SDN-enabled Internet Exchange Point

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Internet2 Innovation Award

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- assume destination IP based routing

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Operating BGP has at least three limitations ***what people really want***

- assume destination IP based routing — customized routing decisions

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- policies are applied to direct neighbors — affect end-to-end paths

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Operating BGP has at least three limitations	***what people really want***
assume destination IP based routing	customized routing decisions
policies are applied to direct neighbors	affect end-to-end paths
indirectly influence forwarding paths	

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Operating BGP has at least three limitations	***what people really want***
assume destination IP based routing	customized routing decisions
policies are applied to direct neighbors	affect end-to-end paths
indirectly influence forwarding paths	directing traffic on specific paths

SDN can enable fine-grained, flexible and direct expression of interdomain policies

SDN devices forward based on any packet-header fields

at line rate, enabling flexible forwarding

SDN controller can be controlled by remote parties

on a bilateral basis, without any global standards

SDN controller exerts direct control on the data plane

using a standardized API such as OpenFlow

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Internet Exchange Points (IXPs) ...

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- connect a large number of participants

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AMS-IX:

- 600 participants

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Internet Exchange Points (IXPs) — AMS-IX:

- connect a large number of participants — 600 participants
- carry a large amount of traffic — > 2250 Gb/s (peak)

Internet Exchange Points are perfect places to deploy new interdomain features

Internet Exchange Points (IXPs)

- connect a large number of participants
- carry a large amount of traffic
- are a hotbed of innovation

AMS-IX:

- 600 participants
- > 2250 Gb/s (peak)
- BGP Route Server
- Mobile peering
- Open peering
- ...

Internet Exchange Points are perfect places to deploy new interdomain features

Internet Exchange Points (IXPs)

- connect a large number of participants
- carry a large amount of traffic
- are a hotbed of innovation

Even a single deployment can have a large impact!

An IXP is a large L2 domain where participants routers peer using BGP

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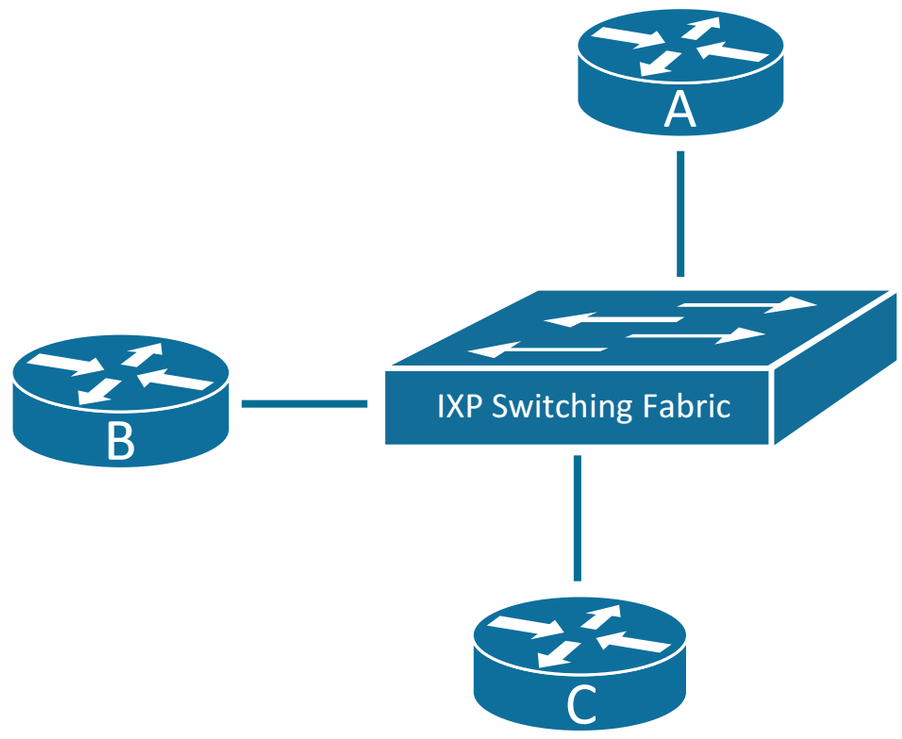
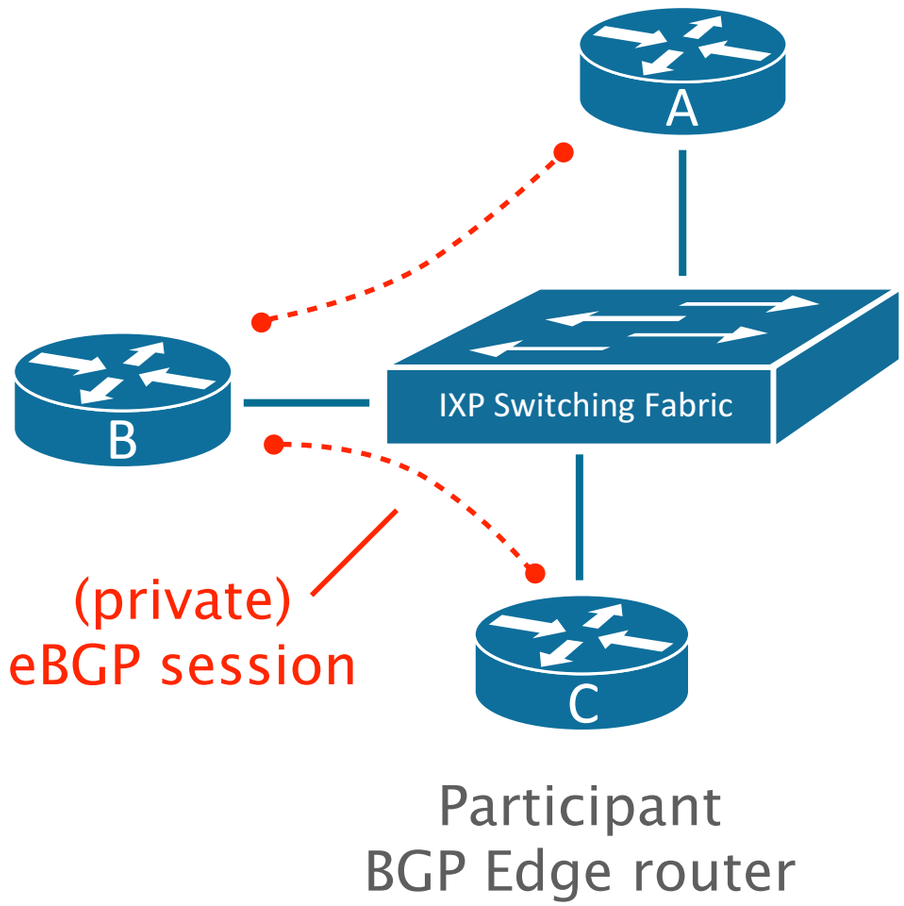


