iSDX: An Industrial-Scale Software-Defined IXP

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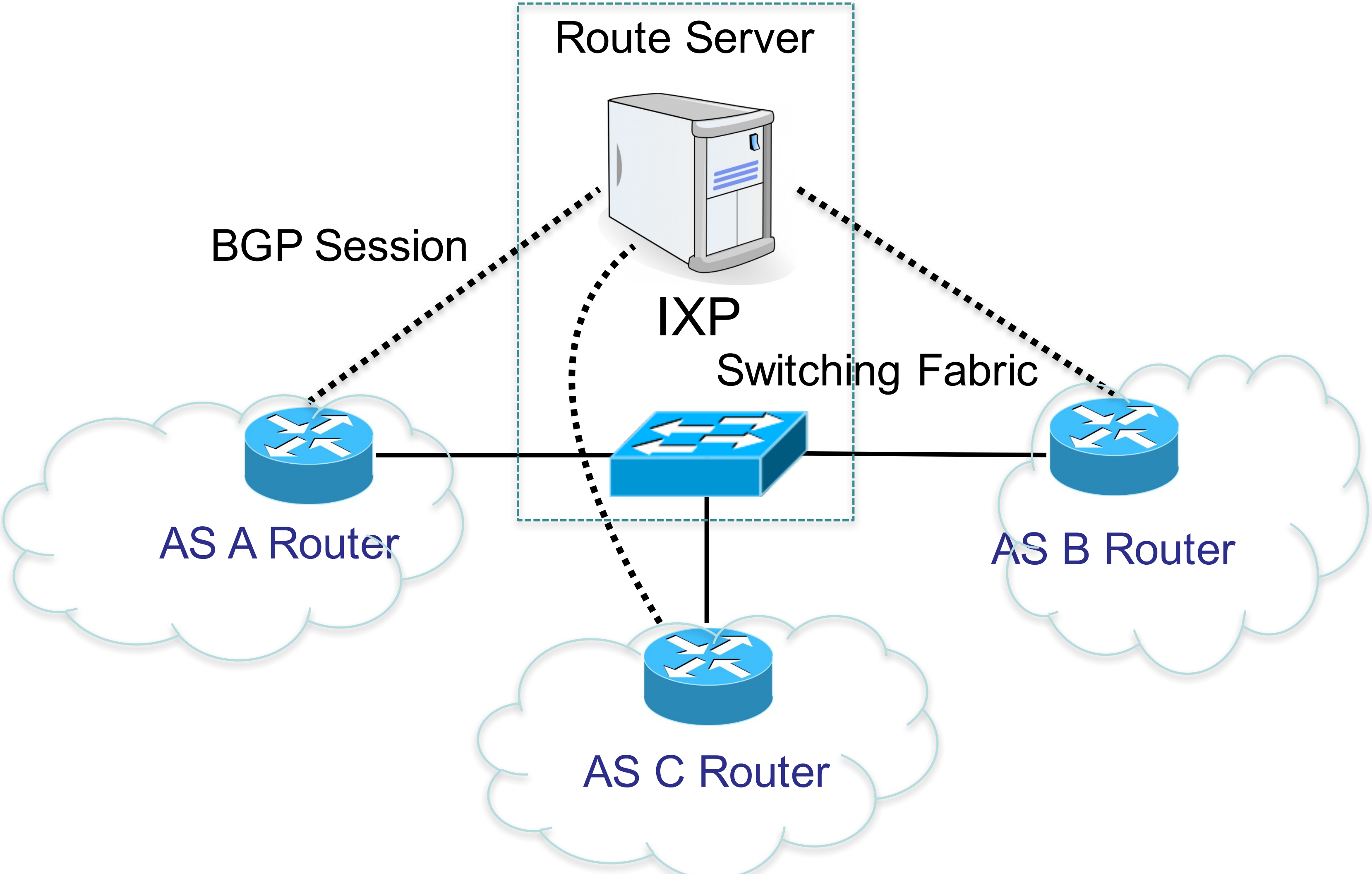
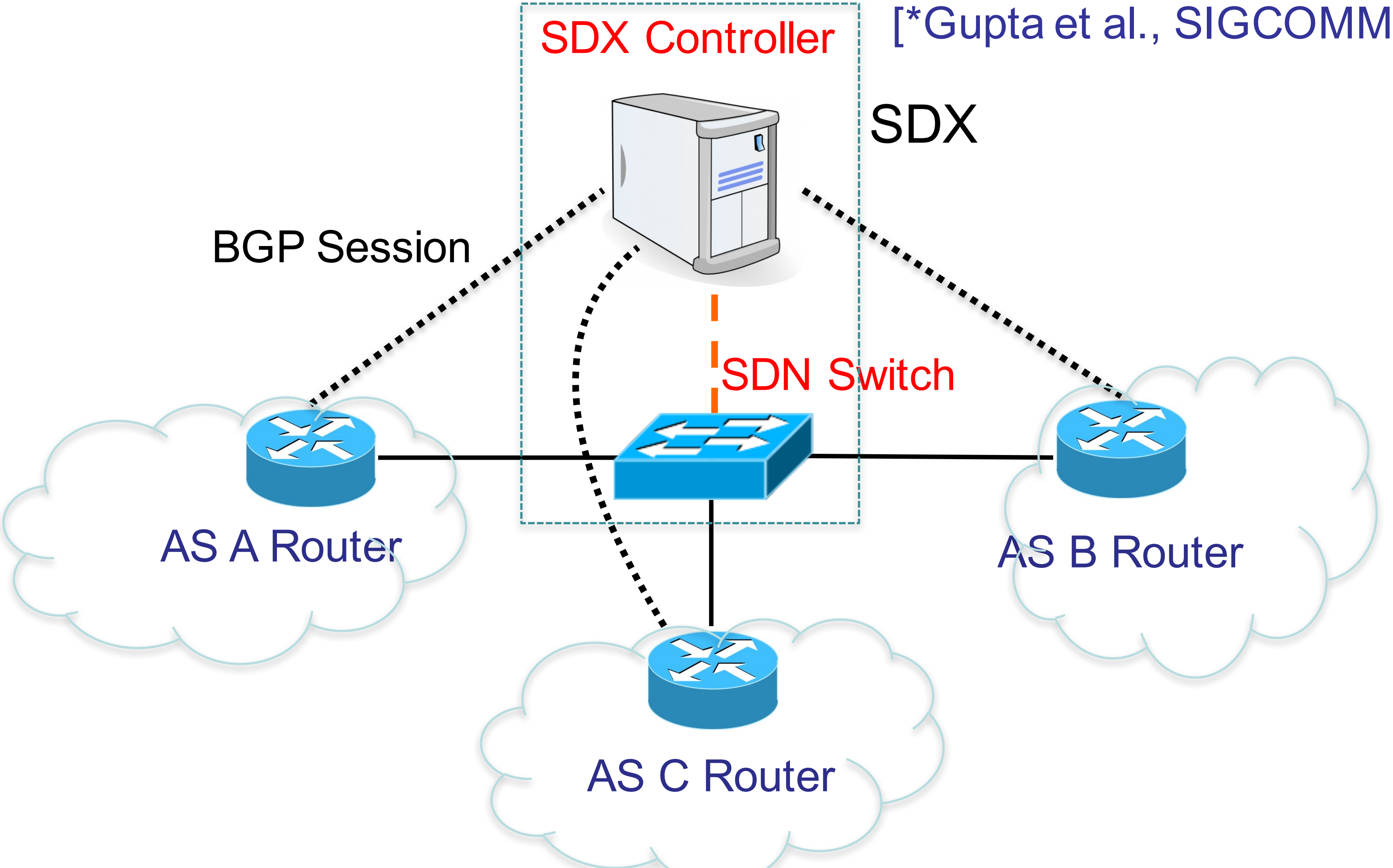
Internet Exchange Points (IXPs)



