Design and Implementation of a Strong Representation System for Network Policies

Fangping Lan, Sanchari Biswas, Bin Gui, Jie Wu and Anduo Wang
Temple University

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Motivation

- Managing networking policies remains hard:
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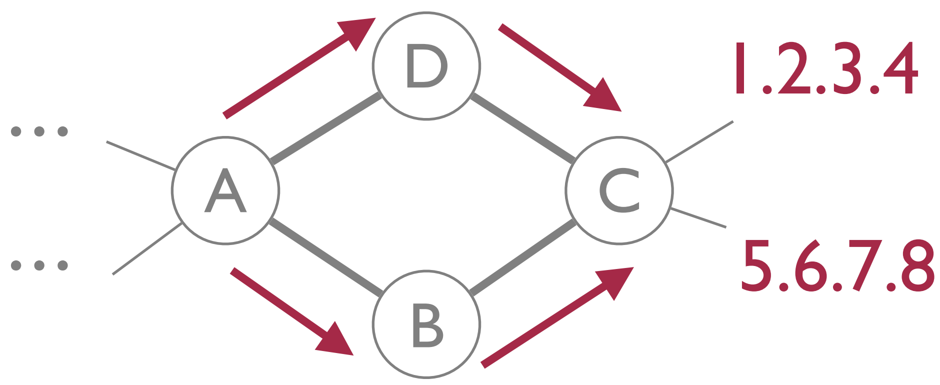
Can we provide a network policy management experience comparable to that on a database?

Network Policy Representation



Two prefixes 1.2.3.4 and 5.6.7.8 over two alternative paths [ABC] and [ADC]

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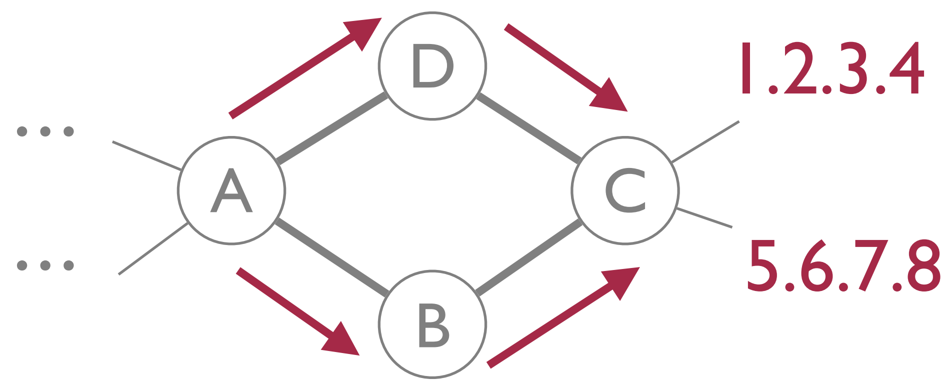

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The destination of the path

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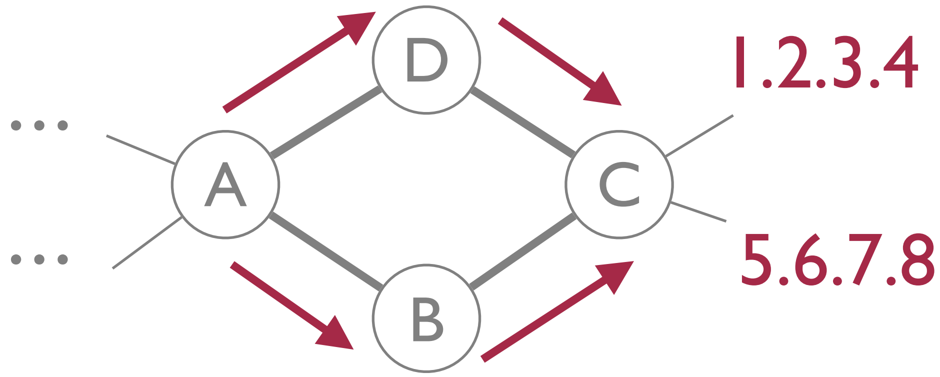

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The path to its destination

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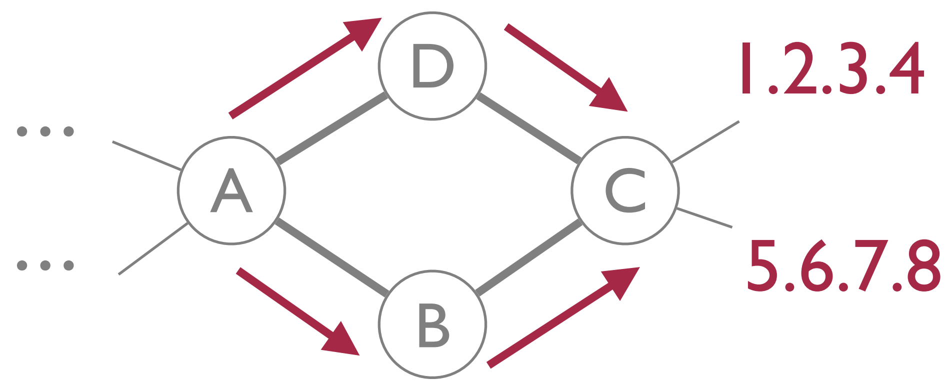

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The constraints over variables

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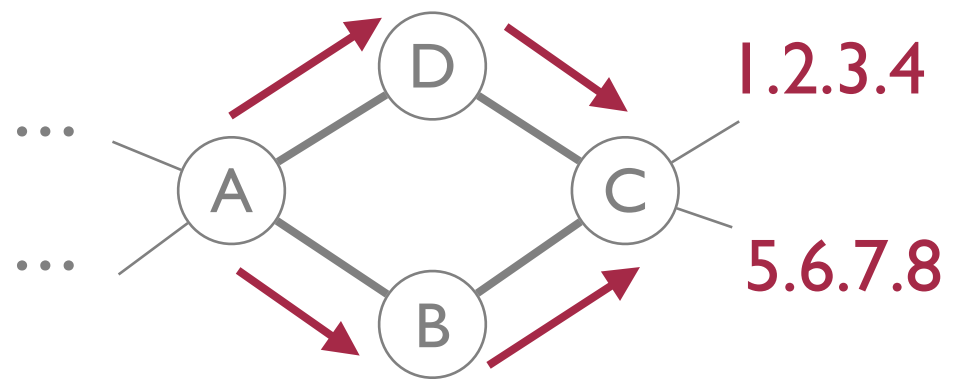

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Represent

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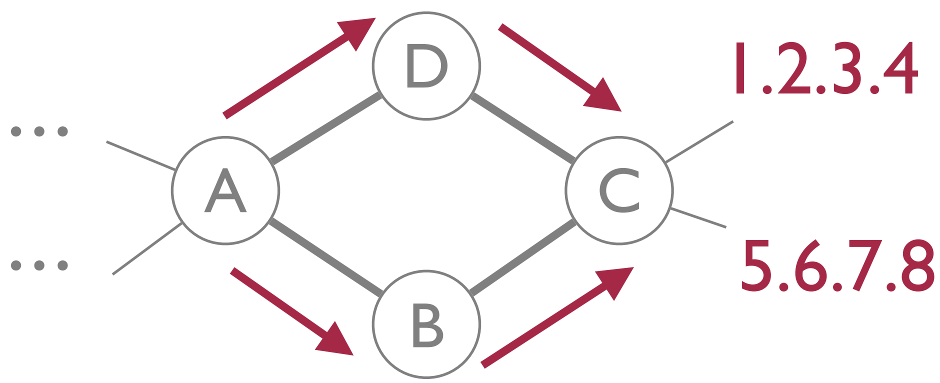

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Conditional Table

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- Traffic balance policy

Balance traffic to 1.2.3.4 and 5.6.7.8

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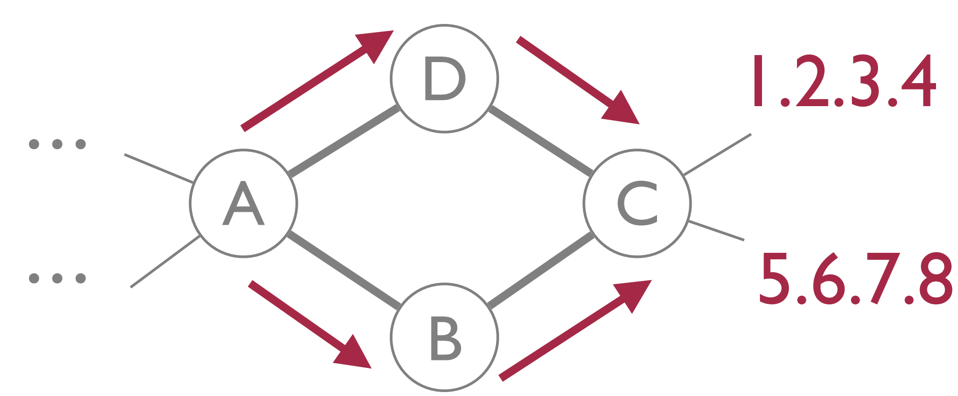

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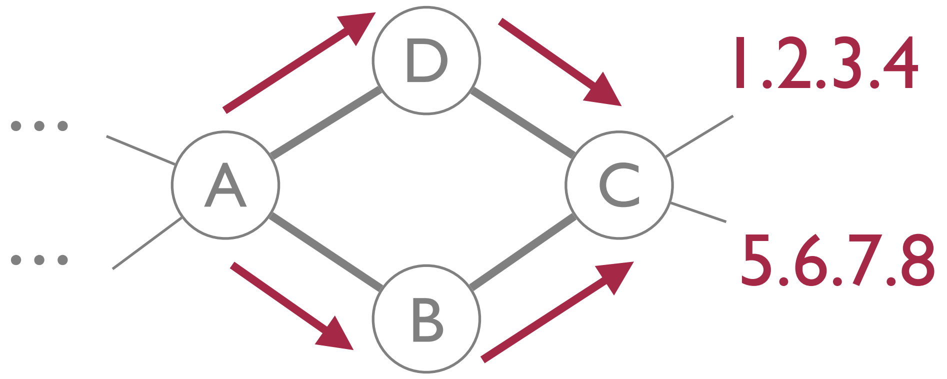

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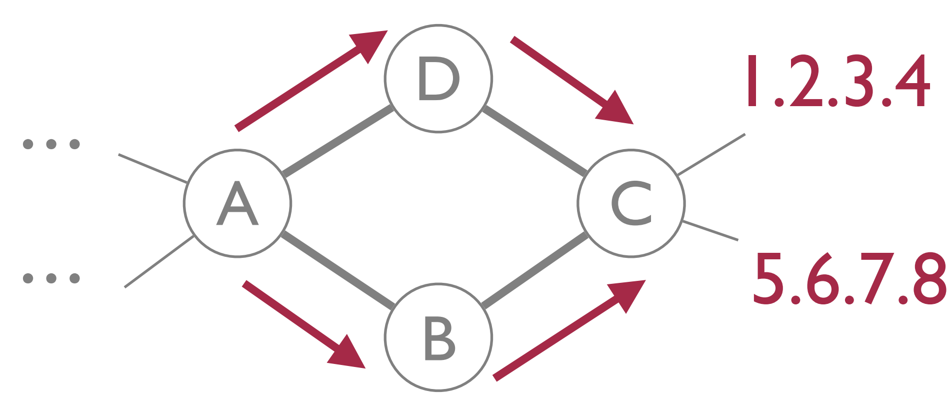

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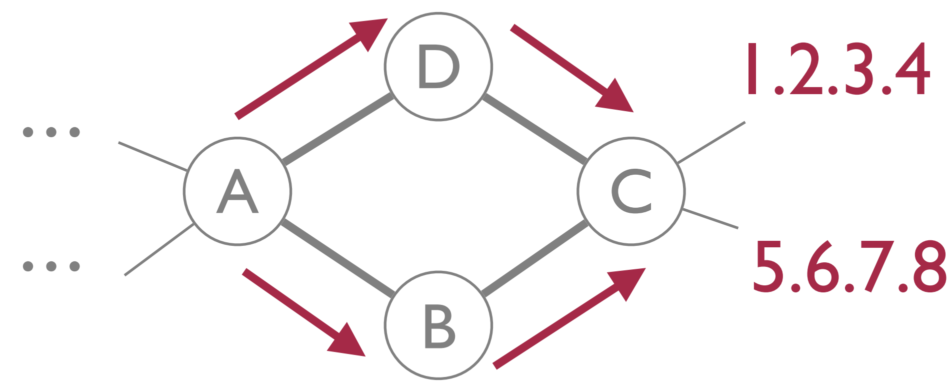

Network Policy Representation

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- Manipulate relational database table:
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- Our contribution:

Manipulating network policies by simply implementing SQL query on conditional table

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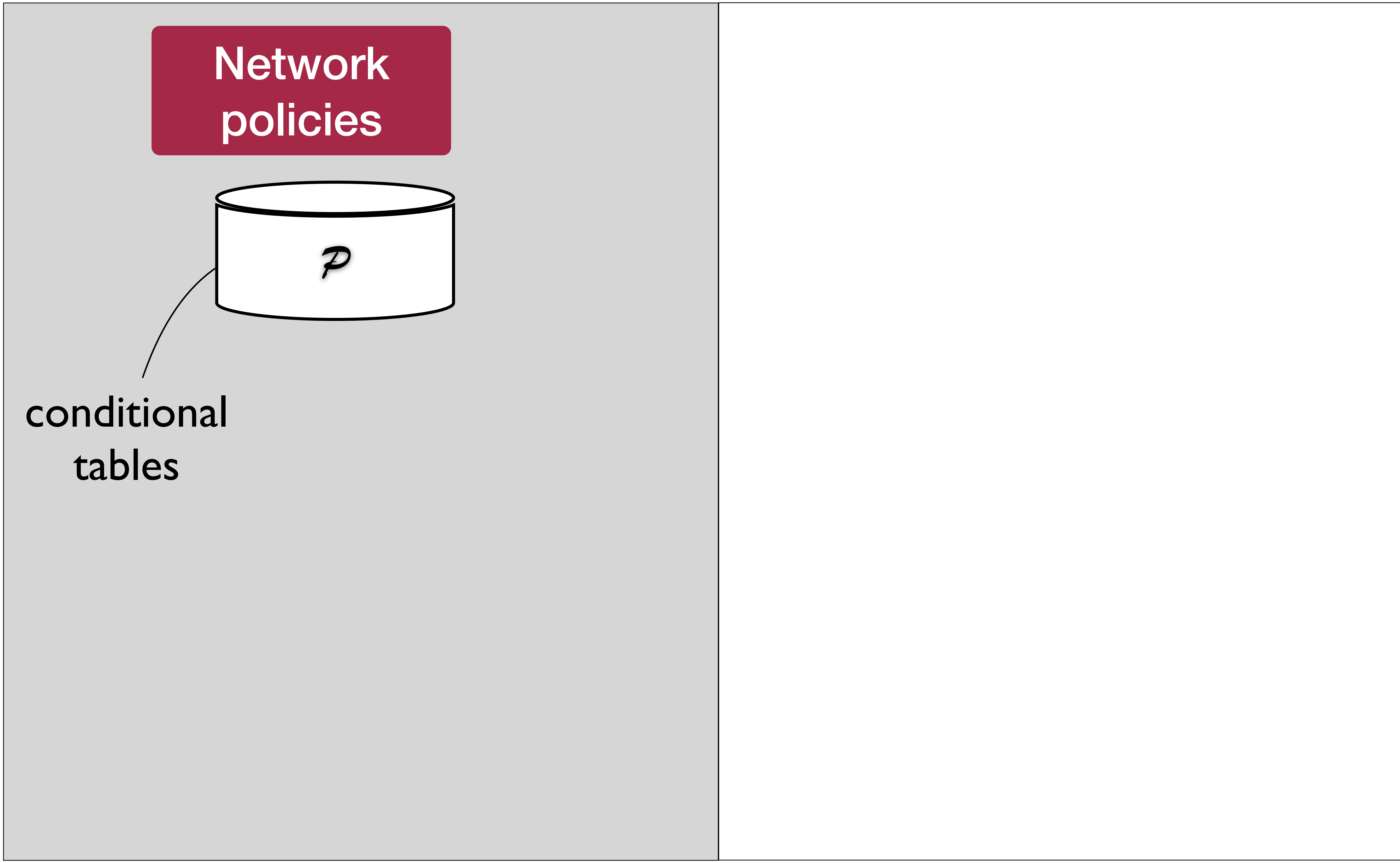