Participant
BGP Edge router

An IXP is a large L2 domain where participants routers peer using BGP



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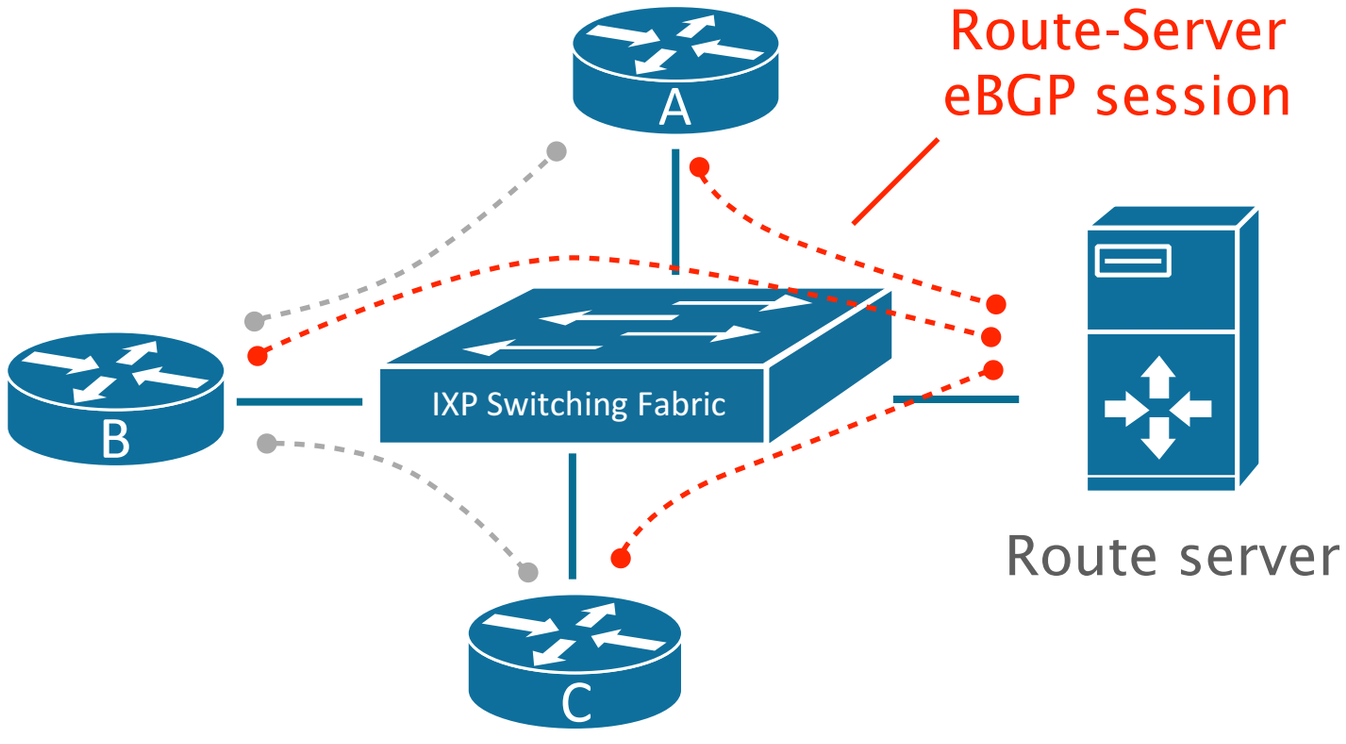

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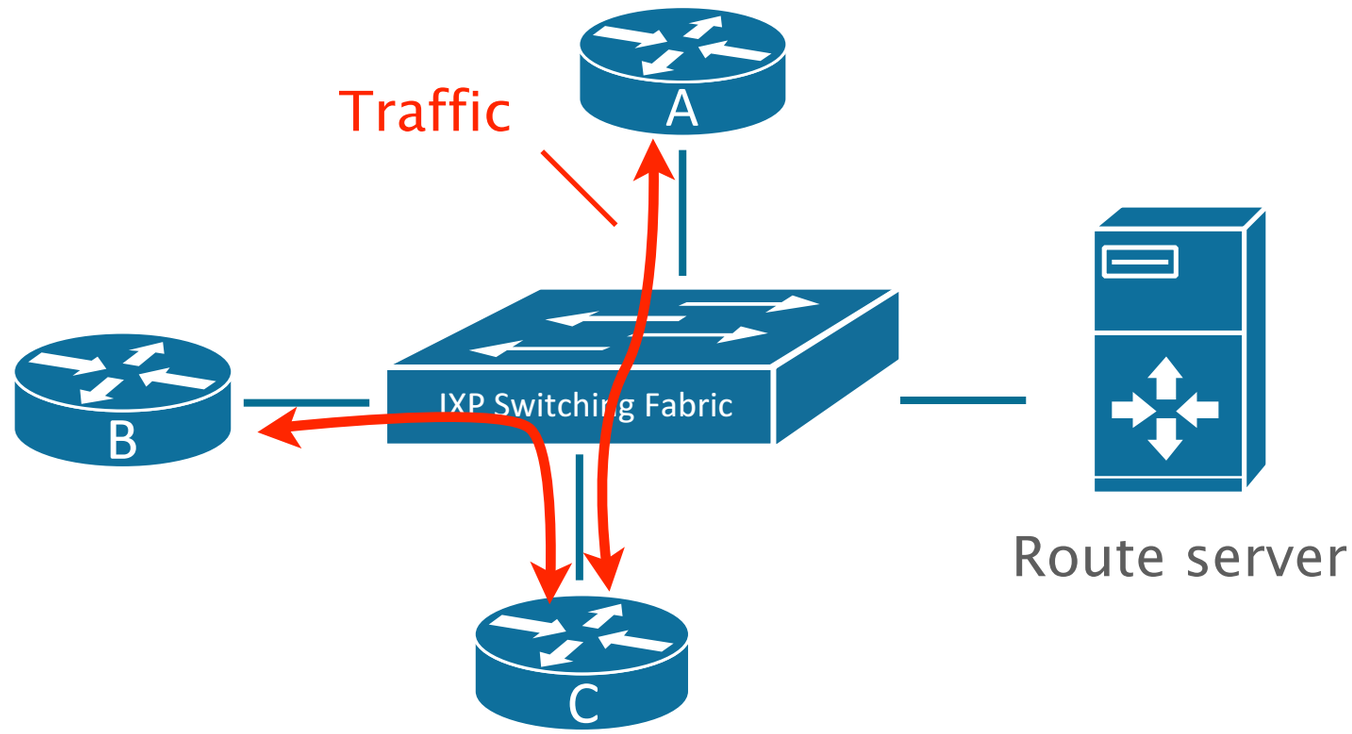
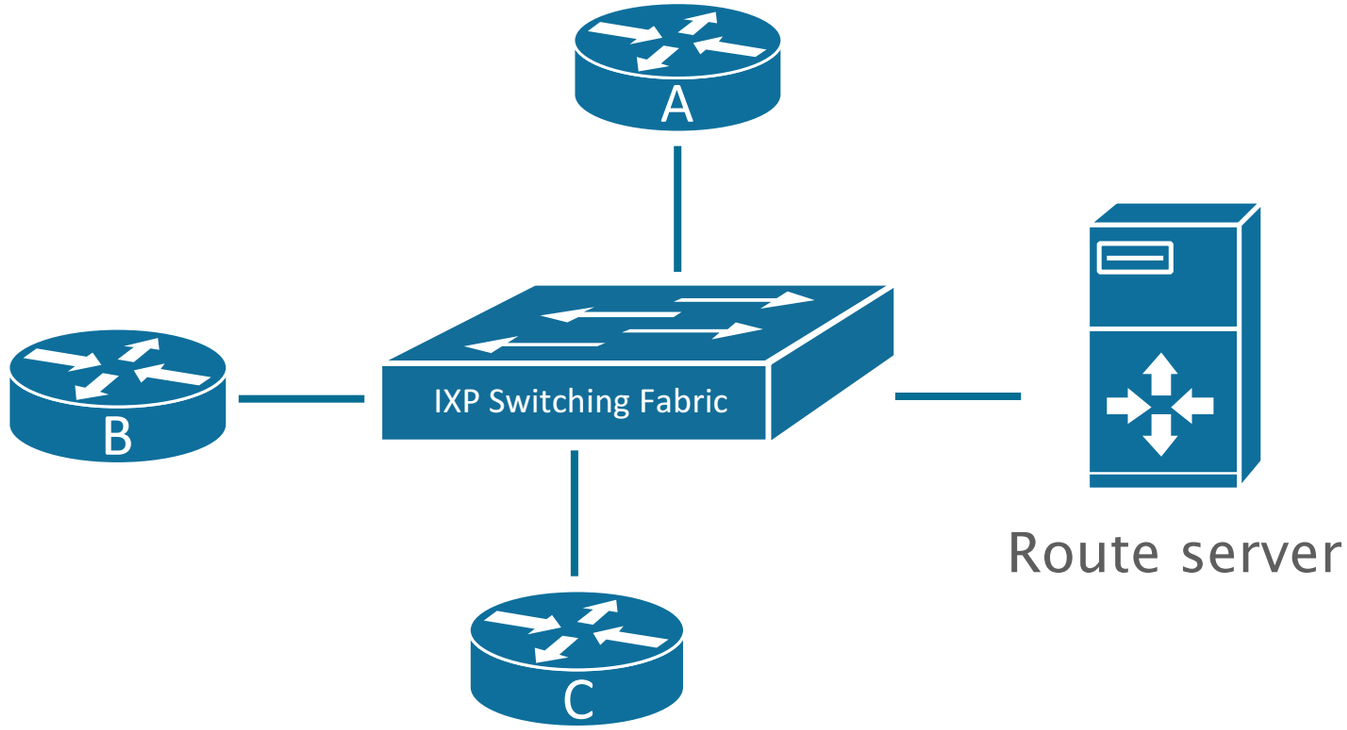
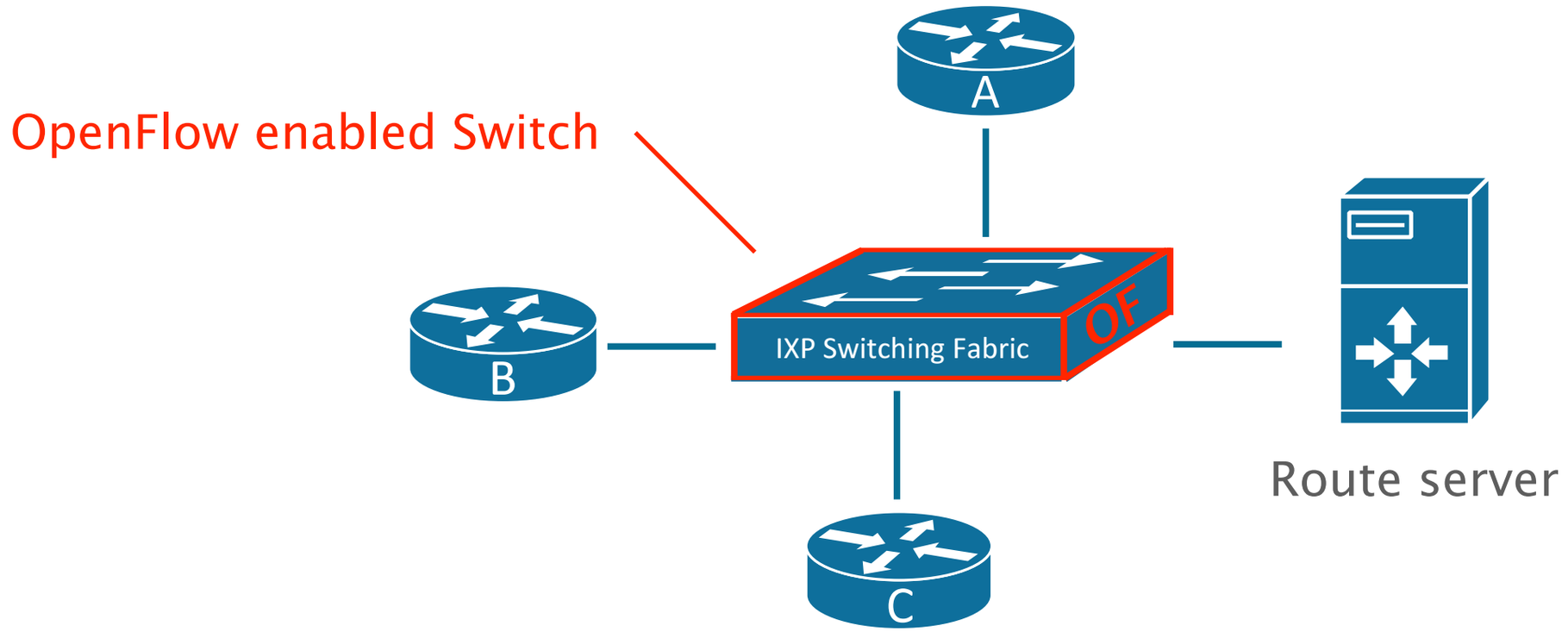


