

VeriCon: Towards Verifying Controller Programs in Software-Defined Networks

Motivation

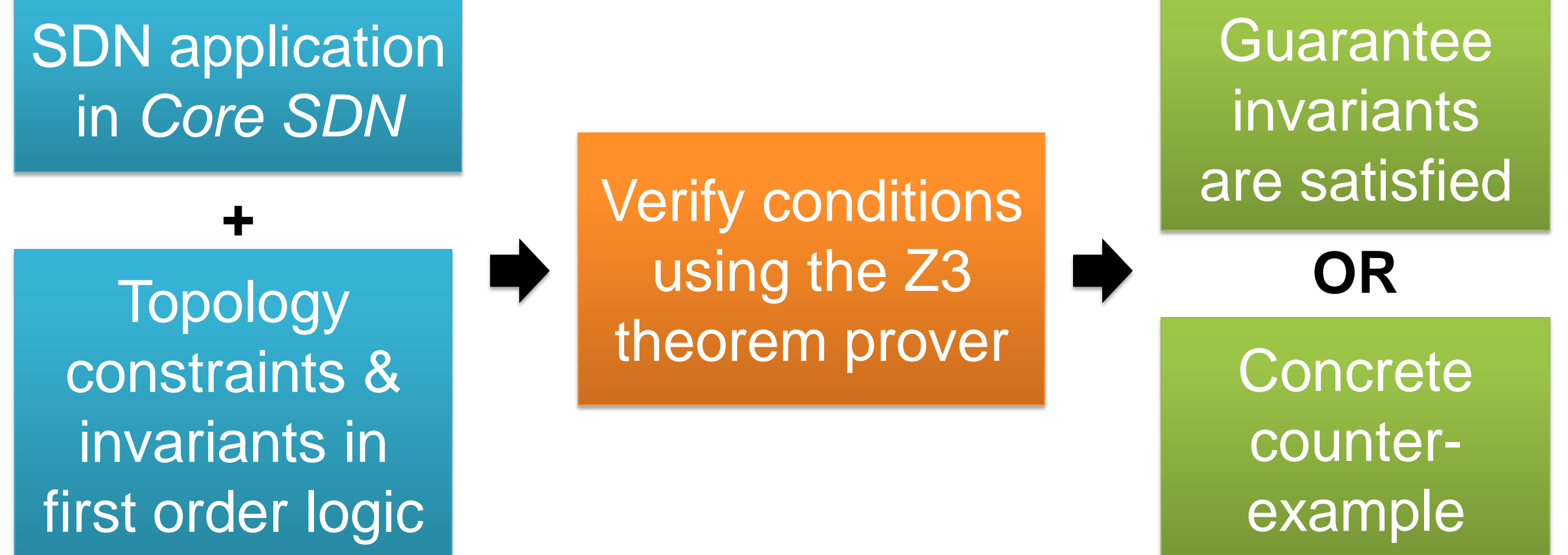


Software defined networking (SDN) aims to simplify network management by removing the control plane from switches and running custom control applications at a logically central controller. Unfortunately, writing control applications that **always** maintain a set of network invariants (e.g., the network does not contain forwarding loops or blackholes) is a challenging task.

Prior work [1, 2] uses finite-state model checking and network snapshots to identify bugs in control applications. They can find errors, but they cannot guarantee the absence of errors.

Overview

VeriCon verifies network-wide invariants for **any** event sequence and **all** admissible topologies



Types of Invariants

- **Topology**: define admissible topologies } assumed to hold initially
- **Safety**: define the required consistency of network-wide states } checked initially & after each event
- **Transition**: define the effect of executing event handlers

Learn More!



