A Distributed and Robust SDN Control Plane for Transactional Network Updates

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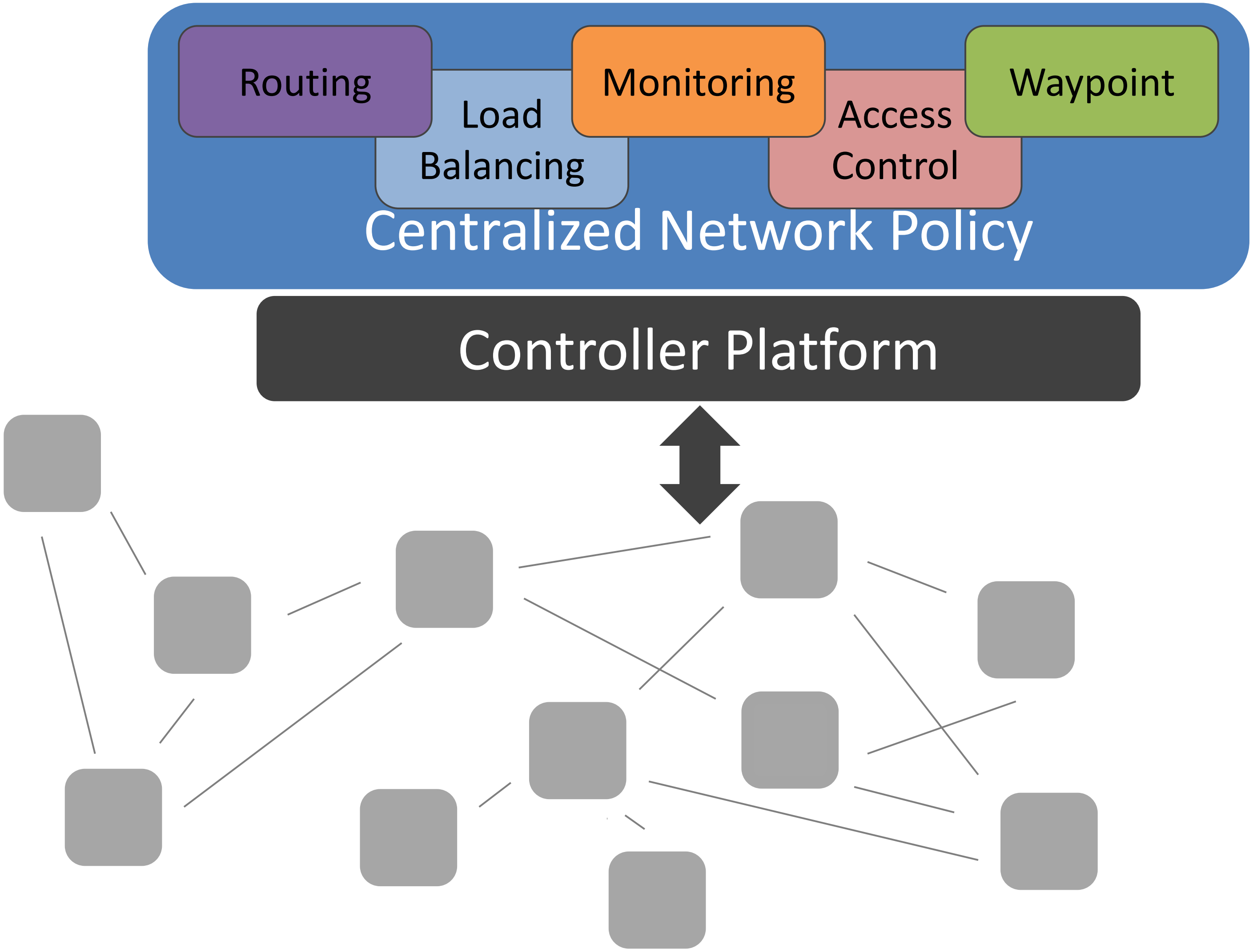
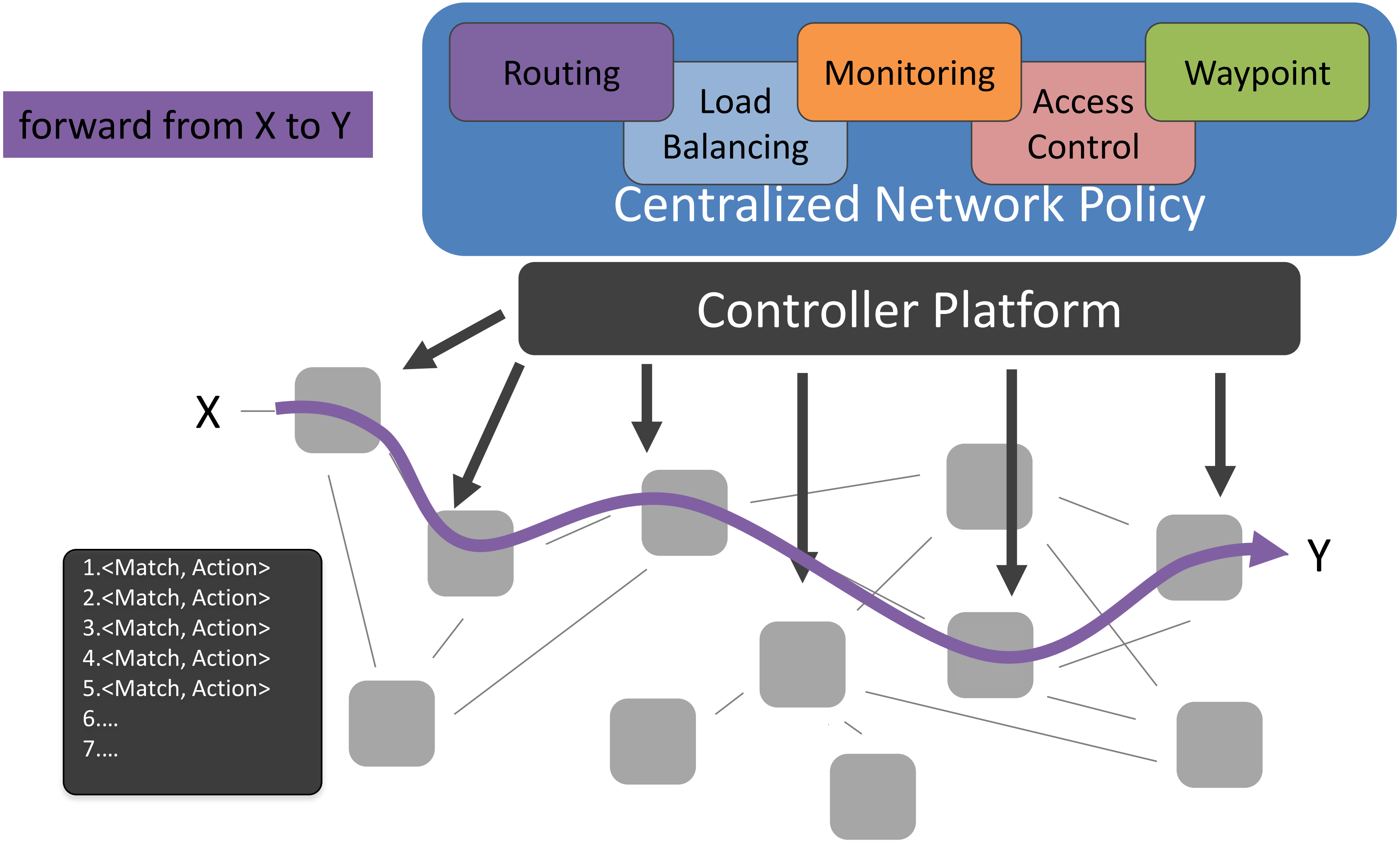
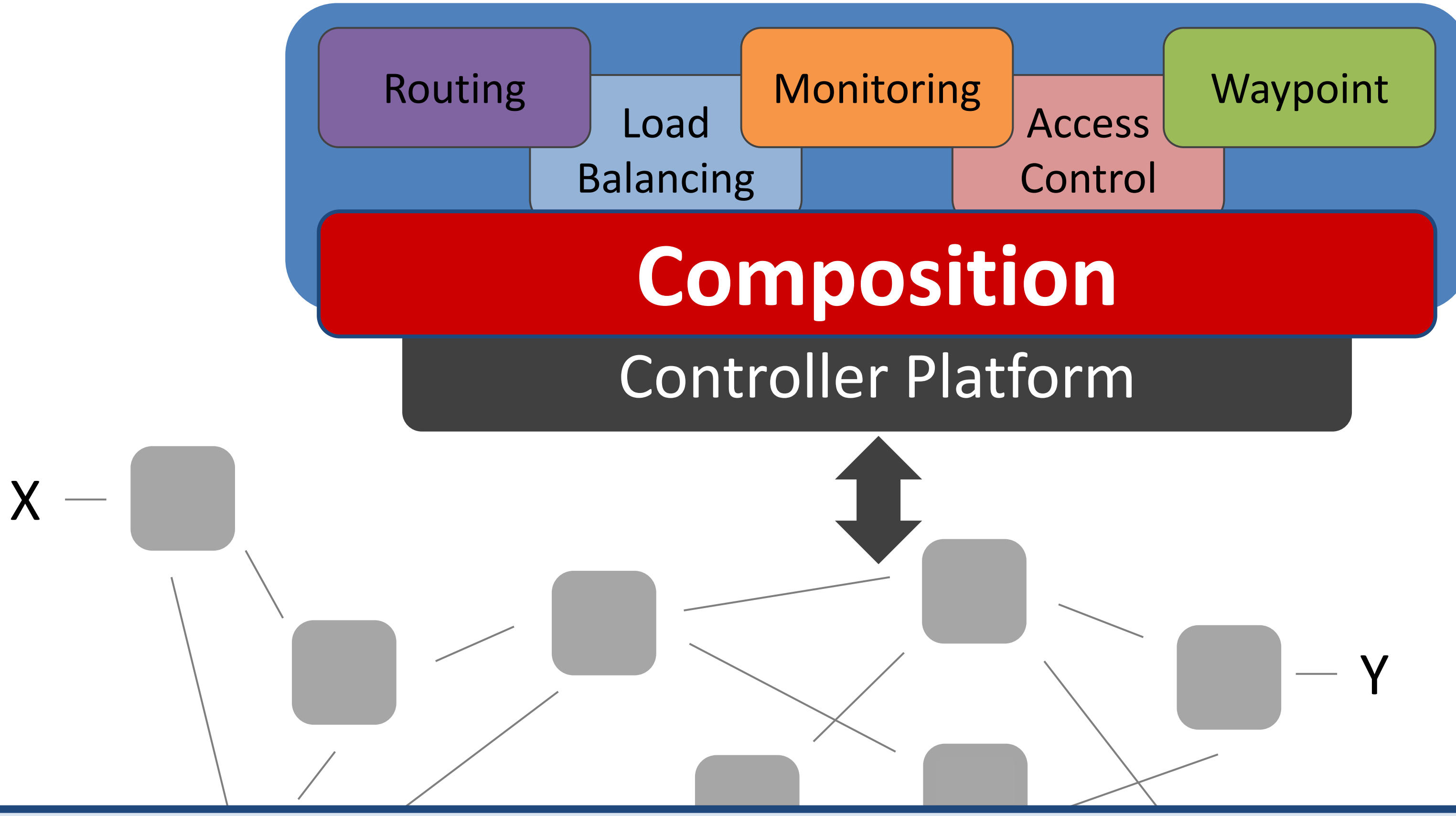
Network Policy Specification



