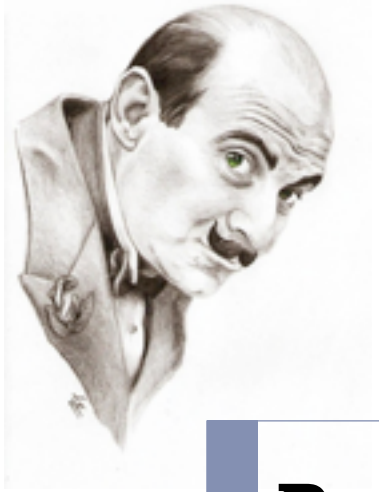

PoiRoot: Investigating the Root Cause of Interdomain Path Changes

Umar Javed[*], Italo Cunha[^], **David Choffnes**[*#], Ethan Katz-Bassett[$], Tom Anderson[*], Arvind Krishnamurthy[*]

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The case of the missing trigger

- BGP: the glue that holds the Internet together

- When paths change, bad things can happen
  - 100ms or more additional user latency caused by interdomain path changes 40% of the time (Google, Zhu et al. '12)
  - 50% of unintelligible VoIP samples caused by a BGP update (Kushman et al. '07)

- When bad things happen, who do you blame?

Root cause of interdomain path changes

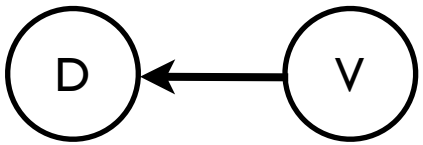
- Goal: Find the network triggering a BGP path change
- Challenge: BGP is an information-*hiding* protocol
- Our contributions
  - New model for path change propagation
  - Algorithm for identifying the root cause of an arbitrary change
  - Evaluation using controlled experiments on real Internet routes

Outline

- Intro
- Motivation
- Root Cause Isolation
- System & Evaluation

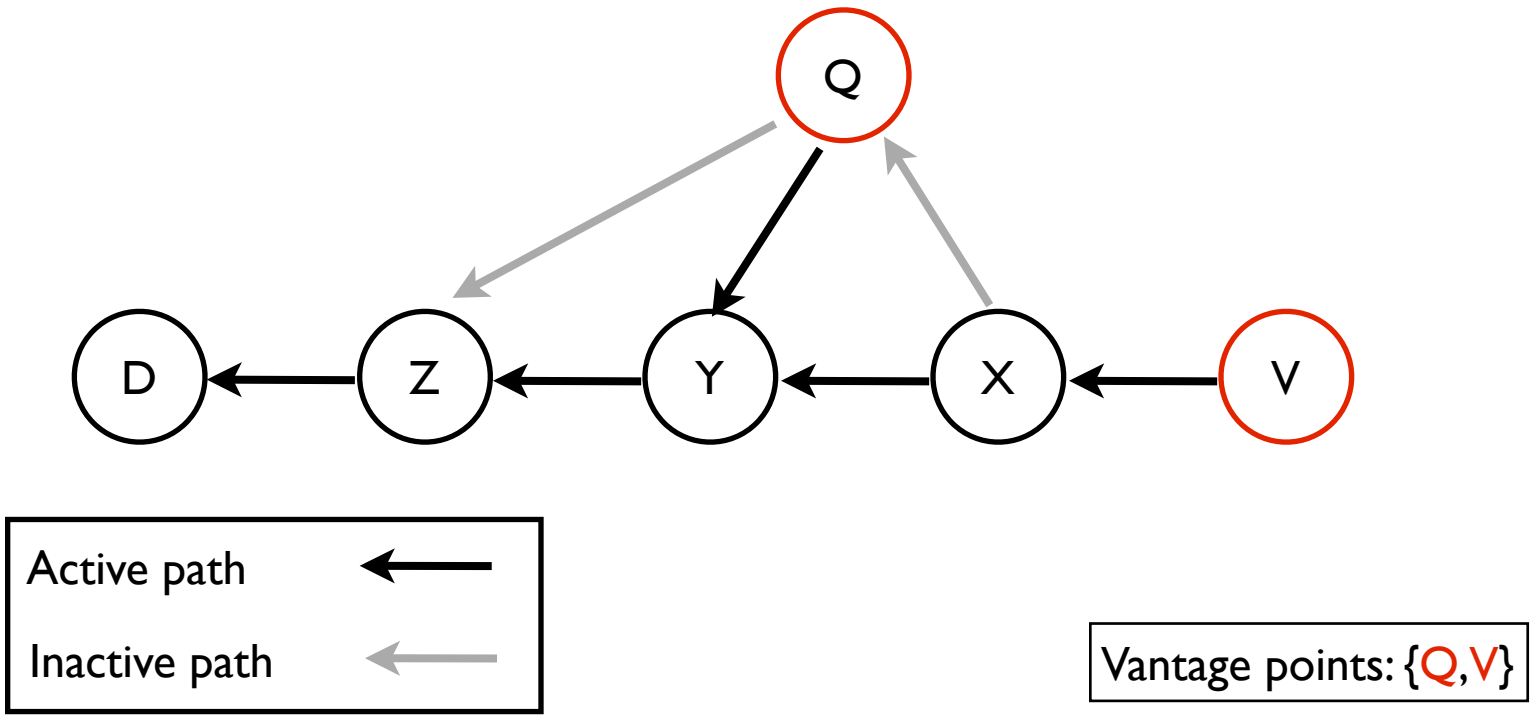
Assumptions in this talk

- Consider a routing toward a single prefix, owned by AS D
  - Path changes for D occur one at a time
- Model ASN as a single node
  - Approaches apply to finer granularity
- Vantage point: Location at which we measure a path to D
  - BGP feed
  - Traceroute (forward and reverse)



Approach from previous work

- Feldmann et al. '04, Caesar et al. '03
  - Key assumption: root cause is on either the **n**ew **o**r **o**ld **p**ath (NOOP)
  - Intersection-based approach



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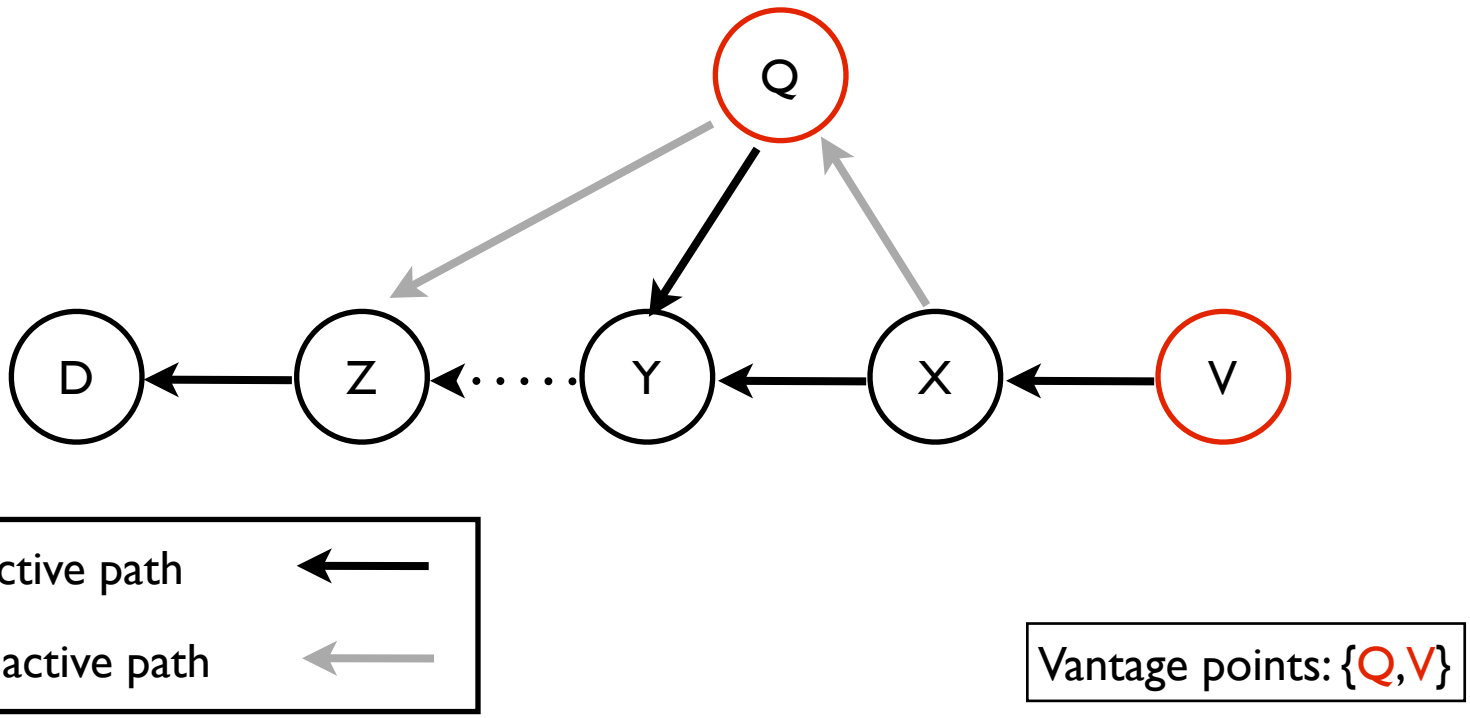

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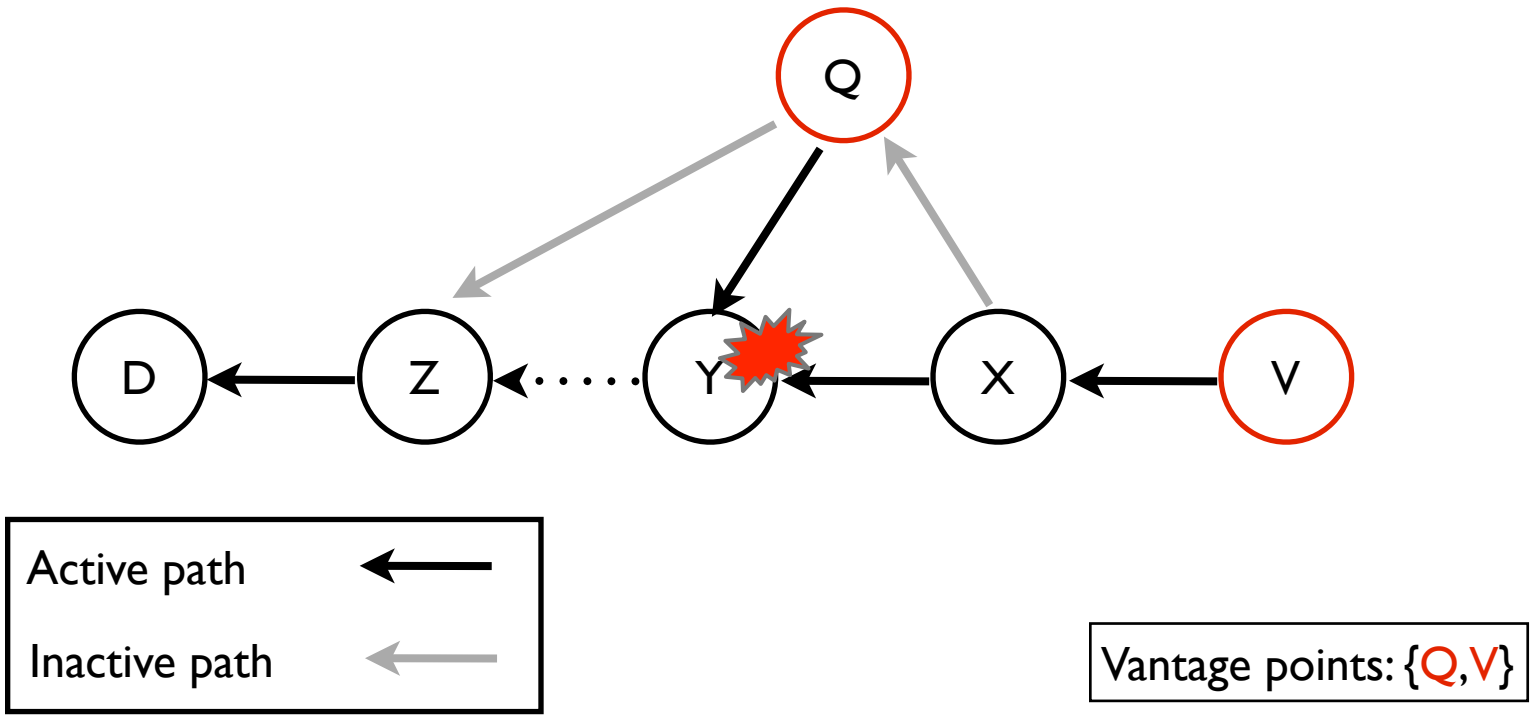

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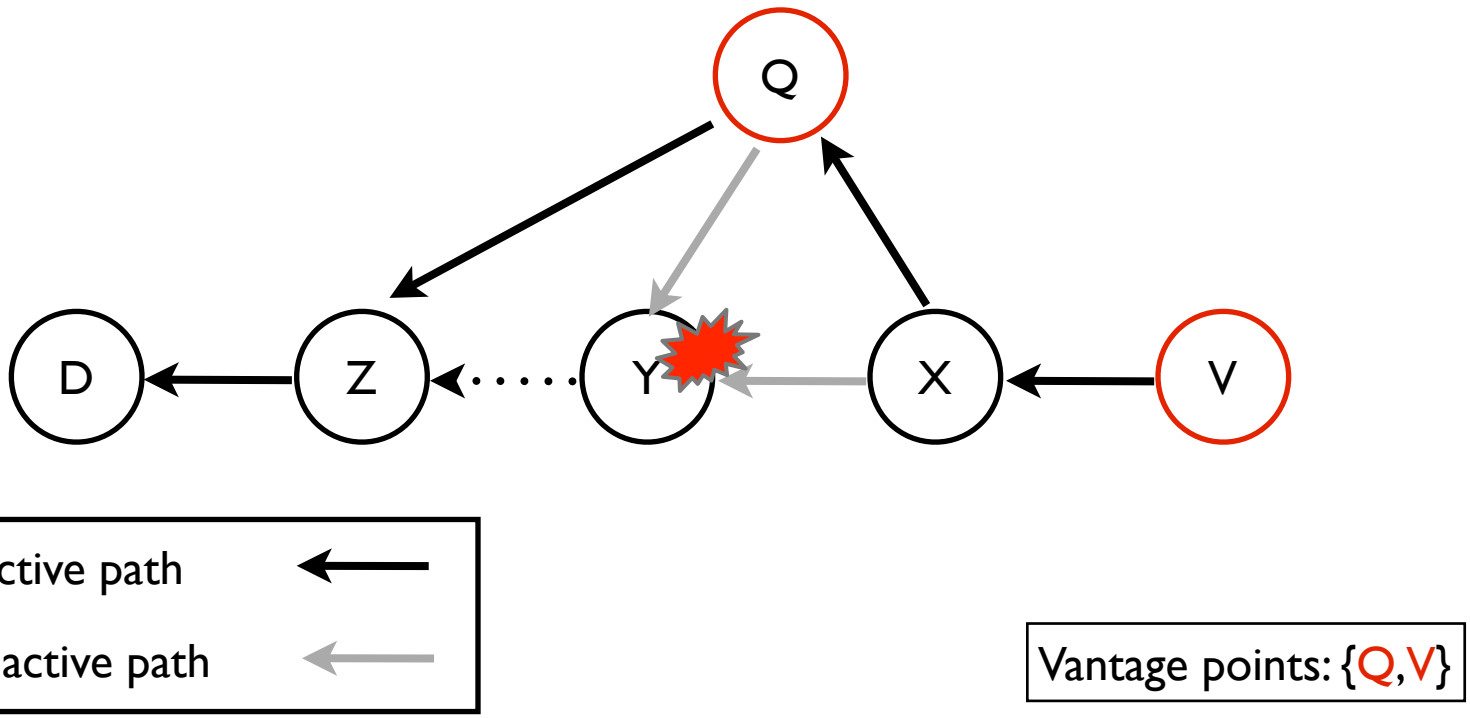

