Reusing Network Services Logic to Improve Network Performance

Yotam Harchol
vmware Research

(This work was done while at the Hebrew University)

Joint work with Anat Bremler-Barr and David Hay

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THE HEBREW UNIVERSITY OF JERUSALEM

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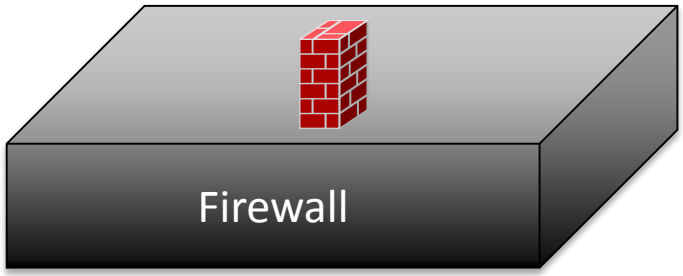
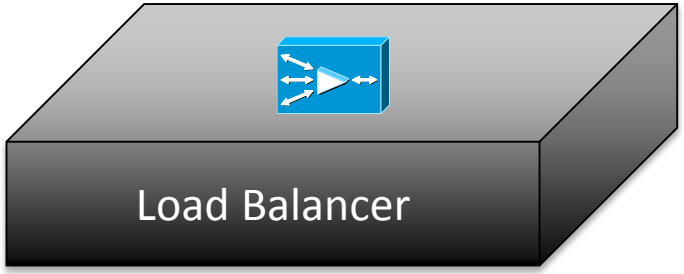
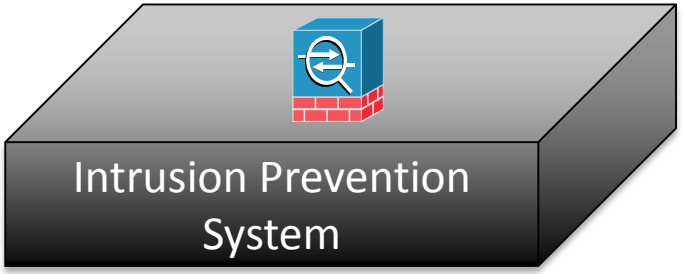
Network Functions (Middleboxes)



- Monolithic **closed** black-boxes
  - ✗ High ***cost***
  - ✗ Limited ***provisioning*** and ***scalability***





Network Function Virtualization (NFV):

- ✓ Reduce ***cost*** (by moving to software)
- ✓ Improve ***provisioning*** and ***scalability*** (by virtualizing software NFs)

At the cost of:

- ✗ Reduced ***performance*** *(mainly **latency**)*

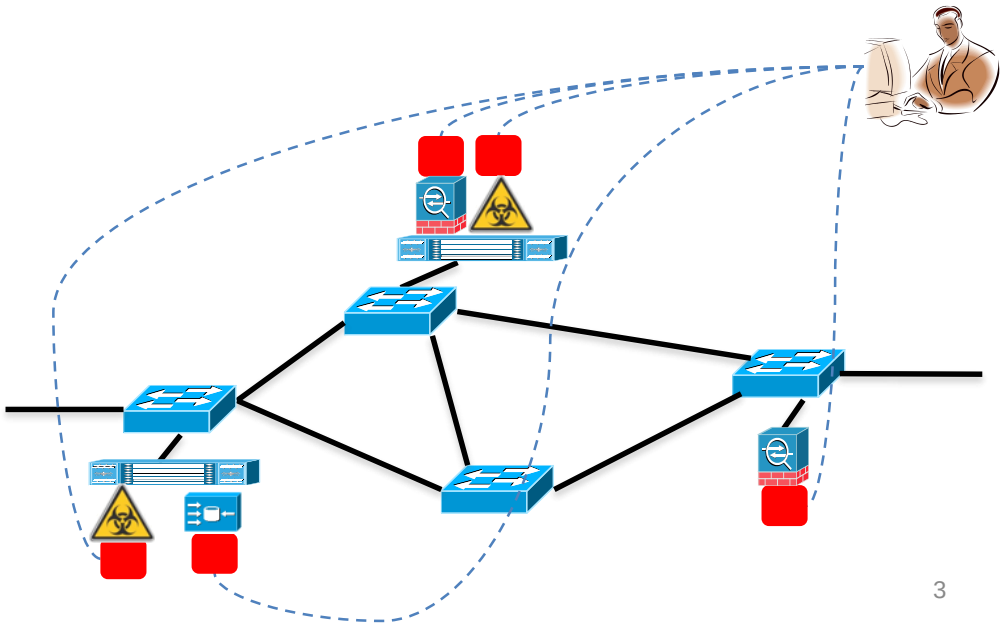
Network Functions (Middleboxes)

✗ High ***cost***

✗ Limited ***provisioning*** and ***scalability***

✗ Limited and separate ***management***

- Different vendors
- No standards
- Separate control plane



Network Functions (Middleboxes)

- Actually, many of these black-boxes are very modular

✗ High ***cost***

✗ Limited provisioning and scalability

✗ Limited and separate management

✗ Limited ***functionality*** and limited ***innovation*** (High entry barriers)

✗ Similar complex processing steps, ***no re-use***

OpenBox

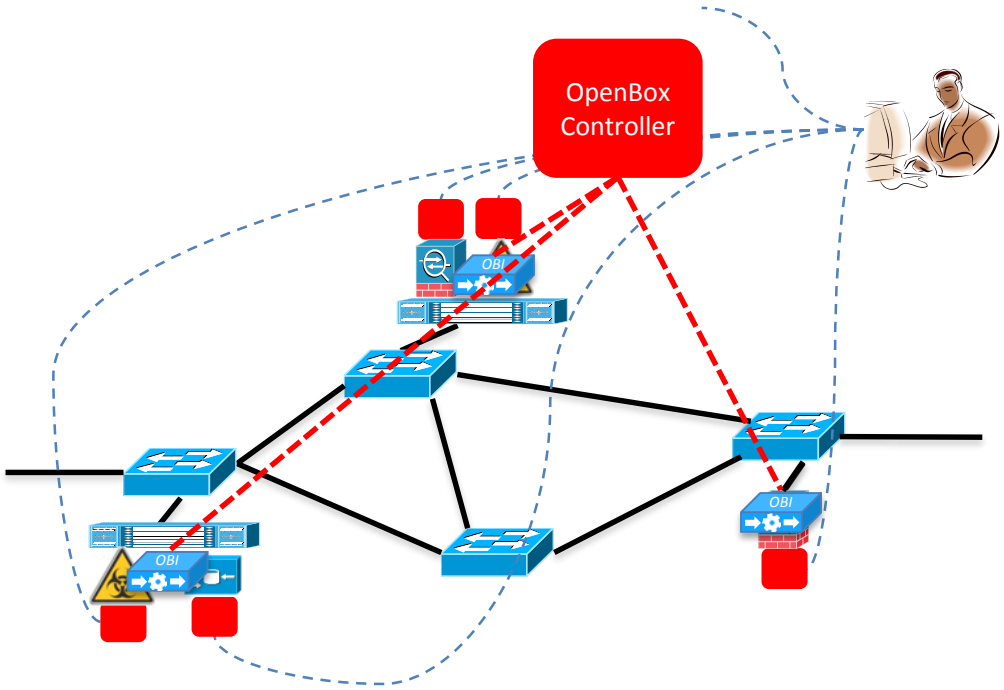
www.openboxproject.org

github.com/OpenBoxProject

- **OpenBox: A new software-defined framework for network functions**
- Decouples network function control from their data plane
- Unifies data plane of multiple network functions

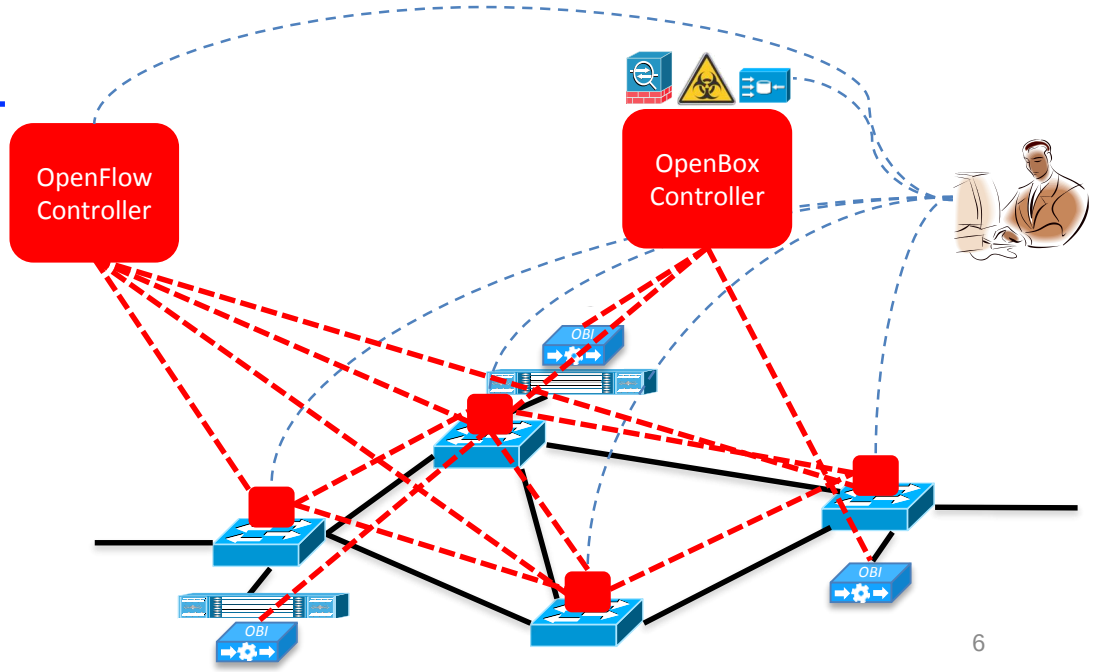
Benefits:

- ✓ Easier, unified control
- ✓ Better performance (improved latency)
- ✓ Scalability
- ✓ Flexible deployment
- ✓ Inter-tenant isolation
- ✓ Innovation



Software Defined Networking

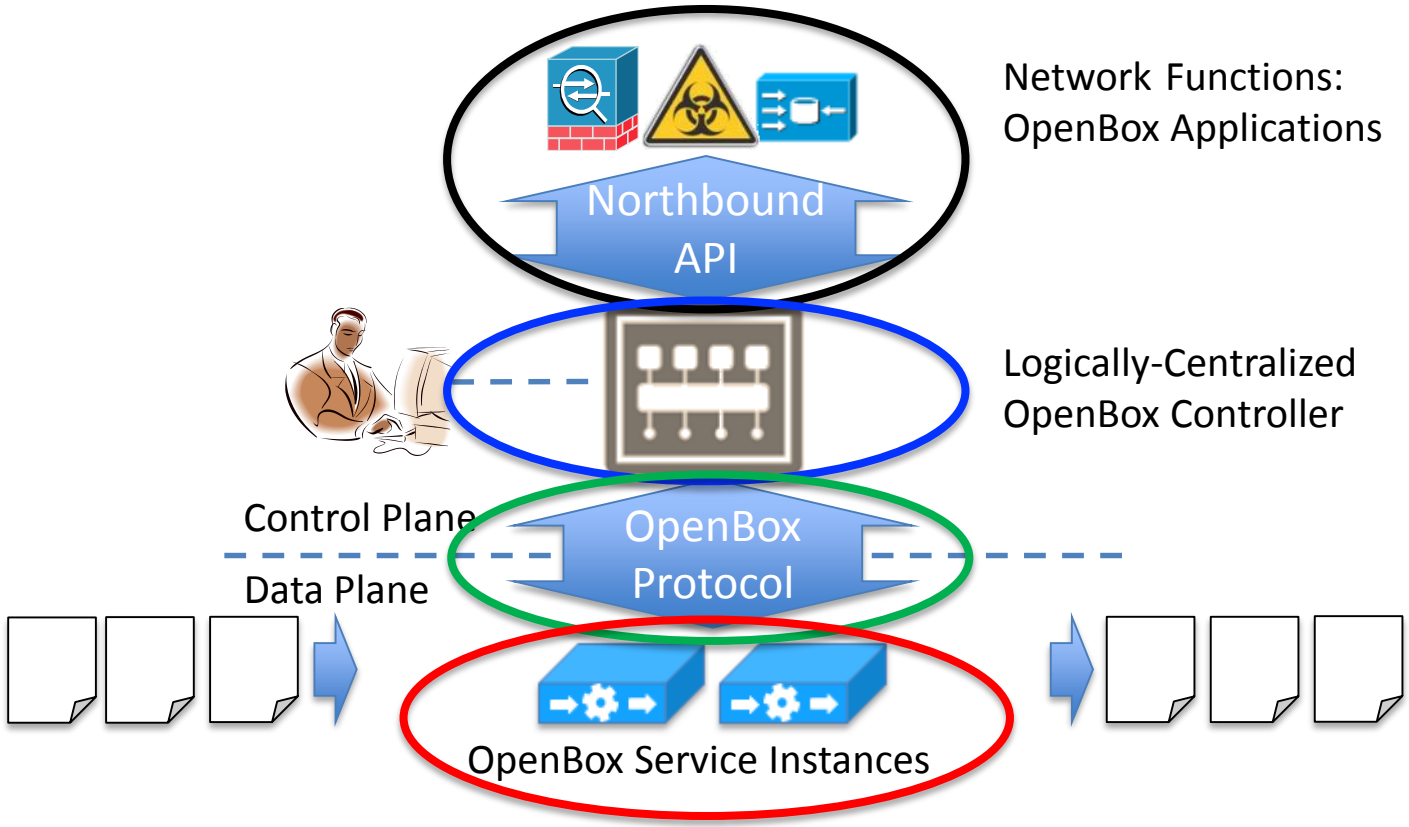
- High ***cost*** of ~~*middleboxes*~~ *switches*
- Limited ***provisioning*** and ***scalability*** of ~~*middleboxes*~~ *switches*
- Limited ***management*** of ~~*middleboxes*~~ *switches*
- Limited ***functionality*** and limited ***innovation***
- Complex ~~processing steps~~ *distributed algorithms*



40%-60% of the appliances in large-scale networks are middleboxes!

