CS519: Computer Networks

Lecture 4, Part 2: Feb 18, 2004

Internet Routing:

This is a graph

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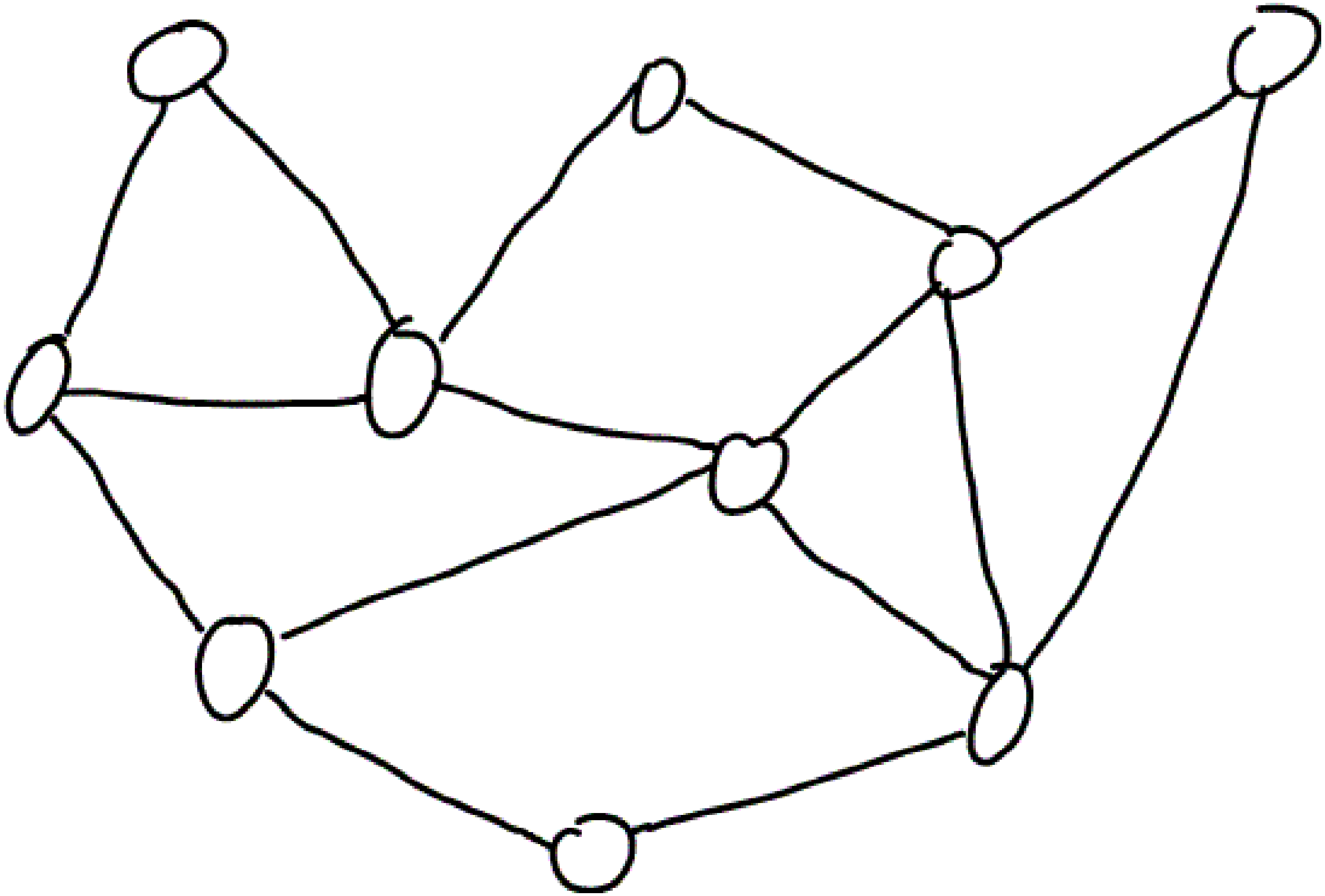

