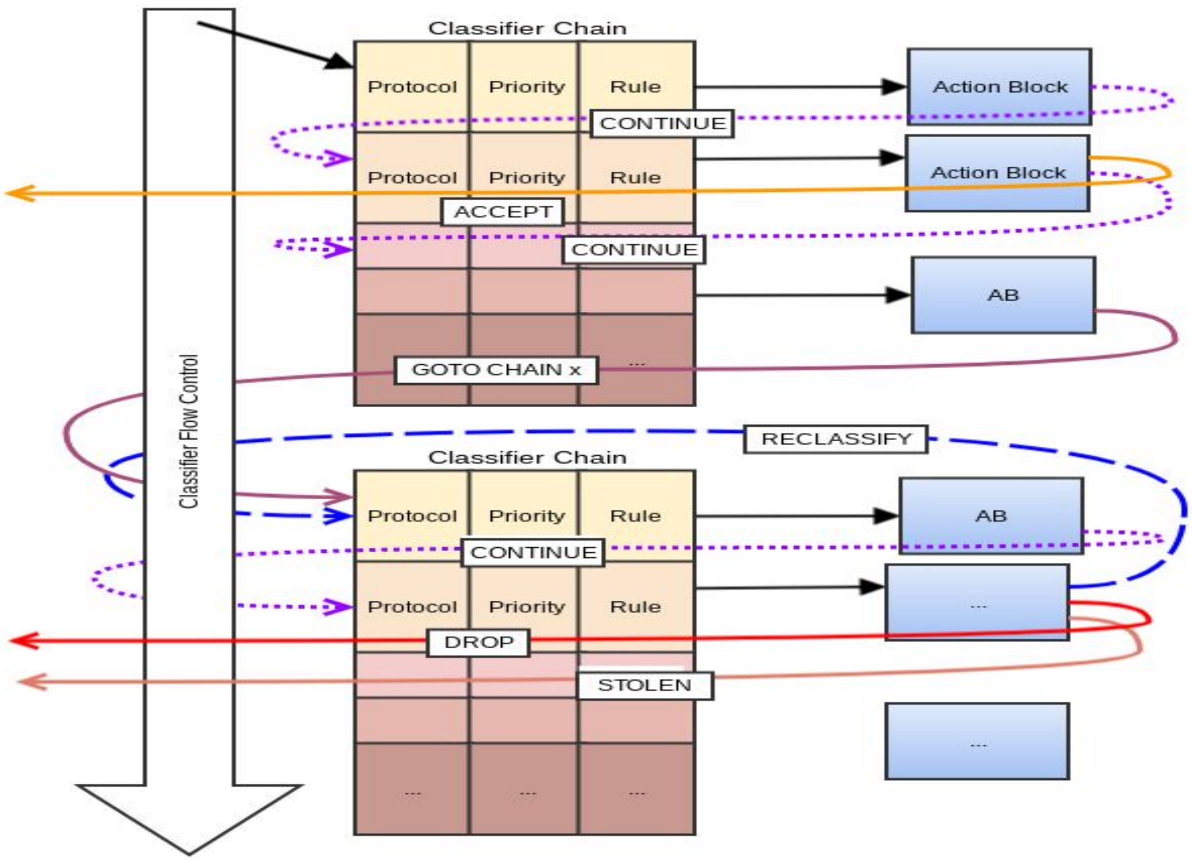


Multi Classifier types in a chain

- Multi tuple (flower)
- Raw OLV matcher (u32)
- String matches, etc

- Pipeline in priority order
- Dynamic runtime control (as opposed to static compile time)
  - Add, remove and reroute CA blocks
  - Add, remove and reroute Actions
- Action Block Result opcodes dictate exec path