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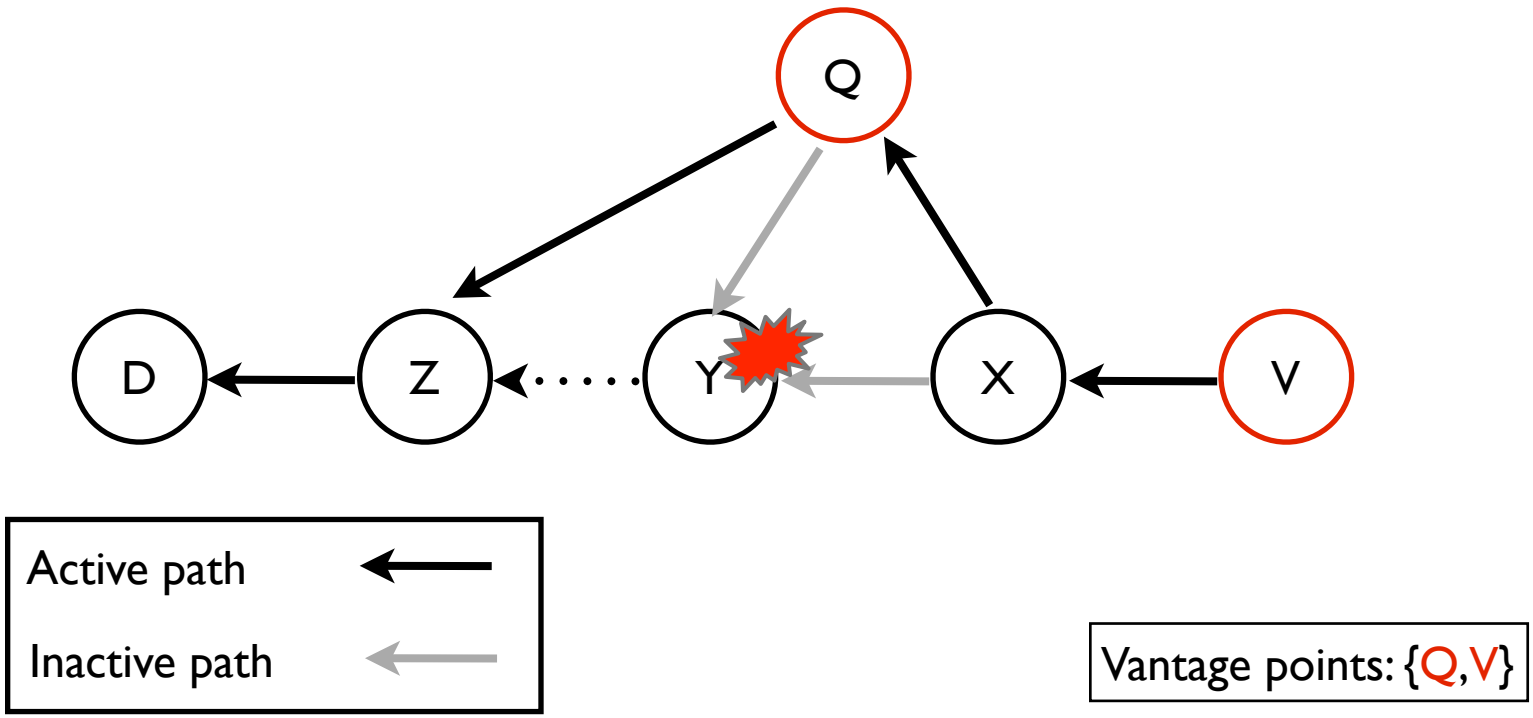
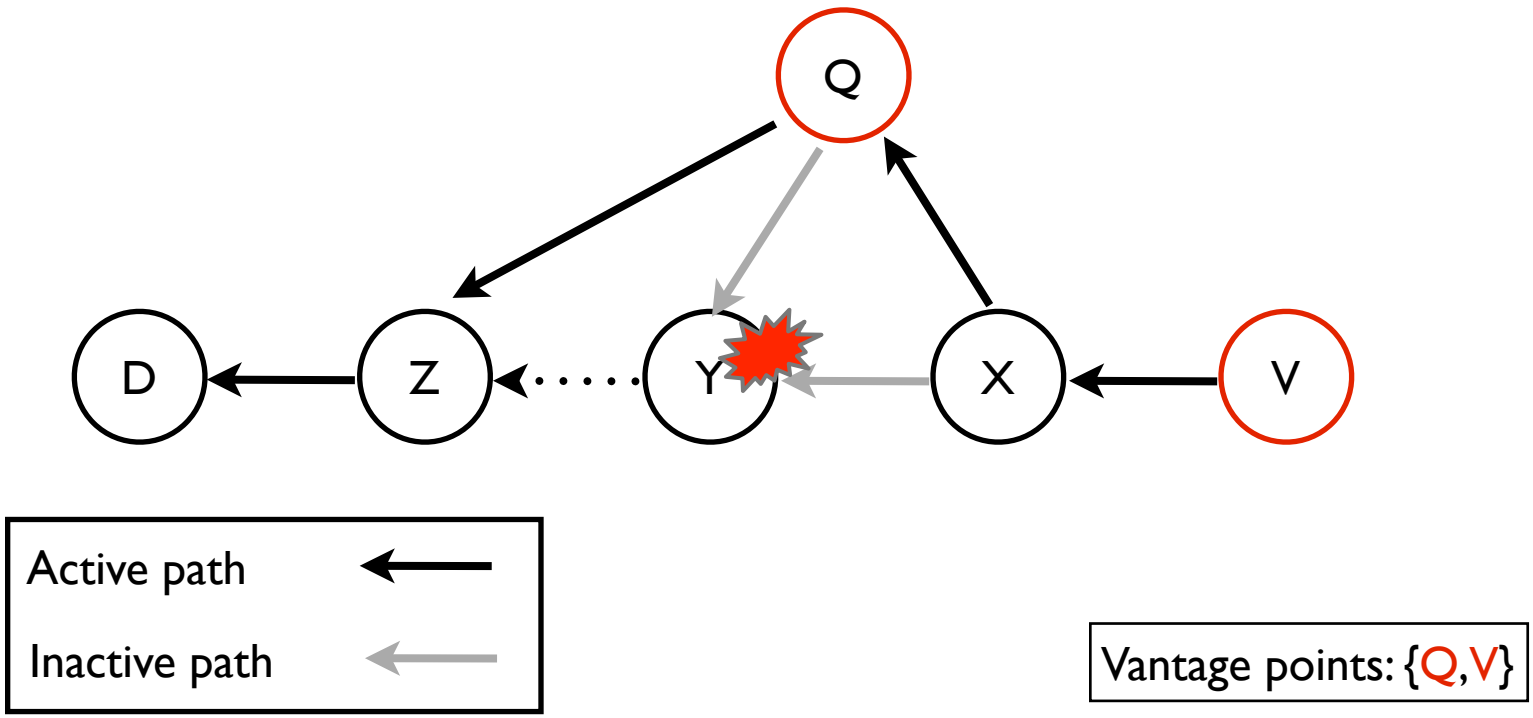
- NOOP algorithm



Approach from previous work

- NOOP algorithm
  - Union of all old and new paths: {Q,V,X,Y,Z}



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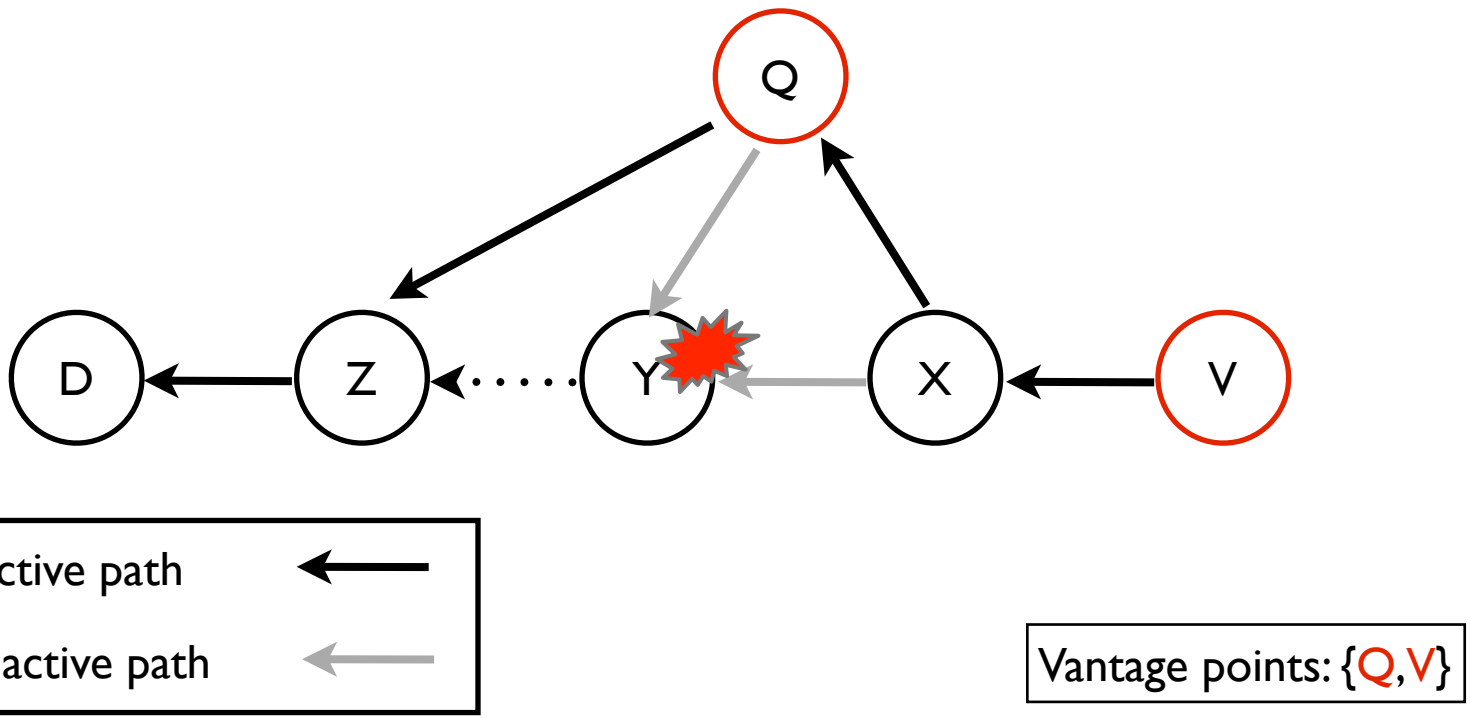
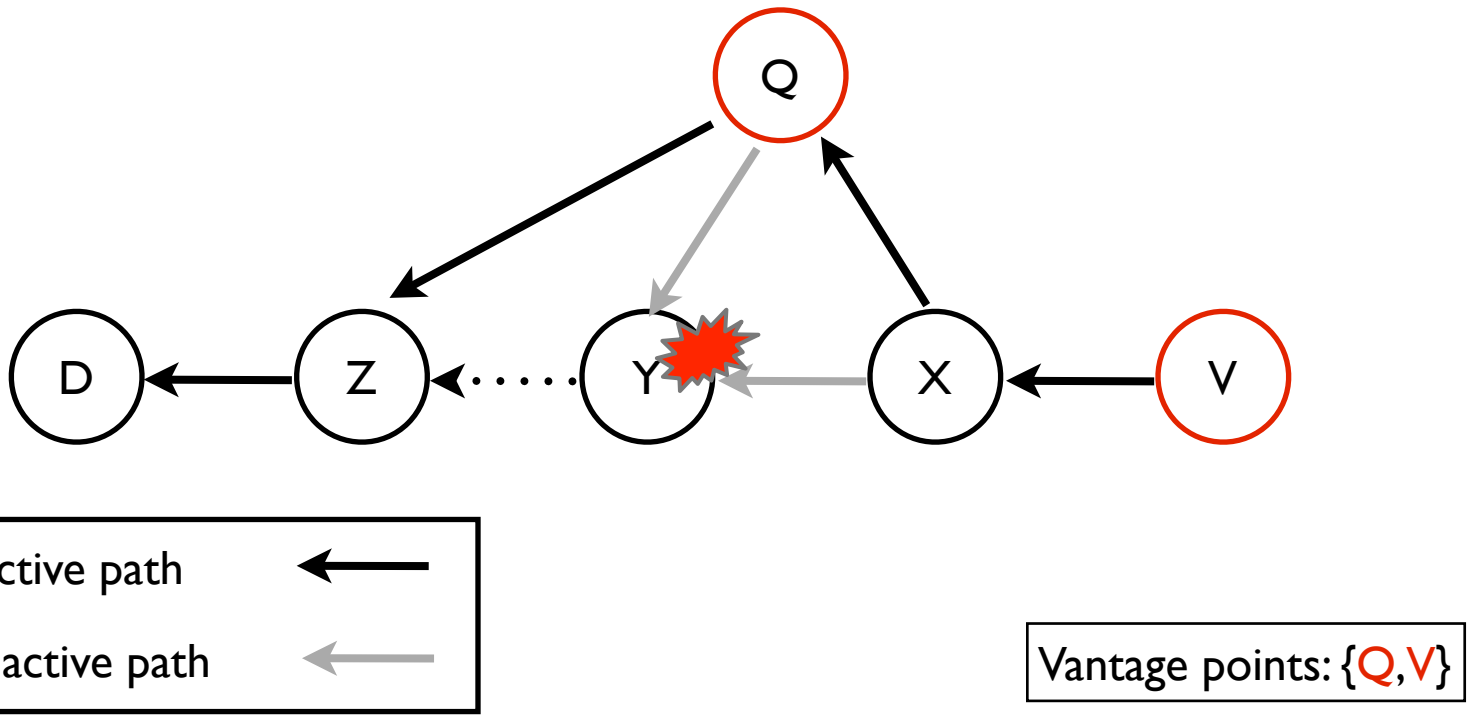
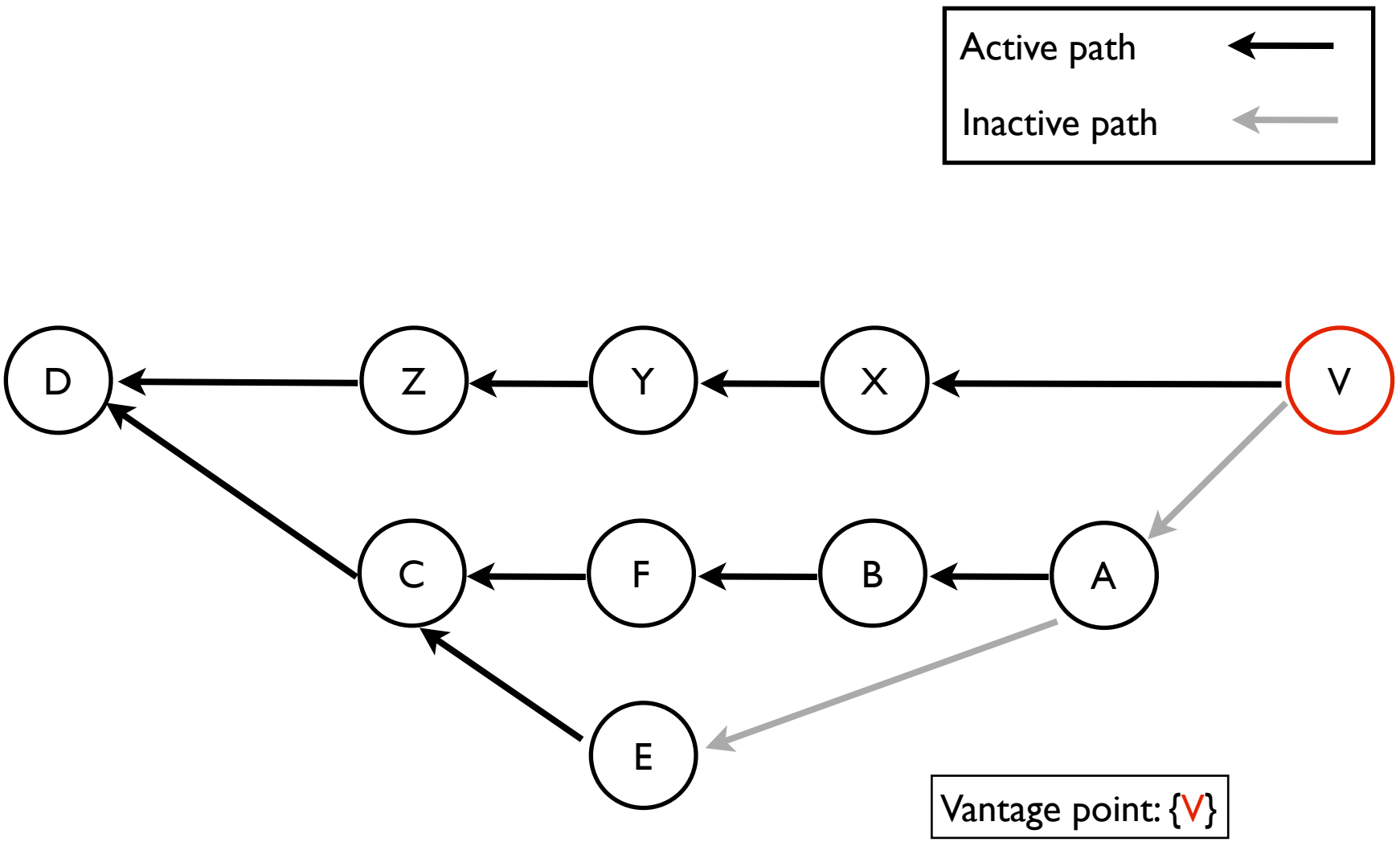