[Sherry & Ratnasamy, '12]

The OpenBox Framework



Additionally:

- ✓ Isolation between NFs / multiple tenants
- ✓ Support for hardware accelerators
- ✓ Dynamically extend the protocol

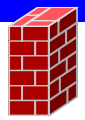
Observation:

Most network functions do very similar processing steps

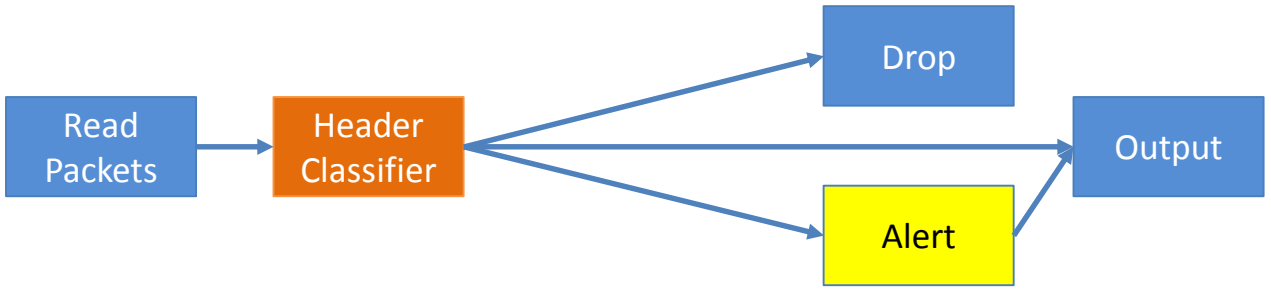
But there is no re-use…

The design the OpenBox framework is based on this observation

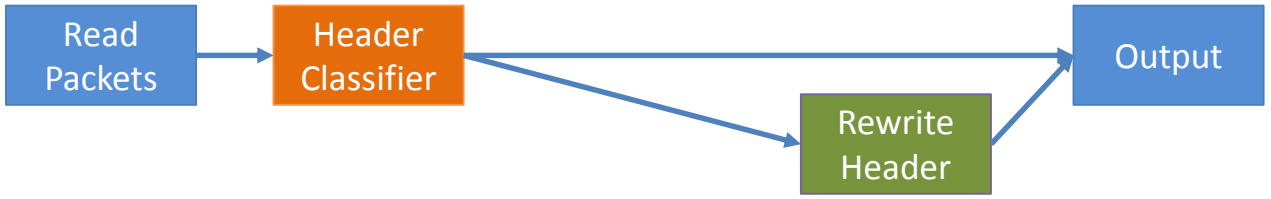
Network Function Decomposition



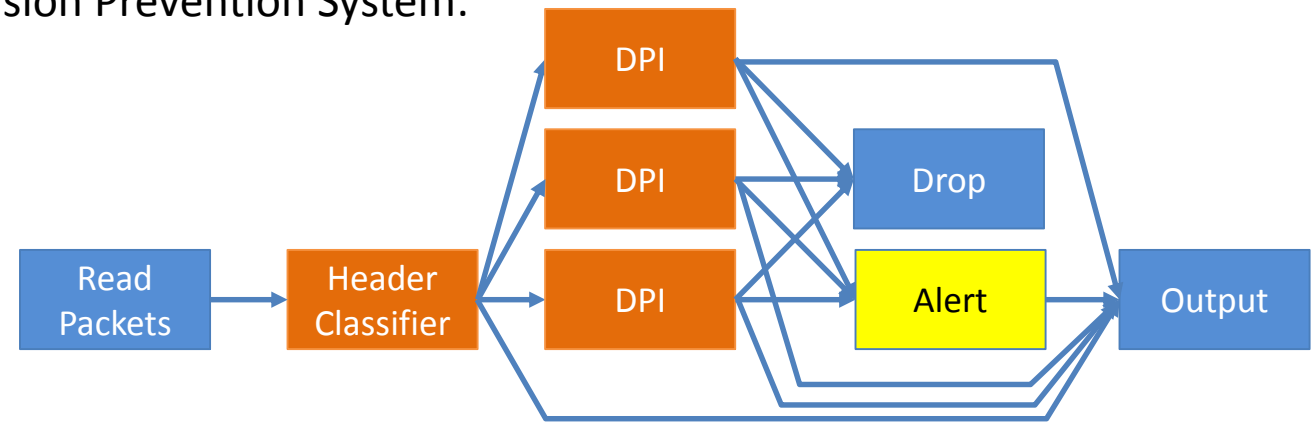
Firewall:



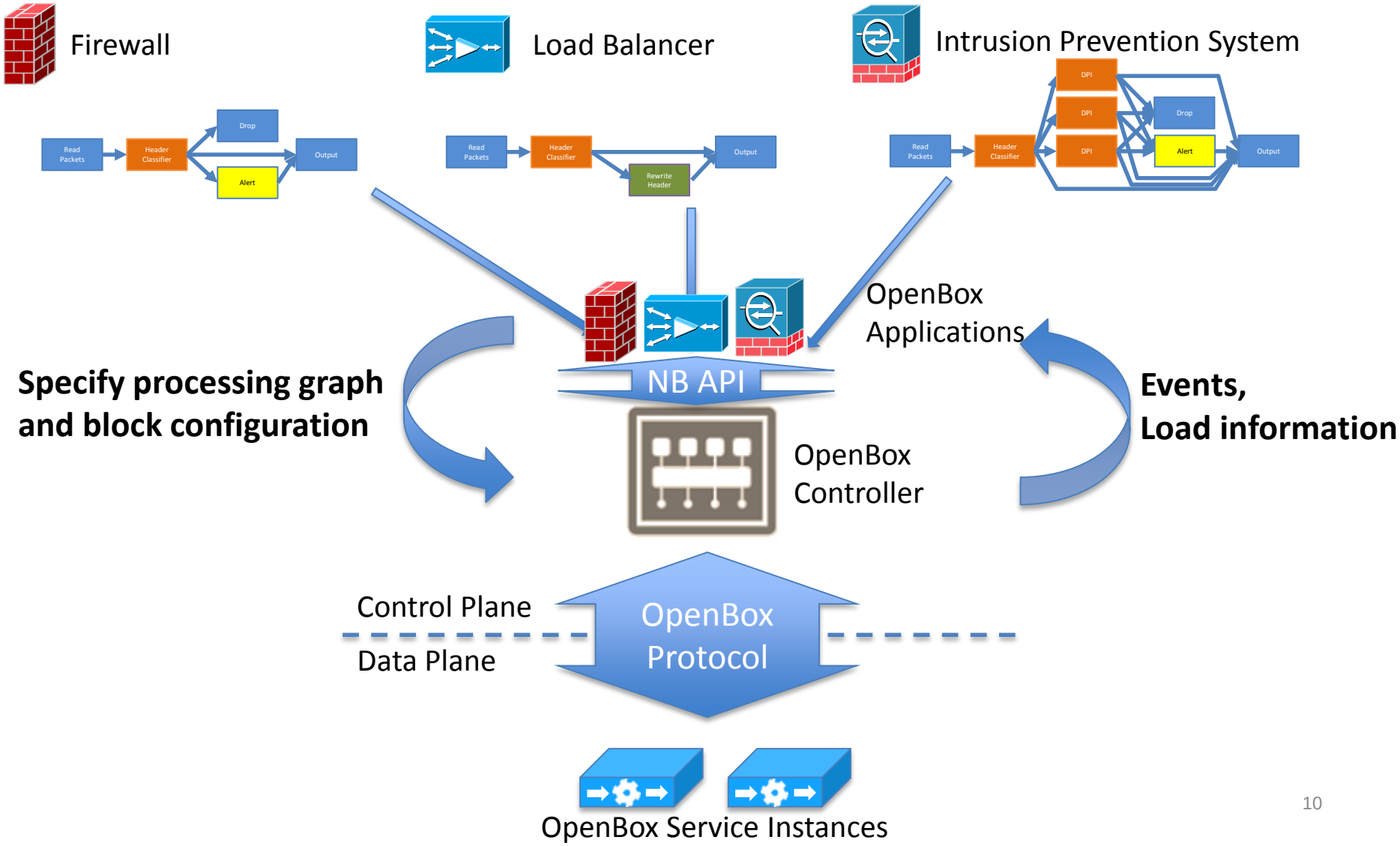
Load Balancer:



Intrusion Prevention System:



Northbound API

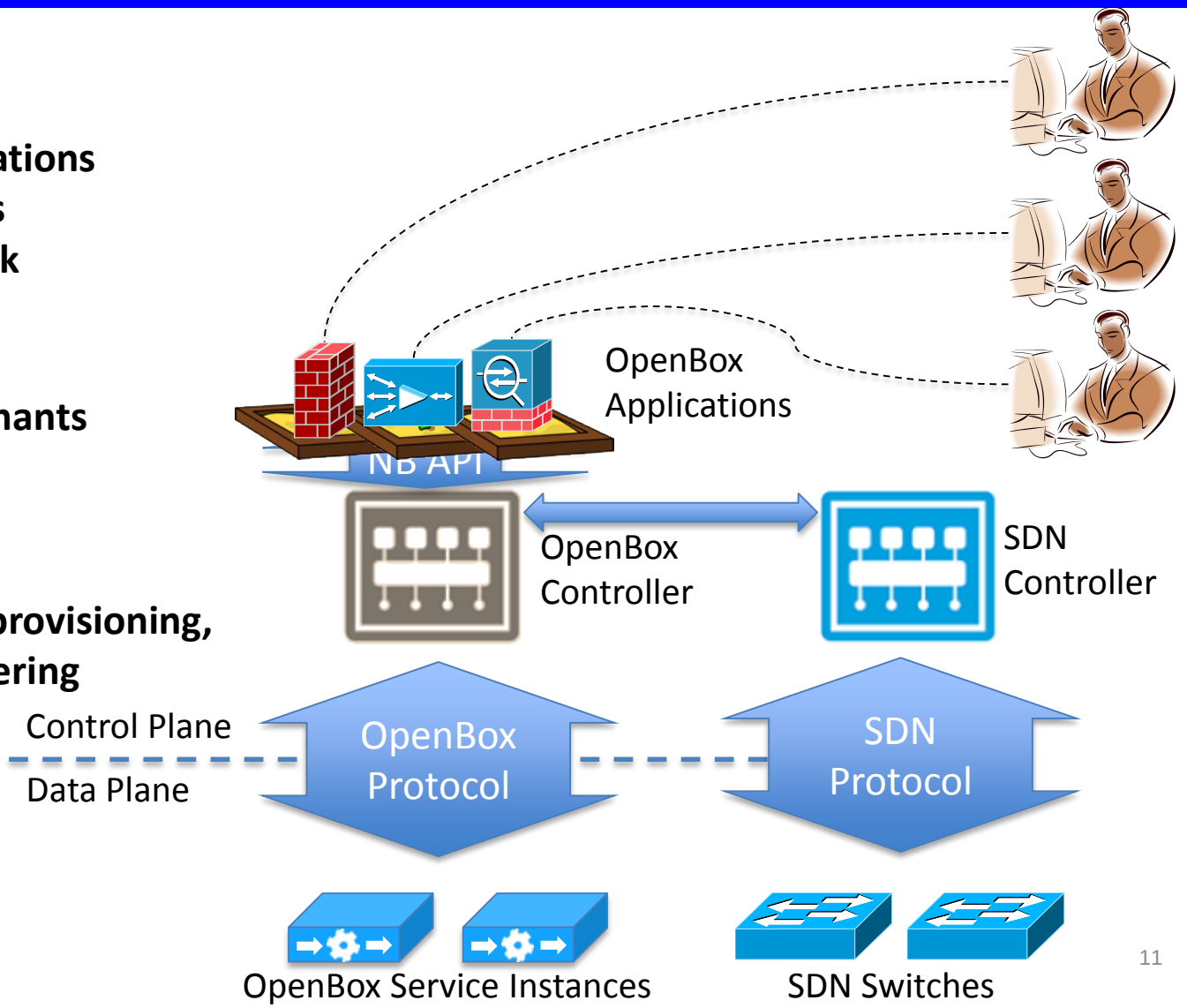


Logically-Centralized Controller

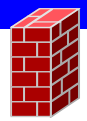
Multiple tenants
run **multiple applications**
for **multiple policies**
in **the same network**

