Algorithms for computing Maximally Redundant Trees for IP/LDP Fast-Reroute

draft-enyedi-rtgwg-mrt-frr-algorithm-00

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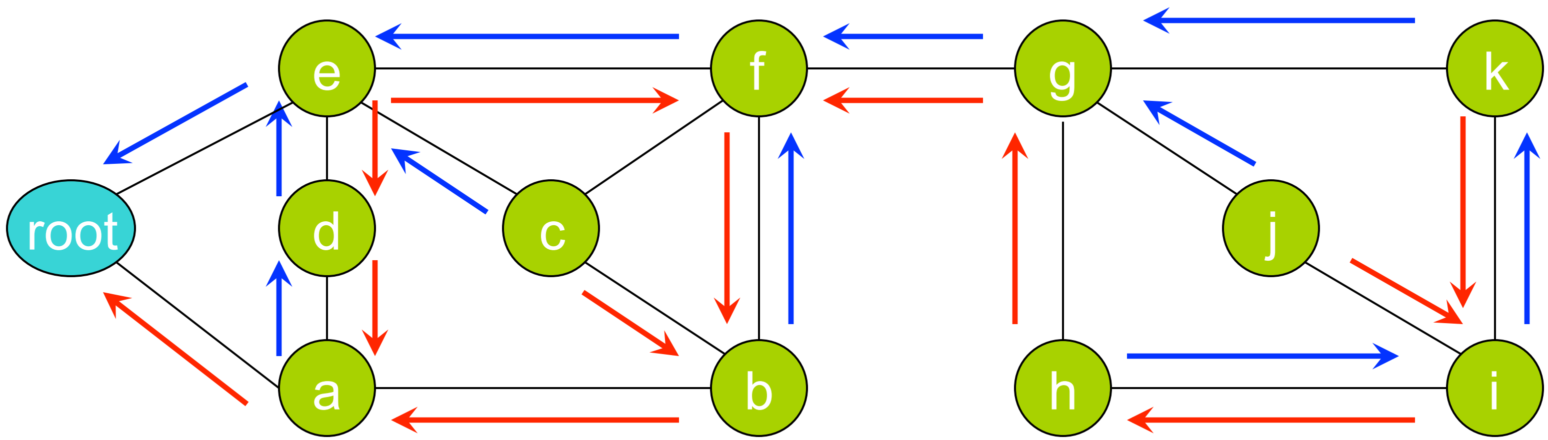
MRT

- Maximally Redundant Trees
  - A pair of directed spanning trees
  - The common root is reachable along both of them
  - The two paths along the two trees are maximally disjoint



Why do we need this draft?

- We need a pair of MRTs rooted at each node
  - All the nodes should compute the same!
  - We will need **standardization** for MRT computation (algorithm) or results of that computation.