Approach from previous work

- NOOP algorithm
  - Union of all old and new paths: {Q,V,X,Y,Z}
  - Intersection of all old and new paths: {Q,V,X,Z}
  - Root cause is U - ∩: {Y}



The case of the induced path change



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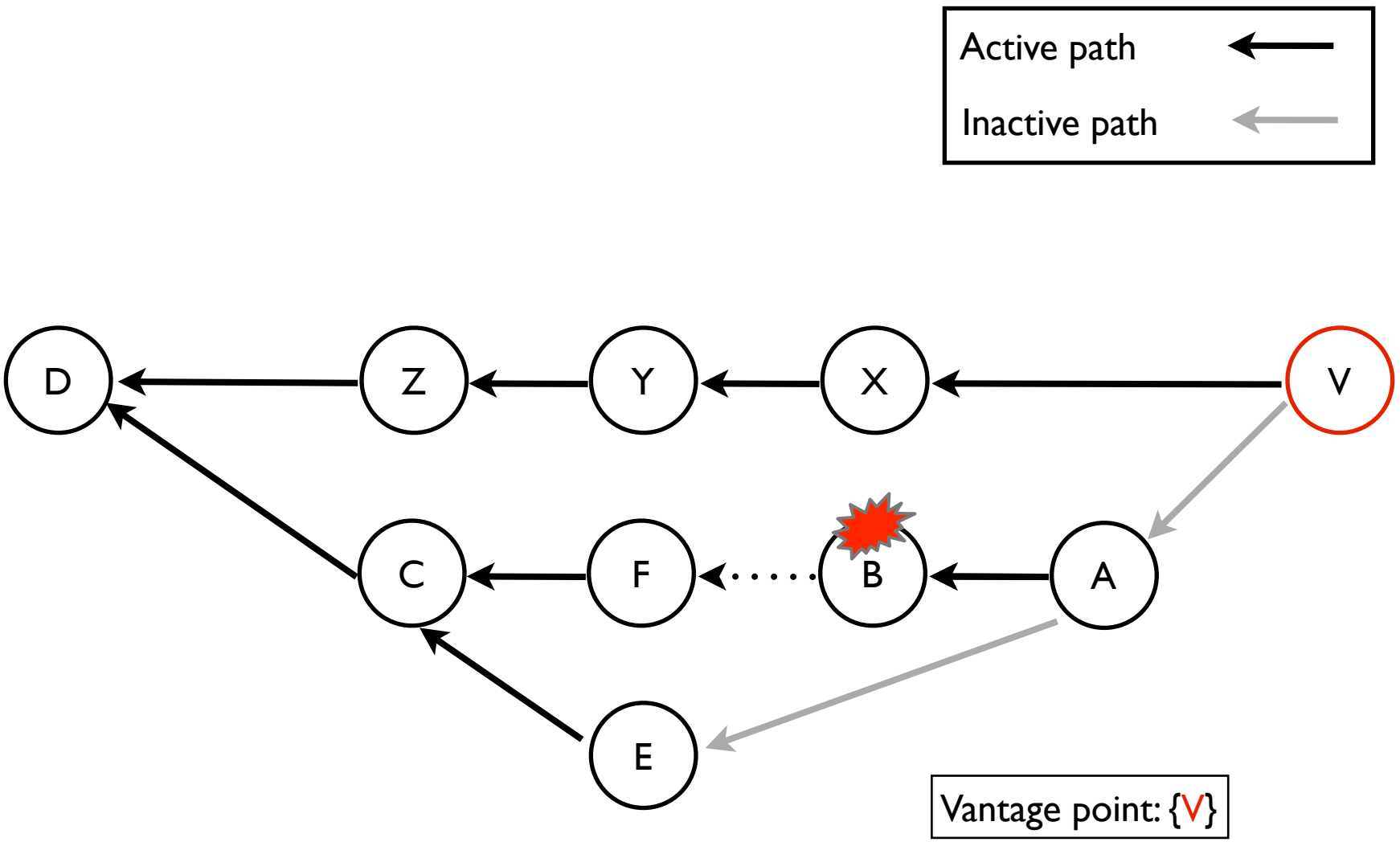

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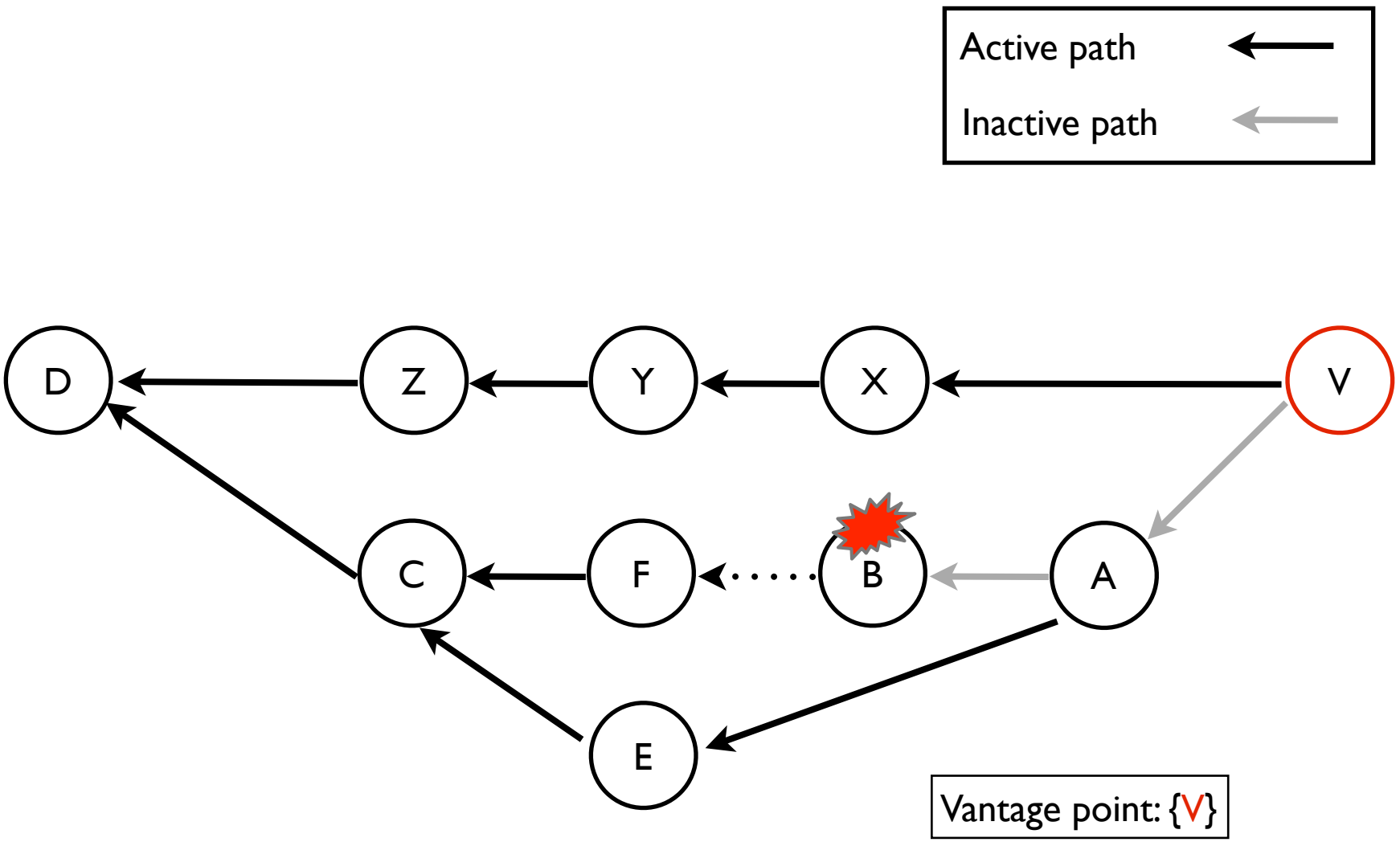

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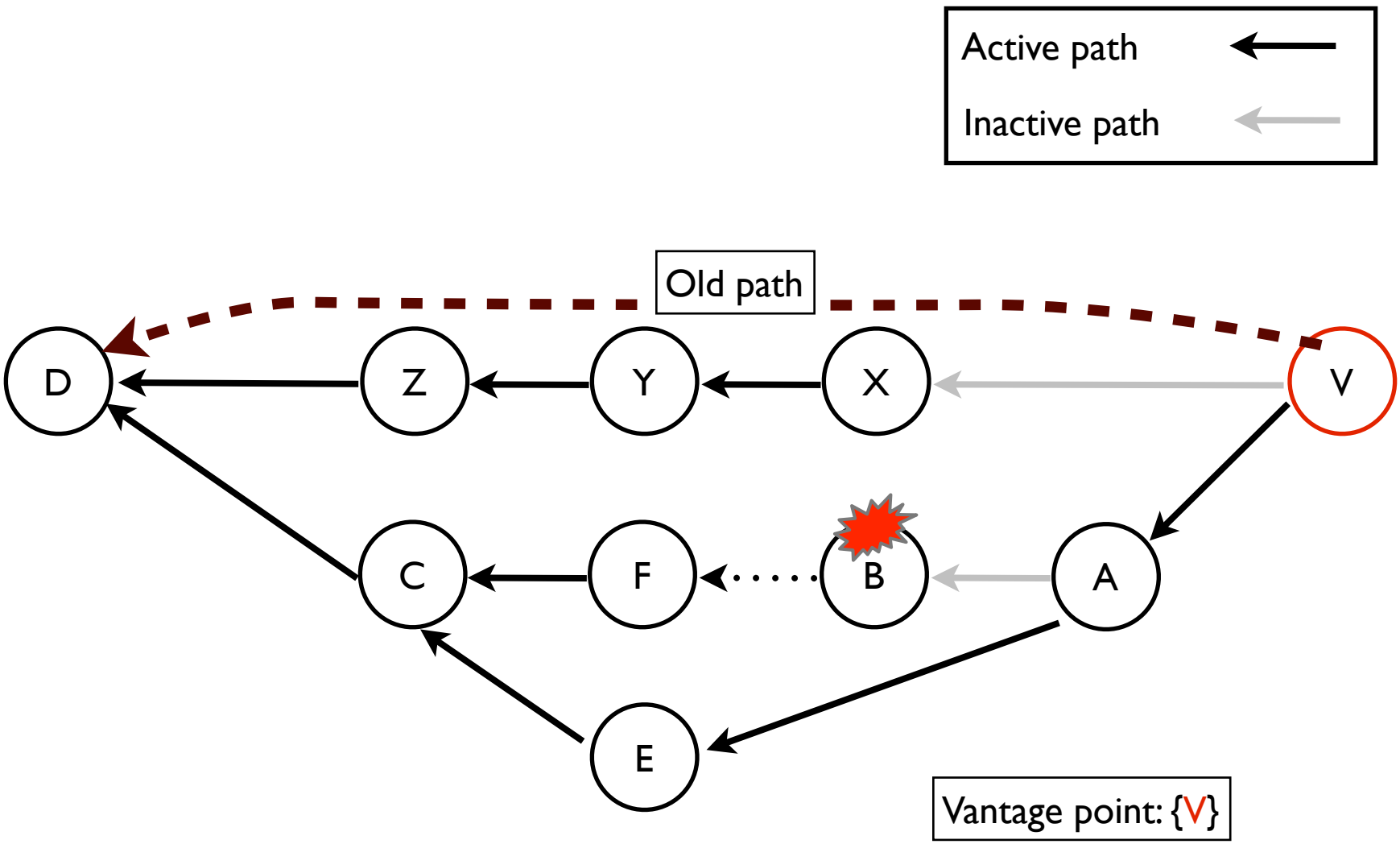