More Complex Classifier Action Pipeline



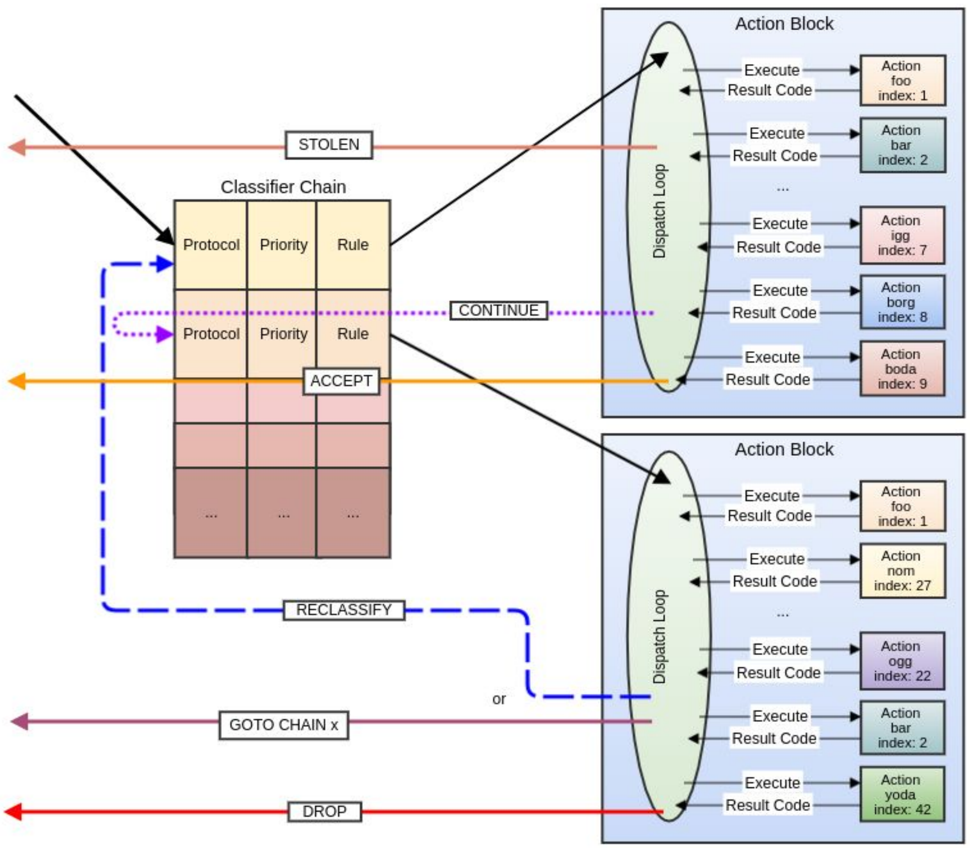
Each classifier match keyed by *{protocol, priority, header}*

- <u>Lowest priority is default</u>
  - No need for speacial Default matches

<u>TC CA Blocks shareable</u>

- *Across ingress, egress +port*
  - *P4 MA can only exist within a control block*

