

Software Development Project (SEP)

# AS Path-Prepending in the Internet And Its Impact on Routing Decisions

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# Background

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## Motivation

- BGP -> core routing protocol
- BGP relies on policy routing -> BGP attributes
- AS path-prepend policy influences BGP routing decision.
- AS path-prepend policy is widely used.

**(25.3% ASes, 15.4% AS paths)**

# Outline

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- **Background**
- Prepending in Observed AS Paths
- Simulation Experiment and Statistics
- Conclusion and Future Work

# Background

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## BGP (Border Gateway Protocol)

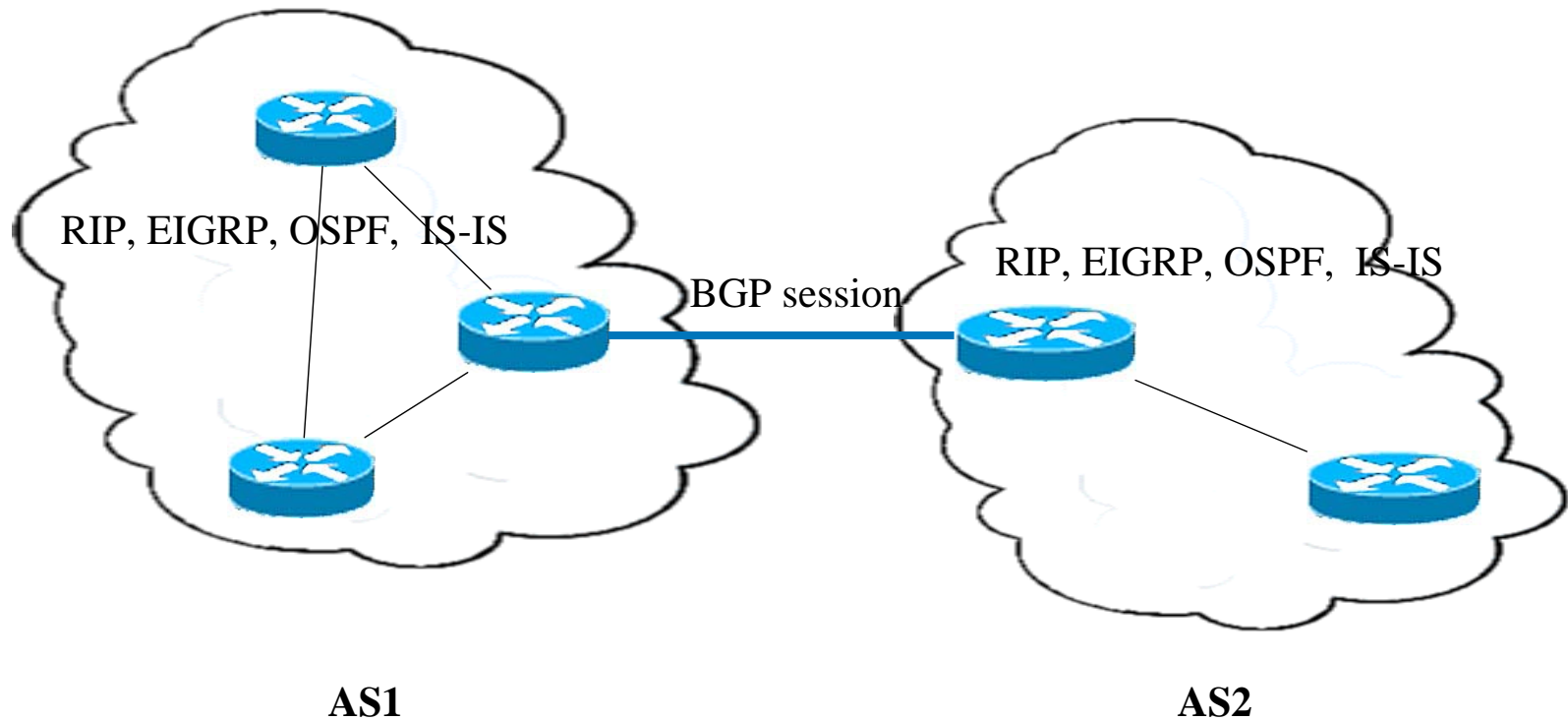
- de-facto standard protocol for inter-domain routing in the Internet