Network Policy Specification

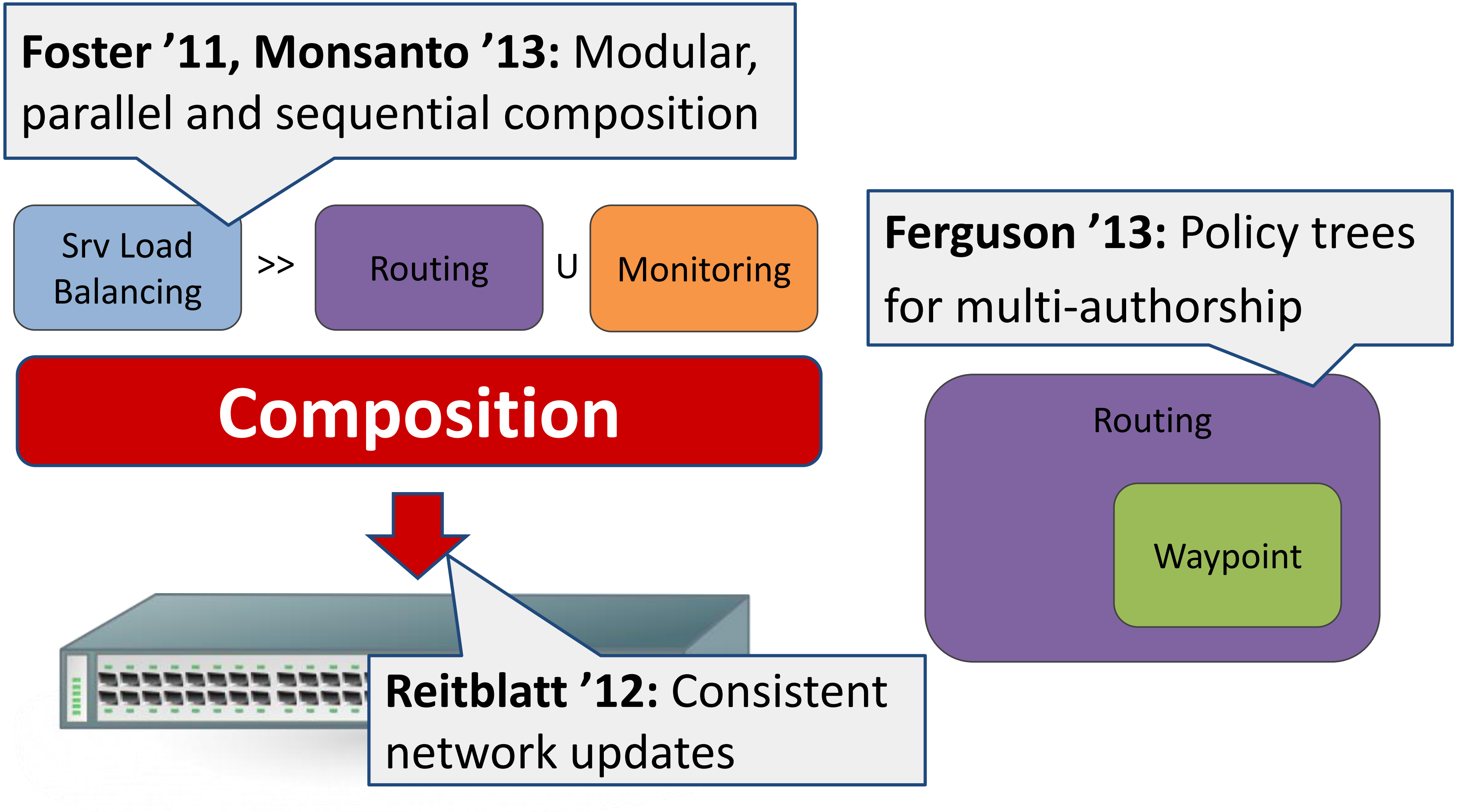


Network Policy Specification



Policy composition assembles data plane updates as a semantically sound set of rules

Policy Composition Review



Conflicting Policies

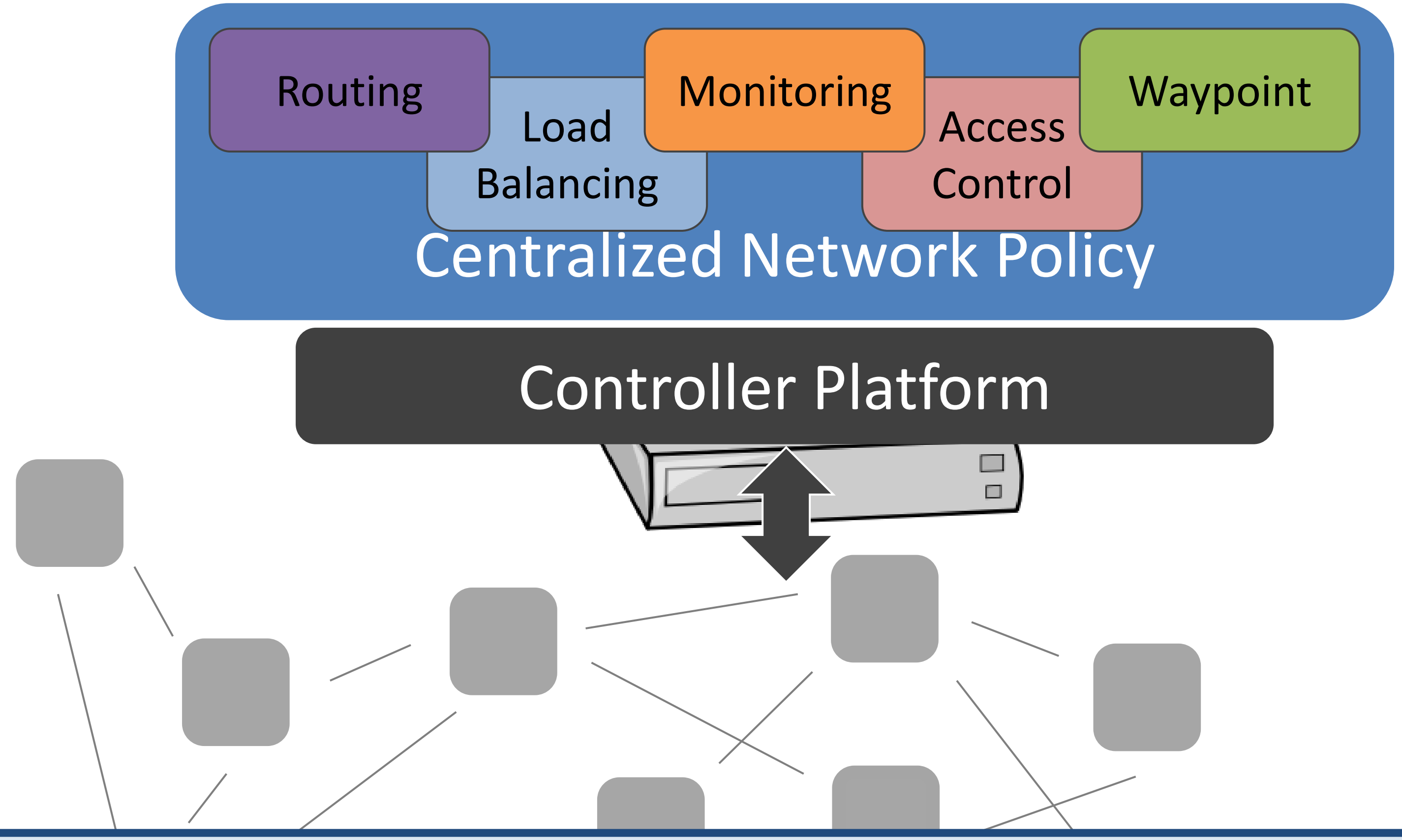
In the general case, policies might conflict

