SDX: A Software-Defined Internet Exchange

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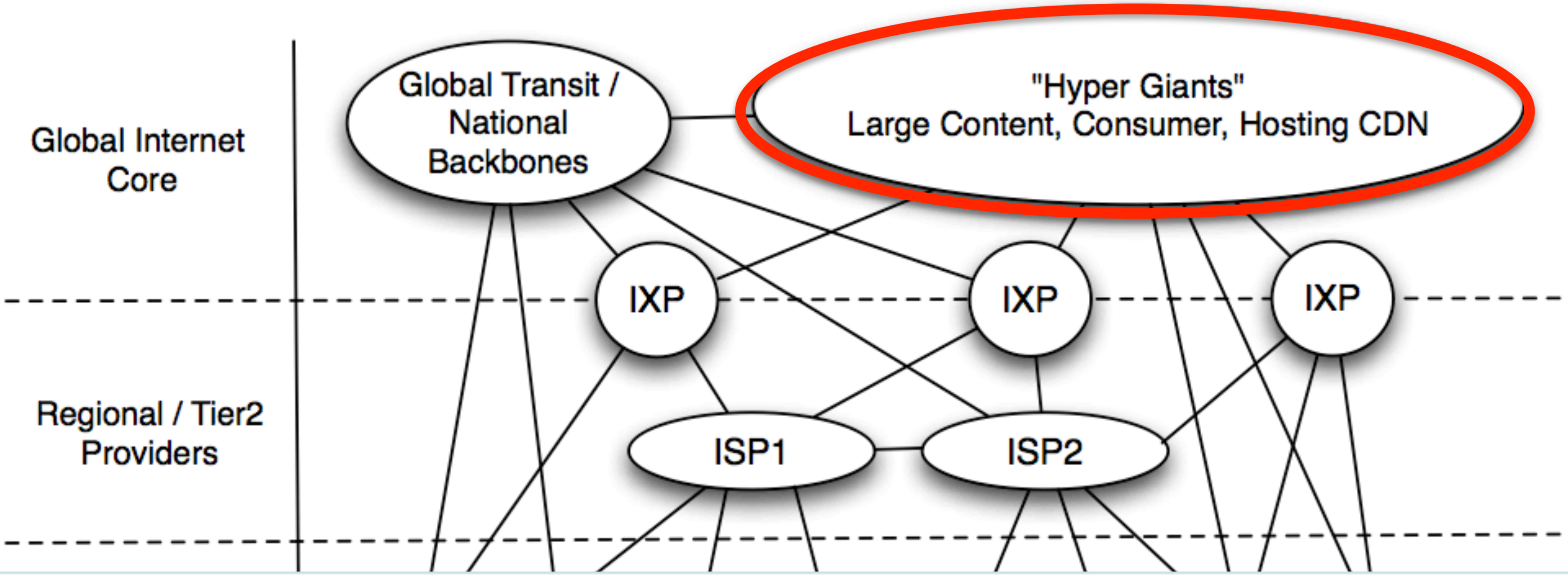
The Interdomain Ecosystem is Evolving ...


Global Internet Core
Global Transit / National Backbones
"Hyper Giants" Large Content, Consumer, Hosting CDN
IXP
IXP
IXP
Regional / Tier2 Providers
ISP1
ISP2

Flatter and densely interconnected Internet*

*Labovitz et al., *Internet Inter-Domain Traffic*, SIGCOMM 2010

…But BGP is Not

- Routing **only on destination IP prefixes**

  (No customization of routes by application, sender)

- Can only influence **immediate neighbors**

  (No ability to affect path selection remotely)

- **Indirect** control over data-plane forwarding

  (Indirect mechanisms to influence path selection)

How to overcome BGP's limitations?

SDN for Interdomain Routing

- Forwarding on **multiple header fields** (not just destination IP prefixes)
- Ability to **control entire networks** with a single software program (not just immediate neighbors)
- **Direct control** over data-plane forwarding (not indirect control via control-plane arcana)

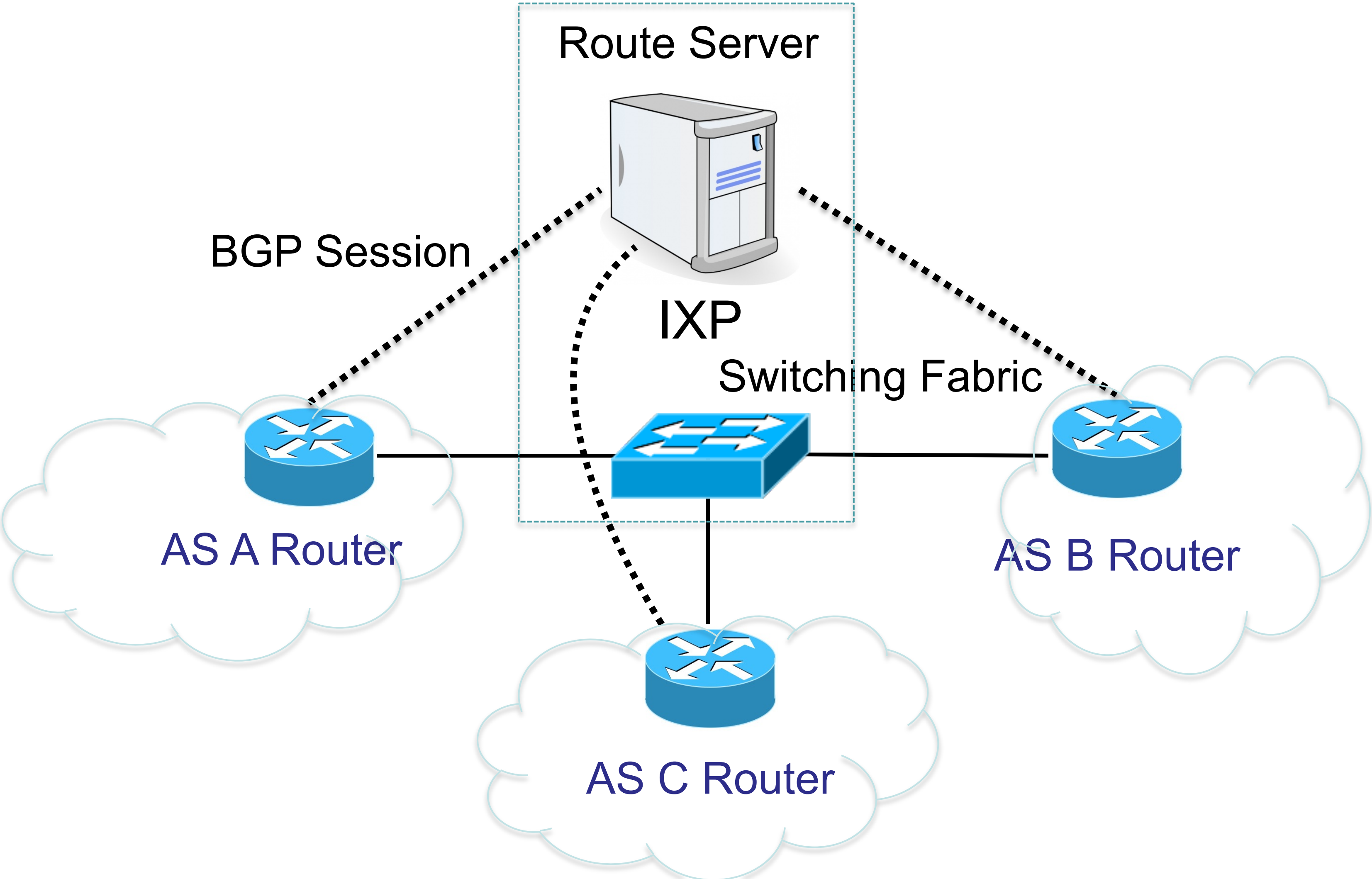
How to incrementally deploy SDN for Interdomain Routing?

