TOWARDS CORRECT-BY-CONSTRUCTION SDN

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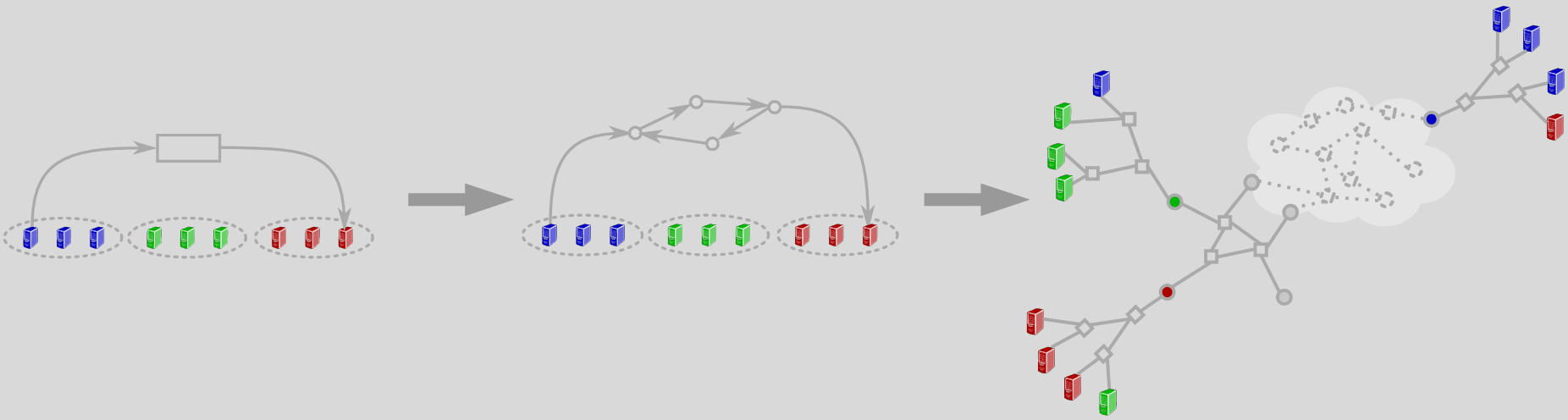
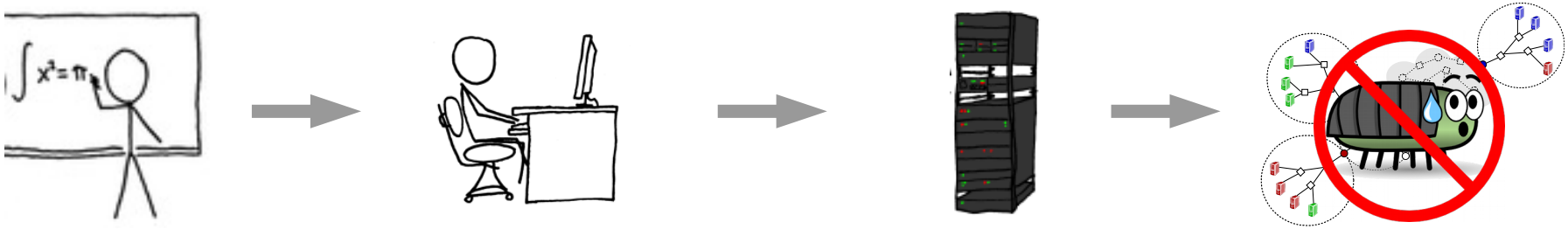


INTRODUCTION

- Cocoon is a
  - high-level SDN programming language
  - verification tool
  - SDN programming methodology
- … based on the principle of **correctness by construction**

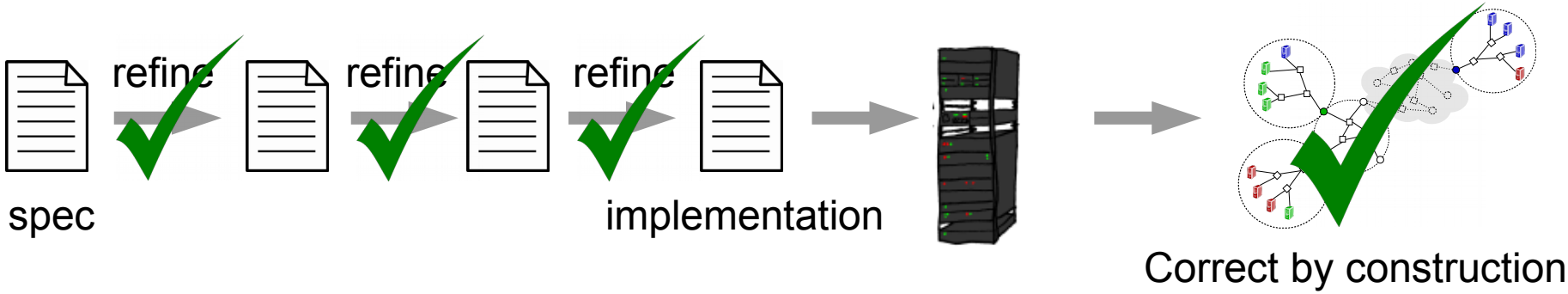
COCOON IN A NUTSHELL

Traditional SDN Verification Workflow



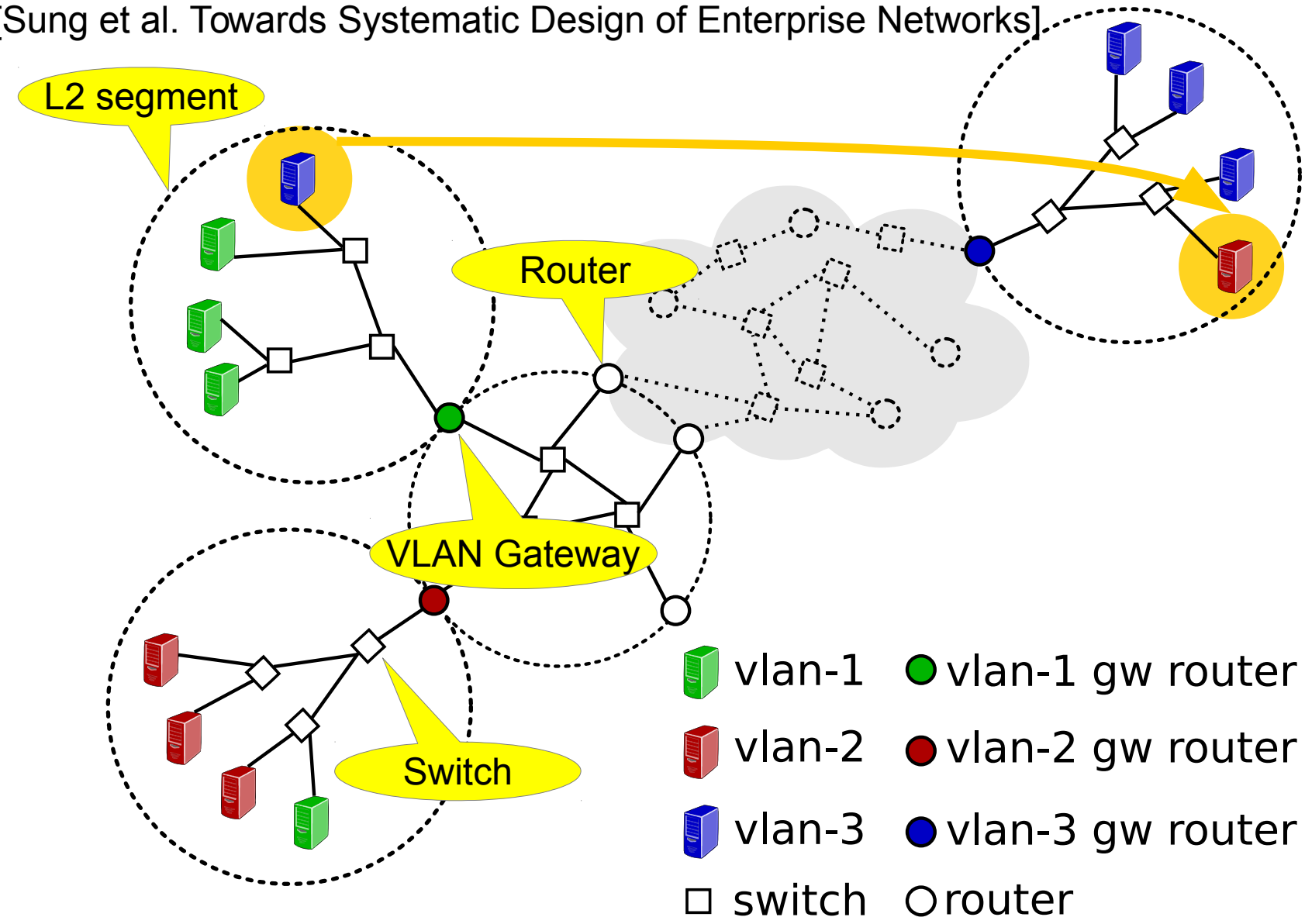
Design → Implement → Run on the controller → Verify generated network configuration

