iSDX: An Industrial-Scale Software-Defined IXP
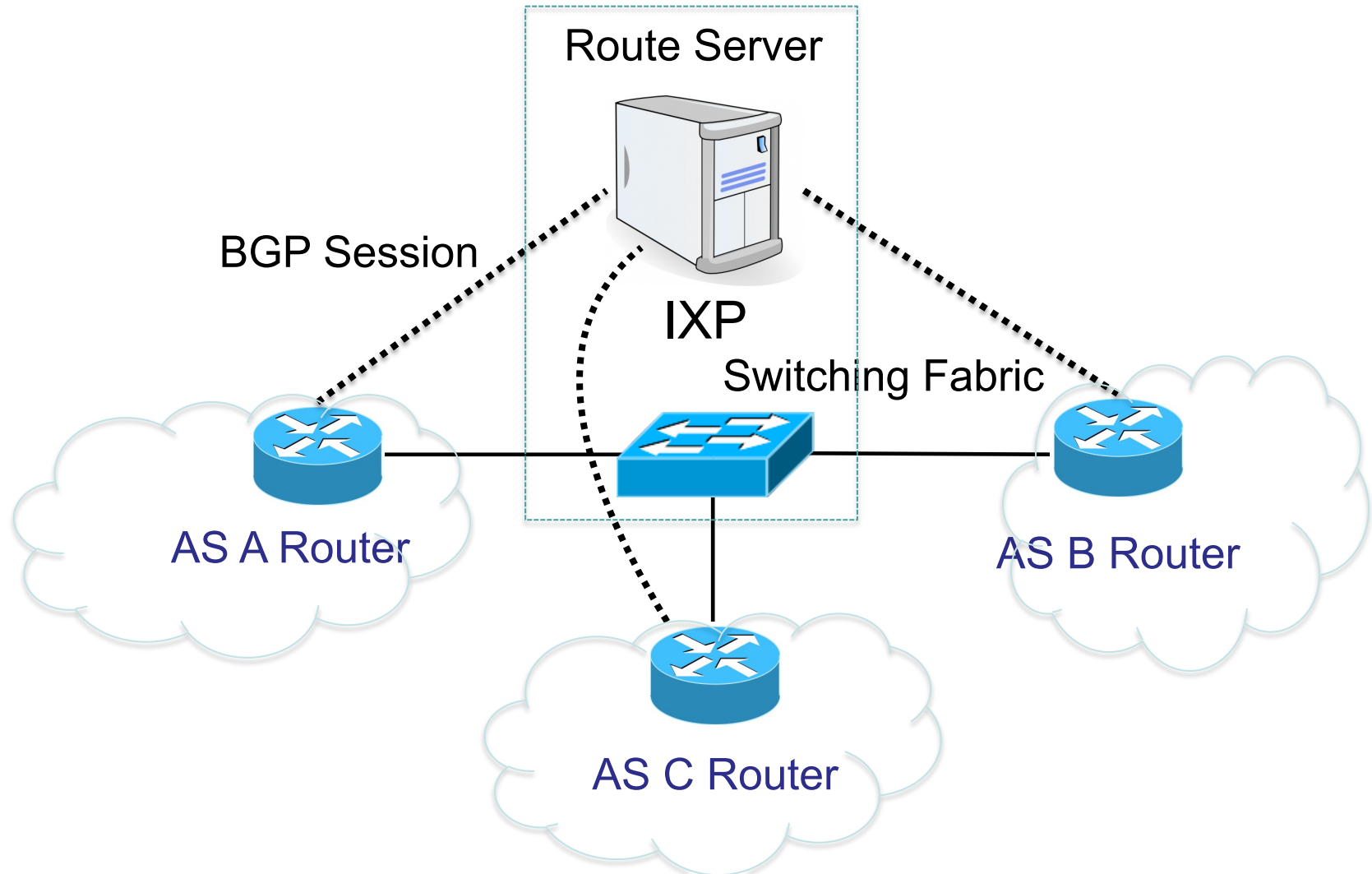
Arpit Gupta

