Bootstrapping evolvability for inter-domain routing

Raja Sambasivan,
David Tran-Lam, Aditya Akella, Peter Steenkiste

Carnegie Mellon University

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Inter-domain routing is stagnant

Many proposed fixes/replacements for BGP

E.g., LISP [RFC 6830], S-BGP [SAC'00], Wiser, R-BGP [NSDI'07]

Many proposed value-added protocols

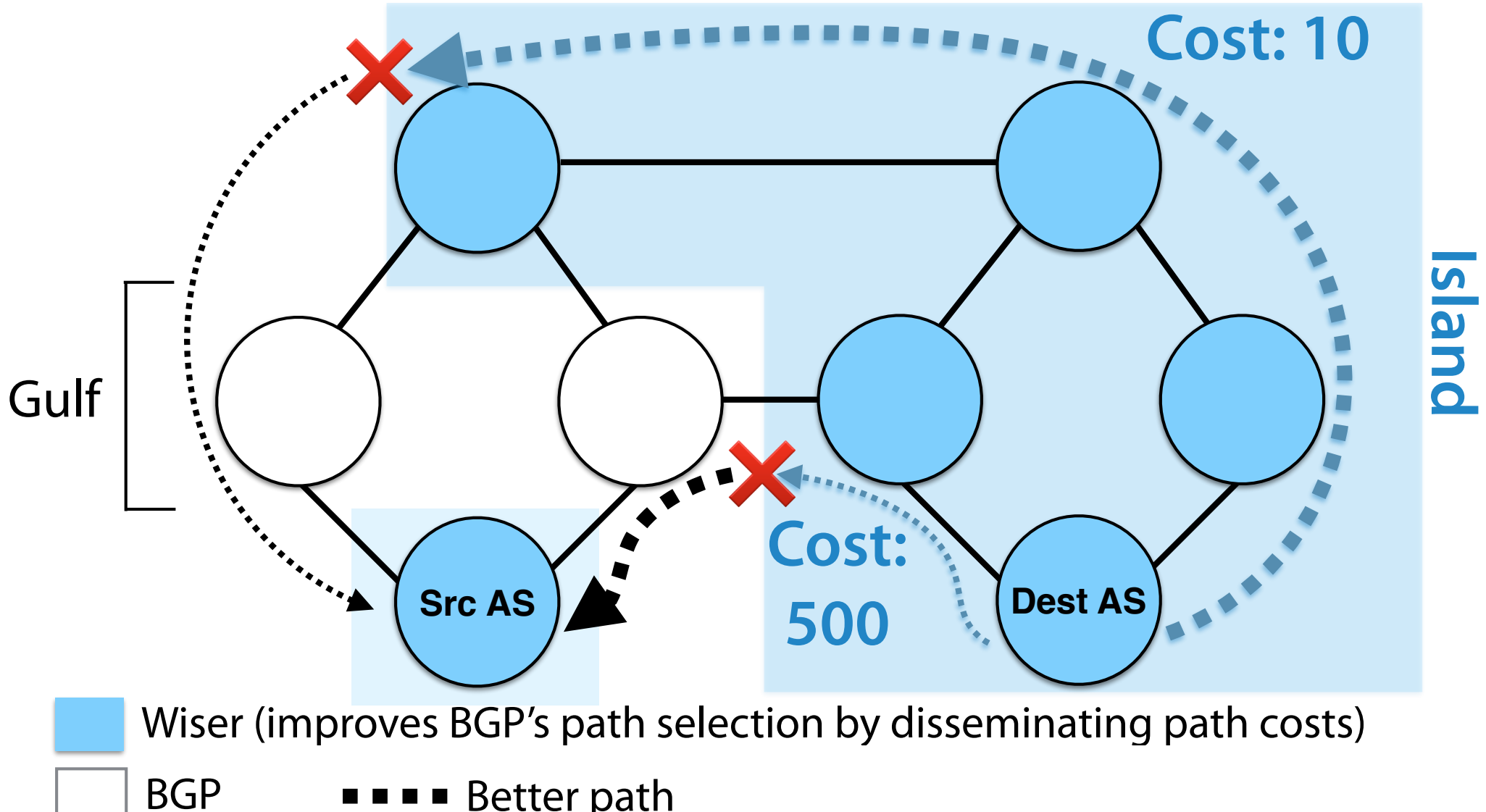
E.g., MIRO [SIGCOMM'06], Arrow [SIGCOMM'14]

Almost no new protocols deployed

(partly) because

BGP **does not** support evolution

BGP **does not** support evolution



Wiser (improves BGP's path selection by disseminating path costs)