Deploy SDN at Internet Exchanges

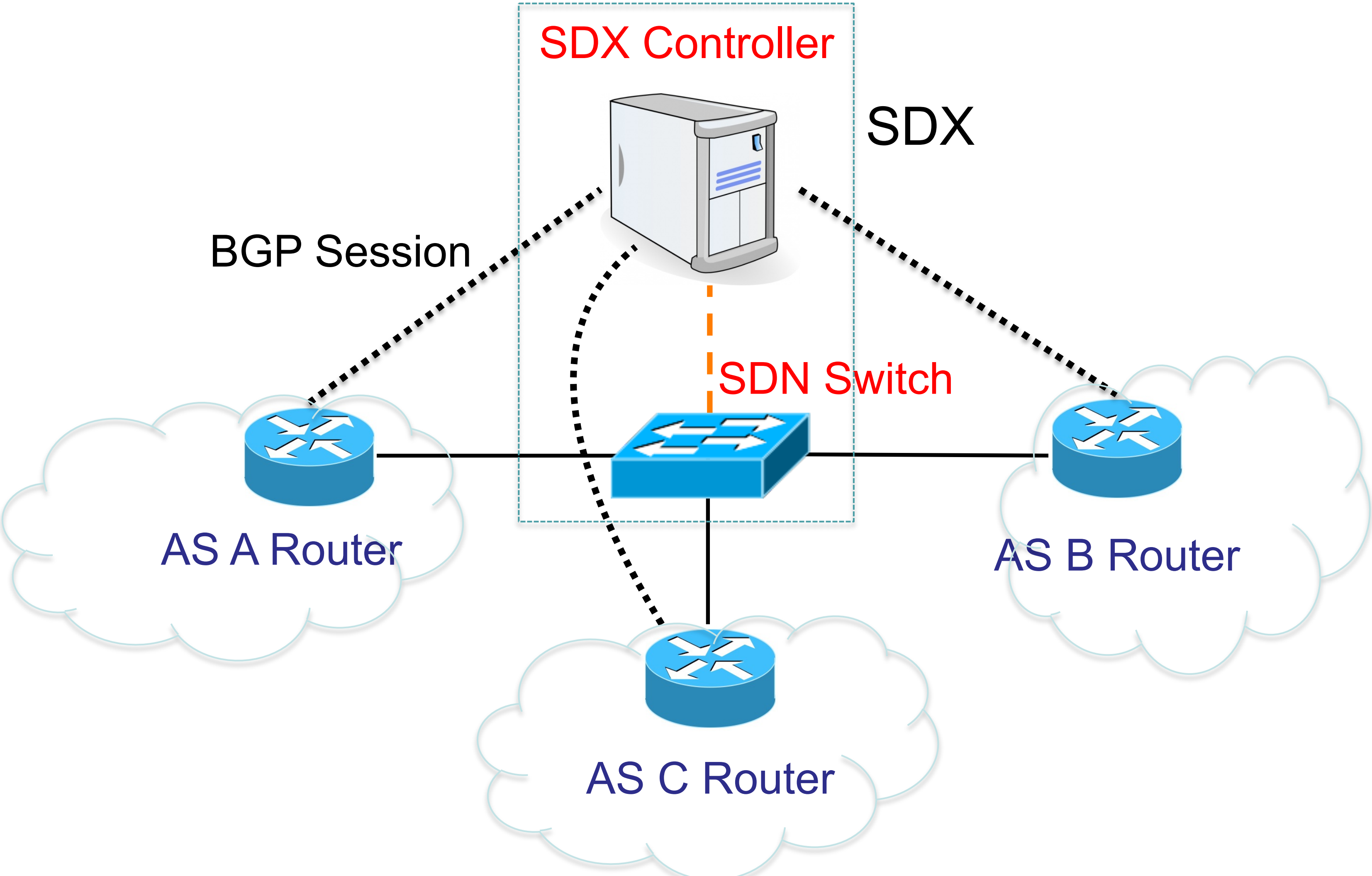
- **Leverage:** SDN deployment even at single IXP can yield benefits for tens to hundreds of ISPs
- **Innovation hotbed:** Incentives to innovate as IXPs on front line of peering disputes
- **Growing in numbers:** ~100 new IXPs established in past three years*