Isolation between
applications and **tenants**
enforced by NB API

Network-wide view
Automatic **scaling, provisioning, placement,** and **steering**



Naïve Graph Merge



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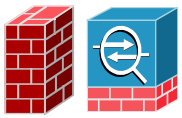


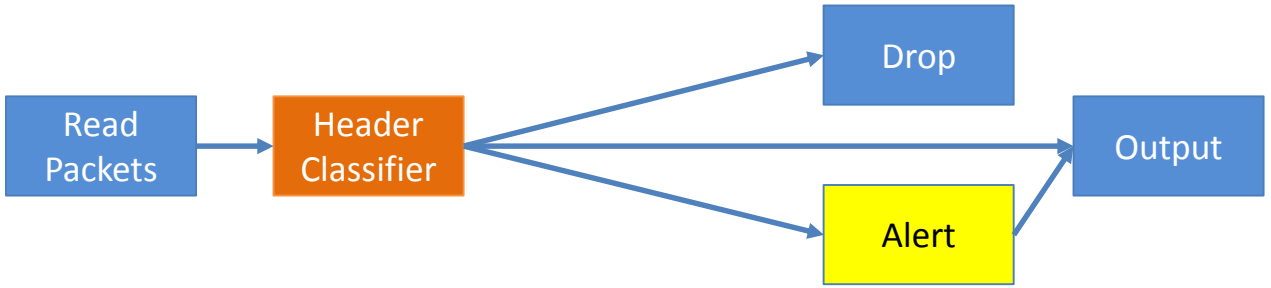
Concatenated Processing Graph:

Intrusion Prevention System:

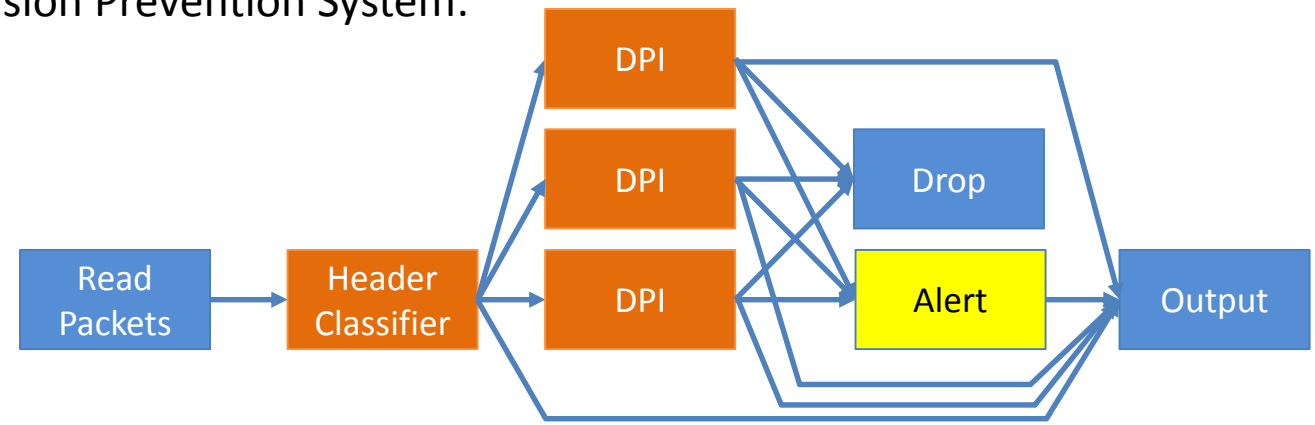
Graph Merge Algorithm

Input Graphs:

Firewall:



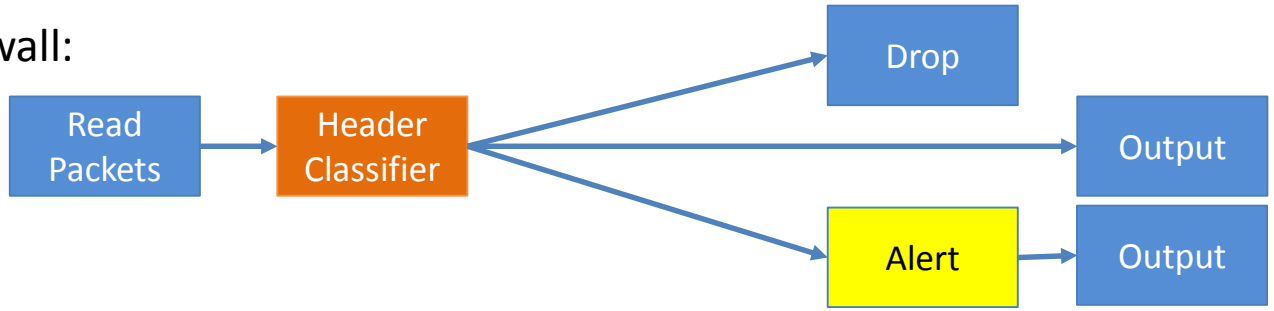
Intrusion Prevention System:



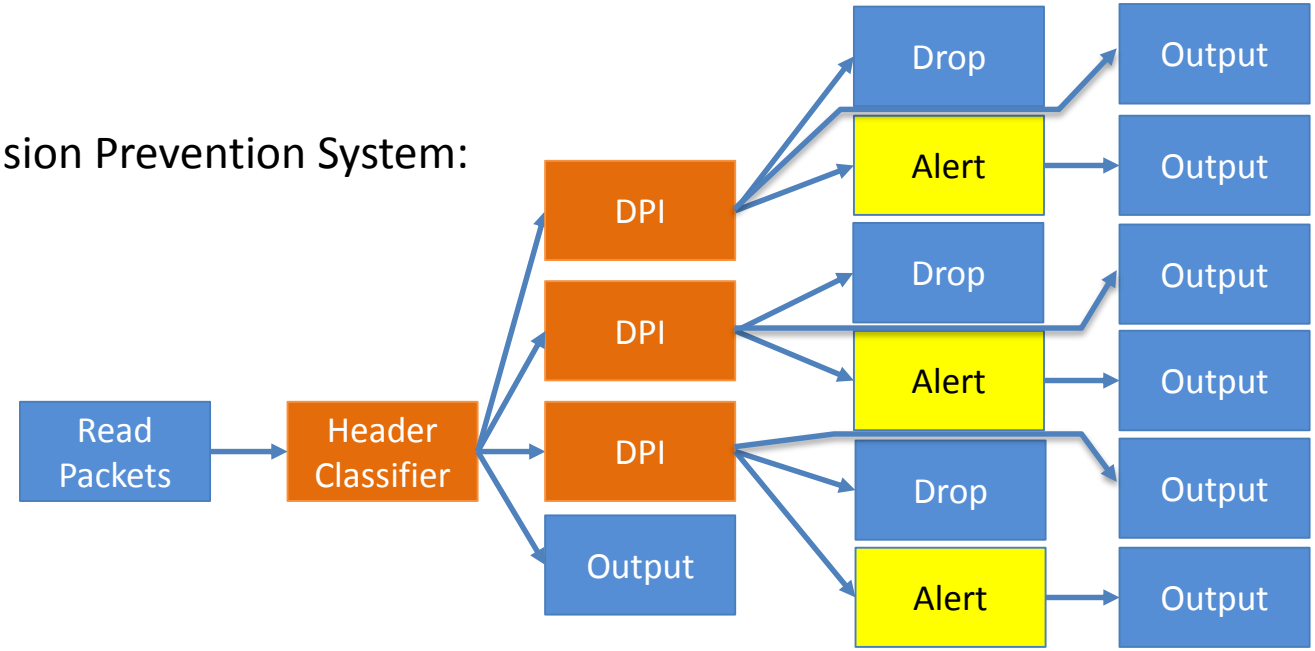
Graph Merge Algorithm

Step 1: Normalize graphs to trees

Firewall:

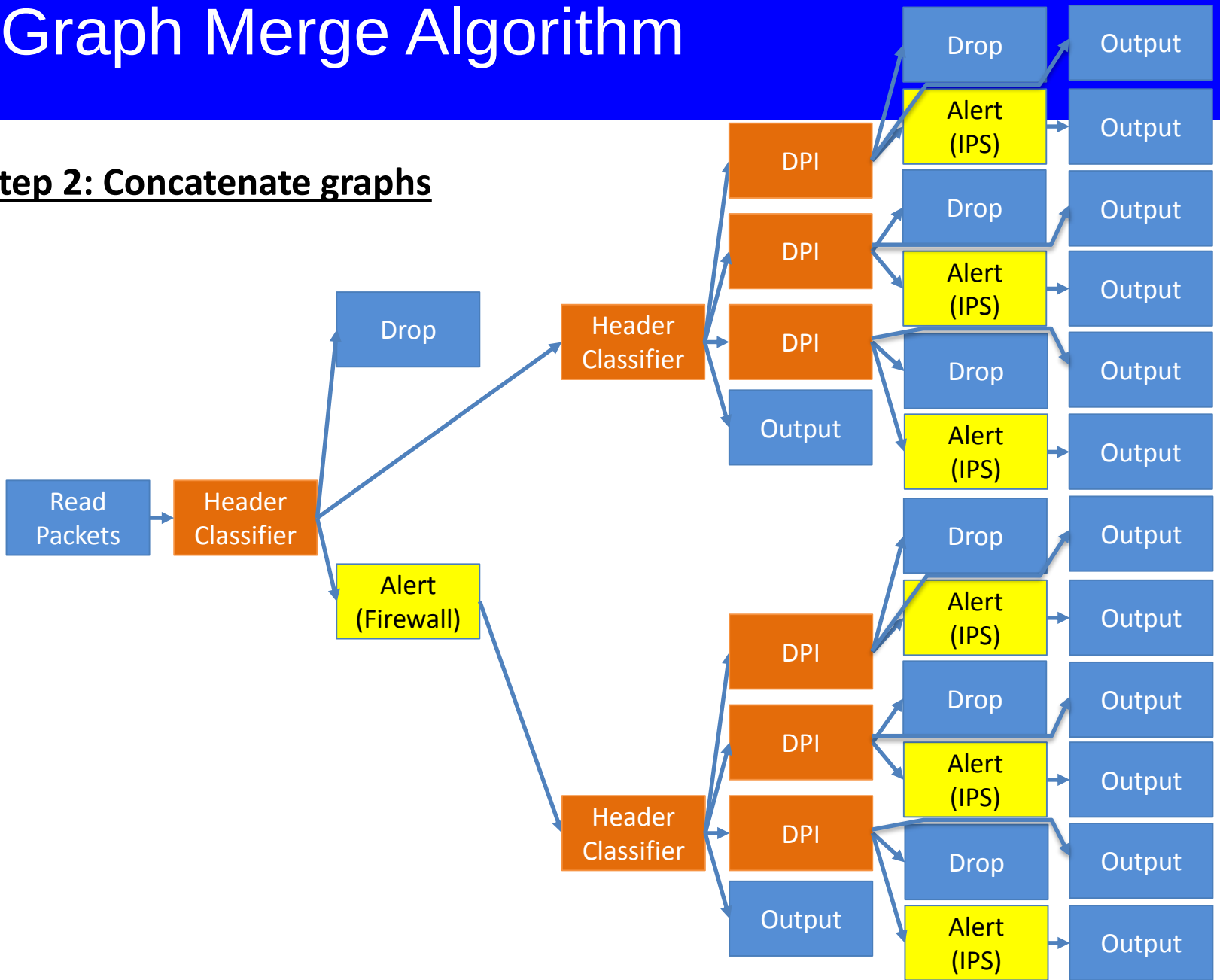


Intrusion Prevention System:



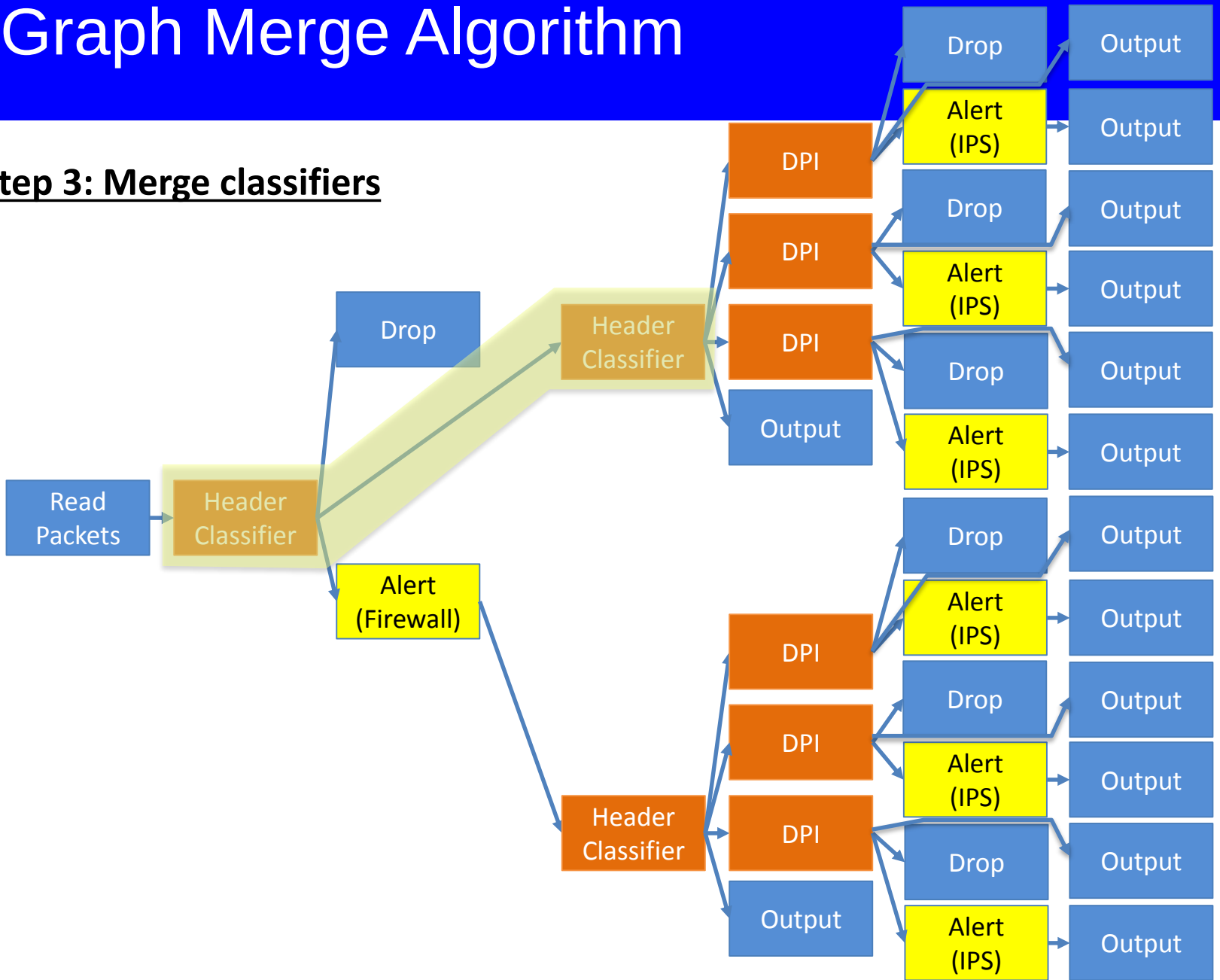
Graph Merge Algorithm

Step 2: Concatenate graphs



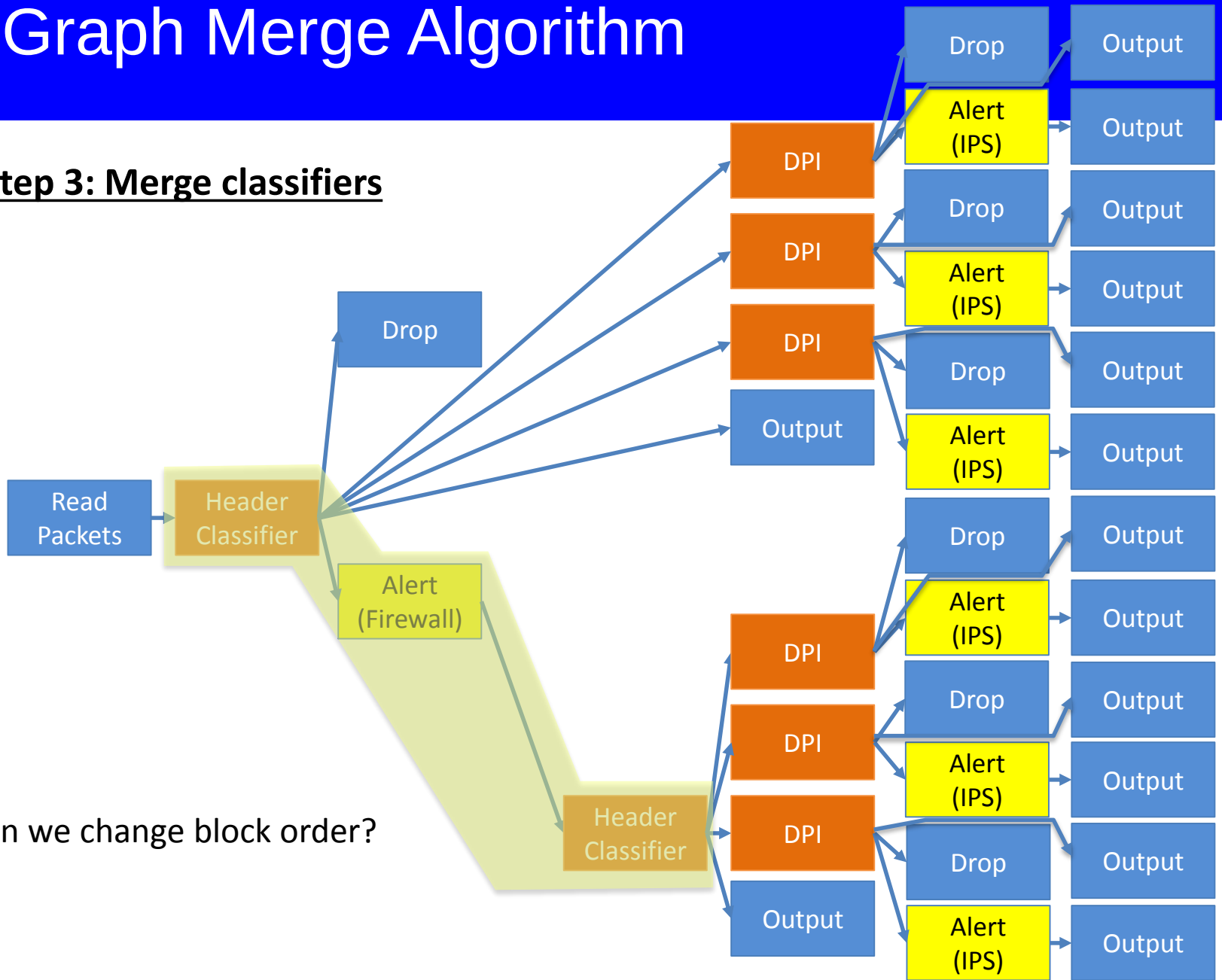
Graph Merge Algorithm

Step 3: Merge classifiers



Graph Merge Algorithm

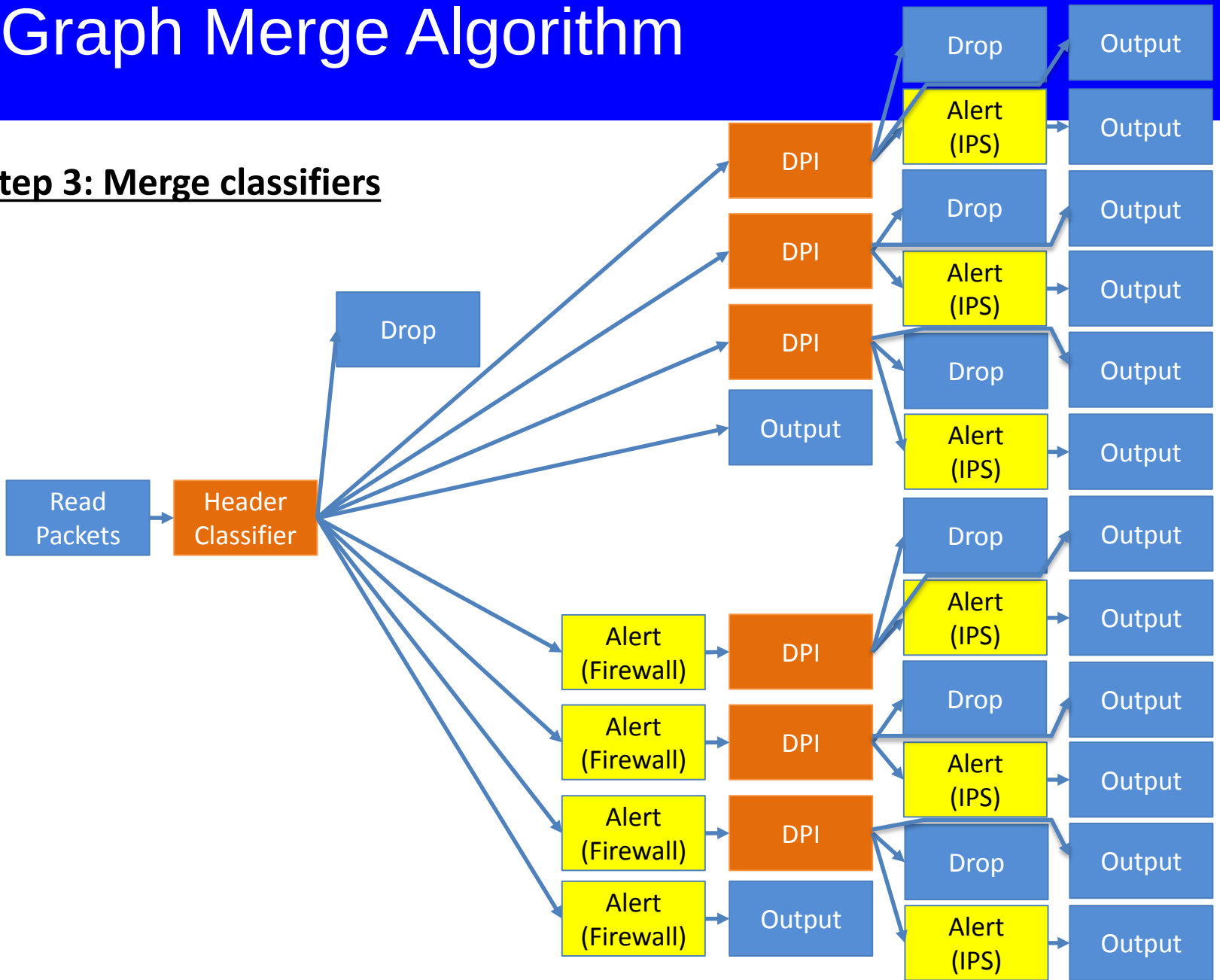
Step 3: Merge classifiers



Can we change block order?

