Université de Strasbourg

The art of detecting forwarding detours

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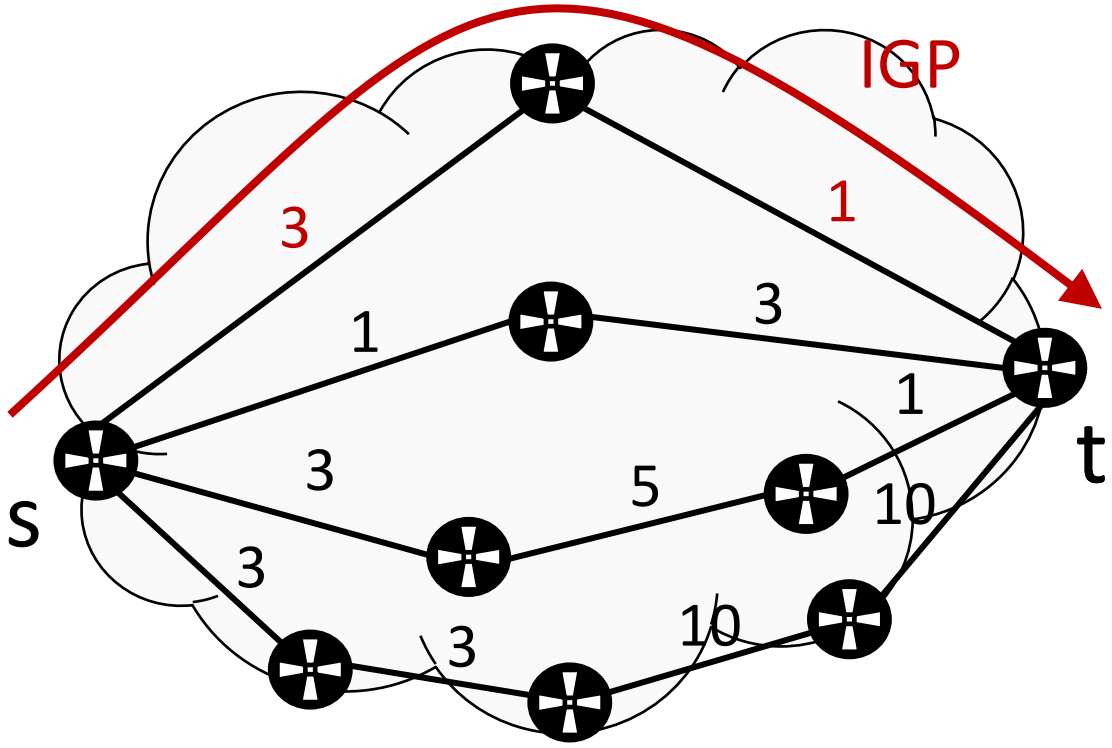
Inside an AS

- In the IGP, links have a cost according to some metric
- The path with minimum cost is used



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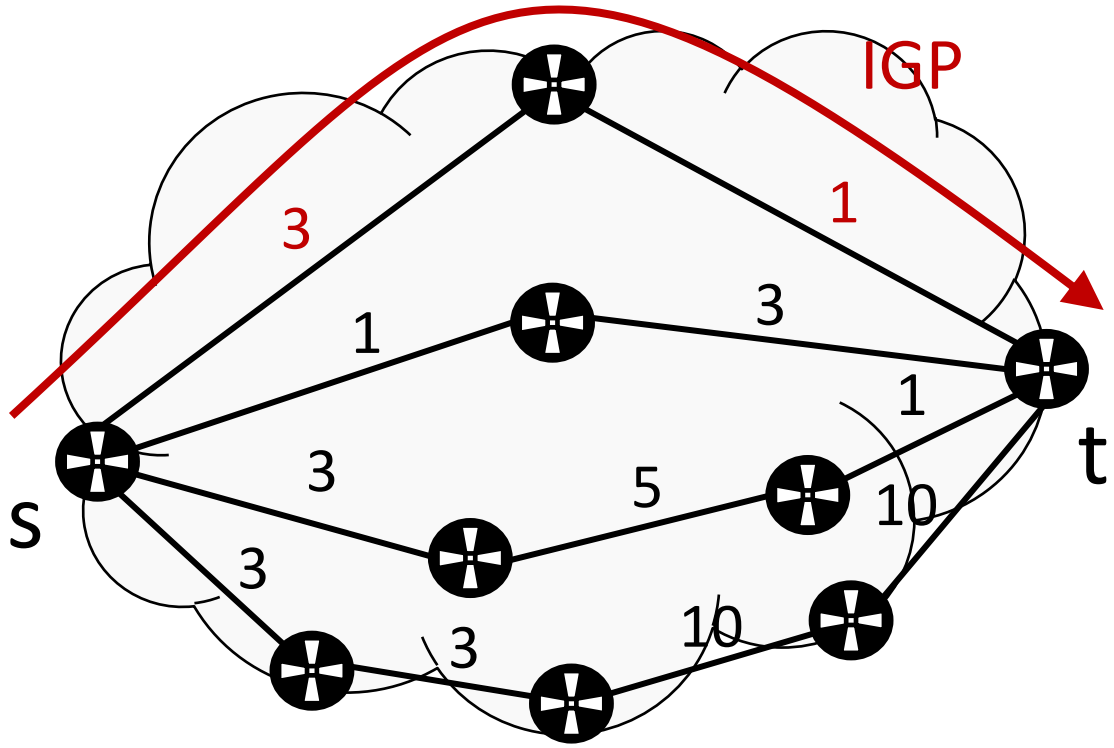
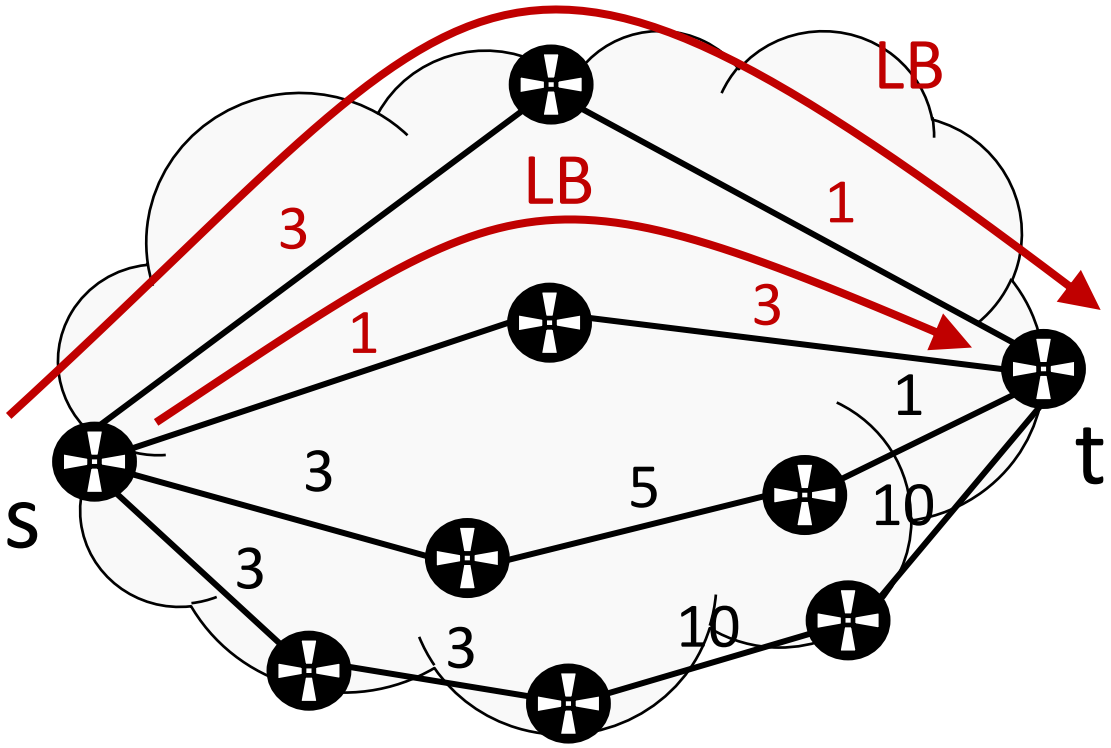