Princeton University
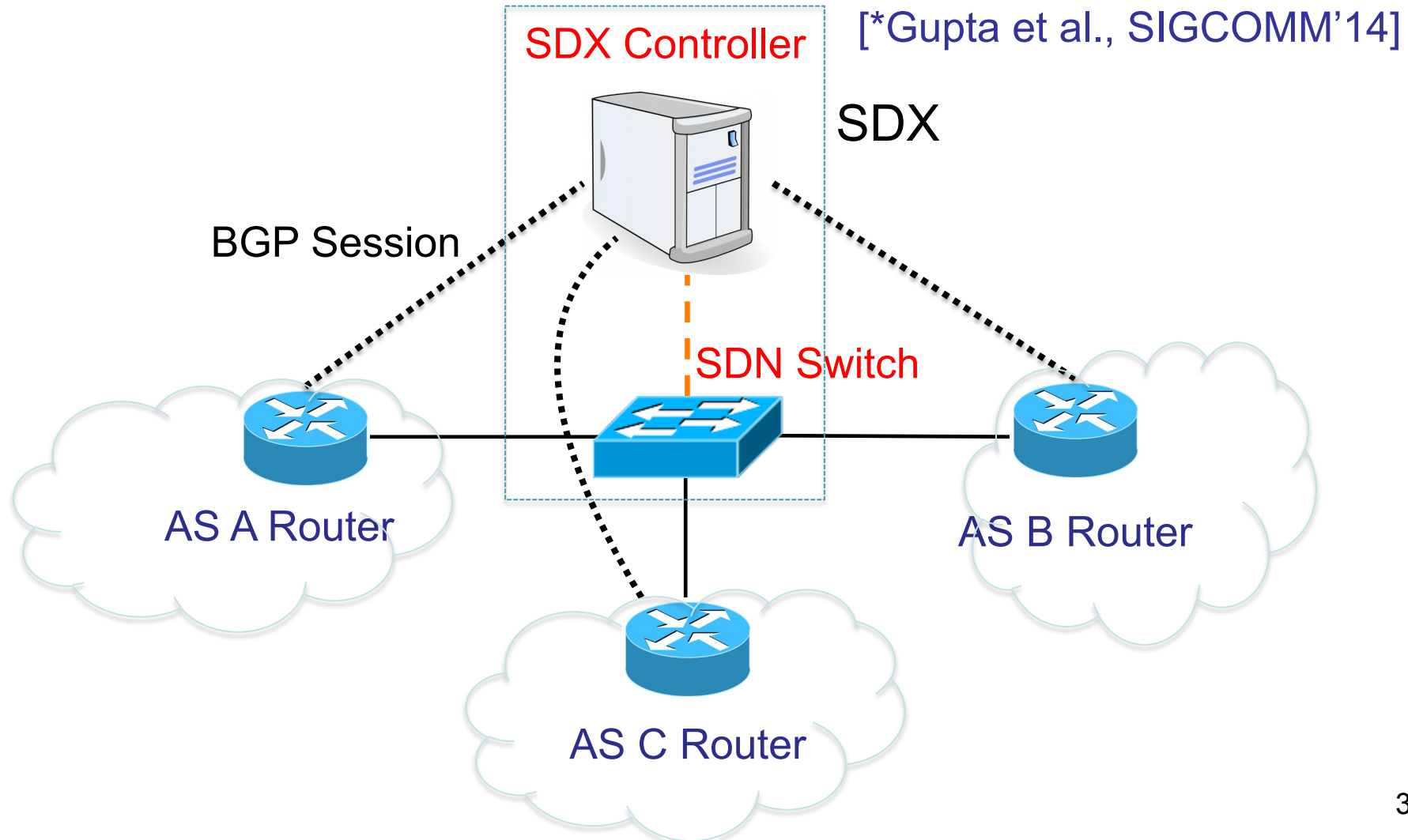
http://sdx.cs.princeton.edu

Robert MacDavid, Rüdiger Birkner, Marco Canini,
Nick Feamster, Jennifer Rexford, Laurent Vanbever

Internet Exchange Points (IXPs)

Route Server

BGP Session

IXP

Switching Fabric

AS A Router

AS B Router

AS C Router

Software Defined IXPs (SDXs)

SDX Controller

[*Gupta et al., SIGCOMM'14]

SDX

BGP Session

SDN Switch

AS A Router

AS B Router

AS C Router

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Deployment Ready SDX is Hard!

- **Deployment Experience:**
  - Inter-Agency Exchange
  - Large IXP in Europe
  - Smaller IXPs in Asia

- **Challenges:**
  - **Data Plane Scalability**
  - …

Data Plane Scalability Challenges

Devices	Operations	Data Plane Performance	
		State (# entries)	Update Rate (flow-mods/s)
	Match-Action on Multiple Headers	100K	2,500

Data Plane Scalability Challenges

Devices	Operations	Data Plane Performance	
		State (# entries)	Update Rate (flow-mods/s)
	Match-Action on Multiple Headers	100K	2,500
	Matches on IP Prefixes only	~1M	N/A

Problem: Optimize the usage of available devices

Simple Example

SDX Controller

AS A   IXP Fabric

AS C
announces
10/8, 40/8

dPort = 443 → fwd(C)
dPort = 22 → fwd(C)

AS D
announces
10/8, 40/8, 80/8

AS B

dPort = 80 → fwd(E)