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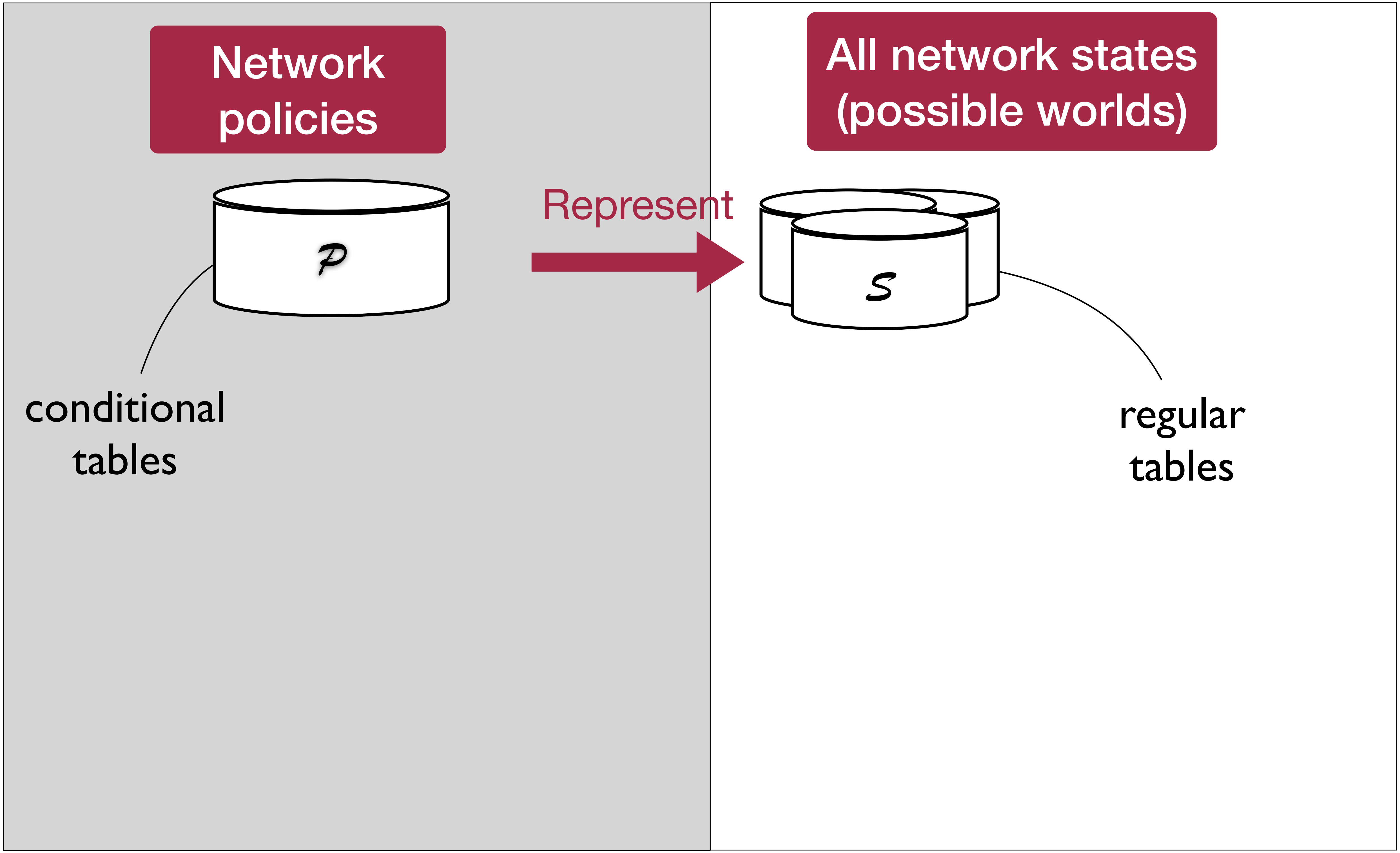

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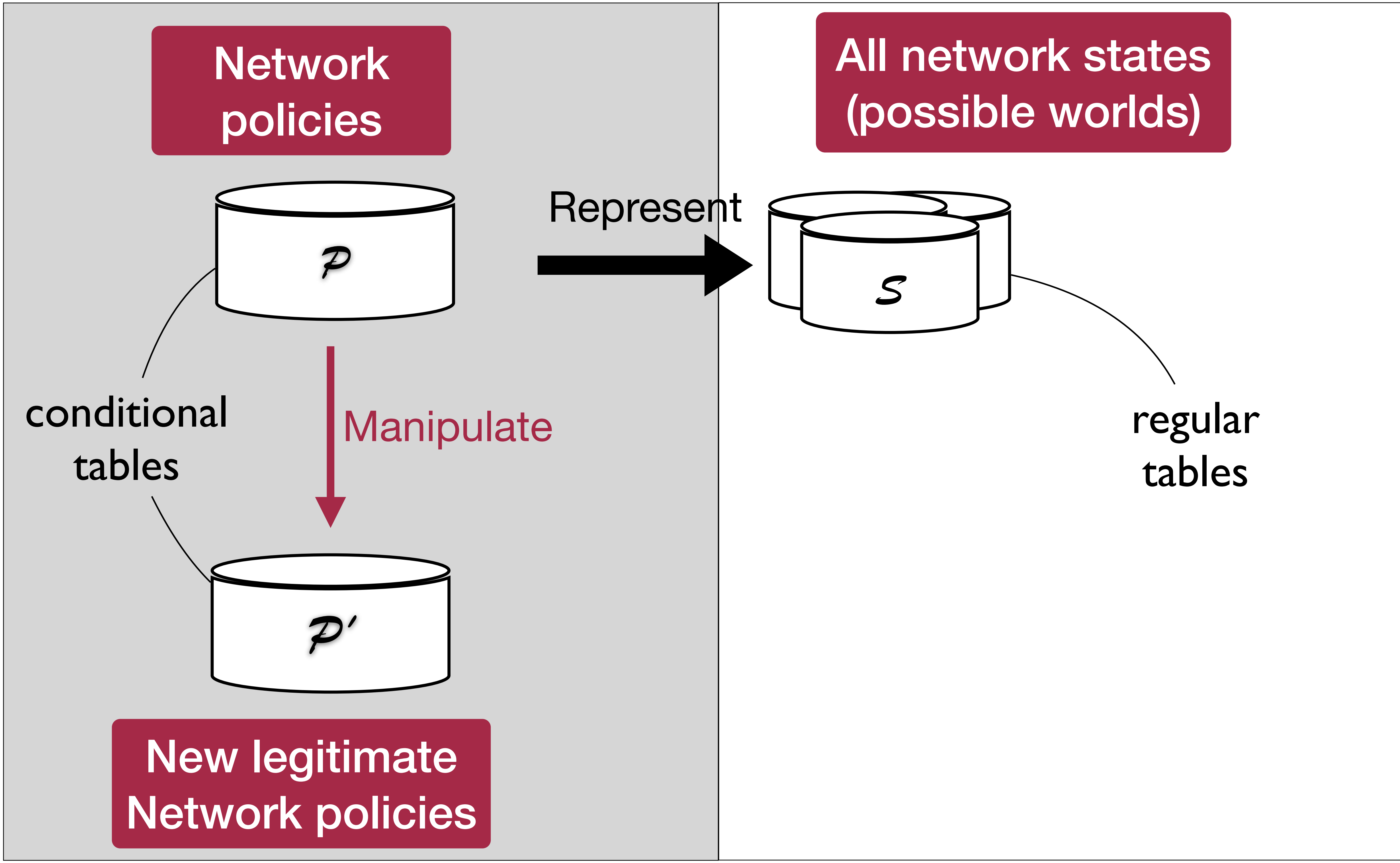

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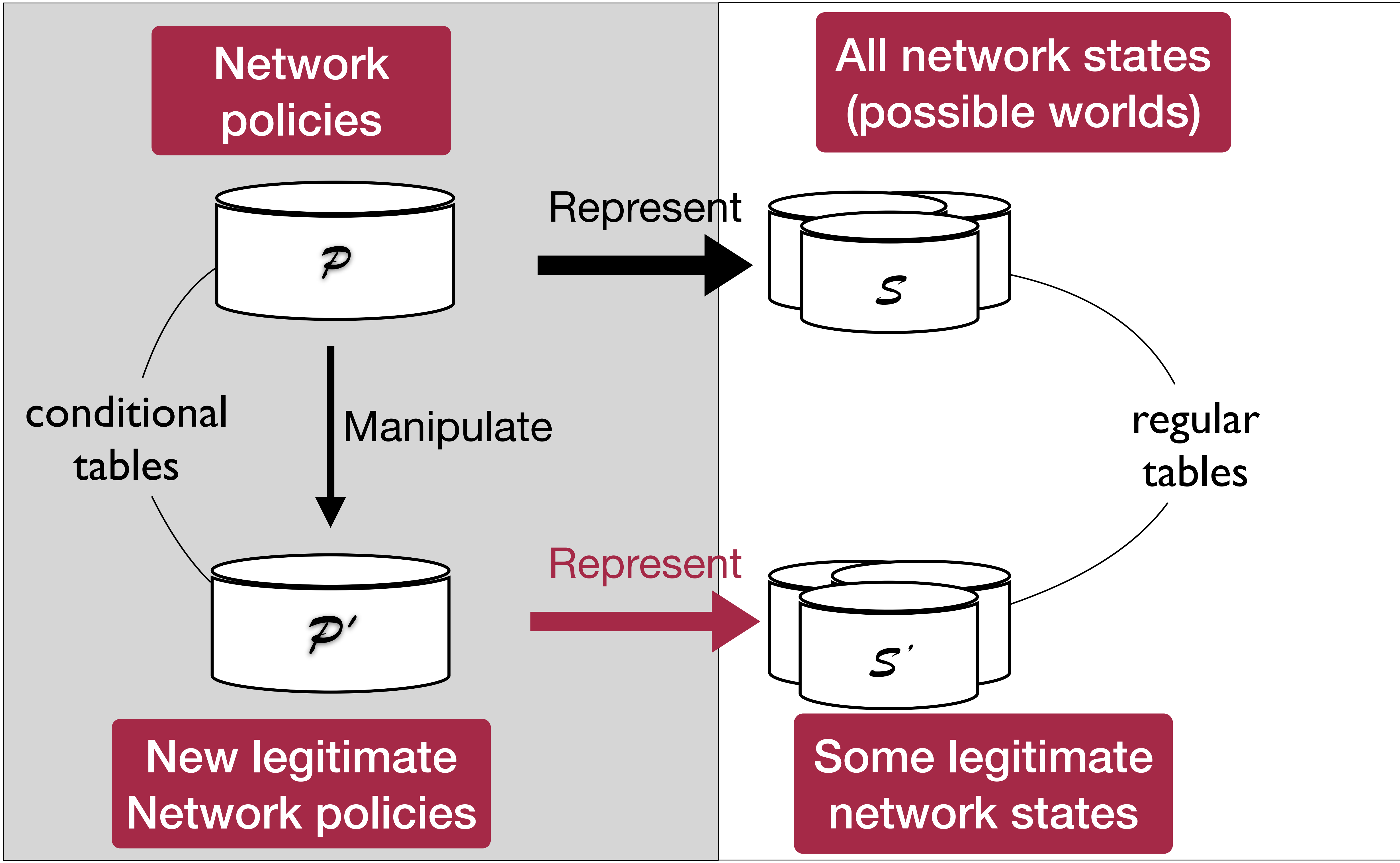