Software Defined IXPs (SDXs)

[*Gupta et al., SIGCOMM'14]

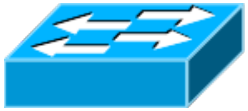


Deployment Ready SDX is Hard!

- **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

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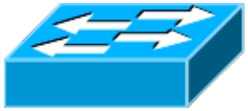
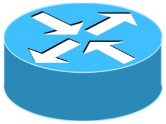
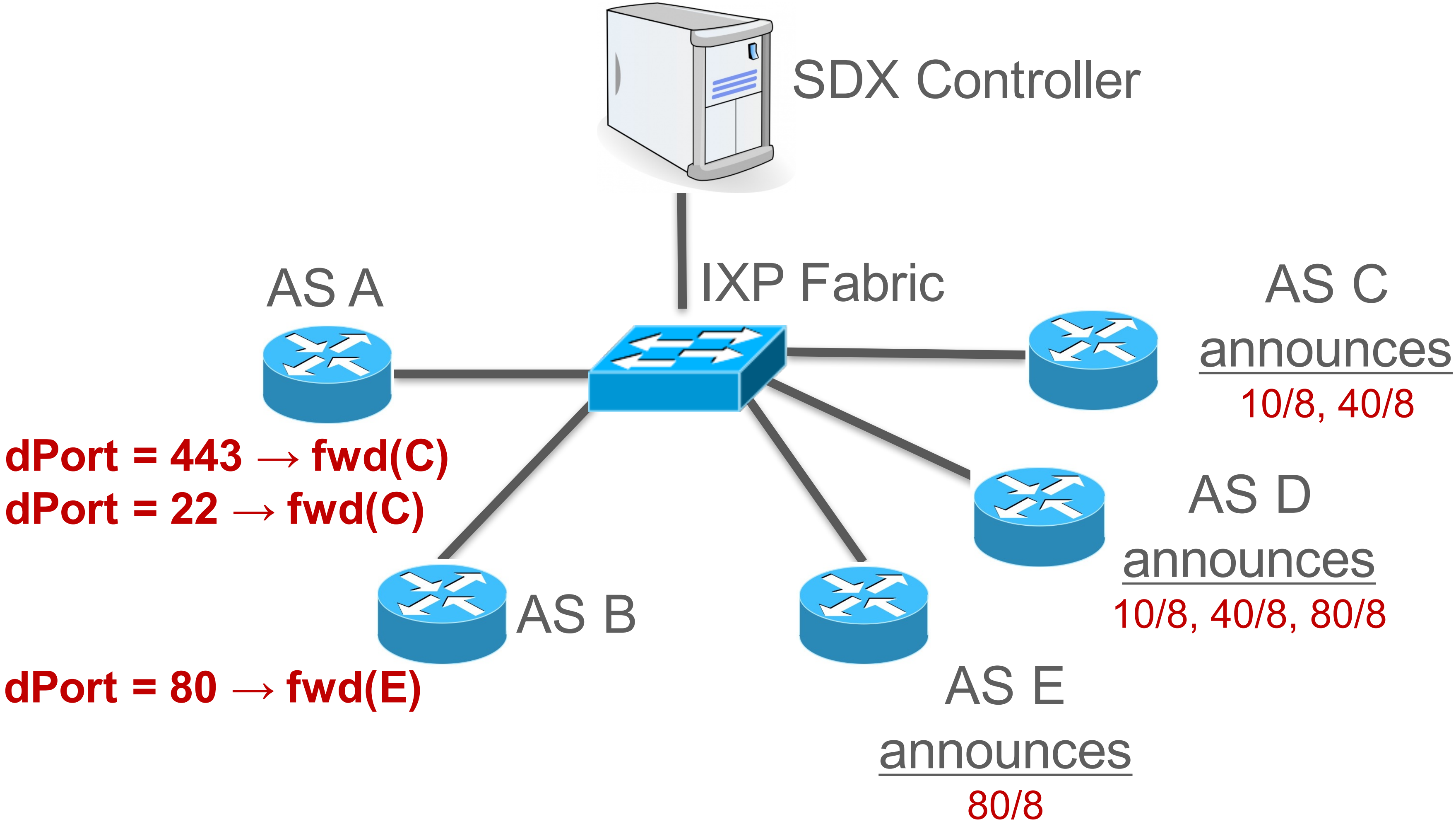
	Match-Action on Multiple Headers	100K	2,500
	Matches on IP Prefixes only	~1M	N/A

Problem: Optimize the usage of available devices

Simple Example



SDX Controller

IXP Fabric

AS A

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

AS B

dPort = 80 → fwd(E)

AS C
announces
10/8, 40/8

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

AS E
announces
80/8

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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  - 511 IXP participants
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Goal Tracker