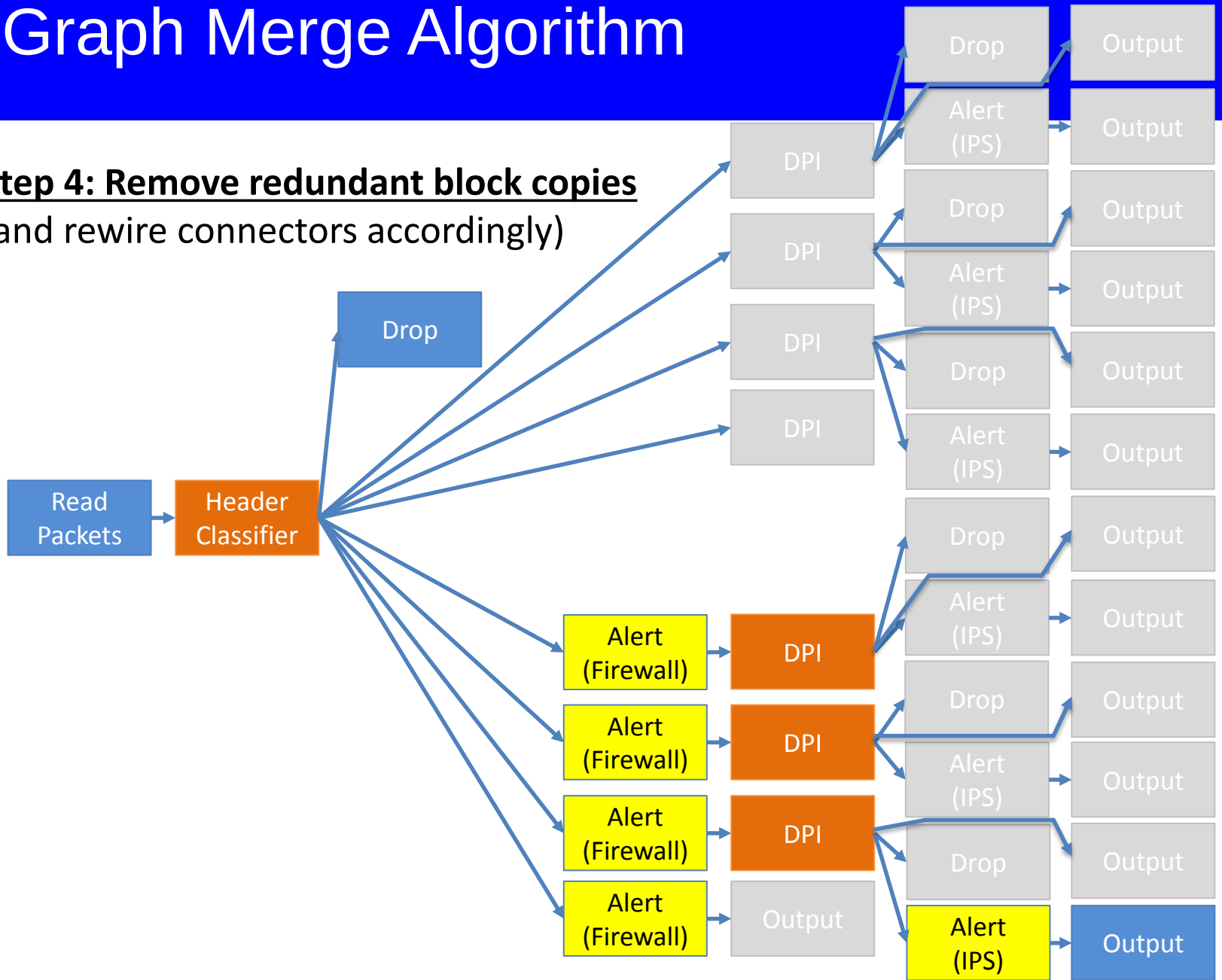
Graph Merge Algorithm

Step 3: Merge classifiers

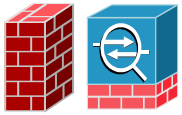


Graph Merge Algorithm

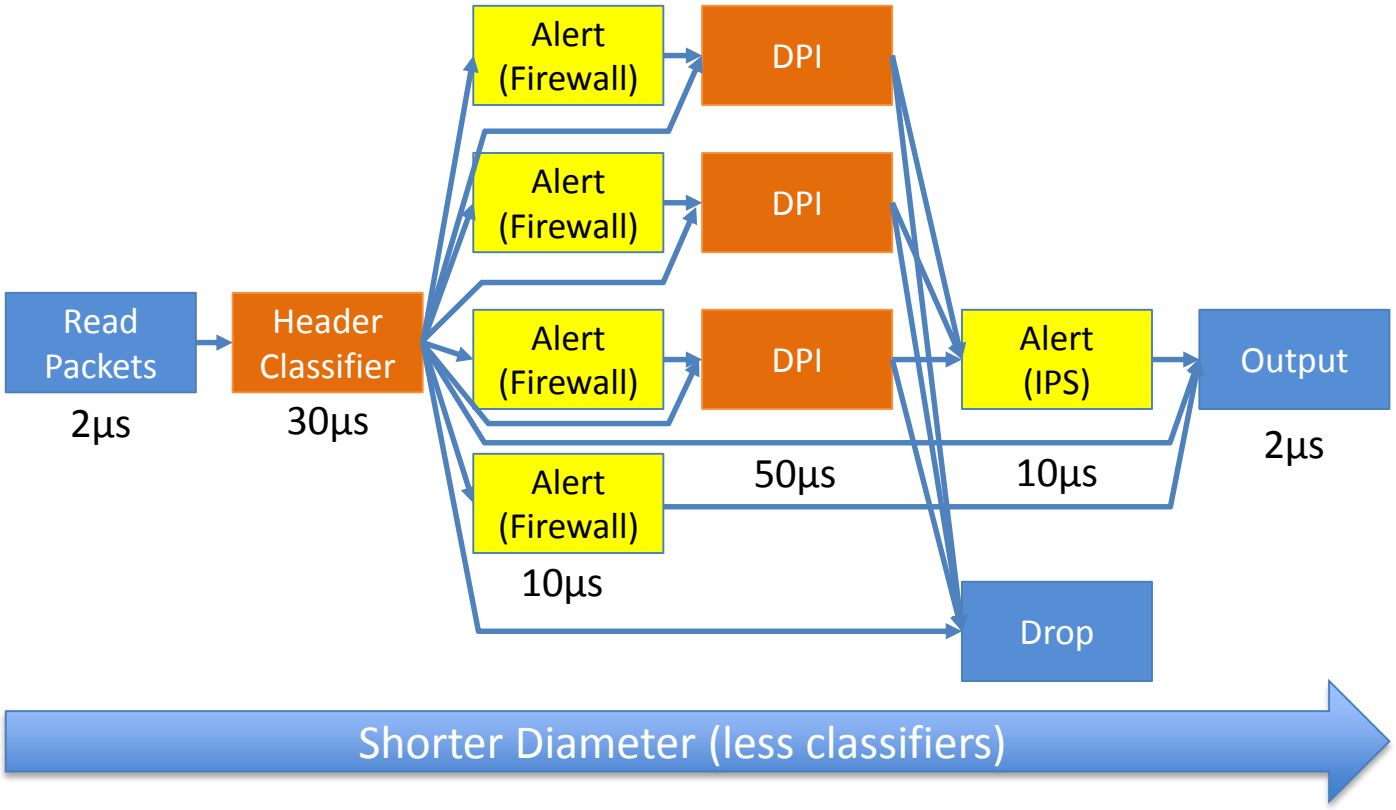
Step 4: Remove redundant block copies
(and rewire connectors accordingly)



Graph Merge Algorithm



Merged Processing Graph:



Total: 104µs (22% improvement)

When NOT to Merge?

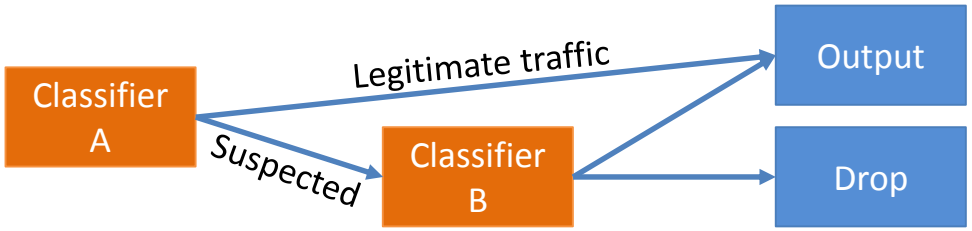
When cross product is too large:

- Two d-dimensional classifiers: A – n rules, B – m rules
- Classification is logarithmic with # of rules, exponential with dimension
- Serial classification time: $(\log n)^{d-1} + (\log m)^{d-1}$
- Cross product: $n \cdot m$ rules (worst case)
- Single classifier worst case time:

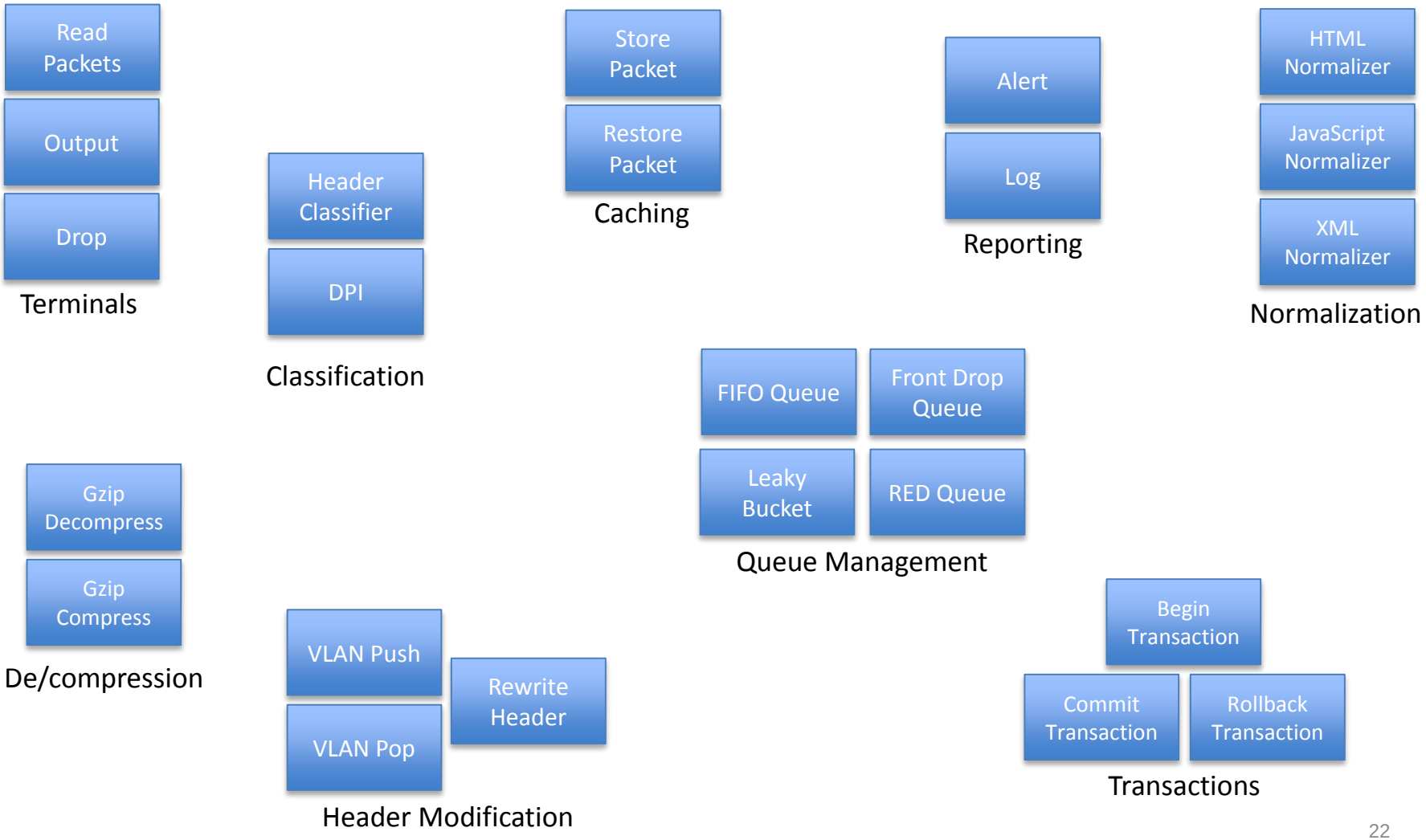
$$\log(n \cdot m)^{d-1} = (\log n)^{d-1} + (\log m)^{d-1} + \sum_{i=1}^{d-2} \binom{d-1}{i} \left((\log n)^{i} + (\log m)^{d-i-1}\right)$$