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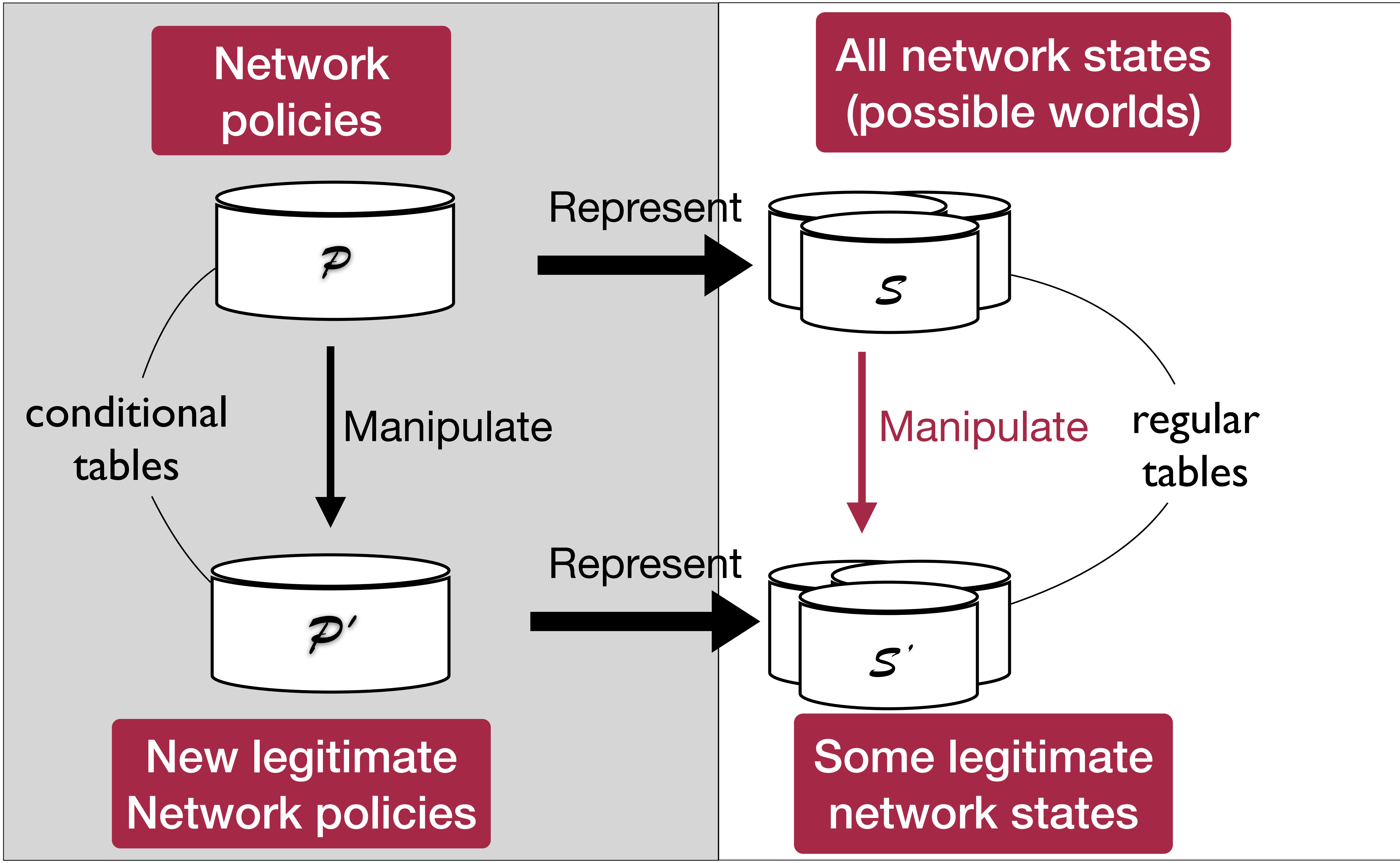

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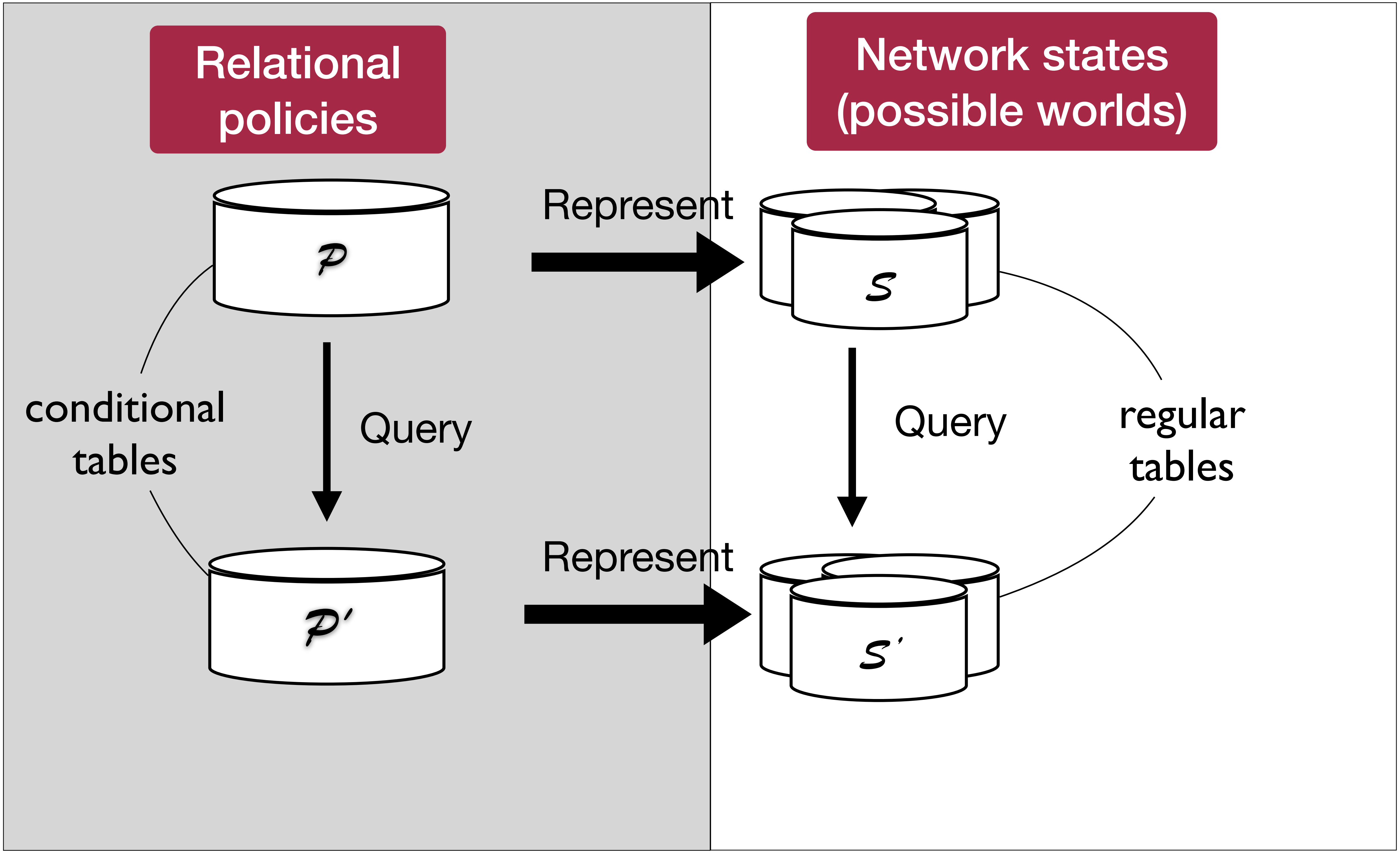

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Using user-defined functions and aggregates

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Function l: return hops of the path

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- Allow sets in conditional table
  - i.e. accommodate variables and conditions
- Two methods:
  - Naive support for sets
  - Leverage SMT(Satisfiability Modulo Theories) solver for sets

Application in inter-domain routing

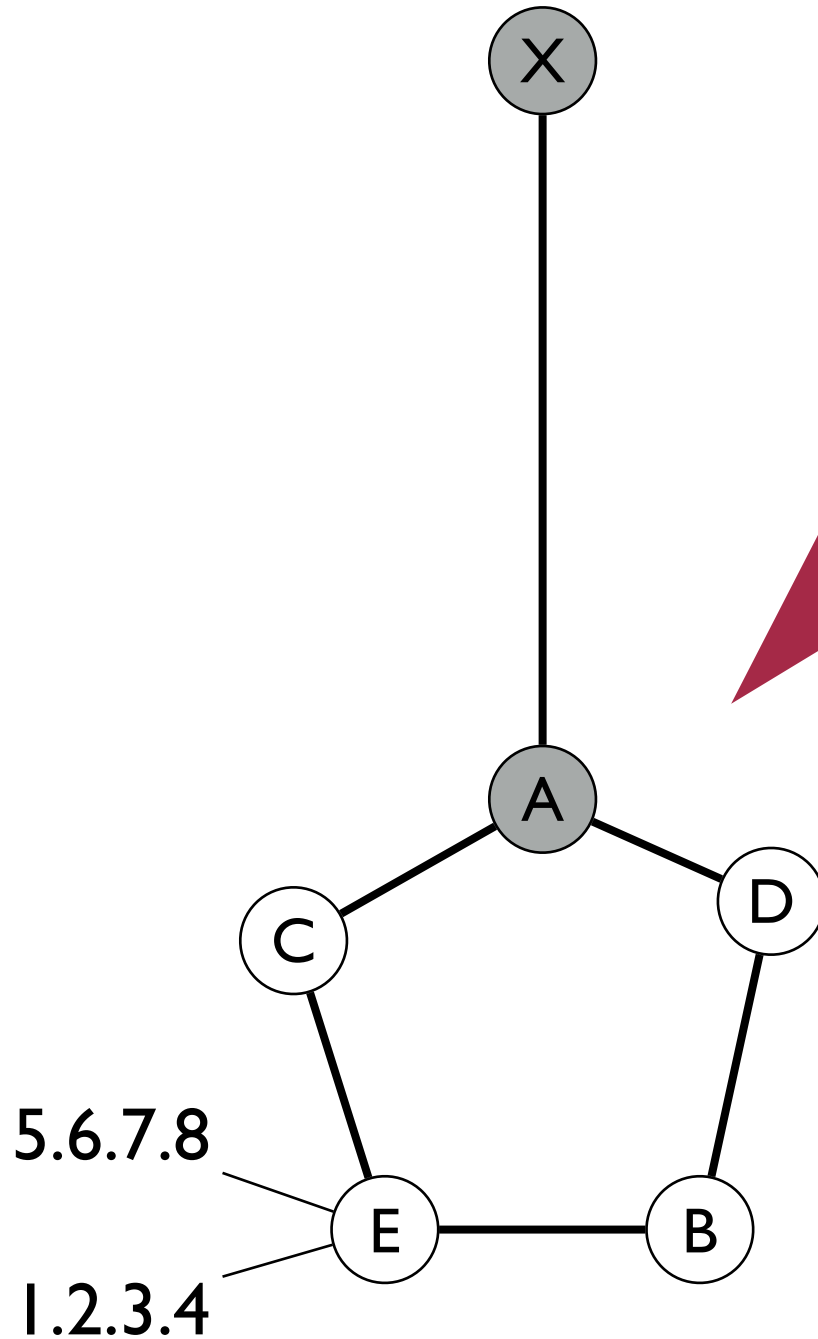
- We show the possibility of coordinating knowledge-driven policies from a single central point

- What about in realistic network scenarios like inter-domain routing?

We show an application -

Policy Exchange

A Brief Picture of BGP



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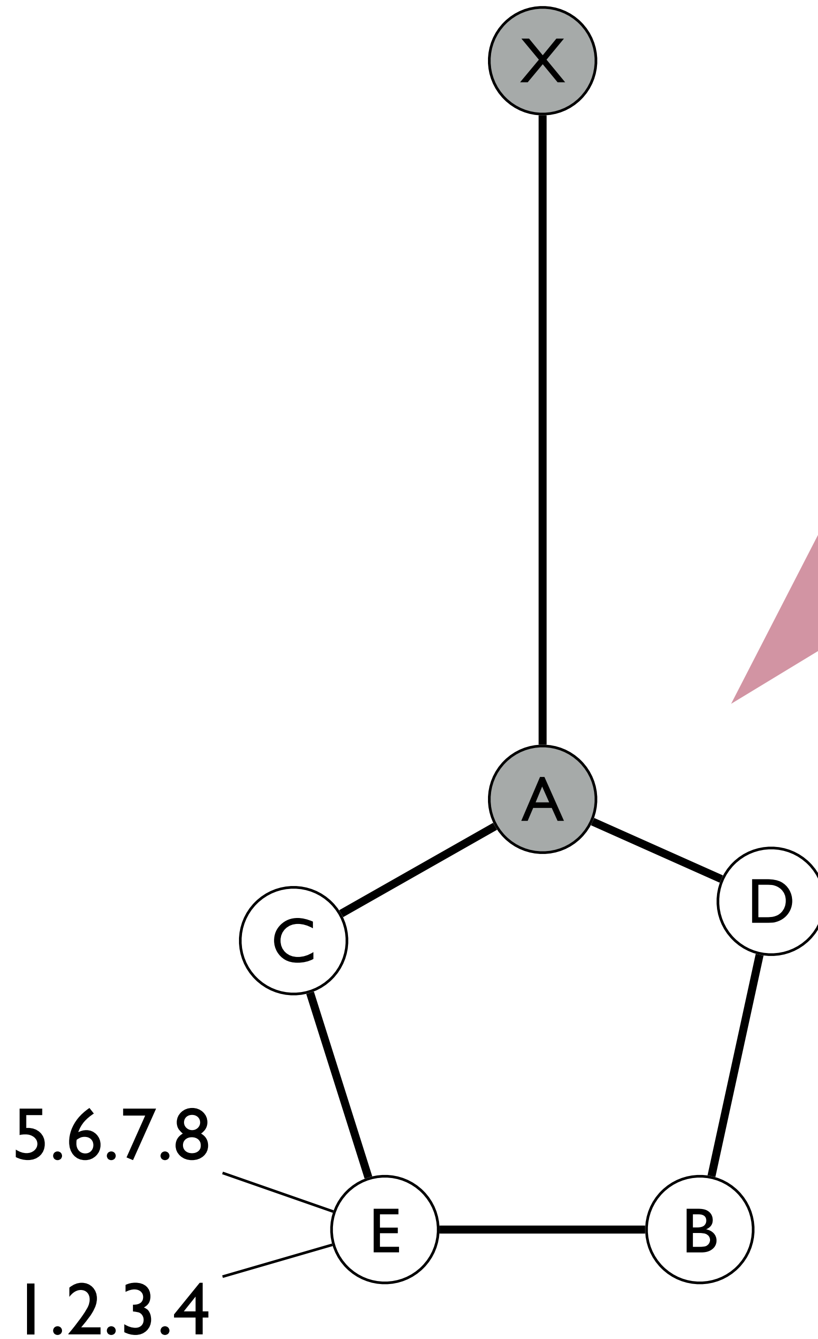