	Simple Example	Large IXP
Baseline	3	62K

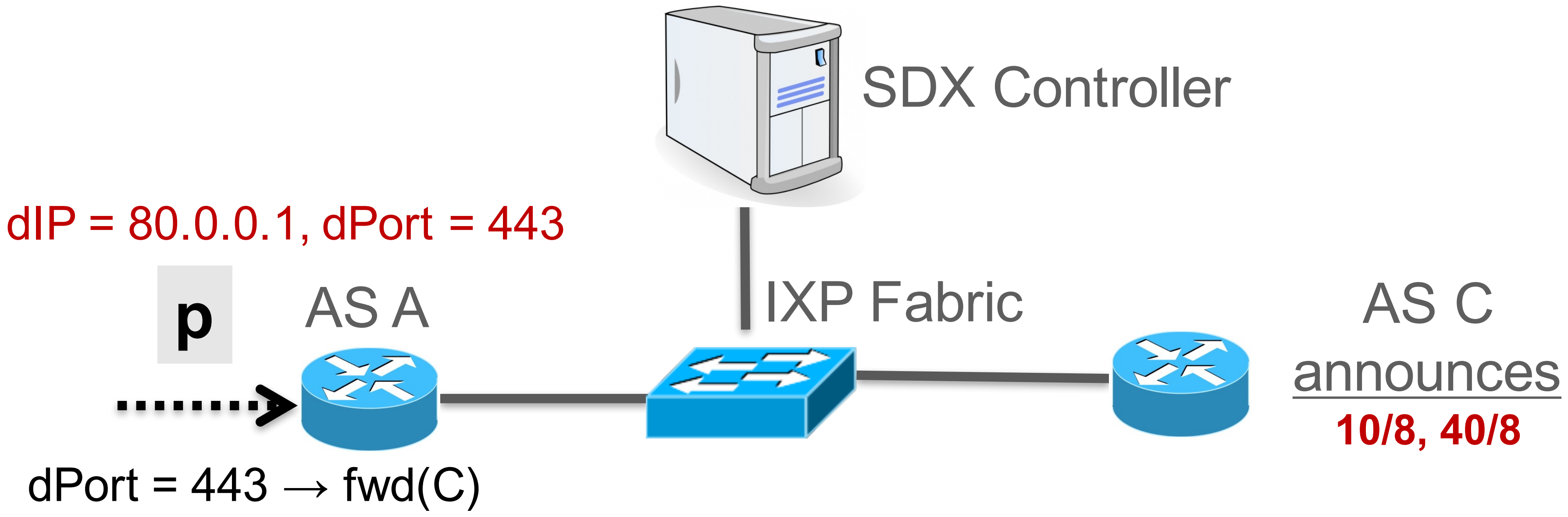
Satisfies design goals, but …

Goal Tracker

	Simple Example	Large IXP
Baseline	3	62K

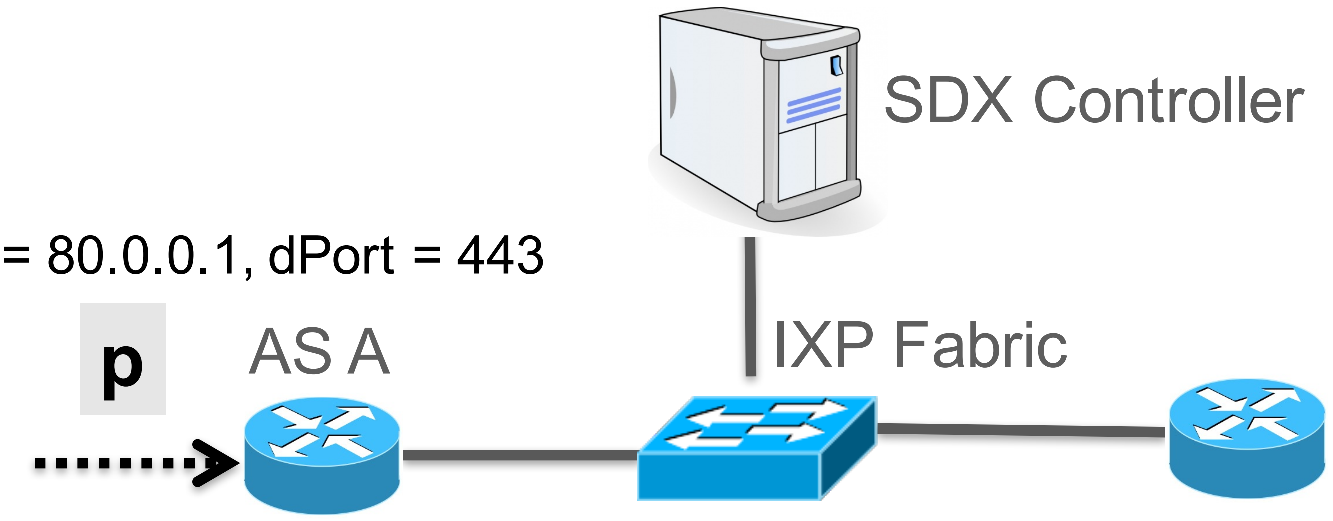
… not congruent with BGP!