*https://prefix.pch.net/applications/ixpdir/summary/growth/

Background: Conventional IXPs



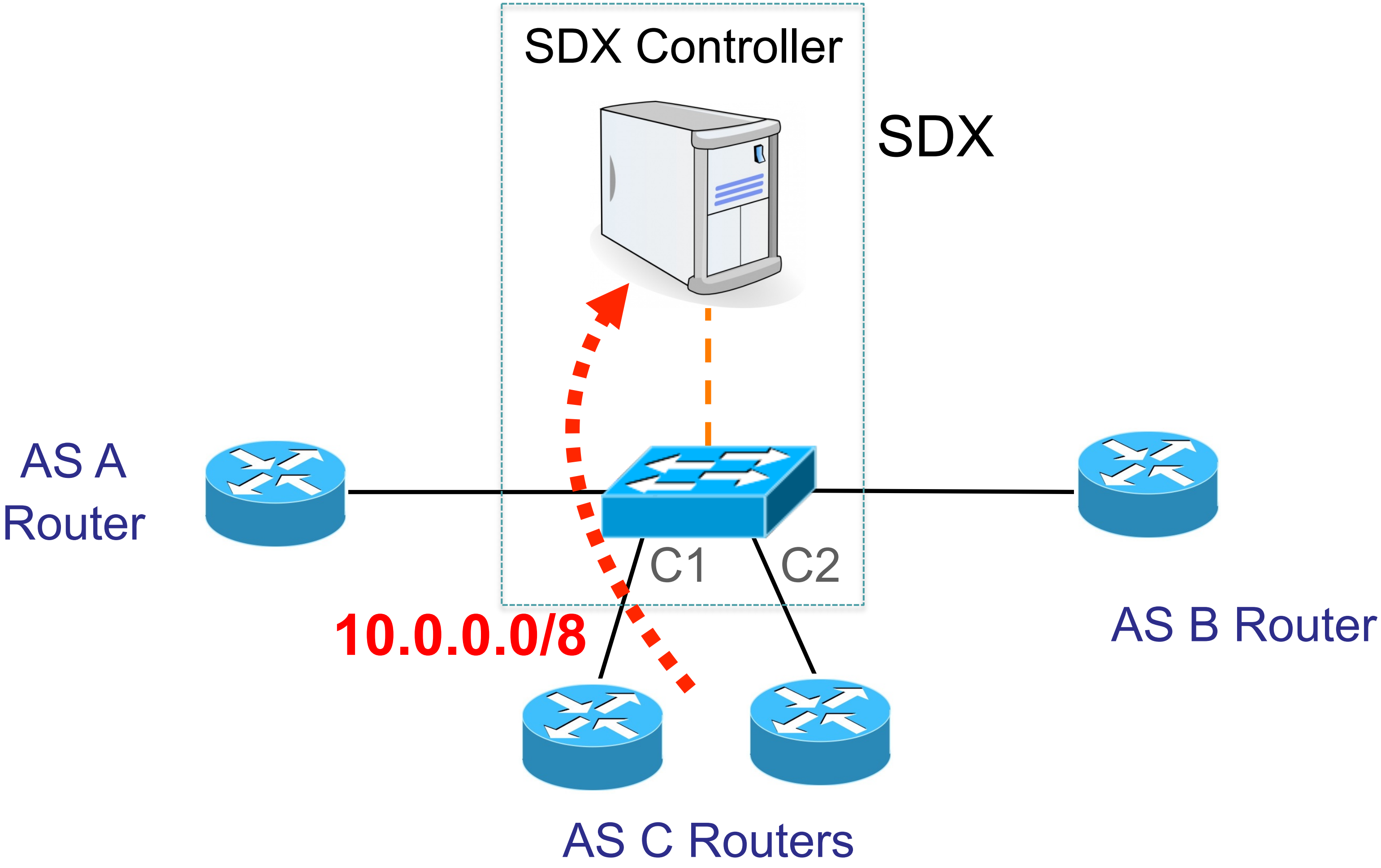
SDX = SDN + IXP


SDX Controller
SDX
BGP Session
SDN Switch
AS A Router
AS B Router
AS C Router

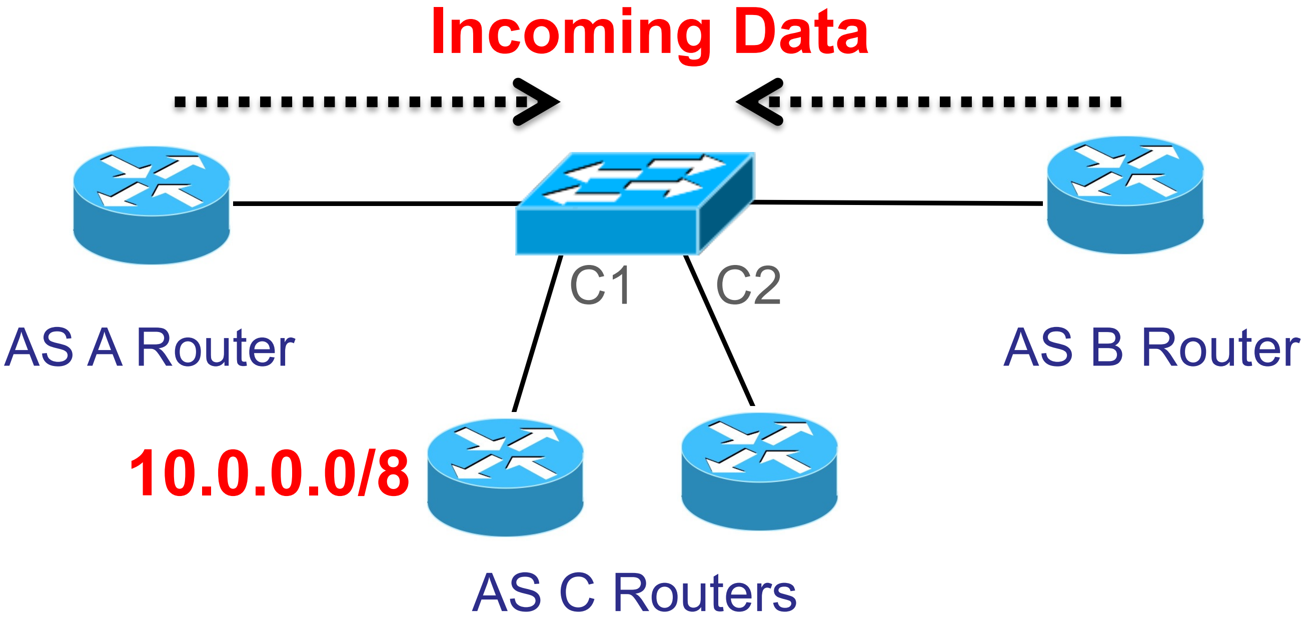
SDX Opens Up New Possibilities

- More flexible **business relationships**
  - Make peering decisions based on time of day, volume of traffic & nature of application
- More direct & flexible **traffic control**
  - Define fine-grained traffic engineering policies
- Better **security**
  - Prefer "more secure" routes
  - Automatically blackhole attack traffic