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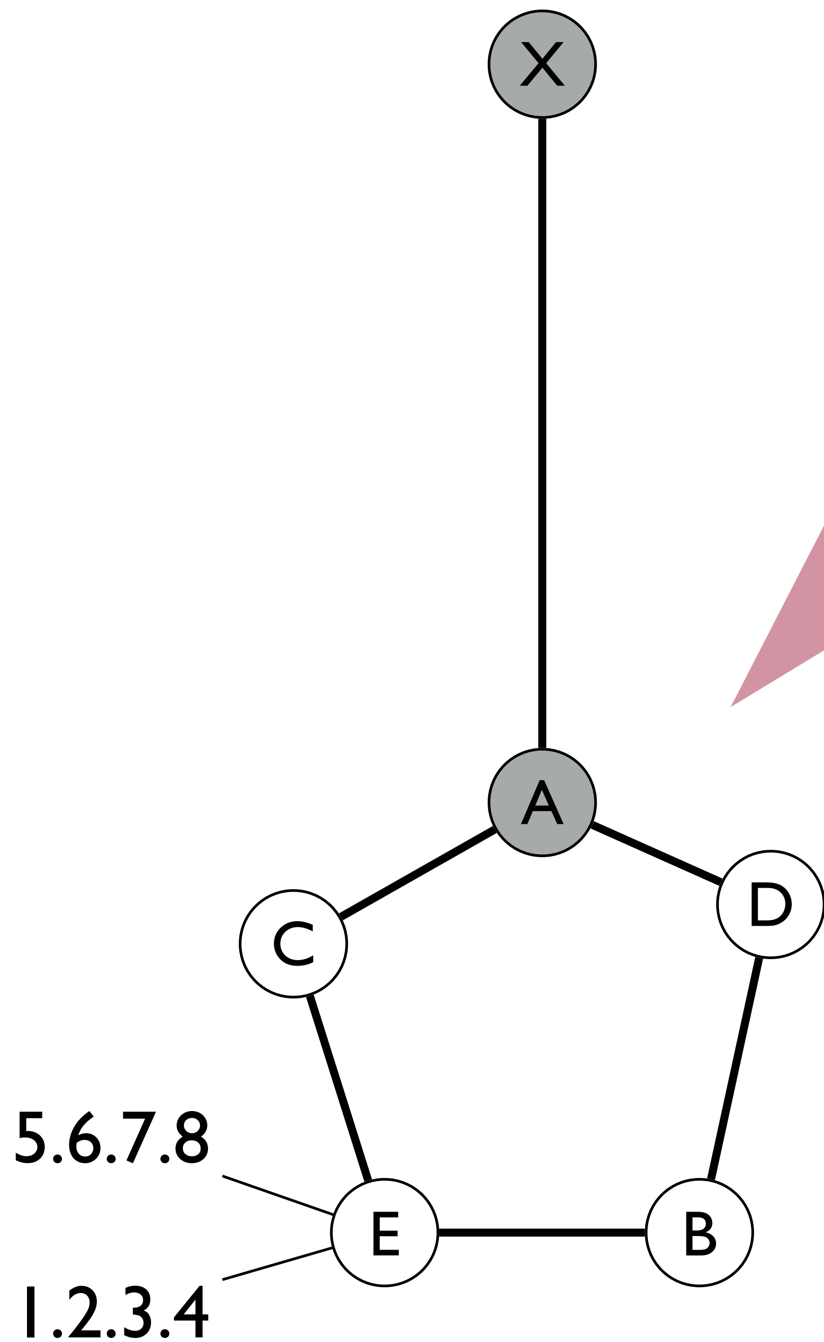

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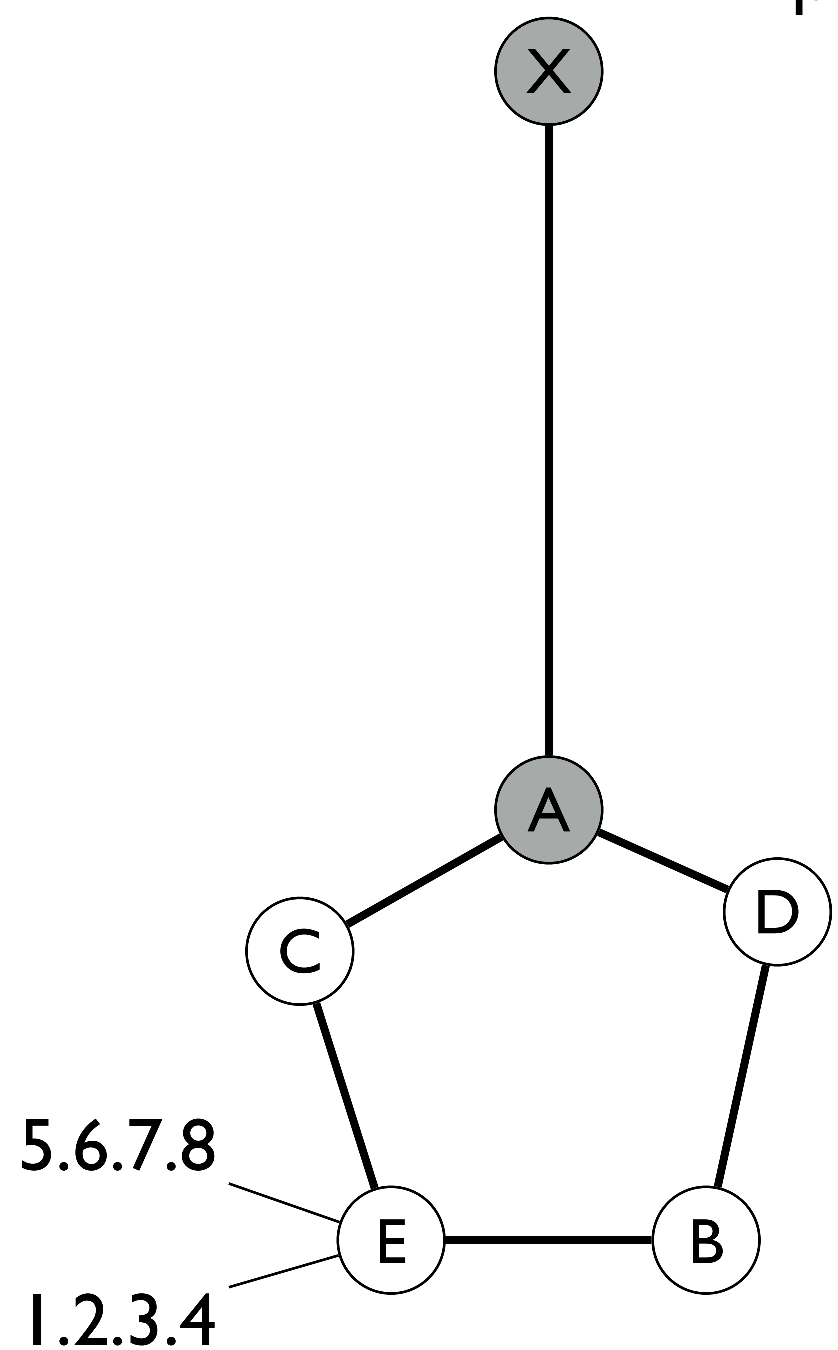
BGP is a shortest path routing protocol

BGP makes routing decision favoring autonomy

Why policy exchange?



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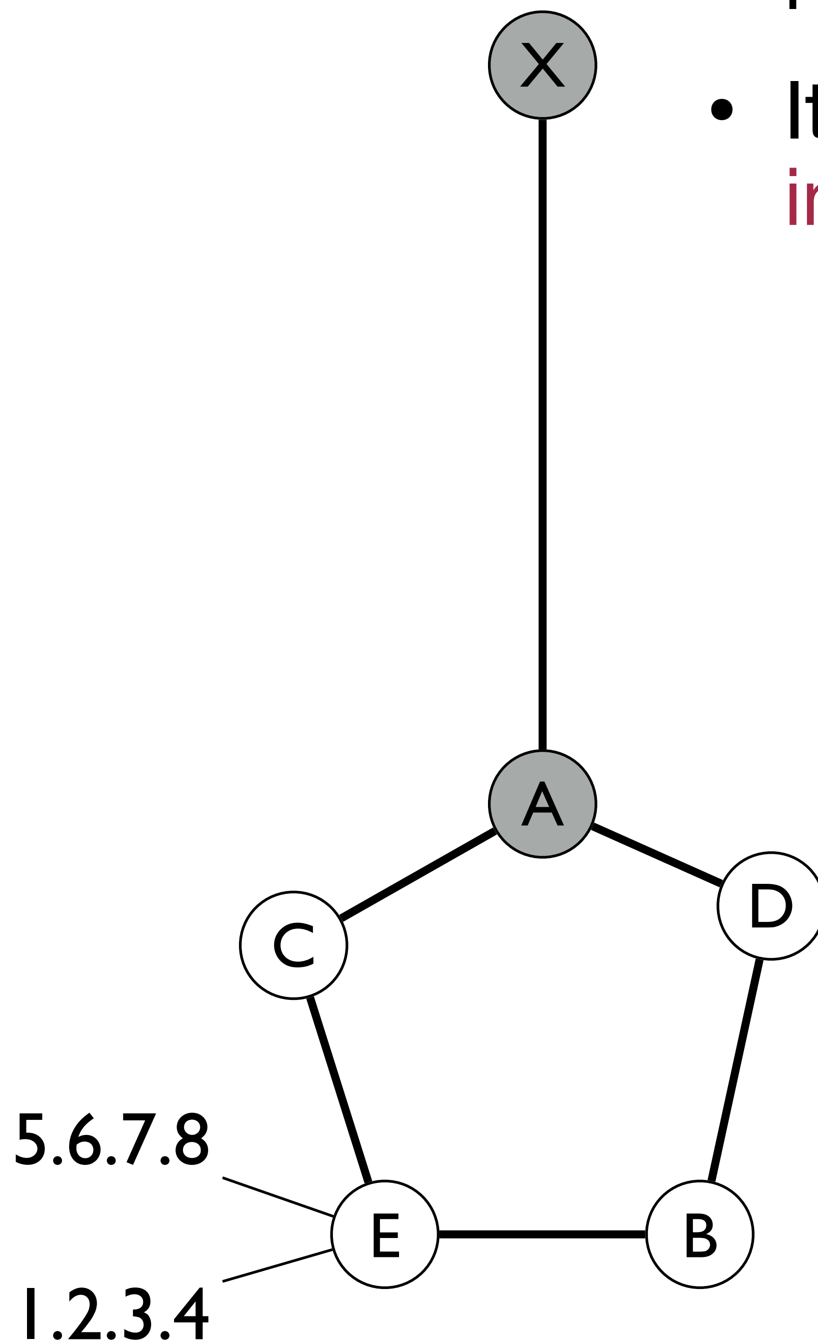

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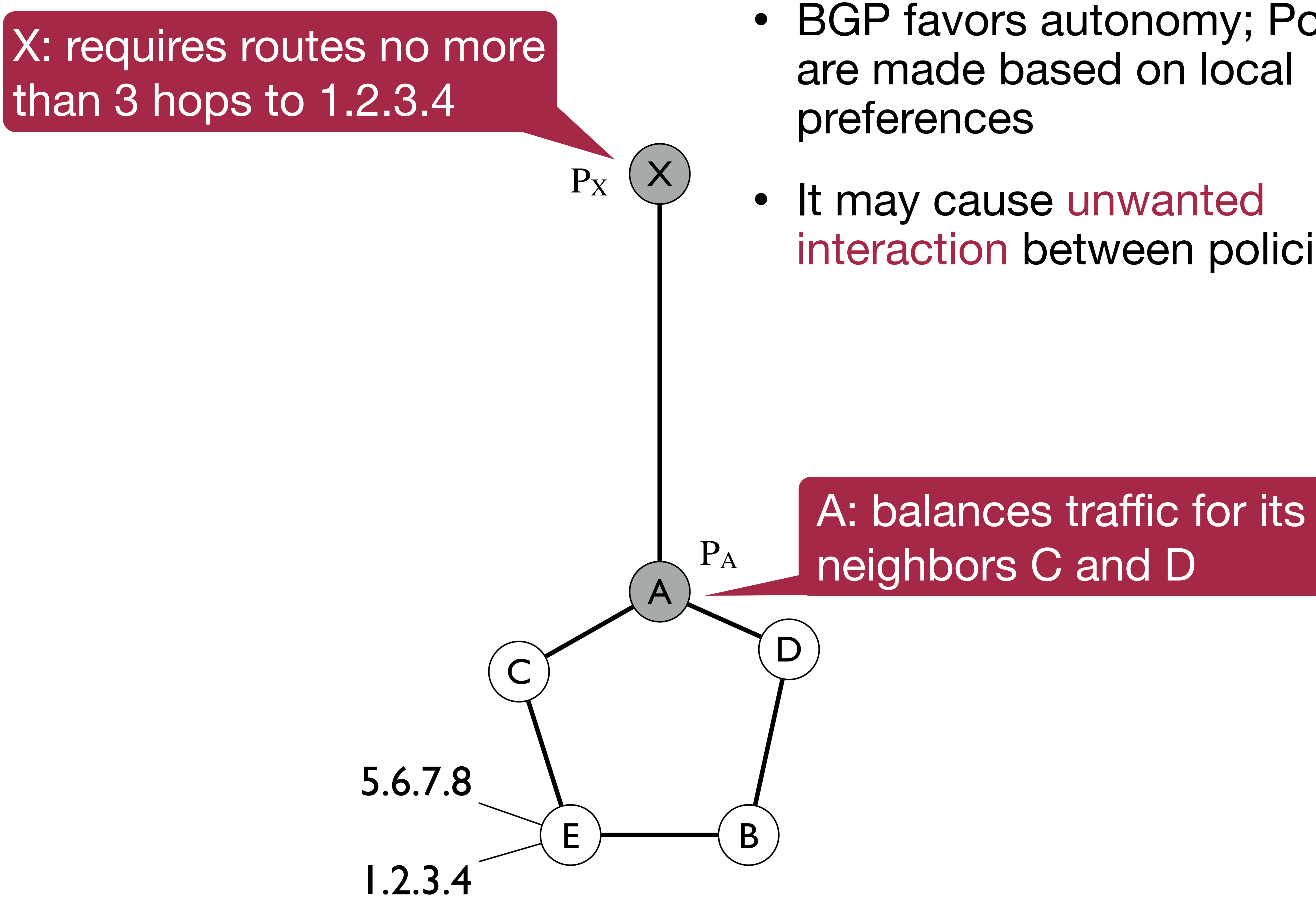
Policy exchange - counter example