SDN verification with Cocoon

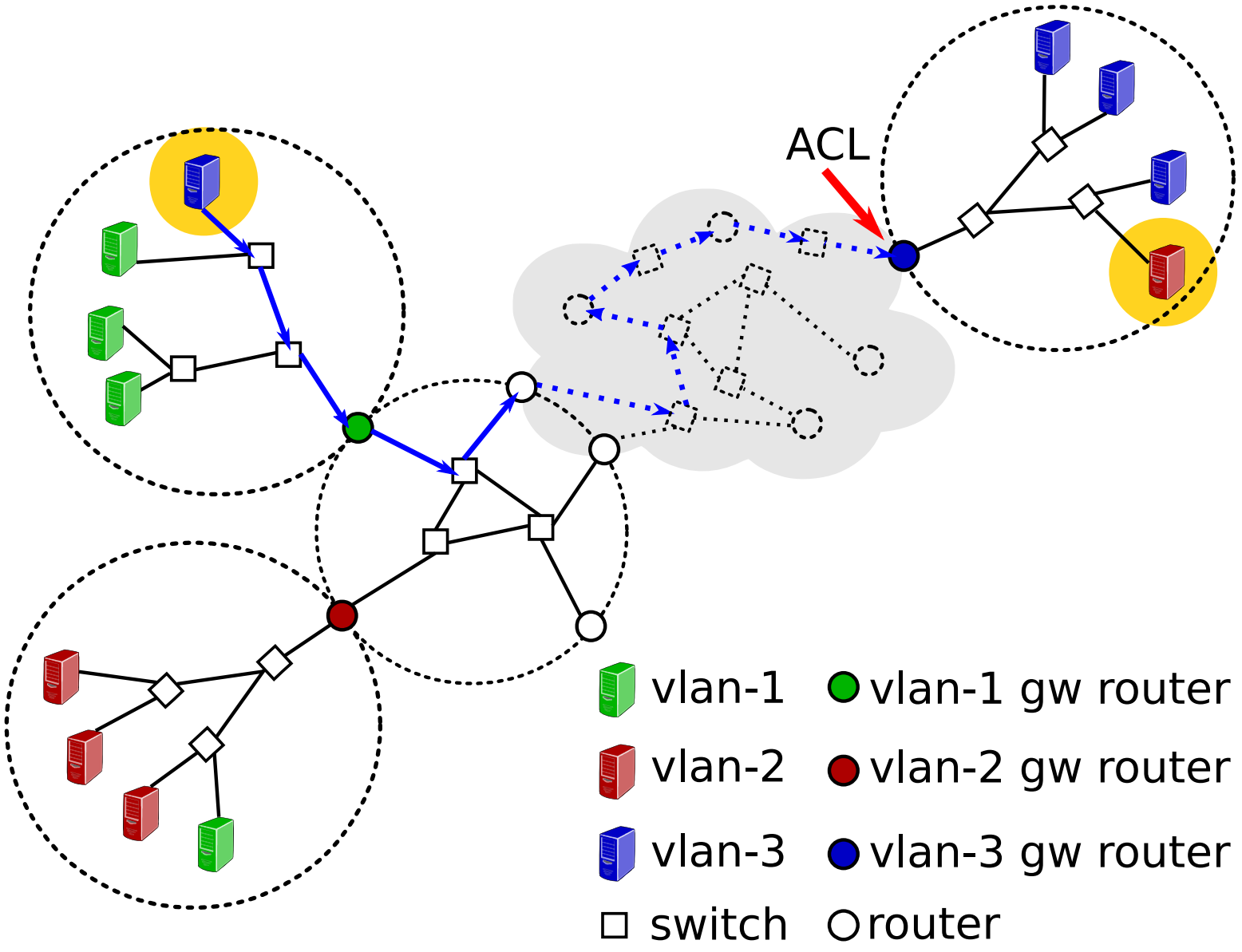


EXAMPLE: CAMPUS NETWORK

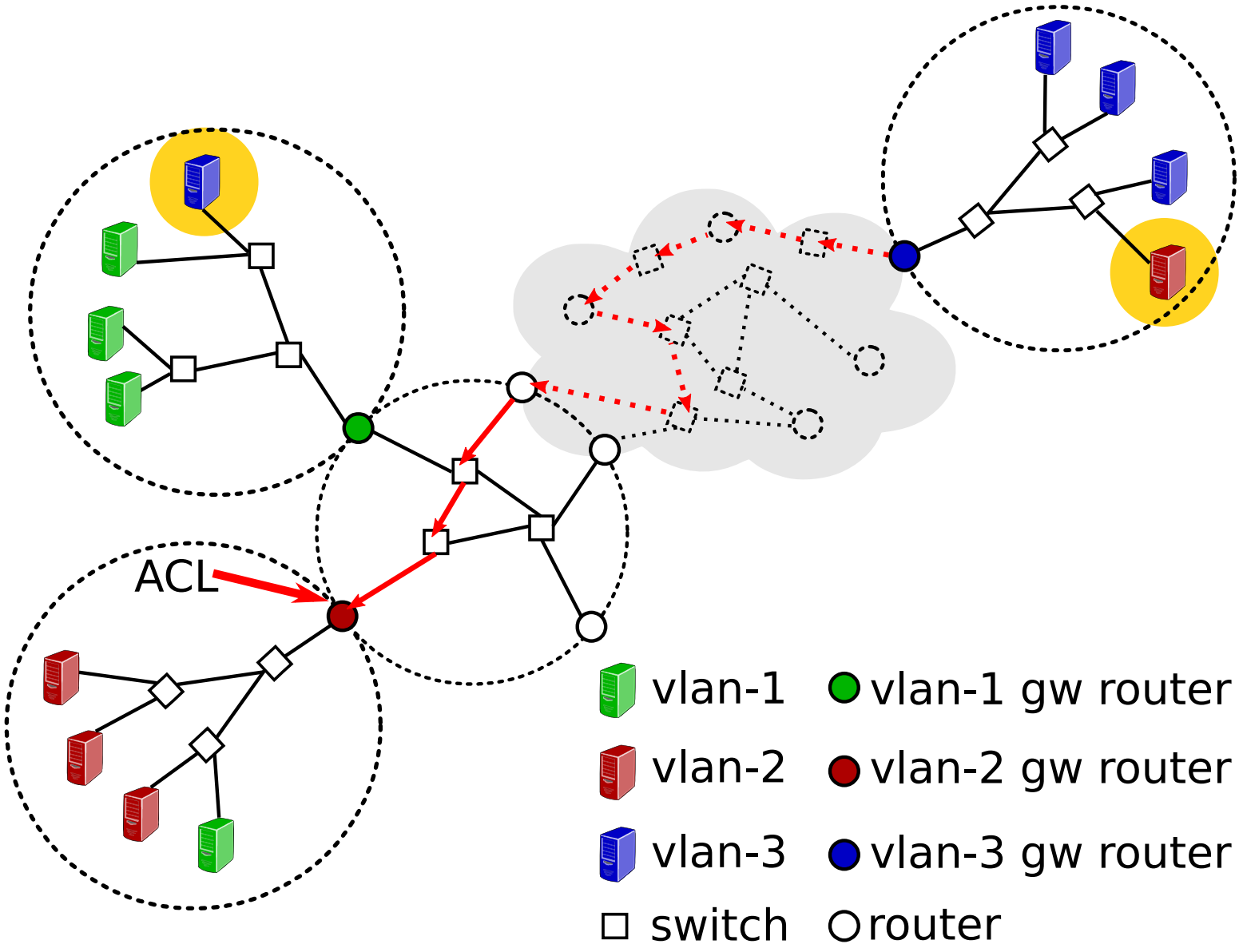
[Sung et al. Towards Systematic Design of Enterprise Networks]



INTER-VLAN ROUTING: HOP1