BGP ▪▪▪▪ Better path

E.g., new protocols **cannot be used** across gulfs

1 ID'd requirements for evolvability

2 Proposed two modifications to BGP

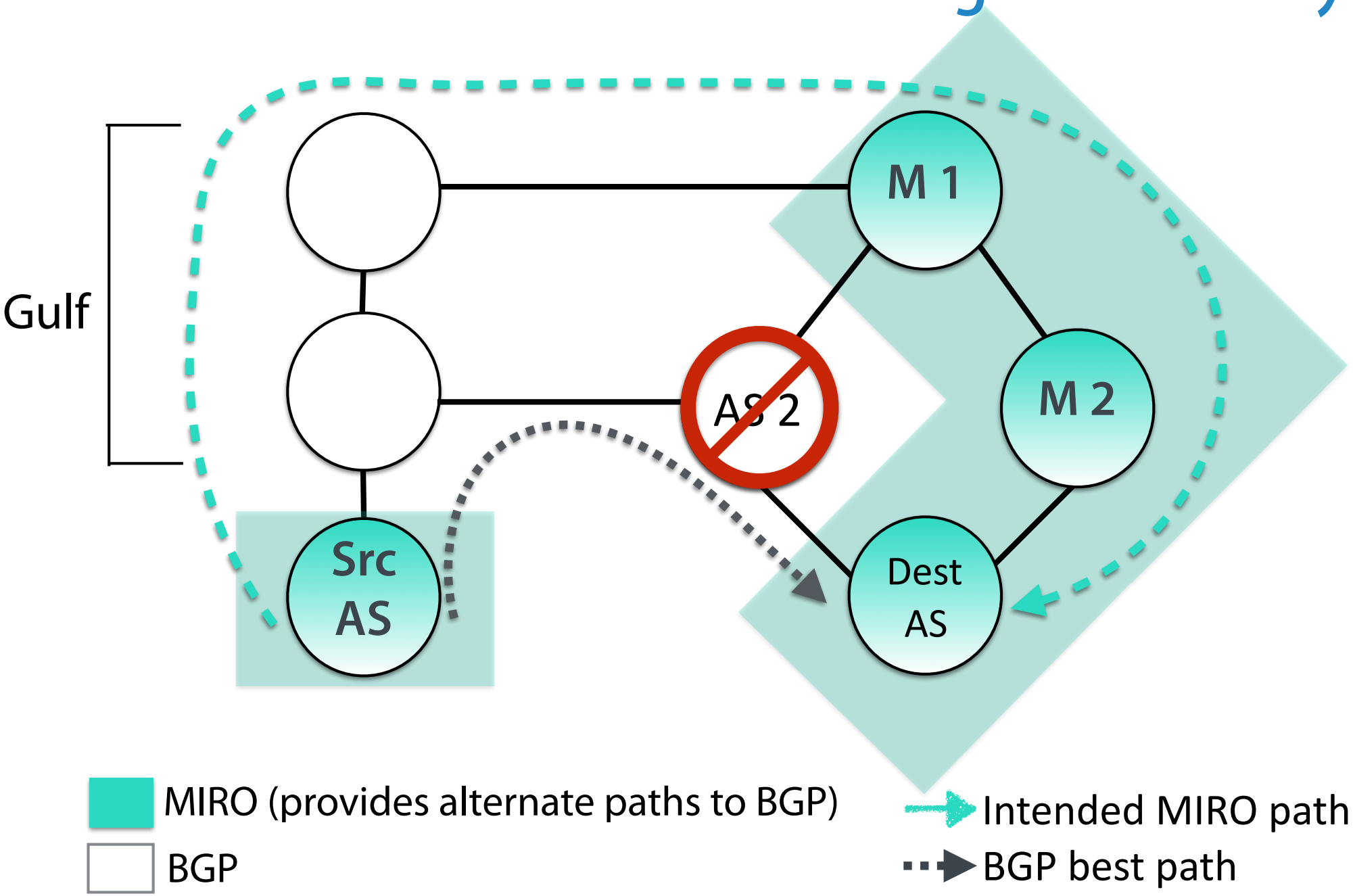
- Pass-through support
- Integrated advertisements (IAs)