AS E
announces
80/8

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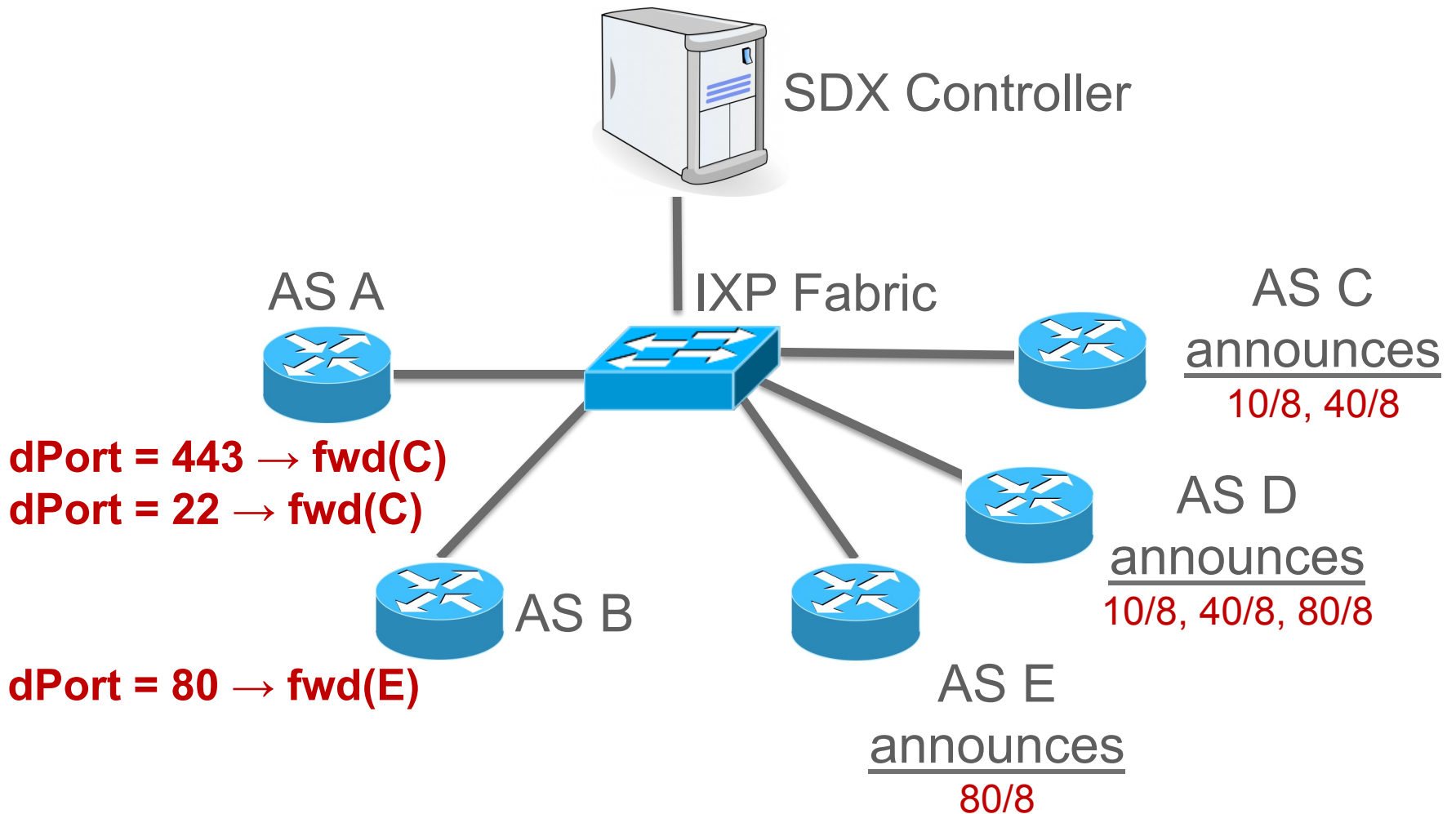
Forwarding Table Entries at SDX

SDN Policies	# Forwarding Table Entries	
dPort = 443 → fwd(C)	1	AS A
dPort = 22 → fwd(C)	1	
dPort = 80 → fwd(E)	1	AS B

Number of forwarding table entries for
A & B's Outbound SDN Policies

Goal Tracker

	Simple Example
Baseline	3

- **Large IXP Dataset:**
  - BGP RIBs & Updates from large IXP
  - 511 IXP participants
  - 96 million peering routes for 300K IP prefixes
  - 25K BGP updates for 2-hour duration

Goal Tracker

	Simple Example	Large IXP
Baseline	3	62K

- **Large IXP Dataset:**
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Goal Tracker

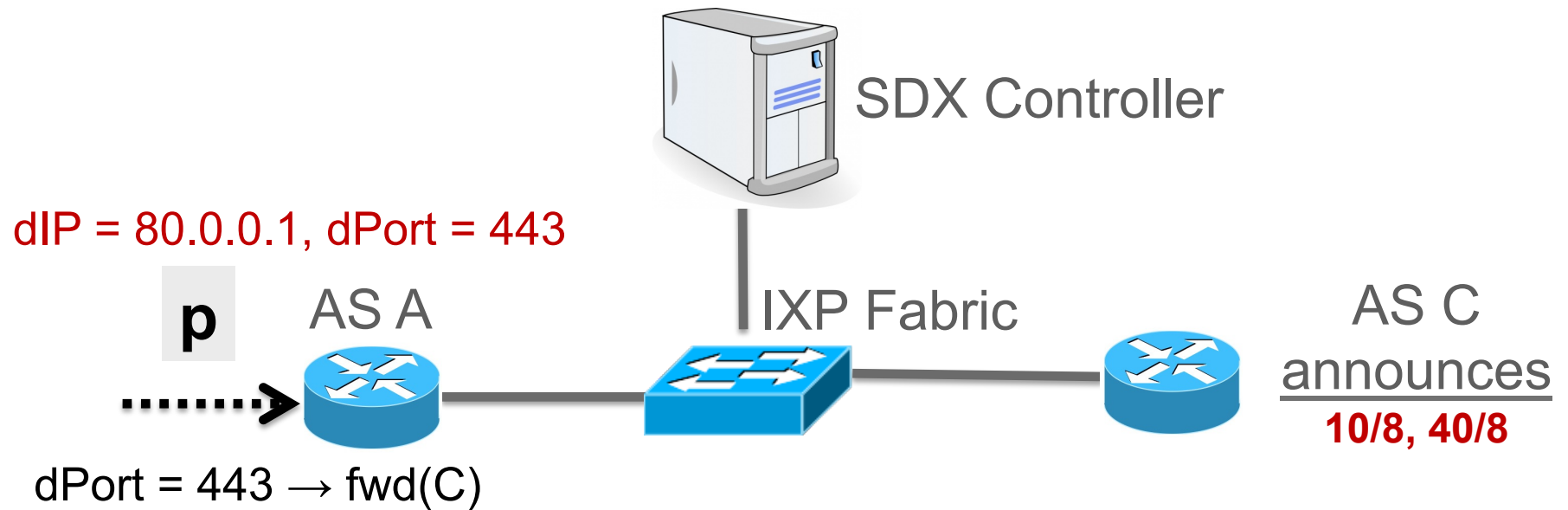|	Simple Example	Large IXP
Baseline	3	62K