Networks can be modeled as a graph

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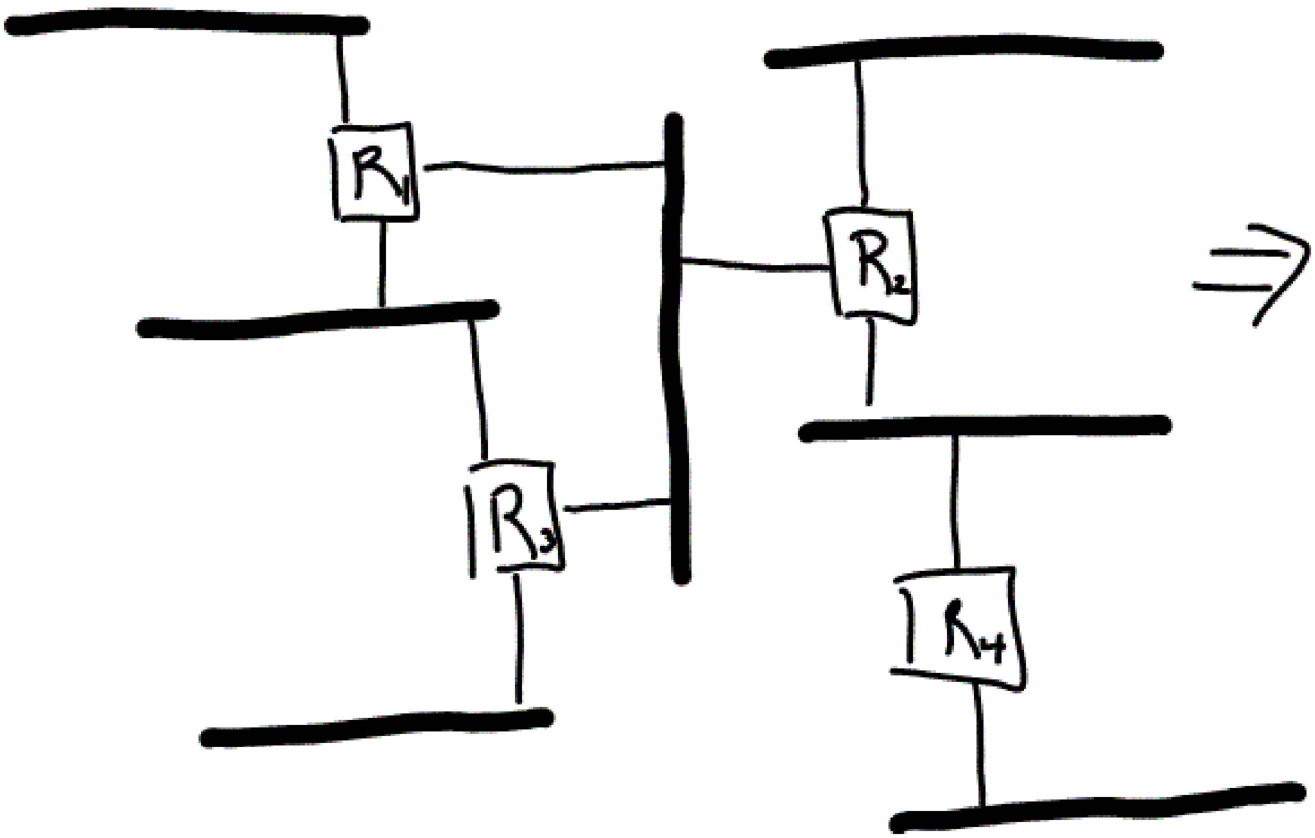

Trees on graphs

- You can superimpose a *directed tree* on a *graph*
  - No *loops* (or *cycles*)
- This tree is rooted at a *destination*
- Every directed *edge* (link) in this tree represents a “next hop”
- Forming these trees (per destination) is the essence of the routing problem
- By the way, what do you get if you reverse the directions of the tree edges?

