The Mathematical Foundations for Mapping Policies to Network Devices

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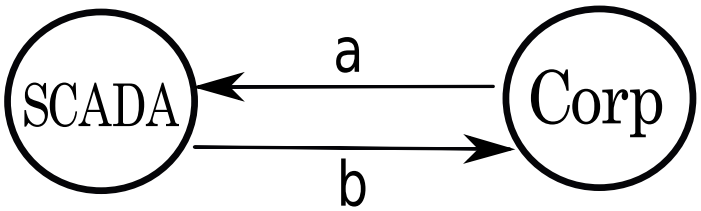
Motivation

- Context is Policy Defined Networking (PDN)
- **Policy** and **Implementation** should be separate
- Then coupled back together (*i.e.*, policy mapped to devices)
- The coupling must be *formally* checkable

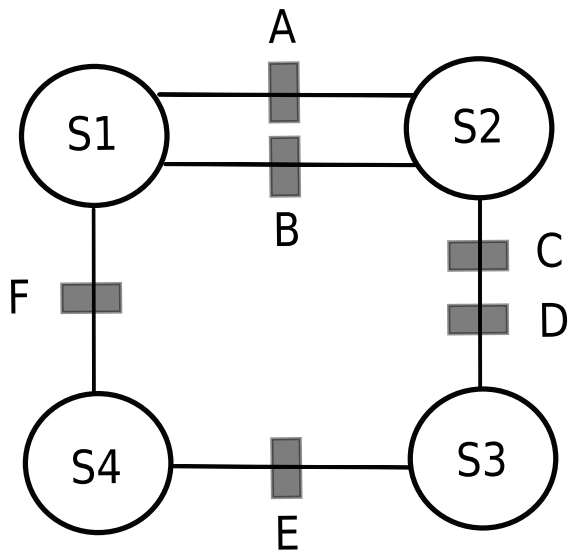
Example

Best-practice policy



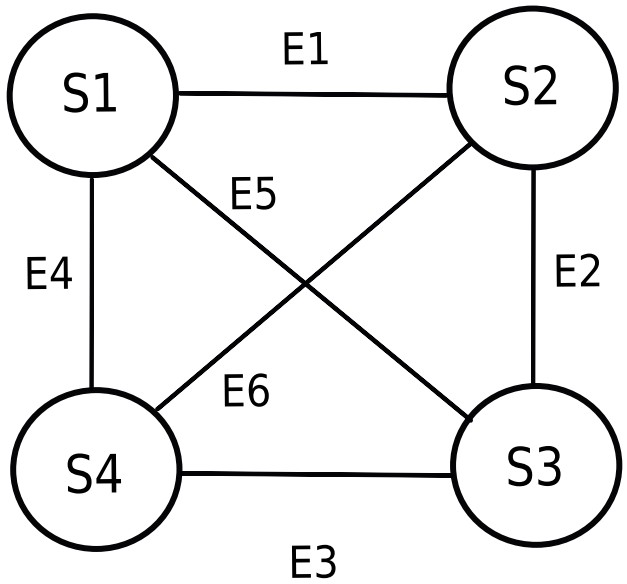
$\Rightarrow$

My network



Correct policy deployment is hard!