<http://agember.com/go/vericon>

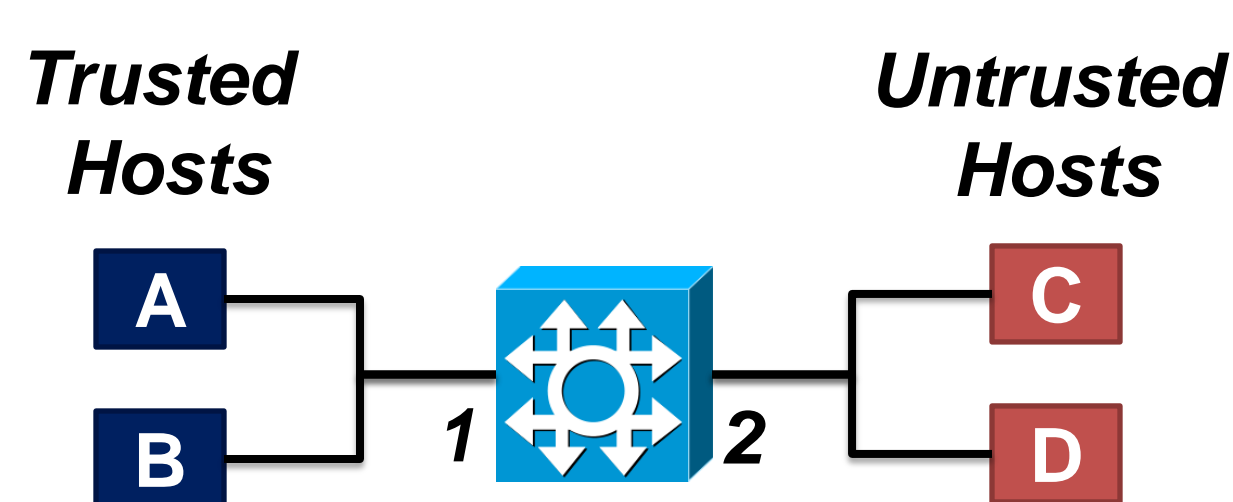
Core SDN (CSDN)

- Define and initialize relations: **rel** $r()$ **init** $r = ()$
 - Topology relations: $link(S,O,H)$ $path(S,O,H)$
 - Forwarding relations: $ft(S,P,I,O)$ $fr(S,P,I,O)$
- Write packet-in event handlers: **pktIn**(S,P,I)
 - Update defined relations: $r.insert()$ $r.remove()$
 - Install rules ($ft.insert$): $S.install(P,I,O)$
 - Forward packet ($fr.insert$): $S.forward(P,I,O)$
 - Conditionals: **if** $Cond$ **then** Cmd^* **else** Cmd^*

Verification Time

Program	LOCs	Topo Inv.	Safety + Trans Inv.	Time (sec)
Firewall	8	1	3 + 0	0.12
Stateless Firewall	4	1	2 + 0	0.06
Firewall + Host Migration	9	0	3 + 0	0.16
Learning Switch	8	1	4 + 2	0.16
Learning Switch + Auth	15	2	5 + 3	0.21
Resonance (simplified)	93	6	5 + 2	0.21
Stratos (simplified)	29	12	3 + 0	0.09