Principles

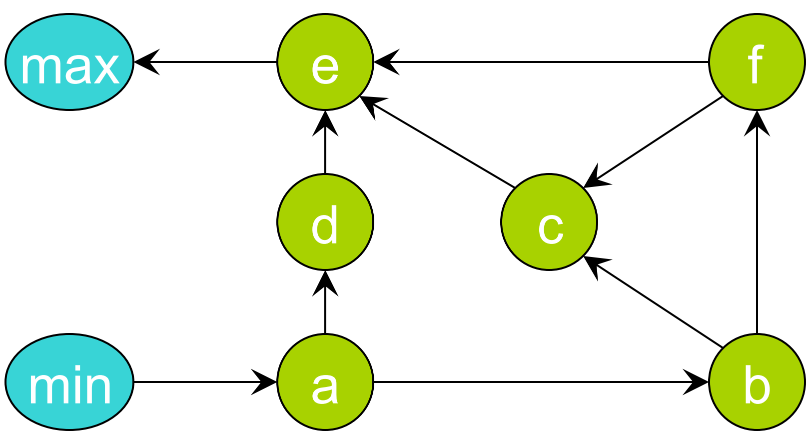
Partial order

ADAG

Blocks and GADAG

Partial order

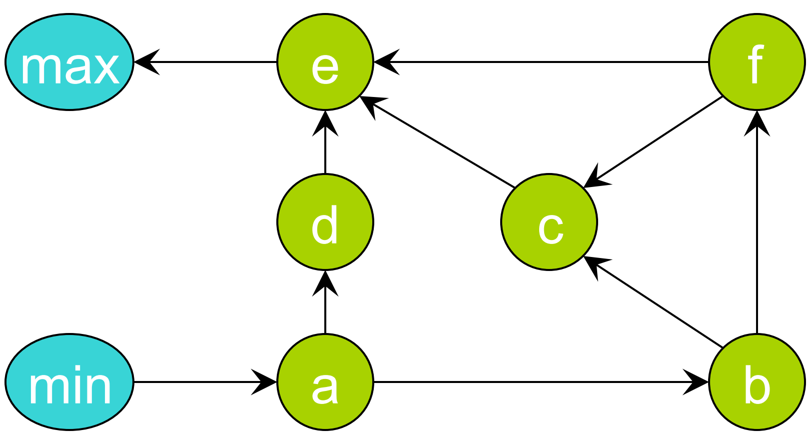
- Partial order of a set (e.g. set of nodes)
  - A relation like a normal set
  - Except: not all the elements can be compared
    - For some **a** and **b** neither **$a<b$** nor **$a>b$**
- Graph representation:
  - Directed Acyclic Graph (DAG)



- $\text{min}<a<b<f<c<e<\text{max}$
- $a<d<e$

Finding node-disjoint paths

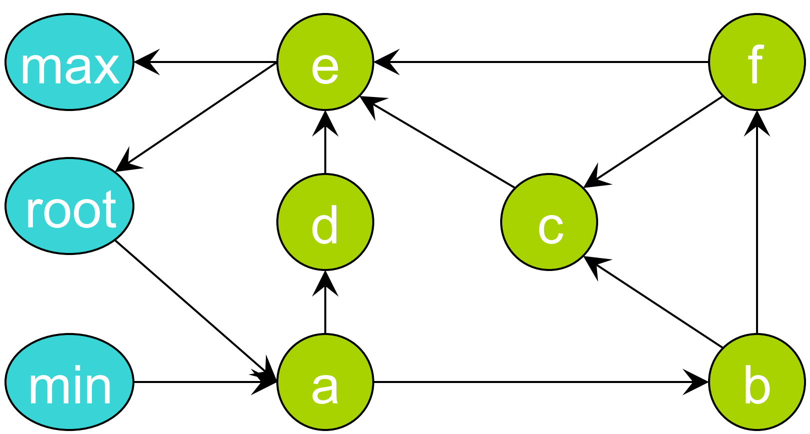
- Suppose that
  - We have a partial order of nodes
  - Exactly one min and max
  - Each node (except min and max) has a lower and greater neighbor
- Walk down and up
  - Min and max are reached
  - The two paths are node-disjoint!



- min<a<b<f<c<e<max
- a<d<e

Two paths to the same node

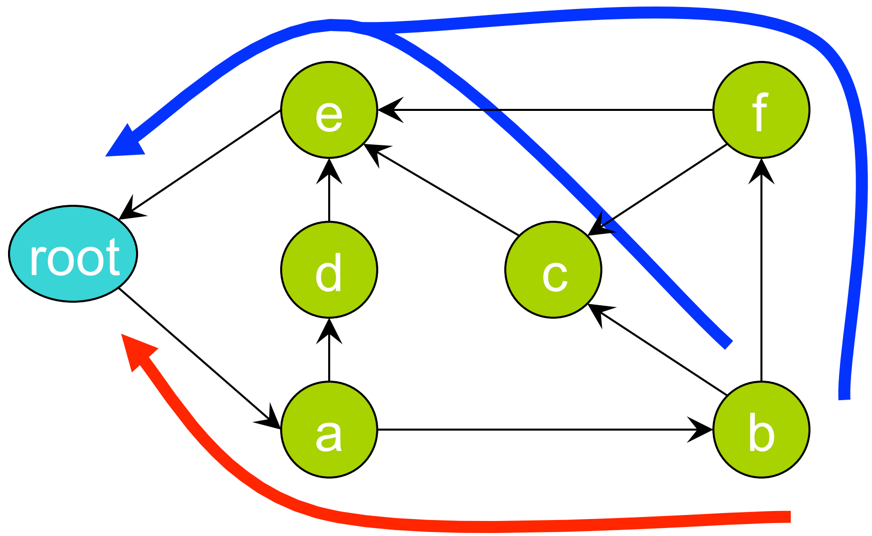
- DAG is not enough
  - Let min and max be the same node!
- Resulting graph is an Almost DAG (ADAG)
  - There is a single node, the root, such that without the root it is a DAG