Peeking into a Classifier Action Block



<u>Multiple Actions per match rule</u>

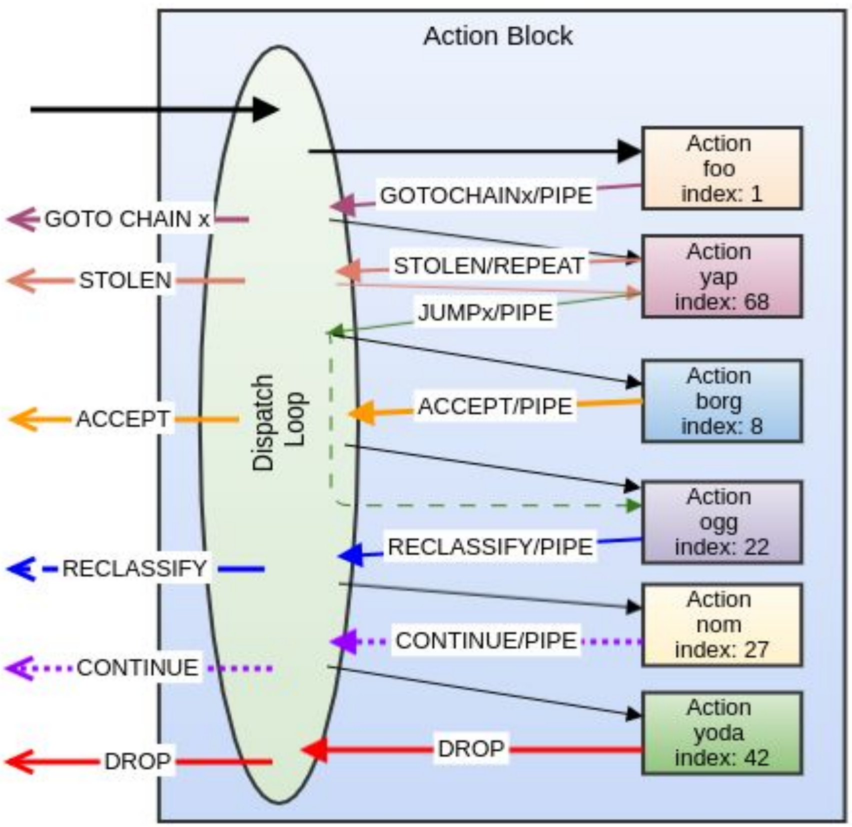
OPCODES are

1. programmed into the actions
2. generated by the actions based on runtime conditions

Each action can act on the whole packet

- Consider an action that does packet compression for example
  - P4 deals with headers only?
  - Means activity where the whole packet is processed requires redirection to an external device?

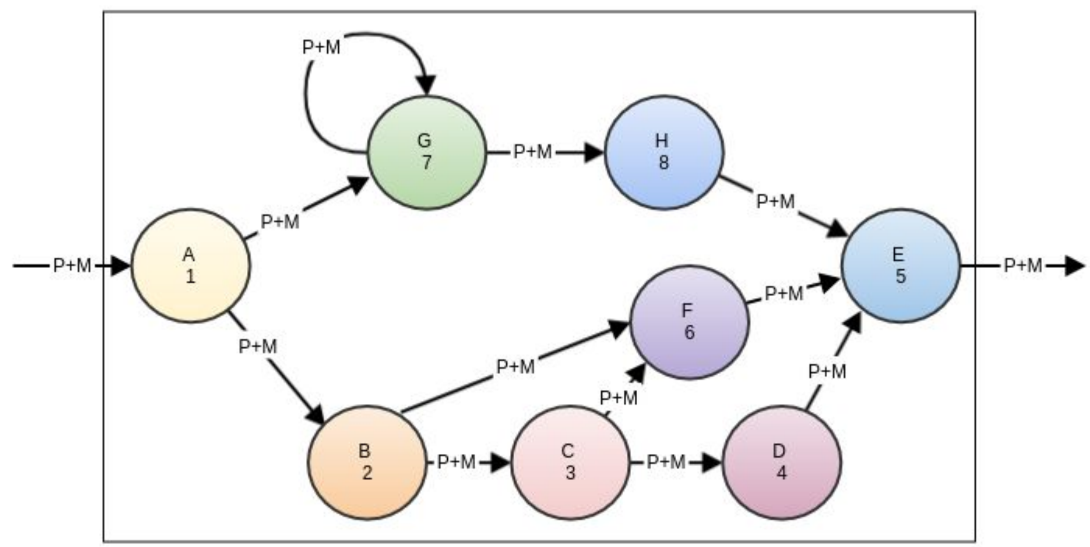
Actions Runtime Implementation vs Abstraction



More OPCODES: *REPEAT, PIPE, JUMPX*

Allows programming control abstraction

- if/else/elseif/while/goto



Peeking Into Actions Implementation

Action kind = foo ID=x

Index	Attribute 1	Attribute 2	t-stamps	cookie (opt.)	stats
1					
2					
3					
4					
. . .					
N					