Use Case:
Inbound Traffic Engineering

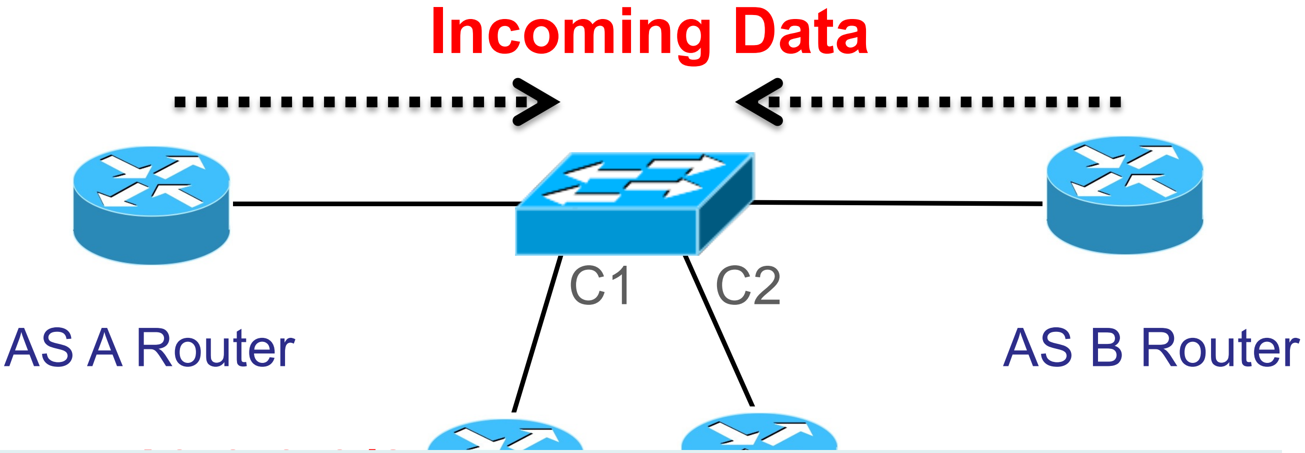


Use Case: Inbound Traffic Engineering



Incoming Traffic	Out Port	Using BGP	Using SDX
dstport = 80	C1		

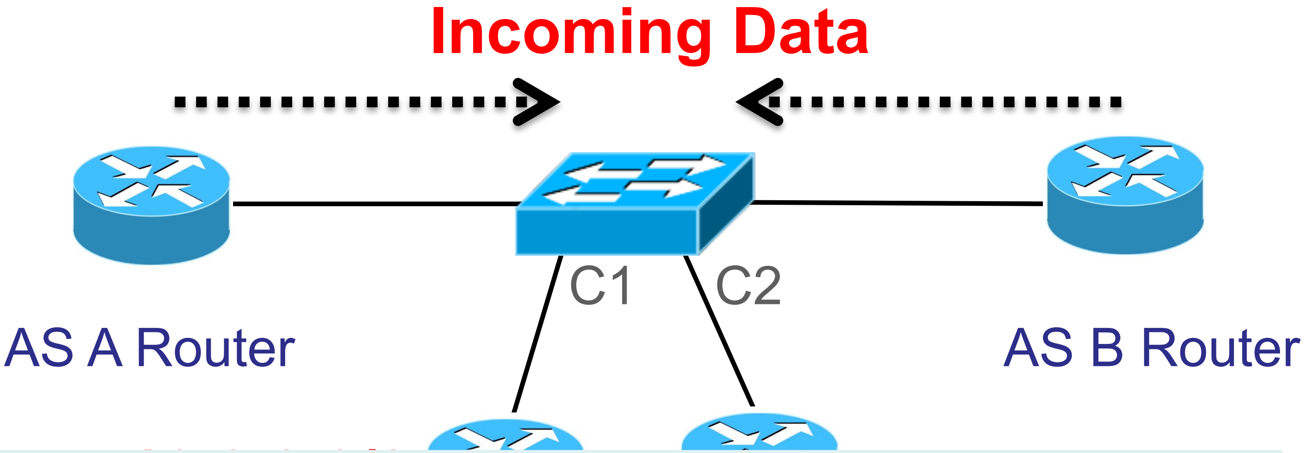
Use Case: Inbound Traffic Engineering



Fine grained policies not possible with BGP

Incoming Traffic	Out Port	Using BGP	Using SDX
dstport = 80	C1	?	

Use Case:
Inbound Traffic Engineering



Enables fine-grained traffic engineering policies

Incoming Traffic	**Out Port**	**Using BGP**	**Using SDX**
dstport = 80	C1	?	match(dstport =80)→ fwd(C1)

Building SDX is Challenging

- Programming **abstractions**
  - How networks define SDX policies and how are they combined together?
- **Interoperation** with BGP
  - How to provide flexibility w/o breaking global routing?
- **Scalability**
  - How to handle policies for hundreds of peers, half million prefixes and matches on multiple header fields?