Satisfies design goals, but …

Goal Tracker

	Simple Example	Large IXP
Baseline	3	62K

… not congruent with BGP!

Challenge: Congruence with BGP

SDX Controller

dIP = 80.0.0.1, dPort = 443

p

AS A

IXP Fabric

AS C
announces
10/8, 40/8

dPort = 443 → fwd(C)

Ensure **p** is not forwarded to C

Solution: SDN Policy Augmentation

SDX Controller

dIP = 80.0.0.1, dPort = 443

p   AS A

IXP Fabric

AS C
announces
10/8, 40/8

dIP ∈ {10/8, 40/8} ∧
dPort = 443 → fwd(C)
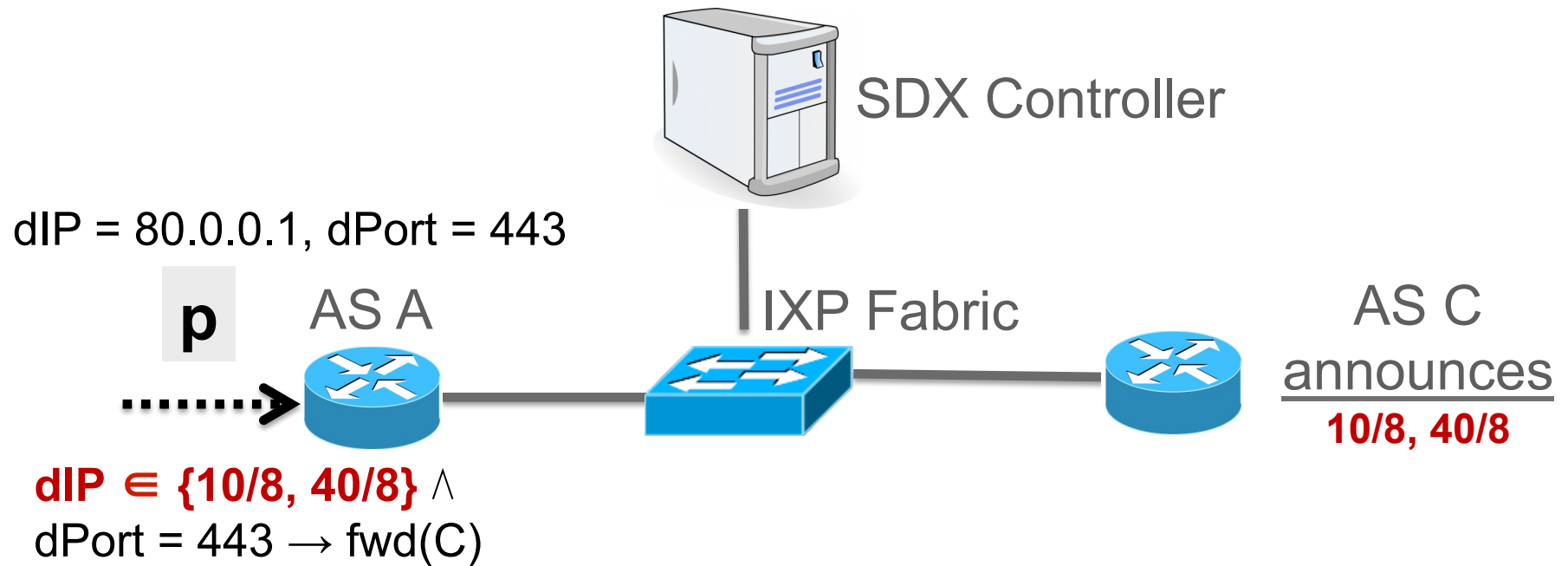
Match on prefixes advertised by C

Data Plane State Explosion!