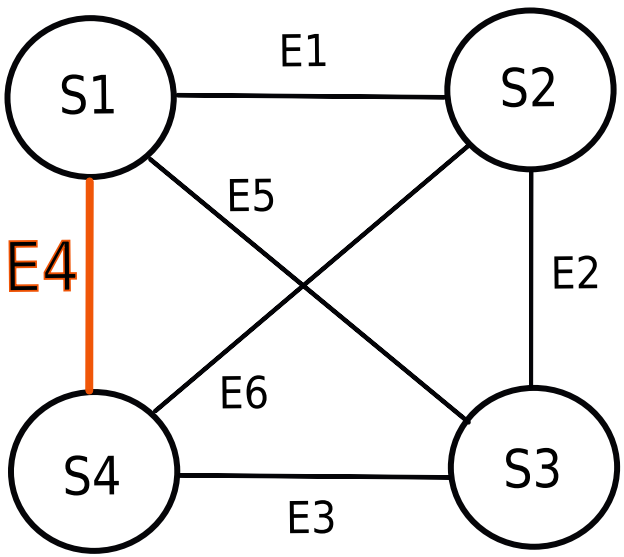
Policy graph



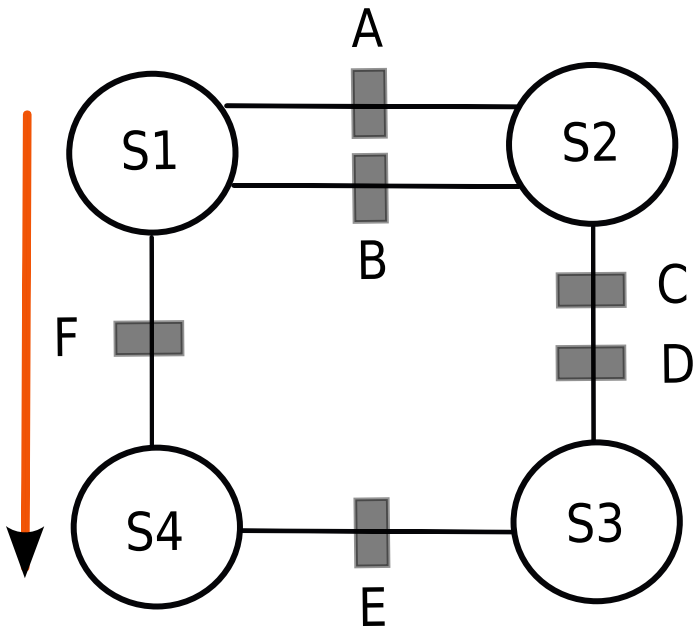
- *(endpoint-group, edge)* : commonly used to decouple policy from the network
  - *endpoint: e.g.,* a subnet, a user-group
  - *edge:* specifies relationship between endpoint-groups

Correct policy deployment is hard!