- min<a<b<f<c<e<max
- root<a<b<f<c<e<root
- a<d<e

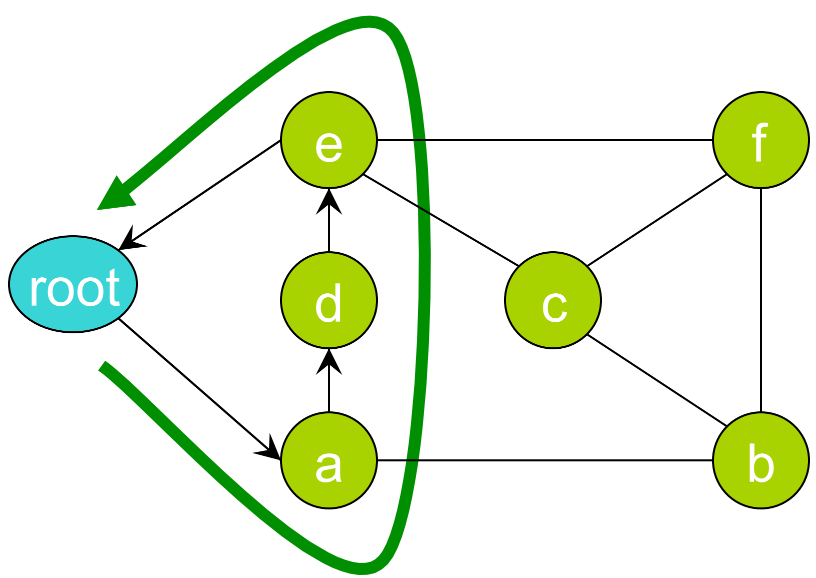
Redundant paths to the root

- Blue path:
  - Nodes must increase
- Red path:
  - Nodes must decrease
- Load sharing is possible



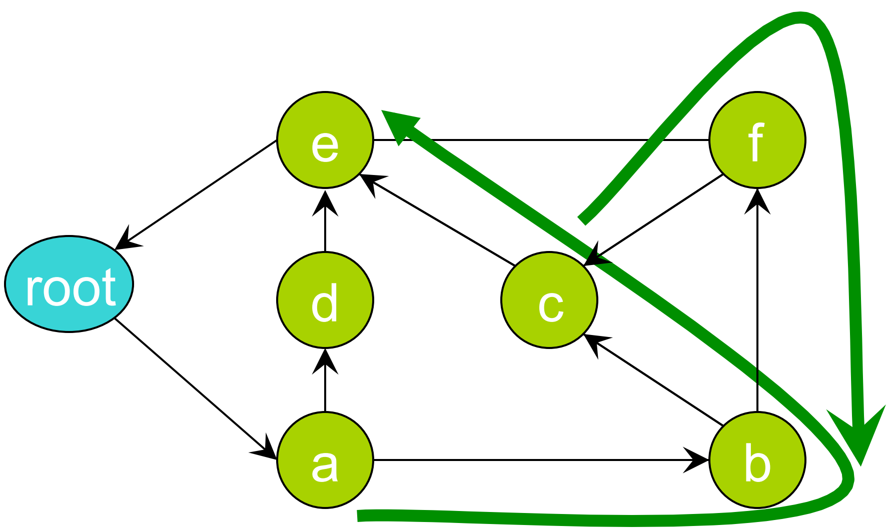
Finding an ADAG (2-connected networks)

- Phase 1 – basic partial ADAG
  - Find a partial ADAG for a cycle containing the root
    - Use either direction
  - Extend partial ADAG into all nodes