SDN Policies	# Forwarding Table Entries		
	10/8	40/8	80/8
dPort = 443 → fwd(C)	1	1	0
dPort = 22 → fwd(C)	1	1	0
dPort = 443 → fwd(D)	1	1	1

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3

SDN Policy Augmentation increases forwarding table entries

Goal Tracker

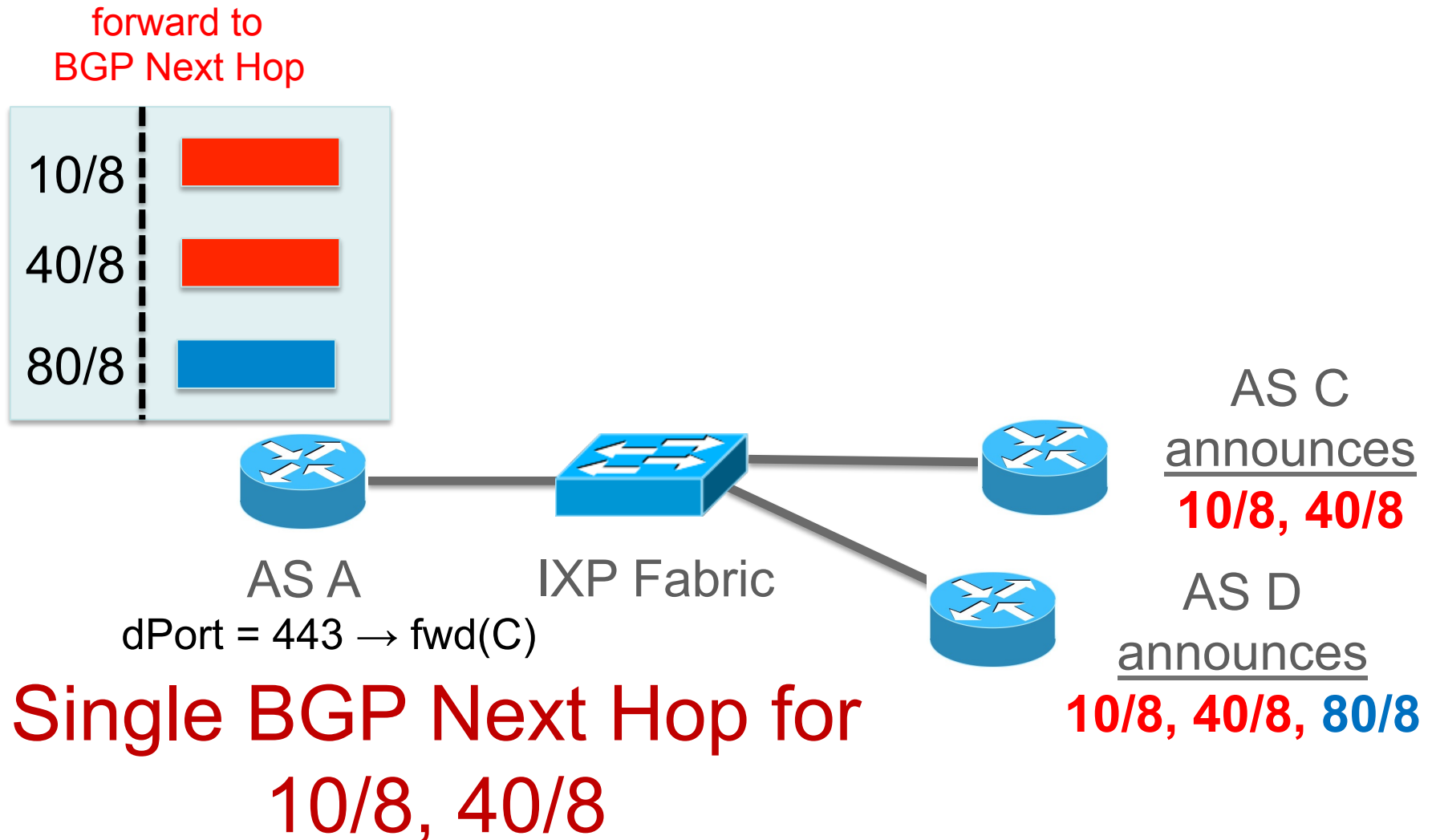|	Simple Example	Large IXP
Baseline	3	62K
Policy Augmentation	7	**68M**

Not possible to support these many forwarding table entries!

Forwarding Equivalence Classes

SDN Policies	# Forwarding Table Entries		
	10/8	40/8	80/8
dPort = 443 → fwd(C)	1	1	0
dPort = 22 → fwd(C)	1	1	0
dPort = 443 → fwd(D)	1	1	1