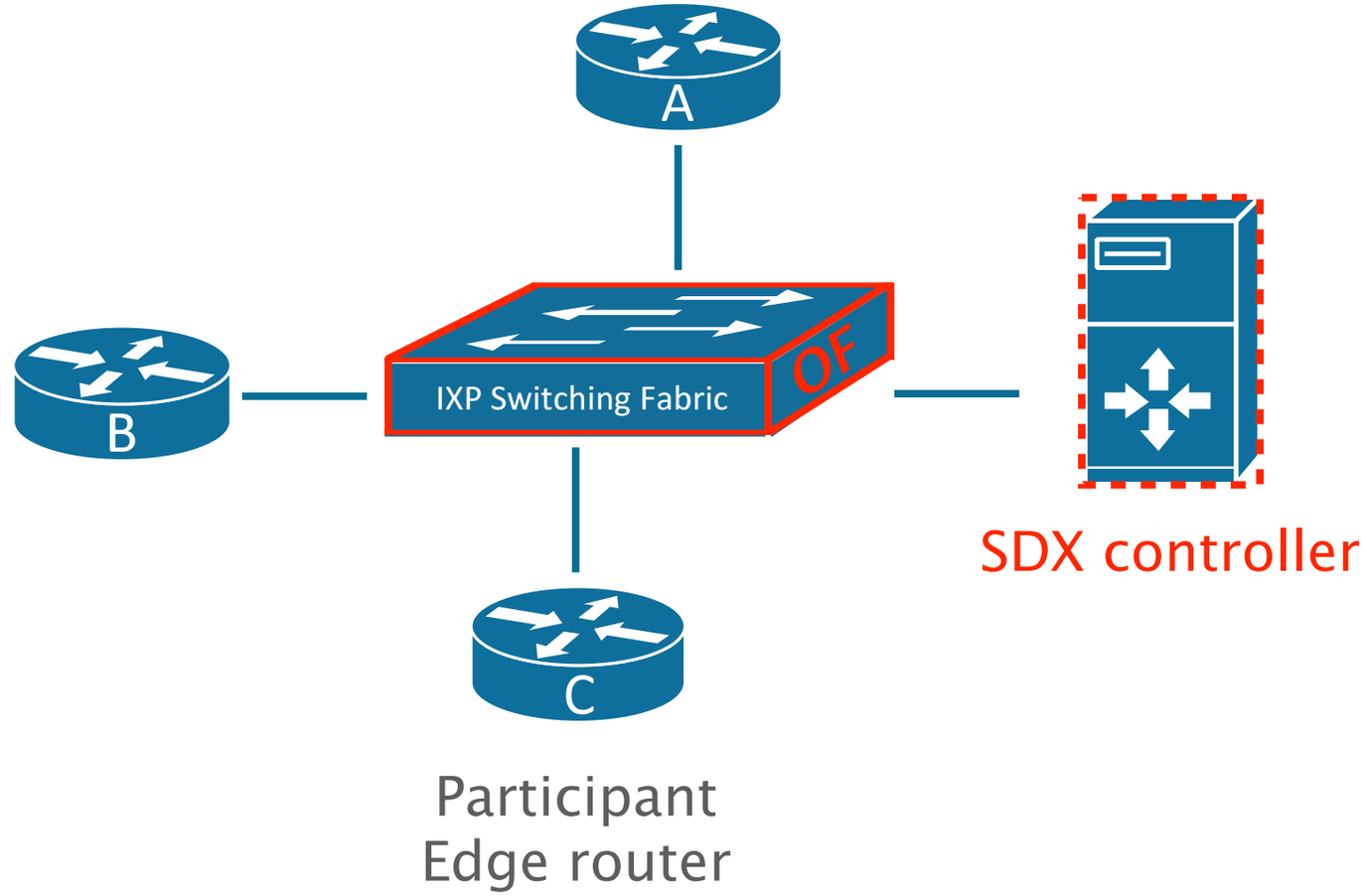
With respect to IXPs, SDN-enabled IXPs (SDX) ...