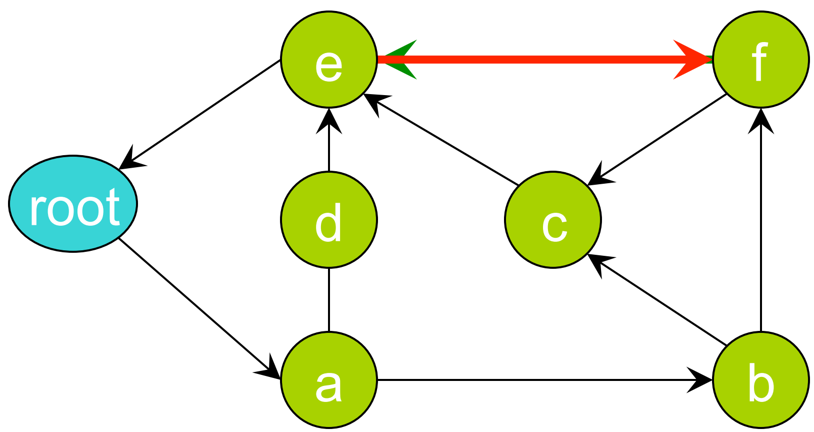
Finding an ADAG (2-connected networks)

- Phase 2 – extending
  - Find a path from one “ready” node to the another
  - Nodes along the path must not be ready (except the endpoints)
  - Add the path to the ADAG in a “proper” direction



Adding not used links

- Some links may be out of the ADAG



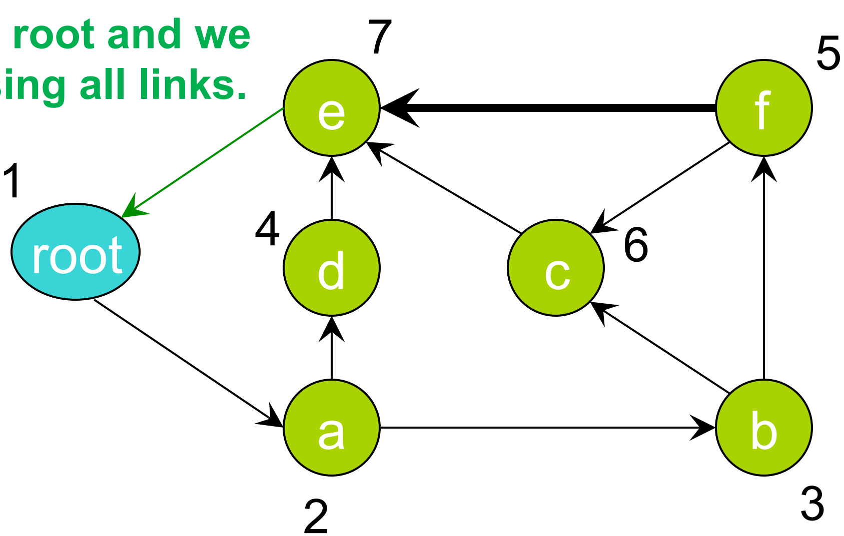
BAD: e<f

OK

How can ordering be kept up?

- ADAG is almost a DAG
  - Let ***root*** be now only the smallest one
  - Now, it's a DAG, create a topological sort
  - This is a total order
    - Add extra links with respect to this