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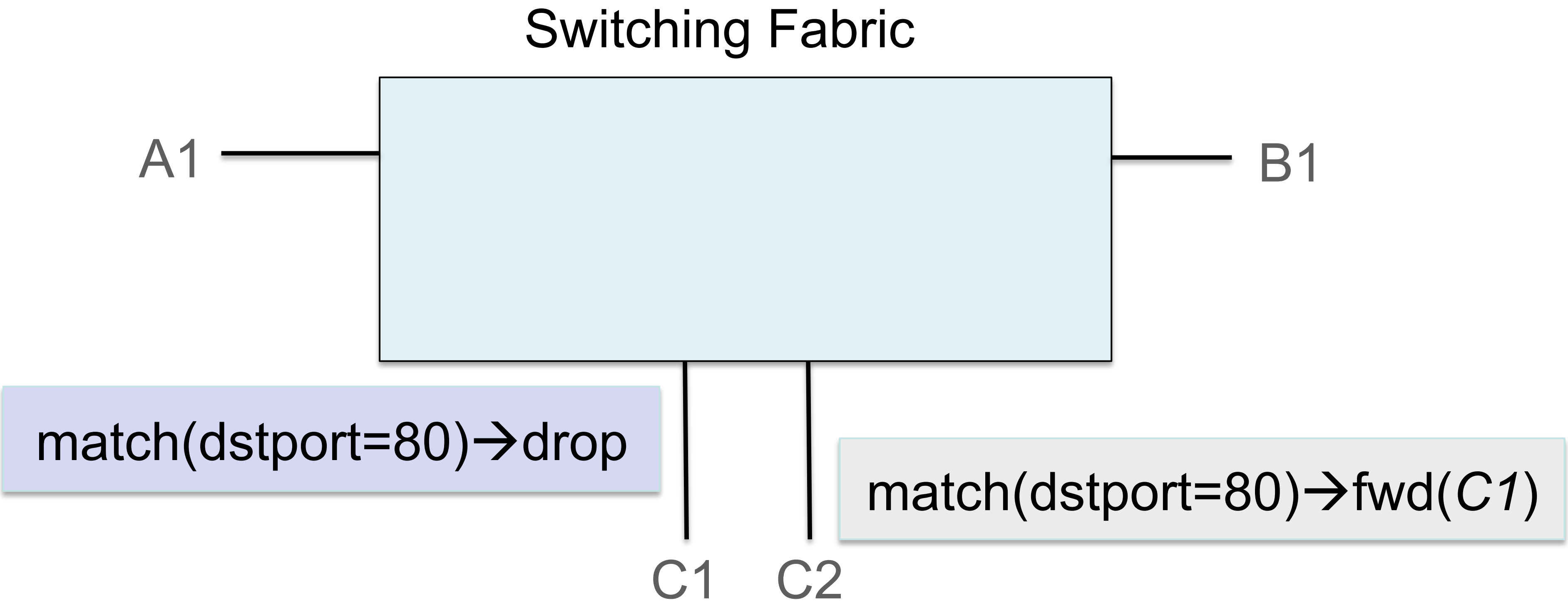
Directly Program the SDX Switch

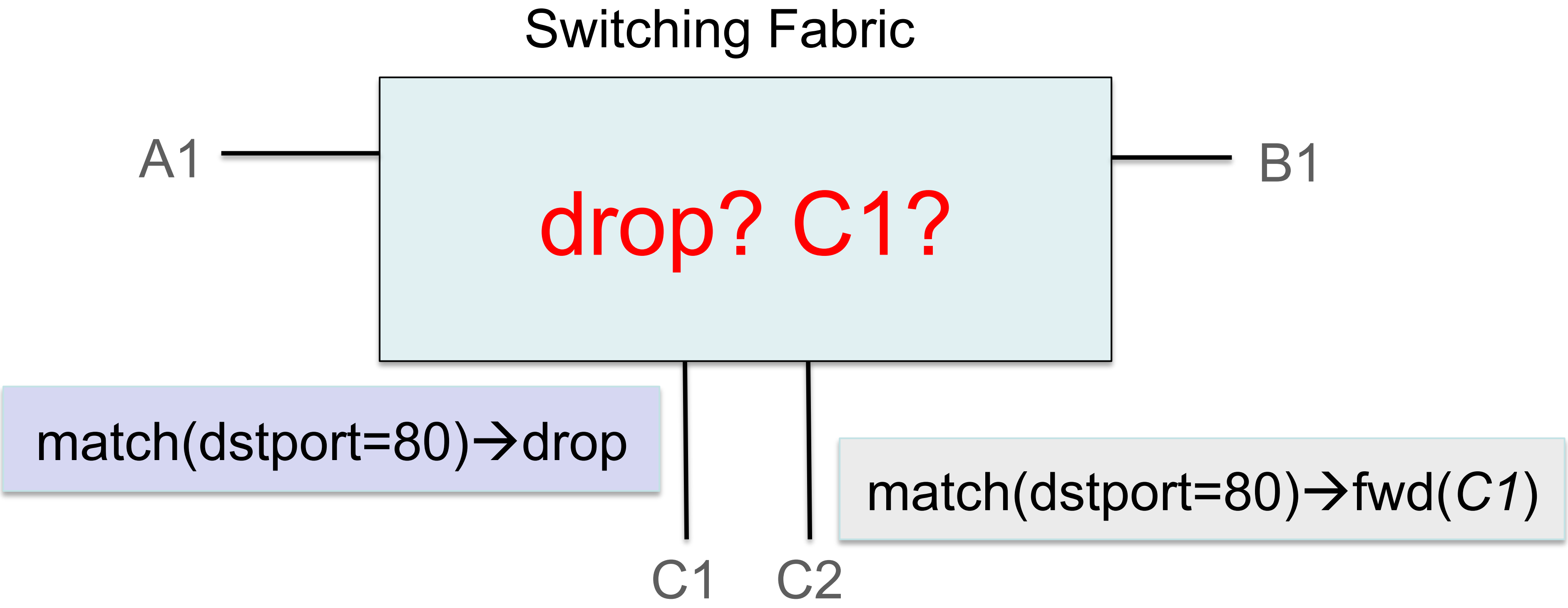


match(dstport=80)→drop

match(dstport=80)→fwd(*C1*)

AS A & C directly program the SDX Switch

Conflicting Policies



Switching Fabric

A1

B1

drop? C1?