Policy graph



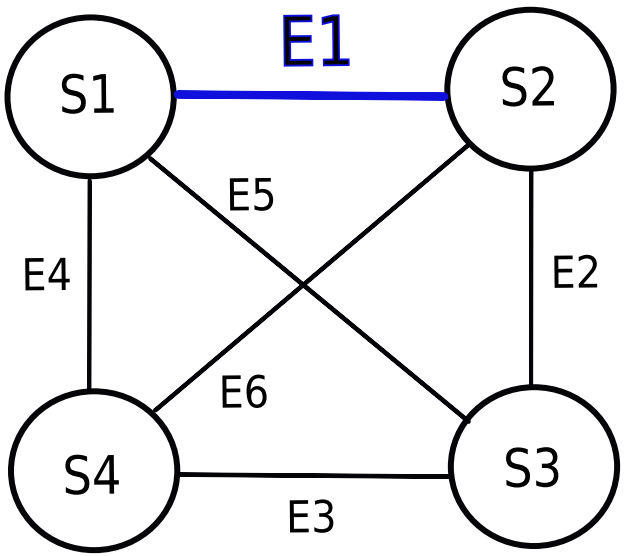
Network topology



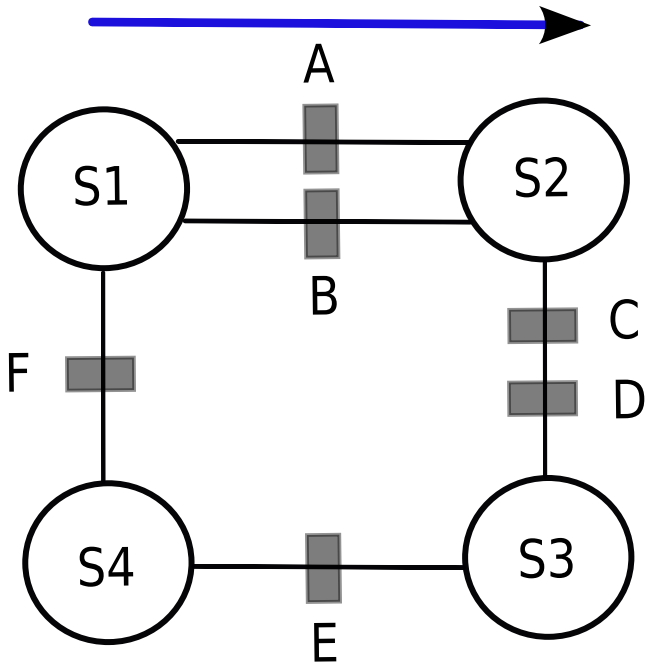
- *e.g.*, E4: $S1 \rightarrow S4$: *ssh allow*

Correct policy deployment is hard!

Policy graph



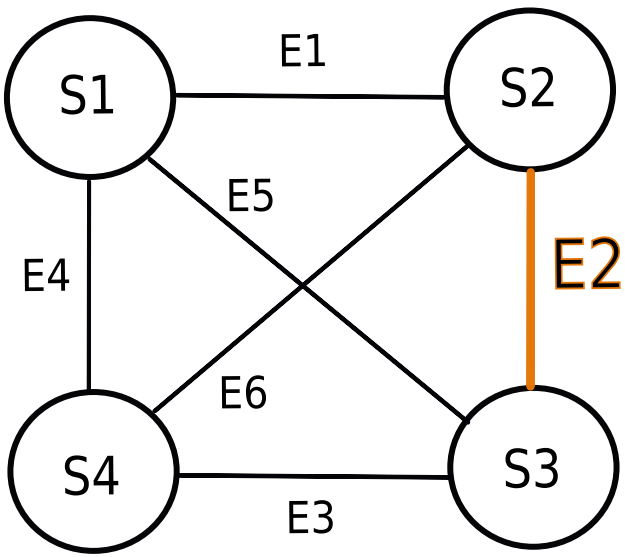
Network topology



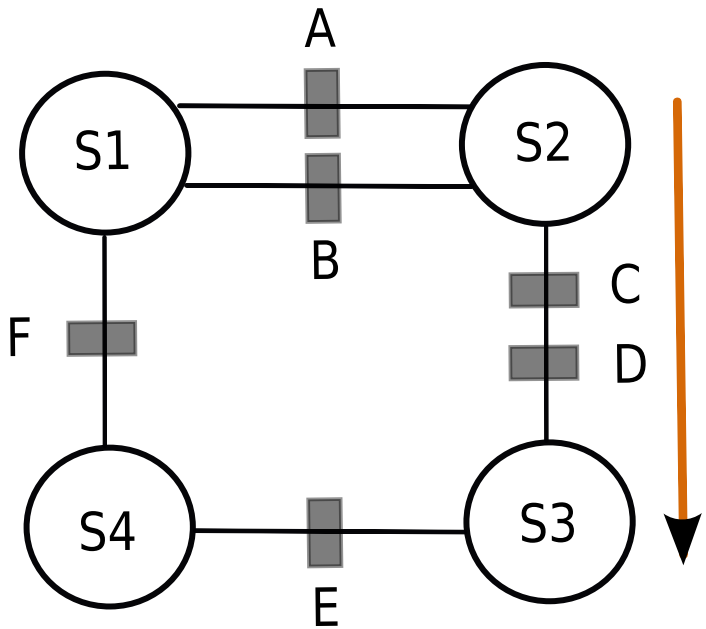
- *e.g.*, E1: $S1 \rightarrow S2$: *ssh allow*

Correct policy deployment is hard!