Example: Stateful Firewall



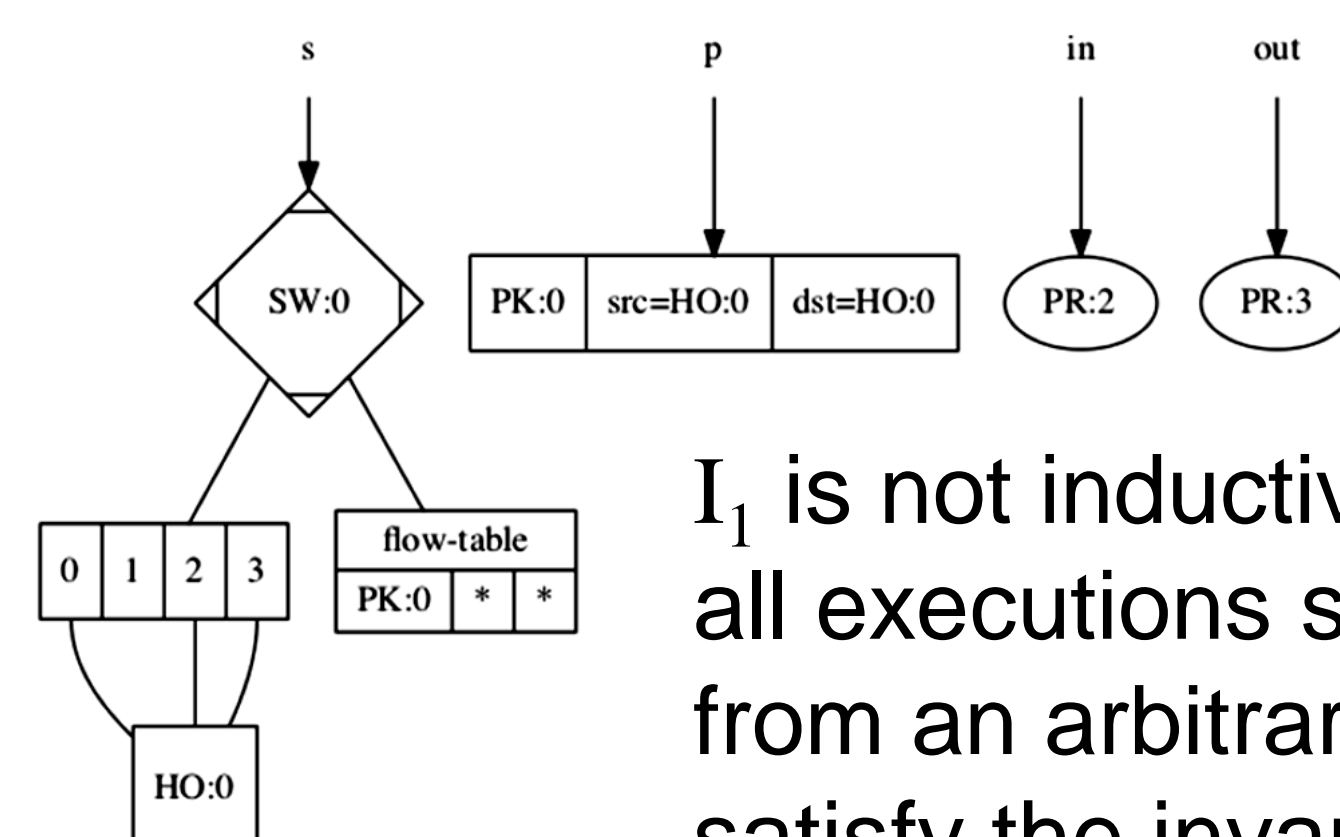
- Always forward from trusted to untrusted hosts
- Only forward from untrusted to trusted hosts if a trusted host previously sent a packet to the untrusted host

Application in Core SDN

```

rel tr(SW, HO)
pktIn(sw, pkt, prt(1)) ->
  sw.forward(pkt, prt(1), prt(2))
  tr.insert(s, pkt.dst)
  sw.install(pkt, prt(1), prt(2))
pktIn(sw, pkt, prt(2)) ->
  if tr(sw, pkt.src) then
    sw.forward(pkt, prt(2), prt(1))
    sw.install(pkt, prt(2), prt(1))
    
```

Counterexample



I_1 is not inductive—not all executions starting from an arbitrary state satisfy the invariant

$I_1 \wedge I_2 \wedge I_3$ is inductive

Invariants

- At least one switch with ports $prt(1)$ & $prt(2)$; a packet P is forwarded from an untrusted host U to a trusted host T

$$\exists U, T: HO, S: SW, P: PK. link(S, prt(2), U) \wedge link(S, prt(1), T) \wedge P.src = U \wedge P.dst = T \wedge fr(S, P, prt(2), prt(1))$$

- For every packet sent from an untrusted host U to a trusted host T there exists a packet sent to U from T

$$I_1 \stackrel{def}{=} fr(S, P, prt(2), prt(1)) \Rightarrow \exists P': PK. P'.dst = P.src \wedge fr(S, P', prt(1), prt(2))$$

- Flow table entries only contain forwarding rules from trusted hosts

$$I_2 \stackrel{def}{=} ft(S, P, prt(2), prt(1)) \Rightarrow \exists P': PK. P'.dst = P.src \wedge fr(S, P', prt(1), prt(2))$$

- Controller relation tr stores the correct hosts

$$I_3 \stackrel{def}{=} tr(S, H) \Rightarrow \exists P: PK. P.dst = H \wedge fr(S, P, prt(1), prt(2))$$

Topology Invariant

Safety Invariants

References

- [1] Kazemian, P., Varghese, G., and McKeown, N. Header Space Analysis: Static Checking For Networks. In *Network Systems Design and Implementation (NSDI)*. 2012.
- [2] Canini, M., Venzano, D., Peres, P., Kostic, D., and Rexford, J. A NICE Way to Test OpenFlow Applications. In *Network Systems Design and Implementation (NSDI)*. 2012.