IGP		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1				
	P_2				
	P_3				
	P_4				
	P_5				
	P_6				
	P_7				
	P_8				

Load Balancing (LB)

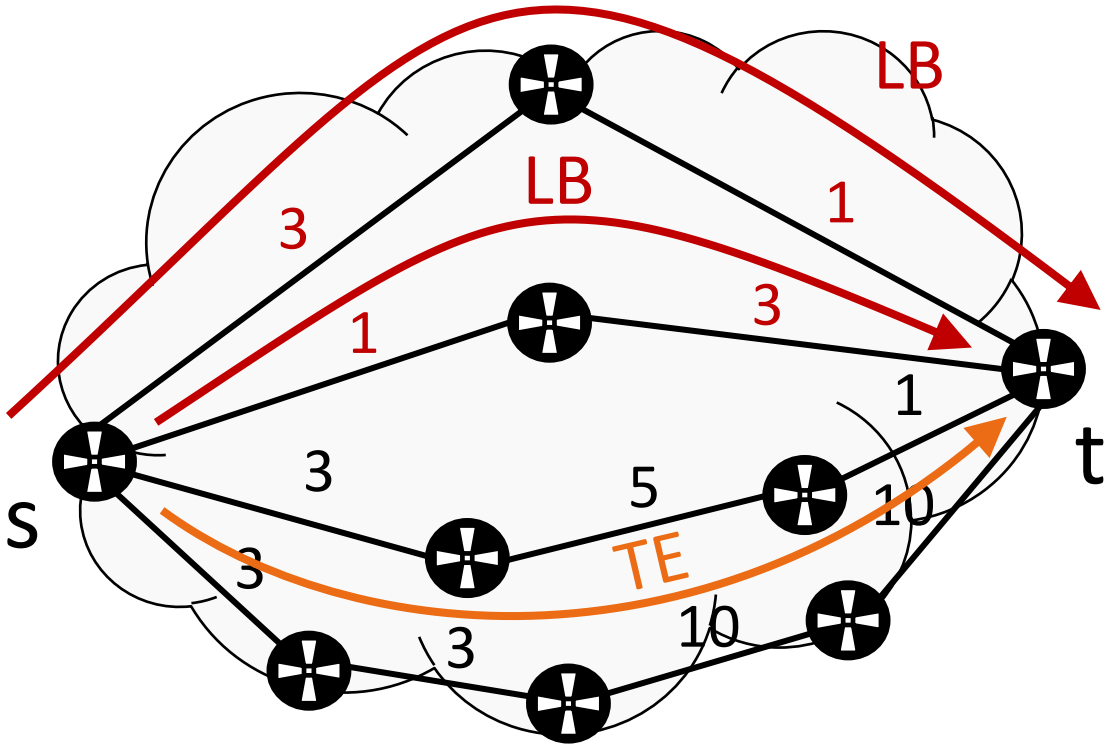
- From one to many best IGP paths
- Usually deployed with equal-cost multipath (ECMP)



LB		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1	◉◉	◉◉		
	P_2	◉◉	◉◉		
	P_3	◉◉	◉◉		
	P_4	◉◉	◉◉		
	P_5	◉◉	◉◉		
	P_6	◉◉	◉◉		
	P_7	◉◉	◉◉		
	P_8	◉◉	◉◉		

Traffic Engineering (TE)

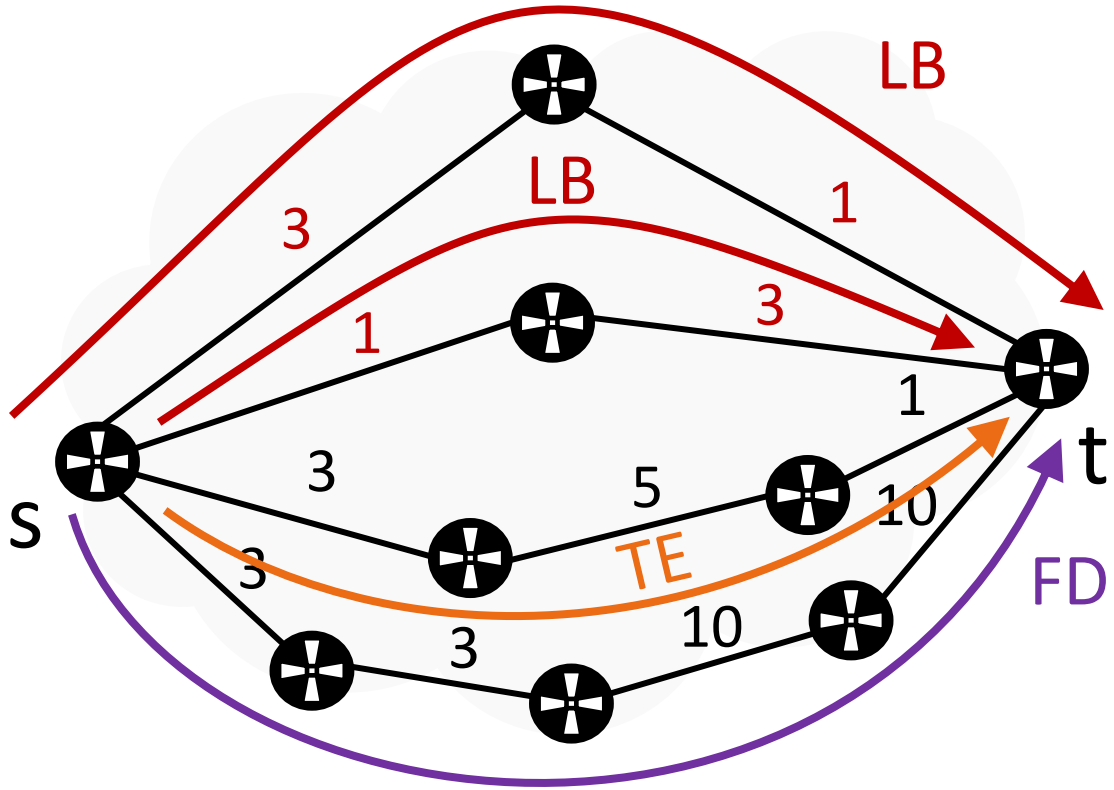
- Allows to craft paths “by hand”
- The crafted paths meet some requirements, e.g. low delay