## AS (Autonomous System)

- a collection of IP networks and routers which has a single and clearly defined routing policy
- a unique AS number (ASN)
- Internet  $\approx$  20,000 ASes

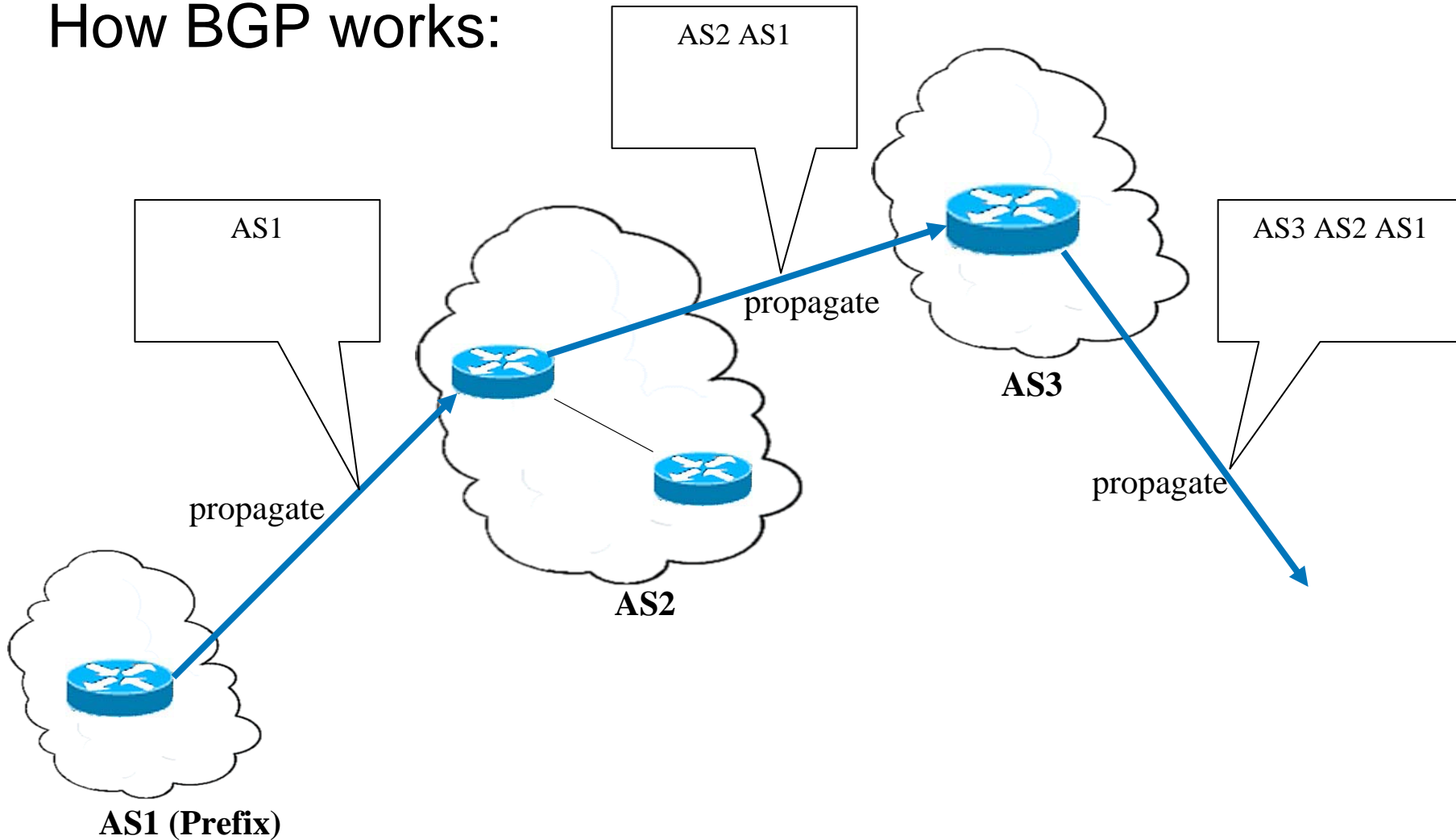
# Background

## AS & BGP



# Background

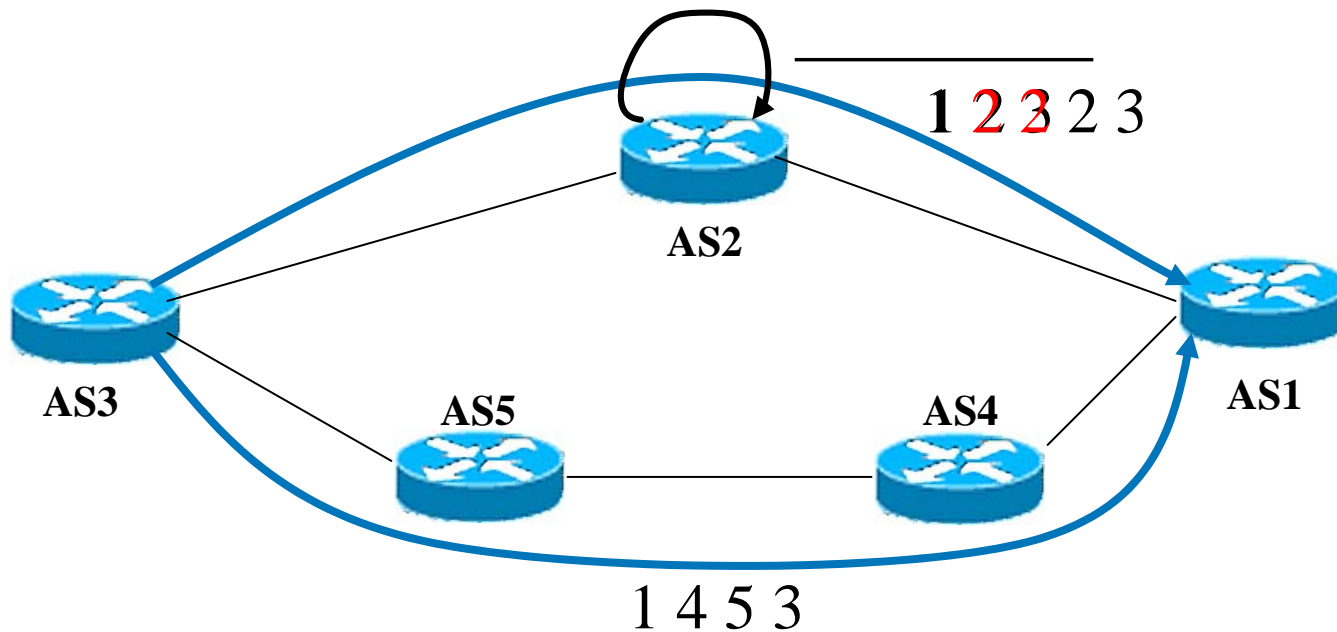
## How BGP works:



# Background

## AS Path

- BGP attributes (e.g. AS path) determine the best route.
- AS path-prepend policy makes AS path long.



- “shortest”  $\neq$  “best”

# Outline

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# Prepending in Observed AS Paths

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## Data Sets & Statistics

- BGP routing table dumps
- “snapshot”, using collector software, incomplete

Distinct AS paths	4,724,722
Count of ASes	21,173
AS-level connections (peerings)	62,595
AS paths with prependings	726,179 (15.4%)

- AS path “1 2 3 4” -> AS-level peerings “1:2”, “2:3”, “3:4”
- AS Path-Prepending widely used (15.4%)

# Prepending in Observed AS Paths

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## Terminologies used

- *Prepended AS-level peering*

1 2 3 3 3 4

AS3 is prepended in AS-level peering 2:3.

- *Prepending frequency*

1 2 3 4

1 5 2 3 3 6

are the only two paths that contain AS-level peering 2:3

AS-level peering 2:3 has a prepending frequency of 50%.

# Prepending in Observed AS Paths

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	Number	Percentage
Peerings	62,595	100%
Peerings sometimes prepended	4,607	7.4%
Peerings 100% prepended	4,792	7.7%
Peerings never prepended	53,196	84.9%

- Peerings sometimes prepended =  
Prepending frequency is neither 0% nor 100%
- Peerings 100% prepended -> “backup” AS ?