INTER-VLAN ROUTING: HOP2

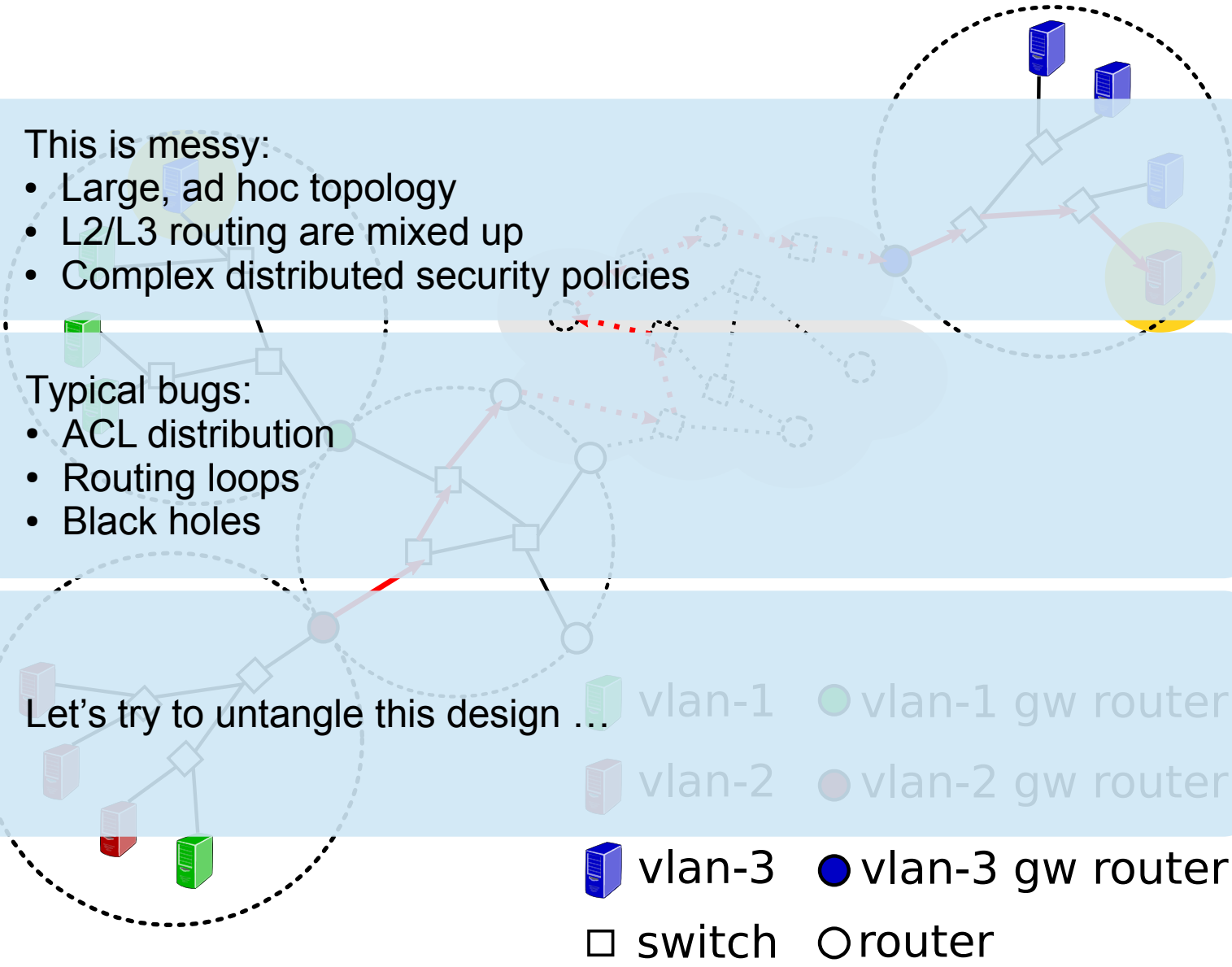


INTER-VLAN ROUTING: HOP3

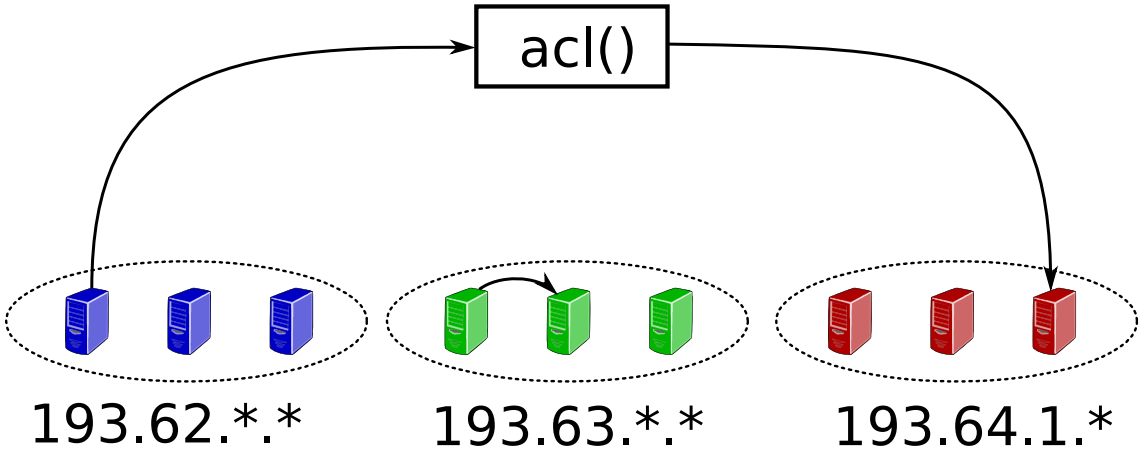
This is messy:
- Large, ad hoc topology
- L2/L3 routing are mixed up
- Complex distributed security policies