LB / TE		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1	◉◉	◉◉		
	P_2	◉◉	◉◉		
	P_3	◉◉	◉◉		
	P_4			◉◉	
	P_5	◉◉	◉◉		
	P_6	◉◉	◉◉		
	P_7	◉◉	◉◉		
	P_8	◉◉	◉◉		

Forwarding Detours (FDs)

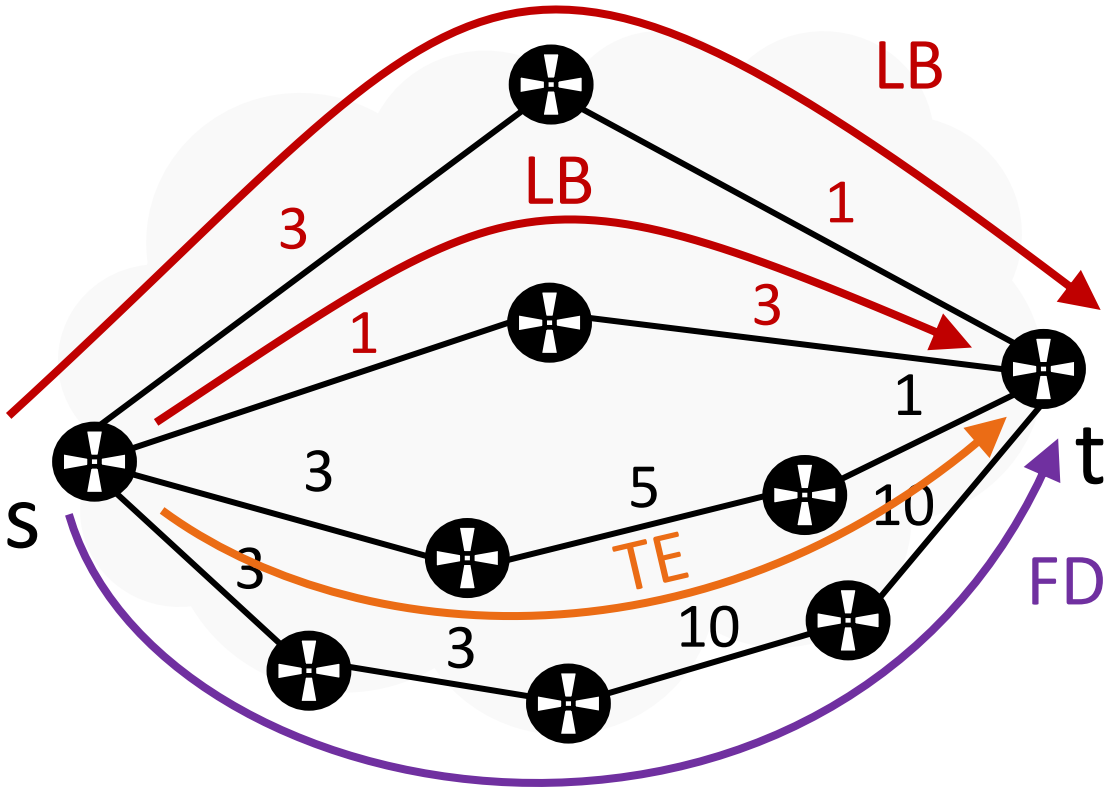
- When the forwarding route diverges from LB and TE paths



LB / TE / FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1	◉◉	◉◉		
	P_2	◉◉	◉◉		
	P_3	◉◉	◉◉		
	P_4			◉◉	
	P_5	◉◉	◉◉		
	P_6	◉◉	◉◉		
	P_7				◉◉
	P_8	◉◉	◉◉		

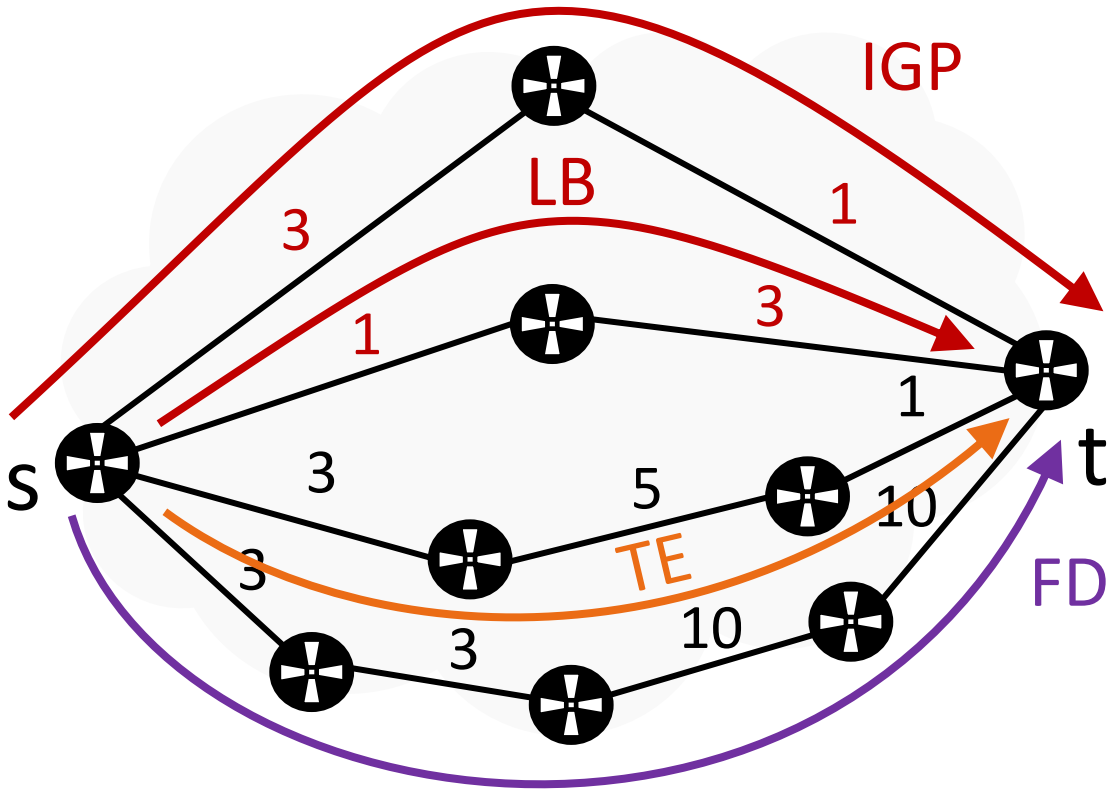
Why detecting Forwarding Detours?