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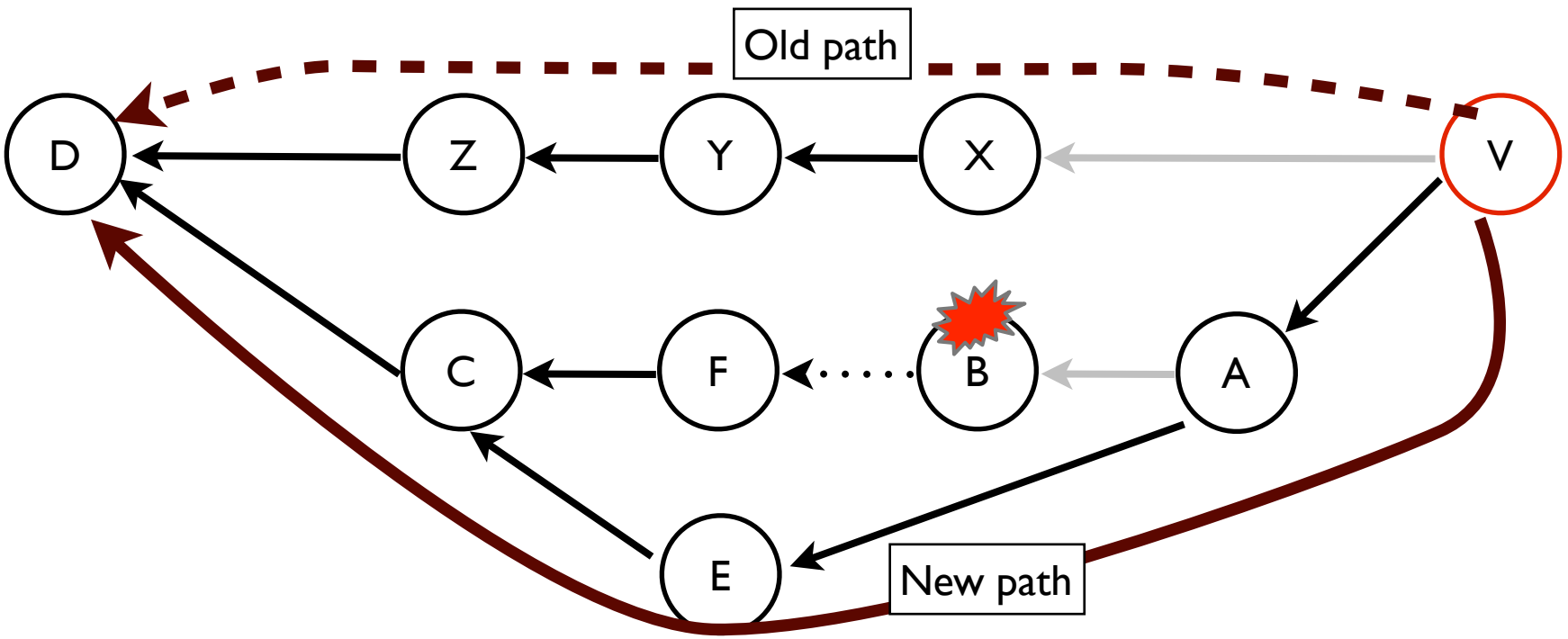
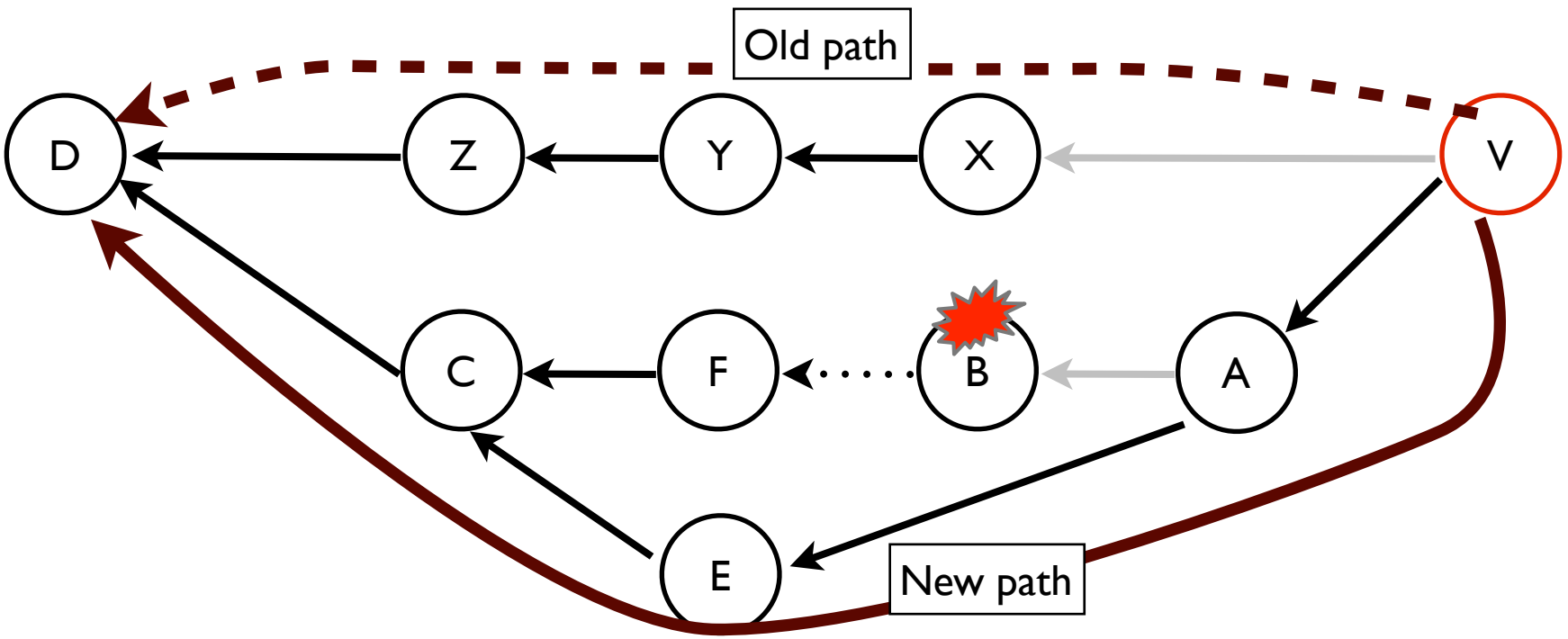


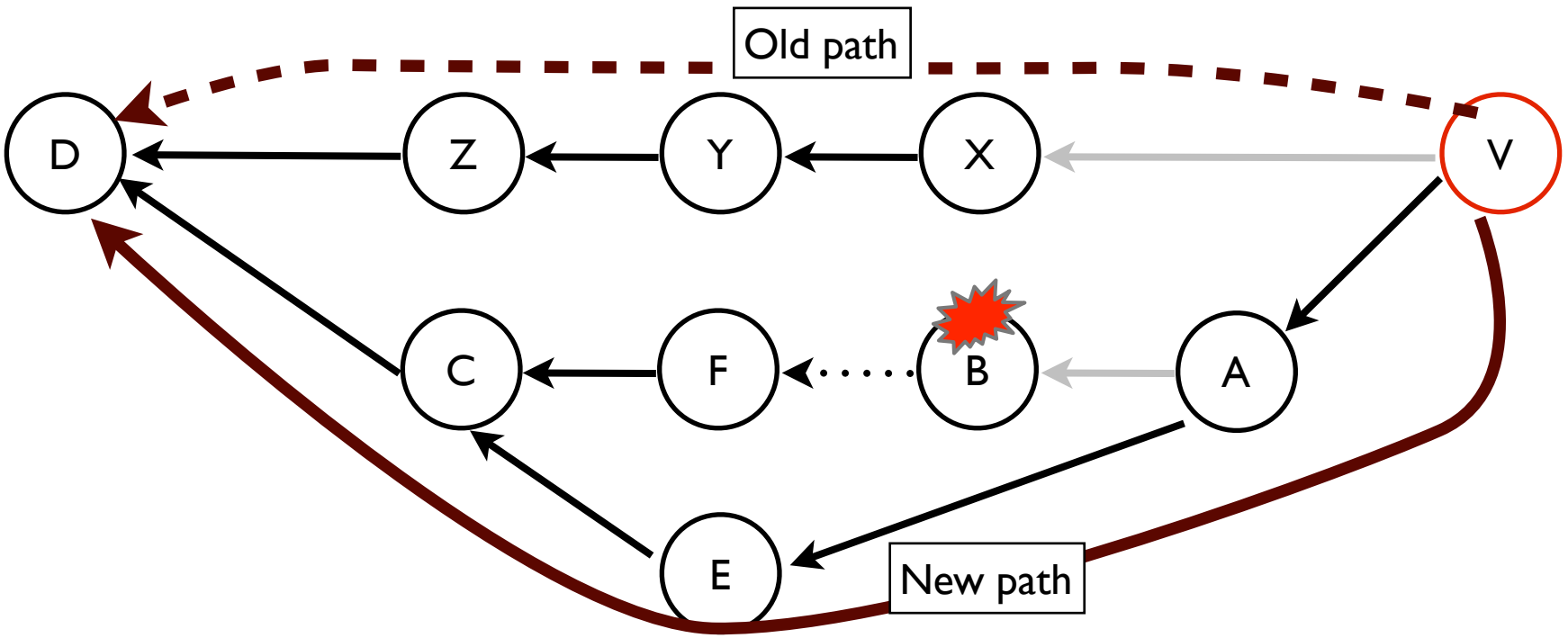
The case of the induced path change

- Root cause (**B**) neither on old or new path!



The case of the induced path change

- Root cause (**B**) neither on old or new path!
  - Need to revisit assumptions and model of path changes



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PoiRoot: Revisiting assumptions

- Theory of candidate ASes responsible for a change
  - Policy (i.e., localPref) trumps path length
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  - We know this is wrong. Do we have to consider all ASes?
  - No, we prove the root cause can also be:
    - Any AS on old paths from ASes in new path from VP
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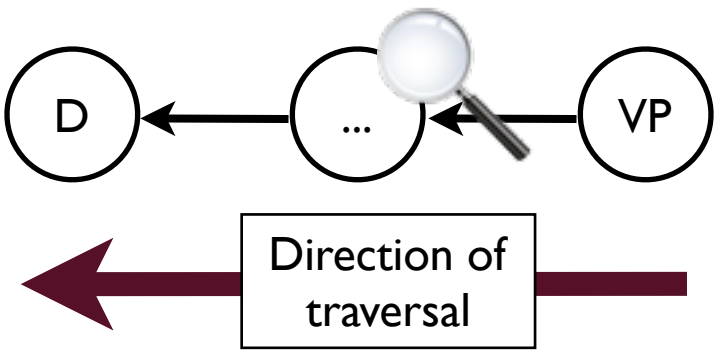
For now, let's assume I can obtain this.

PoiRoot: Theory in action

- Model tells us which networks *may* be root cause in general

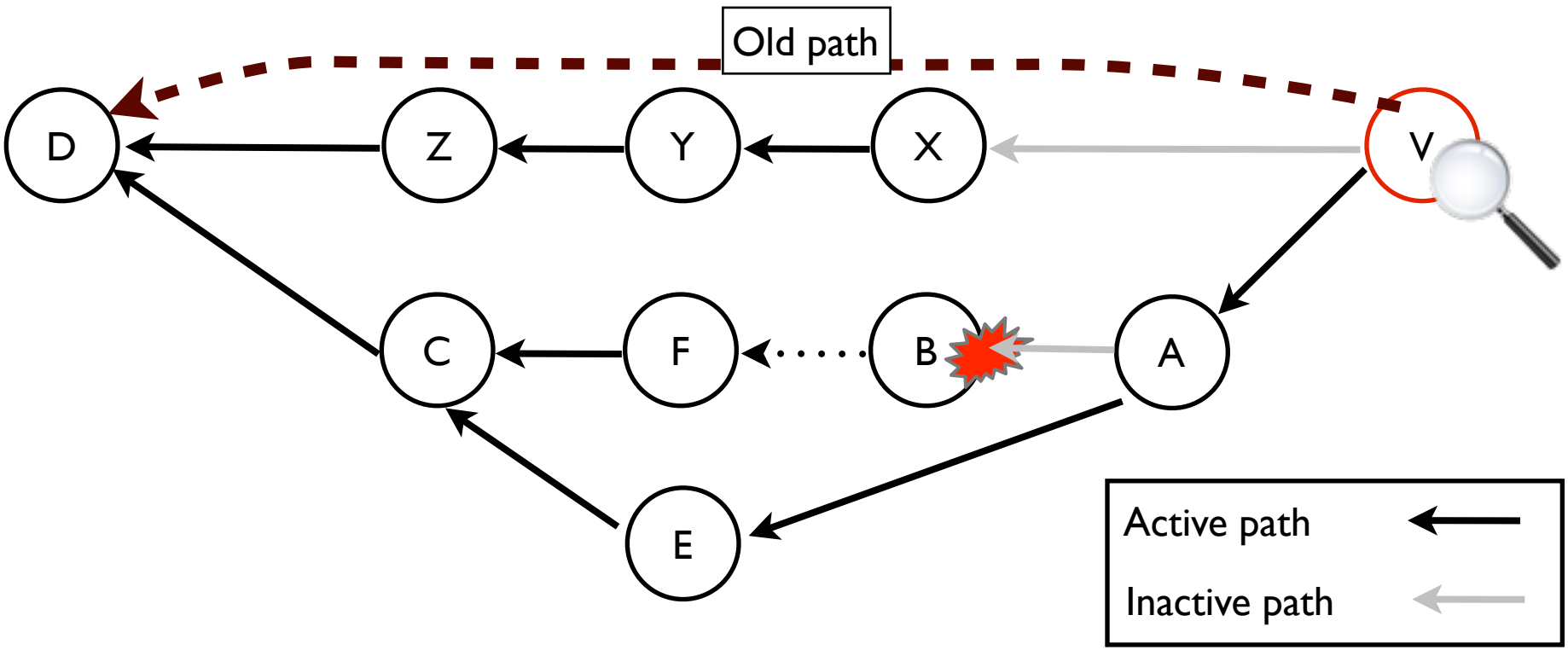
- Algorithm to identify cause of *specific* change
  - Visit all ASes in candidate set
  - Move from VP toward D (DFS traversal)
  - Eliminate ASes that cannot the root cause