[sheet18](#)

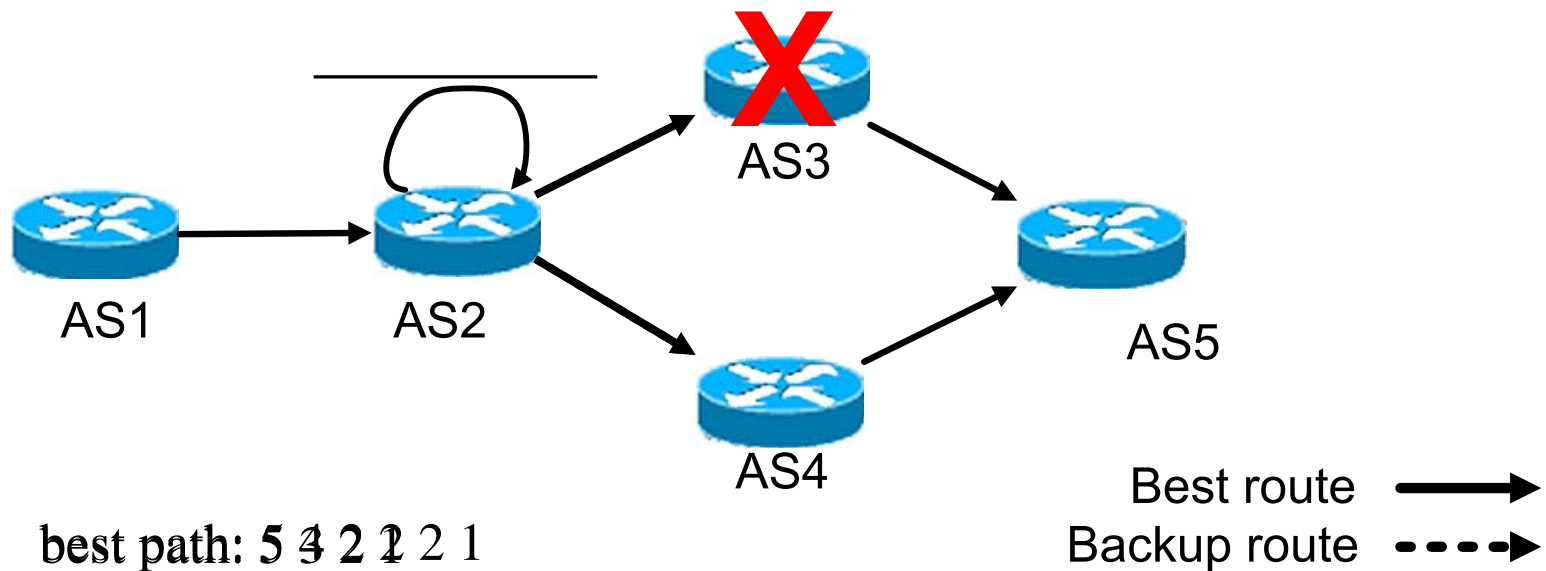
# Prepending in Observed AS Paths

## “Backup” AS

Best route 2->3