Typical bugs:
- ACL distribution
- Routing loops
- Black holes

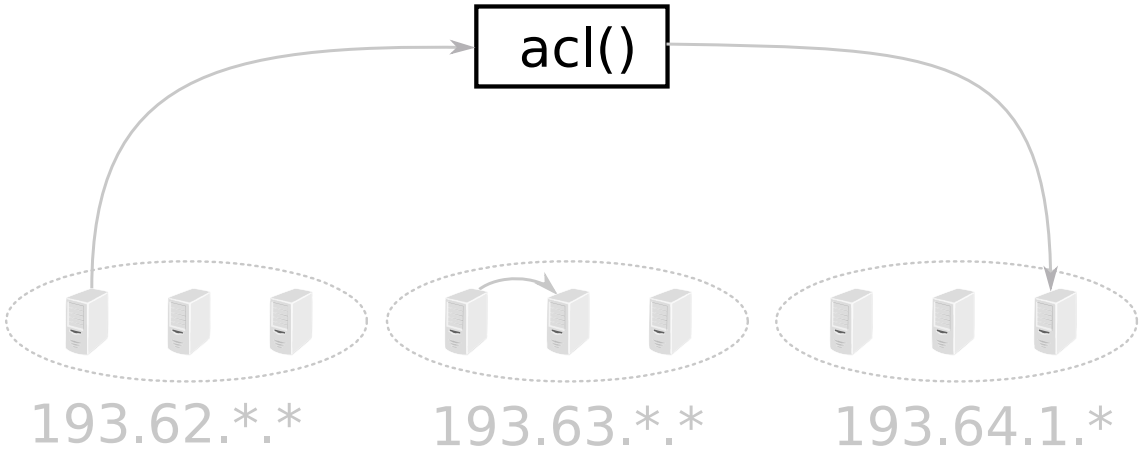
Let's try to untangle this design …



STEP 1: HIGH-LEVEL SPECIFICATION



STEP 2: DISTRIBUTED ACLs



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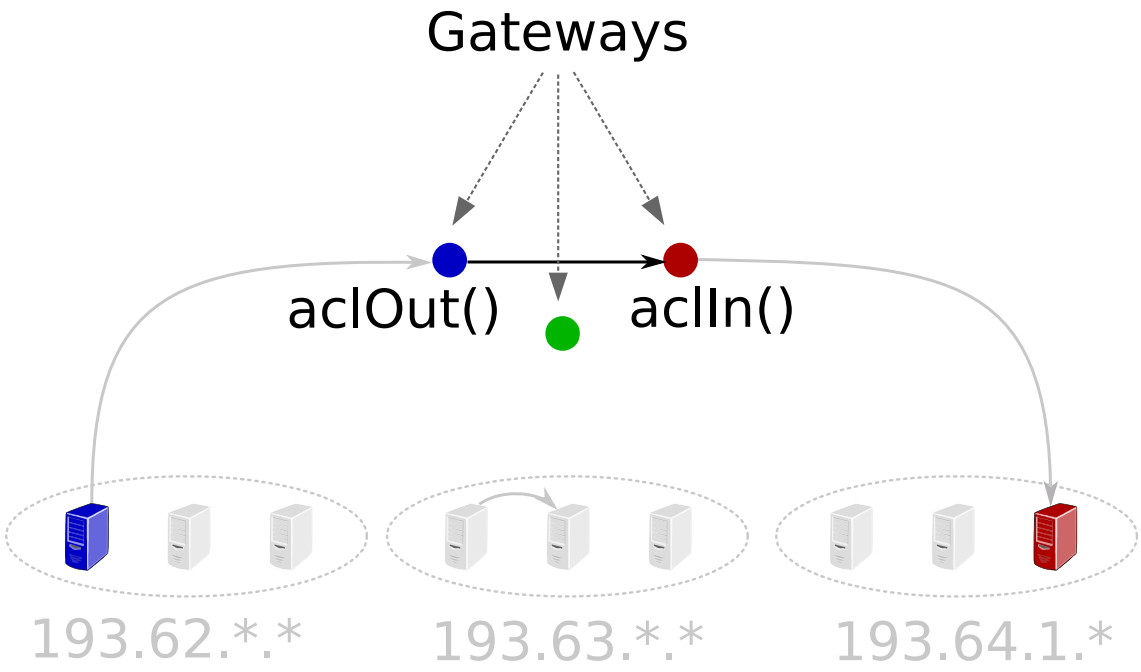
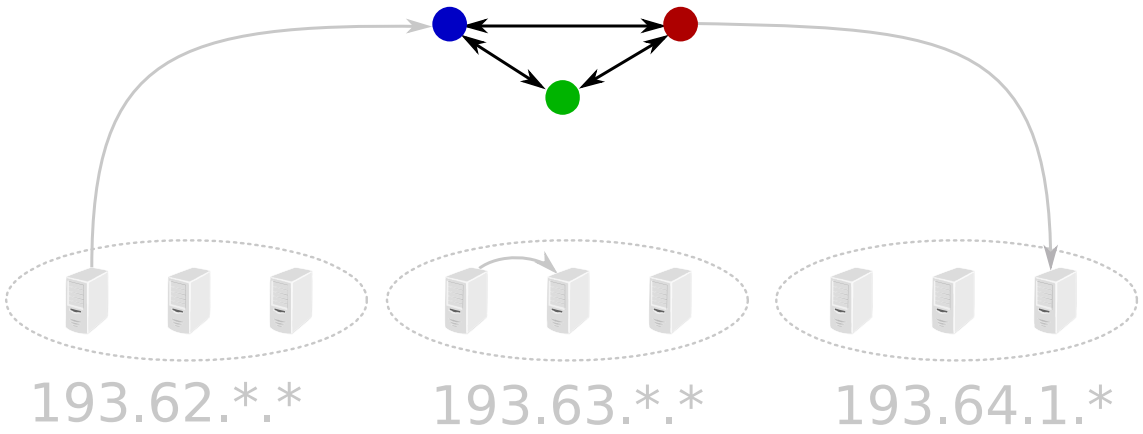
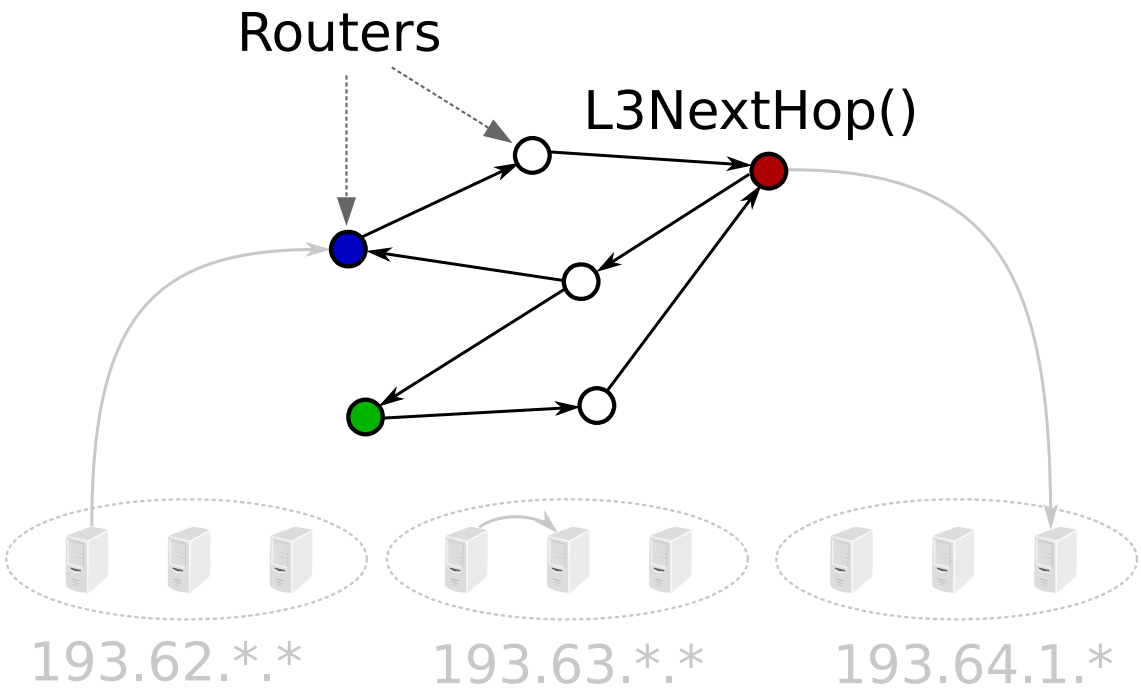