How we identified evolvability requirements

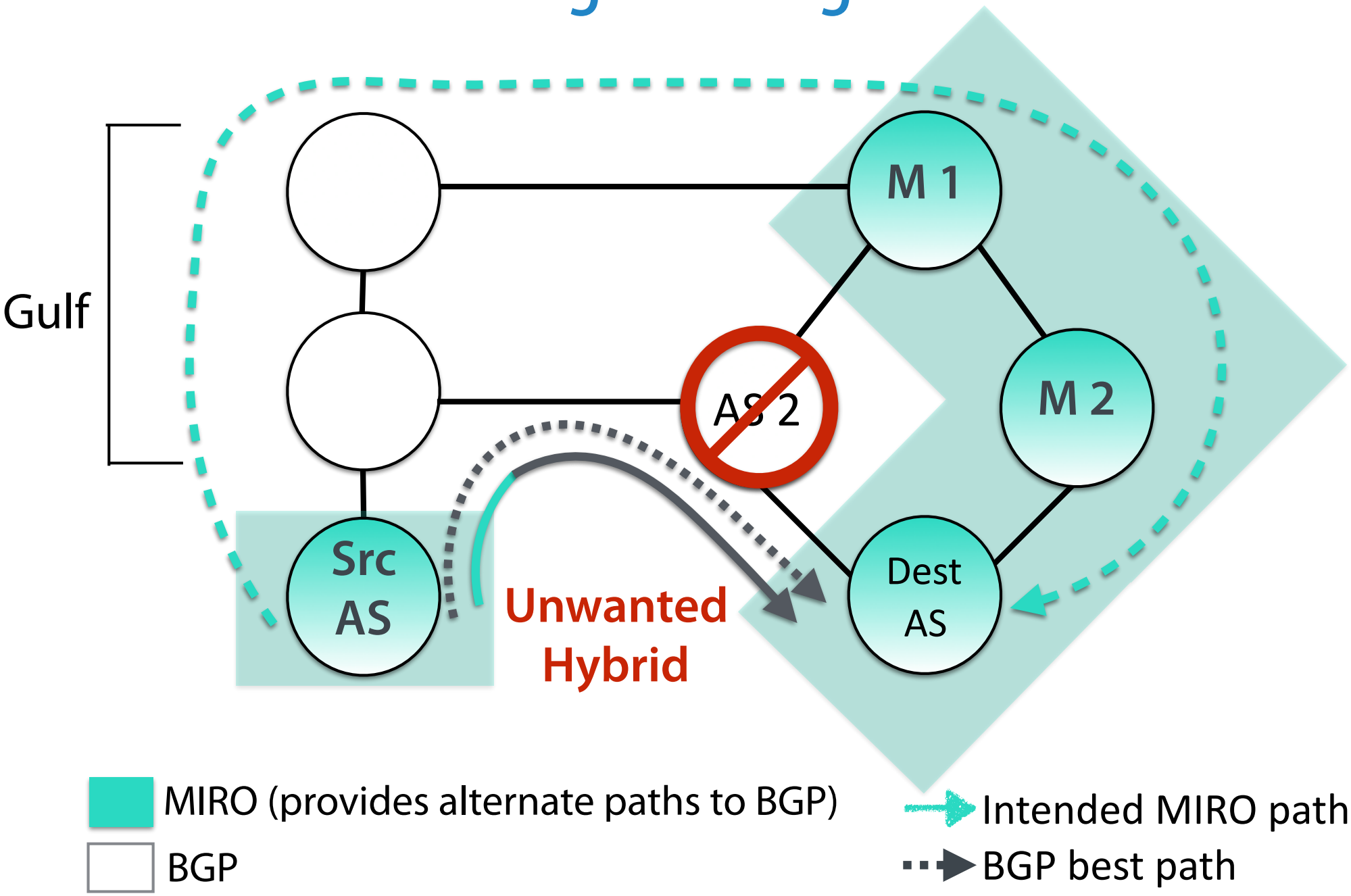
Deployment methods
Differ in routing consistency provided

BGP	BGP	BGP
↓	=	↓
Critical fix	Custom protocol	New-paradigm protocol
↓	↓	↓
Reqs	Reqs	Reqs

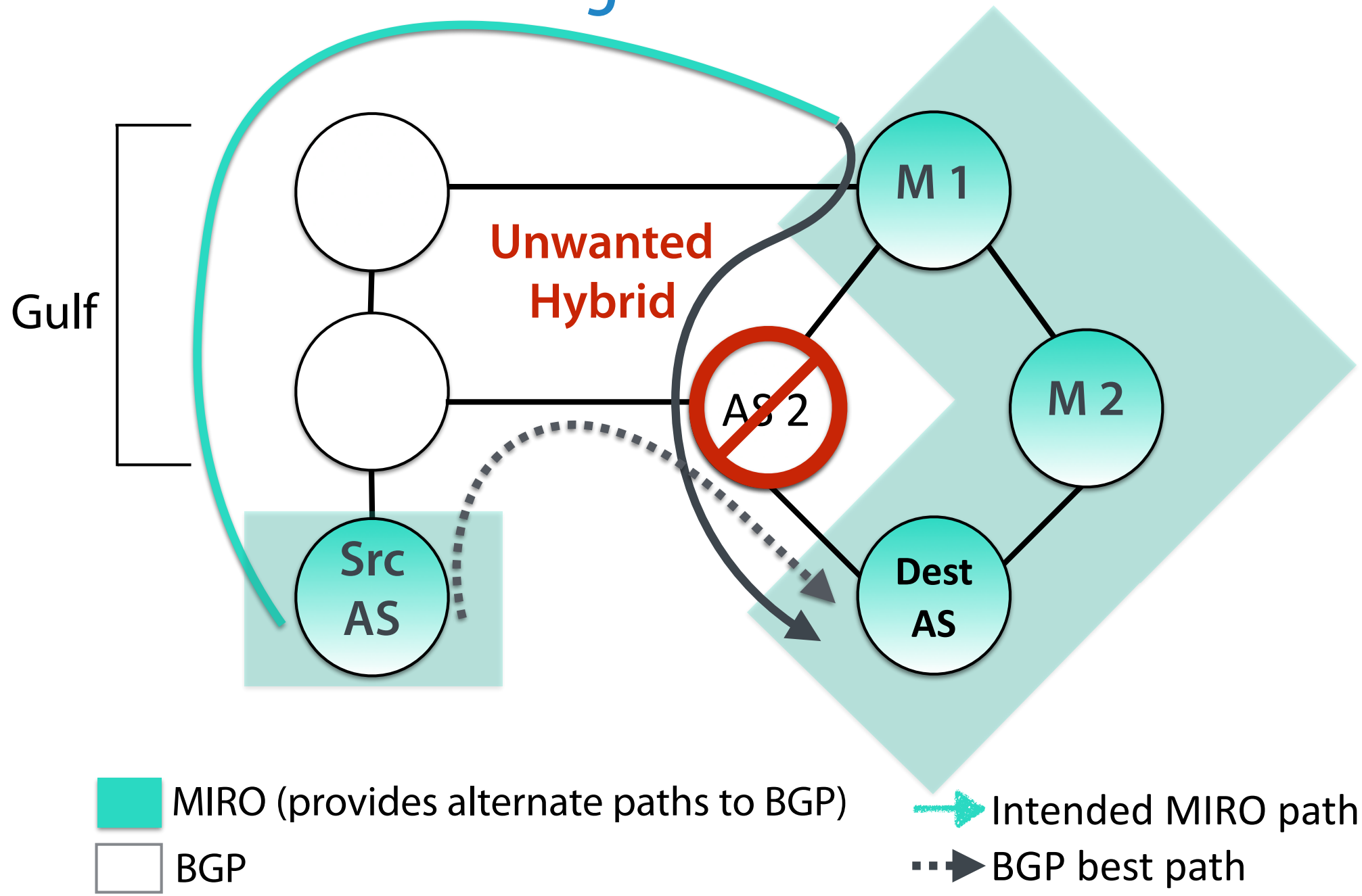
MIRO suffers from lack of routing consistency