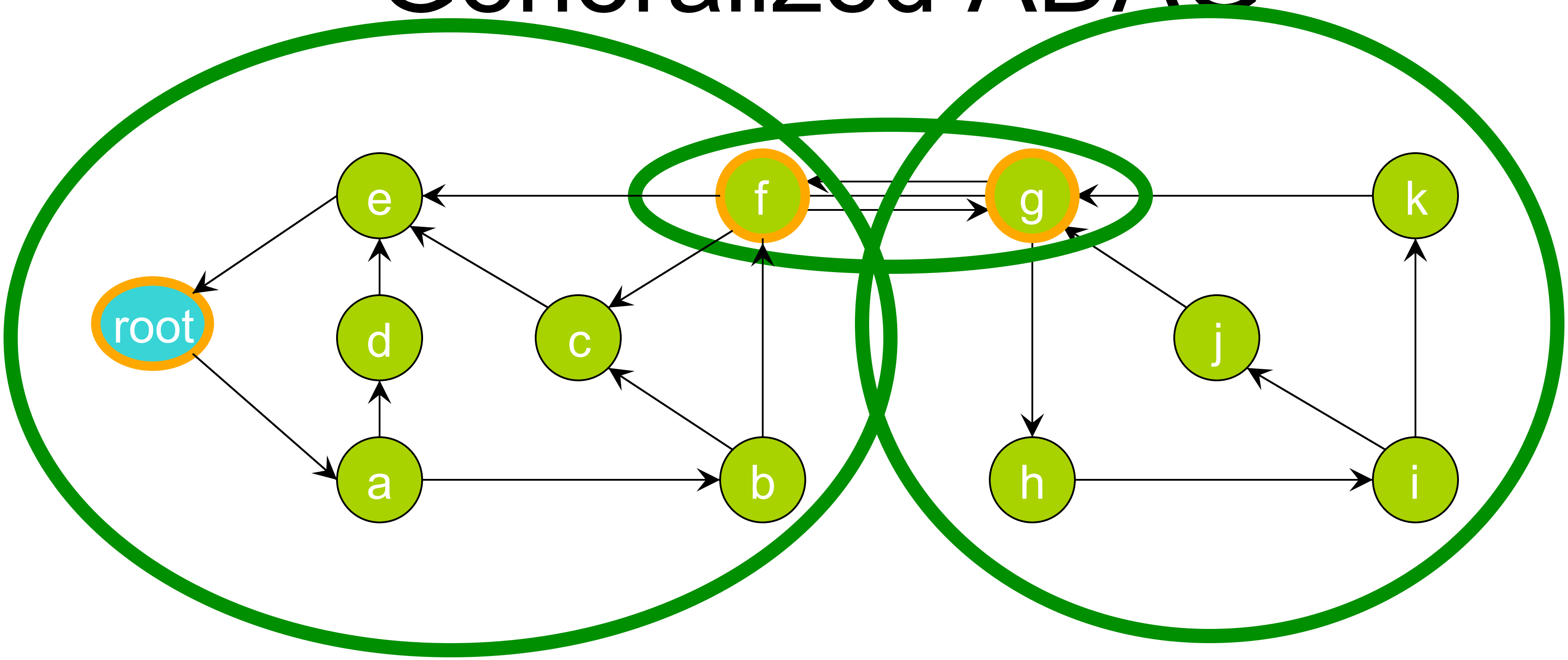
Add back links to root and we have an ADAG using all links.



What if the network is not 2-connected?

- We need to split the graph into blocks
  - Block:
    - Maximally 2-connected subgraph
    - Two connected nodes
    - (Isolated node)
  - Each block has its local-root
    - That is the cut-vertex towards the root
  - Compute an ADAG in all the blocks
  - This is a Generalized ADAG

Generalized ADAG



- Block1: root, a, b, c, d, e, f
- Block2: f, g
- Block3: g, h, i, j, k

The algorithm

MRTs in a block

MRTs in the whole network

How to Find MRTs

- If it is complex, then we break the problem down
  - Transform network into its blocks
  - Find ADAGs in each block
  - Connect up the ADAGs to make a GADAG
  - Add all the other links in – with the proper directionality
- From a GADAG, compute your next-hops to each destination
  - First for those in the same block
  - Destinations outside the block inherit their next-hops from a proxy in the block

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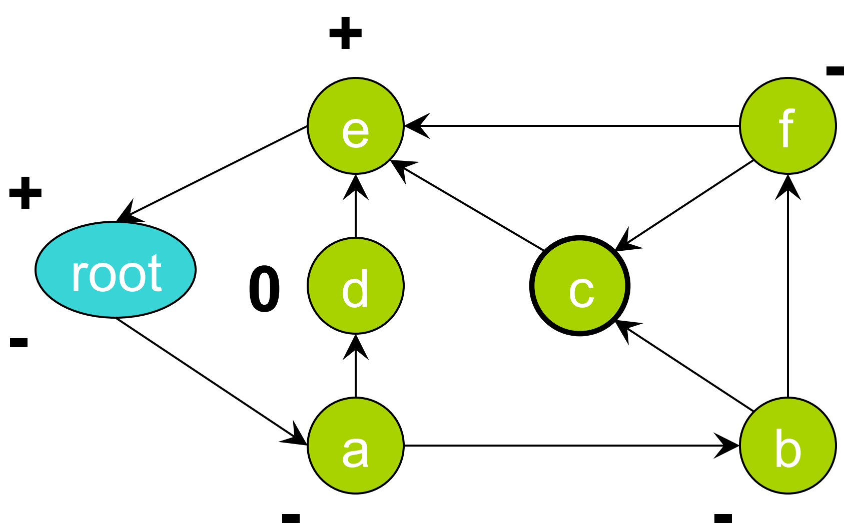
MRTs in a single block