Examples:

- Overlapping domains and same precedence
- Scarce flowtable resources

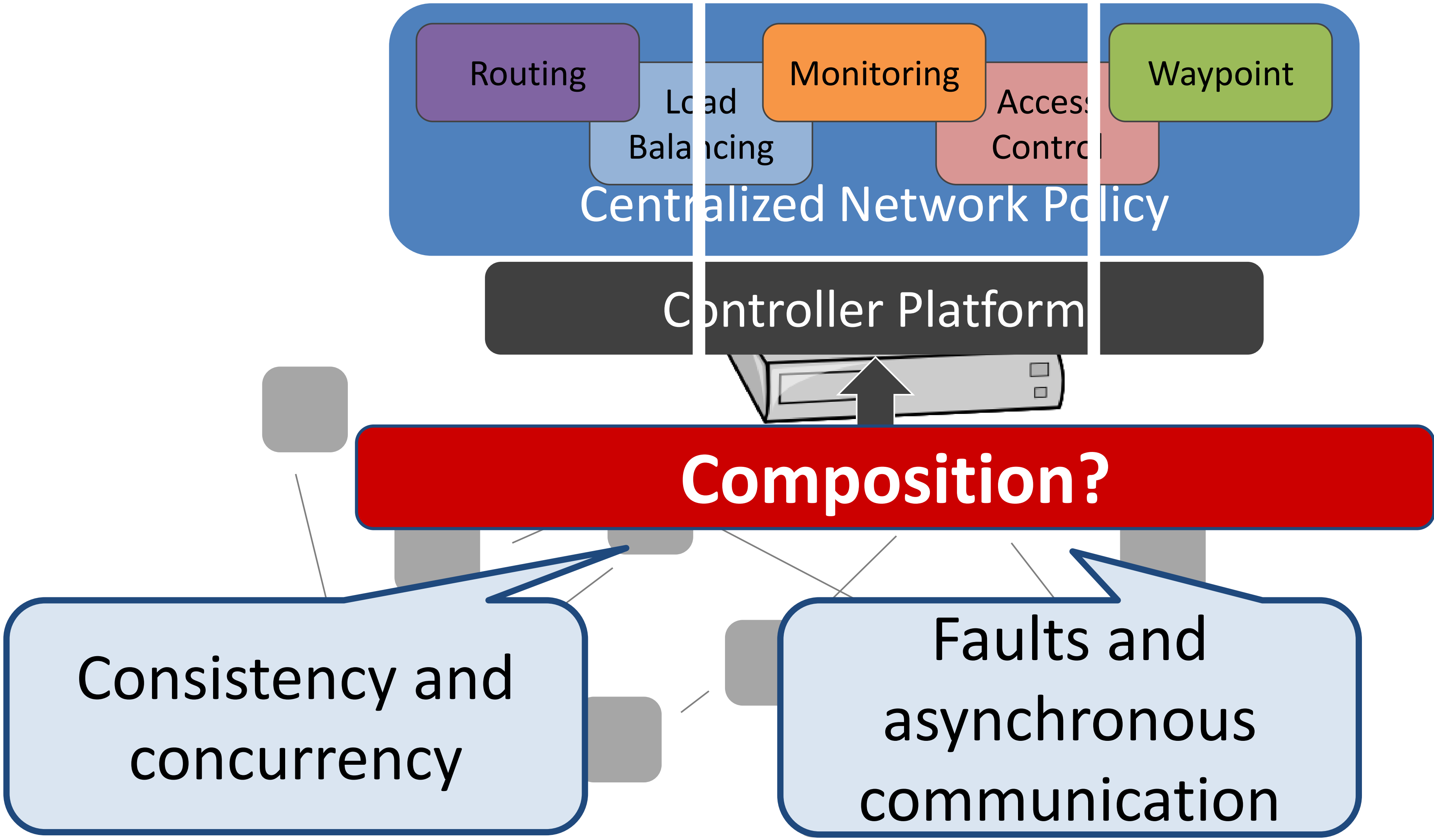
Goal: Must avoid conflicting policies!

Centralized Network Control?