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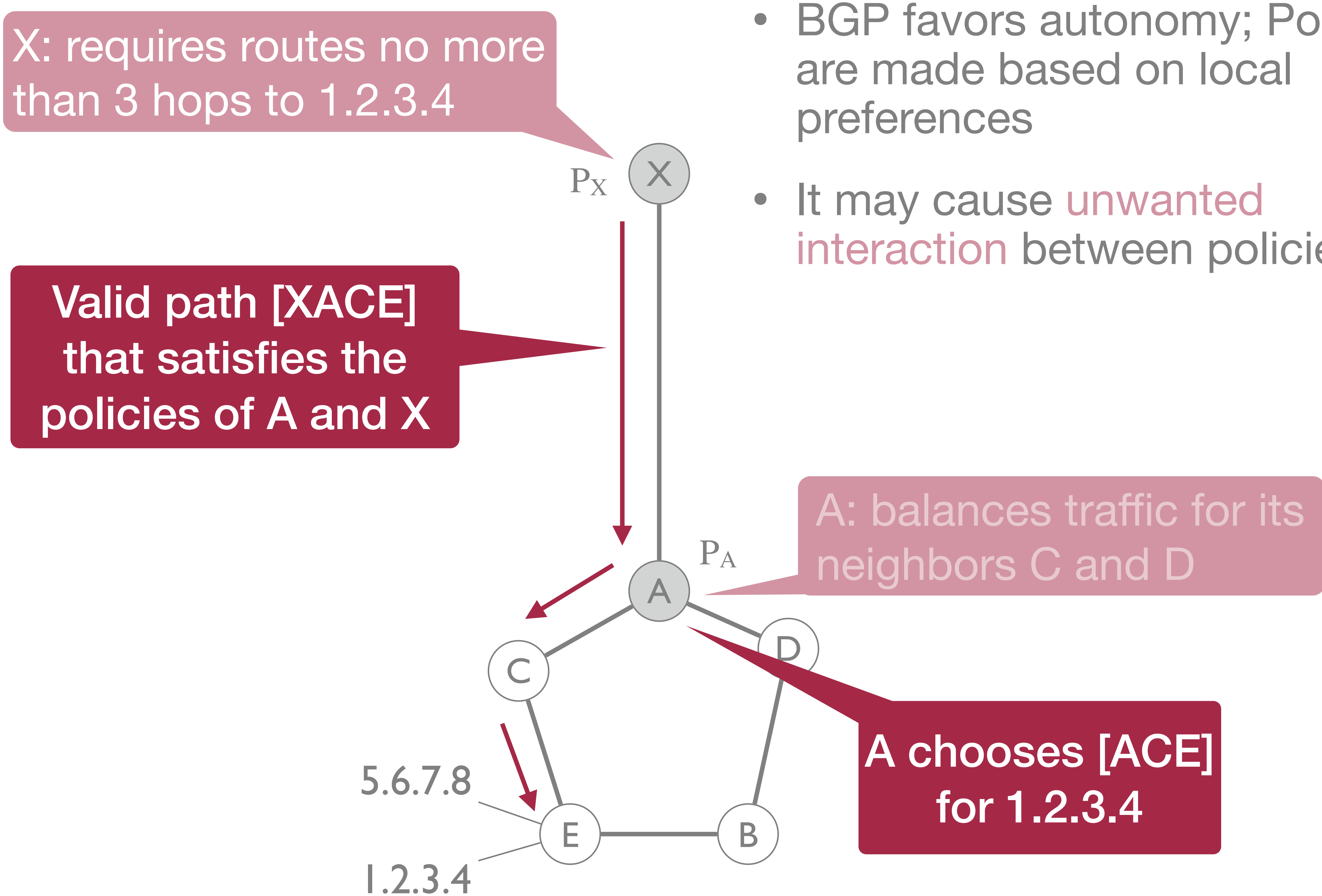

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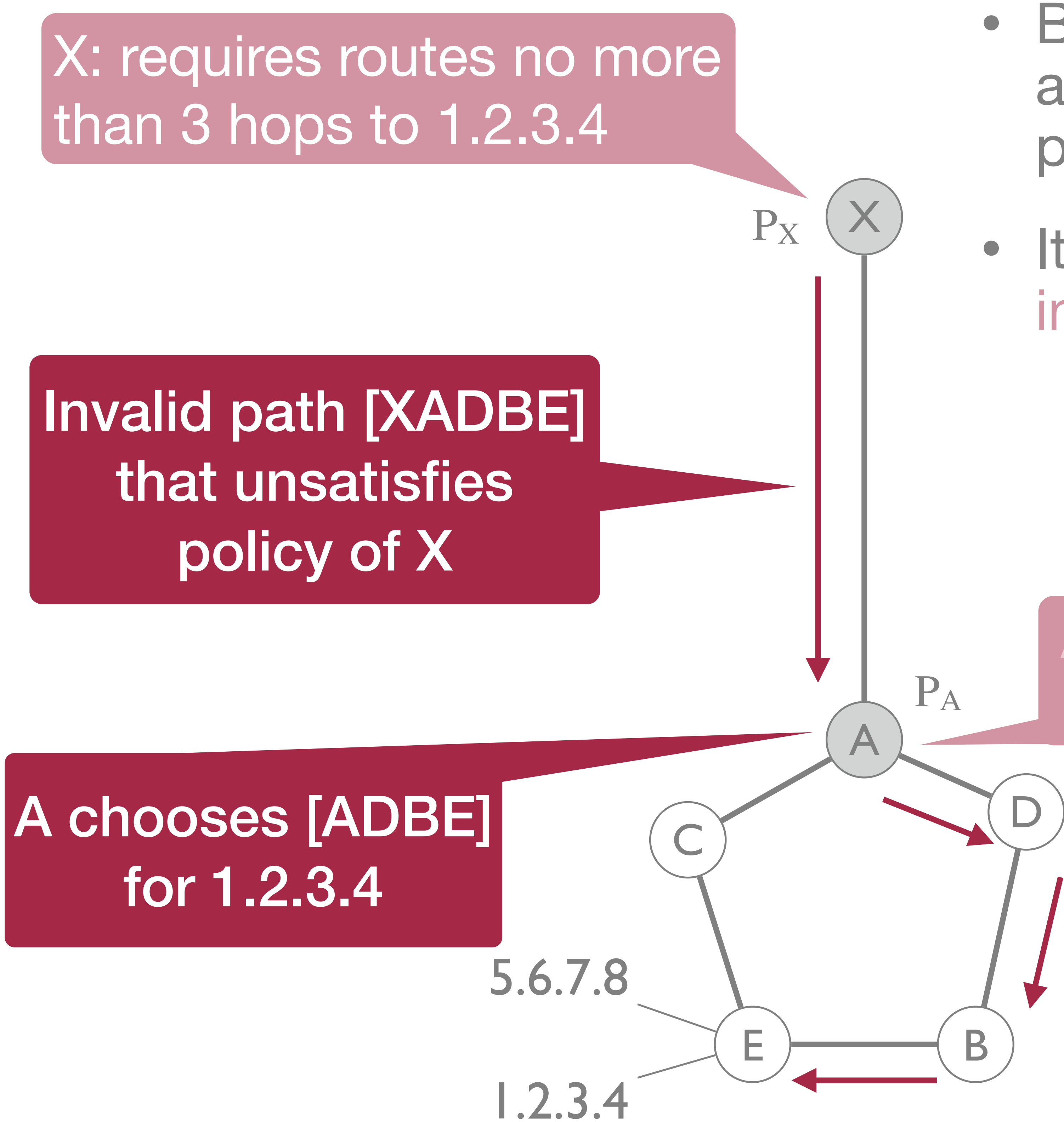

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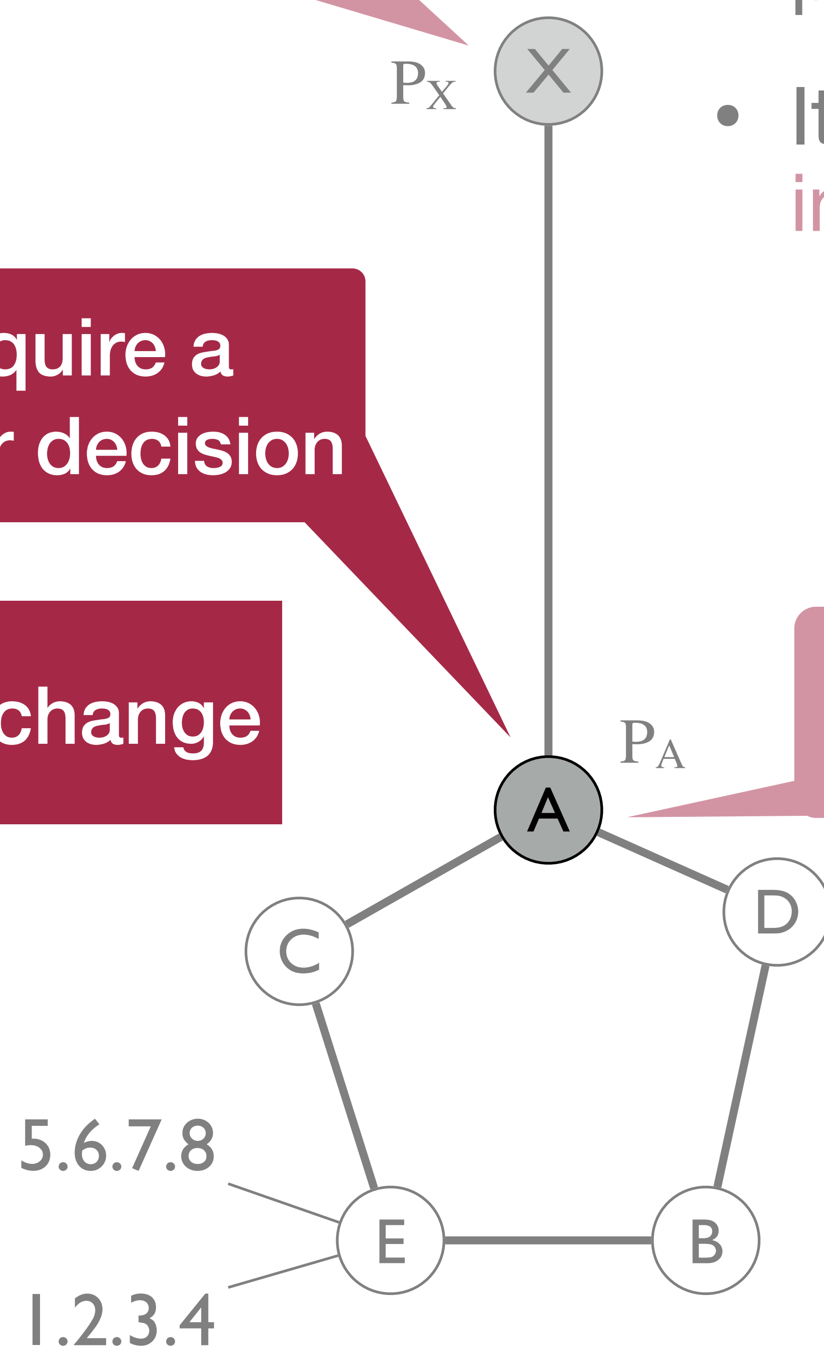
Require a proper decision

Approach: policy exchange

A: balances traffic for its neighbors C and D



How to do policy exchange?

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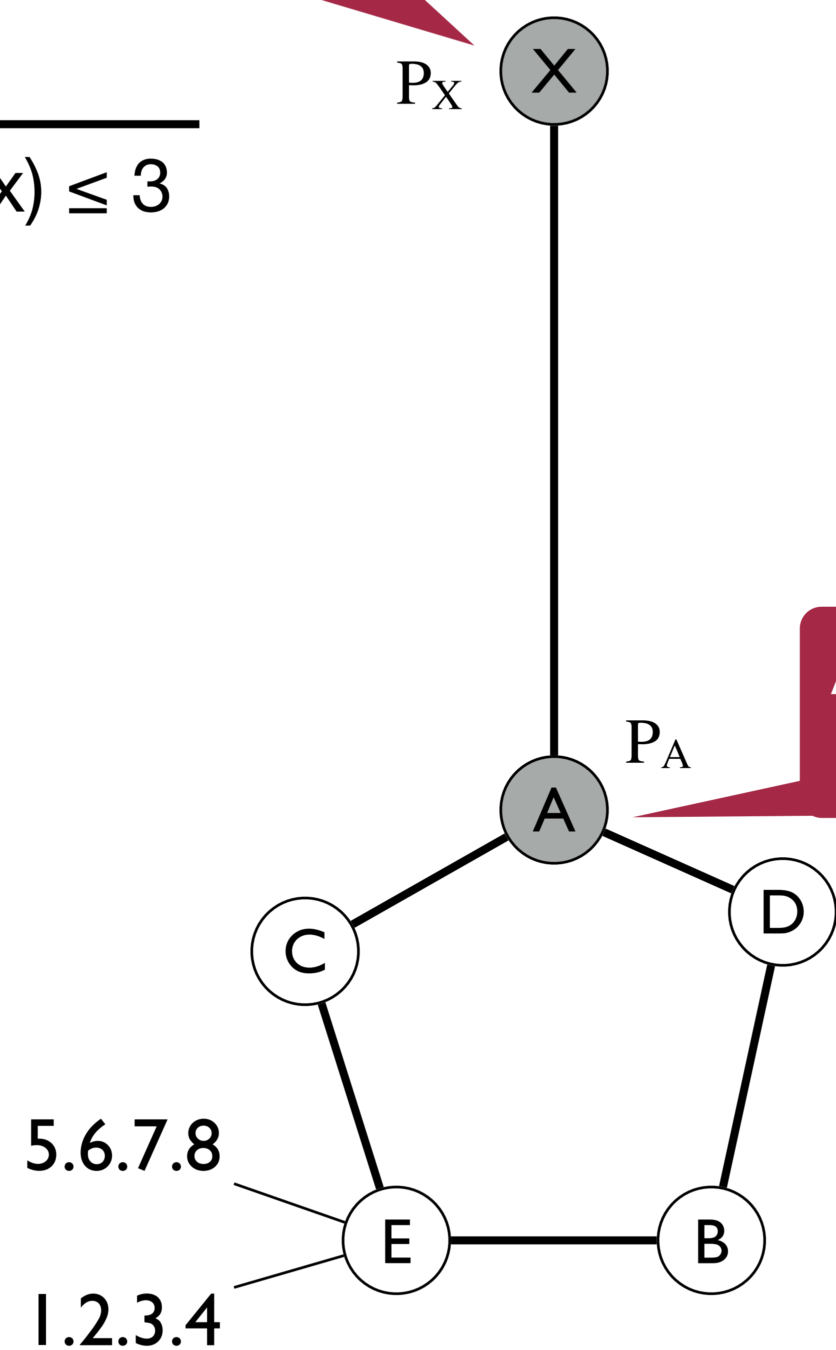