Policy graph



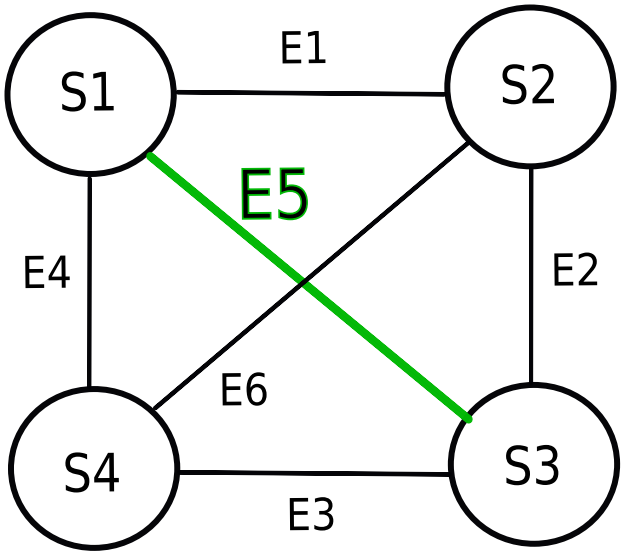
Network topology



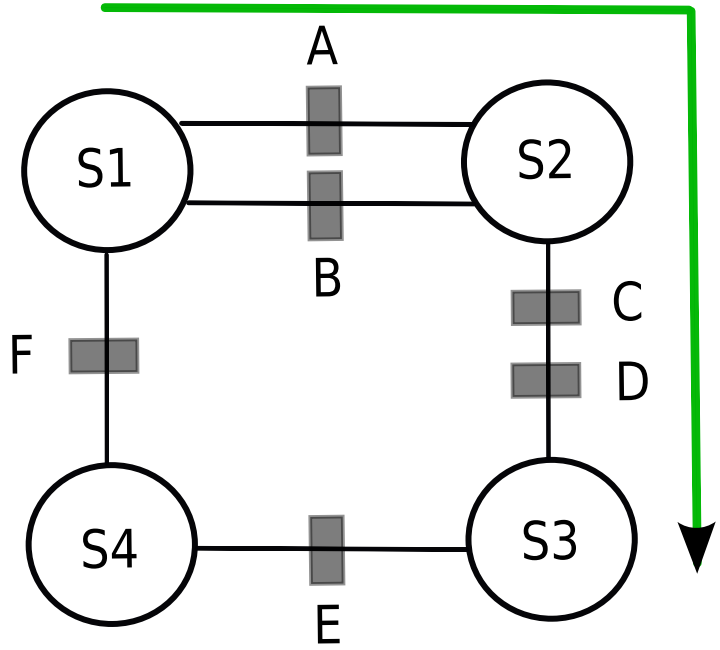
- *e.g.*, E2: $S2 \rightarrow S3$: *ssh allow*

Correct policy deployment is hard!