- As the computing router S: From the GADAG, can use SPF and reverse SPF to find next-hops to all destinations in the same block
  - SPF gives nodes definitely greater
  - rSPF gives nodes definitely lesser
  - Remaining nodes are not ordered
- Then use some simple rules

MRTs in a single block: source perspective

- Find greater and lesser nodes
- Rules
  1. If **S < D** – increase to D decrease to root
  2. If **S > D** – increase to root decrease to D
  3. No order – decrease to root increase to root
  4. If D=root – increase to root decrease to root
  5. If S=root – increase to D decrease to D



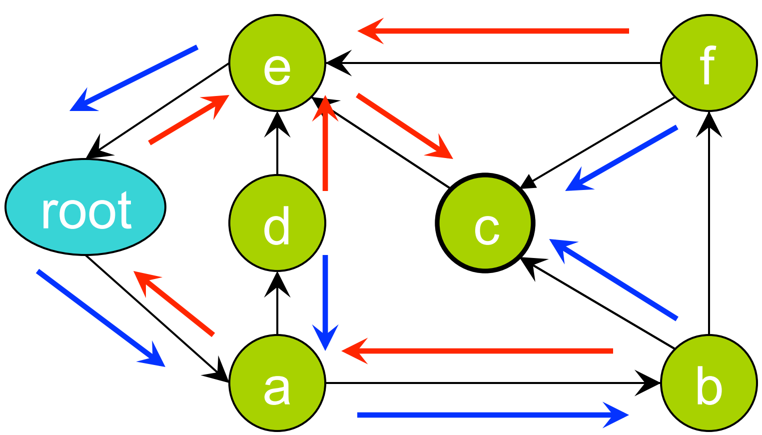
Routing table of **node c (S = c)**:

Dest (D)	Rule Used	Blue Next-hop	Red Next-hop
a	2	e	b
b	2	e	b
d	3	b	e
e	1	e	b
f	2	e	f
root	4	e	b

MRTs in a single block: destination perspective

- Find greater and lesser nodes
- Rules

1. If **S < D**	–	increase to D	decrease to root
2. If **S > D**	–	increase to root	decrease to D
3. No order	–	decrease to root	increase to root
4. If d=root	–	increase to root	decrease to root
5. If s=root	–	increase to D	decrease to D



Destination: **node c (D = c)**

Src (S)	Rule Used	Blue Next-hop	Red Next-hop
a	1	b	root
b	1	c	a
d	2	a	e
e	3	root	c
f	2	c	e
root	1	a	e

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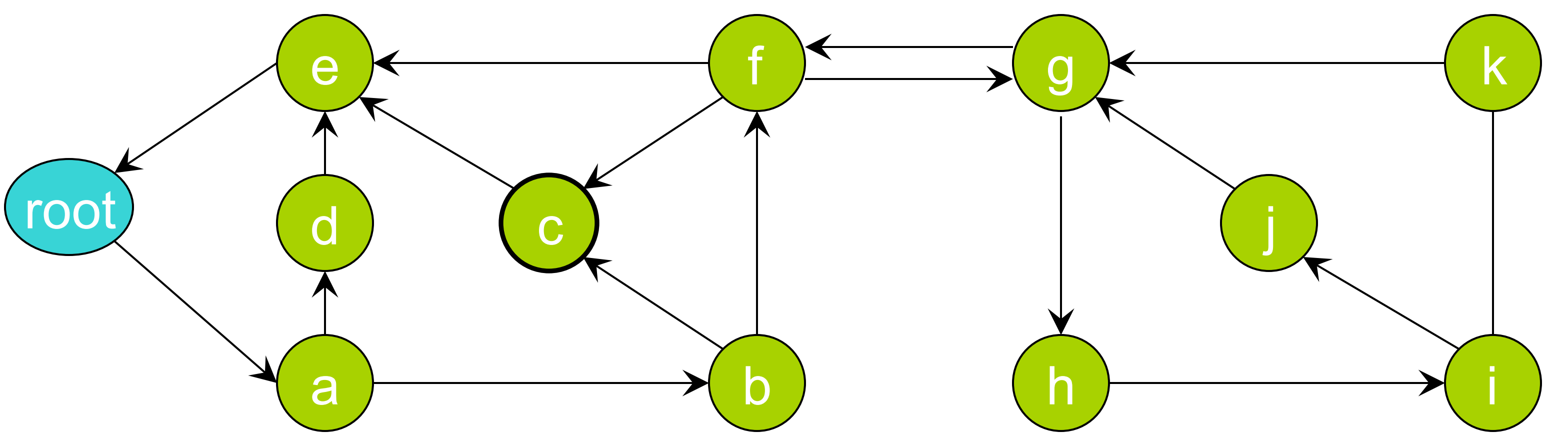
Inter-block MRTs