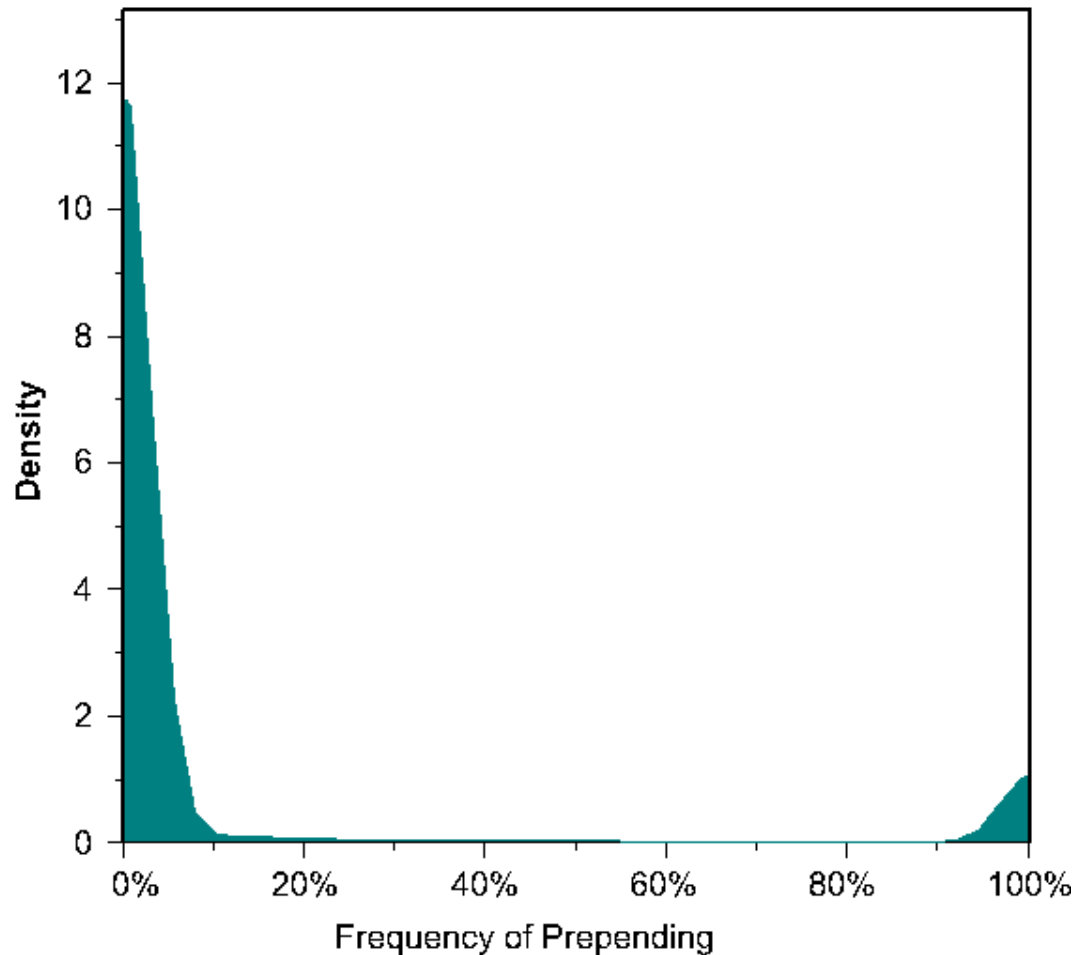
“backup” route 2->4

In peering 4:2, AS2 is **always** prepended.