Trees on graphs

- Lots of trees are possible
- Two of interest:
  - Shortest path spanning tree
    - Sum of weights on links from any node to destination is the smallest
  - Minimum weight spanning tree
    - Sum of weights of all links is the smallest
- In the internet, we calculate shortest paths

Setting costs on links

- Each “link” is actually two unidirectional links
  - But we’ll pretend they are bidirectional in the lecture for convenience
- One way: set link cost as the inverse of the BW
  - i.e., take highest BW link, give it a cost of one, weight all other links inverse proportionally
- Does this work?

Setting costs on links

- Ultimate goal is to balance traffic over links
  - No overloaded or underloaded links
- Load on links depends on traffic matrix
  - That is, amount of traffic between every src-dest pair
- In practice, costs are “hand tuned” to get good balance
  - Of course, BW is added or removed as needed
- Link underloaded? Lower its cost a bit . . .

Can we dynamically set costs?

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- Measure volume of traffic, increase cost as volume increases, decrease cost as volume decreases
- It turns out that this is hard to get right
  - Route oscillations---must be damped

Can we dynamically set costs?

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- If network is lightly loaded, traffic-sensitive routing doesn't help
  - All routes are good
- If network is overloaded, traffic-sensitive routing also doesn't help
  - Alternate routes also bad
- What you really want is to throttle sources at times of overload. **This is the big win**.

Multiple link metrics?

- What if we care about BW and latency and MTU and QoS???
- Many people have studied multi-metric routing
  - It gets complex, and it is hard to figure out what to do with it
- In practice: Over-provision, throttle sources!

Three classes of IP routing algorithm in the Internet today

- Distance-vector
  - RIP
- Distance-path
  - A variant of distance-vector
  - BGP
- Link-state
  - OSPF, IS-IS

Distance Vector

- Also known as Bellman-Ford
- Each node's routing table:
  - The distance to each destination via each neighbor
- Building the forwarding table:
  - The next hop to each destination is the neighbor with the shortest distance
- The algorithm:
  - Periodically tell each neighbor the shortest distance to all destinations
  - This is the so-called "distance vector"