- FDs relate to unexpected paths being used
- Possible negative impact on performance



Methodology to detect FDs

Forwarding Pattern - Run measurements and find the matrix



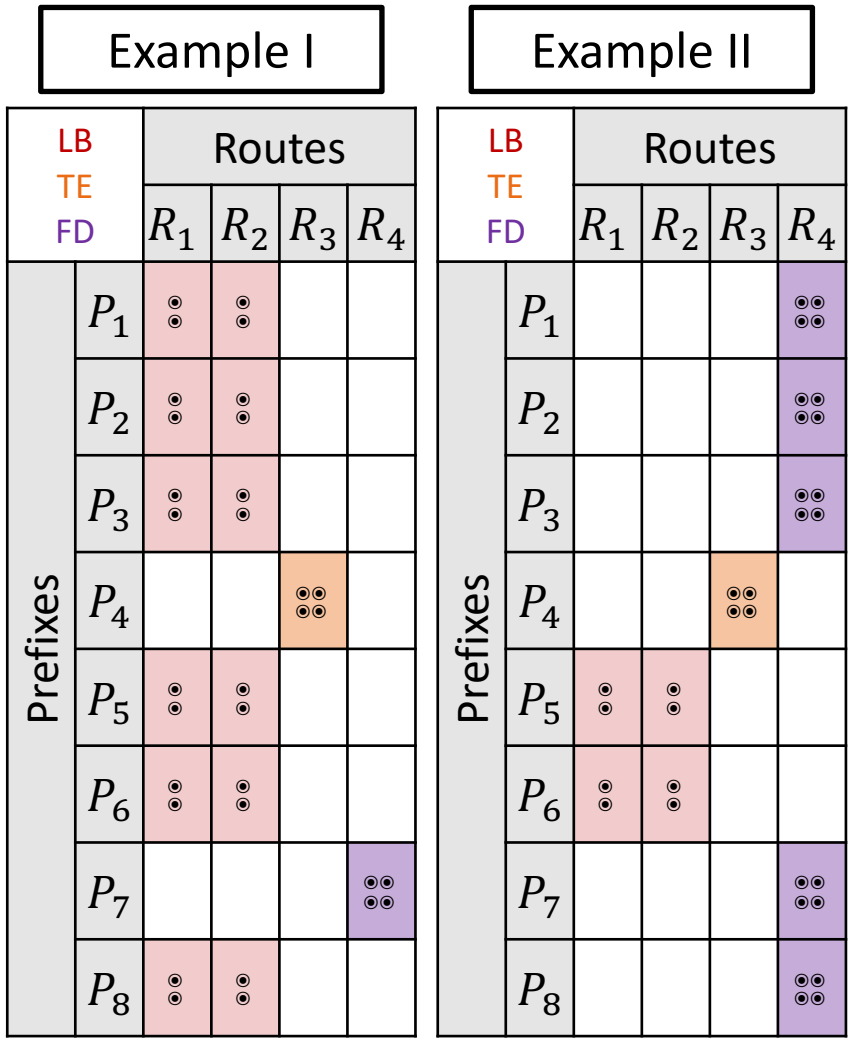
Example I

LB / TE / FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1	◉	◉		
	P_2	◉	◉		
	P_3	◉	◉		
	P_4			◉◉	
	P_5	◉	◉		
	P_6	◉	◉		
	P_7				◉◉
	P_8	◉	◉		

Example II

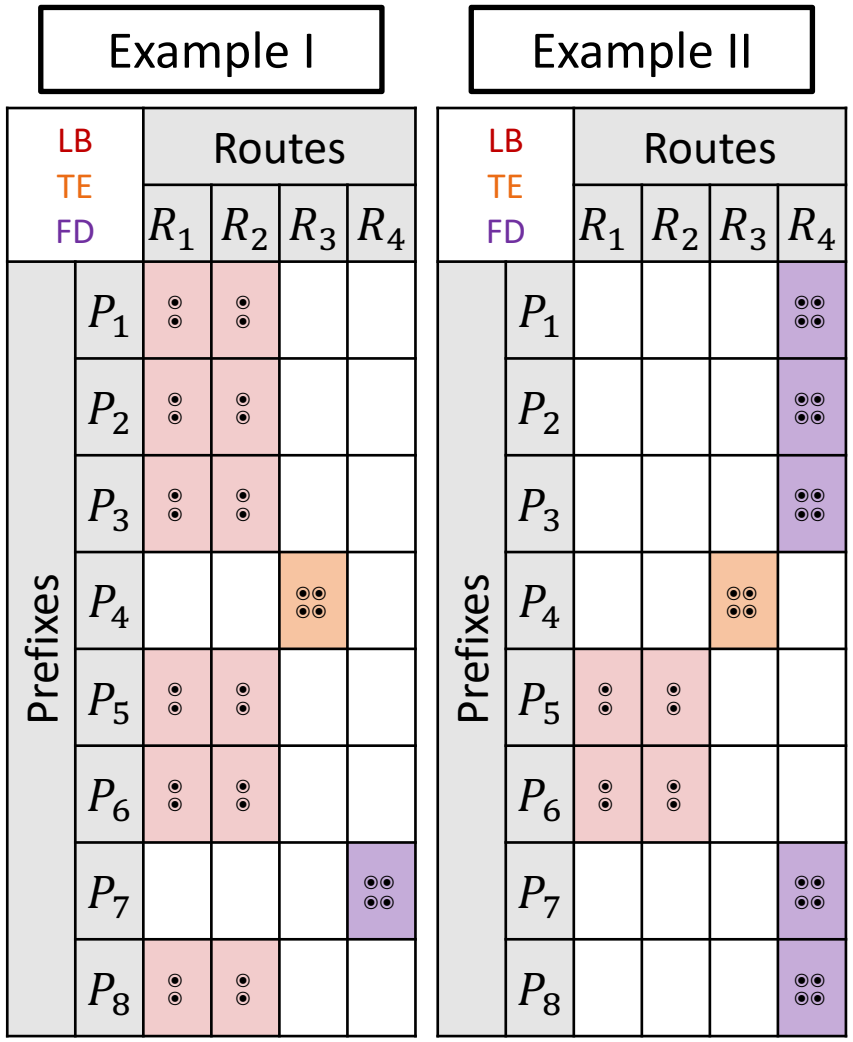
LB / TE / FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1				◉◉
	P_2				◉◉
	P_3				◉◉
	P_4			◉◉	
	P_5	◉	◉		
	P_6	◉	◉		
	P_7				◉◉
	P_8				◉◉