# Prepending in Observed AS Paths

Density distribution of prepending frequency for AS-level peerings



# Outline

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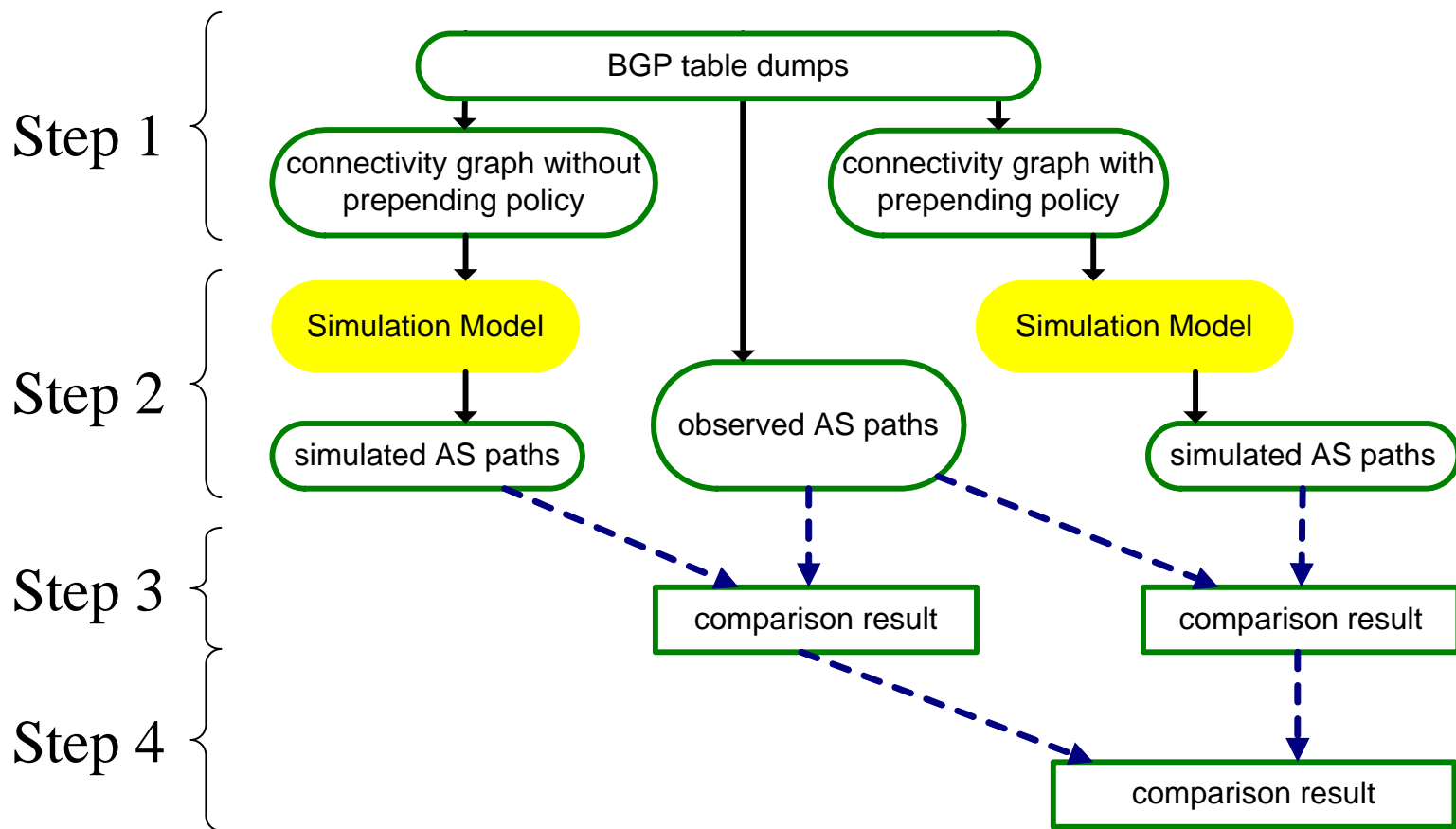
# Simulation Experiment and Statistics

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- Goal of simulation experiment
  - Reproduce routing with & without prepending policy
  - Obtain statistics
  - Disclose the impact of prepending policy on BGP routing decisions

# Simulation Experiment and Statistics

## General approach



## Step 1: Construct AS-level connectivity graph

- ASes -> nodes
- AS-level peerings -> edges

Example:

AS path: 1 2 3 3 4  $\Rightarrow$   $\left\{ \begin{array}{l} \text{ASes: 1, 2, 3, 4} \\ \text{AS-level peerings: 1:2 2:3 3:4} \end{array} \right.$

## Step 1: Construct AS-level connectivity graph

- With prepending policy & without policy
- Prepend AS 5 times to maximize the effect.

(93.2% prepending length  $\leq 5$  )

- Apply path-prepend policy only to the 100% prepended peerings. [sheet 12](#)

# Simulation Experiment and Statistics

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## Step 2: Simulate BGP routing decision process

Simulator: C-BGP

- BGP decision process simulator
- Scalable, high efficiency
- Easy Configuration