Assumption: acl() ≡ aclOut() Λ aclIn()

STEP 3: L3 ROUTING

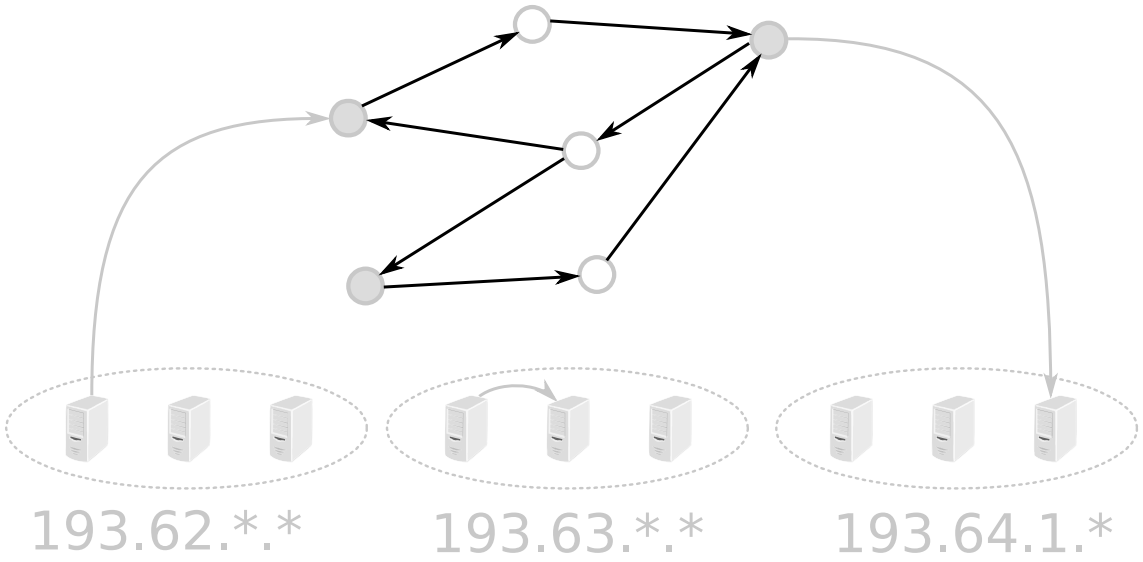


STEP 3: L3 ROUTING

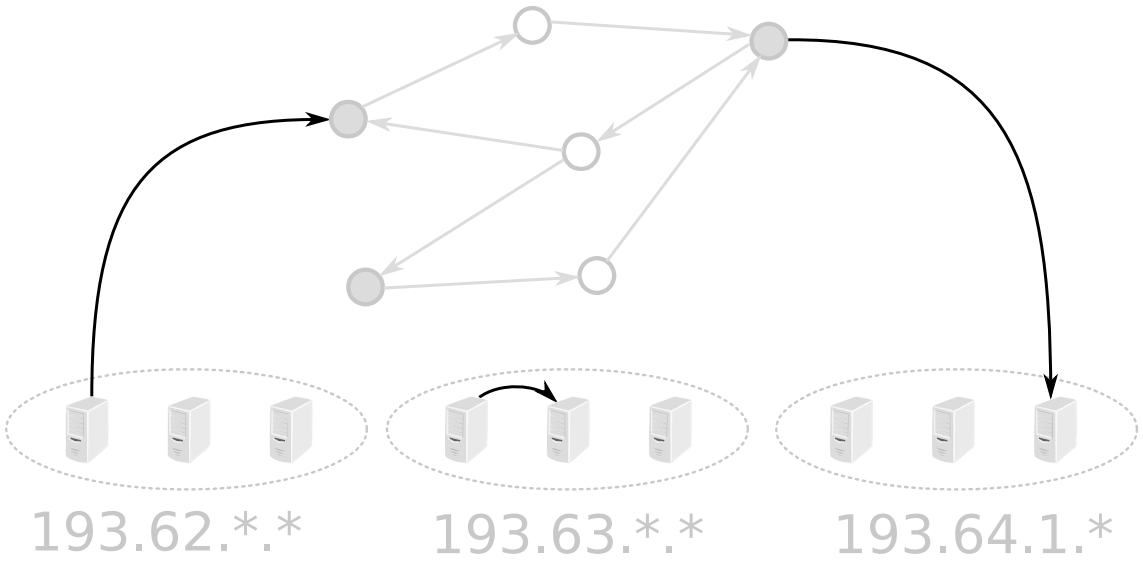


Assumption: L3NextHop(pkt)* = Gateway(pkt)