10/8, 40/8 exhibit similar forwarding behavior

Leveraging Forwarding Equivalence
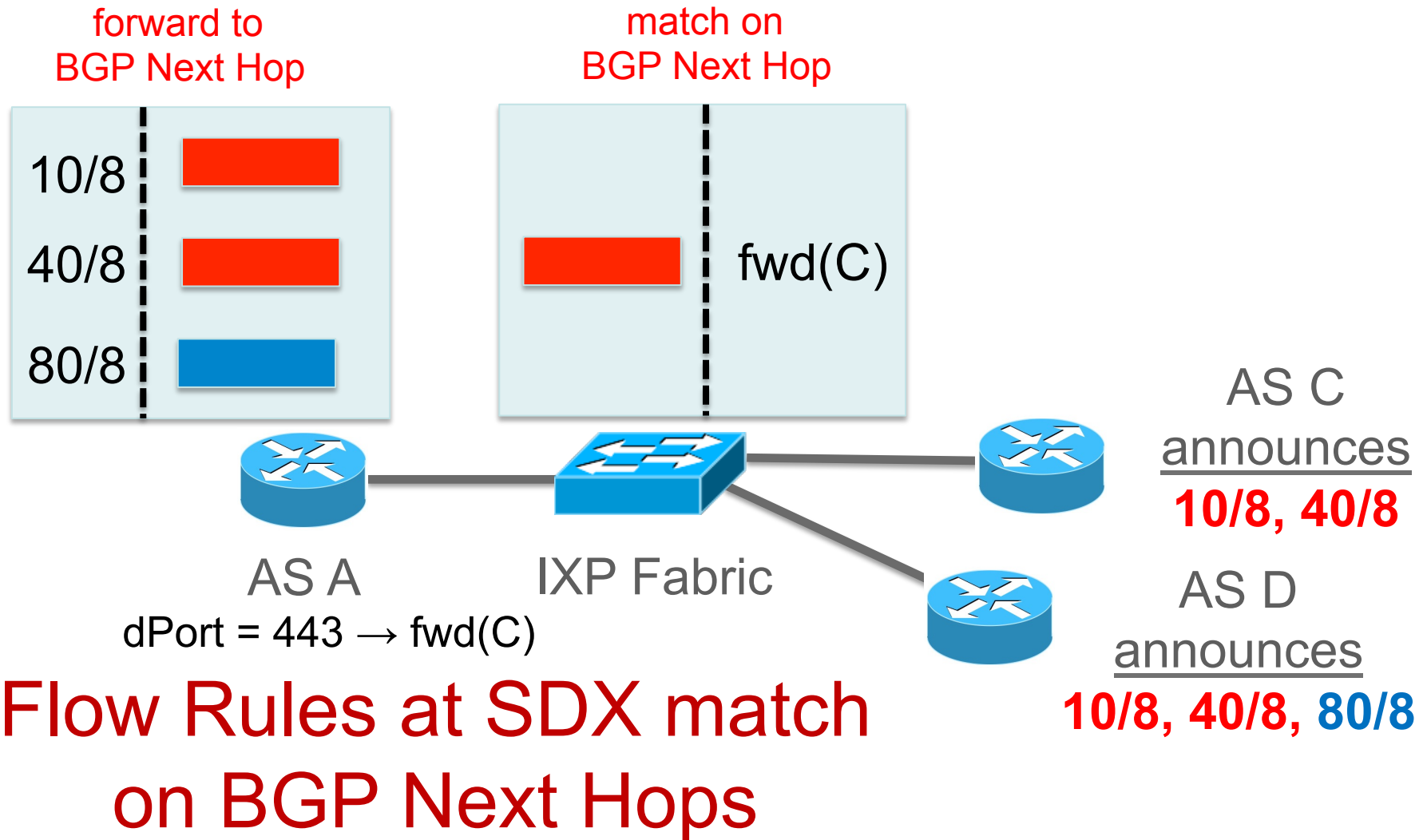
forward to
BGP Next Hop

10/8

40/8

80/8

AS A

AS C
announces
10/8, 40/8

IXP Fabric

AS D
announces
10/8, 40/8, 80/8

dPort = 443 → fwd(C)

Single BGP Next Hop for
10/8, 40/8

Leveraging Forwarding Equivalence

forward to
BGP Next Hop

match on
BGP Next Hop

10/8

40/8

80/8

fwd(C)

AS C
announces
10/8, 40/8

AS A

IXP Fabric

AS D
announces
10/8, 40/8, 80/8

dPort = 443 → fwd(C)

Flow Rules at SDX match
on BGP Next Hops

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Goal Tracker

	Simple Example	Large IXP
Baseline	3	62K
Policy Augmentation	7	68M
*FEC Computation	**4**	**21M**

[*Gupta et al., SIGCOMM'14]

Still not possible to support these many forwarding table entries!

More Efficient FEC Computation

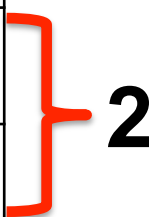| SDN Policies	# Forwarding Table Entries	
	{10/8, 40/8}	80/8
dPort = 443 → fwd(C)	1	0
dPort = 22 → fwd(C)	1	0
dPort = 443 → fwd(D)	1	1

Independent FEC Computation
can be more efficient

Partitioning FEC Computation

- **Large number of SDX participants**
  - Many different policies on groups of prefixes
  - Leads to a large number of small FECs of prefixes

- **Compute FECs independently**
  - Separate computation per participant
  - Leads to small number of large FECs, and less frequent recomputation
  - Enables "scale out" of the FEC computation

FEC Computation Partitioning in Action

SDN Policies	# Forwarding Table Entries	
	{10/8, 40/8}	80/8
dPort = 443 → fwd(C)	1	0
dPort = 22 → fwd(C)	1	0

2

dPort = 443 → fwd(D)	1

1

A & B independently compute FECs

Goal Tracker

	Simple Example	Large IXP
Baseline	3	62K
Policy Augmentation	7	68M
FEC Computation	4	21M
Independent FEC Computation	**3**	**763K**