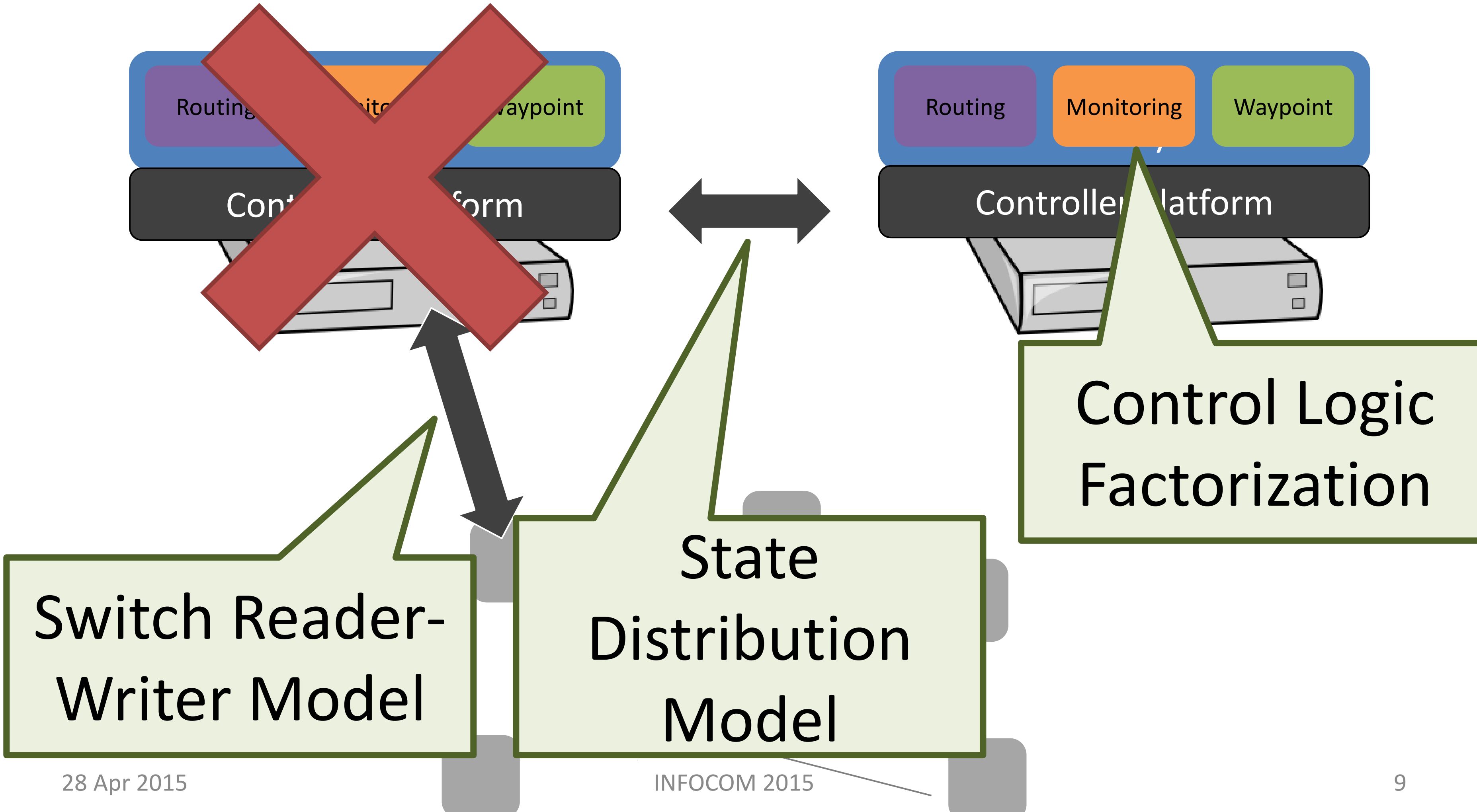


Fully centralized → Inadequate availability, scalability and responsiveness

Distributed Network Control

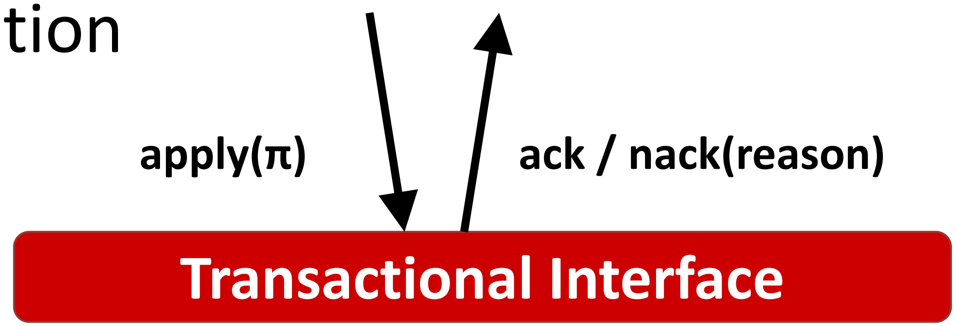


Now, consider policy composition in the distributed control plane...