Challenge: Congruence with BGP



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

4

3

SDN Policy Augmentation increases forwarding table entries

Goal Tracker

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

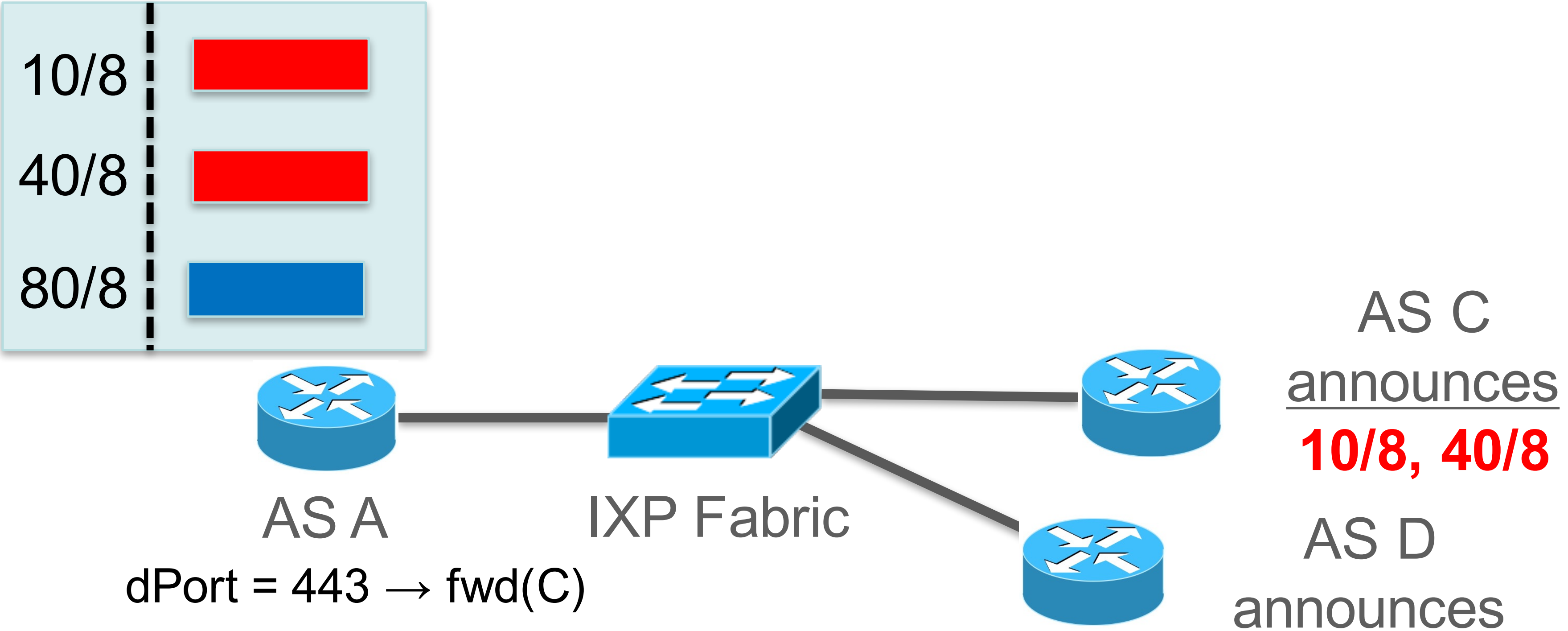
Not possible to support these many forwarding table entries!