Concluding if FDs occur



Concluding if FDs occur

1. Identify prefixes related to the same routes



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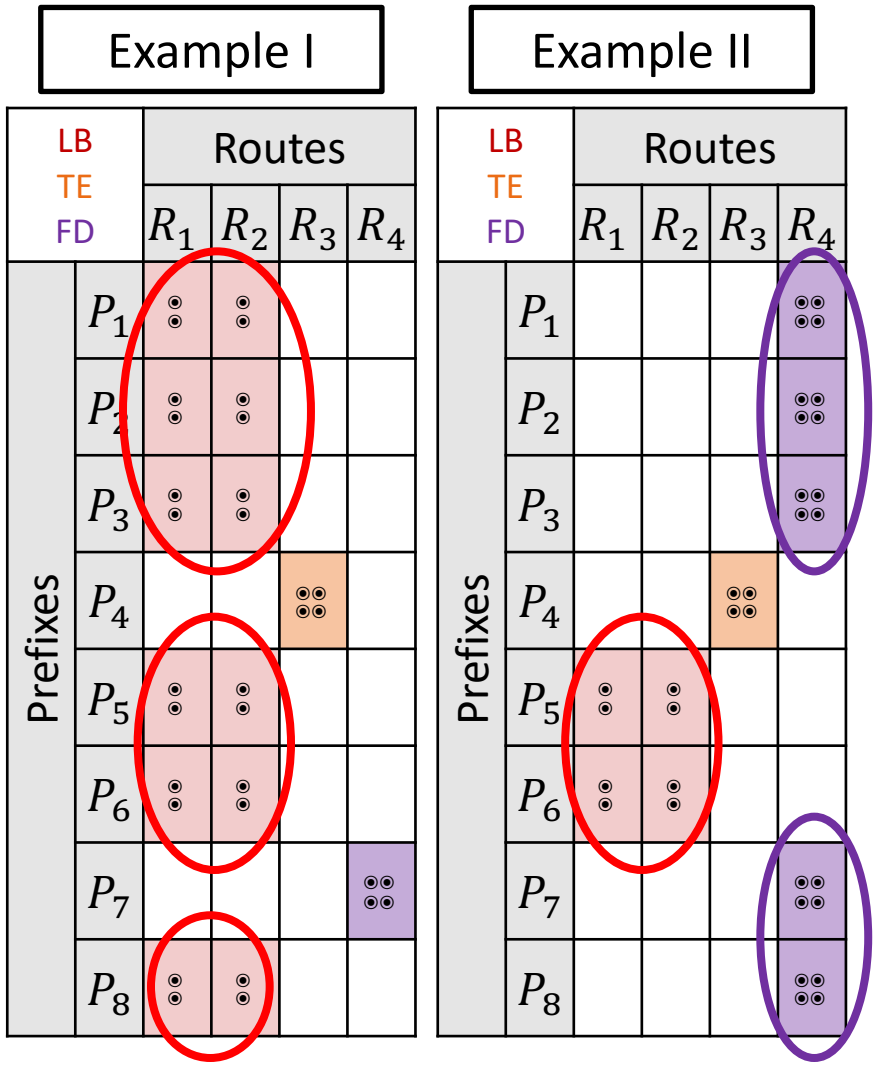
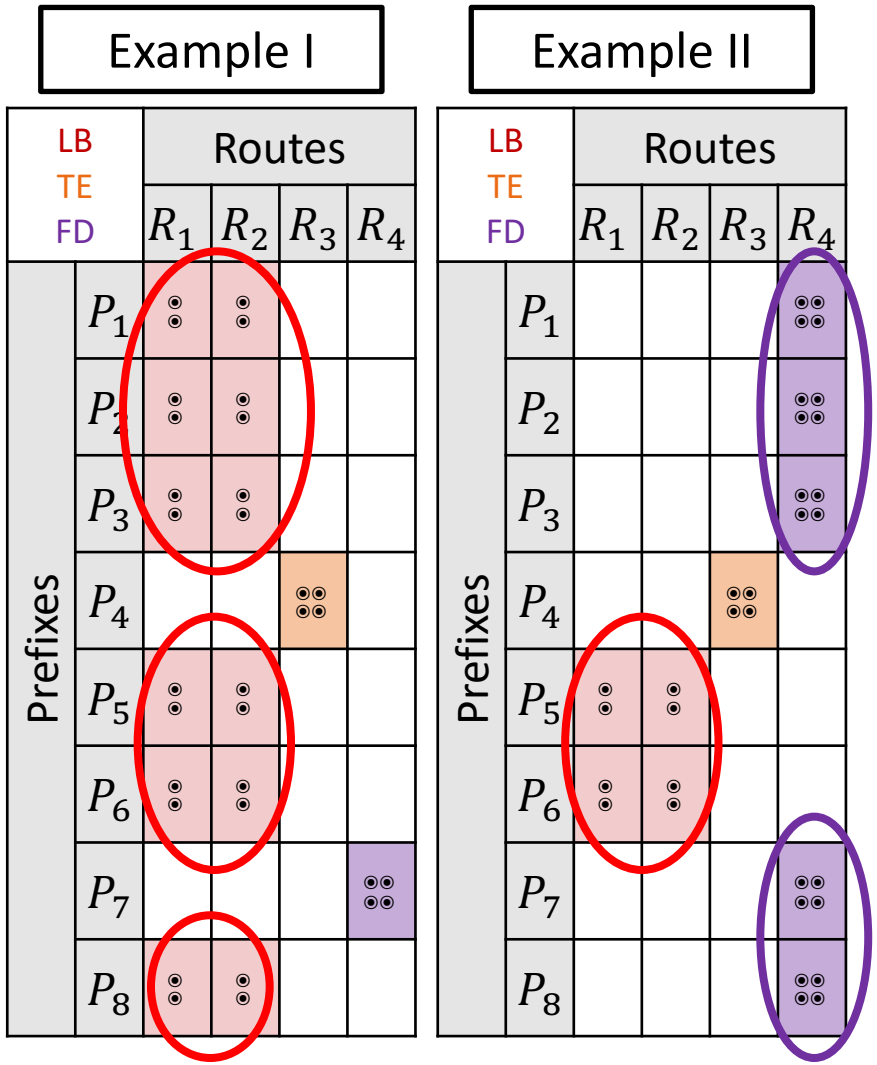


Concluding if FDs occur

1. Identify prefixes related to the same routes
2. Group the related prefixes in sets



Concluding if FDs occur

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Example I

LB TE FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8				
	P_4				
	P_7				

Example II

LB TE FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_7 P_8				
	P_4				
	P_5, P_6				