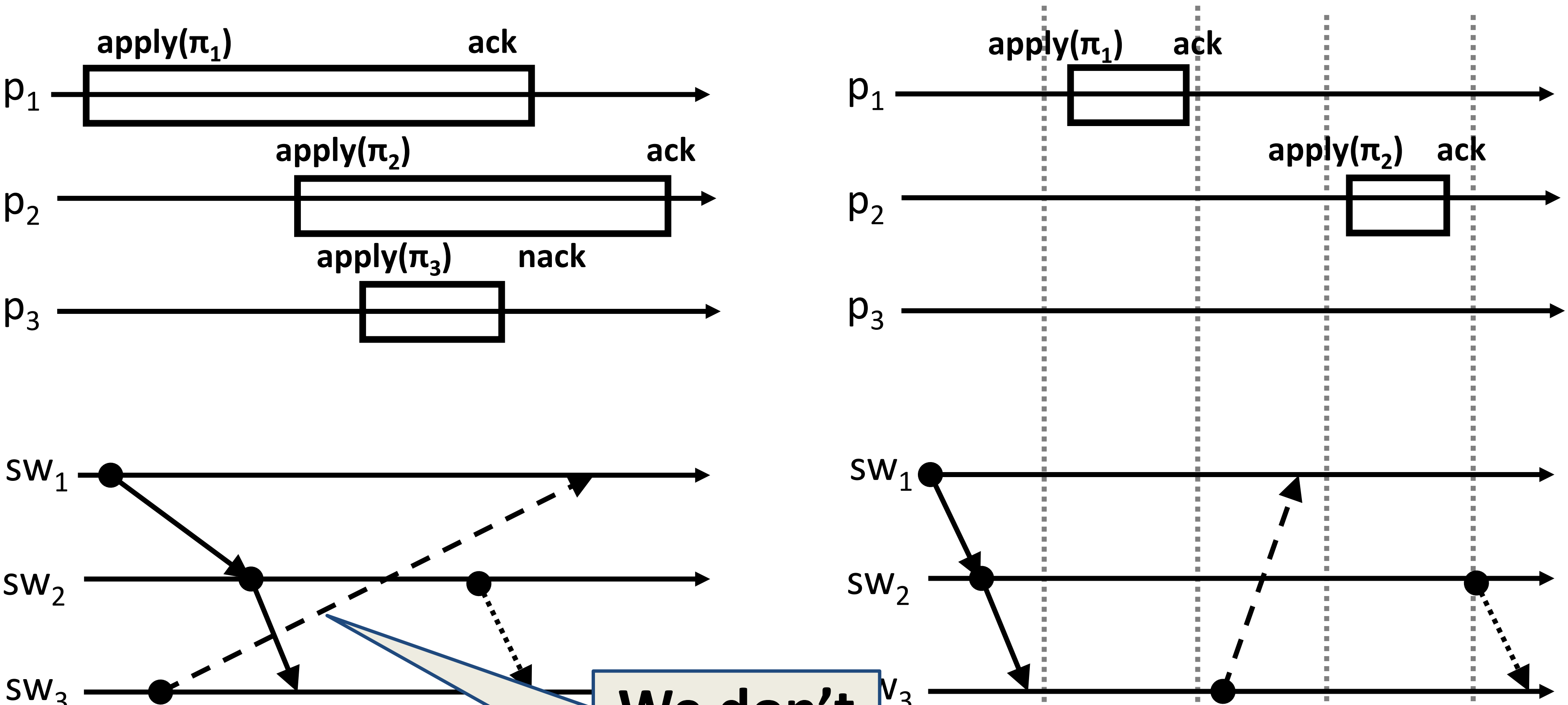


Why should the programmer care?

- We believe the programmer should not!
- Enter Software Transactional Networking
  - Let a dedicated component implement a general solution to all hard-to-solve, low-level concurrency and fault tolerance issues to policy composition

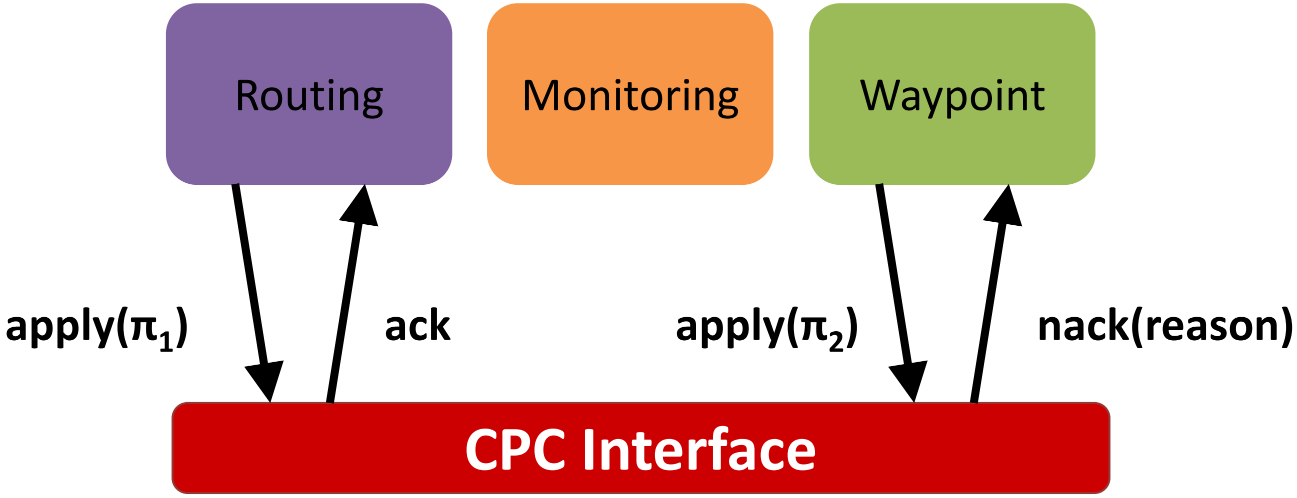


Consistency: Linearizability of updates



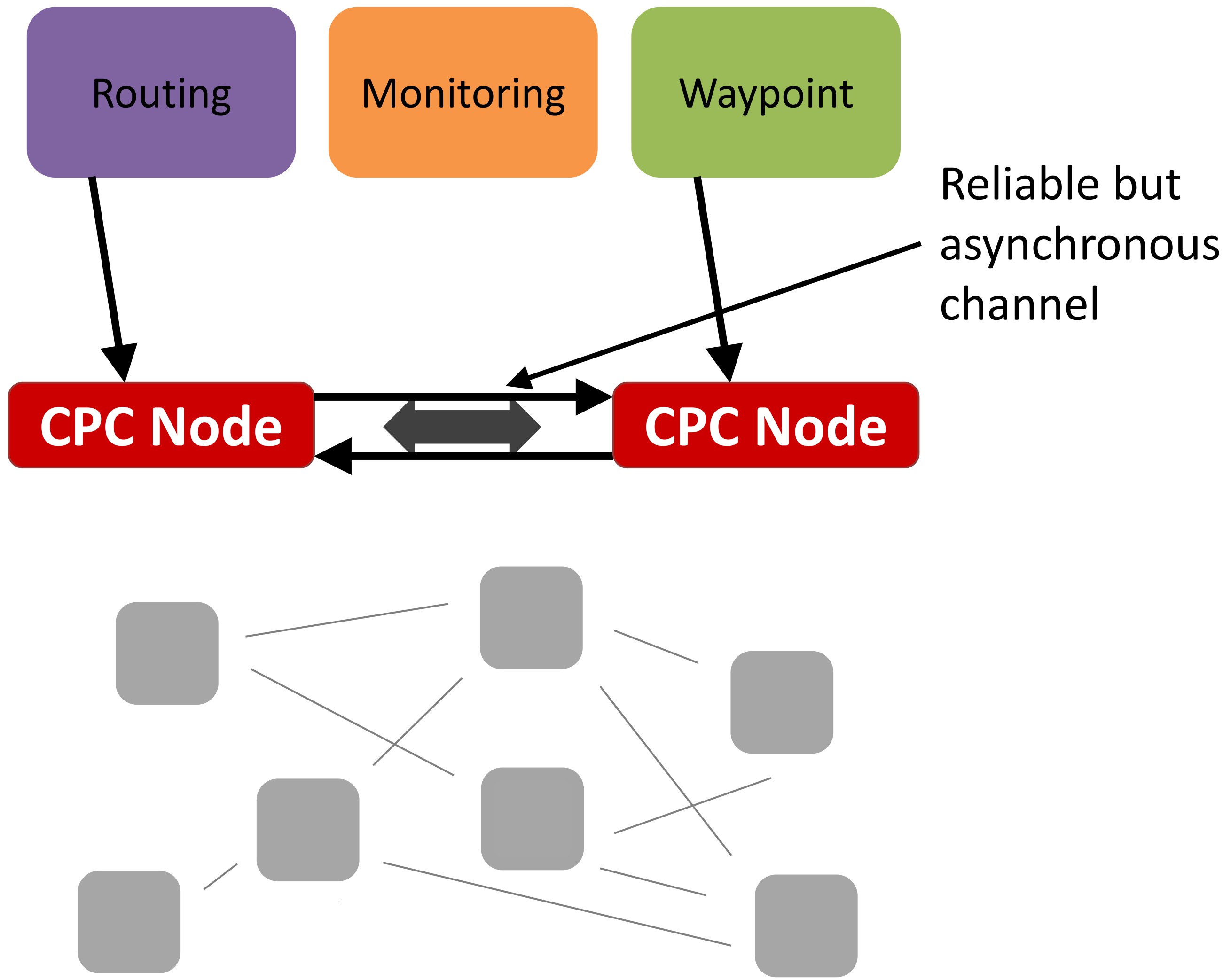
Manipulate the network as though there is no concurrency