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

IXP Fabric

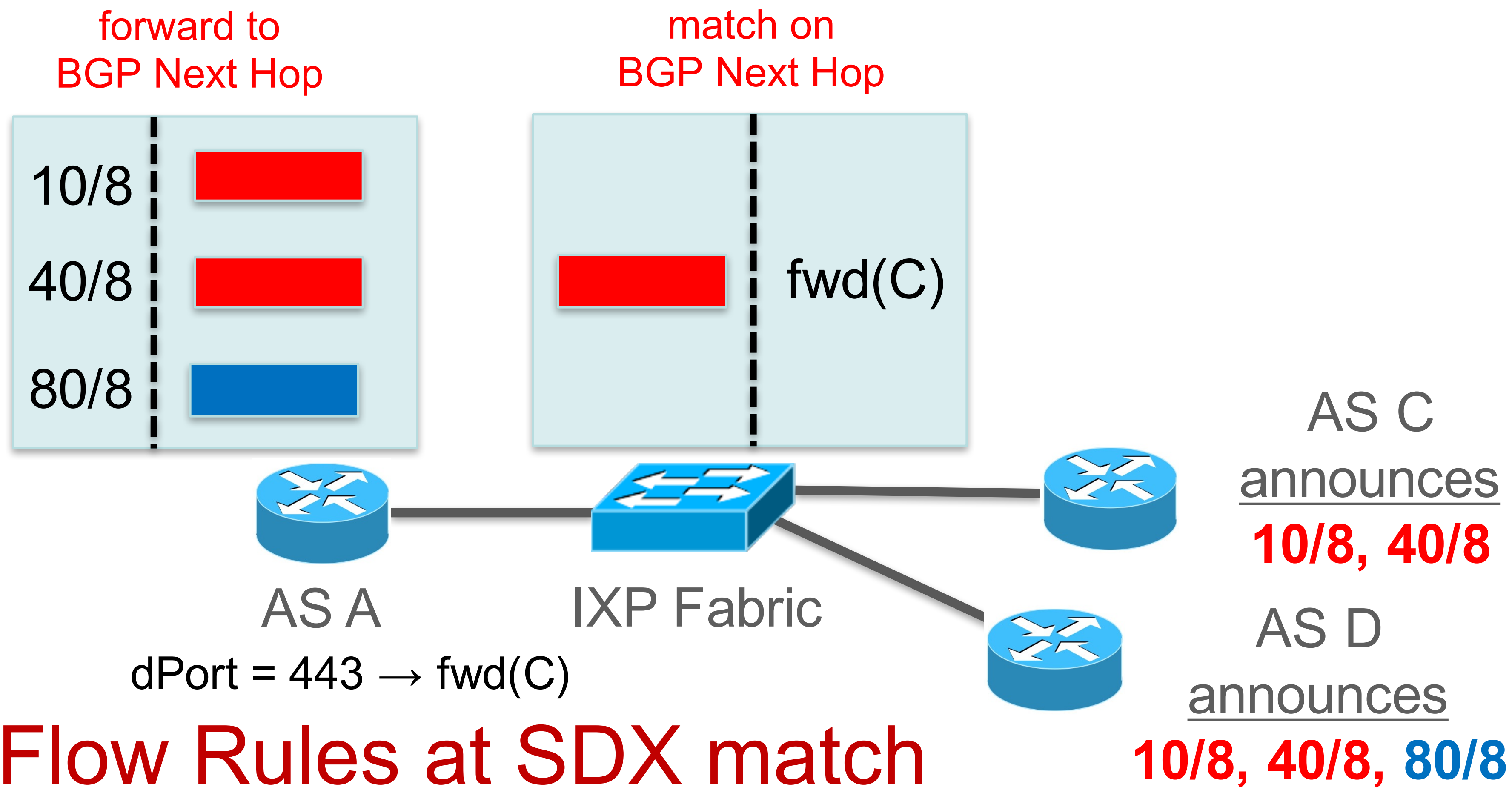
AS C
announces
10/8, 40/8

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

10/8	🟥
40/8	🟥
80/8	🟦

match on
BGP Next Hop

🟥	fwd(C)