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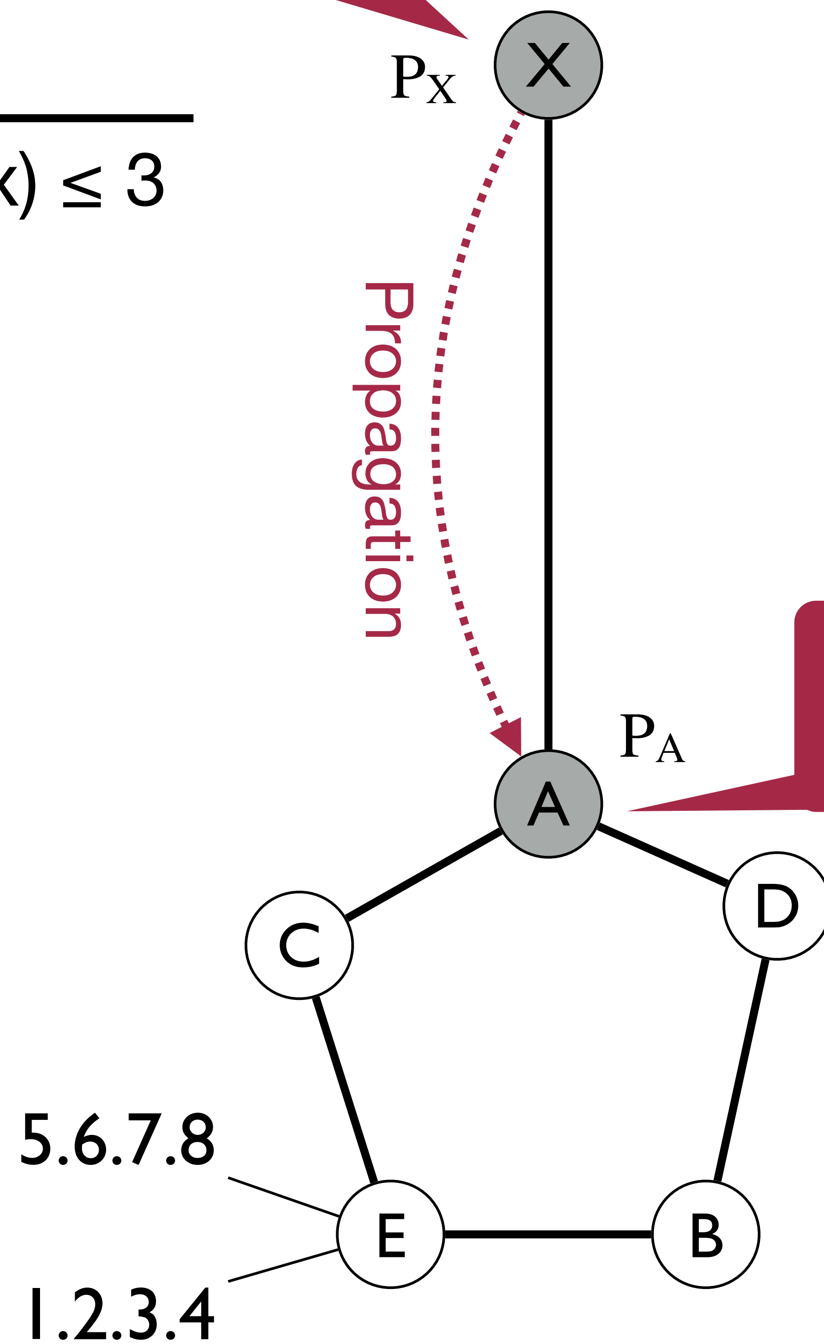

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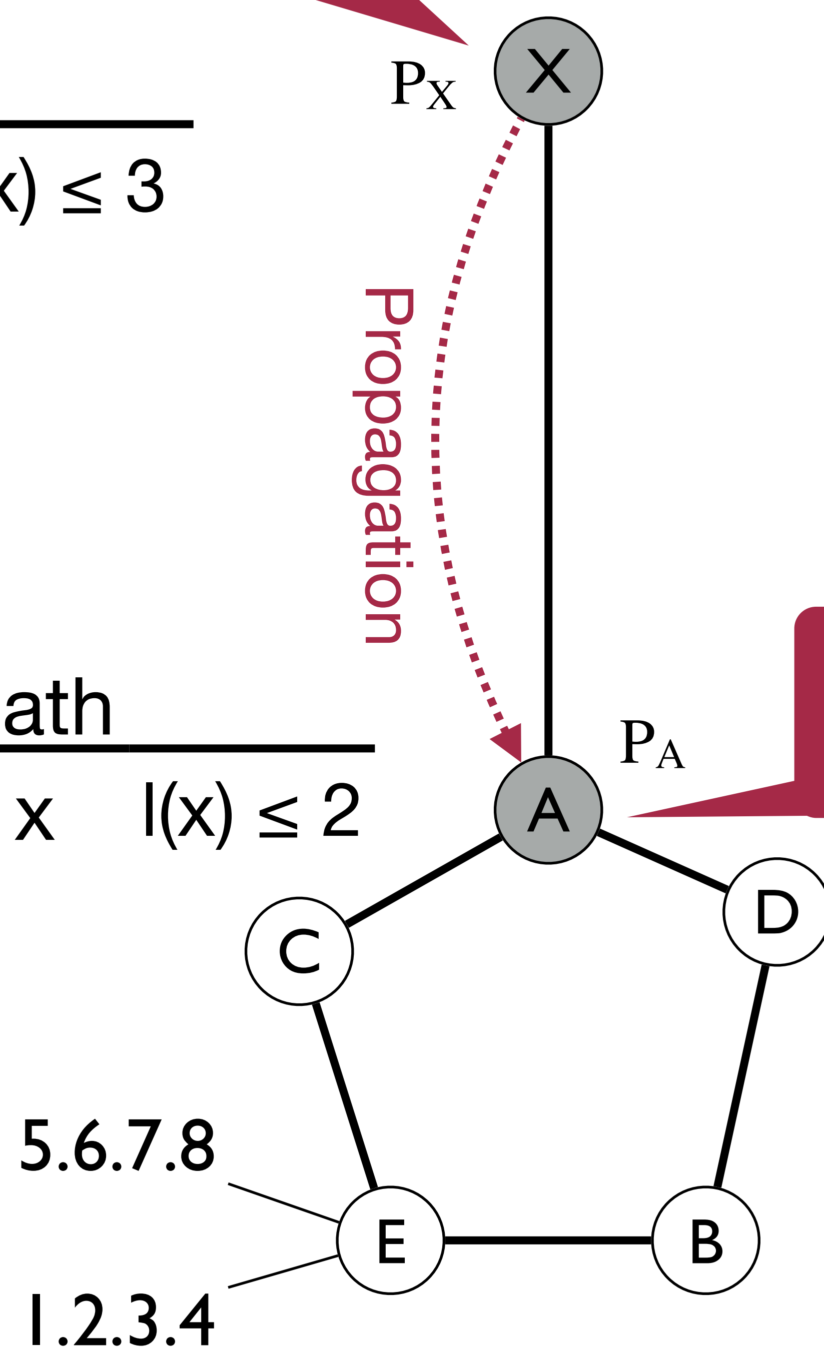

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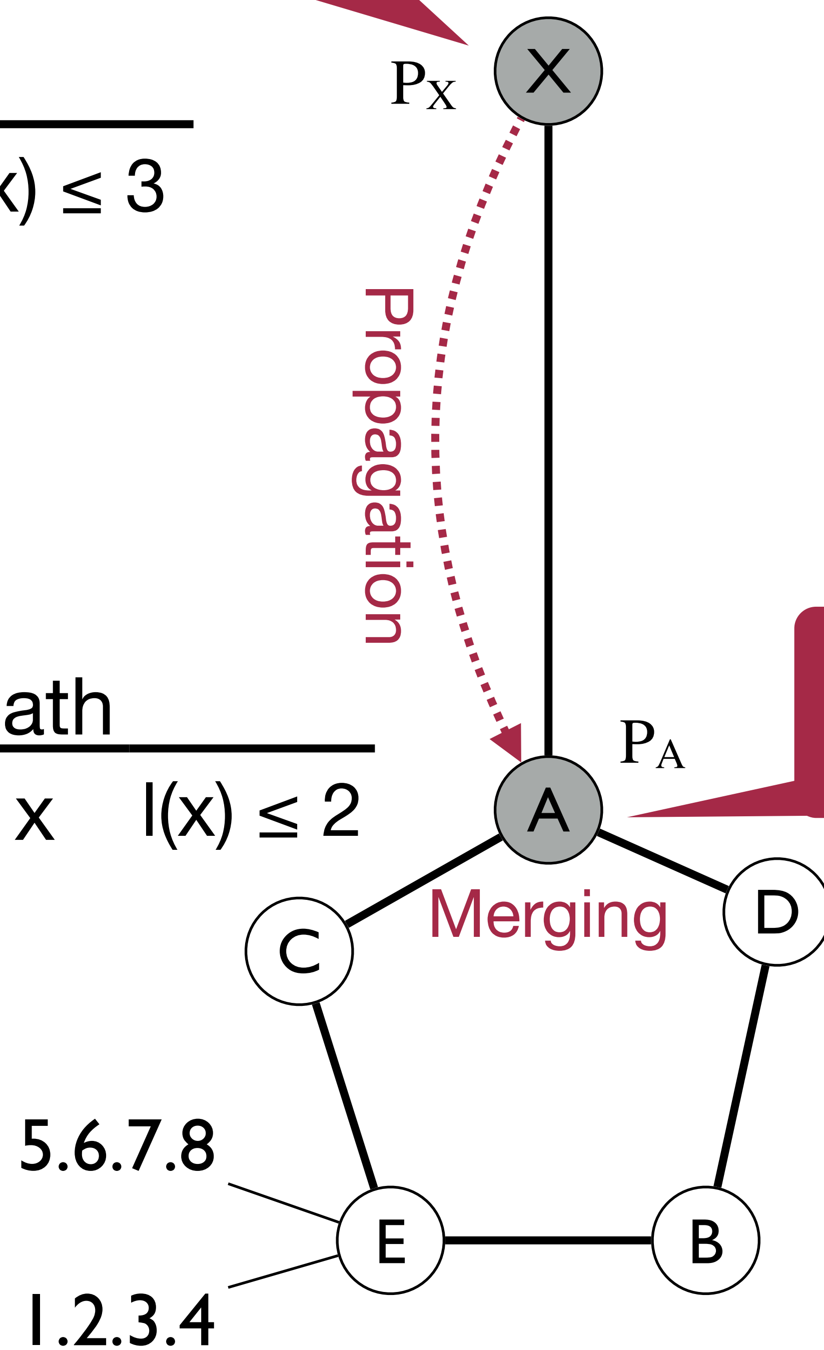

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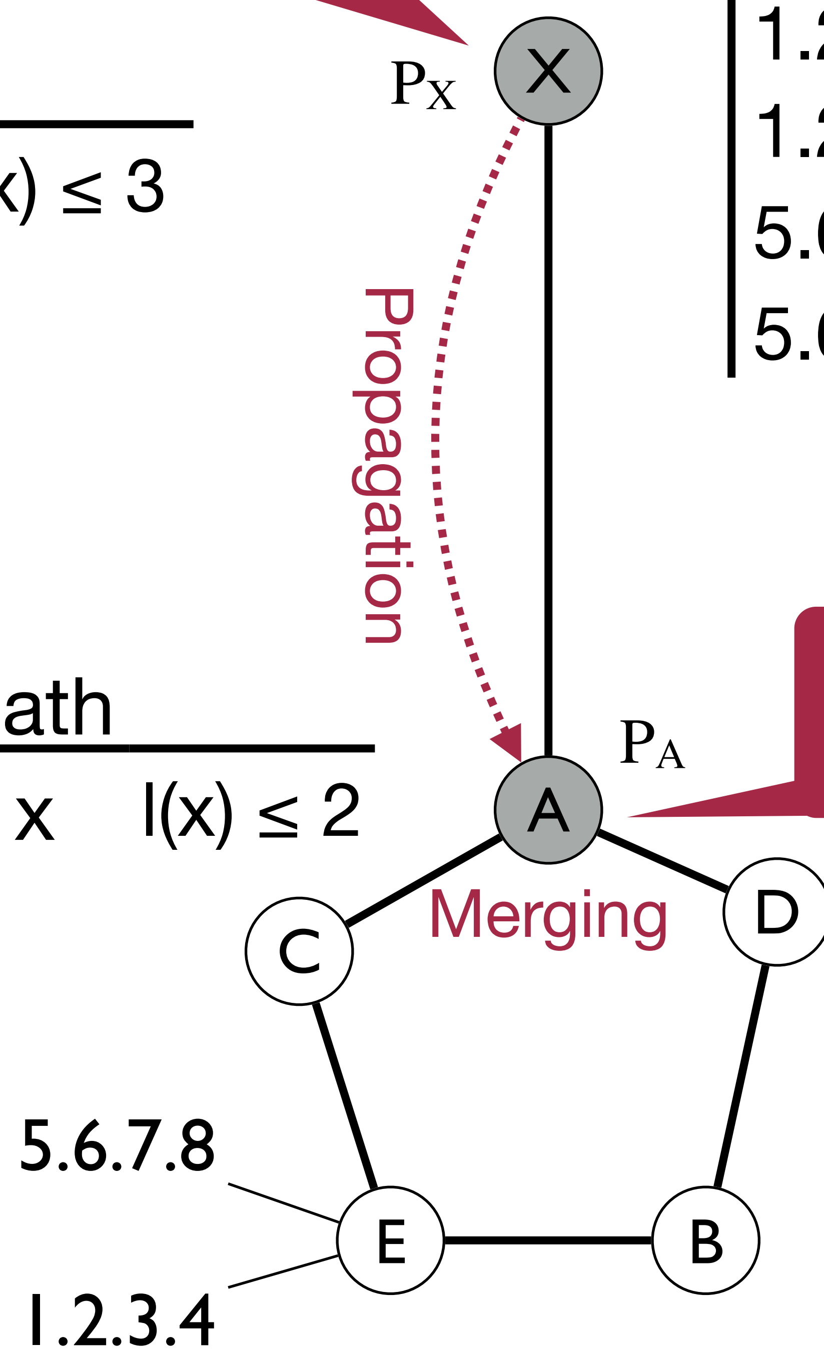