Software Transactional Networking: Consistent Policy Composition (CPC)



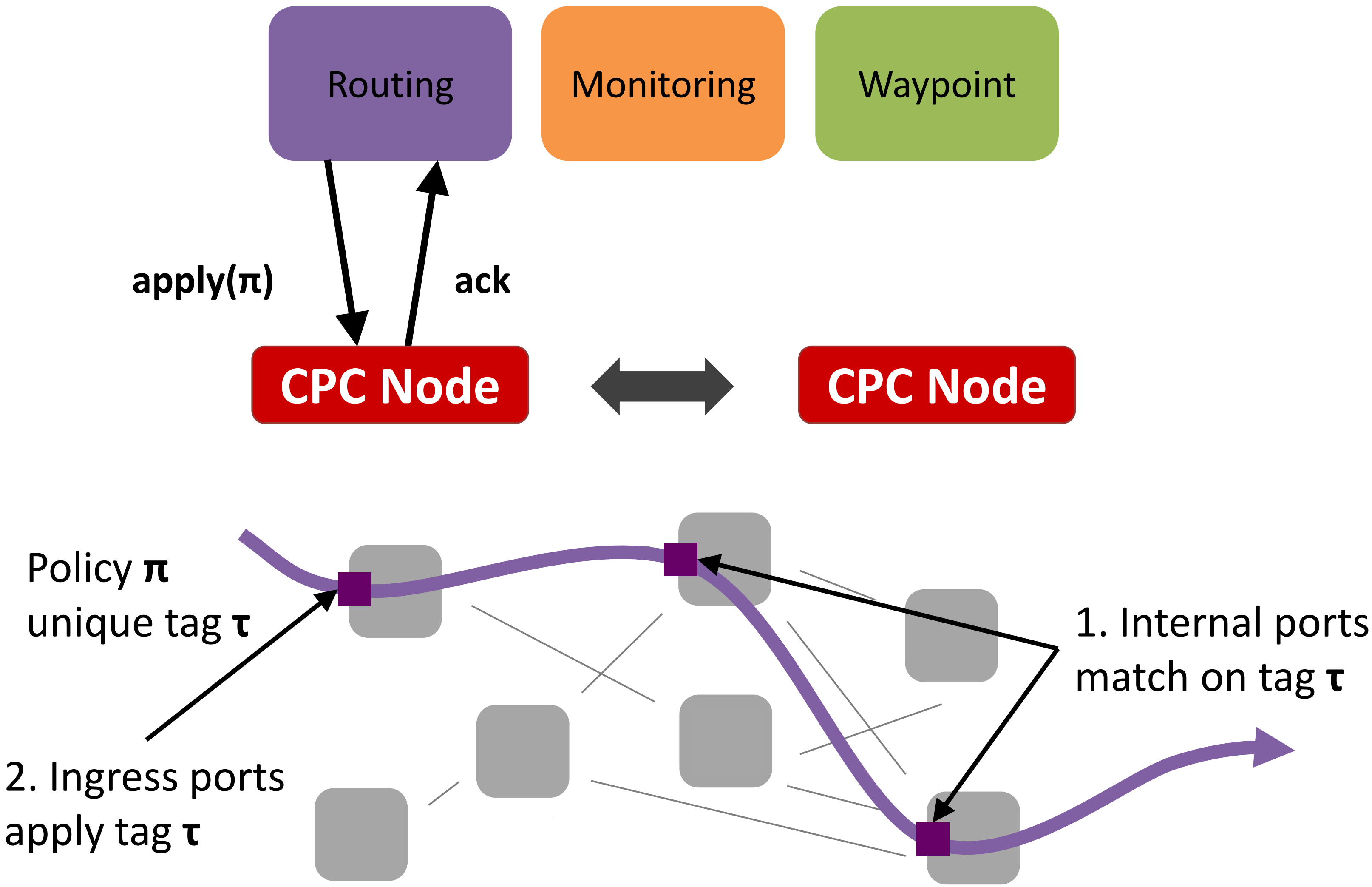
1. All-or-nothing semantics
2. Tolerate up to **f** controller node crash failures
3. Non conflicting policies eventually installed and **at least one policy commits (among conflicting ones)**
4. Ensure policy updates affect traffic as a sequential composition of their policies