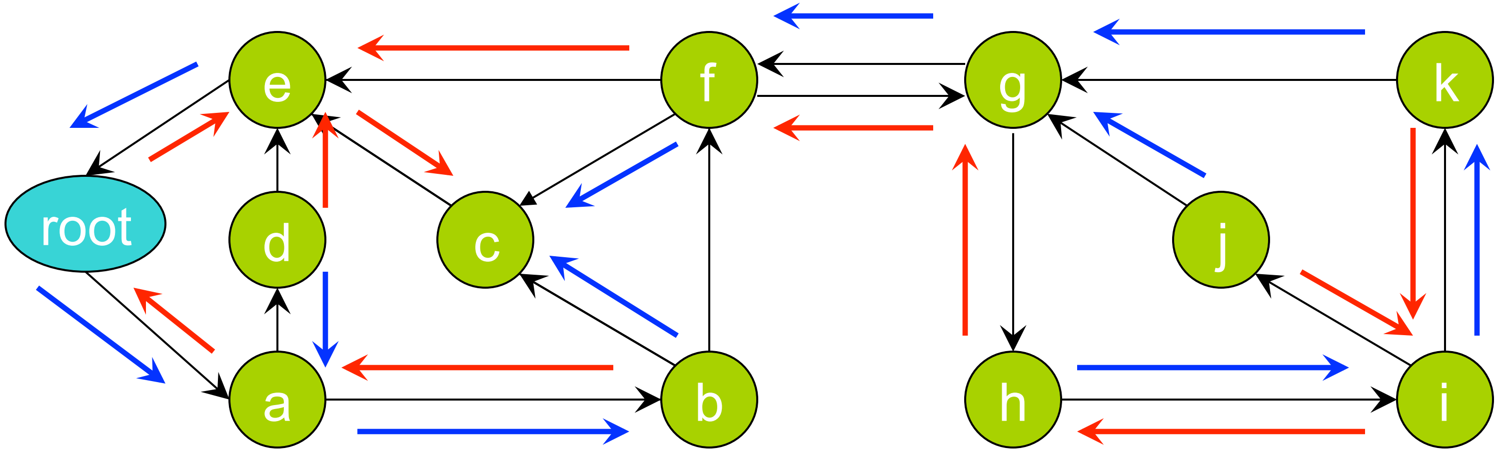
Proxy node: the last vertex in the block to the destination (along ***any*** path)

Dest (D)	Rule Used	Blue Next-hop	Red Next-hop
a	2	e	b
b	2	e	b
d	3	b	e
e	1	e	b
f	2	e	f
root	4	e	b

Dest (D)	Proxy	Blue Next-hop	Red Next-hop
g	f	e	f
h	f	e	f
i	f	e	f
j	f	e	f
k	f	e	f



Example – destination is node C



- Block1: root, a, b, c, d, e
- Block2: e, f
- Block3: f, g, h, i, j

Summary

- Algorithm
  - Find GADAG
    - ADAG in each block
    - Add not used links
  - Find next-hops along the MRTs
    - Do an SPF and an rSPF to find ordered nodes
    - Use rules to find NHs your block
    - Find proxy nodes

Thanks for the attention