Example RIB, FIB, and routing update message

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RIB

	N_1	N_2	N_3
D_1	5	1	7
D_2	2	9	3
D_3	11	2	6
D_4	3	3	4

FIB

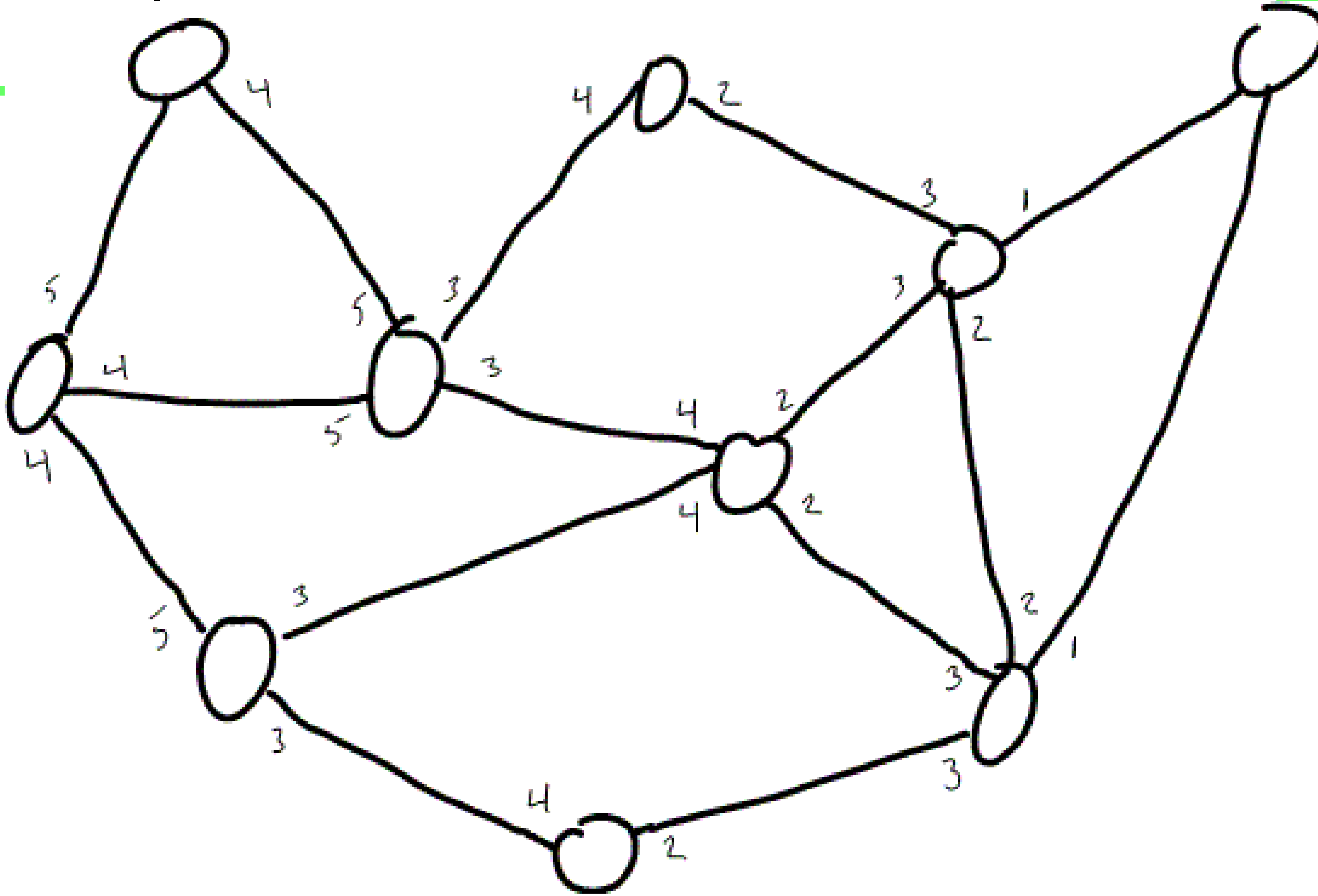
Dest	Next Hop
D_1	N_2
D_2	N_1
D_3	N_2
D_4	N_1

Update Message: $(D_1 : 1)(D_2 : 2)(D_3 : 2)(D_4 : 3)$

Examples

- Show establishment of tree
- Show link addition and changes in tree
- Show link deletion and changes in tree
- Show node removal and count-to-infinity