Problem 1 : Routing across gulfs



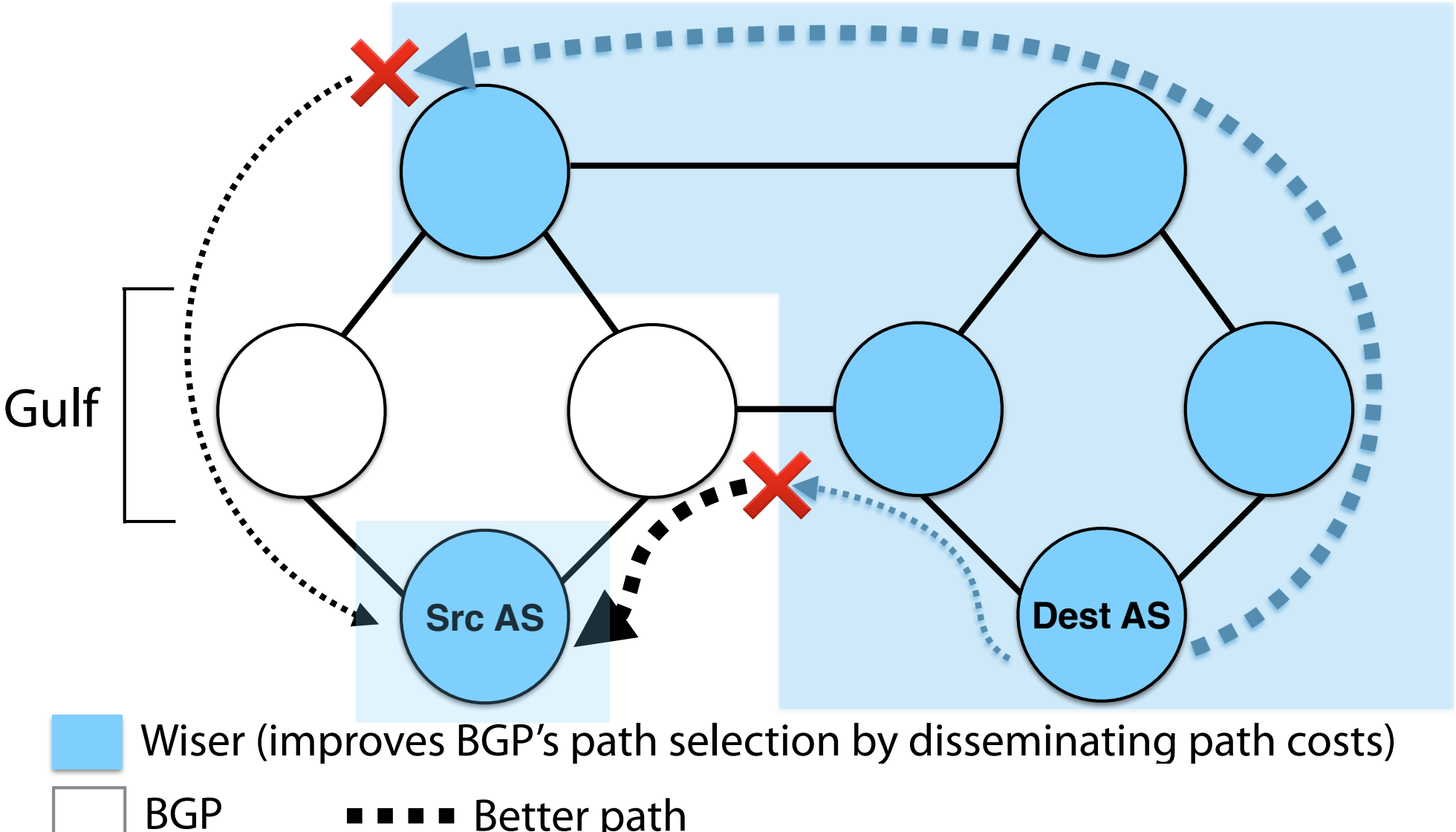
Problem 2 - Routing within islands



The three deployment methods

	Hybrid	
	Across gulfs	*Within islands*
Consistency	✗	✗
Best used for	BGP → Critical fix	
Examples	Wiser [NSDI'07], R-BGP [NSDI'07], S-BGP [SAC'00]	
Reqs	**Cross gulfs** **Deprecate BGP**	

Wiser can be deployed using Hybrid routing

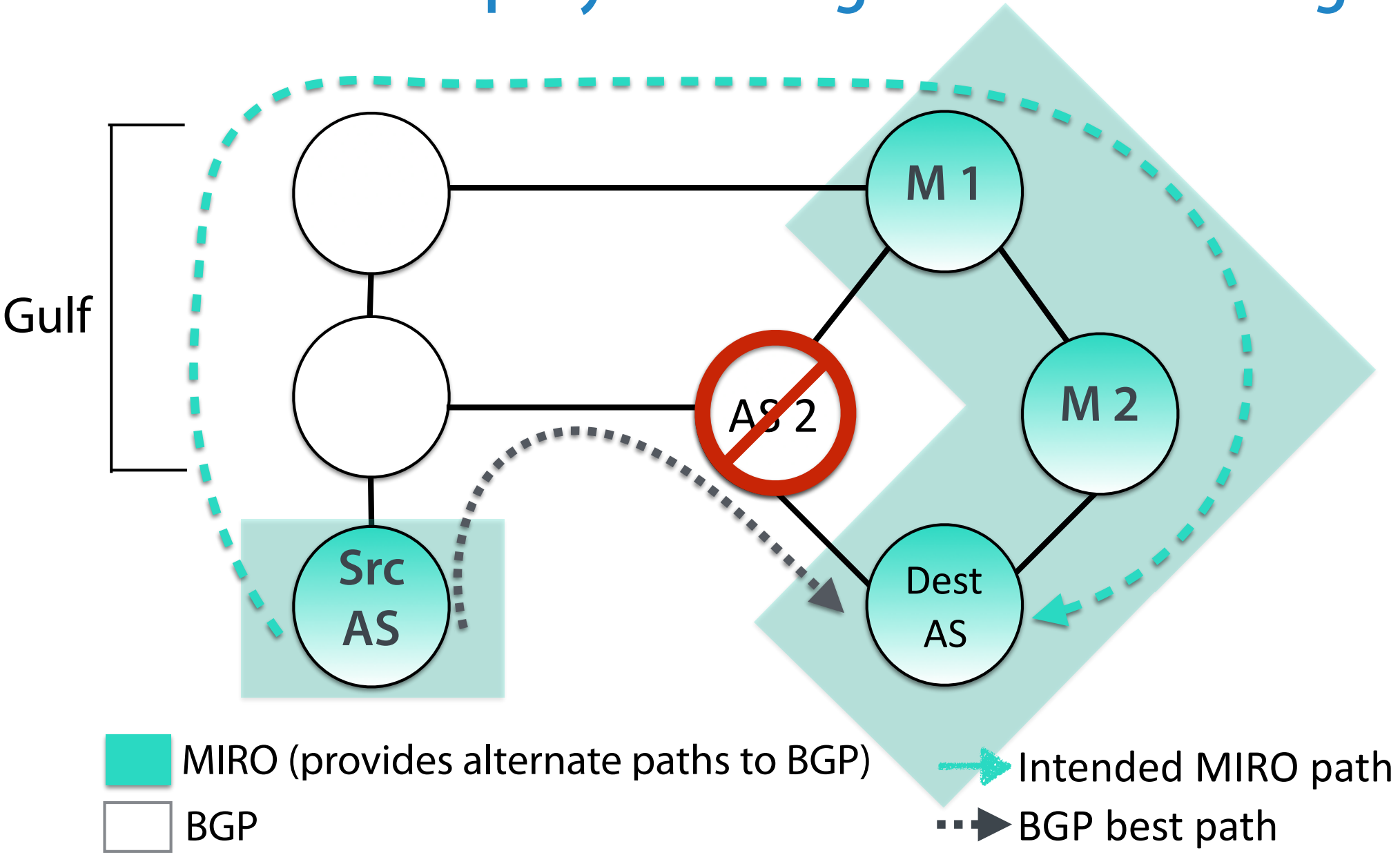


Requirements: Cross gulfs, Deprecate BGP

The three deployment methods

	Hybrid		Consistent	
	Across gulfs	*Within islands*	*Across gulfs*	*Within islands*
Consistency	✗	✗	✔	✔
Best used for	BGP → Critical fix		BGP ∥	Custom protocol
Examples	Wiser [NSDI'07], R-BGP [NSDI'07], S-BGP [SAC'00]		MIRO [SIG06], SCION [SP14] Pathlets [SIG09]	
Reqs	**Cross gulfs Deprecate BGP**		**Off-BGP-path discovery**	