Also requires support for
15K flow-mods/seconds

Undesired BGP & SDN Coupling

SDN Policies	# Forwarding Table Entries		
	10/8	40/8	80/8
dPort = 443 → fwd(C)	1	1	0
dPort = 22 → fwd(C)	1	1	0
dPort = 443 → fwd(D)	1 → 0	1	1

Incoming BGP Update:
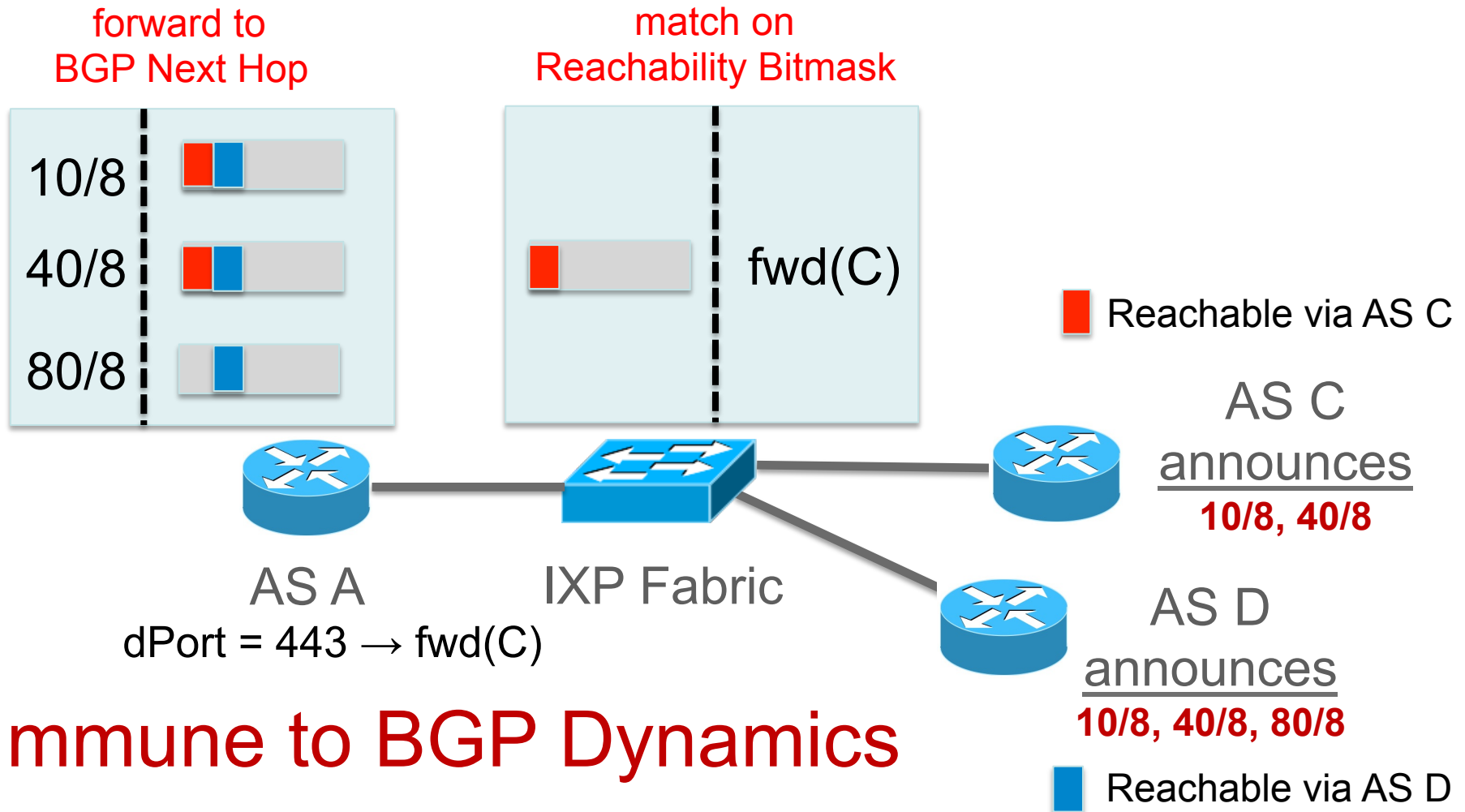*{AS D withdraws route for prefix 10/8}*

Decoupling BGP from SDN Policies

- Leverage advances in commodity hw switches
  - Support for Bitmask Matching (L2 headers)

- Extend BGP "next hop" encoding
  - So far: encode FECs (single field)
  - New idea: encode **reachability bitmask** (multi field)

- Changing only the BGP announcements
  - No need to update the SDX data plane!