STEP 4: L2 SWITCHING



STEP 4: L2 SWITCHING



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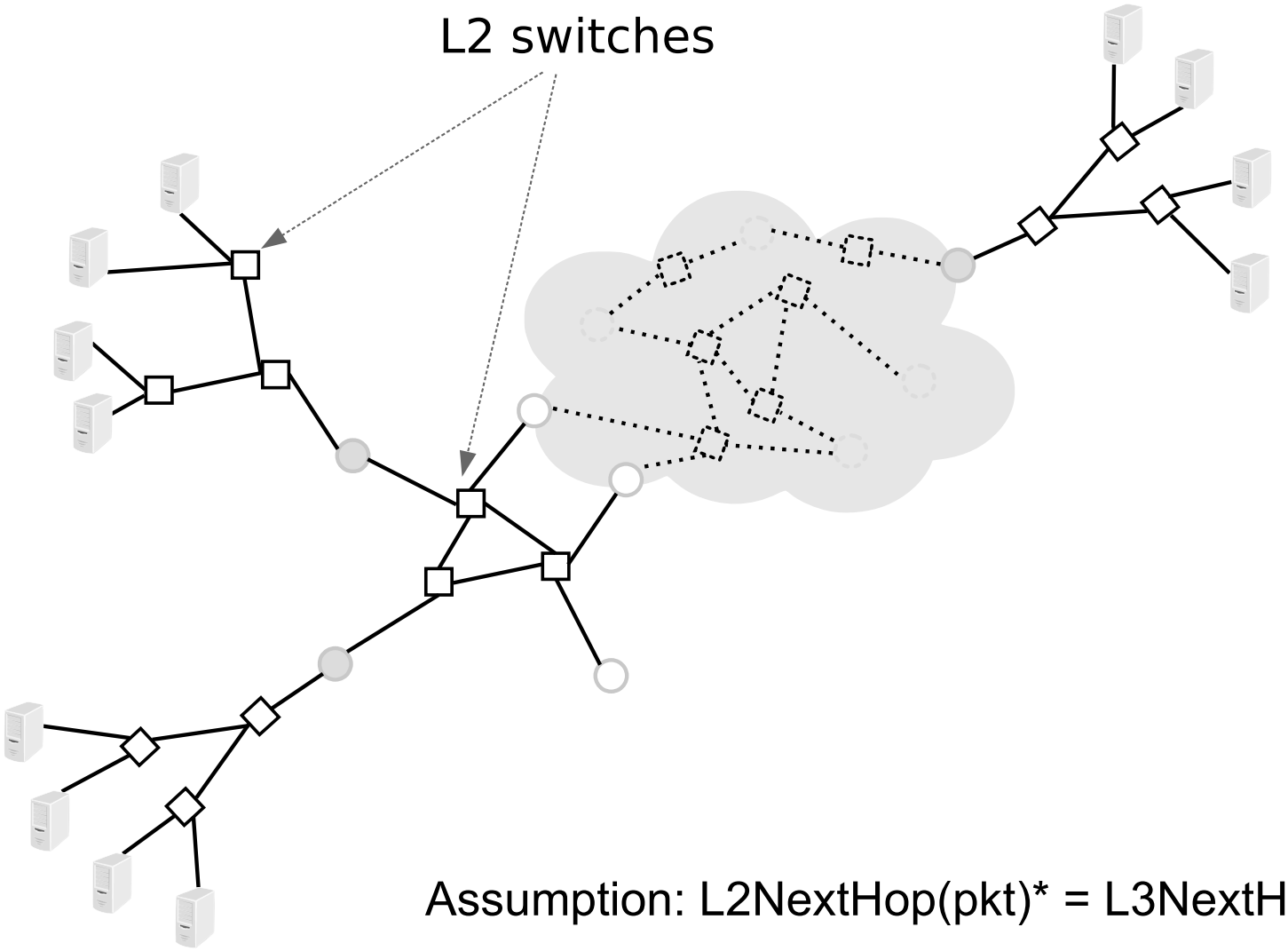
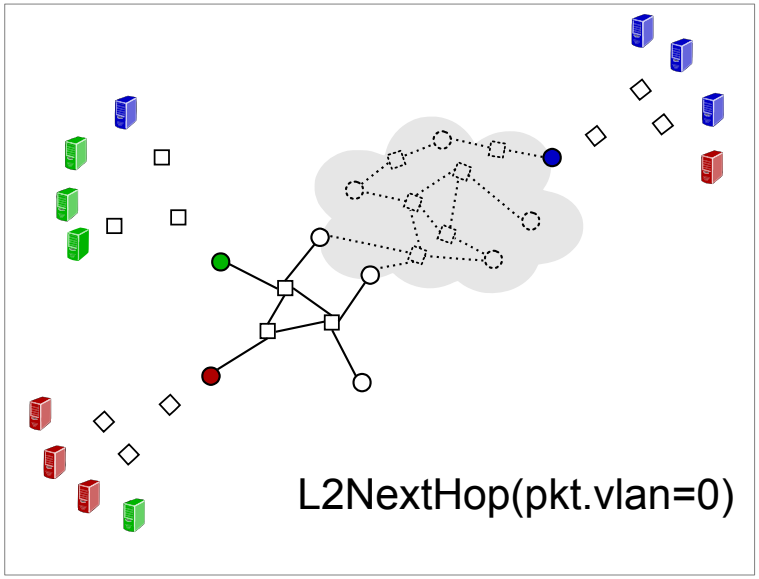
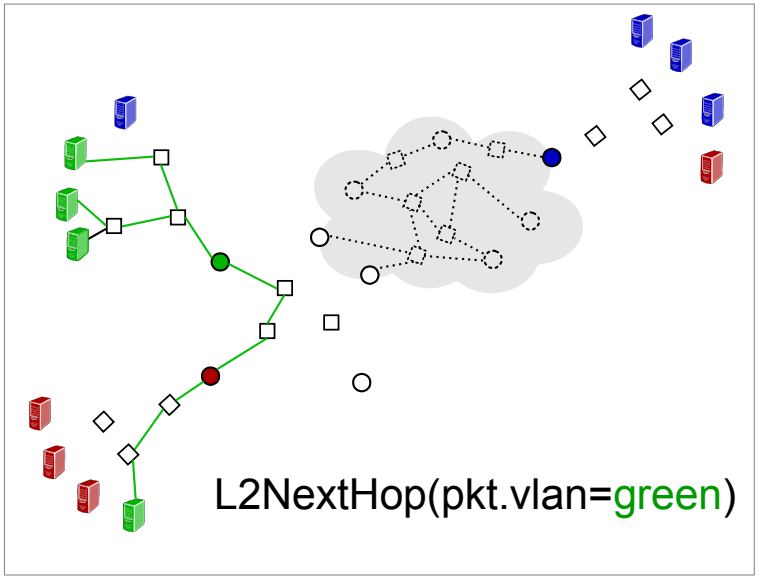
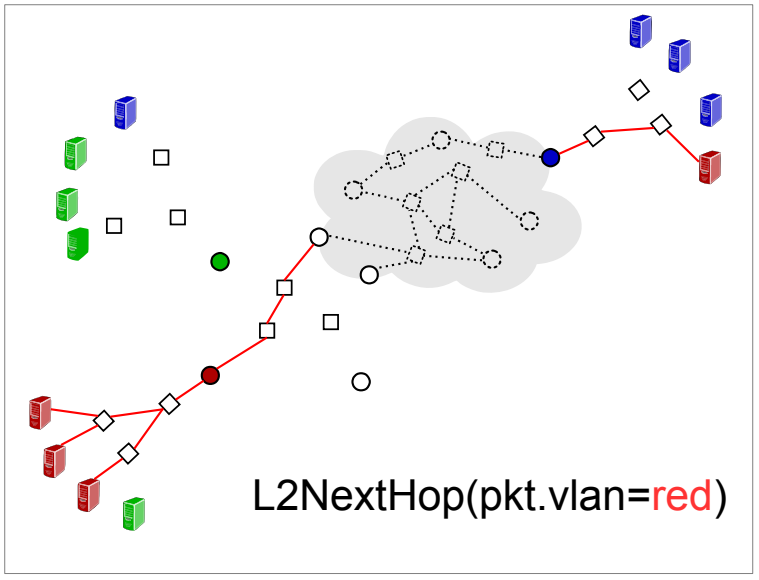