Conceptualizing CPC

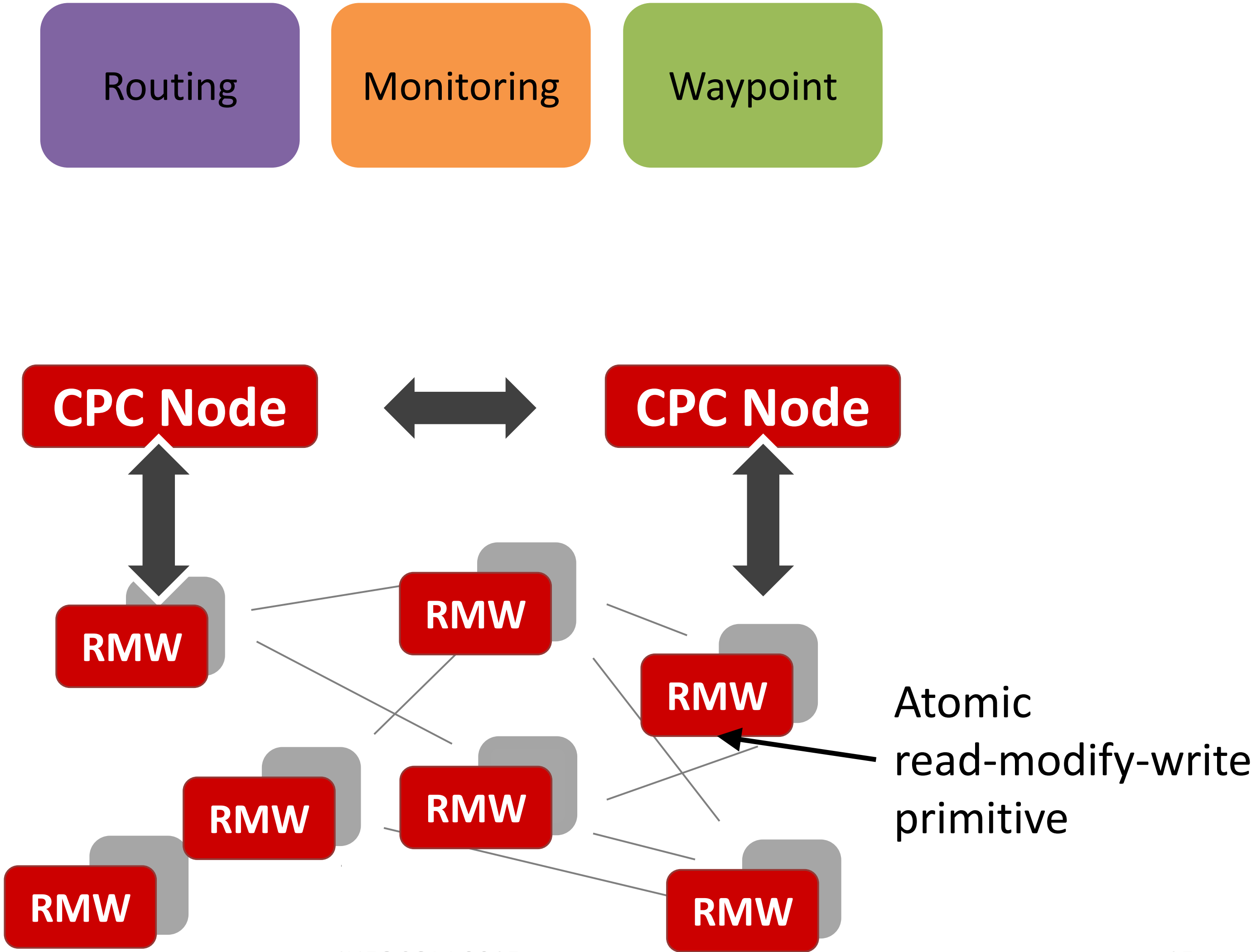


Every controller node receives and participate in installing every policy update

Conceptualizing CPC

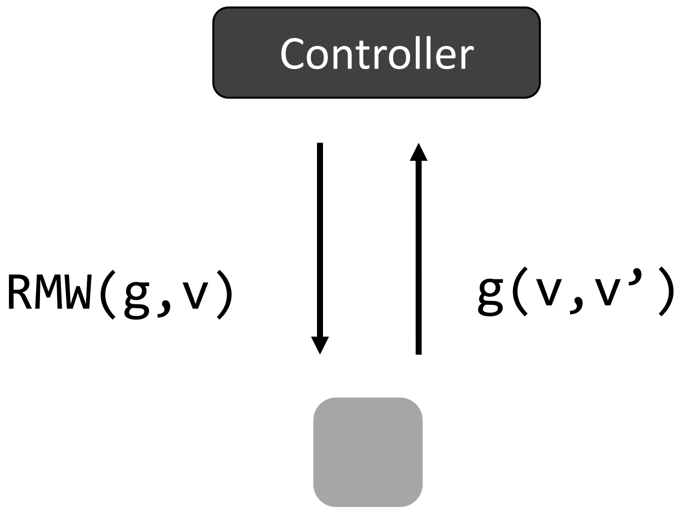


Conceptualizing CPC



RMW model

- Controllers access ports with atomic read-modify-write primitive RMW(g,v):
  - read current state v’
  - apply and return g(v,v’)



- **Intuition:** do not update if policy update conflicts with currently installed policy
- In the paper: **Theorem:** 1-resilient read-write CPC is impossible

FixTag: upper bound algorithm

Operation:

1. Unique tag per path
2. Broadcast policy **π** to all other controllers
3. Update ingress ports in predefined order
4. … add rule to tag all packets matching **dom(π)** with the tag corresponding to the path $\boldsymbol{\pi}^{(i)}$ for ingress port **i**

Upsides: wait-free (tolerates all failure patterns)

- Controllers only synchronize through the data plane

Downsides: tag complexity linear in # possible policies and paths

- May grow super-exponential in the size of the network

Can we lower the tax complexity?

- No, if we get no feedback from the network
  - Tag **τ** cannot be reused if a packet tagged with **τ** is still “in flight”
- Suppose, we can correctly evaluate the set of active tags
  - Correct (but asynchronous) oracle
- Single-controller scenario: one bit is enough!
  - Upon policy update $\boldsymbol{\pi_i}$, wait until (**i mod 2**)-traffic is over, and use tag **i mod 2**
- Two or more controllers: inherent price of concurrency?
  - Between constant and super-exponential?
- Yes, if controllers coordinate the use of tags

ReuseTag: linear complexity

- Proportional to the level of resilience:
  - Up to **f** failures: **f+2** tags needed (proved optimal)

- Controllers use replicated state machine that imposes a total order on the policy updates and ensures coordinated use and reuse of tags
  - All requests are serialized, even non-conflicting ones

Summary

- Software Transactional Networking framework for consistent policy composition (CPC) in distributed SDN control planes
  - Transactional interface to manipulate the network as though there is no concurrency
  - Policies compose or conflict (and abort)
    - Formal model of the problem is in the paper
- Two CPC algorithms
  - FixTag
  - ReuseTag: **f+2** tags (minimal number)

Backup

Acknowledgements

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