Policy graph



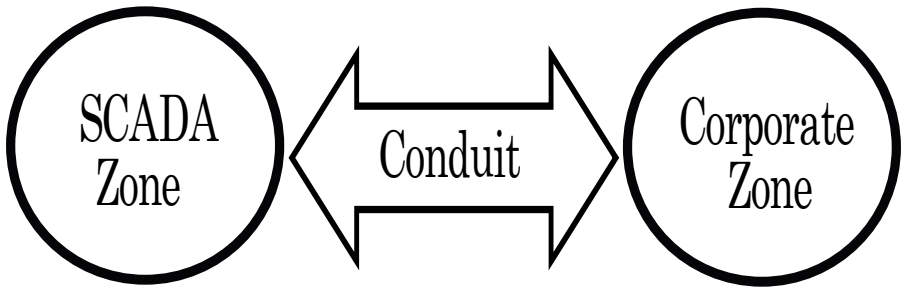
Network topology



- *e.g.*, E5: $S1 \rightarrow S3$: *ssh allow*

Existing standard for decoupling security policy from network

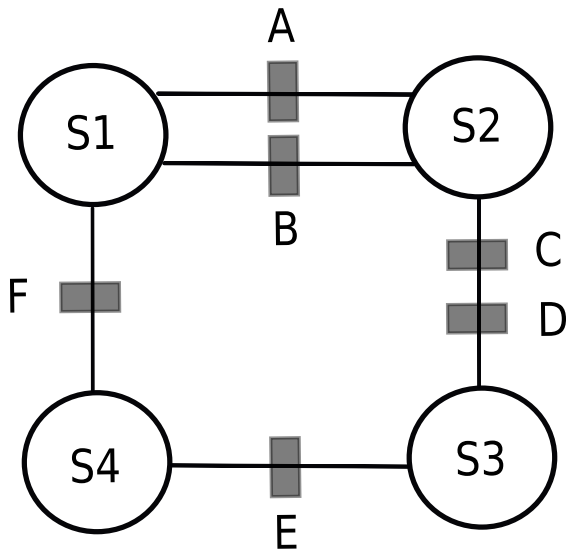
ANSI/ISA Zone-Conduit model [ANSI/ISA-62443-1-1]:



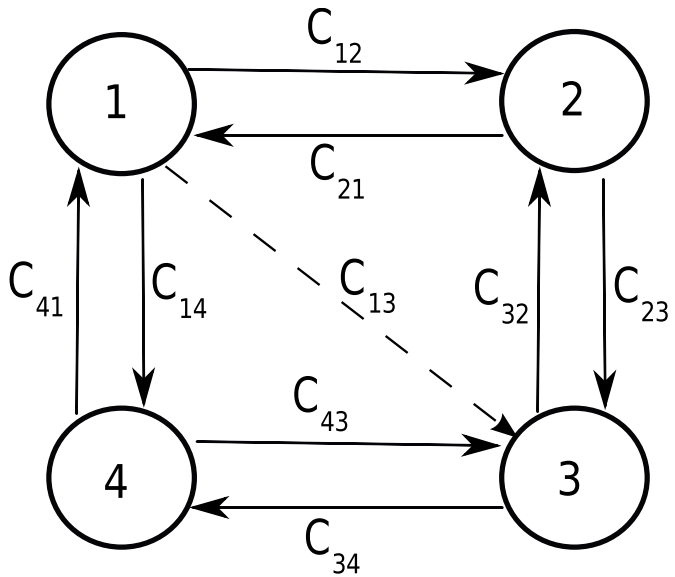
- Concrete instance of *(endpoint-pair, edge)* abstraction
- Allows to construct network-wide high-level security policy

Mapping security policy to firewalls: a simple example

(a) Network topology



(b) Zone-Conduit model of (a)



- *Primary* vs *Secondary* conduits
- How do we find all feasible primary- and secondary-conduits between zones?

Need a Mathematical approach

Why?

- Precision
- Unambiguity
- Verifiability
- Avoid redundant policy updates

What Maths in particular?

- Semiring algebra, why?
  - semiring properties allow lifting computations to a matrix and it converges
  - idea already used in meta-routing
- Consequences
  - policies need to adhere to semiring axioms
  - how policy should be described in a language

Implementation

- Computational limitation $O(n^4)$; n - number of zones
- n should be moderate
- We used it to map security control policies to real firewalls

Application to real SCADA case studies

SUC	Fire-walls	Zones	Max. hosts	ACLs	Average rules per ACL	Wrong firewall	Wrong interface	Wrong direction
1	3	7	67580	8	237	15	13	19
2	6	21	2794	12	16	3	2	5
3	4	10	886	8	6	2	1	4
4	3	9	2038	3	80	5	12	13
5	3	12	2664	12	677	15	8	26
6	3	13	3562	8	1034	21	15	19
7	6	15	3810	17	724	9	5	17

Conclusions

- Many obstacles to correct policy deployment in networks
- We address these challenges
  - network and vendor independent high-level policy semantics
  - generic algebraic framework to allocate policy to network devices
  - implementation that maps security policies to real firewalls

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