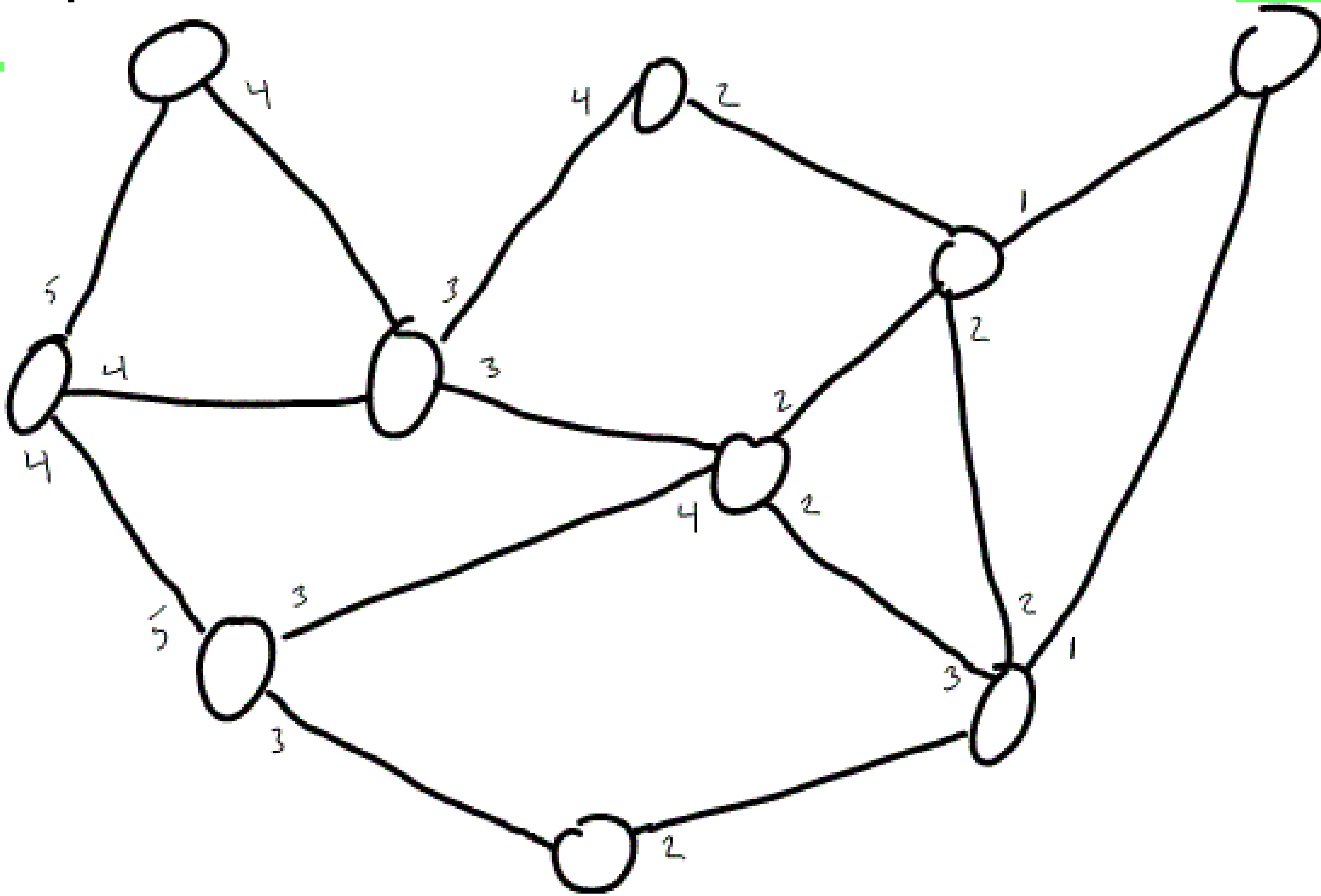
Examples



Count-to-infinity fix

- Split horizon
  - Don’t advertise reachability to a neighbor if the destination is reached via that neighbor
- Also triggered updates
  - Instantly report changes (not just periodically)
  - Count-to-infinity fast!
- This fixes “ping-pong” CTI, but doesn’t solve the general problem…

Example with split horizon



RIP-2 header (RFC 2453)