Let's walk through an example

PoiRoot: Recursion

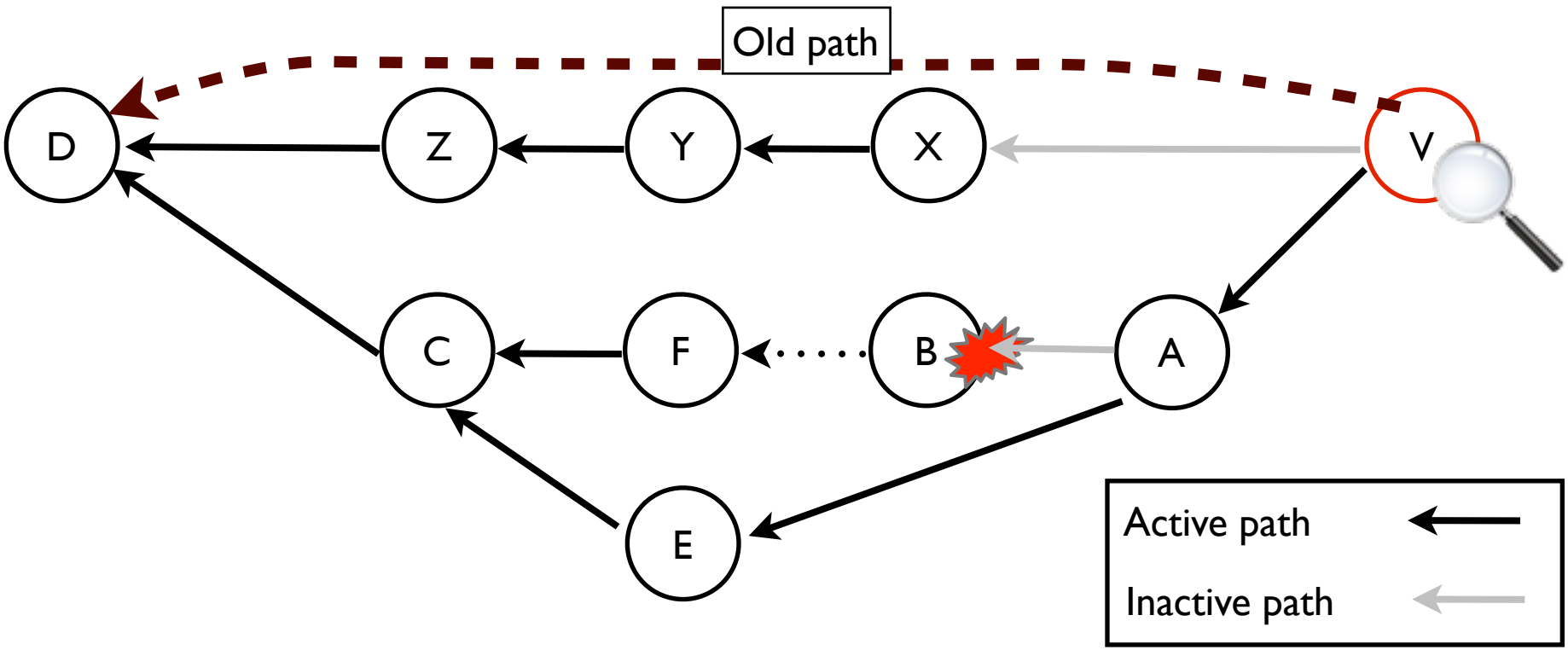
- Start at V
  - Check ASes on old path O(V)
  - After reaching D, check ASes on new path N(V)



PoiRoot: Recursion

Axiom 1:

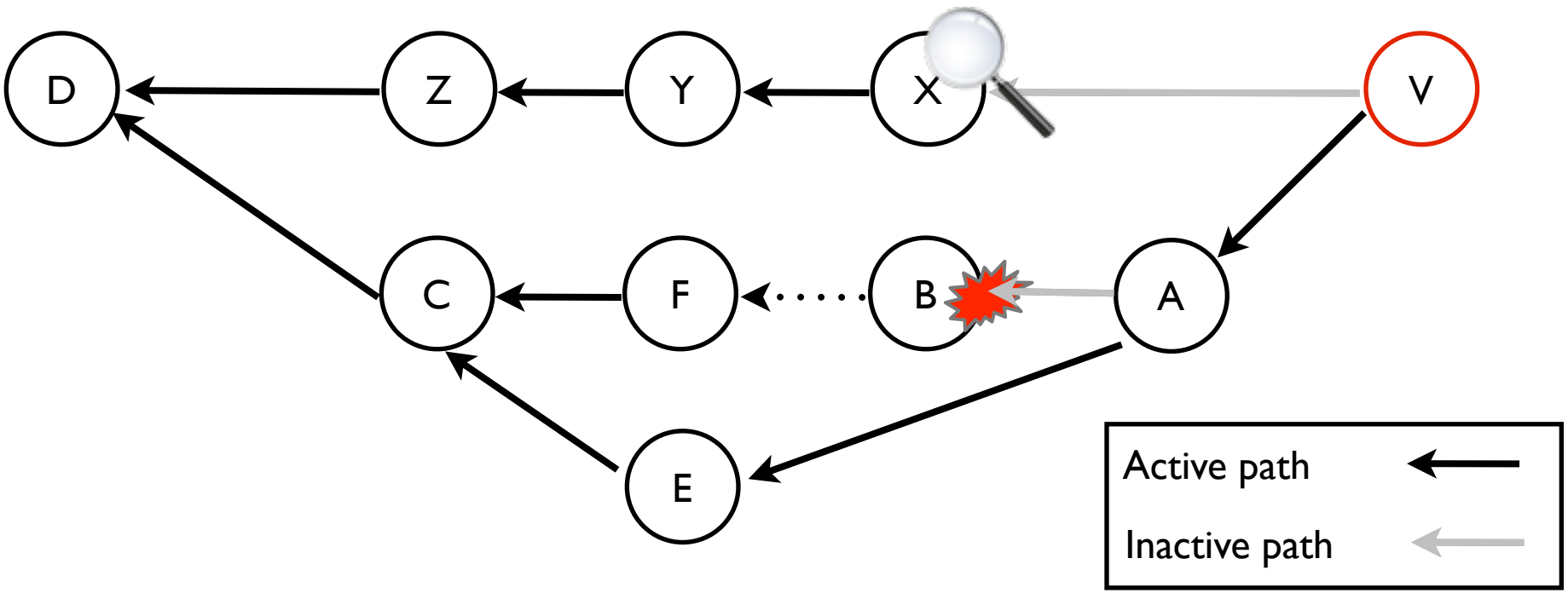
- If O(V) != N(V),V **may be** the root cause
  but ASes upstream of V **are not** the root cause



PoiRoot: Recursion

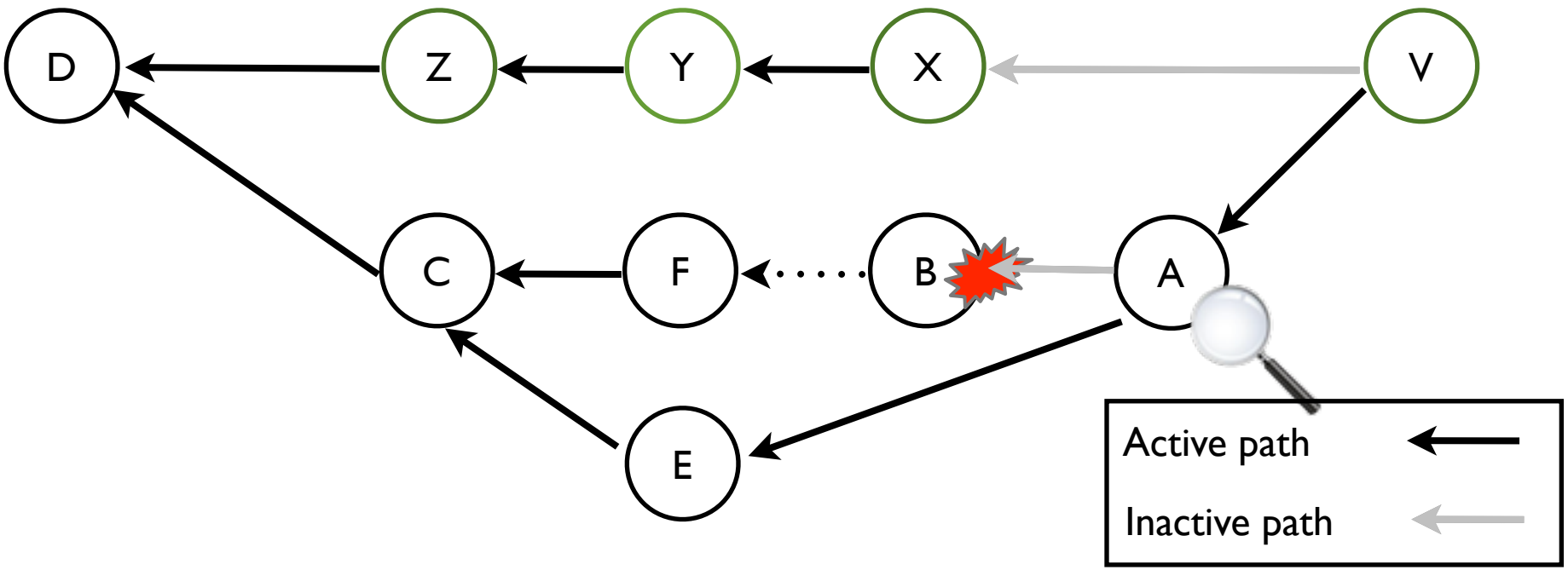
Axiom 2:

- If O(X) == N(X), X is **not** the root cause



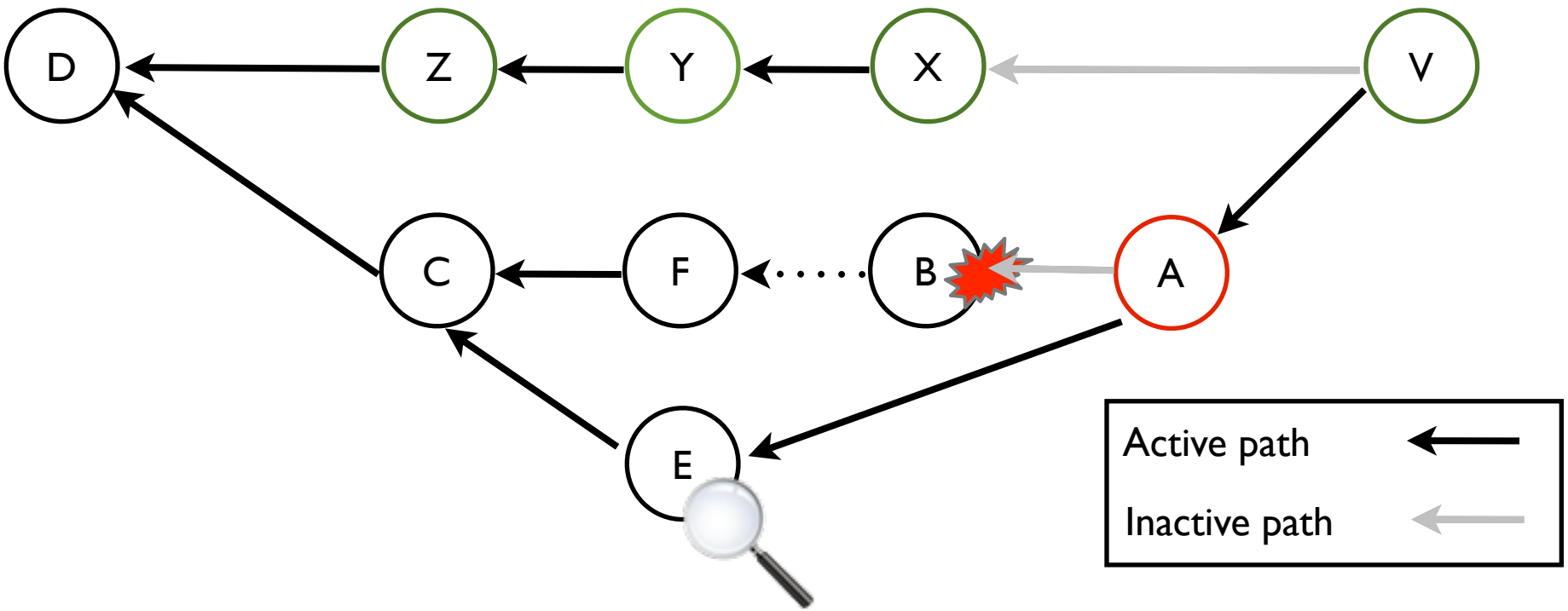
PoiRoot: Recursion

- O(A) != N(A):
  A might be root cause, but V is not



PoiRoot: Recursion

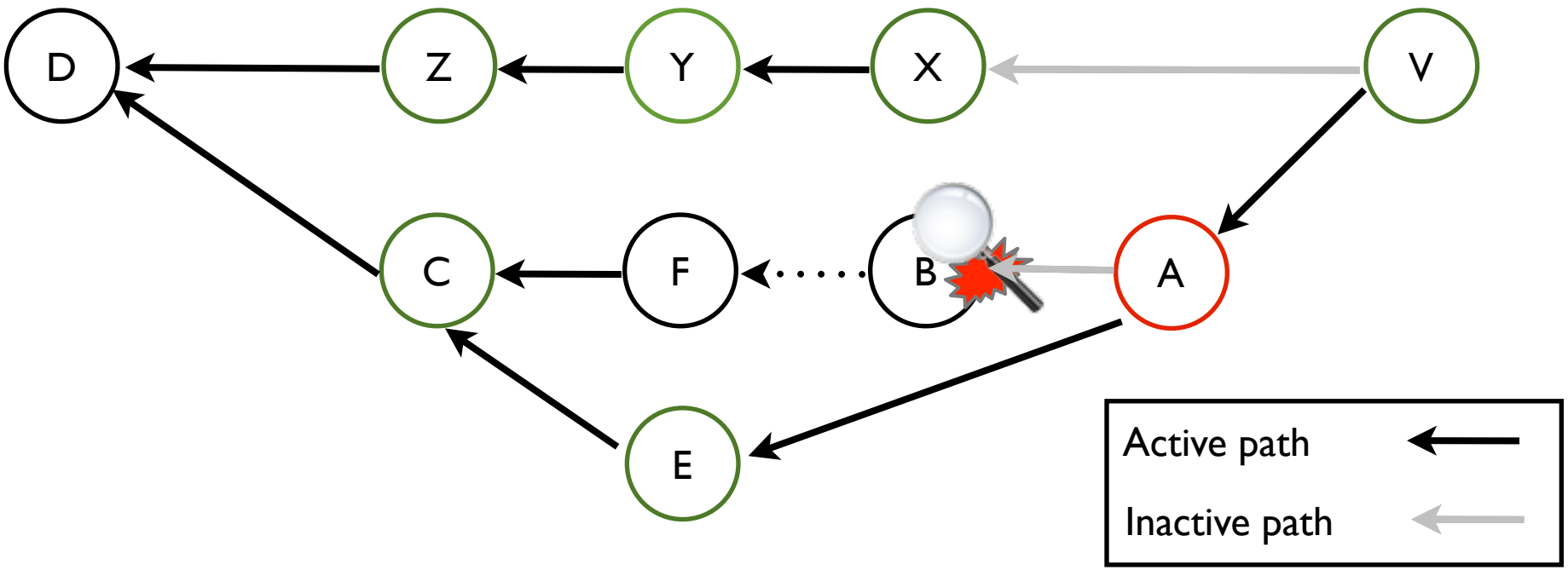
- O(E) == N(E):
  E is not the root cause