match(dstport=80)→drop

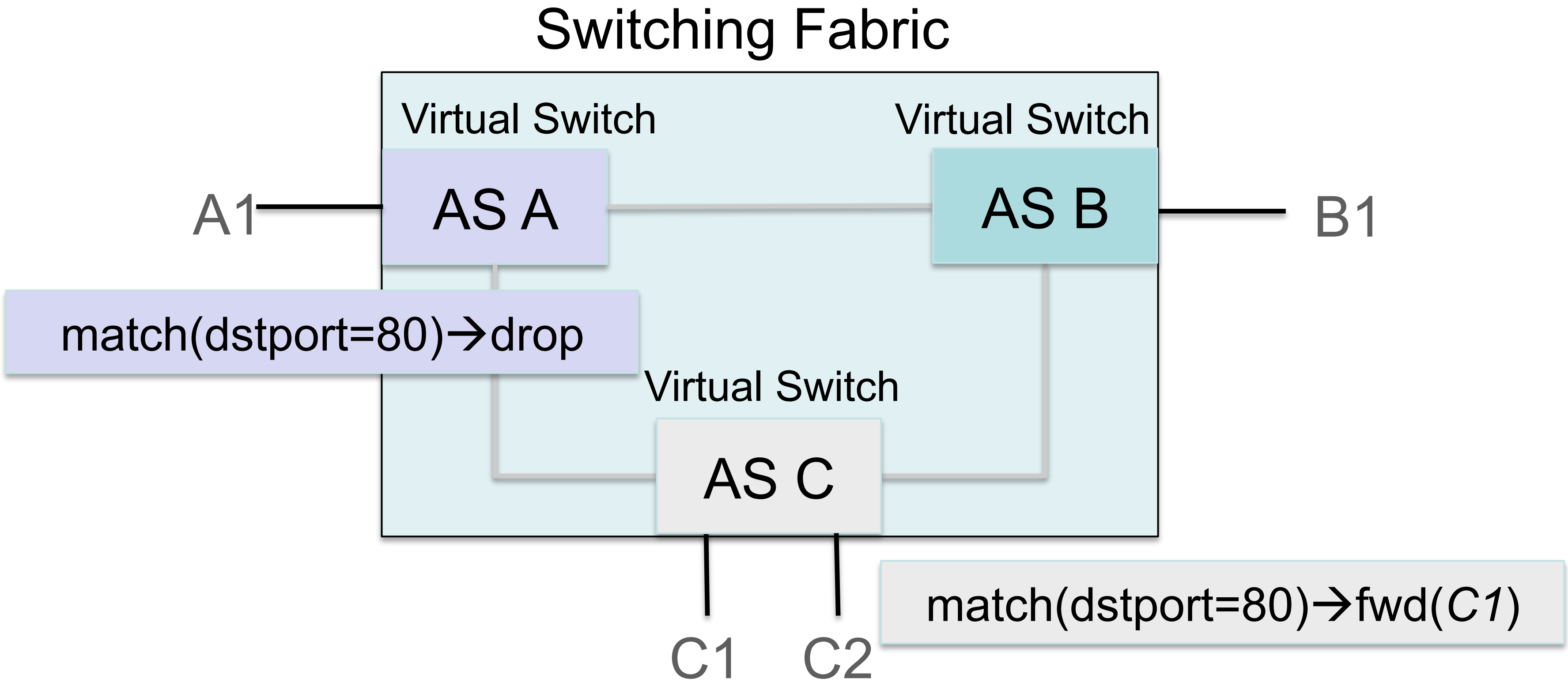
match(dstport=80)→fwd(*C1*)

C1

C2

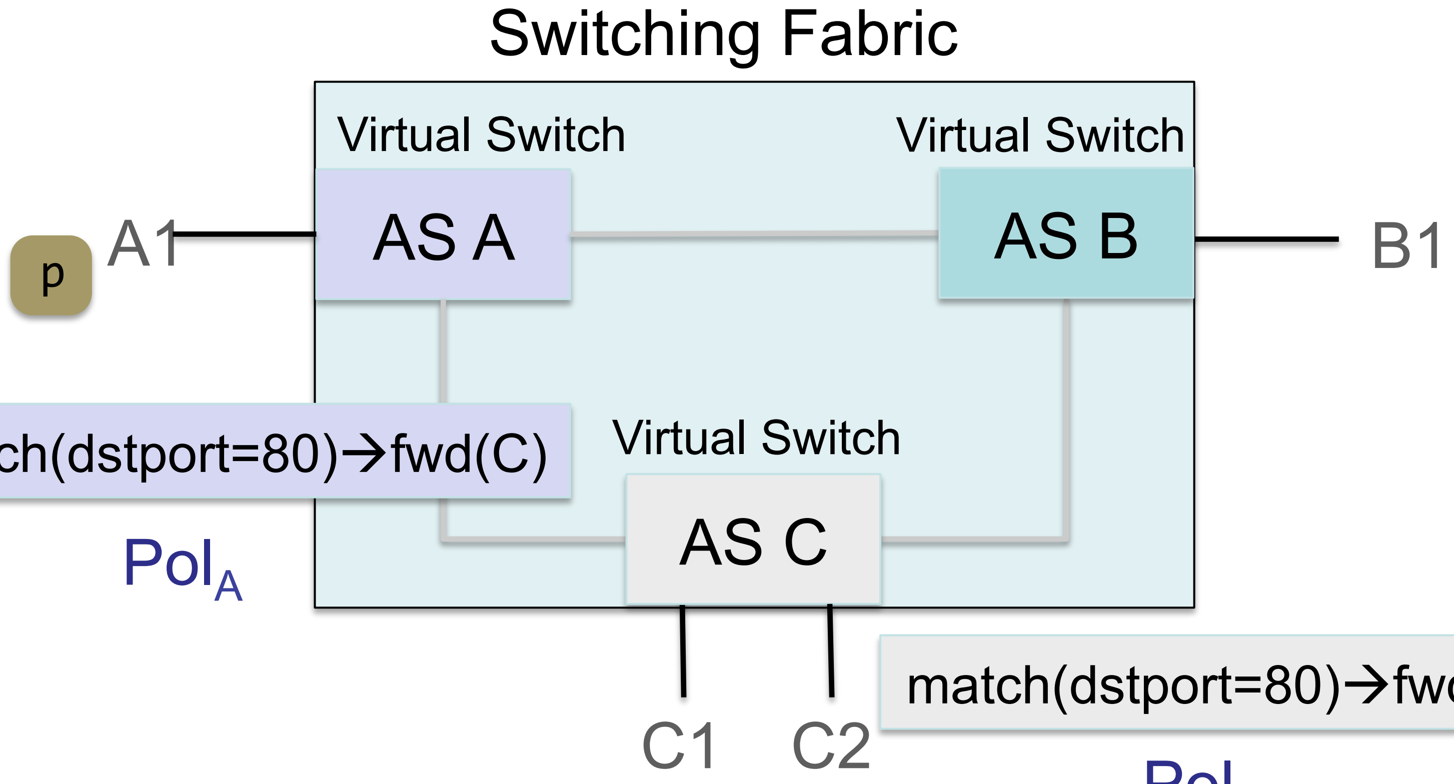
How to restrict participant's policy to traffic it sends or receives?