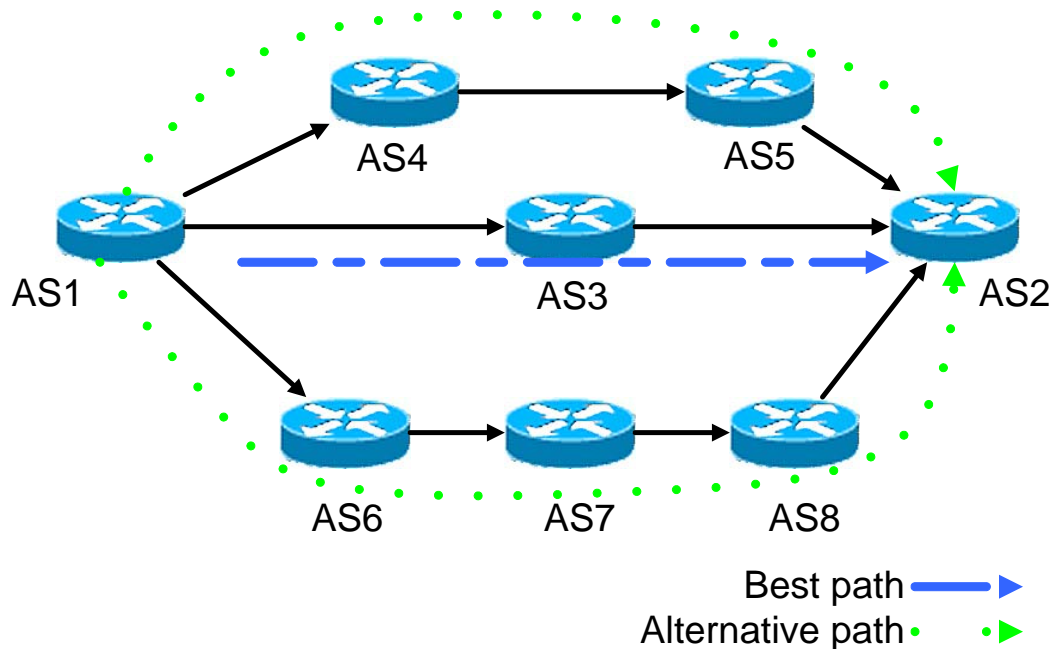
<b>Number of prefixes simulated each time</b>	<b>CPU time per prefix (approximately)*</b>	<b>Memory (approximately)</b>
<b>1</b>	<b>2 min 30 sec</b>	<b>60M</b>
<b>5</b>	<b>1 min 37 sec</b>	<b>80M</b>
<b>50</b>	<b>2 min 10 sec</b>	<b>730M</b>

\*using 2 AMD Opteron 240 (1.4GHz) simultaneously

# Simulation Experiment and Statistics

## Step 3: Compare simulated AS paths with observed paths

Two kinds of simulated paths



# Simulation Experiment and Statistics

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- Discard AS path prependings while comparing

Path1 (observed): 1 2 2 3 4  
Path2 (reproduced): 1 2 2 2 2 2 2 3 4

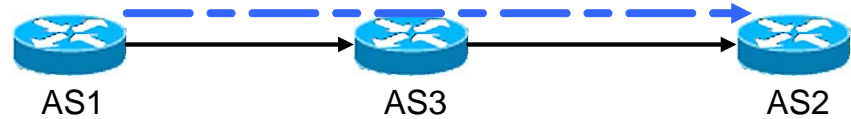
} ⇒ Path1=Path2

# Simulation Experiment and Statistics

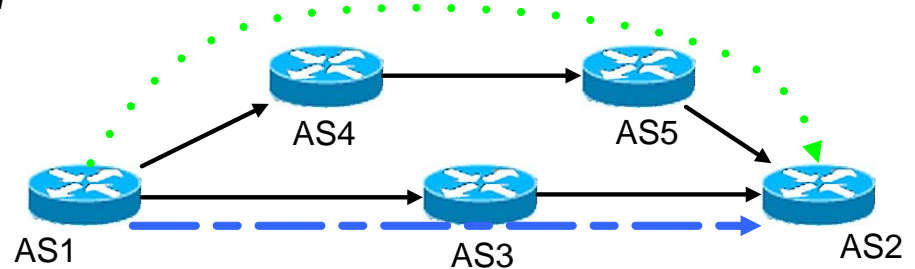
3 cases by comparing simulated paths with observed paths

- Case 1:  
Best path match
- Case 2:  
Alternative path match
- Case 3:  
No path match

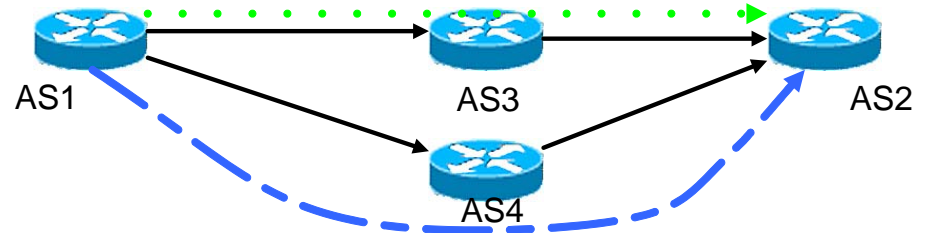
*In the Internet*



*Case 1*



*Case 2*



Best path ———▶  
Alternative path ···▶

# Simulation Experiment and Statistics

## Simulation results: without policy vs. with policy

	without prepending policy		with prepending policy	
Best path match	25.8%	54.2%	25.4%	53.2%
Alternative path match	28.4%		27.8%	
No match	45.8%		46.8%	
Sum	100%			

1. Simulation result different from the observed paths, why?
2. Simulation without prepending policy is better than that with prepending policy ->unexpected!!! Why?