AS A

IXP Fabric

AS C
announces
10/8, 40/8

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

dPort = 443 → fwd(C)

Flow Rules at SDX match
on BGP Next Hops

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

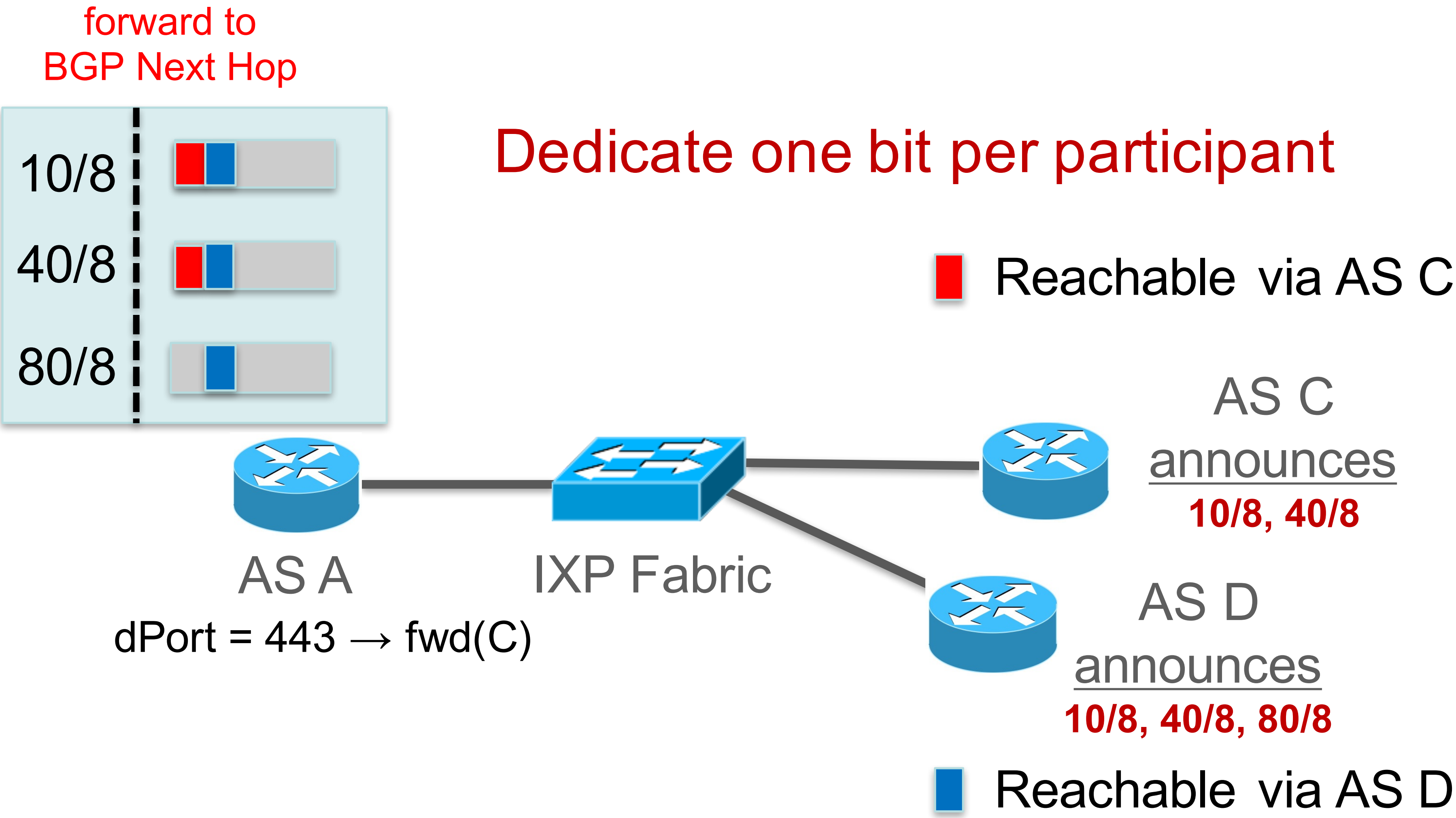
- Leverage advances in commodity hw switches
  - Support for Bitmask Matching (L2 headers)