Concluding if FDs occur

1. Identify prefixes related to the same routes
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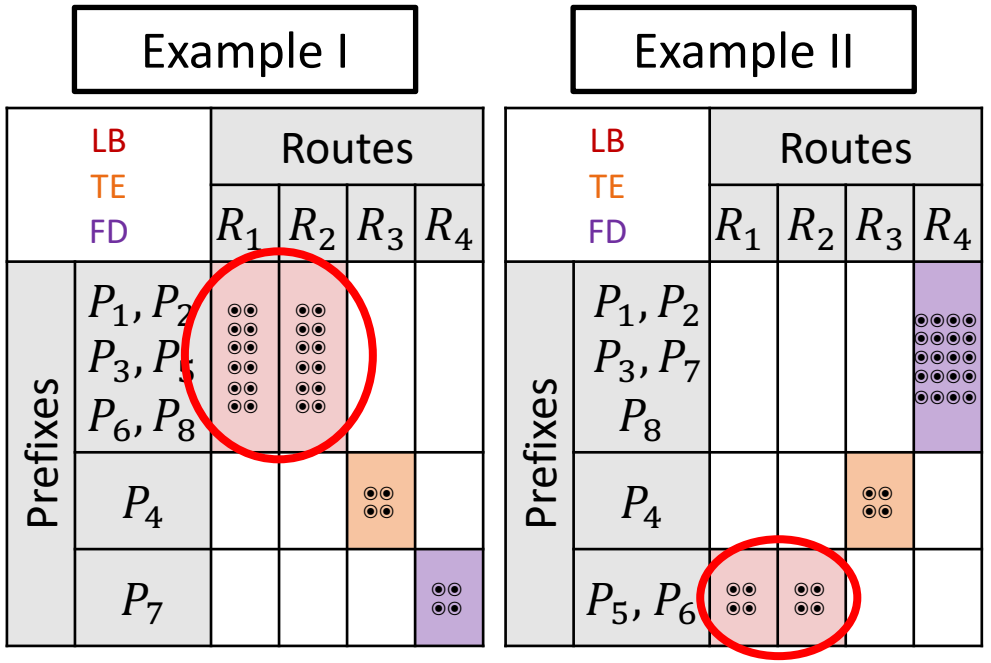
3. Identify the LB set targeting router t



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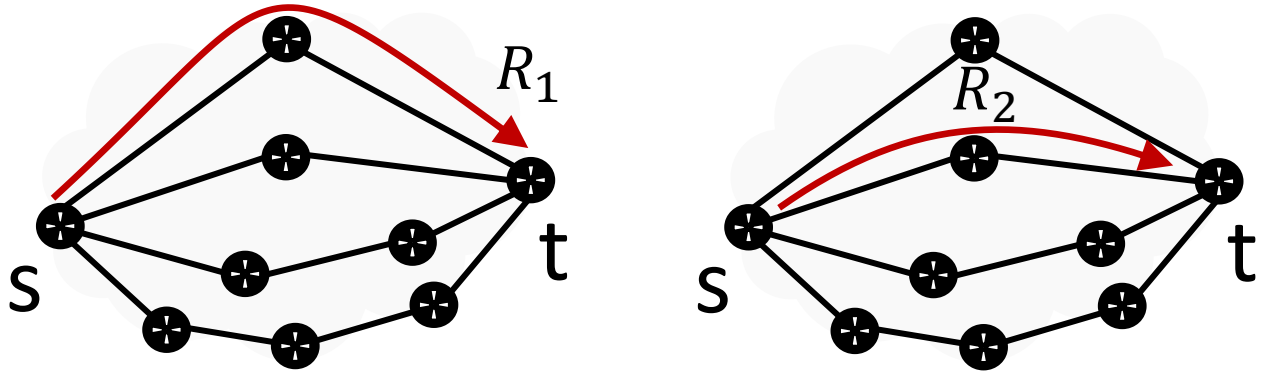

Example I

LB / TE / FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8	⊛	⊛		
	P_4			⊛	
	P_7				⊛

Example II

LB / TE / FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_7 P_8				⊛
	P_4			⊛	
	P_5, P_6	⊛	⊛		

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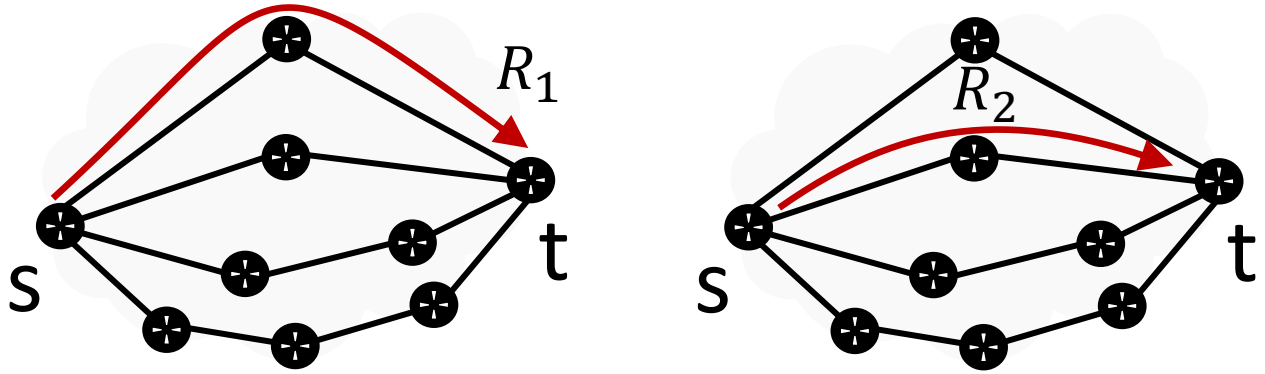

Example I

LB / TE / FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8	⊛	⊛		
	P_4			⊛	
	P_7				⊛

Example II

LB / TE / FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_7 P_8				⊛
	P_4			⊛	
	P_5, P_6	⊛	⊛		

4. Compute #pfxs in each set: (6, 1, 1) and (5, 1, 2)

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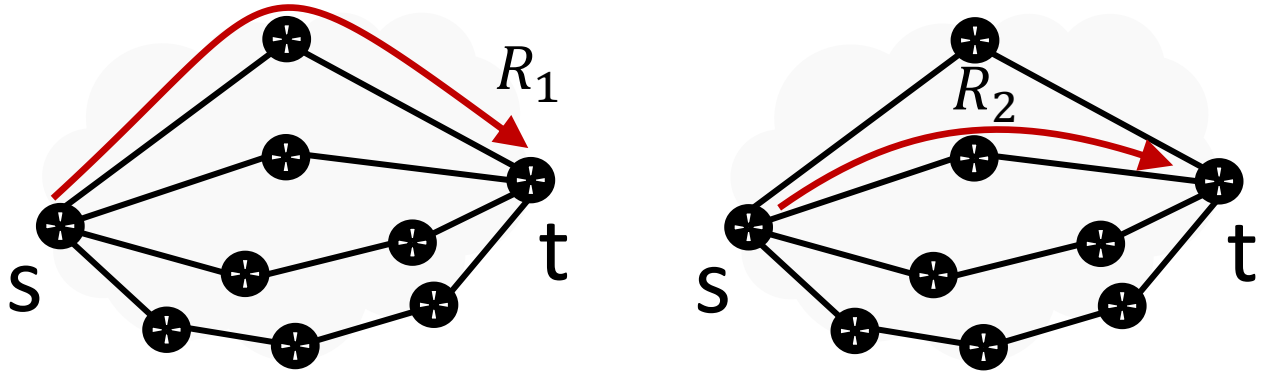

Example I

LB / TE / FD		Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8	●●●●●●	●●●●●●		
	P_4			●●	
	P_7				●●

Example II

LB / TE / FD		Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_7 P_8				●●●●●●
	P_4			●●	
	P_5, P_6	●●	●●		

4. Compute #pfxs in each set: (6, 1, 1) and (5, 1, 2)
5. Turn it into proportions: (0.75, 0.125, 0.125) and (0.625, 0.125, 0.25)