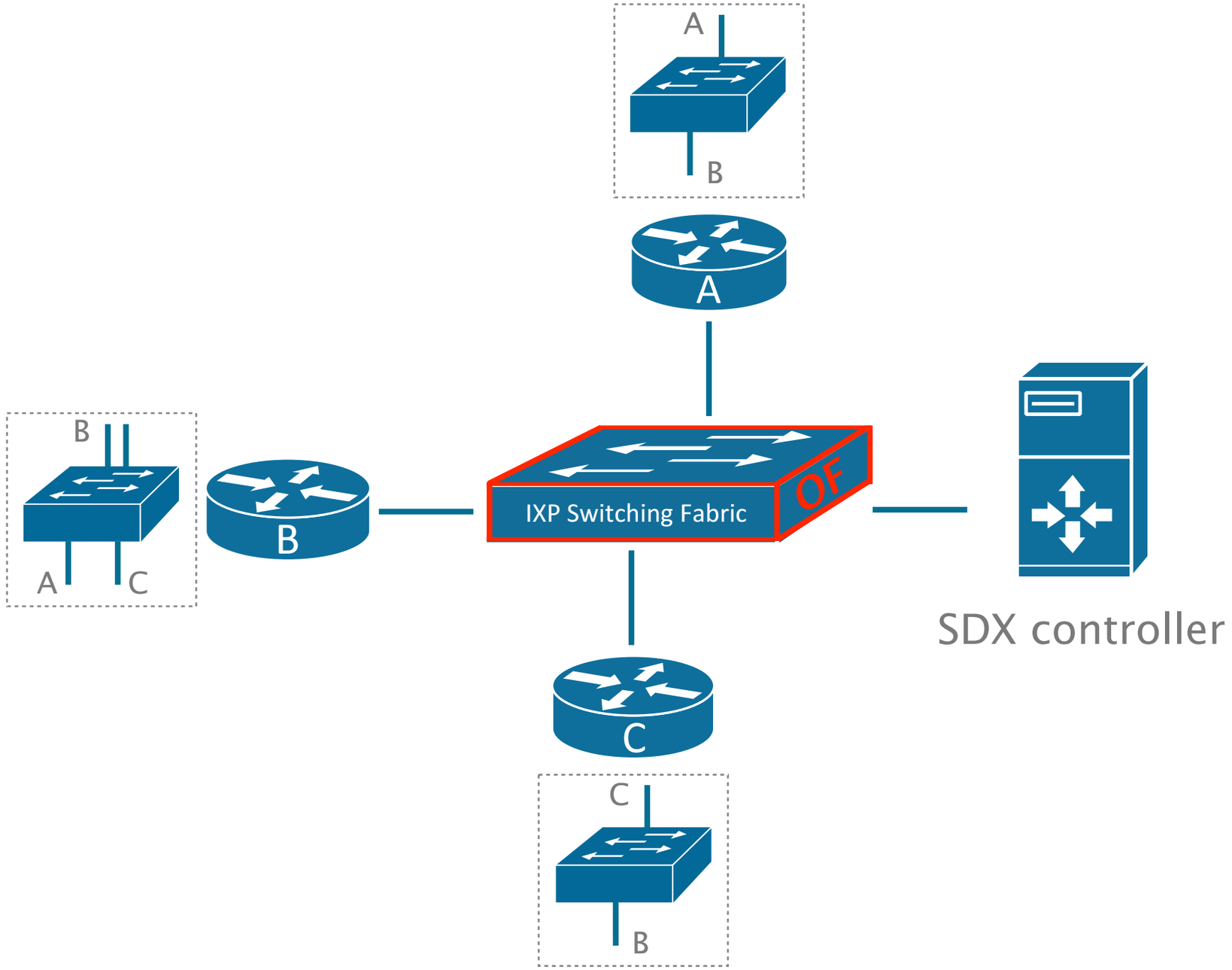
With respect to IXPs, SDN-enabled IXPs (SDX) *data plane* relies on SDN-capable devices



With respect to IXPs, SDN-enabled IXPs (SDX) *control plane* relies on a SDX controller



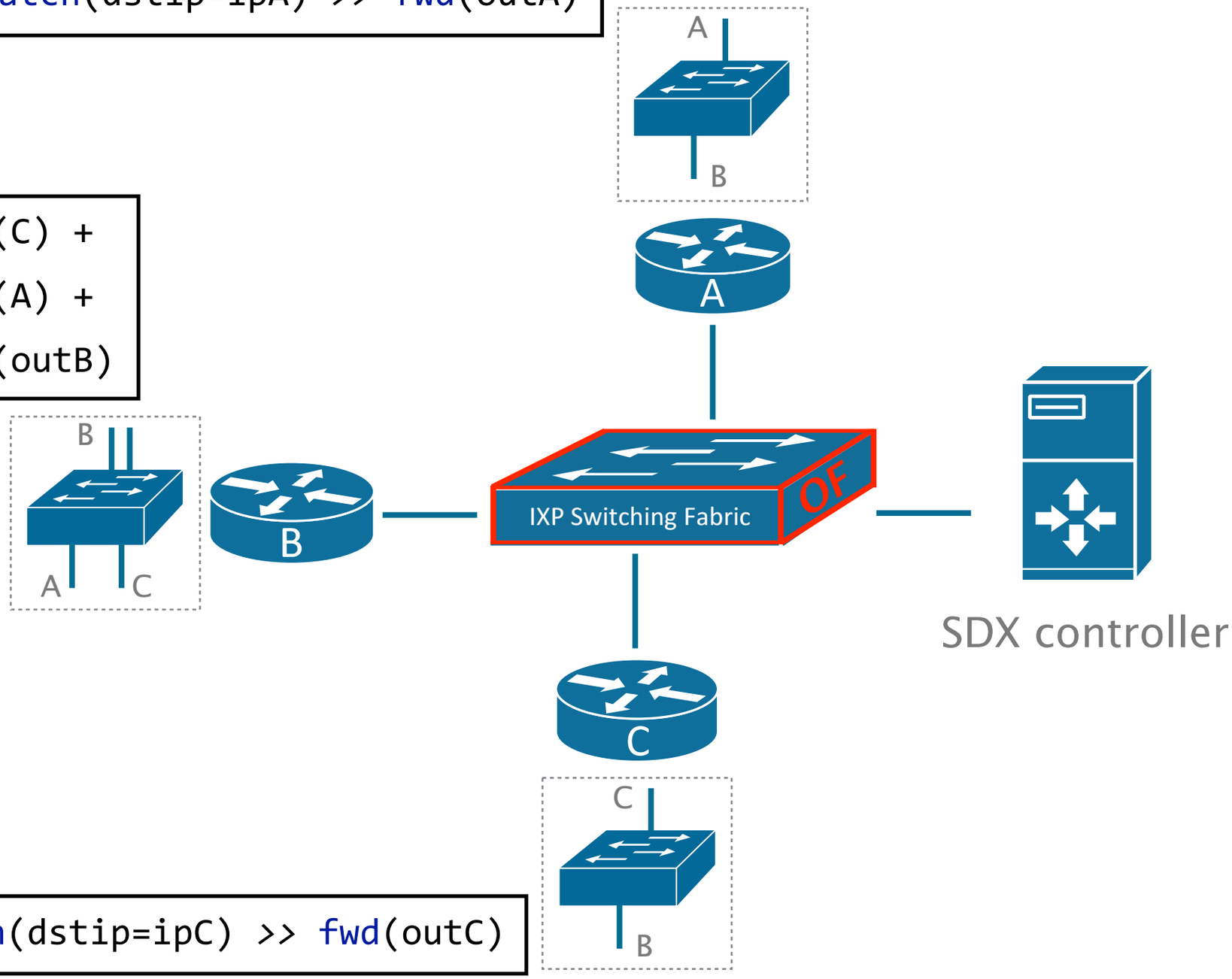
SDX participants write policies using a high-level language on top of a virtual topology