PoiRoot: Recursion

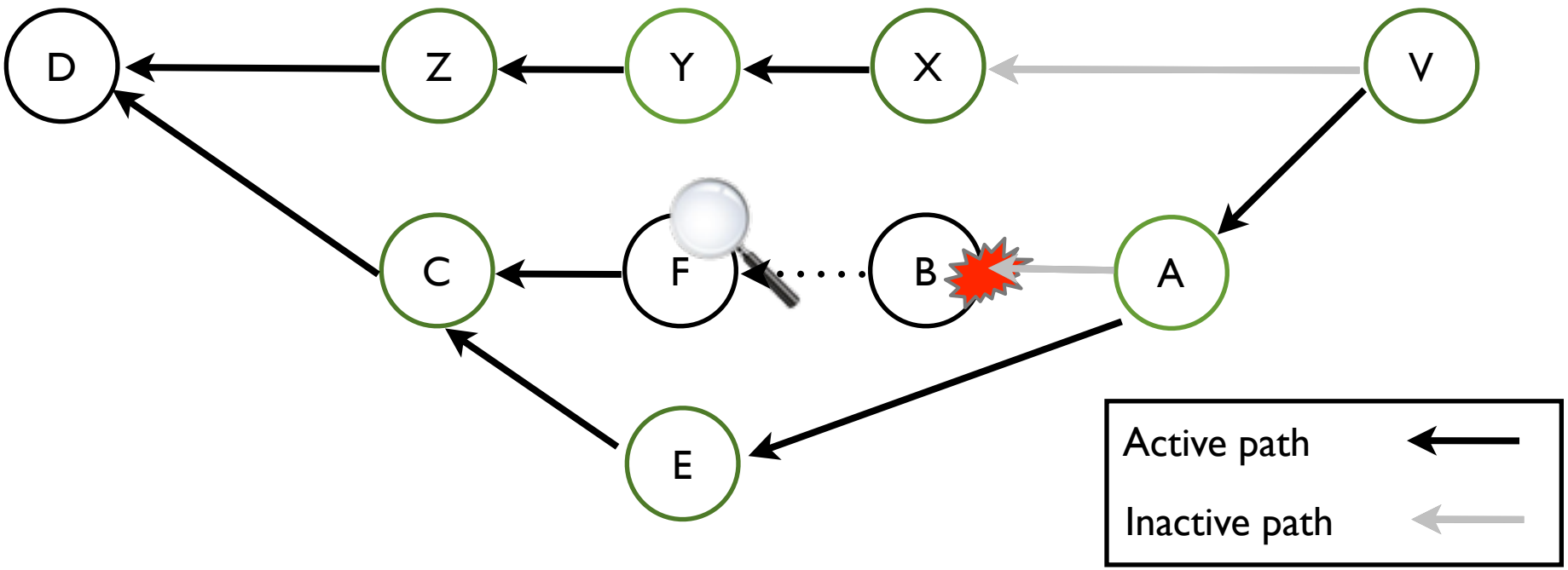
Now check ASes on **old paths** from ASes in N(V)

- O(B) != N(B):
  B may be the root cause



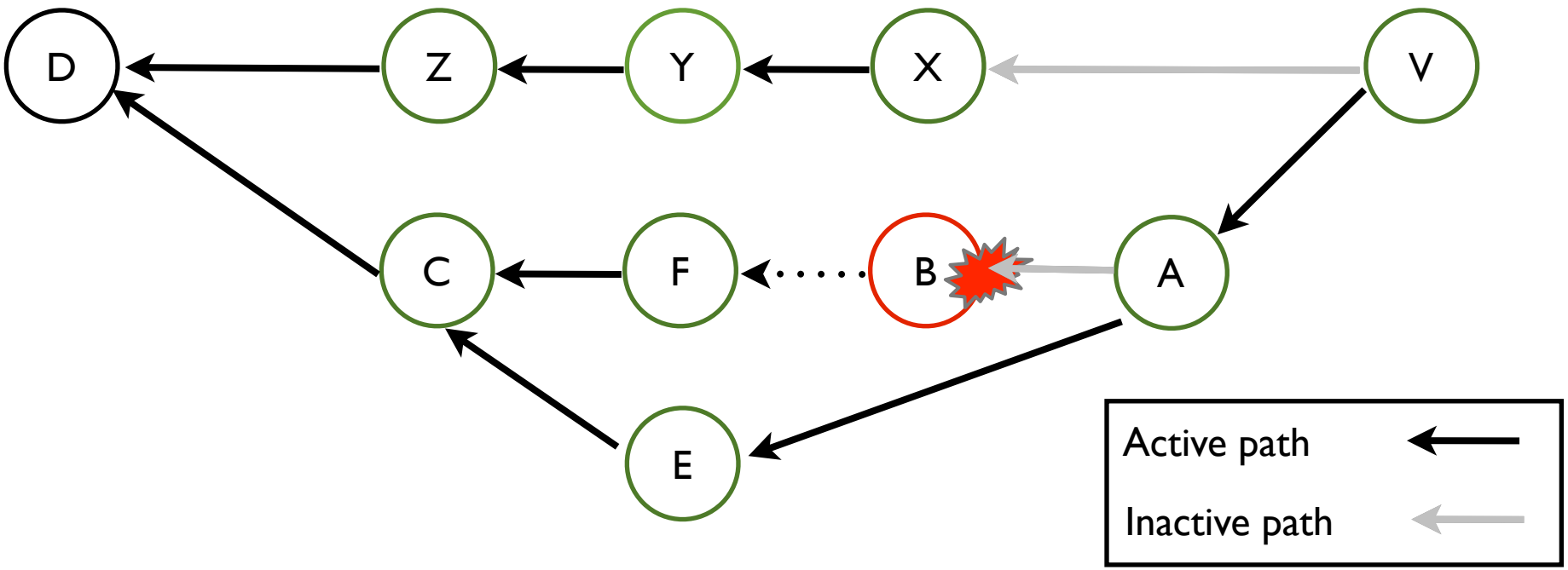
PoiRoot: Recursion

- O(F) == N(F):
  F is not the root cause



PoiRoot: Recursion

- Only candidate AS left is B, the root cause



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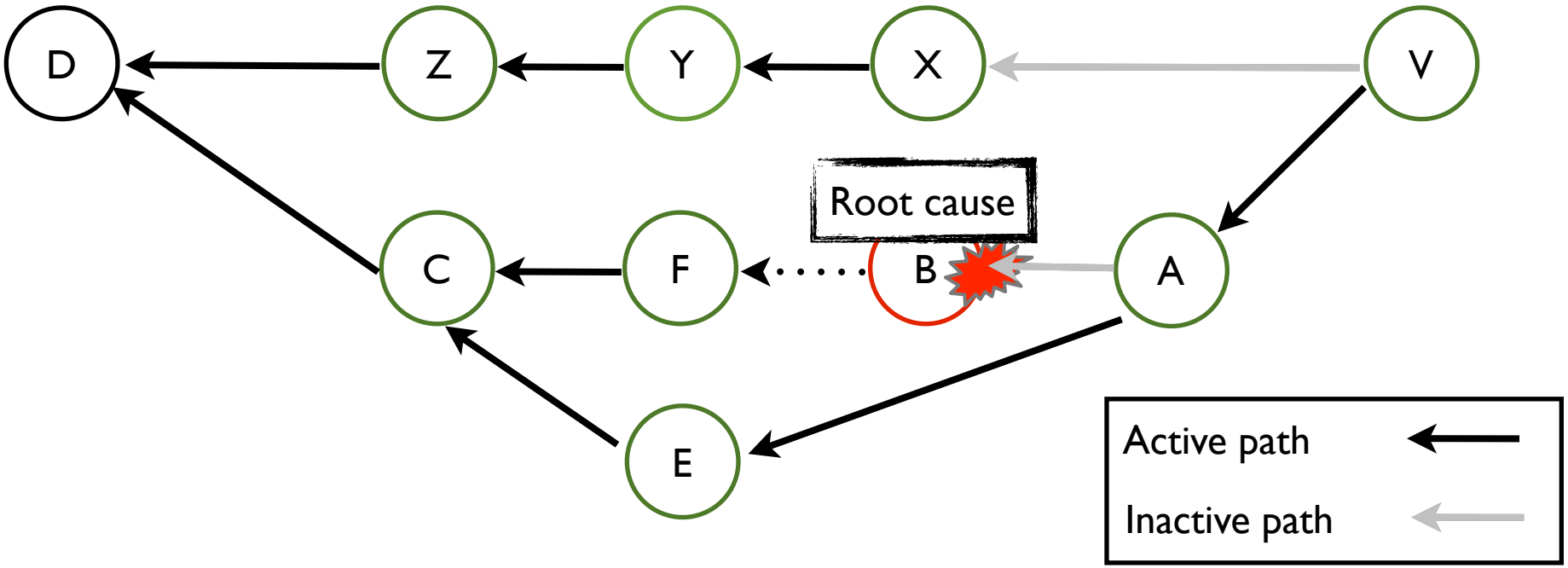
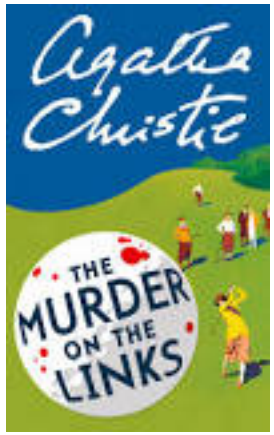


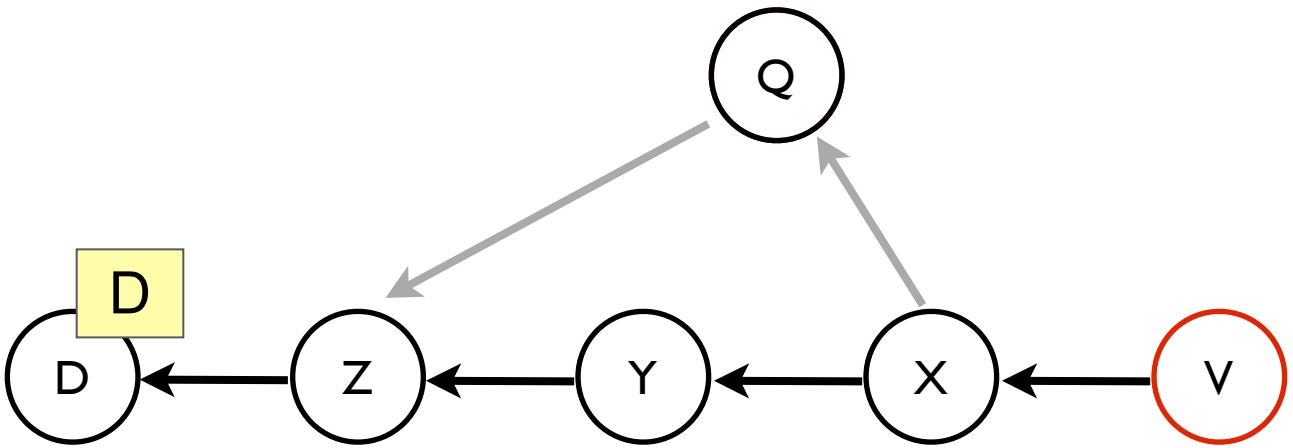
Other considerations

- Requires measuring paths that *might* be used in the future
  - Use *poi*soning to explore less preferred paths *before* a change
  - Measure those paths (e.g., via reverse traceroutes)

Poisoning on the BGP Links

- Normal case (no poisoning)





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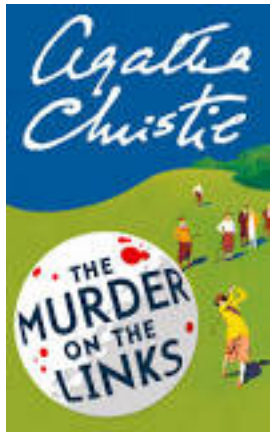

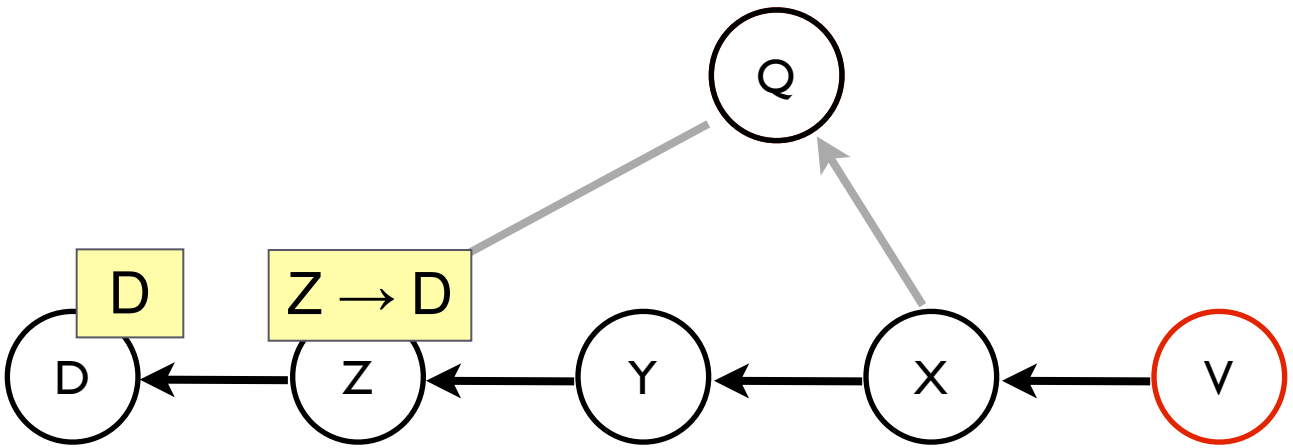

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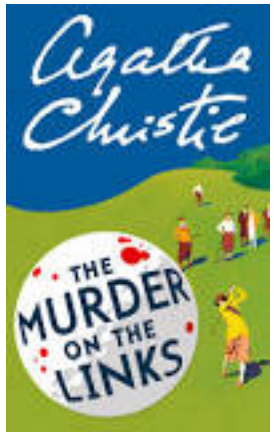