Virtual Switch Abstraction



Each AS writes policies for its own virtual switch

Combining Participant’s Policies



match(dstport=80)→fwd(C)

Pol_A

match(dstport=80)→fwd(*C1*)

Pol_C

$$Policy(p) = Pol_A \rightarrow Pol_C$$

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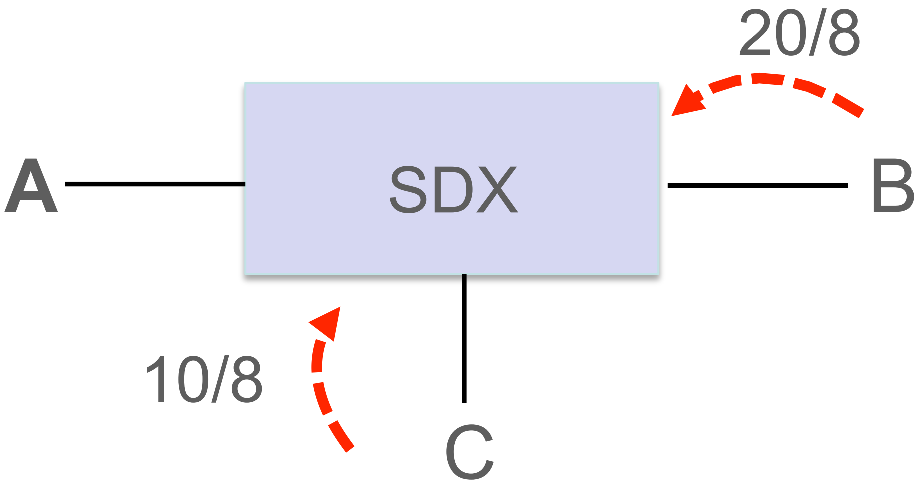
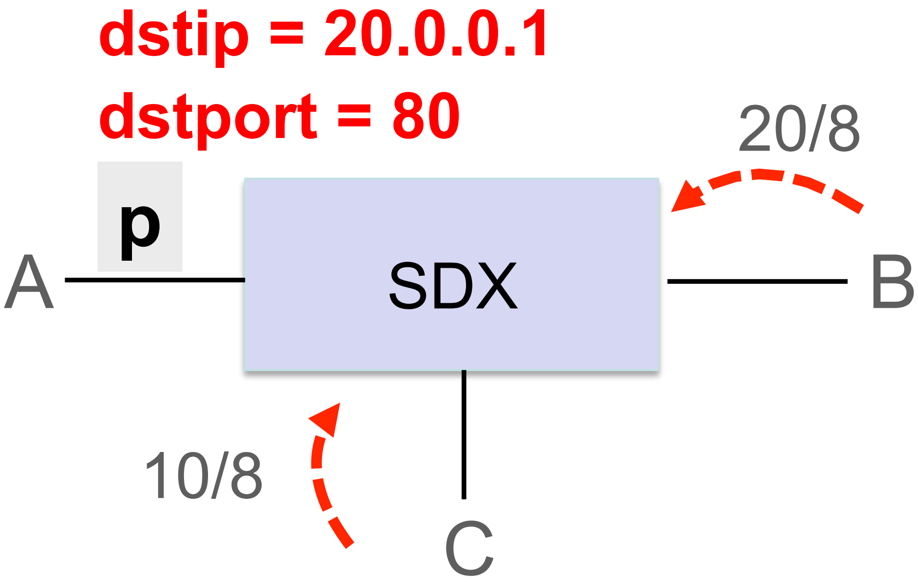
Requirement: Forwarding Only Along BGP Advertised Routes



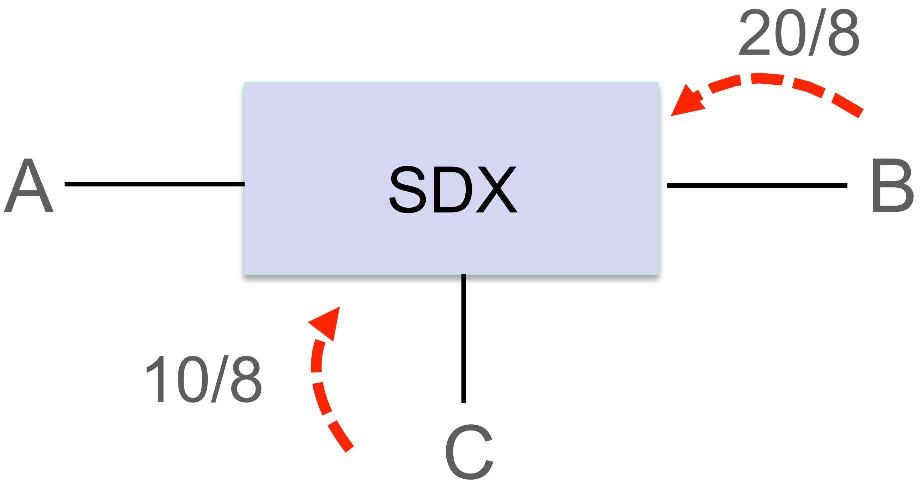
match(dstport=80) → fwd(*C*)

Ensure ‘p’ is not forwarded to C



match(dstport=80) → fwd(*C*)

Solution: Policy Augmentation



(match(dstport=80) && **match(dstip = 10/8)**)→ fwd(*C*)

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Scalability Challenges

- **Reducing Data-Plane State:** Support for all forwarding rules in (limited) switch memory

- **Reducing Control-Plane Computation:** Faster policy compilation

Scalability Challenges

- **Reducing Data-Plane State:** Support for all forwarding rules in (limited) switch memory
  millions of flow rules possible

- **Reducing Control-Plane Computation:** Faster policy compilation
  policy compilation could take hours

Reducing Data-Plane State: Observations

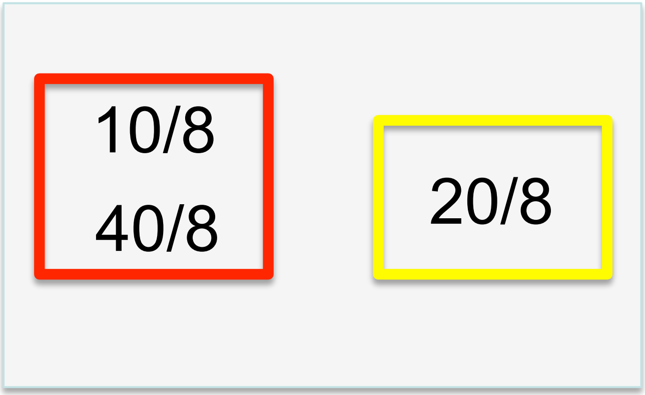
- Internet routing policies defined for **groups of prefixes**.*

- **Edge routers** can handle matches on hundreds of thousands of IP prefixes.