SDX participants write policies using a high-level language on top of a virtual topology

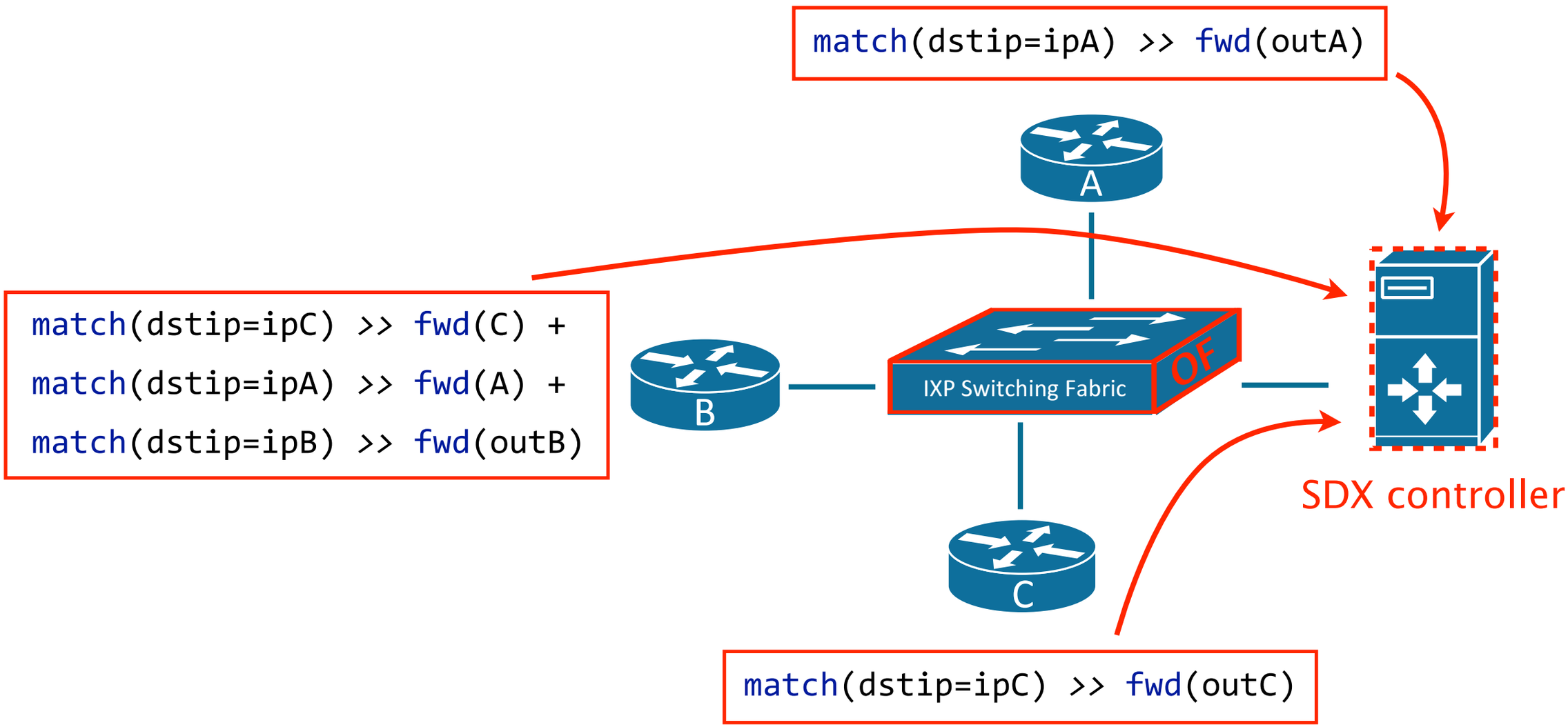
```
match(dstip=ipA) >> fwd(outA)
```

```
match(dstip=ipC) >> fwd(C) +
match(dstip=ipA) >> fwd(A) +
match(dstip=ipB) >> fwd(outB)
```




```
match(dstip=ipC) >> fwd(outC)
```

The SDX controller composes policies together ensuring *isolation* and *correctness*