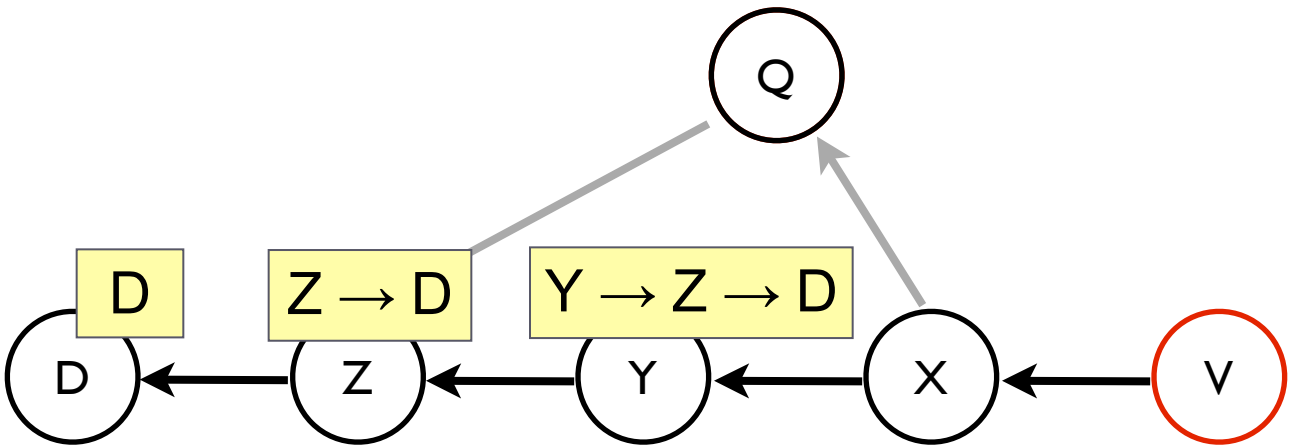

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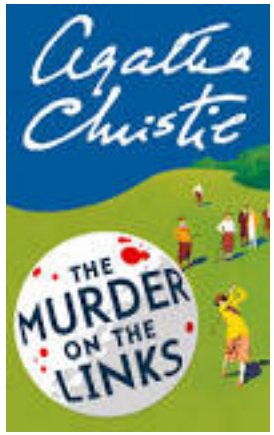
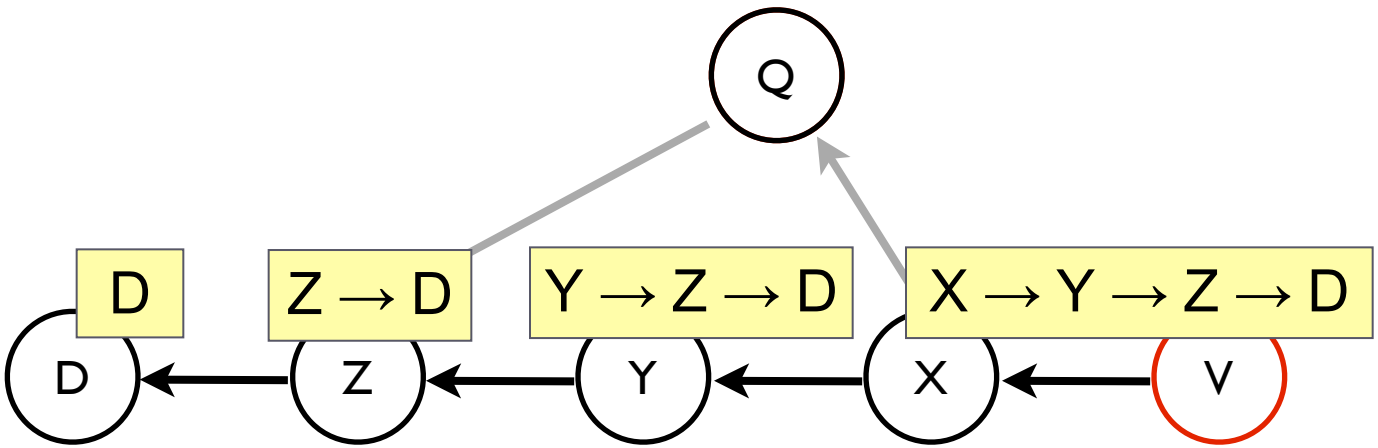
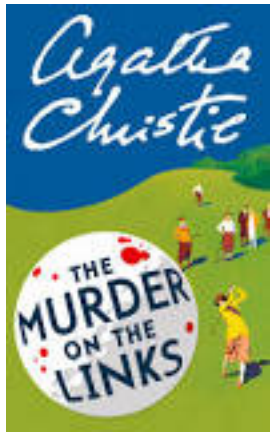
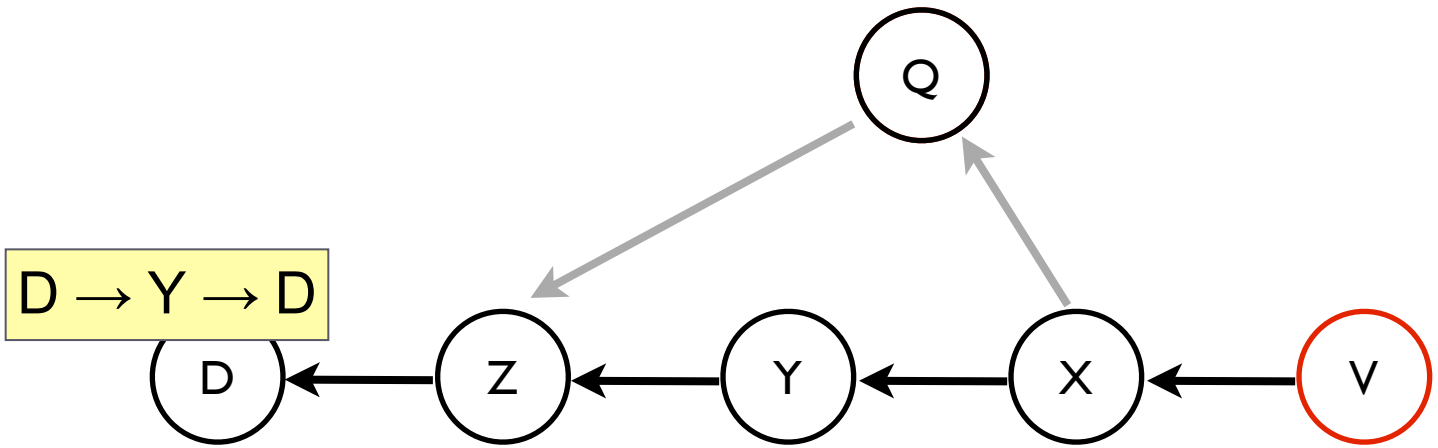




Poisoning on the BGP Links

- Poisoning Y to force X to explore less preferred paths





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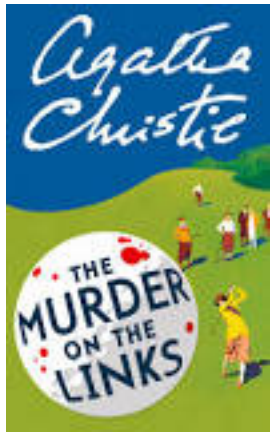

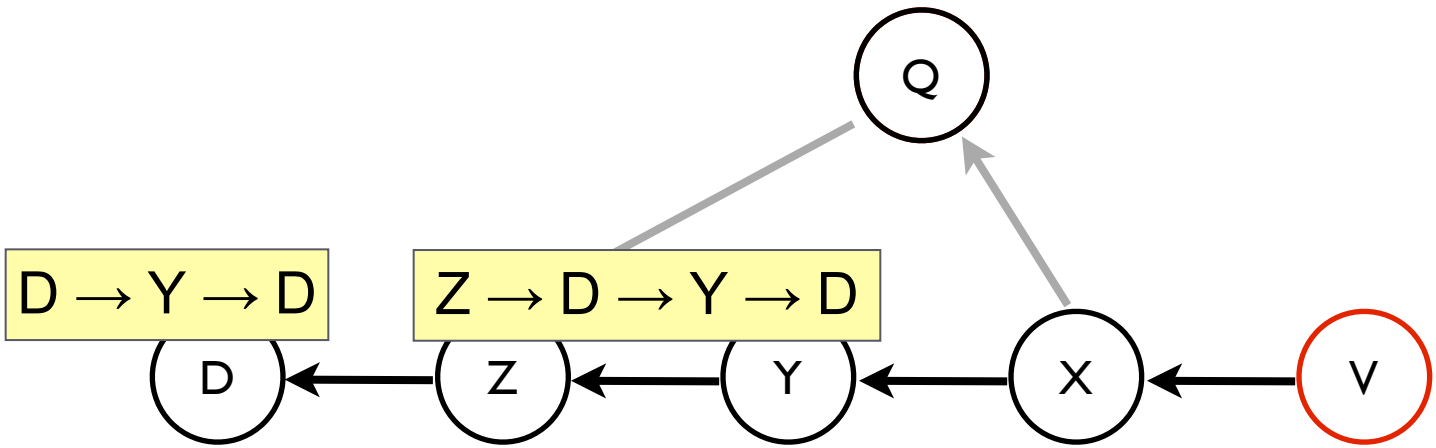

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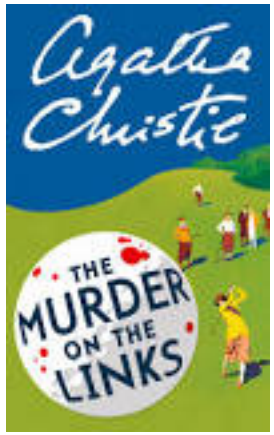

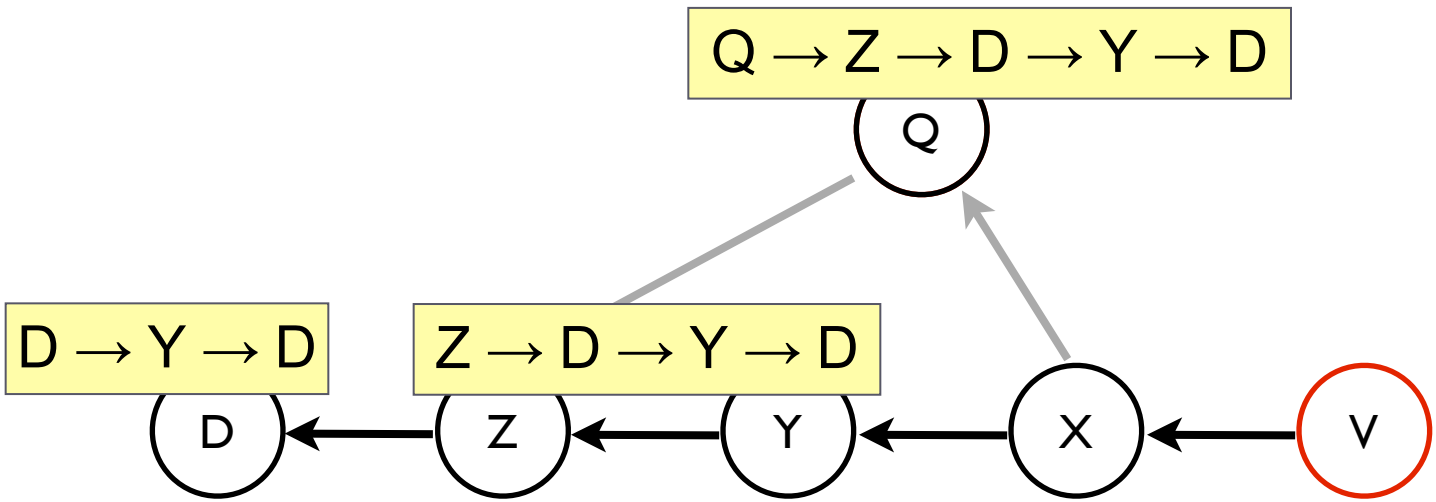

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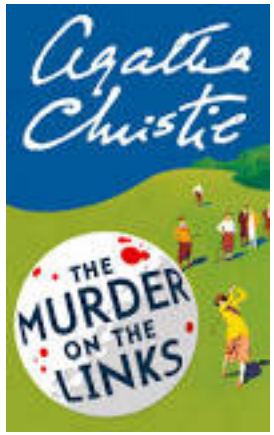

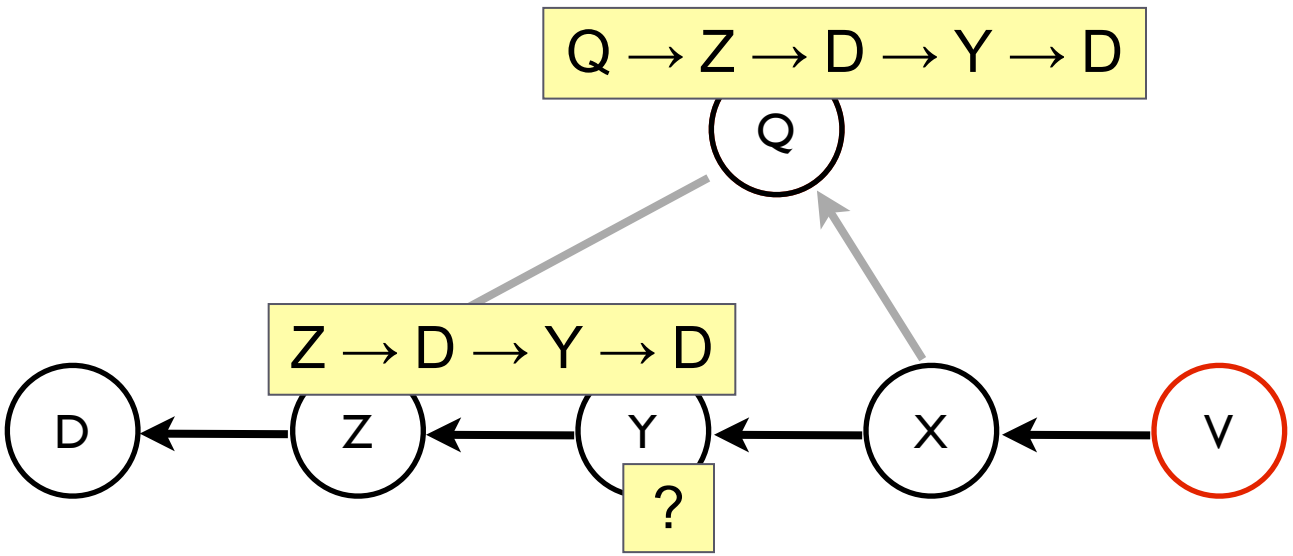

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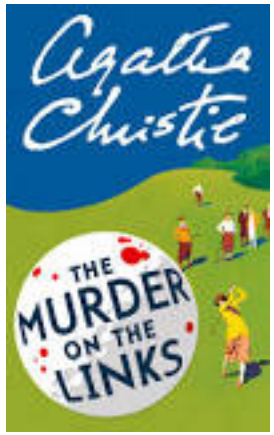