*Feamster et al.,*Guidelines for Interdomain TE, CCR 2003*

Reducing Data-Plane State: Solution

Group prefixes with similar forwarding behavior



10/8

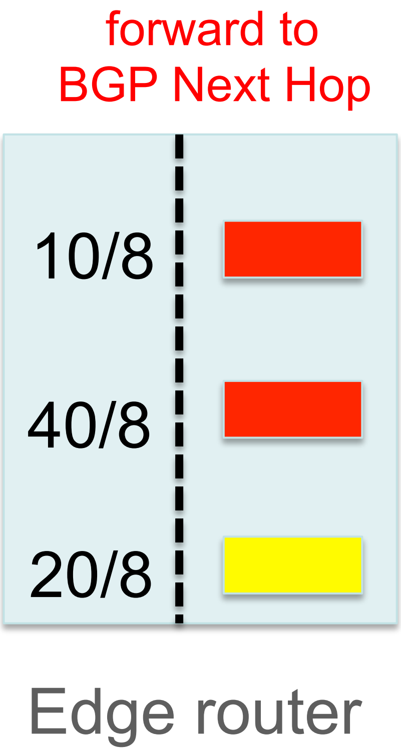
40/8

20/8

SDX Controller

Reducing Data-Plane State: Solution

Advertise one BGP next hop for each such prefix group



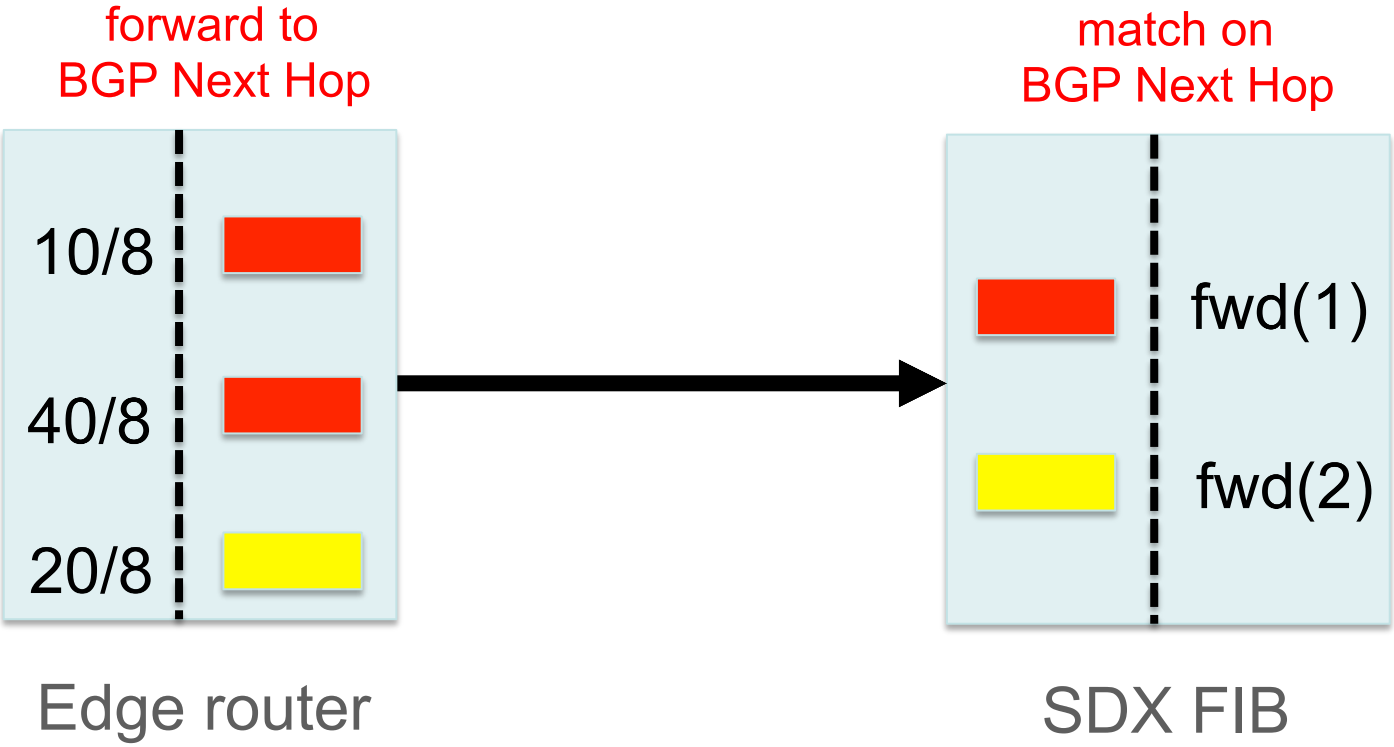
forward to
BGP Next Hop

10/8	🟥
40/8	🟥
20/8	🟨

Edge router

Reducing Data-Plane State: Solution

Flow rules at SDX match on BGP next hops



forward to
BGP Next Hop

10/8	🟥
40/8	🟥
20/8	🟨

Edge router

match on
BGP Next Hop

🟥	fwd(1)
🟨	fwd(2)

SDX FIB

Reducing Data-Plane State: Solution

For hundreds of participants’ policies, few *millions* → < 35K flow rules

Reducing Control-Plane Computation

- **Initial policy compilation time**
  - Leveraged domain-specific knowledge of policies
  - Hundreds of participants requires **< 15 minutes**
- **Policy recompilation time**
  - Leveraged bursty nature of BGP updates
  - Most recompilation after a BGP update **< 100 ms**

SDX Testbed

- Mininet-based Testbeds
  - Uses Transit Portal
  - Emulates edge routers
- Check out our demo
  - Application specific peering
  - Inbound traffic engineering
- Github repo: https://github.com/sdn-ixp/sdx/

Summary

- **SDN-based exchange (SDX)** is promising for fixing Internet routing

- Solved various challenges in building a real deployable SDX

- Many open research problems, both for building and using SDX