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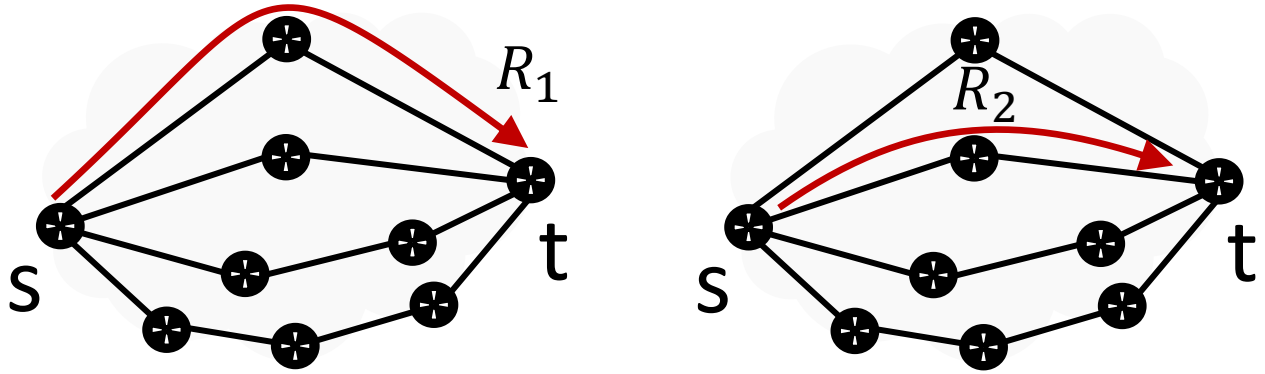

Example I

LB / TE / FD		Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8	●●●●●●	●●●●●●		
	P_4			●●	
	P_7				●●

Example II

LB / TE / FD		Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_7 P_8				●●●●●●
	P_4			●●	
	P_5, P_6	●●	●●		

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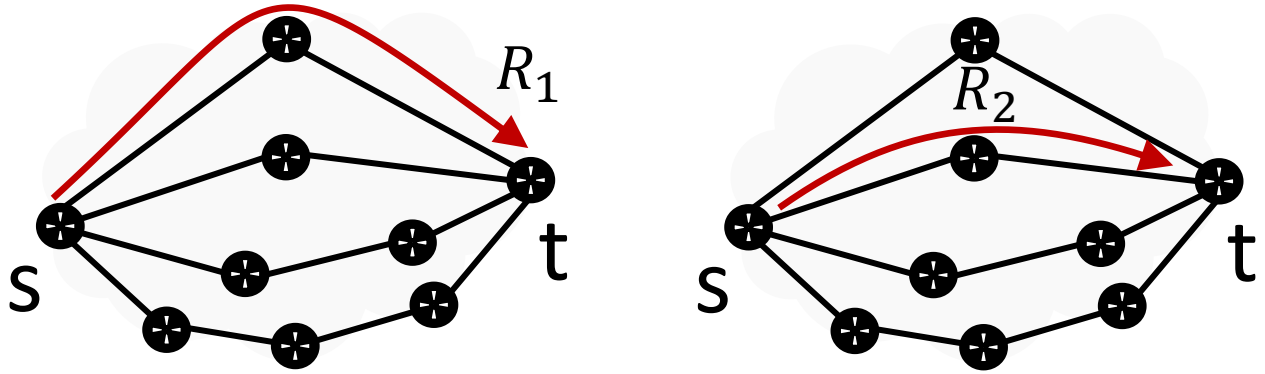

Example I

	LB / TE / FD	Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8	●●●	●●●		
	P_4			●●	
	P_7				●●

Example II

	LB / TE / FD	Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_7 P_8				●●●●●
	P_4			●●	
	P_5, P_6	●●	●●		

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6. Compute the n number of sets ... in this case $n = 3$ for both examples...
7. Conclude that FDs occur if LB is associated to less than $\frac{1}{n} = 0.33$ pfxs...

Concluding if FDs occur

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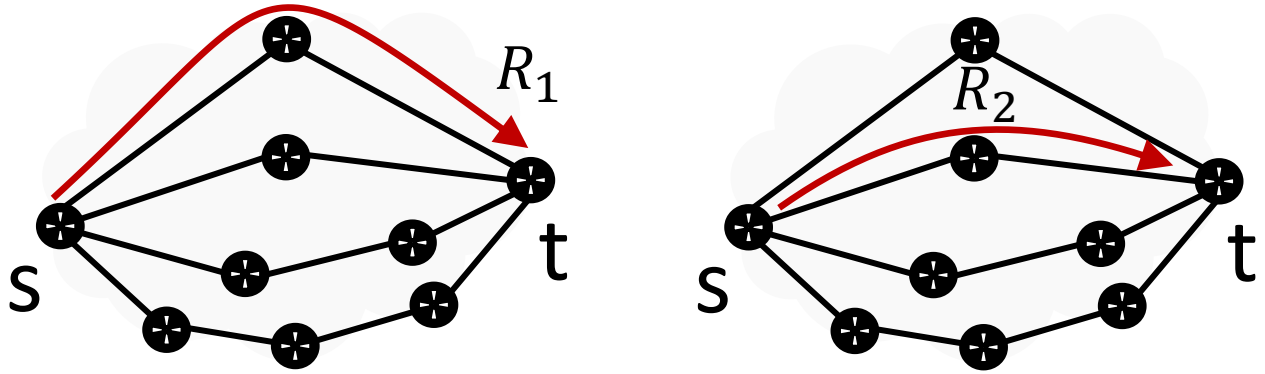

Example I

LB / TE / FD		Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8	●●●	●●●		
	P_4			●●	
	P_7				●●

Example II

LB / TE / FD		Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_7 P_8				●●●●●
	P_4			●●	
	P_5, P_6	●●	●●		

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0.33 < 0.75 ... no FDs and 0.33 > 0.25 ... there are FDs

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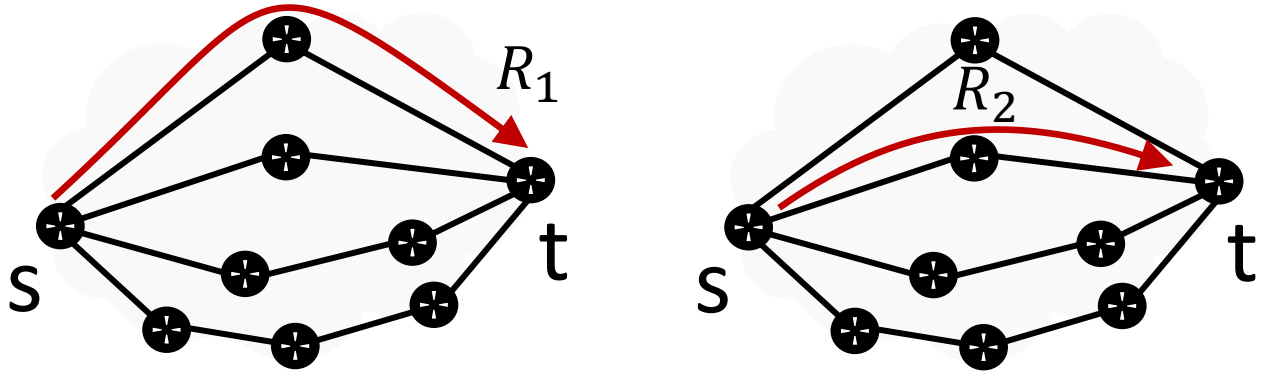


Example I

	LB / TE / FD	Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8	●●●	●●●		
	P_4			●●	
	P_7				●●

Example II

	LB / TE / FD	Routes R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_7 P_8				●●●●●
	P_4			●●	
	P_5, P_6	●●	●●		

4. Compute #pfxs in each set: (6, 1, 1) and (5, 1, 2)

...we are conservative!