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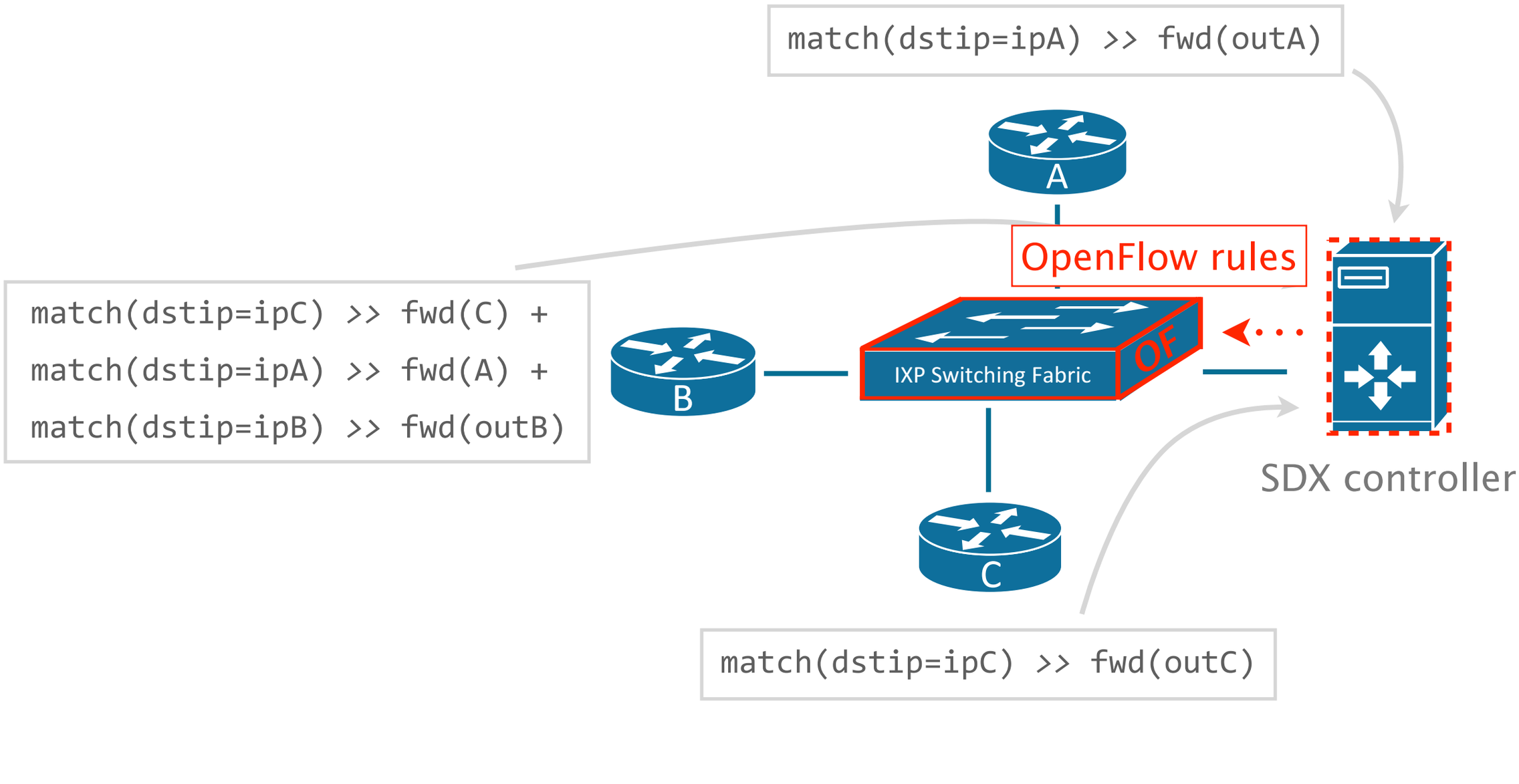
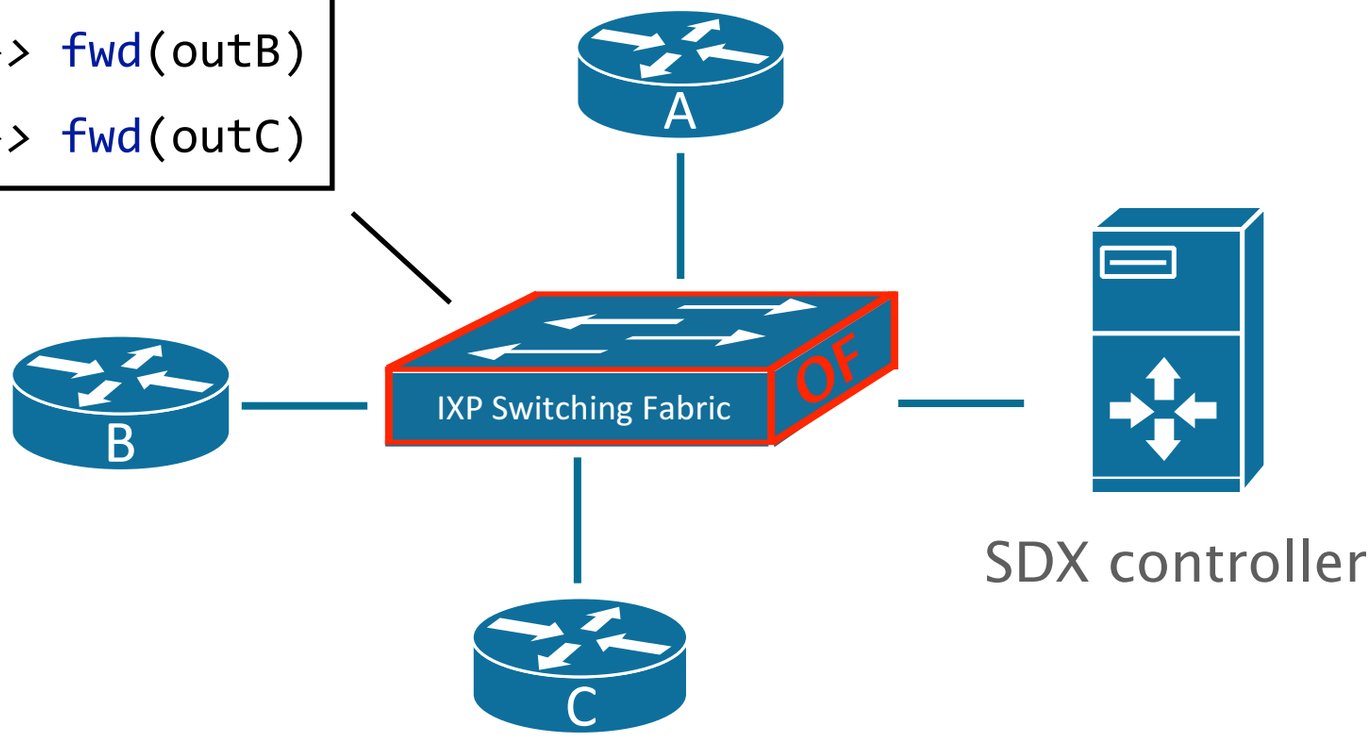
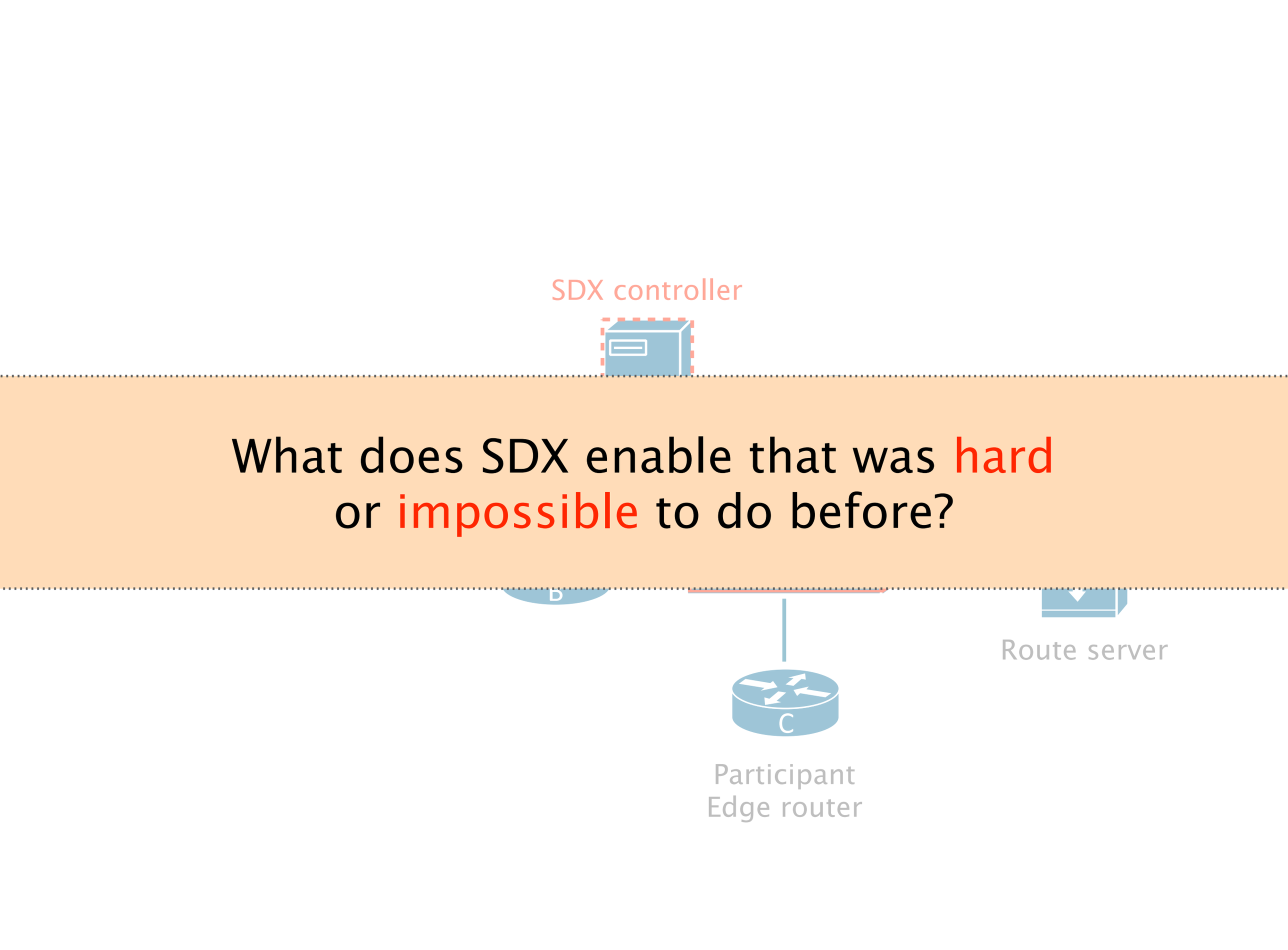


To ensure compatibility and scalability, SDX supports MAC-based forwarding by default

```
match(dstmac=MACA) >> fwd(outA)
match(dstmac=MACB) >> fwd(outB)
match(dstmac=MACC) >> fwd(outC)
```



Participants' policies subsume default forwarding behavior



What does SDX enable that was hard or impossible to do before?