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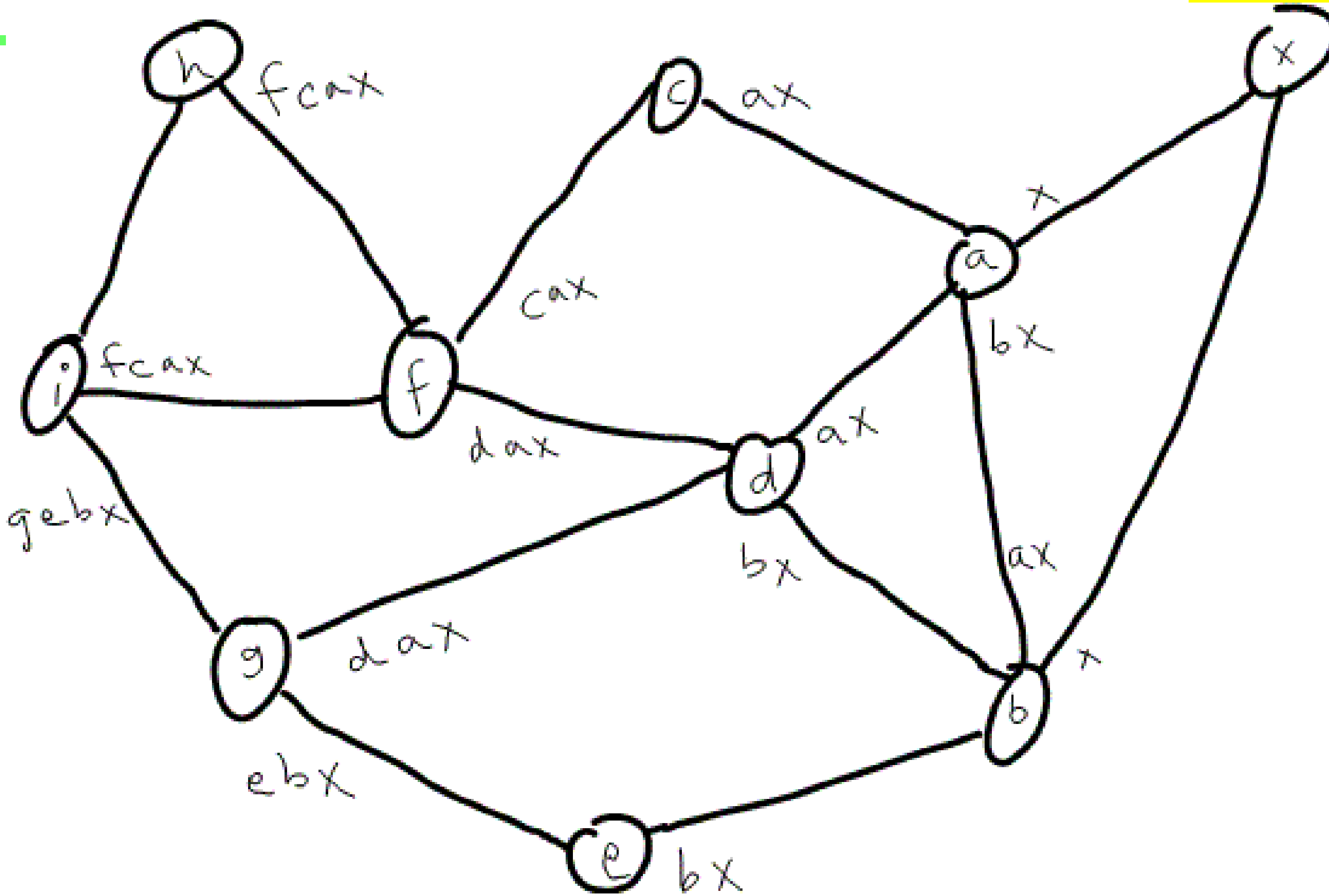
```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Address Family Identifier (2) |        Route Tag (2)          |
+-------------------------------+-------------------------------+
|                         IP Address (4)                        |
+---------------------------------------------------------------+
|                        Subnet Mask (4)                        |
+---------------------------------------------------------------+
|                          Next Hop (4)                         |
+---------------------------------------------------------------+
|                           Metric (4)                          |
+---------------------------------------------------------------+
```

Distance-path

- The problem with distance-vector is that a node never knows whether a path loops back through itself
- With distance-path algorithm, the entire path to the destination is reported
  - This is not so much overhead, because network diameters are generally small

Distance-path example



Distance-path pros and cons

- New paths have to be advertised even when the distance doesn't change
  - More traffic overhead…this has caused havoc in BGP
- More policy control (BGP)
  - Path is known, so can make more intelligent selection among alternatives
  - But still "hostage" to policy decisions made before you in the path