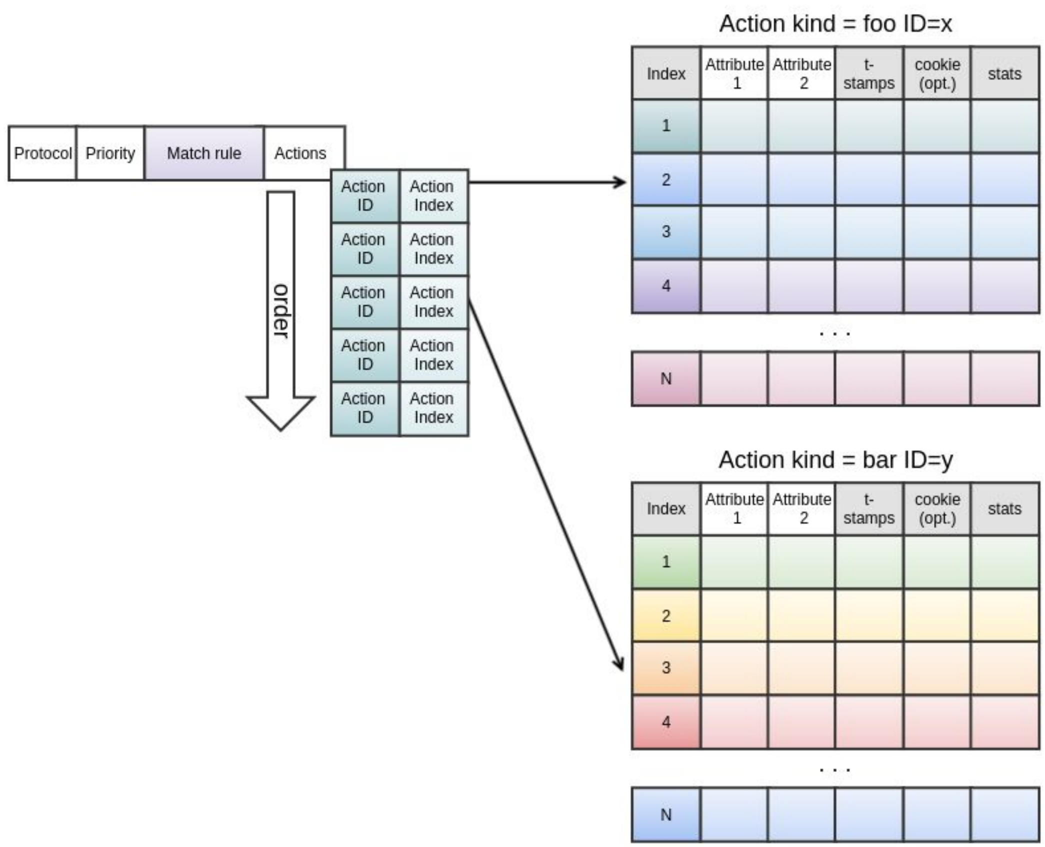
Actions are abstracted as <u>indexed tables</u>

- Each action has one table per instance

Control instantiates action table rows with desired attributes

- When specifying the actions with matches (*<u>by value</u> as in P4 semantics*)
- Independently then binding to matches (*<u>by reference</u>*)