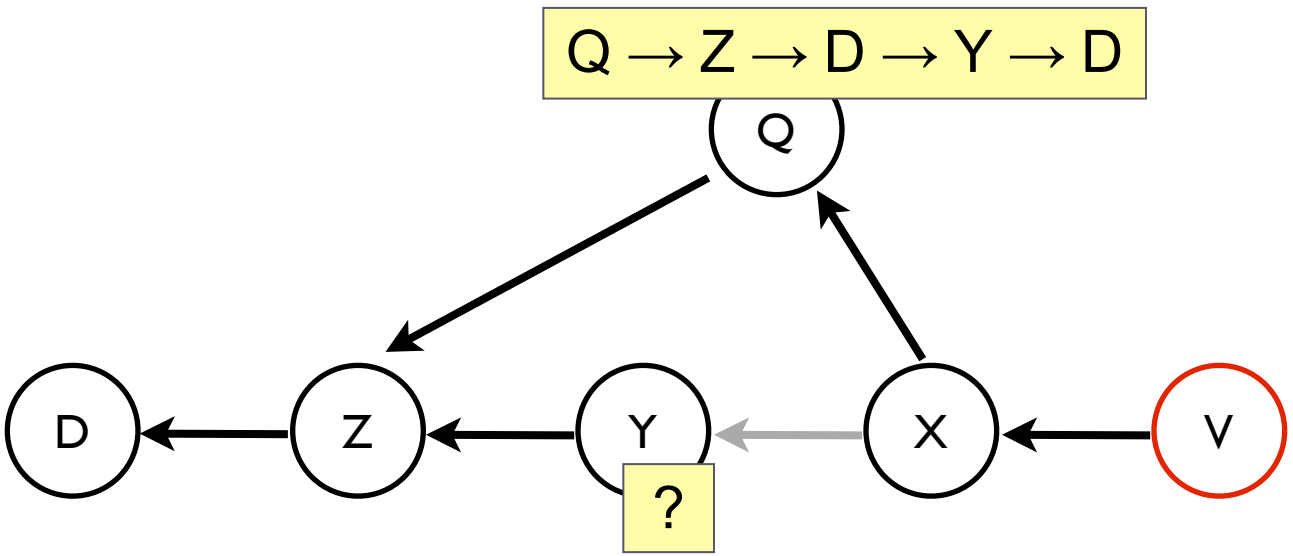

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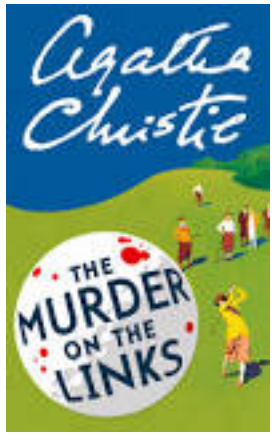
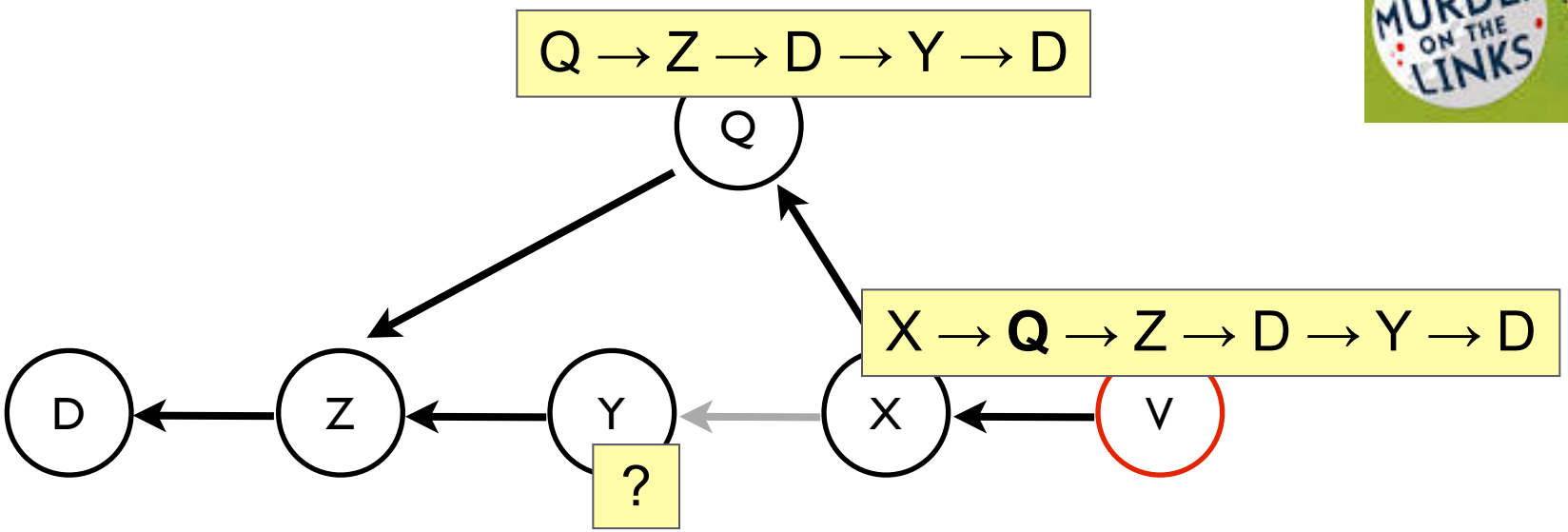




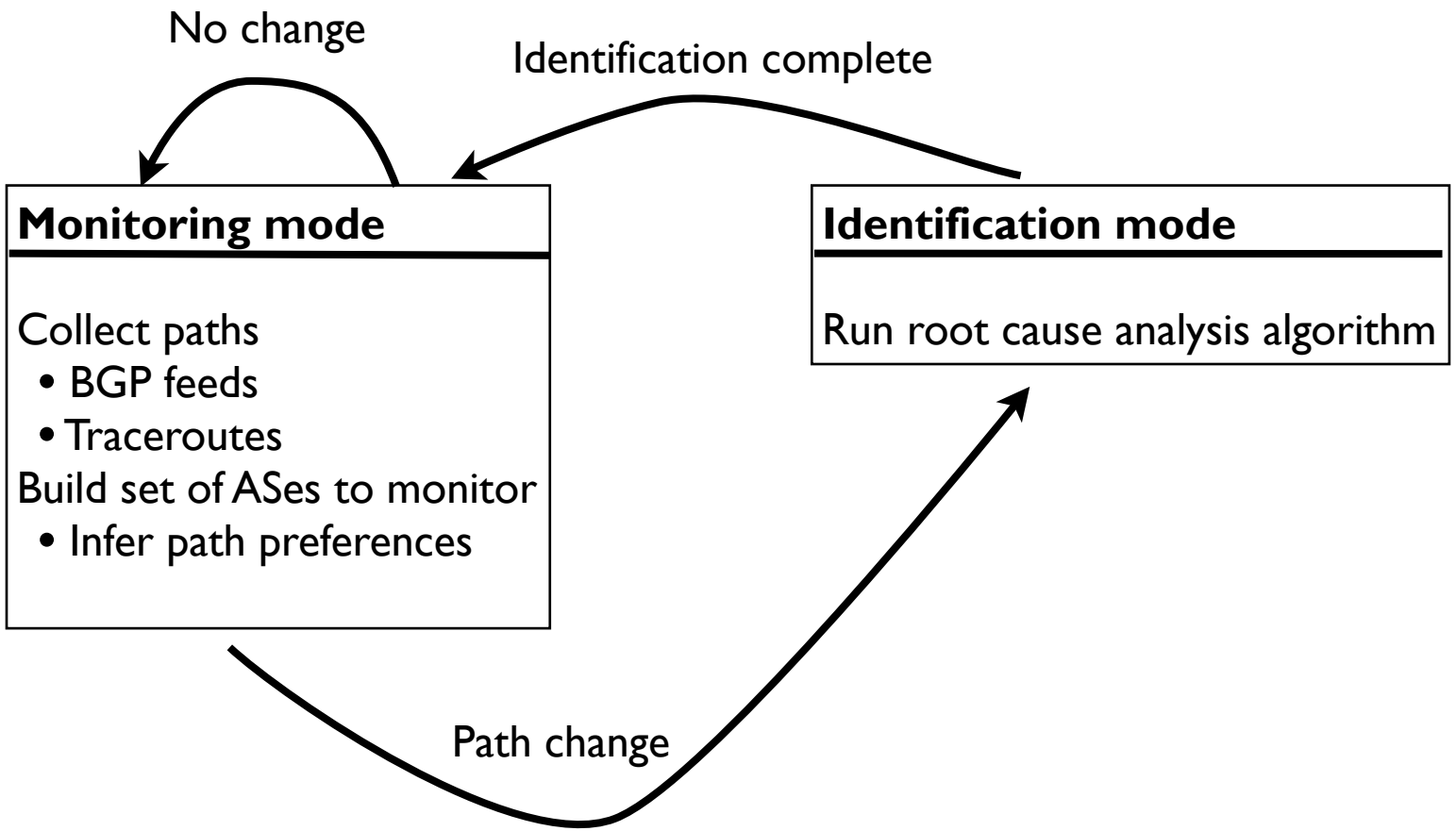
Other considerations

- Requires measuring paths that *might* be used in the future
  - Use *poi*soning to explore less preferred paths *before* a change
  - Measure those paths (e.g., via traceroutes)
- Potential set of ASes to monitor can grow quite large
  - Consider next-less-preferred and all more preferred paths
- May not have all measurements
  - Use correlation to reduce candidate set

Outline

- Intro
- Motivation
- Root Cause Isolation
- System & Evaluation

System overview



Evaluation

- What we want to know
  - **Accuracy**: How often do I identify the root cause?
  - **Precision**: How large is the candidate set?

- Key challenge: **Ground truth**!
  - Requires an AS to experiment with, ...
  - ... known triggers for path changes, ...
  - and running code to identify the root cause during the change

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    - Continuous path measurements from a large set of VPs

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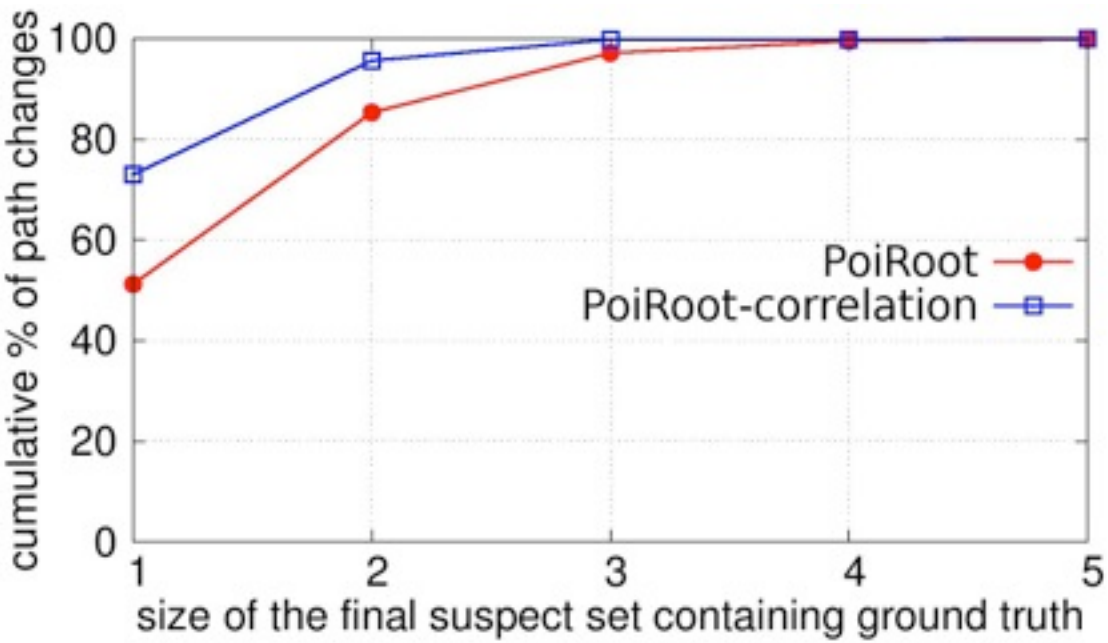

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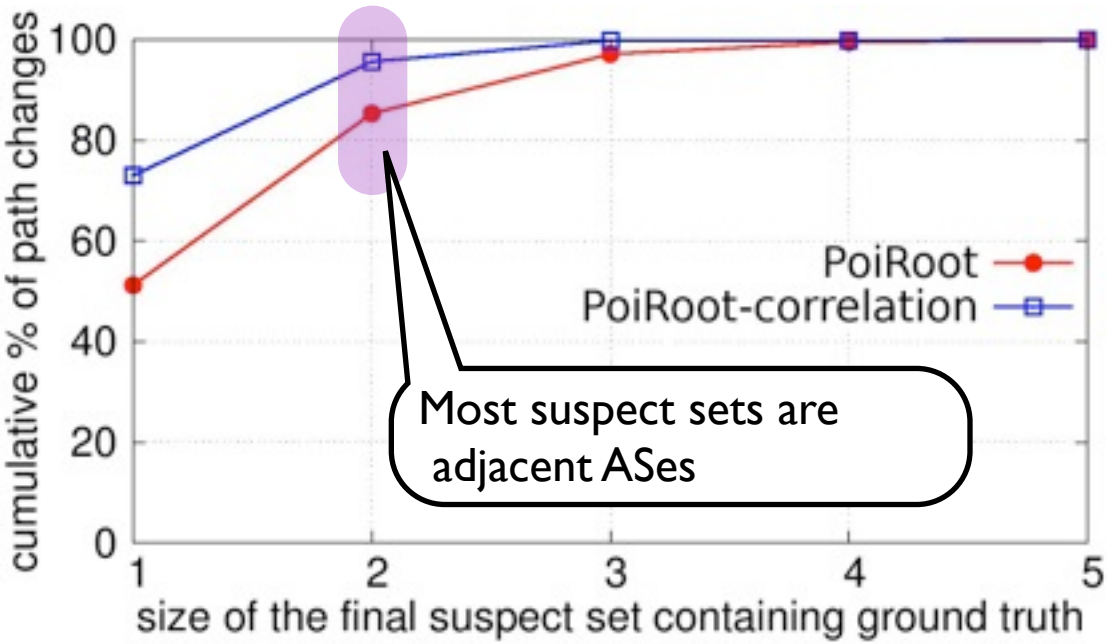

Conclusion

- Identify network triggering an interdomain path change
  - Both accurate and precise
  - Handles arbitrary changes
- New model to reason about path changes
  - Relies on few, generally valid, assumptions about routing
- Evaluation using controlled experiments on Internet paths

Questions?