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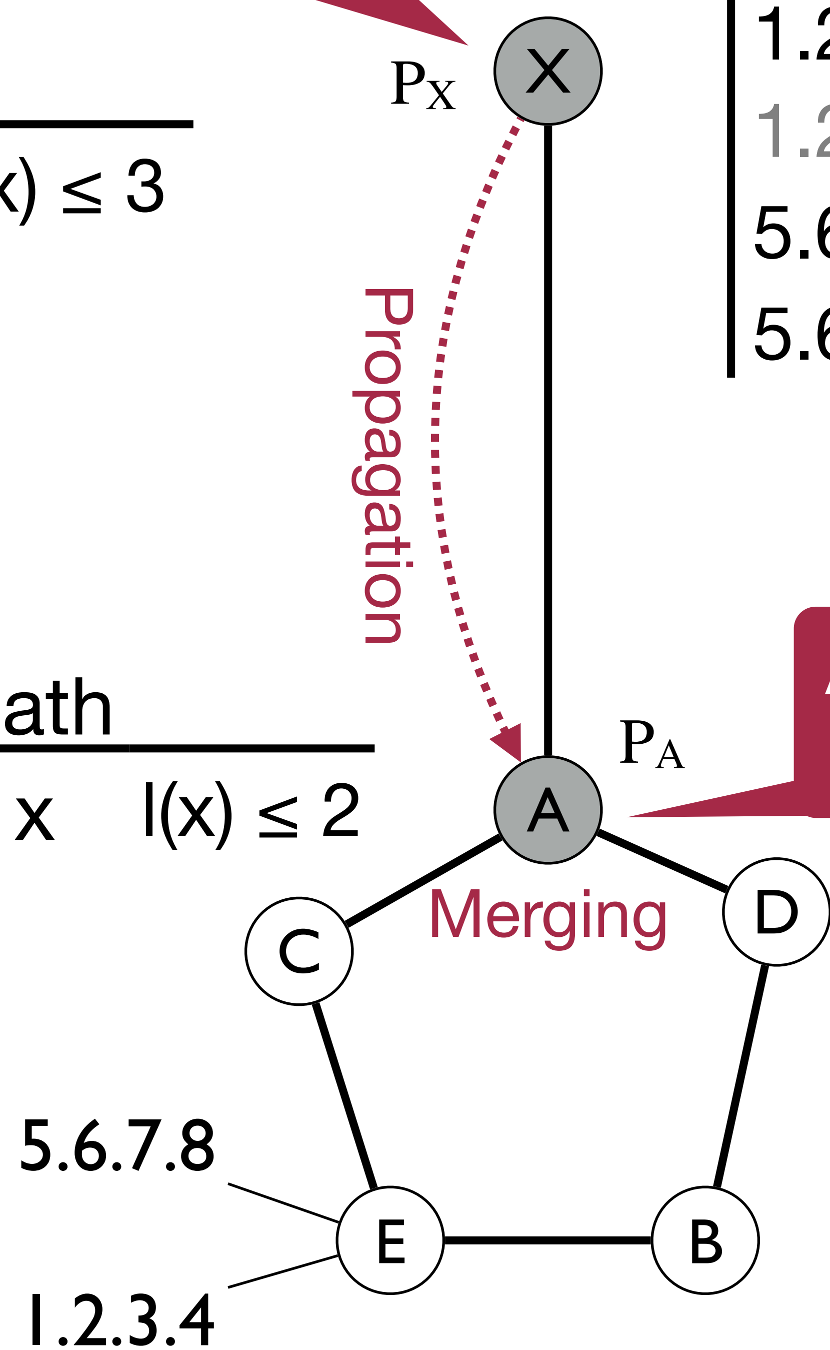
P_X'	dest	nh	flag	path	
	1.2.3.4	-	-	x	$l(x) \leq 2$



P_A'	dest	nh	flag	path	
	1.2.3.4	C	u	x	$u = 1 \wedge l(x) \leq 2$
	1.2.3.4	D	v	x	$v = 1 \wedge l(x) \leq 2$
	5.6.7.8	C	u	-	$u \neq 1$
	5.6.7.8	D	v	-	$v \neq 1$

A: balances traffic for its neighbors C and D

P_A	dest	nh	flag	
	1.2.3.4	C	u	$u = 1$
	1.2.3.4	D	v	$v = 1$
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	5.6.7.8	D	v	$v \neq 1$

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Mimicking the behavior of the BGP speaker as it receives announcement from their neighbors

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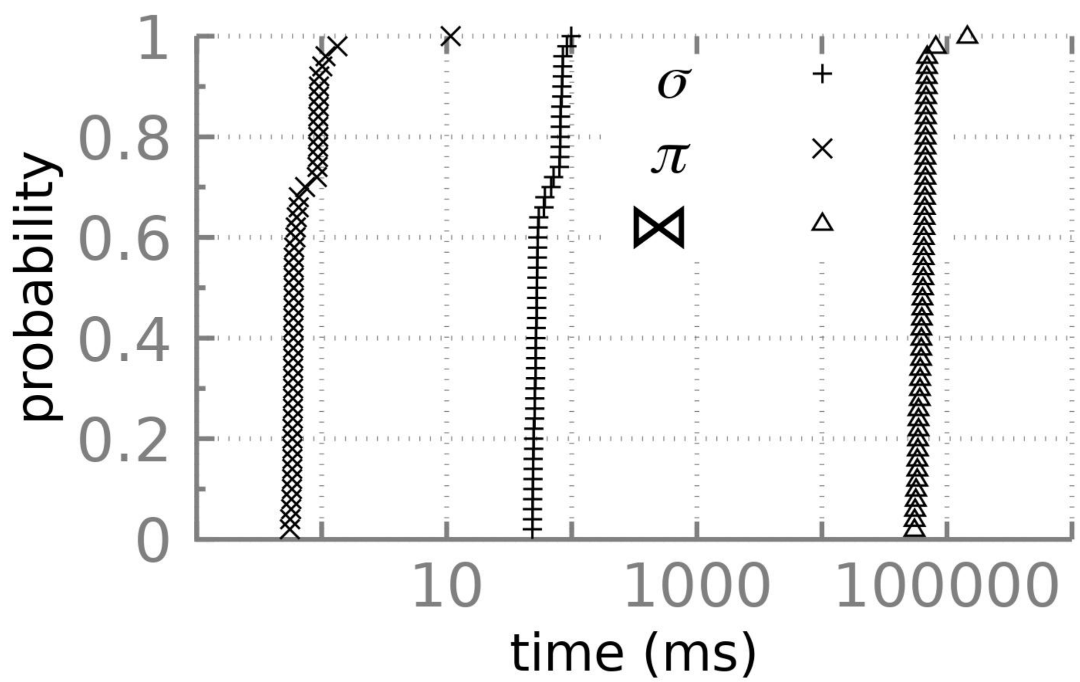
Benchmark

- Using MRT format RouteView BGP data - RIBs and UPDATEs - from route-view2.oregon-ix.net to generate synthetic policies and realistic topologies

Performance - Relational Operators

Projection Selection ⋈



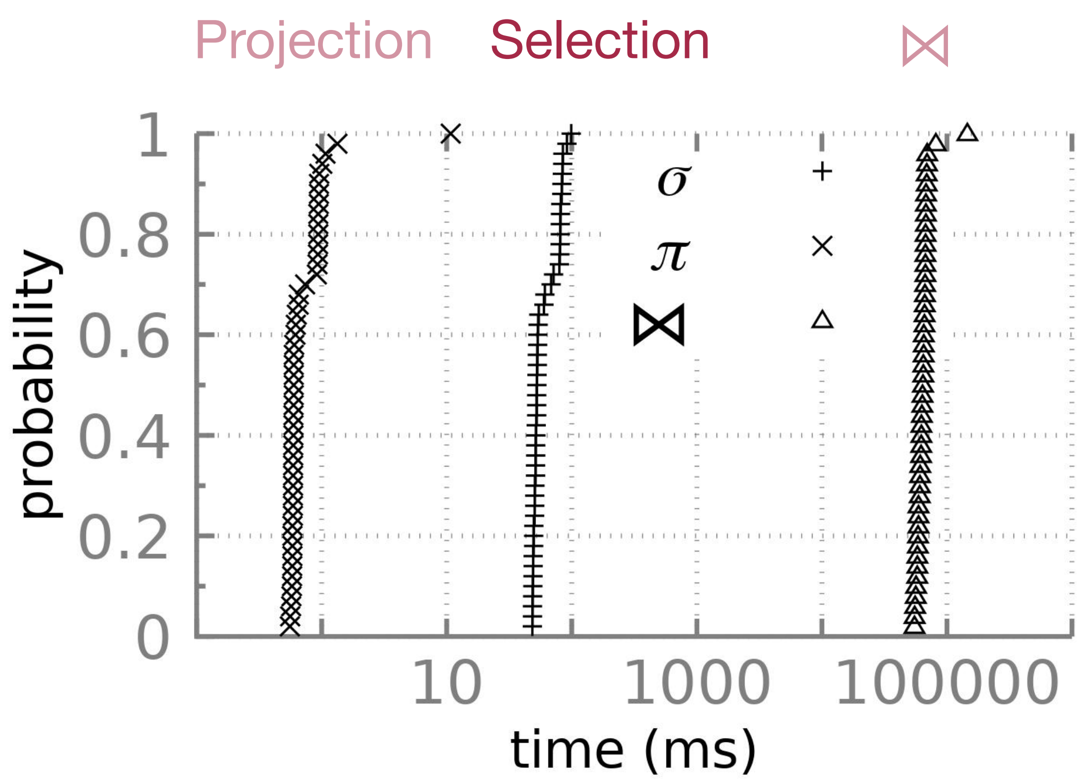
Realistic destination

⋈: $P_1 \bowtie P_3$

P_1: static-route & filter policy

P_3: traffic balance policy

Performance - Relational Operators



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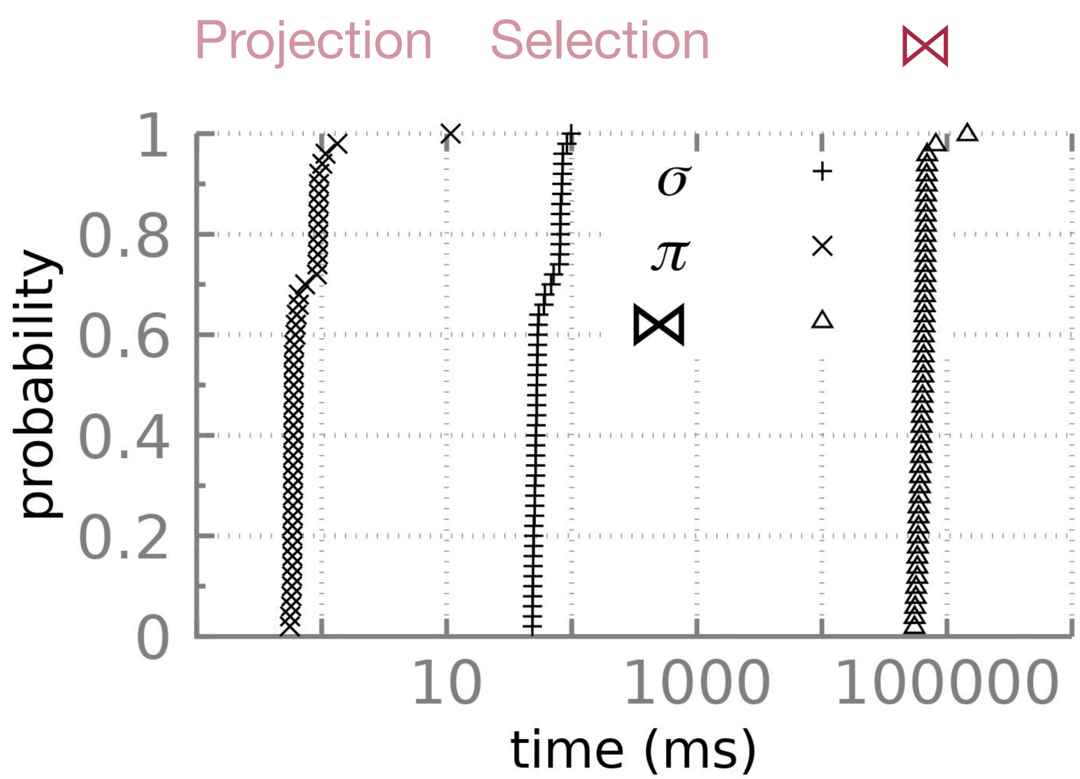

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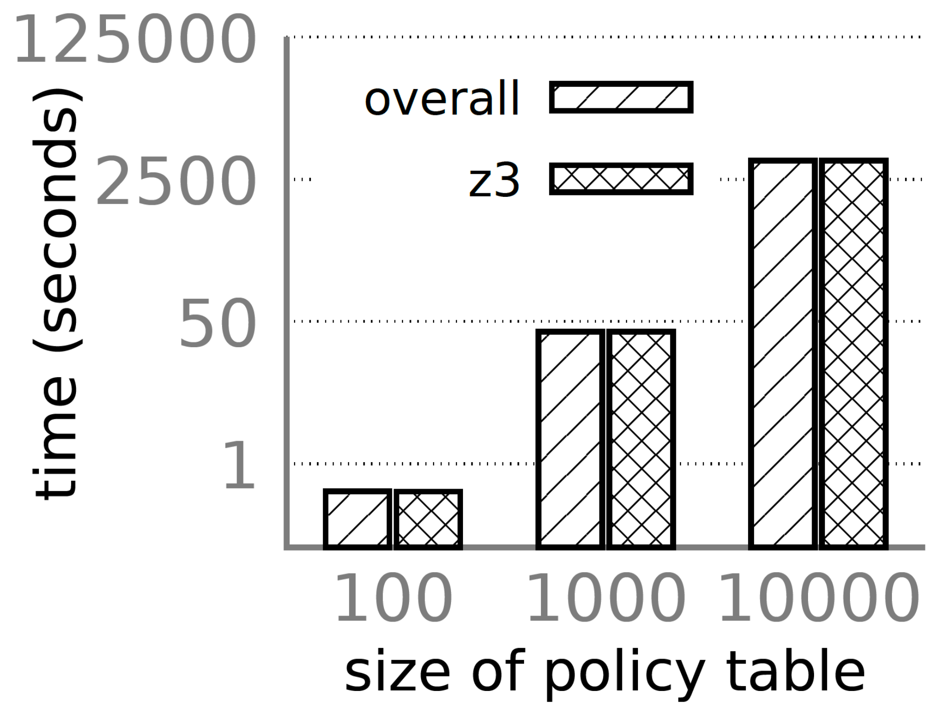
Performance - Scalability



Apply ⋈ on three policy sizes

Scalability property of ⋈

- SMT(Z3) takes 96% of the running time
- Our implementation can handle 10,000 policies in ≤ 70 minutes

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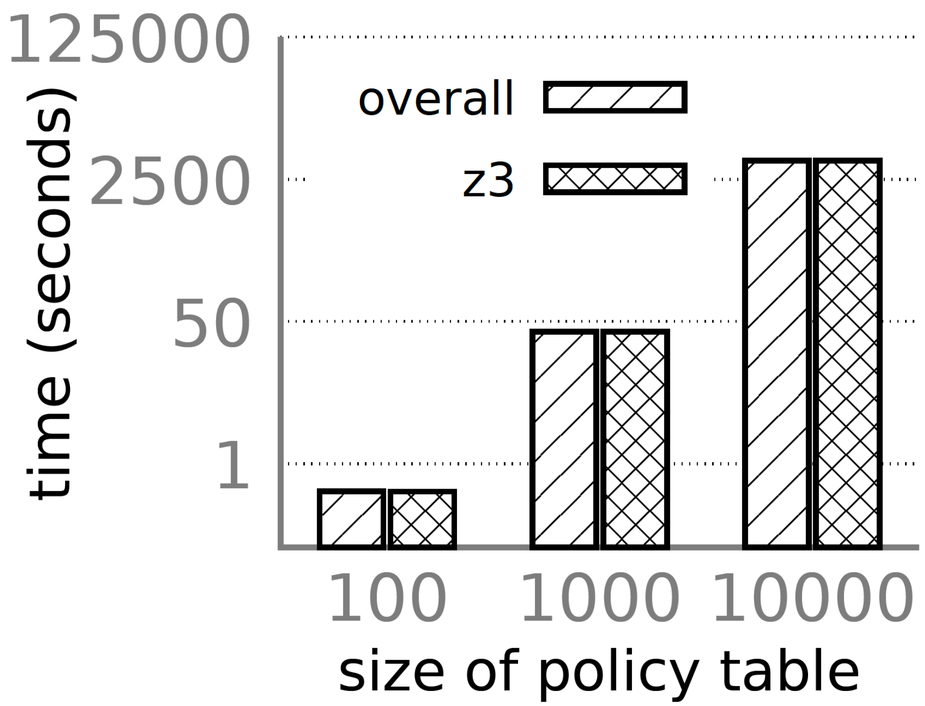