MIRO can be deployed using custom routing



Requirements: Off-BGP-path discovery

The three deployment methods

	Hybrid		Consistent		Exclusive	
	Across gulfs	*Within islands*	*Across gulfs*	*Within islands*	*Across gulfs*	*Within islands*
Consistency	✗	✗	✔	✔	✔	✗
Best used for	BGP → Critical fix		BGP ‖ Custom protocol		BGP → New-paradigm	
Examples	Wiser [NSDI'07], R-BGP [NSDI'07], S-BGP [SAC'00]		MIRO [SIG06], SCION [SP14] Pathlets [SIG09]		⇢	"
Reqs	Cross gulfs Deprecate BGP		Off-BGP-path discovery		Scalable dissemination	

This talk: Adding evolvability support to BGP

1 ID'd requirements for evolvability

2 Proposed two modifications to BGP

- Pass-through support
- Integrated advertisements (IAs)

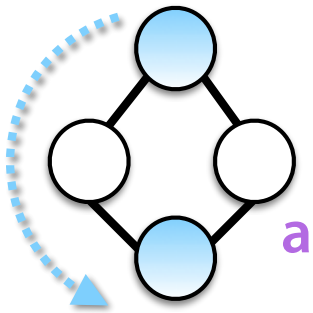
Pass-throughs & IAs overview

Replace BGP's advs. & processing

Can be implemented in routers or SDNs

Limited to path-vector protocols

Enable evolvability for hybrid routing by:

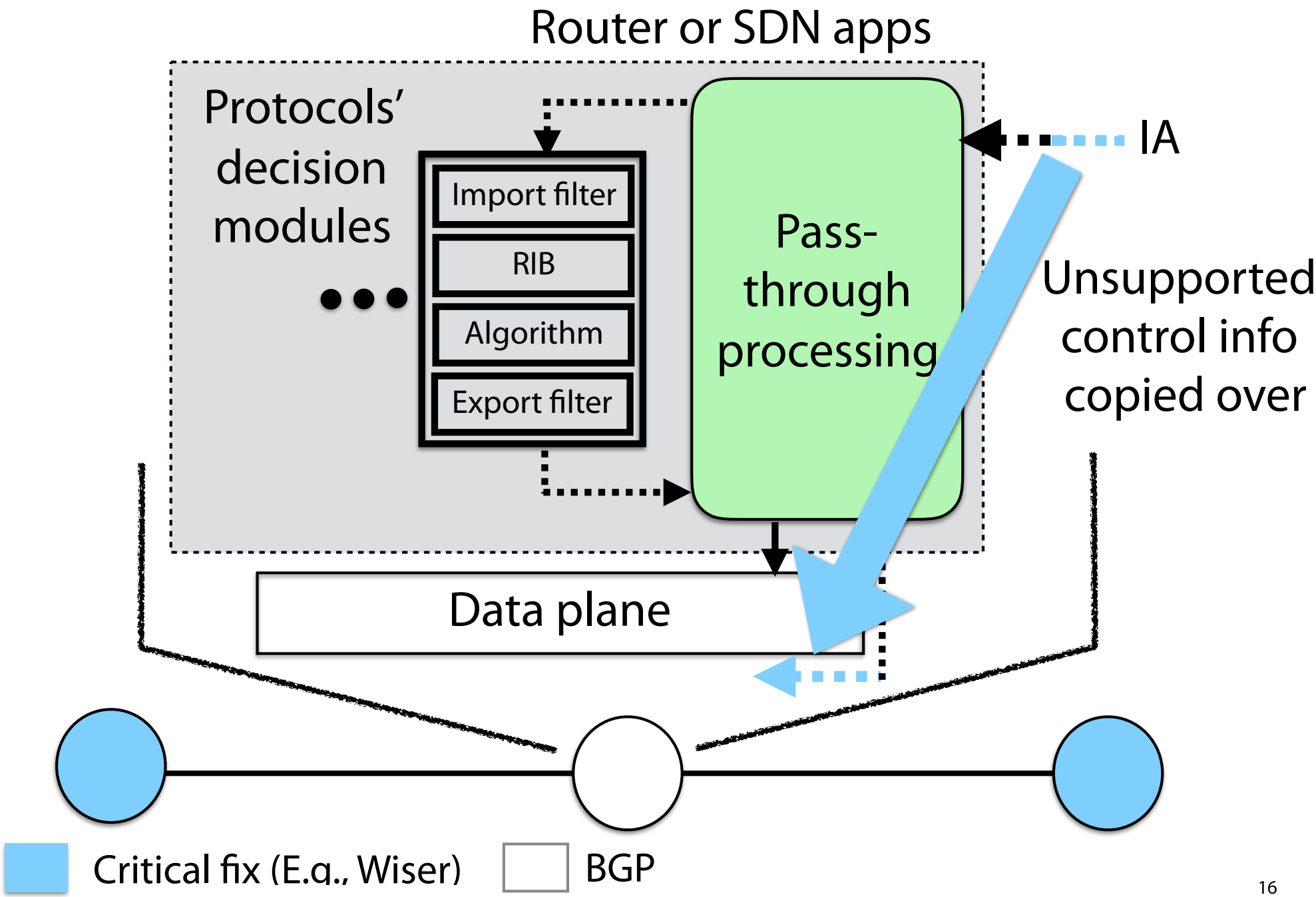


Enabling protocols across gulfs

BGP

Supporting BGP's gradual deprecation

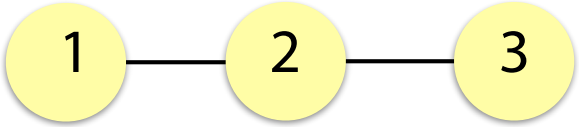
Pass-through modules



IA data-structure goals

1. State protocols on routing paths
2. Be expressive enough
3. Detect loops across all protocols
4. Limit message sizes

IA data structure

A: 

	Path IDs	*Protocol(s)*	*Field(s)*	*Value(s)*
Path descs.	A	Wiser	Path cost	430
		✶	Prefix	128.1.1.2
			Next hop	127.1.2.1
Node descs.	1	Wiser	AS	30
	2	BGP	AS	3168
	3	Wiser	AS	4027
Edge descs.				
AS Desc.	AS 30 {	AS 3168 {	AS 4027 {	MIRO

✶ Wildcard

Open questions

What are expressiveness limits?

How does aggregation affect IA sizes?

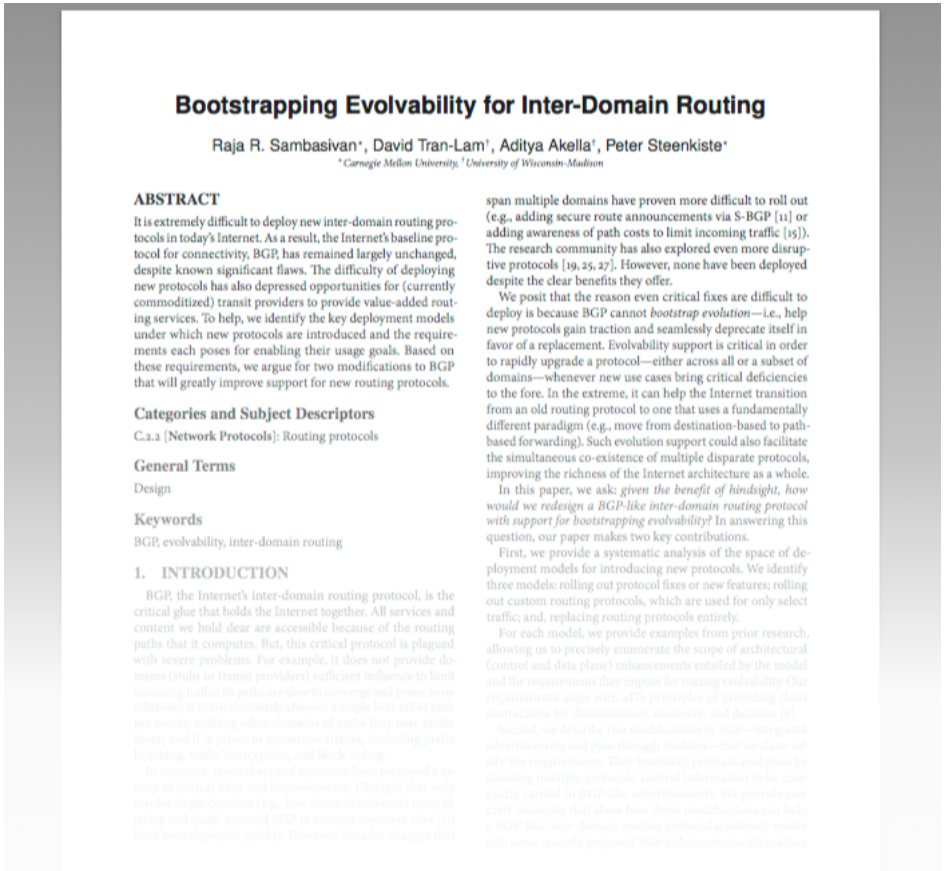
How to handle differing timing reqs?

Summary

Inter-domain routing is not evolvable

ID'd requirements for enabling evolvability

Pass-throughs / IAs sufficient to satisfy them



Bootstrapping Evolvability for Inter-Domain Routing

Raja R. Sambasivan*, David Tran-Lam†, Aditya Akella†, Peter Steenkiste*

*Carnegie Mellon University, †University of Wisconsin-Madison

ABSTRACT

It is extremely difficult to deploy new inter-domain routing protocols in today's Internet. As a result, the Internet's baseline protocol for connectivity, BGP, has remained largely unchanged, despite known significant flaws. The difficulty of deploying new protocols has also depressed opportunities for (currently commoditized) transit providers to provide value-added routing services. To help, we identify the key deployment models under which new protocols are introduced and the requirements each poses for enabling their usage goals. Based on these requirements, we argue for two modifications to BGP that will greatly improve support for new routing protocols.