$$> (\log n)^{d-1} + (\log m)^{d-1}$$

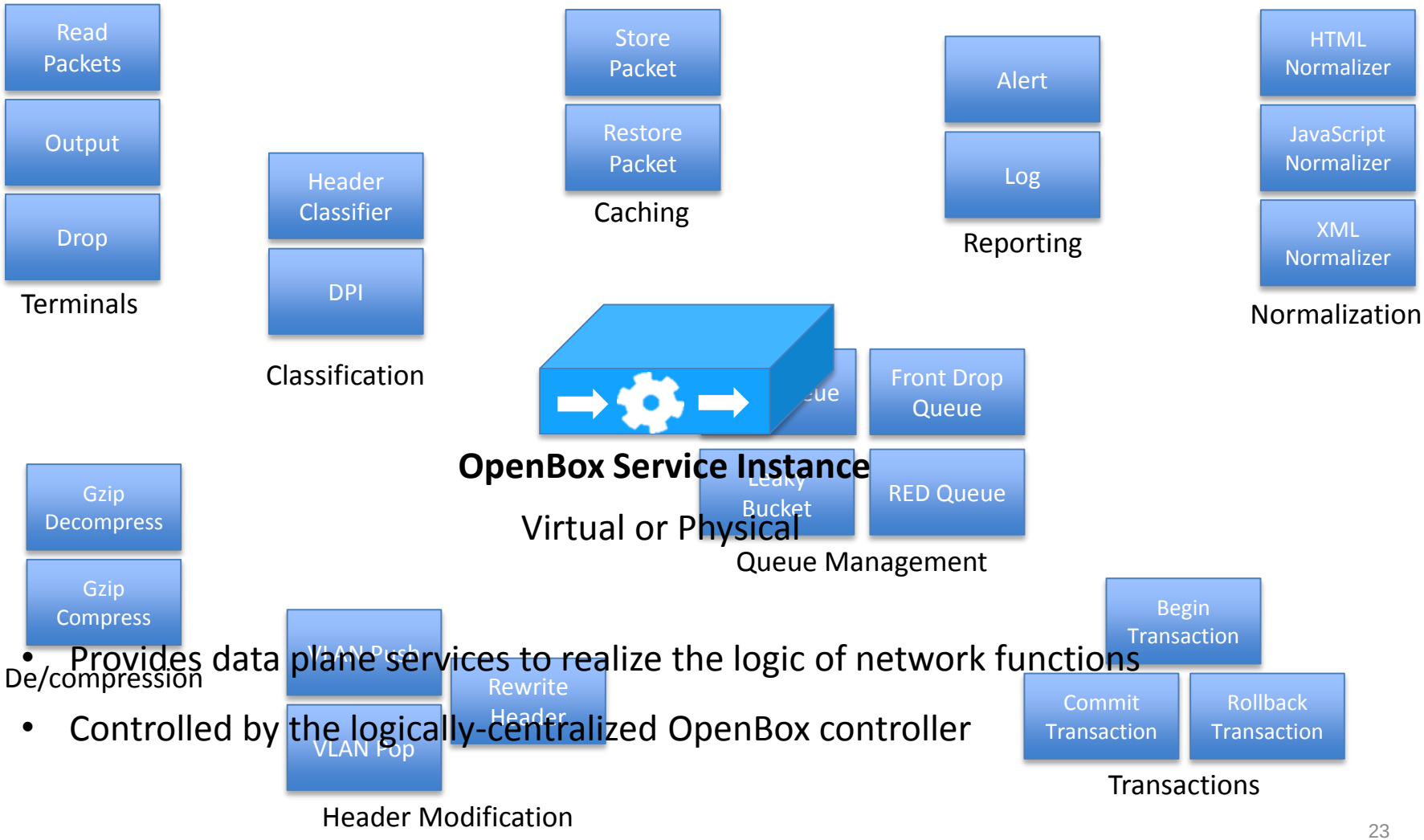
When most packets won't go through both classifiers:



OpenBox Data Plane Processing

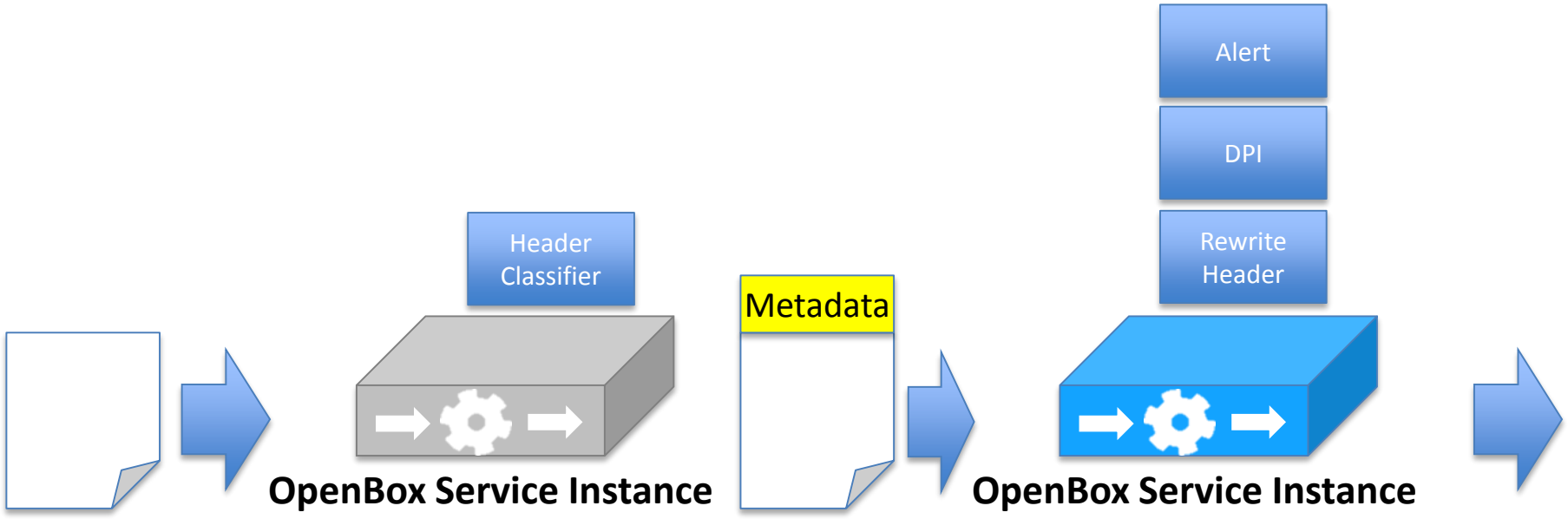


OpenBox Data Plane Processing



- Provides data plane services to realize the logic of network functions
- Controlled by the logically-centralized OpenBox controller

Distributed Data Plane



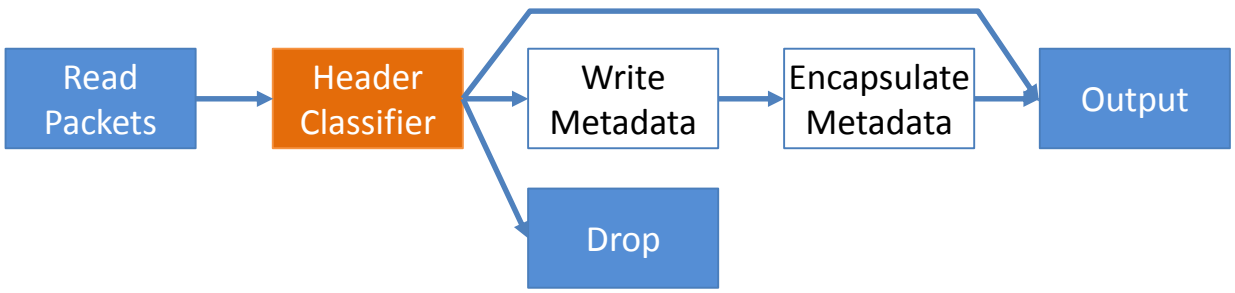
Hardware
(TCAM)

Software

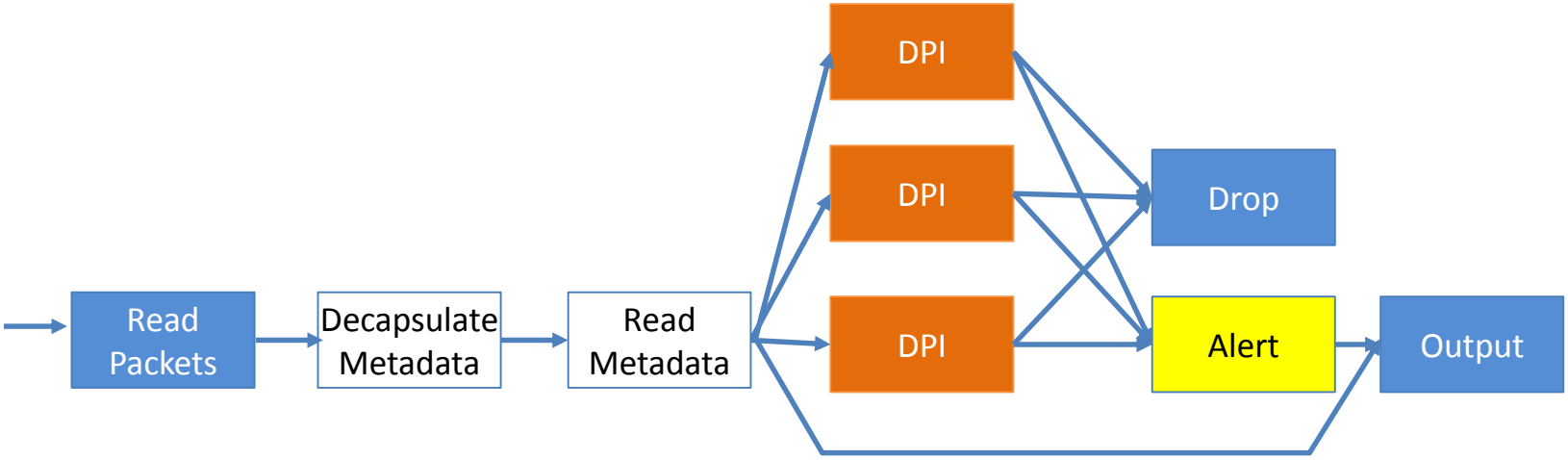
E.g., an OpenFlow switch
with encapsulation features
(e.g., NSH, Geneve, FlowTags)

Split Processing Graph

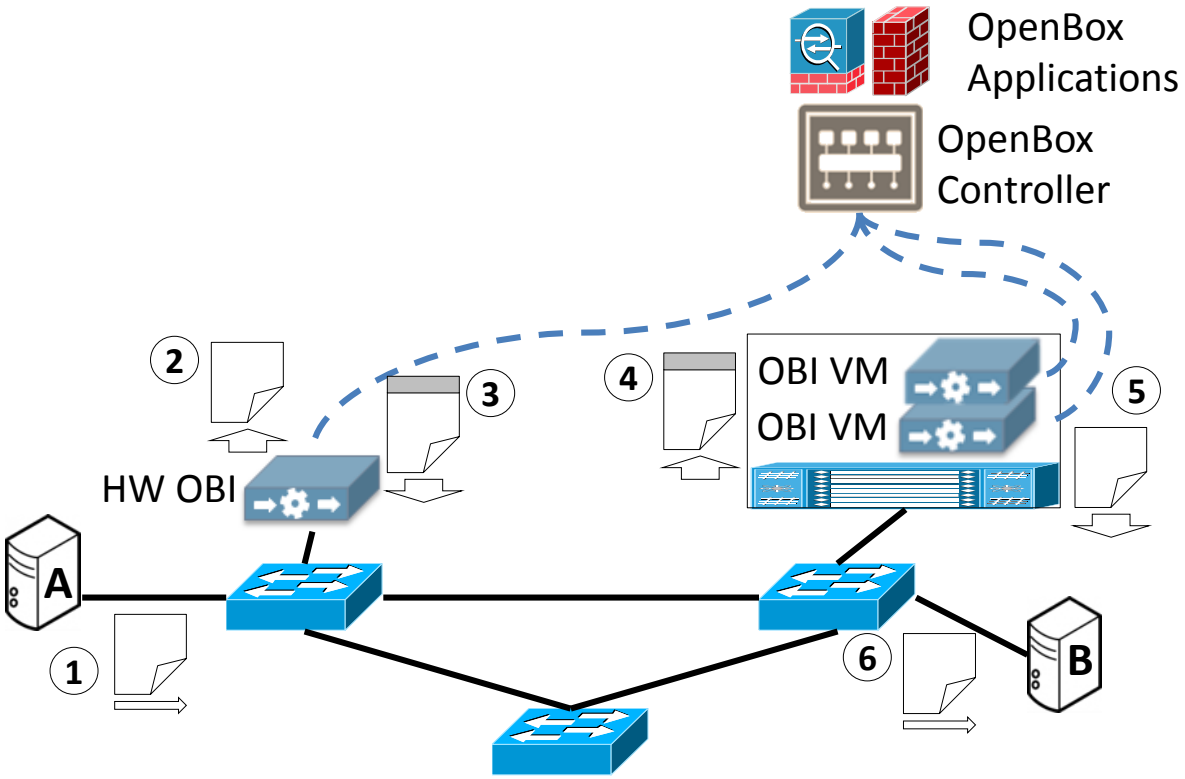
HW Instance:



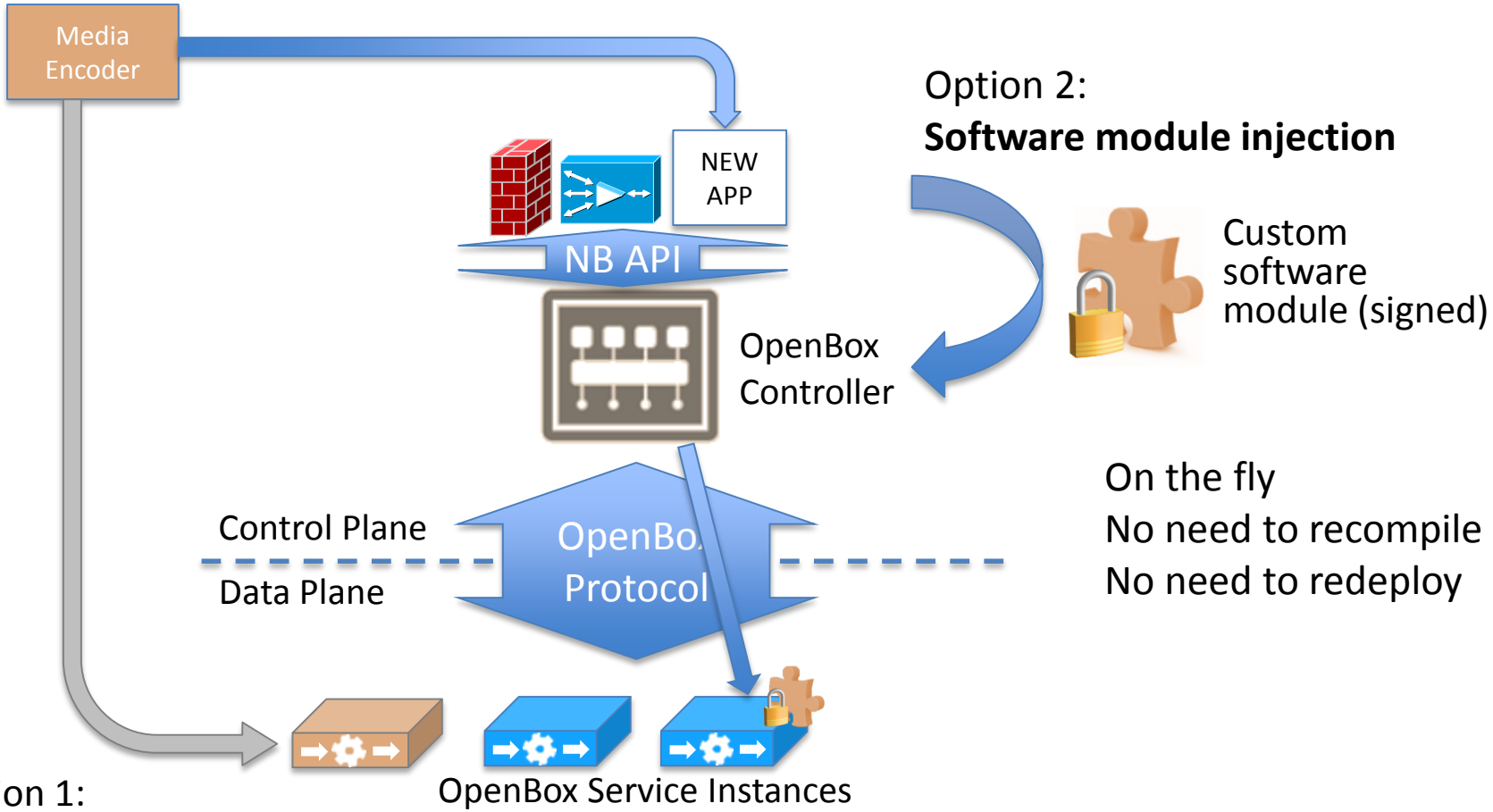
SW Instance:



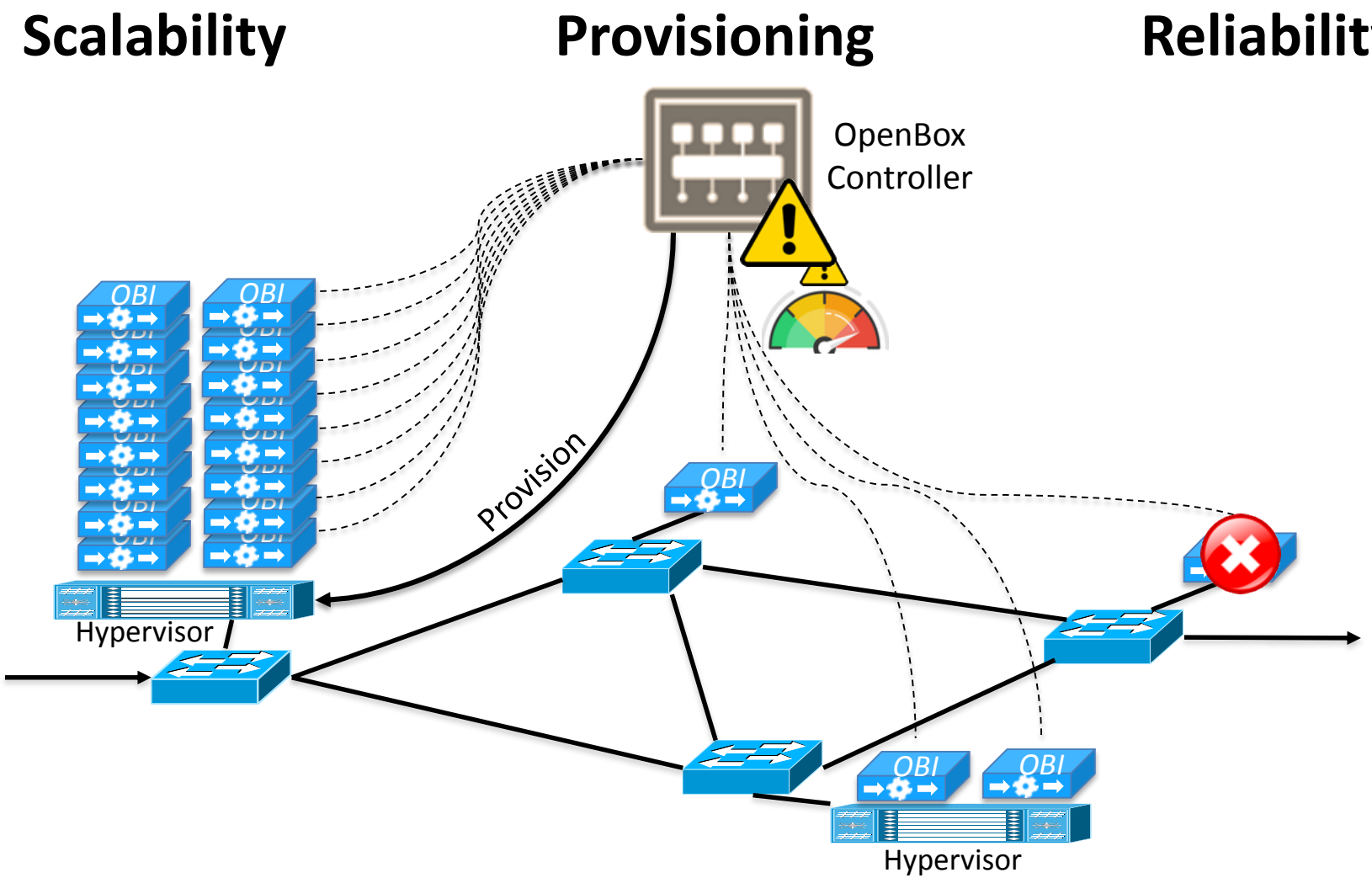
Distributed Data Plane



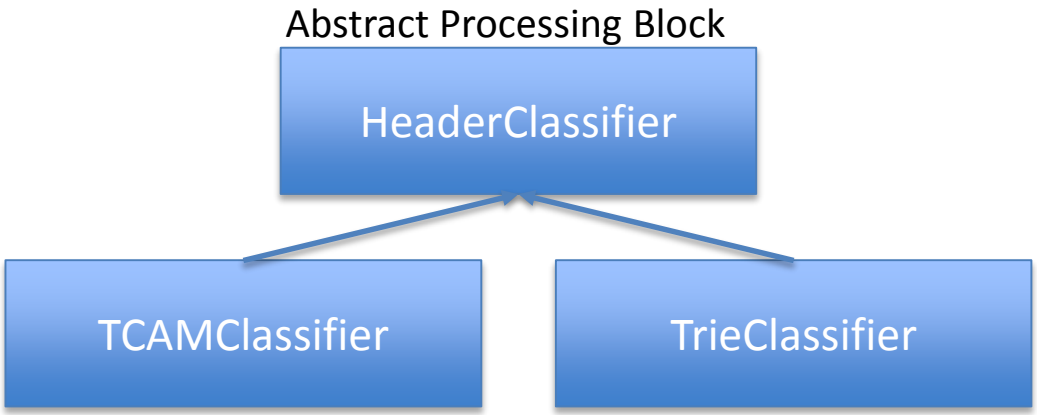
Extensible Data Plane

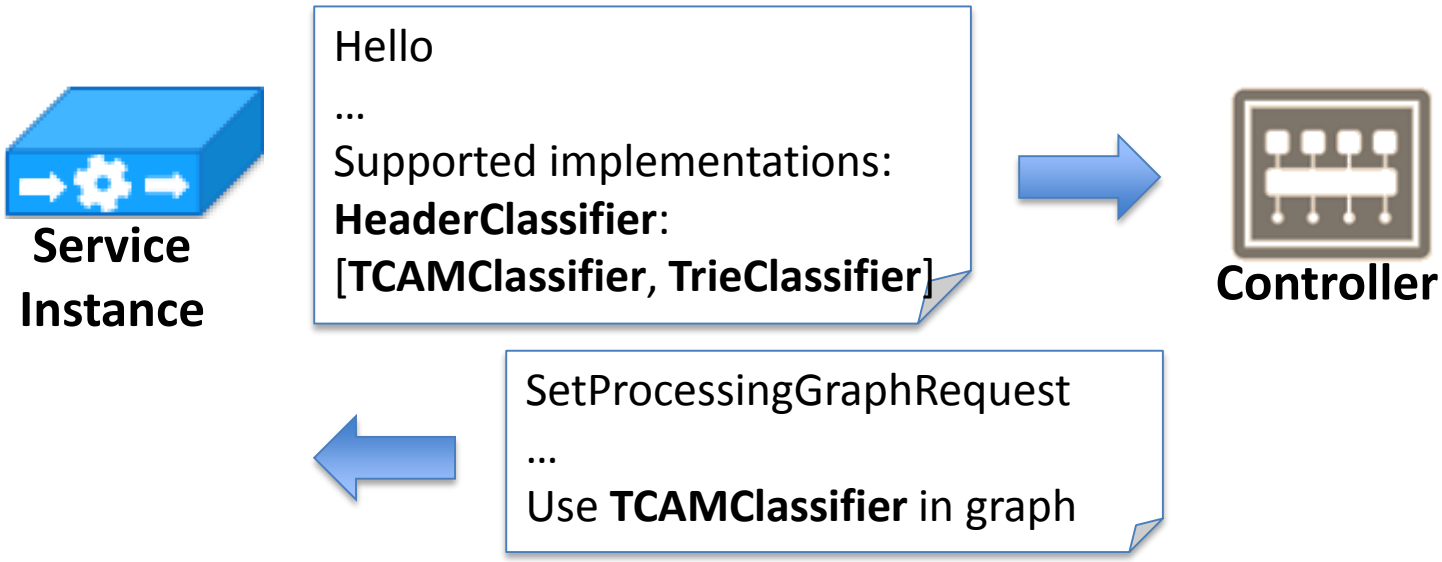


Scalable & Reliable Data Plane



OpenBox Protocol: Block Hierarchy



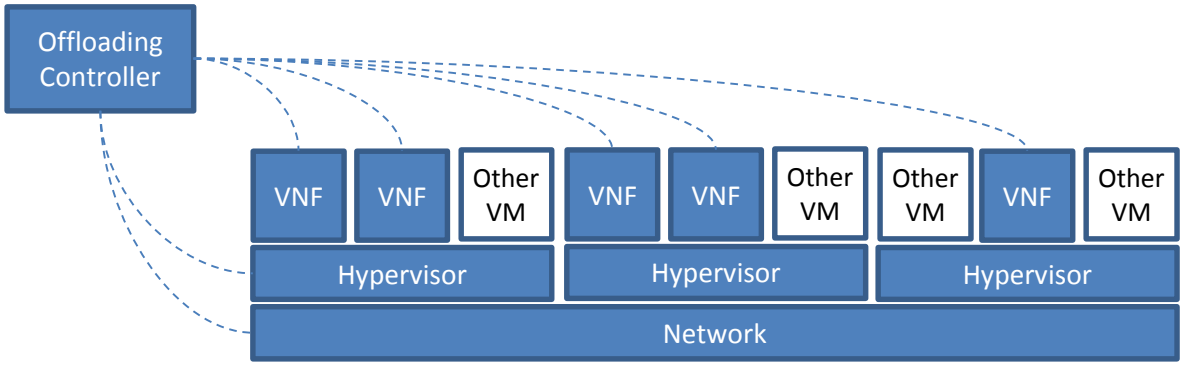


Future Work: Infrastructure Support

- Infrastructure can help VNFs
  - Provide high performance (e.g., hardware accelerators)
  - Reuse processing (e.g., packet switching, “outsourced” services)