SDX enables a wide range of novel interdomain applications

security	Prevent/block policy violation
	Prevent participants communication
forwarding optimization	Middlebox traffic steering
	Traffic offloading
	Inbound Traffic Engineering
peering	Application-specific peering
remote-control	Wide-area load balancing
	Influence BGP path selection
	Upstream blocking of DoS attacks

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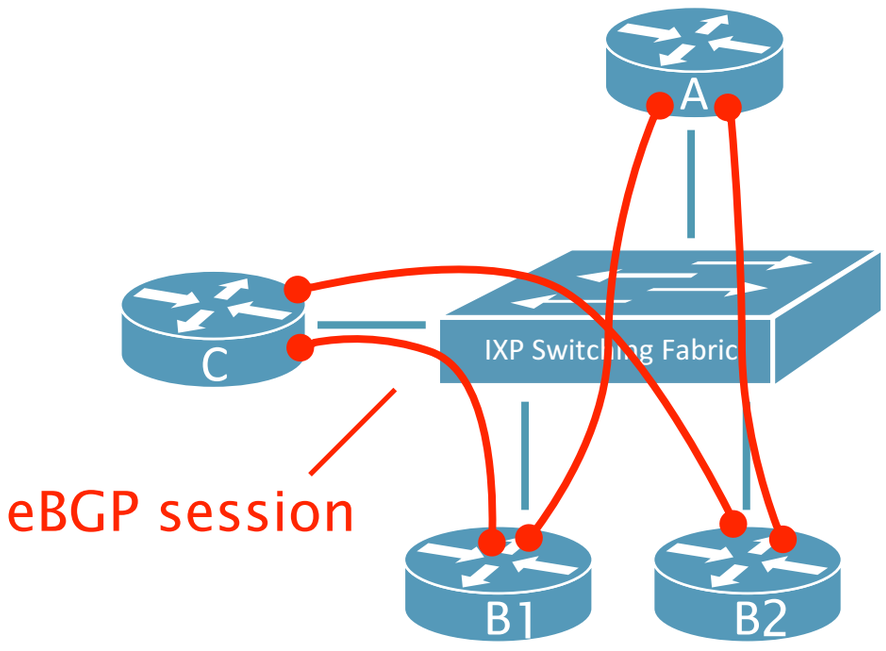
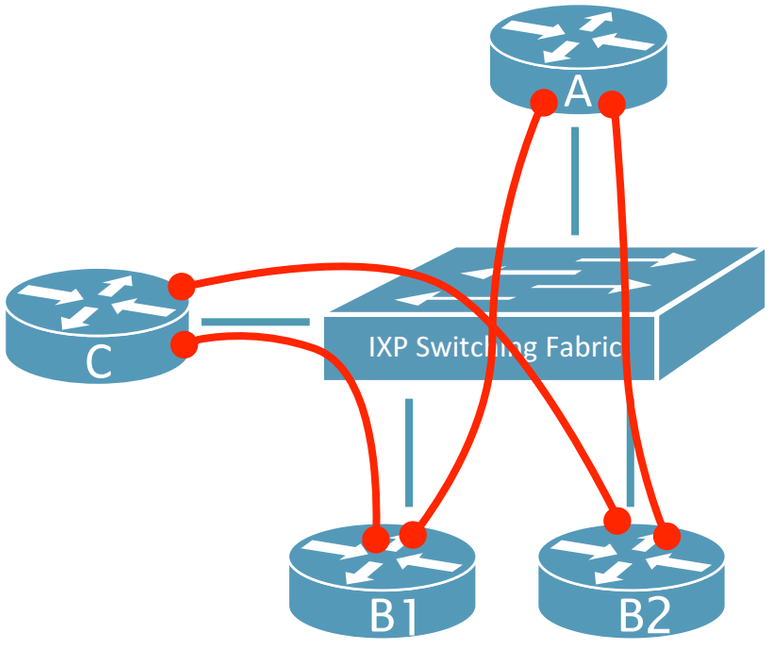
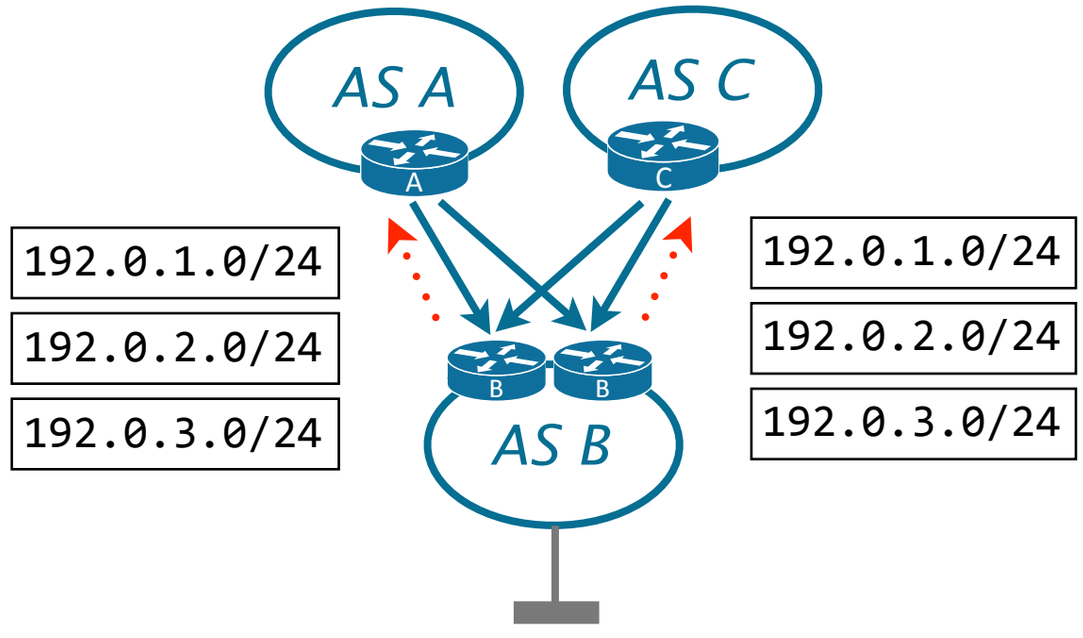
Given an IXP Physical Topology