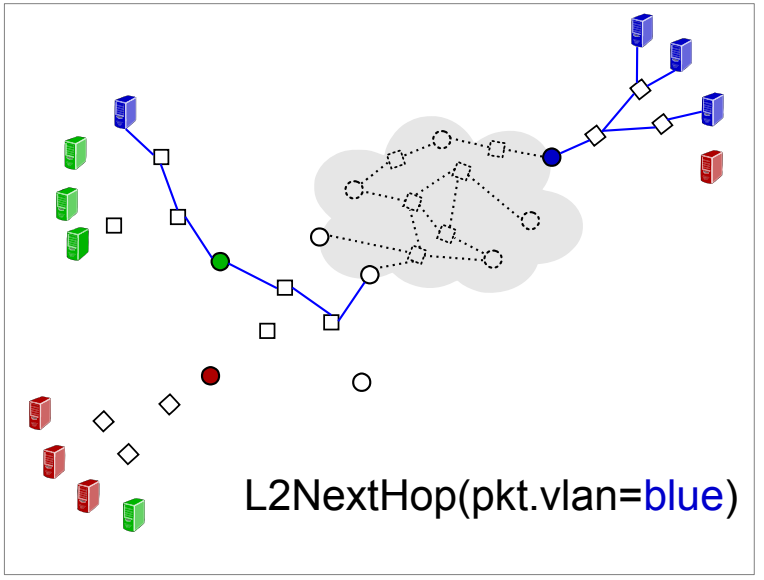
Assumption: L2NextHop(pkt)* = L3NextHop(pkt)