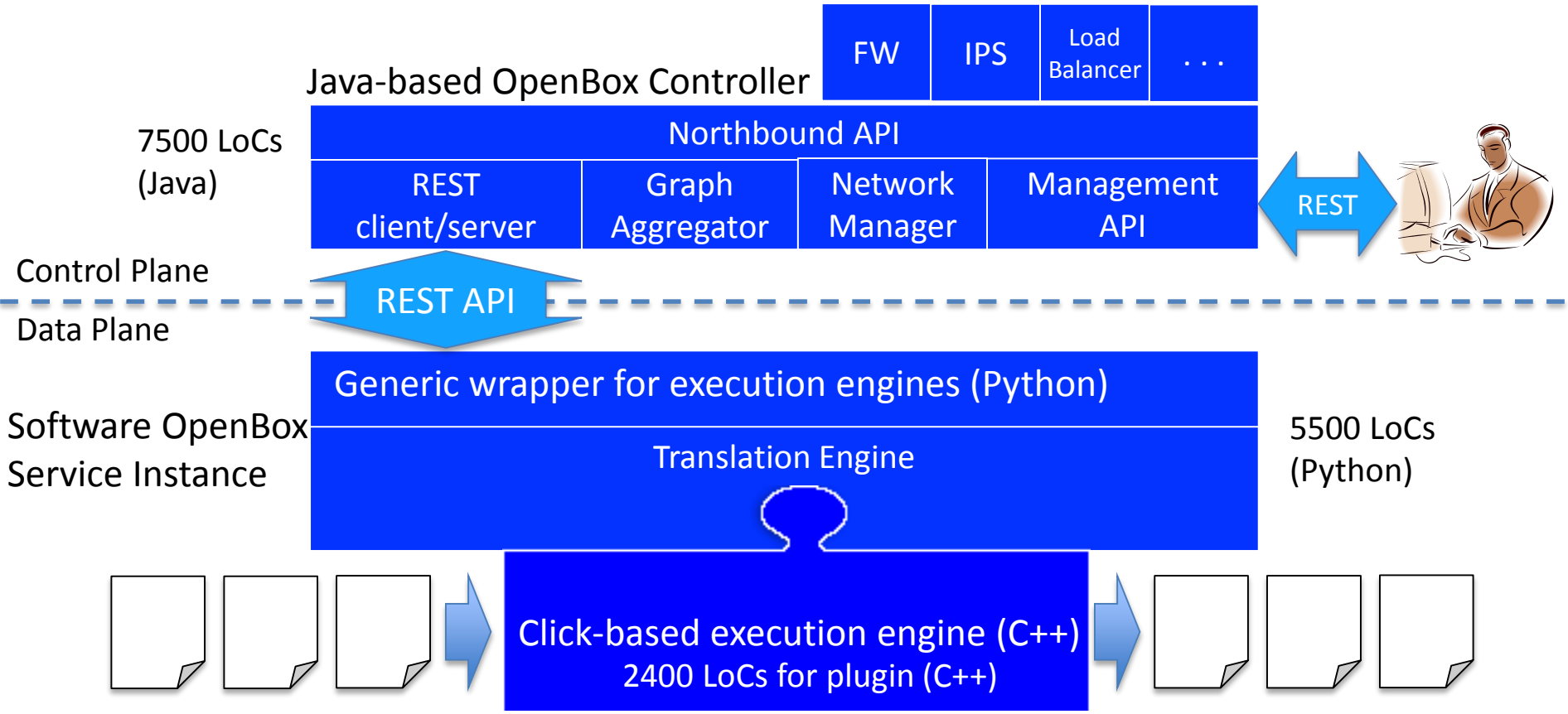
- Challenge: Design a system, define a protocol to offload processing from VNFs to infrastructure

- Gradual solution, easier to adopt for existing VNFs



Implementation

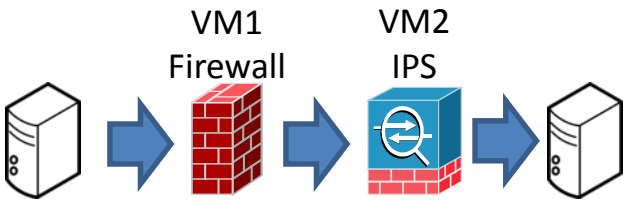
github.com/OpenBoxProject



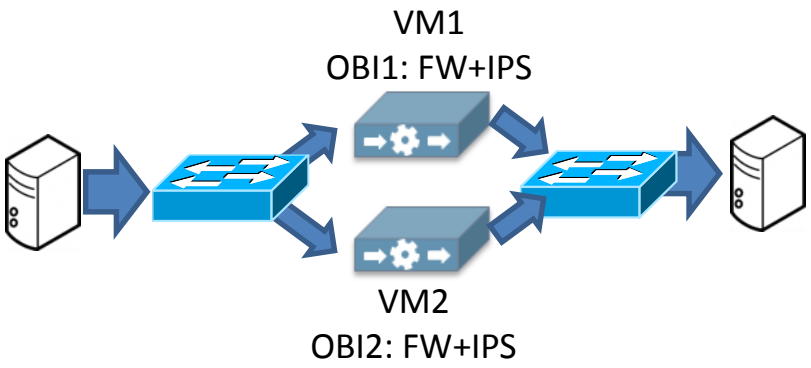
(Plug here other execution engines. E.g., ClickNP [SIGCOMM '16])

Performance Improvement

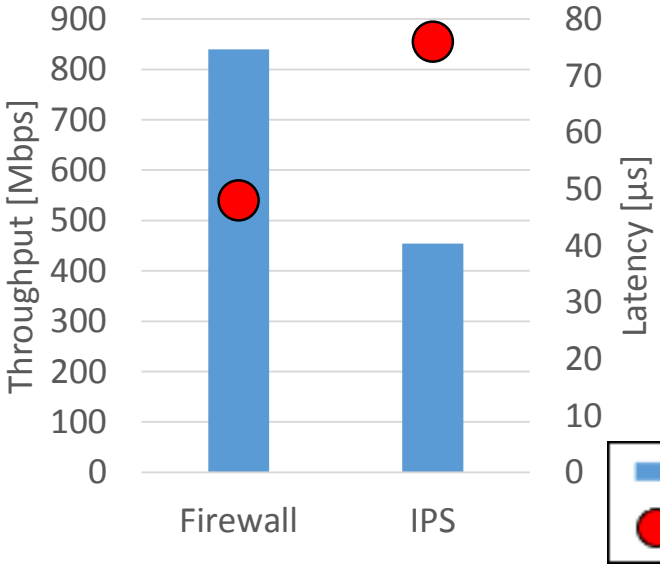
Without OpenBox



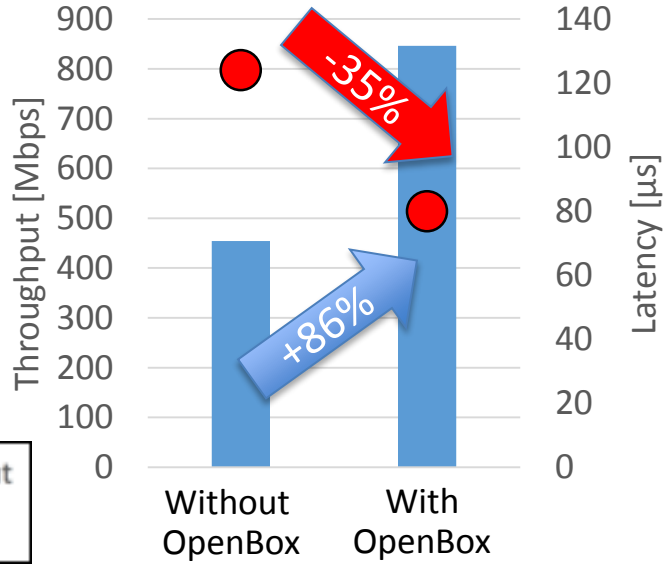
With OpenBox



Standalone VM



NF Pipeline

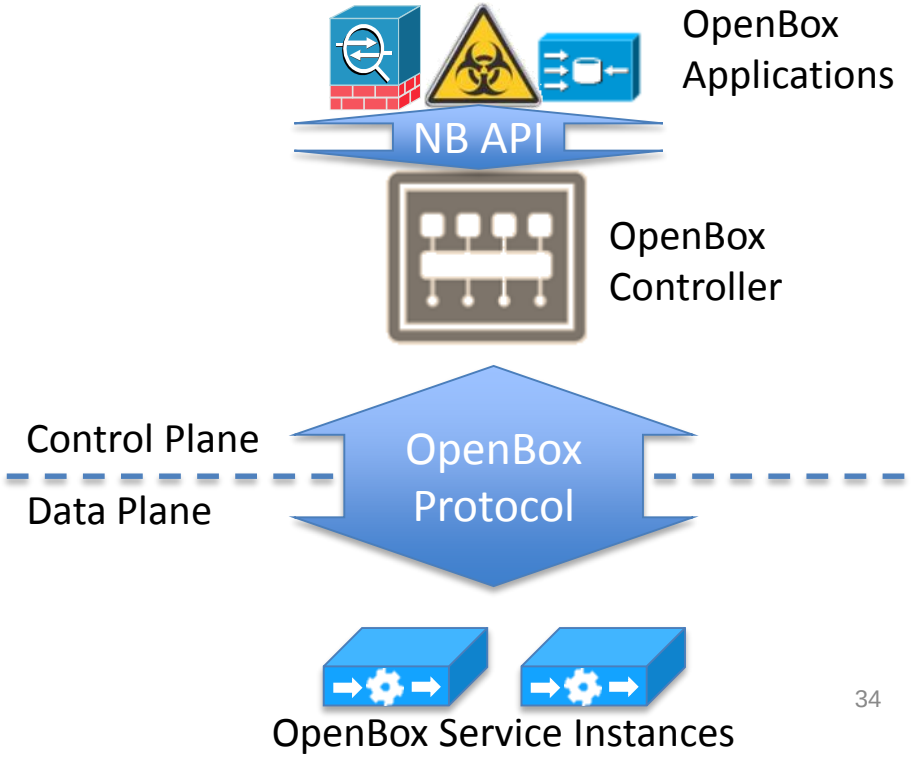


Related Work

- Orthogonal to OpenBox:
  - NF traffic steering (e.g., SIMPLE [SIGCOMM ’14])
  - NF orchestration (e.g., Stratos, OpenMano, OpenStack)
  - Runtime platforms (e.g., xOMB [ANCS ‘12], ClickNP [SIGCOMM ‘16])
- Similar Motivation:
  - CoMb [NSDI ‘12] – focuses on resource sharing and placement
  - E2 [SOSP ‘15] – composition framework for virtual NFs
  - Slick [SOSR ’15] – focuses on the placement of data plane units
- Only OpenBox provides:
  - Core processing decomposition and reuse
  - Standardization and full decoupling of NF control and data planes

Conclusions

- Network functions are currently a real challenge in large scale networks
- By decoupling the data plane processing of NFs their control logic we:
  - Reduce costs
  - Enhance performance
  - Improve scalability
  - Increase reliability
  - Provide inter-tenant isolation
  - Allow easier innovation
- There is still work to do…



Questions?

THANK YOU!

Play with OpenBox on a Mininet VM:
github.com/OpenBoxProject/openbox-mininet