SDX can improve inbound traffic engineering

Given an IXP Physical Topology and a BGP topology



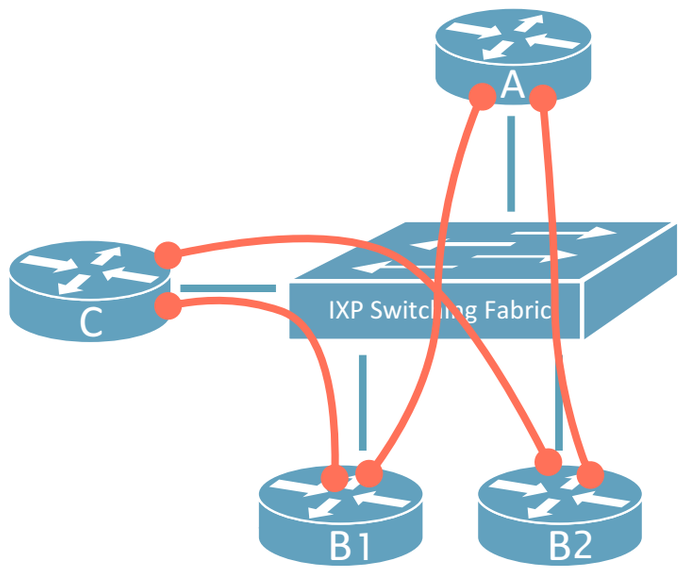


192.0.{1,2,3}.0/24

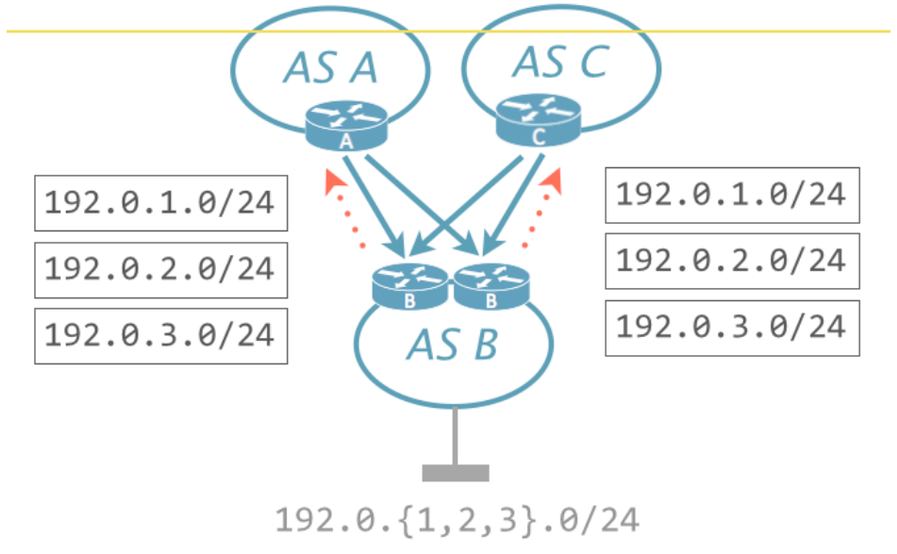
SDX can improve inbound traffic engineering

Implements B's inbound policy

to	from	receive on
192.0.1.0/24	A	B1
192.0.2.0/24	B	B2
192.0.2.0/24	ATT_IP	B2
192.0.2.0/24	*	B1
192.0.3.0/24	*	B2



IXP Topology

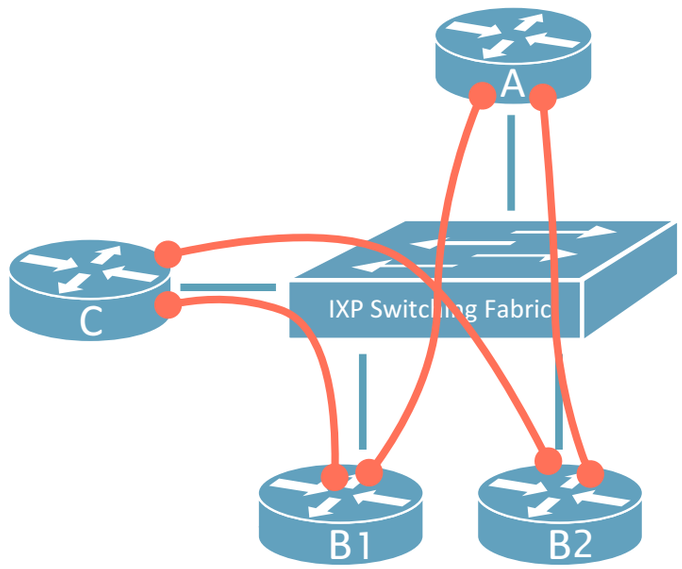


BGP Topology

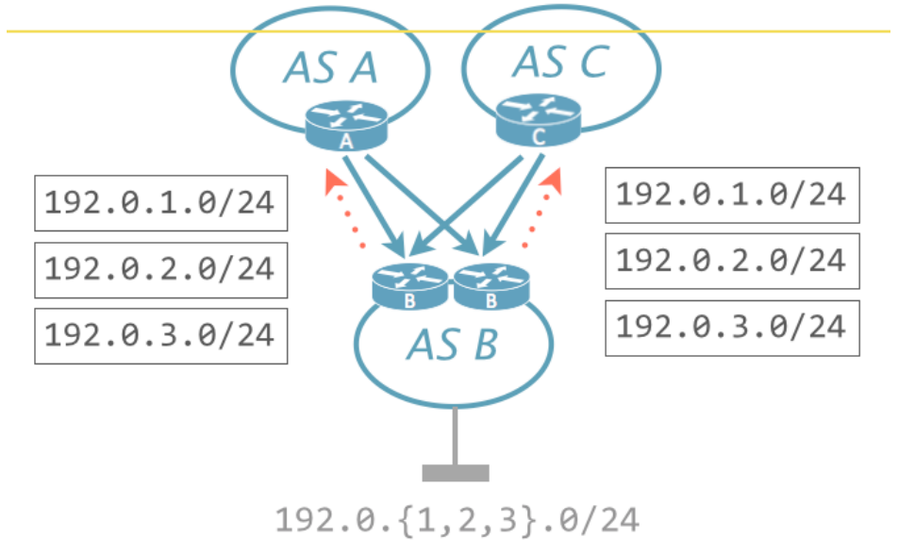
How do you do that with BGP?

Implements B's inbound policy

to	from	receive on
192.0.1.0/24	A	B1
192.0.2.0/24	B	B2
192.0.2.0/24	ATT_IP	B2
192.0.2.0/24	*	B1
192.0.3.0/24	*	B2



IXP Topology



BGP Topology

It is at least hard... BGP provides few knobs to influence remote decisions

Implementing such a policy is configuration-intensive

using AS-Path prepend, MED, community tagging, etc.

and even impossible for some requirements...

BGP policies **cannot** influence remote parties
decisions based on source addresses

to	**from**	receive on
`192.0.2.0/24`	**`ATT_IP`**	B2

In any case, the outcome is unpredictable

Implementing such a policy is configuration-intensive

using AS-Path prepend, MED, community tagging, etc.

Absolutely no guarantee that the remote party will comply

one can only “influence” remote decisions

Networks engineers have no choice but to “try and see”

which makes it difficult to adapt to traffic pattern

With a SDX, implementing B's inbound policy is easy

SDX policies give B *direct* control on its forwarding paths

to	from	fwd
192.0.1.0/24	A	B1
192.0.2.0/24	B	B2
192.0.2.0/24	ATT_IP	B2
192.0.2.0/24	*	B1
192.0.3.0/24	*	B2

B's SDX Policy

```
match(dstip=192.0.1.0/24, srcmac=A) >> fwd(B1)

match(dstip=192.0.2.0/24, srcmac=B) >> fwd(B2)

match(dstip=192.0.2.0/24, srcip=ATT) >> fwd(B2)

match(dstip=192.0.2.0/24) >> fwd(B1)

match(dstip=192.0.3.0/24) >> fwd(B2)
```

Several challenges remain

We need authentication mechanisms to validate policies

e.g., using Resource Public Key Infrastructure (RPKI)

We need “access-control” to constrain the policies

e.g., limiting the capabilities available to each participant

We need to make the platform scalable

as SDN devices currently support a relatively small # of rules

SDN-enabled Internet Exchange Point

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April, 9 2014