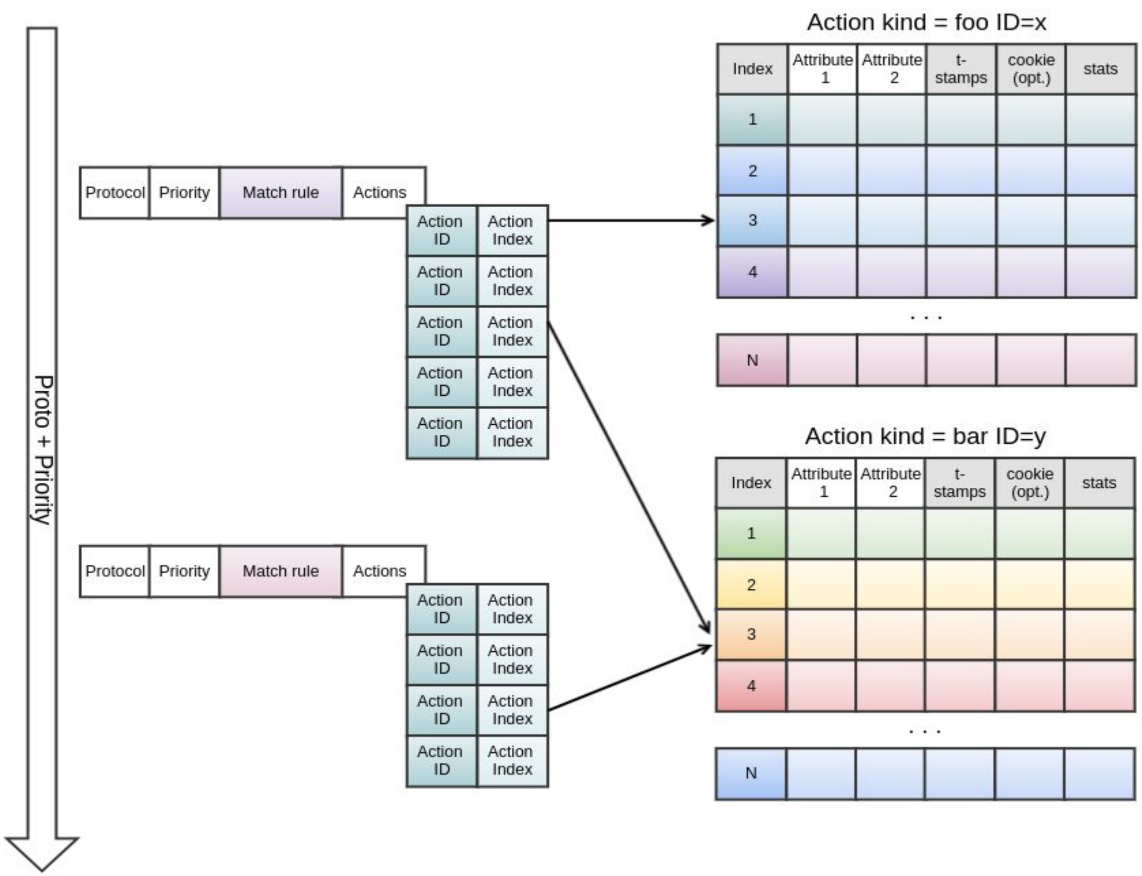
Peeking Into A Classifier Action Block



Matches point to an <u>ordered list of actions</u>

- From a table perspective actions are referred to using a foreign key
- From a s/w implementation perspective they are pointers to the action info structures

Action Sharing



Because actions are referenced by their {type id, index} they can be shared by multiple matches

How TC Can Help P4

Suggestions: Modularity And Policy Control

Allow for decomposable construction of match-action

- Runtime binding
- Independent upgrades and maintenance
  - Add a new action without recompiling the P4 program

Q: How difficult would it be to have *hardware* implement dispatchers for Classifier-Action?

Move *apply()* out to control plane

- New policy language? tc cli has a BNF grammar that would be a good start
- Graph policy definition of the different constructs
  - Independent policy updates

Suggestions: Traffic Management

Schedulers and enqueue algorithms

- Is PIFO sufficient?

Hierarchical construction

- Possible if TC graph abstraction is adopted

Suggestions: Multiple Actions Per Match

Doable with an action dispatch loop

Suggestions: Sharing Of Tables And Actions

TC supports Match-Action blocks to be shared on different controls

- Achievable on P4 hardware?

TC supports sharing of actions across controls

- P4 already supports it for meters and counters
  - Just need to make it generic for <u>all</u> actions

Suggestions: Event Modelling

Not sure how well to define eventing to controller

- TC kernel allows to notify subscribers of datapath and control activities (table changes etc)