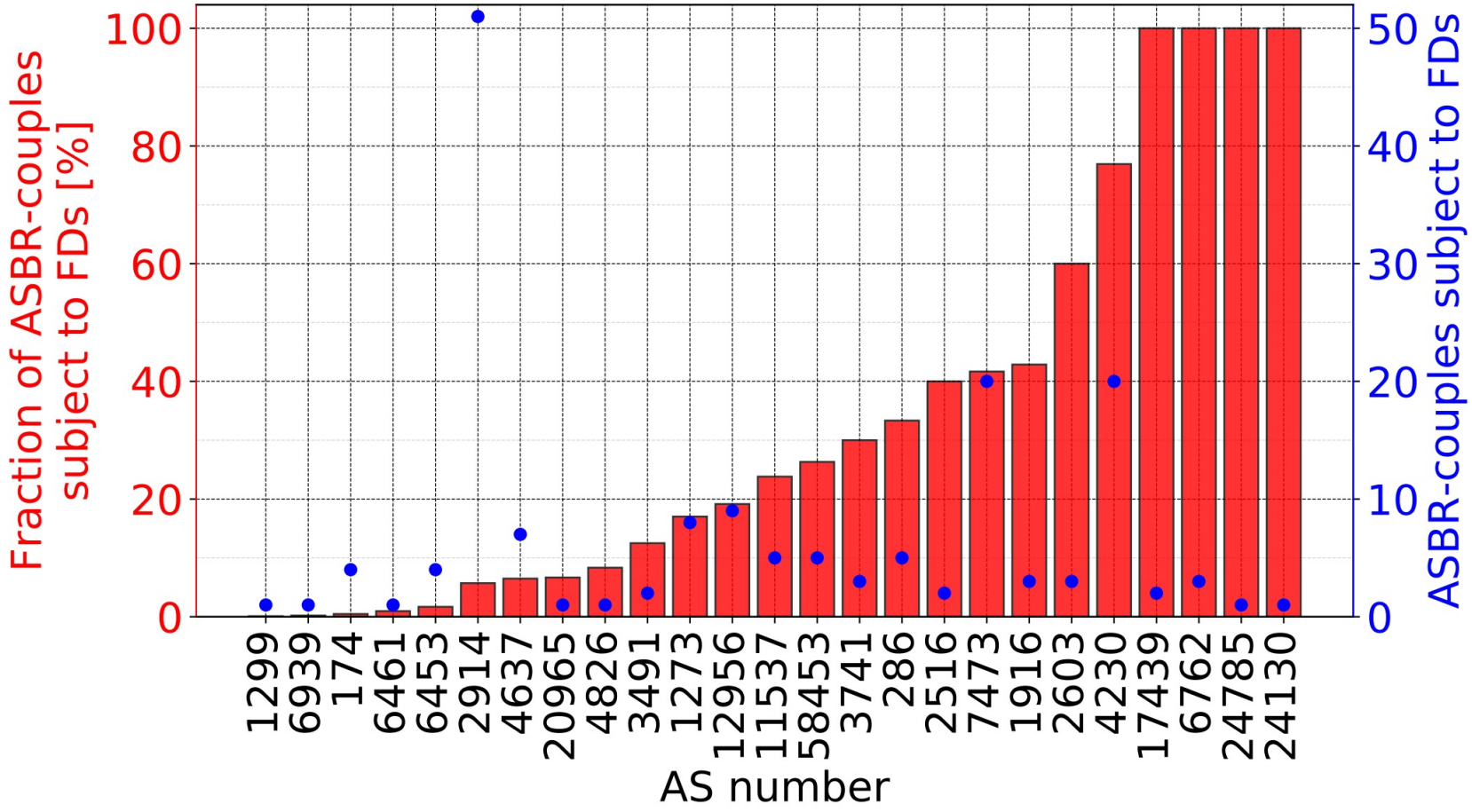
5. Turn it into proportions: (0.75, 0.125, 0.125) and (0.625, 0.125, 0.25)
6. Compute the n number of sets ... in this case $n = 3$ for both examples...
7. Conclude that FDs occur if LB is associated to less than $\frac{1}{n} = 0.33$ pfxs...

0.33 < 0.75 ... no FDs and 0.33 > 0.25 ... there are FDs

Our experiments

In the wild, FDs are a thing!

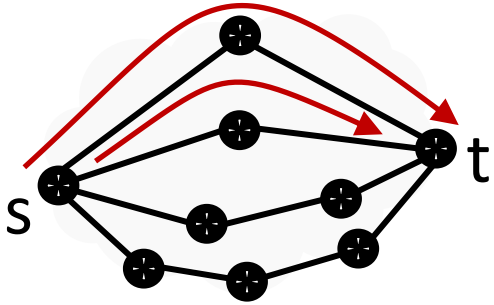
- We measure from 100 VPs
- We look for FDs between AS border routers (ASBRs) and request #pfxs > 100
- We find FDs in 25/54 ASs, with an heterogeneous distribution



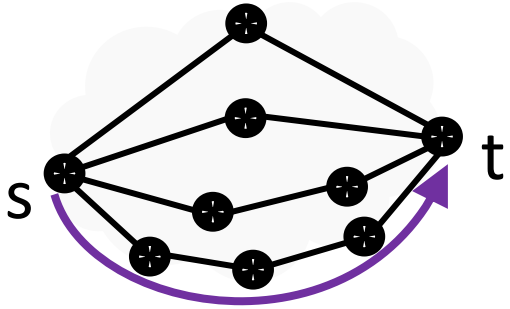
Digging into the results: a binary pattern

- According to the FDs we found, all traffic detours or none does

LB TE FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_4 P_5, P_6 P_7, P_8	●● ●● ●● ●● ●●	●● ●● ●● ●● ●●		



LB TE FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_4 P_5, P_6 P_7, P_8				●●● ●●● ●●● ●●●



...in other words...

No cases like this!

LB TE, FD		Routes			
		R_1	R_2	R_3	R_4
Prefixes	P_1, P_2 P_3, P_5 P_6, P_8	●● ●● ●● ●● ●●	●● ●● ●● ●● ●●		
	P_4			●●	
	P_7				●●

Conclusion

- Routing inconsistencies produce FDs
- Our measurements show that FDs exist
- FDs are distributed heterogeneously and have a binary pattern