STEP 4: L2 SWITCHING

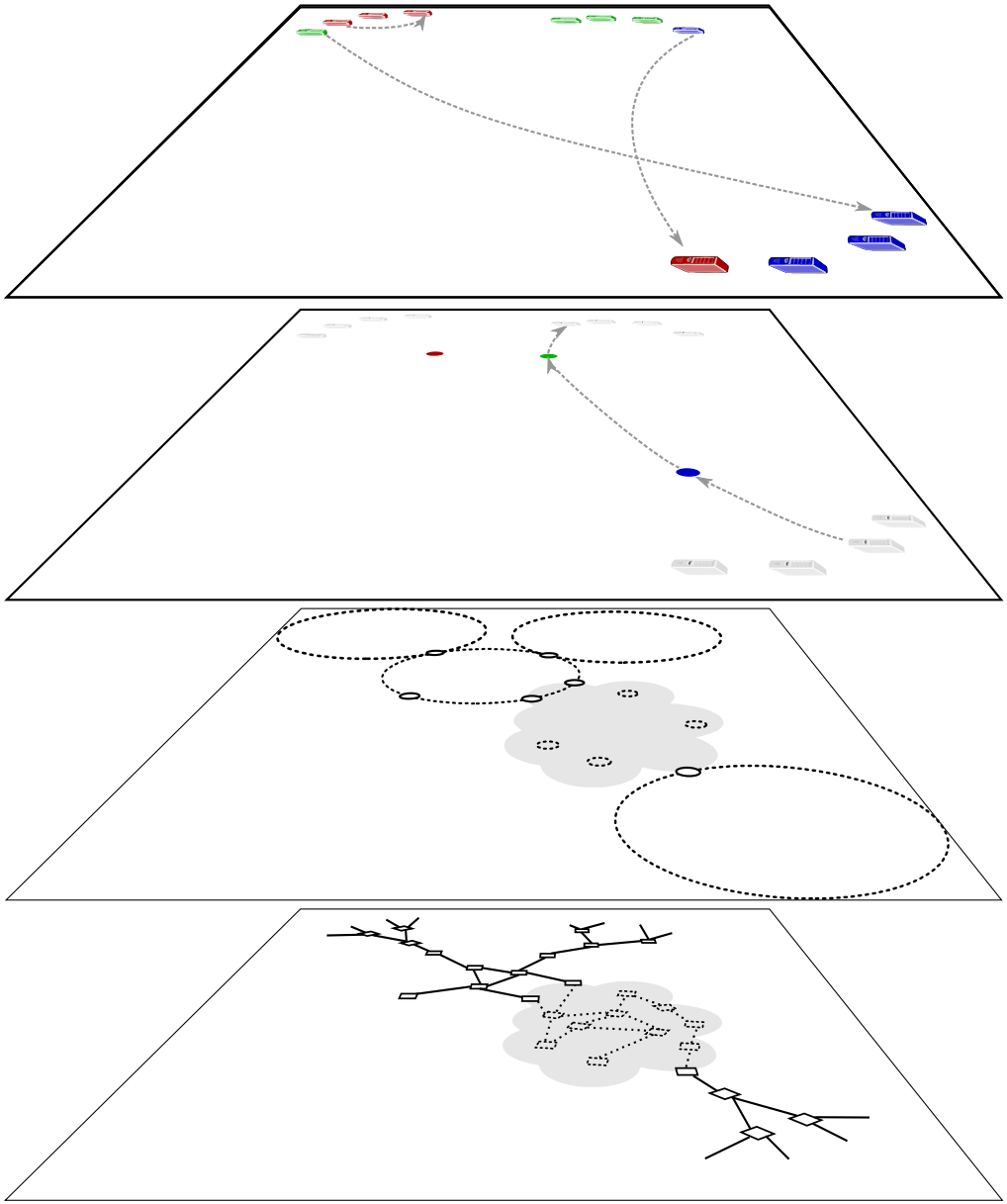








SEPARATION OF CONCERNS



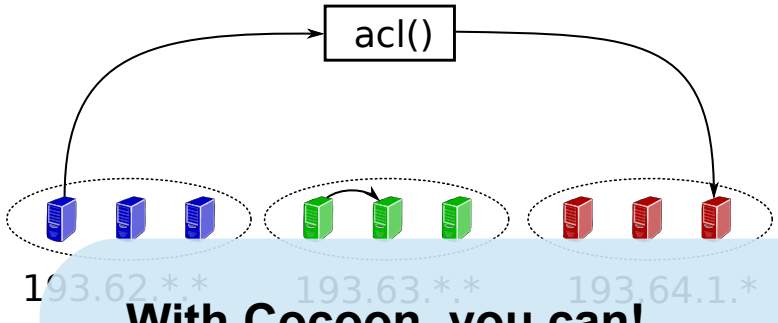
High-level spec

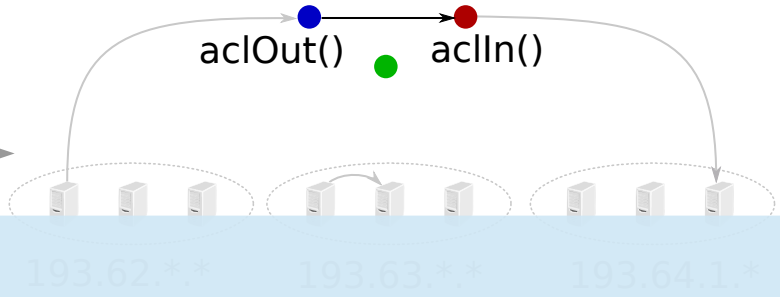
Distributed access control

L3 routing

L2 switching

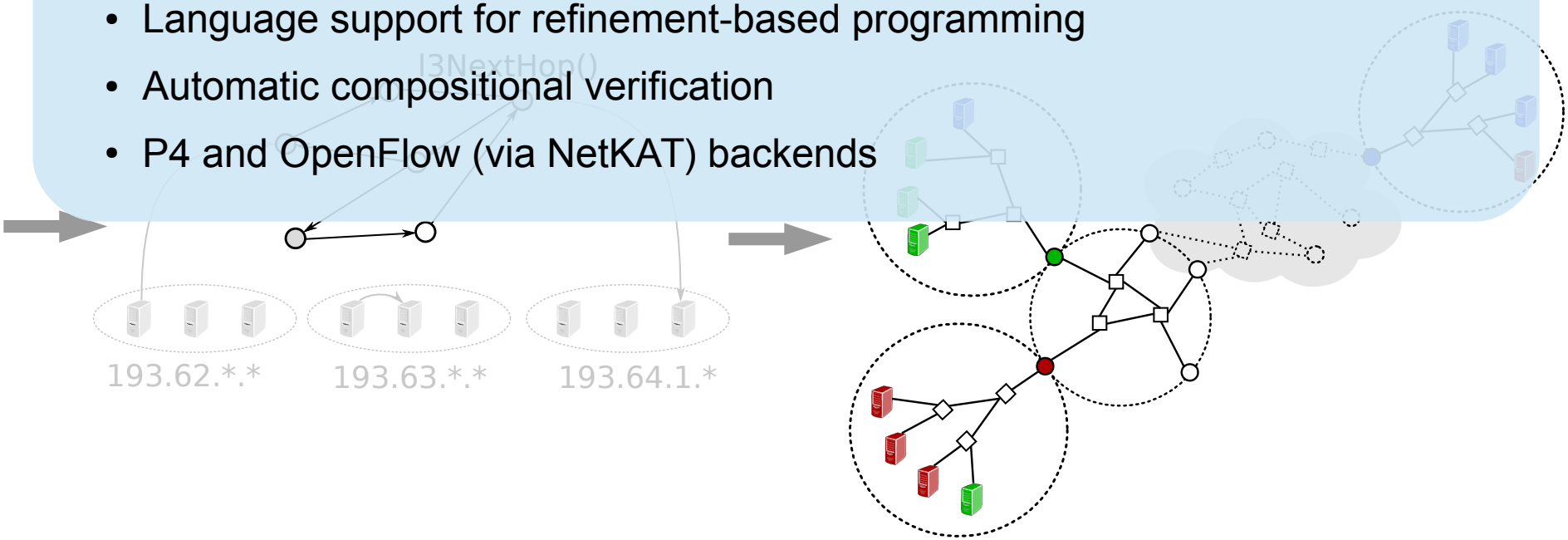
WOULDN'T IT BE GREAT TO BUILD SDNs THIS WAY?





With Cocoon, you can!

- Language support for refinement-based programming
- Automatic compositional verification
- P4 and OpenFlow (via NetKAT) backends



PARAMETERIZED SPECIFICATIONS

- Parameterized specifications
  - Spec may contain *undefined functions*, e.g., acl(), l2NextHop(), l3NextHop()
  - Verification relies on *assumptions*
  - These functions are defined when the network design is instantiated
  - They can also change at runtime, e.g., in response to link failures
  - Assumptions are validated when concrete definitions are provided (statically or at runtime)

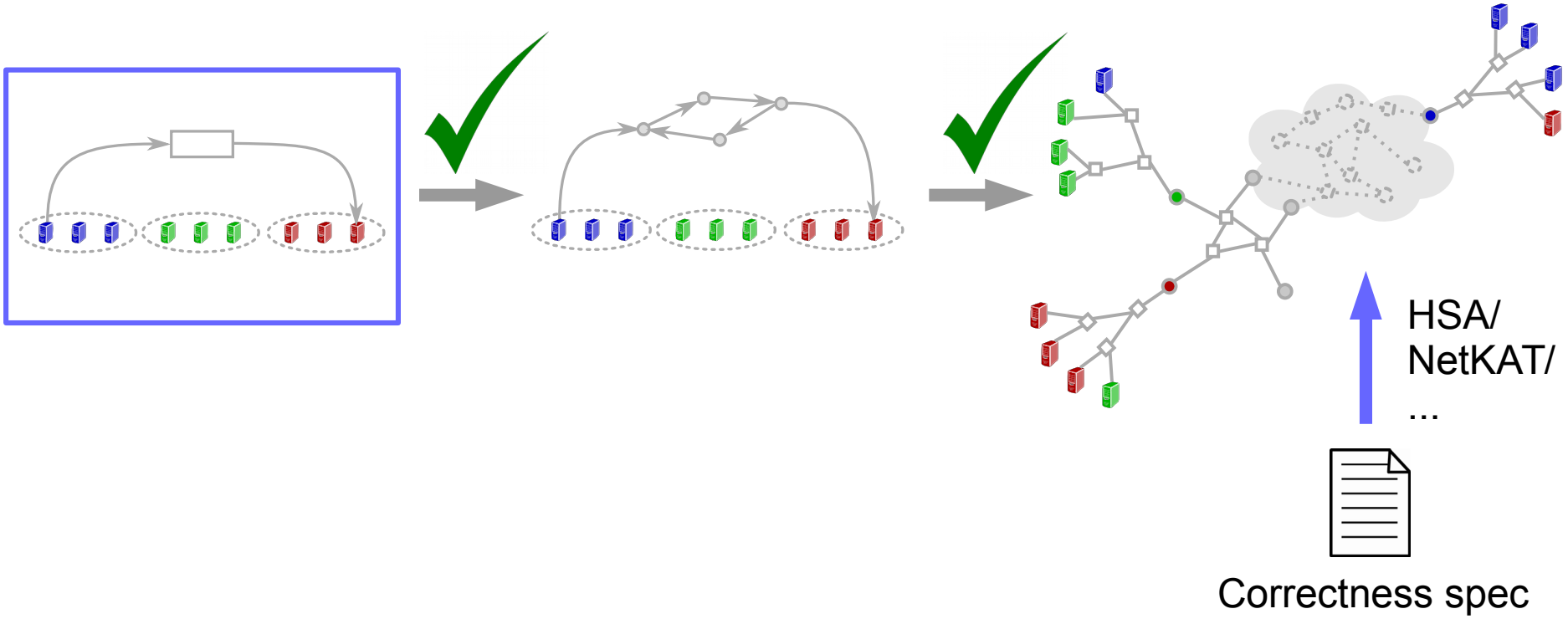
CASE STUDIES

- **Campus network**
  [Sung et al. Towards Systematic Design of Enterprise Networks]
- **F10**
  [Liu et al. F10: A Fault-Tolerant Engineered Network]
- **B4-style WAN**
  [Jain et al. B4: Experience with a Globally-Deployed Software Defined WAN]
- **iSDX** (Software-defined Internet Exchange)
  [Gupta et al. An Industrial-Scale Software Defined Internet Exchange Point]
- **NSX-style network virtualization framework**
  [Koponen et al. Network Virtualization in Multi-tenant Datacenters]
- **Stag** (source-based routing + security labels for fat-tree topology)

PERFORMANCE

- All case studies verified in ~10 sec,
  - Compositional verification (1 refinement at a time)
  - Parameterized verification amplifies the power of symbolic reasoning
- Verification results apply to a family of topologies and all runtime configurations produced by the SDN app
- No direct comparison (yet) with existing tools like NetKAT, HSA, but expect them to slow down for larger topologies

COCOON VS TRADITIONAL NETWORK VERIFICATION



CONCLUSIONS

- Correct-by-construction SDN via iterative refinement:
  - Enforces modular design
  - Enables strong static correctness guarantees
  - Scales to complex realistic networks