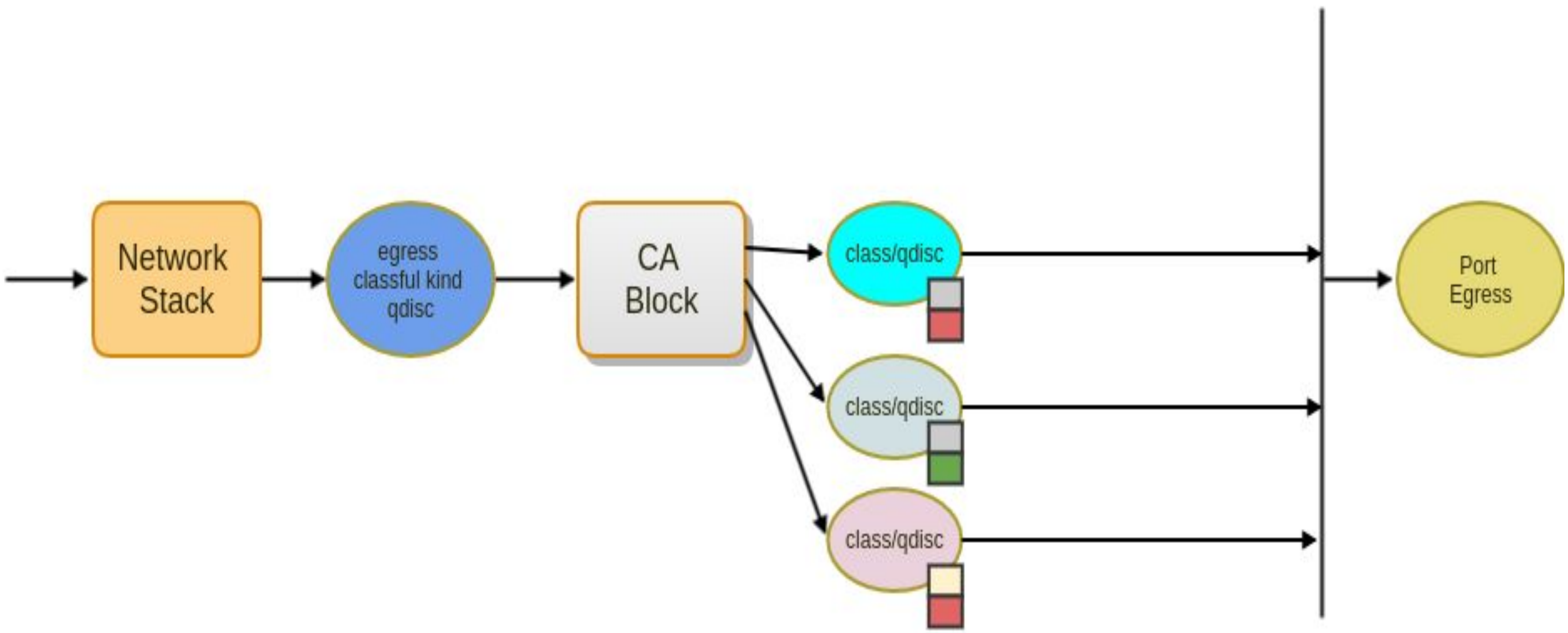
Back Slides: Sample Service Topologies

EGRESS Classless Service Topology

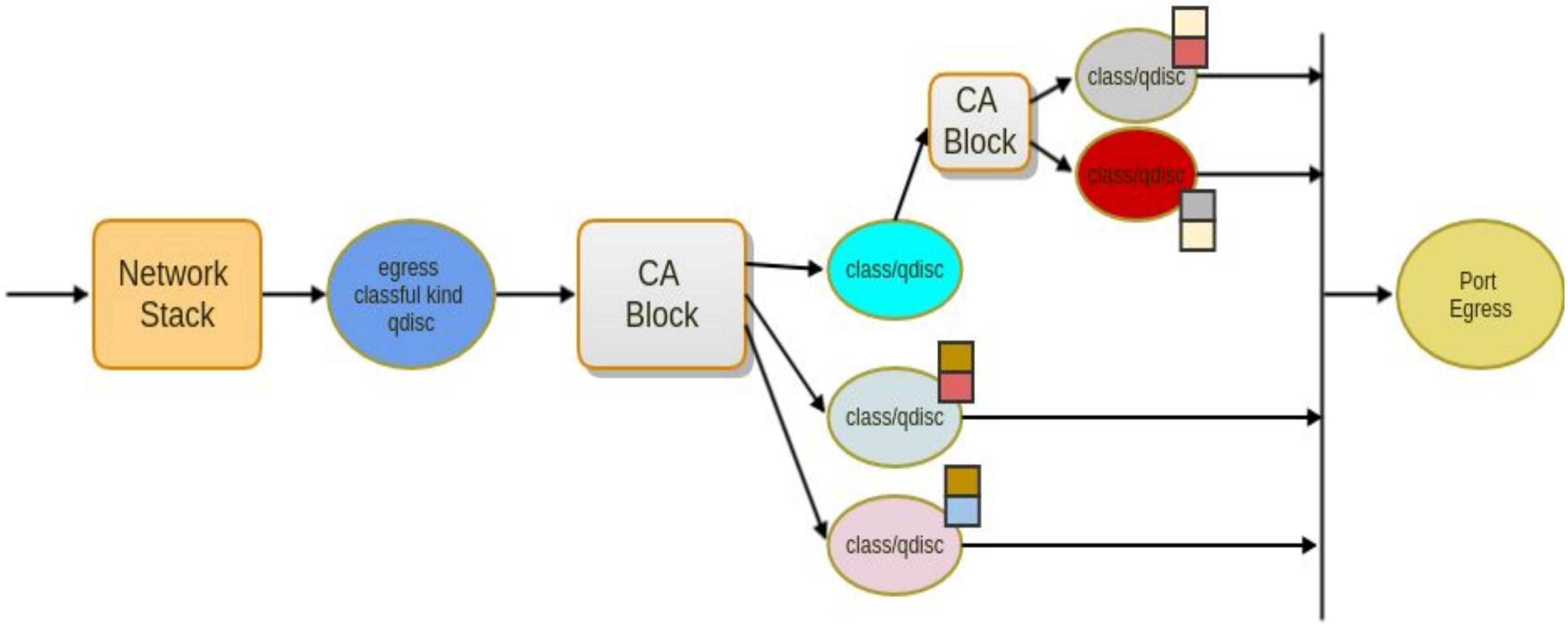
Very simple service topology

- No matches or actions
  - Implicit metadata classification
- Anchored at Egress of a port/netdev