- 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

Dedicate one bit per participant



forward to
BGP Next Hop

10/8 🟥🟦
40/8 🟥🟦
80/8 🟦

🟥 Reachable via AS C

AS C
announces
10/8, 40/8

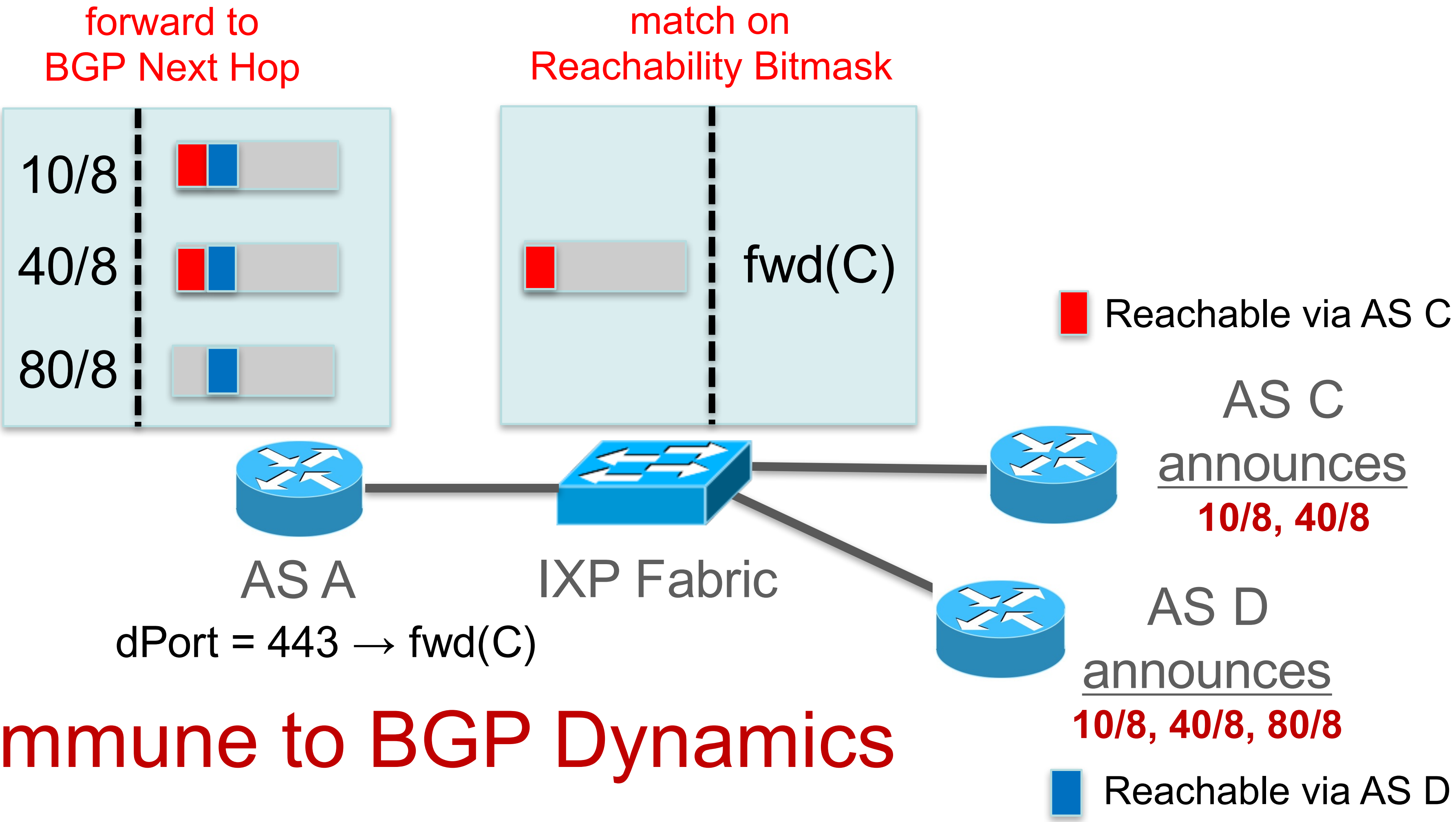
AS A
dPort = 443 → fwd(C)

IXP Fabric

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

🟦 Reachable via AS D

Reachability Bitmask in Action



Immune to BGP Dynamics

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