Categories and Subject Descriptors

C.2.2 [Network Protocols]: Routing protocols

General Terms

Design

Keywords

BGP, evolvability, inter-domain routing

1. INTRODUCTION

BGP, the Internet's inter-domain routing protocol, is the critical glue that holds the Internet together. All services and content we hold dear are accessible because of the routing paths that it computes. But, this critical protocol is plagued with severe problems. For example, it does not provide domains (stubs or transit providers) sufficient influence to limit incoming traffic; its paths are slow to converge and prone to oscillations; it indiscriminately chooses a single best-effort path per router, robbing other domains of paths they may prefer; and it is prone to numerous attacks, including prefix hijacking, traffic interception, and black holing.

In response, researchers and operators have proposed a variety of critical fixes and improvements. Changes that only involve single domains (e.g., new forms of multi-exit route filtering and route-protocol BGP to convert customer static routes) have been deployed quickly. However, broader changes that span multiple domains have proven more difficult to roll out (e.g., adding secure route announcements via S-BGP [11] or adding awareness of path costs to limit incoming traffic [15]). The research community has also explored even more disruptive protocols [19, 25, 27]. However, none have been deployed despite the clear benefits they offer.

We posit that the reason even critical fixes are difficult to deploy is because BGP cannot *bootstrap evolution*—i.e., help new protocols gain traction and seamlessly deprecate itself in favor of a replacement. Evolvability support is critical in order to rapidly upgrade a protocol—either across all or a subset of domains—whenever new use cases bring critical deficiencies to the fore. In the extreme, it can help the Internet transition from an old routing protocol to one that uses a fundamentally different paradigm (e.g., move from destination-based to path-based forwarding). Such evolution support could also facilitate the simultaneous co-existence of multiple disparate protocols, improving the richness of the Internet architecture as a whole.

In this paper, we ask: *given the benefit of hindsight, how would we redesign a BGP-like inter-domain routing protocol with support for bootstrapping evolvability?* In answering this question, our paper makes two key contributions.

First, we provide a systematic analysis of the space of deployment models for introducing new protocols. We identify three models: rolling out protocol fixes or new features; rolling out custom routing protocols, which are used for only select traffic; and, replacing routing protocols entirely.

For each model, we provide examples from prior research, allowing us to precisely enumerate the scope of architectural (control and data plane) enhancements entailed by the model and the requirements they impose for routing evolvability. Our requirements align with [17]'s principles of providing clean abstractions for dissemination, discovery, and decision [6].

Second, we describe two modifications to BGP—integrated advertisements and pass-through modules—that we claim satisfy the requirements. They bootstrap protocol evolution by allowing multiple protocols' control information to be simultaneously carried in BGP route advertisements. We provide case study examples that show how these modifications can help a BGP-like inter-domain routing protocol seamlessly evolve into some recently proposed BGP enhancements/alternatives.

References (I)

[CCR'14]: Named Data Networking. Lilia Zhang, kc claffy, Patrick Crowley, Christos Papadopoulos, Lan Wang, Beichuan Zhang. SIGCOMM CCR vol. 44 (3), 2014.

[NSDI'07, R-BGP]: R-BGP: Staying Connected In a Connected World. Nate Kushman, Srikanth Kandula, Dina Katabi, Bruce M. Maggs. NSDI'07.

[NSDI'07, Wiser]: Mutually Controlled Routing with Independent ISPs. Ratul Mahajan, David Wetherall ,Thomas Anderson. NSDI'07.

References (II)

[RFC 6830]: The Locator/ID Separation Protocol (LISP). D. Farinaci, V. Fuller, D. Meyer, D. Lewis. RFC 6830, 2013.

[SAC'00]: Secure Border Gateway Protocol (S-BGP). Stephen Kent, Charles Lynn, Karen Seo. IEEE Journal on Selected Areas in Communication vol. 18 (4), 2000.

[S&P'11]: SCION: Scalability, Control, and Isolation On Next-Generation Networks. Xin Zhang, Hsu-Chun Hsiao, Geoffrey Hasker, Haowen Chan, Adrian Perrig and David G. Andersen. IEEE S&P'11.

References (III)

[SIGCOMM'06]: MIRO: Multi-path Interdomain ROuting. Wen Xu, Jennifer Rexford. SIGCOMM'06.

[SIGCOMM'09]: Pathlet Routing. P. Brighten Godfrey, Igor Ganichev, Scott Shenker, Ion Stoica. SIGCOMM'09.

[SIGCOMM'14]: One Tunnel is (Often) Enough. Simon Peter, Umar Javed, Qiao Zhang, Doug Woos, Thomas Anderson, Arvind Krishnamurthy. SIGCOMM'14.