Why is simulation result different from observed paths?

1. Incomplete data set
2. Intra-domain routing
3. Missing policies

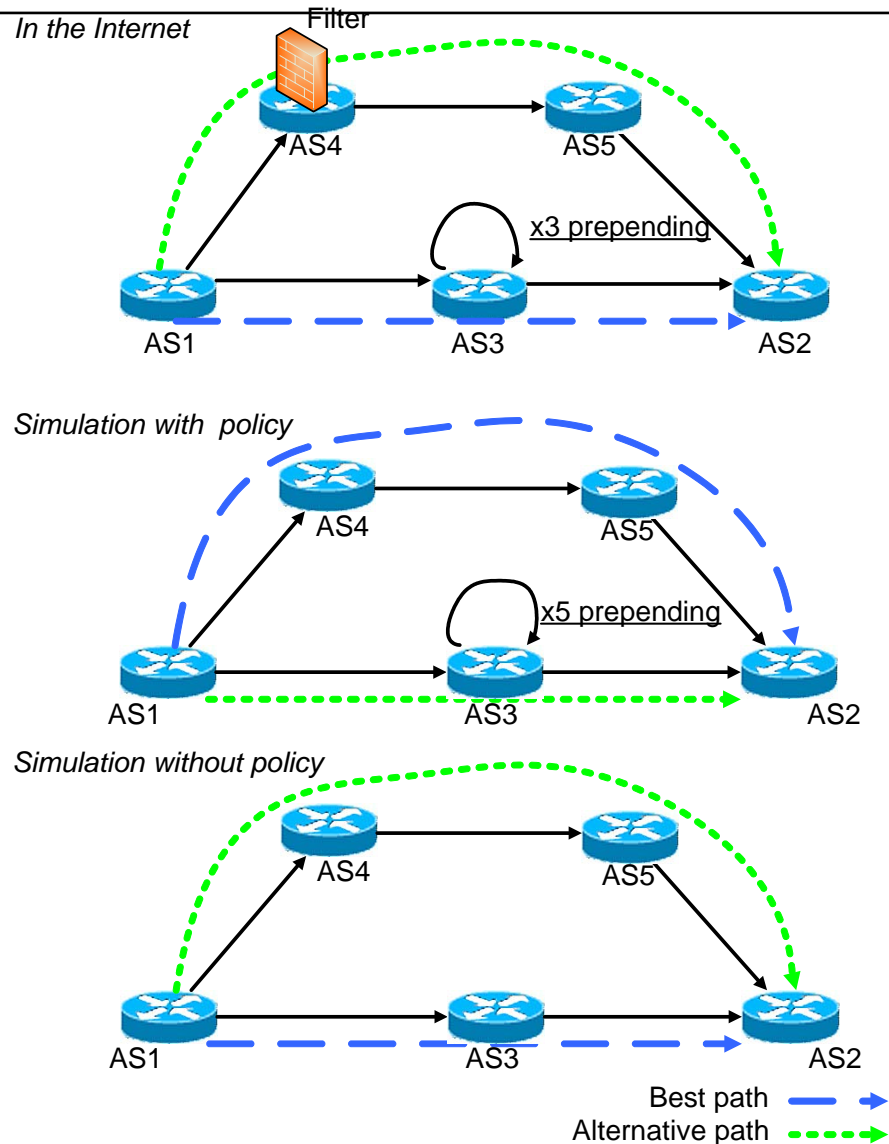
Why is simulation without prepending policy better than that with prepending policy?

->Missing policies

# Simulation Experiment and Statistics

## Example

Best path not selected after adding prepending policy



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# Conclusion and Future Work

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## Conclusion:

- AS path-prepend policy widely used
- Impact of AS path-prepend policy can't be seen  
->integrating AS-path prepending policy alone is insufficient

Future work-> Improvement of simulation

End

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Thanks for your attention!