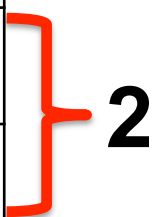# Reachability Bitmask in Action

forward to
BGP Next Hop

10/8

40/8

80/8

Dedicate one bit per participant

■ Reachable via AS C

AS C
announces
10/8, 40/8

AS A   IXP Fabric

dPort = 443 → fwd(C)

AS D
announces
10/8, 40/8, 80/8

■ Reachable via AS D

Reachability Bitmask in Action

forward to
BGP Next Hop

match on
Reachability Bitmask

10/8

40/8

80/8

fwd(C)

■ Reachable via AS C

AS C
announces
10/8, 40/8

AS A

IXP Fabric

dPort = 443 → fwd(C)

AS D
announces
10/8, 40/8, 80/8
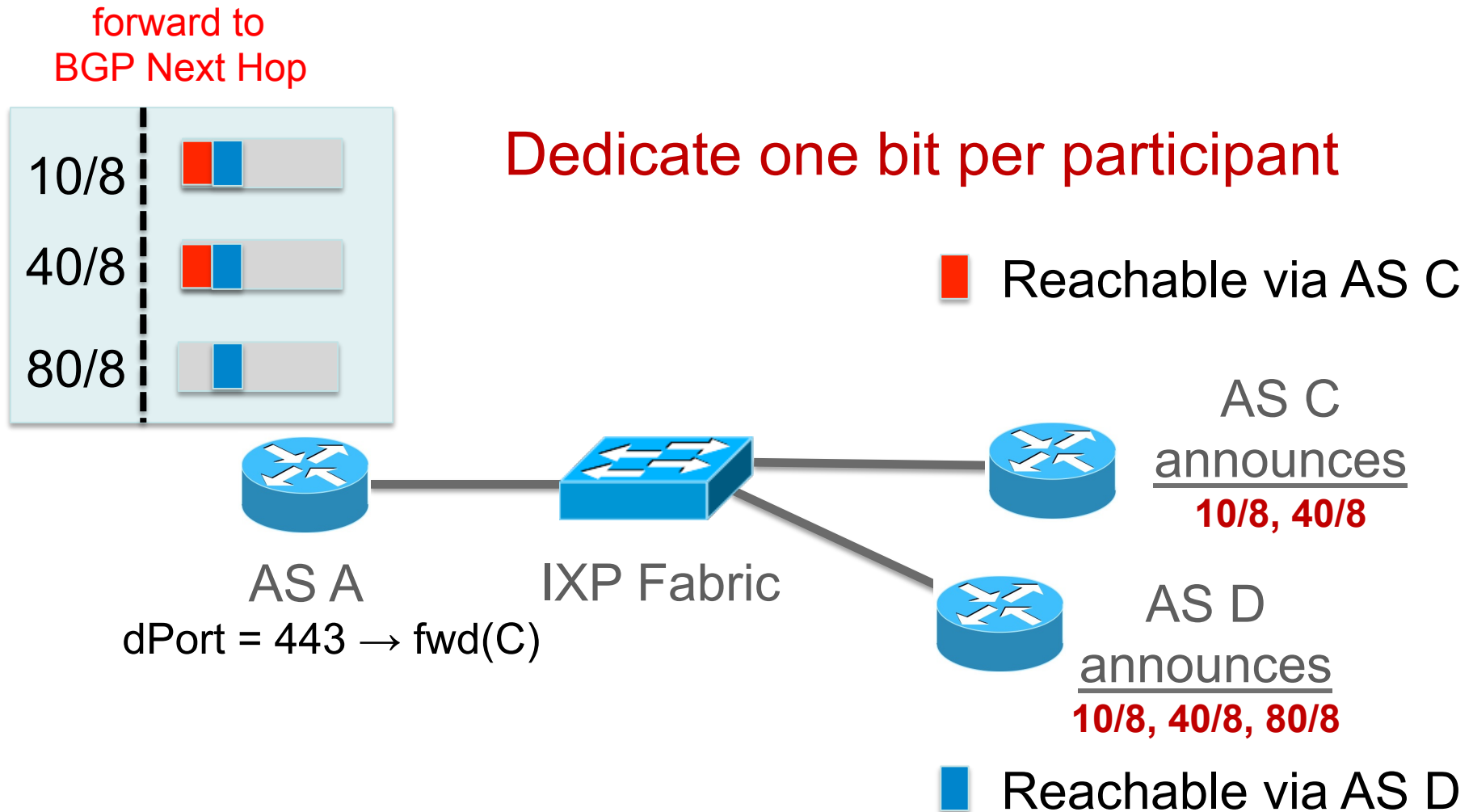
Immune to BGP Dynamics

■ Reachable via AS D

Reachability Bitmask in Action

SDN Policies	# Forwarding Table Entries
	C
dPort = 443 → fwd(C)	1
dPort = 22 → fwd(C)	1

2

dPort = 443 → fwd(D)	1

1

Reduces Data Plane State

Goal Tracker

	Simple Example	Large IXP
Baseline	3	62K
Policy Augmentation	7	68M
FEC Computation	4	21M
Independent FEC Computation	3	763K
Reachability Encoding	**3**	**65K**

We can now run SDX over commodity hardware switches

iSDX Evaluation Summary

- **Data Plane State:**
  - Requires **65K < 100K** forwarding table entries

- **Data Plane Update Rate:**
  - Requires **0** < **2500** flow-mods/second

- **Other Goals:**
  - Processes BGP update bursts in real time **(50 ms)**
  - Requires only **360 BGP Next Hops** compared to 25K from previous solutions

You Can Run iSDX Today!

http://sdx.cs.princeton.edu

- Running code
  - Vagrant & Docker based setup
  - Instructions to run with **Hardware Switches**

- ONF's Open Source SDN
  - Community: https://community.opensourcesdn.org/wg/iSDX/dashboard
  - Mailing List
    isdx@community.OpenSourceSDN.org