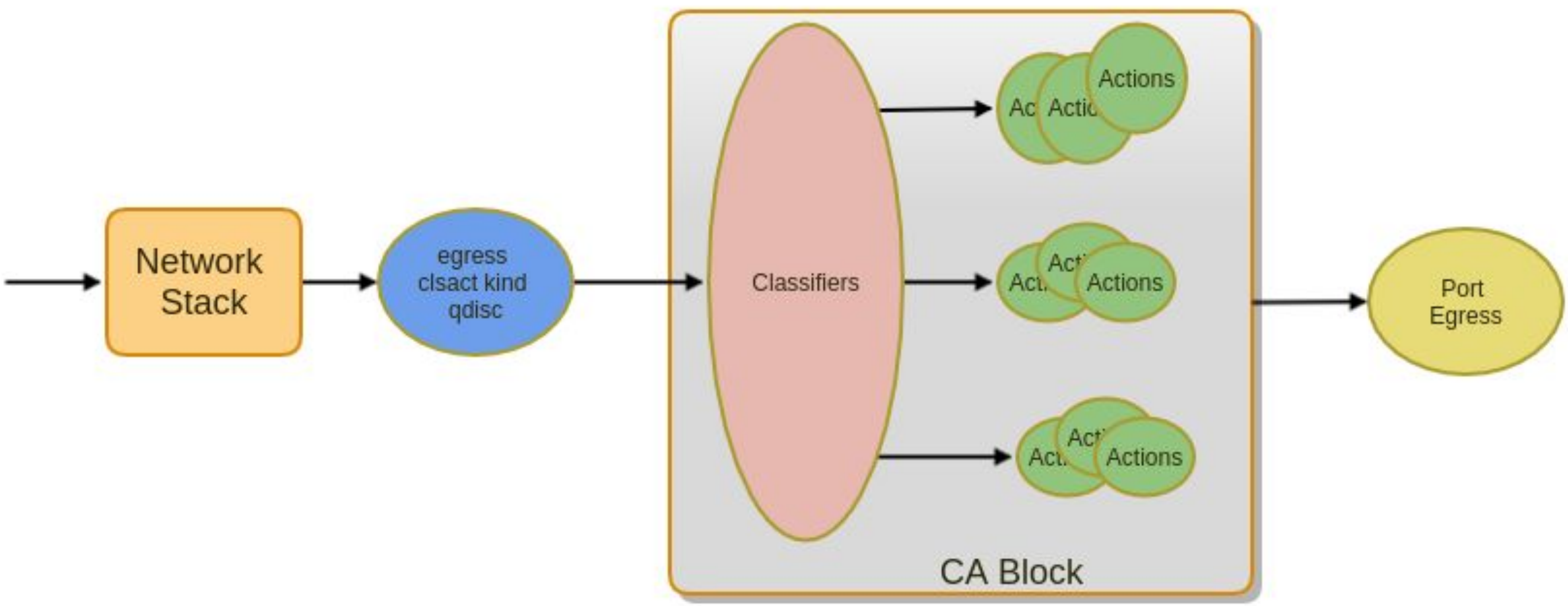
EGRESS Classful Service Topology



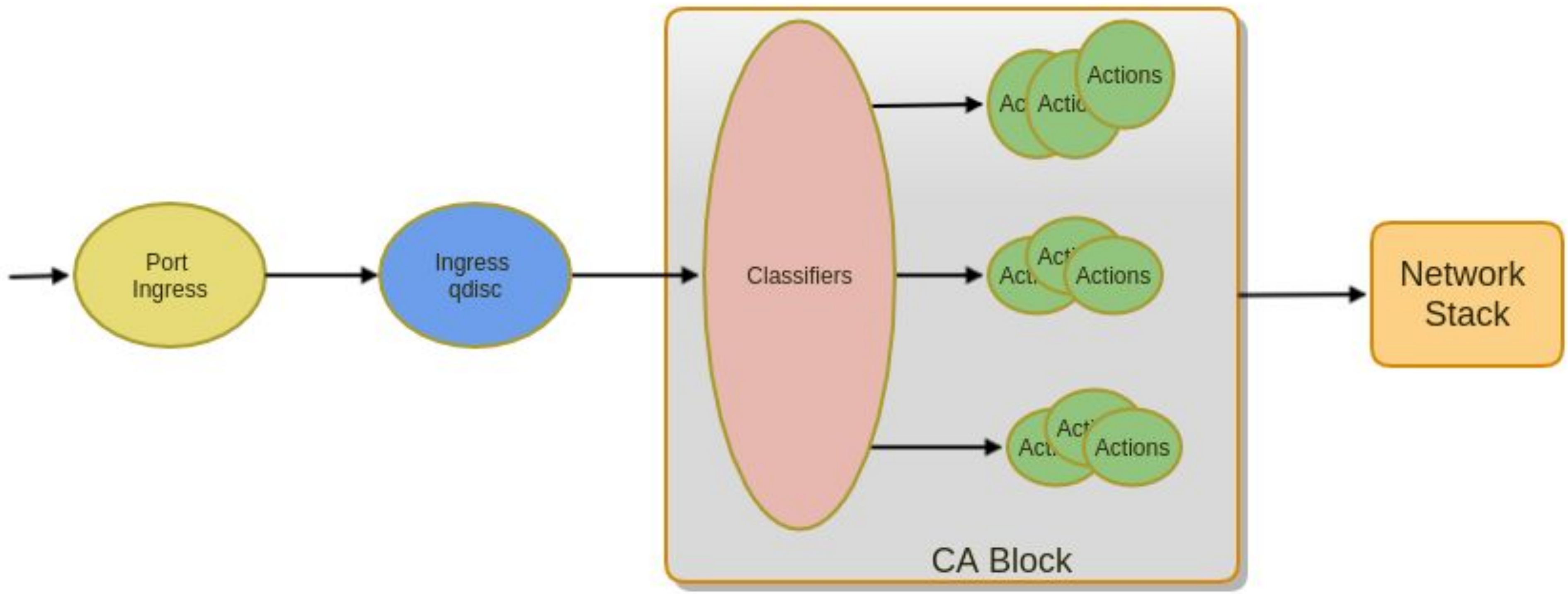
EGRESS Complex Classful Service



EGRESS Clsact Service Topology



INGRESS Service Topology



INGRESS To Egress Service Topology