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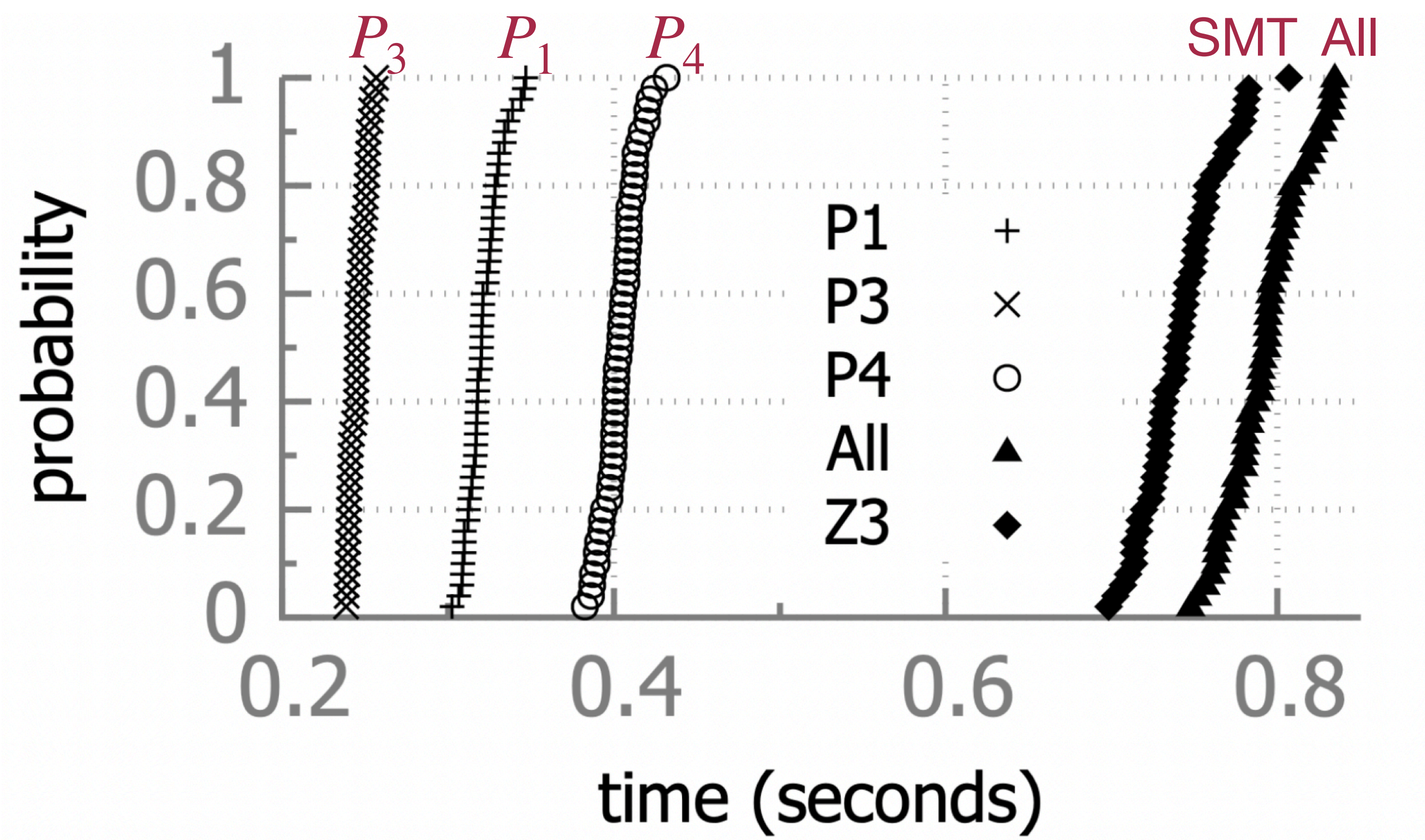
Performance - More Policy Examples



Processing time breakdown of poss(s, p)

P_1: static route policy
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SMT: reasoning time

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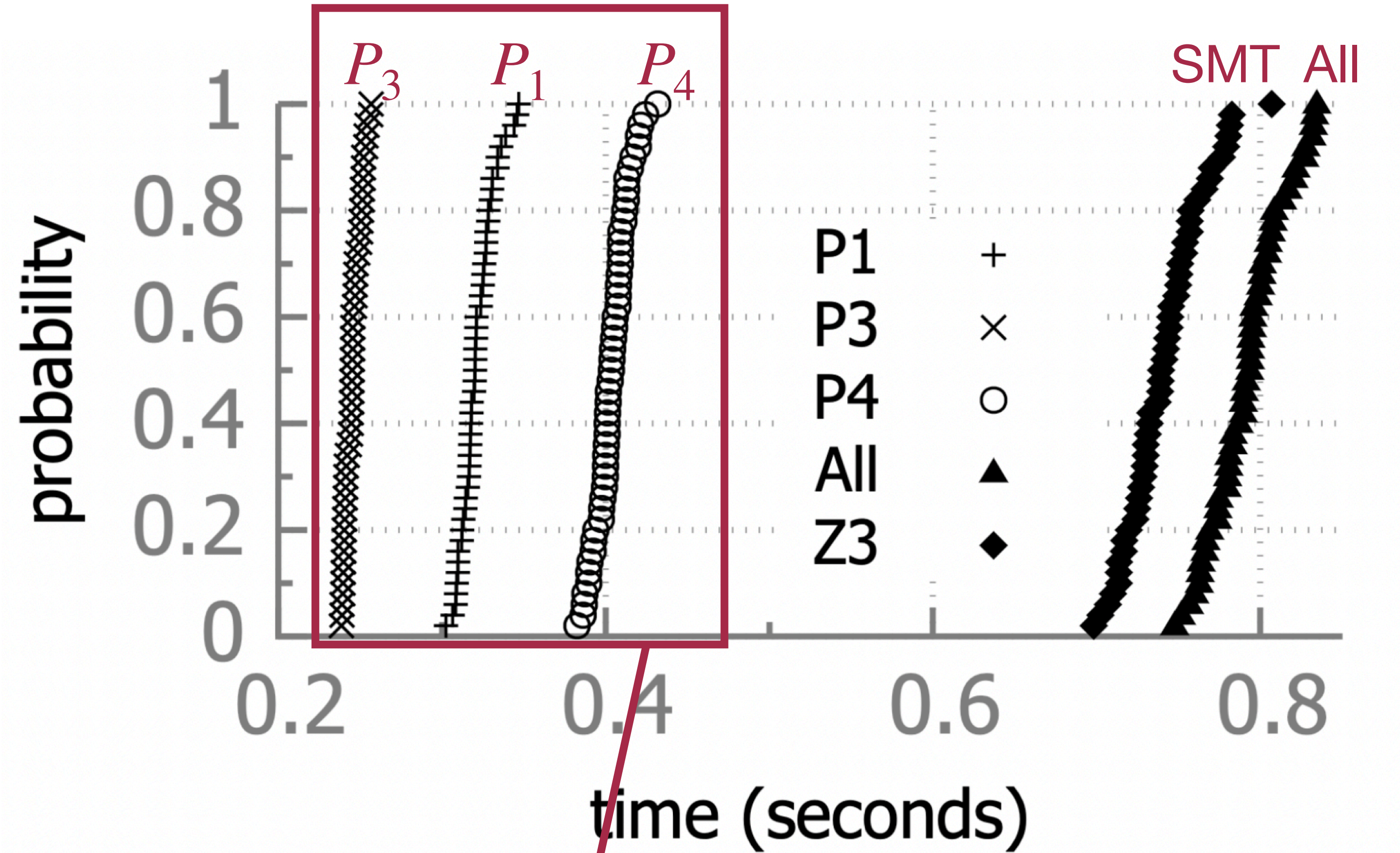

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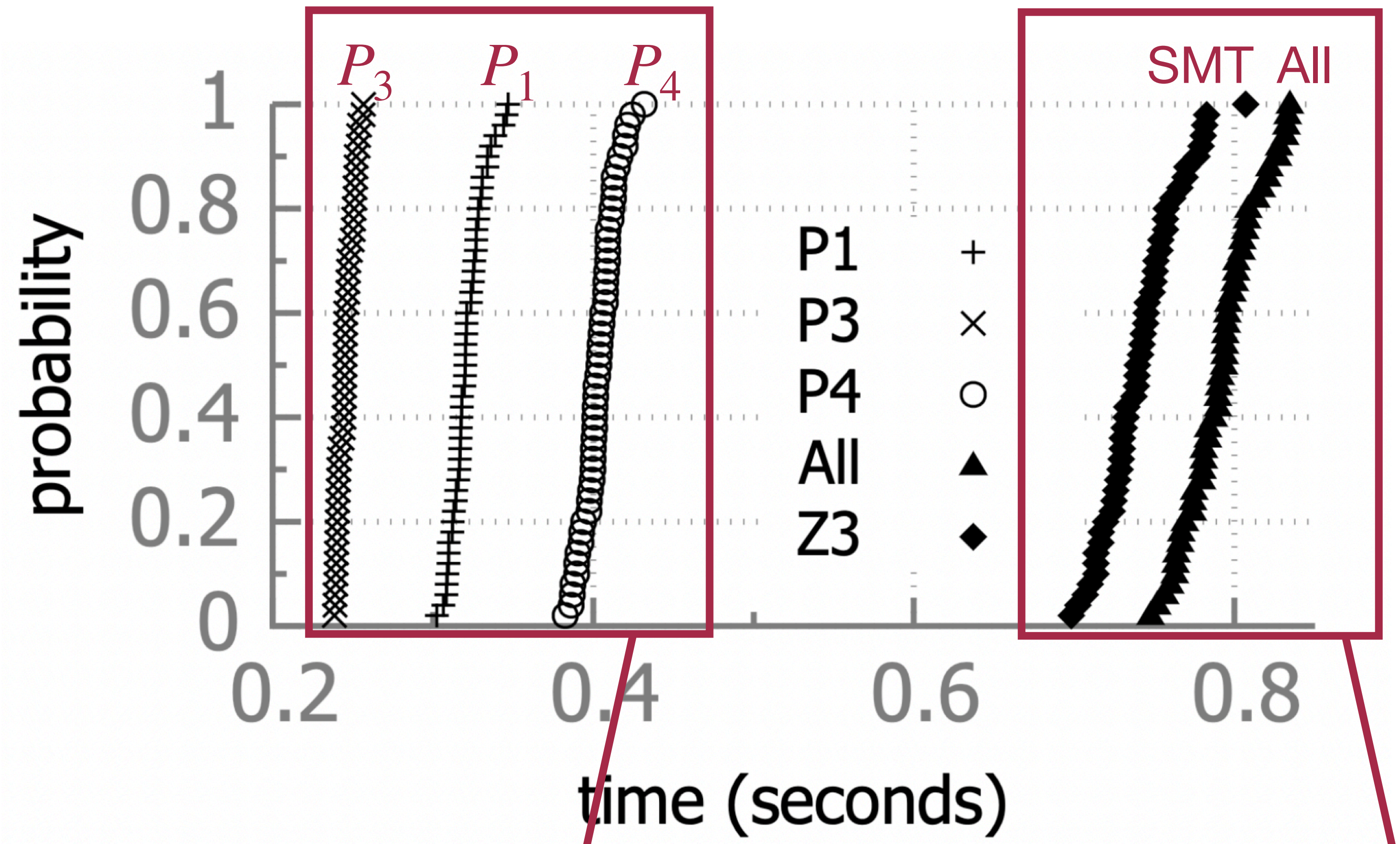

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Related Work

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  - D-BGP and Trotsky: partial deployments of protocols, requires their co-existence on the global internet
- Declarative Networking:
  - We share database usage in networking
  - We introduce and implement a novel use of conditional tables

Thank you

http://ravel-net.org/

Other Relational Operations

- Support full set of relational operators

Union: $\cup$

Selection: σ

Difference: $-$

Projection: π

Rename: ρ

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Rename: ρ

e.g. Rename column dest to prefix

Combine Policies using Join Operation

- Static route and filter policy

P_1	dest	path	
	1.2.3.4	x	x=[ABC]
	y	z	y≠1.2.3.5∧y≠1.2.3.4

- Traffic balance policy

P_3	dest	path	flag	
	1.2.3.4	[ABC]	u	u = 1
	5.6.7.8	[ABC]	u	u ≠ 1
	1.2.3.4	[ADC]	v	v = 1
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Can we generate a new policy that satisfies P_1 and P_3 simultaneously?

P_1 join P_3

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	1.2.3.4	x	v	x=[ABC] ∧ x=[ADC] ∧ v=1
	y	z	u	y≠1.2.3.5∧y≠1.2.3.4∧y=1.2.3.4∧z=[ABC]∧u=1
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Contradictory

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Combine Policies using Join Operation

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P_1	dest	path	
	1.2.3.4	x	x=[ABC]
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	~~1.2.3.4~~	~~x~~	~~v~~	~~$x=[ABC] \wedge x=[ADC] \wedge v=1$~~
	~~y~~	~~z~~	~~u~~	~~$y \neq 1.2.3.5 \wedge y \neq 1.2.3.4 \wedge y=1.2.3.4 \wedge z=[ABC] \wedge u=1$~~
	y	z	u	$y \neq 1.2.3.5 \wedge y \neq 1.2.3.4 \wedge y=5.6.7.8 \wedge z=[ABC] \wedge u \neq 1$
	~~y~~	~~z~~	~~v~~	~~$y \neq 1.2.3.5 \wedge y \neq 1.2.3.4 \wedge y=1.2.3.4 \wedge z=[ADC] \wedge v=1$~~
	y	z	v	$y \neq 1.2.3.5 \wedge y \neq 1.2.3.4 \wedge y=5.6.7.8 \wedge z=[ADC] \wedge v \neq 1$

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Redundancy

$P_1 \bowtie P_3$	dest	path	flag	
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	y	z	u	y≠1.2.3.5∧y≠1.2.3.4∧y=5.6.7.8∧z=[ABC]∧u≠1
	y	z	v	y≠1.2.3.5∧y≠1.2.3.4∧y=5.6.7.8∧z=[ADC]∧v≠1