CS144
An Introduction to Computer Networks

Routing

Distance Vector Protocol:
Bellman Ford algorithm

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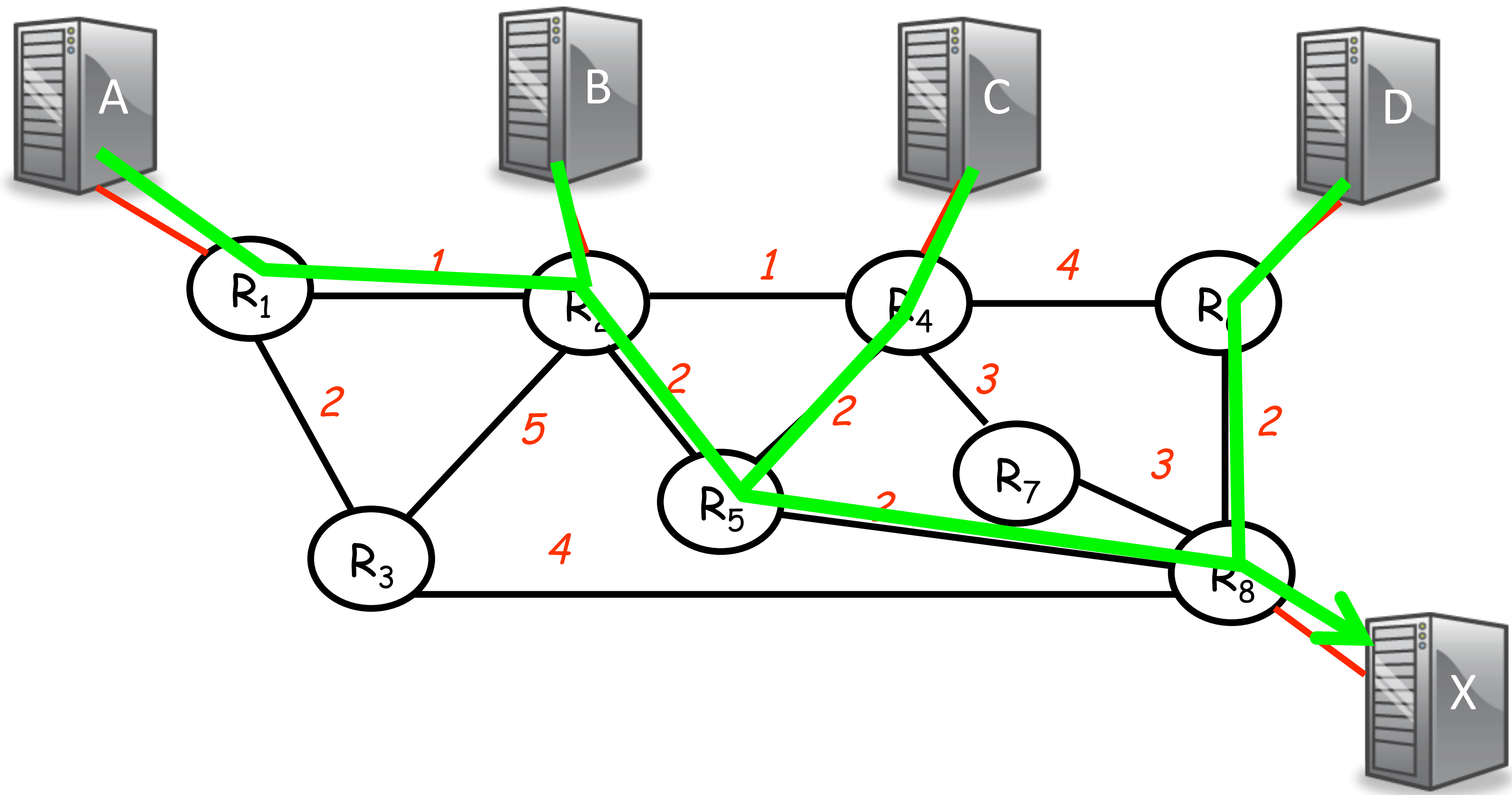
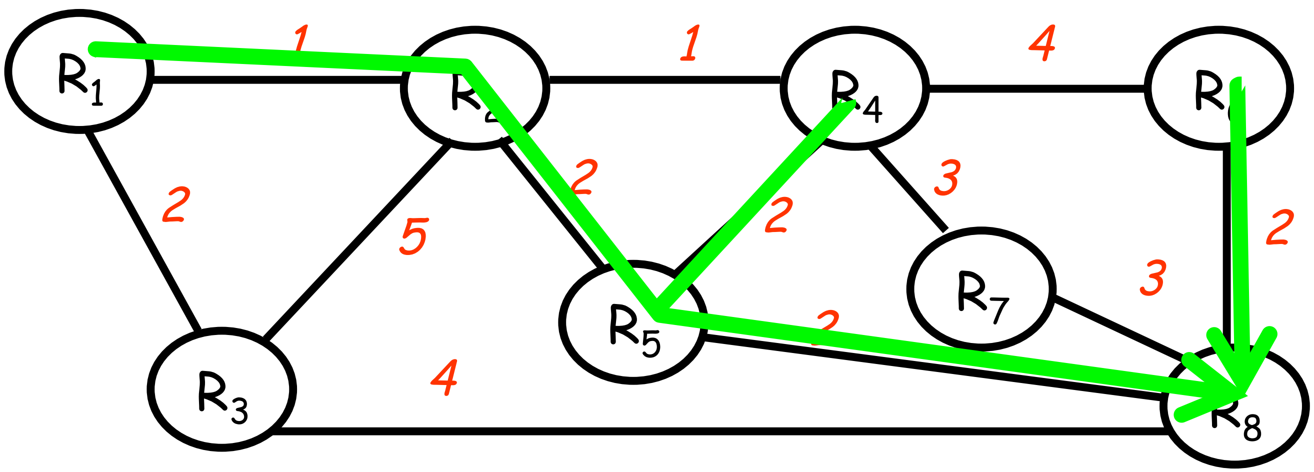
Problem: How can routers work together to find minimum cost spanning tree?



Equivalent to finding minimum cost spanning tree among routers only



The Distributed Bellman-Ford Algorithm

Example: Find min-cost spanning tree to R_8

Assume routers know cost of link to each neighbor.

Router R_i maintains value cost C_i to reach R_8.

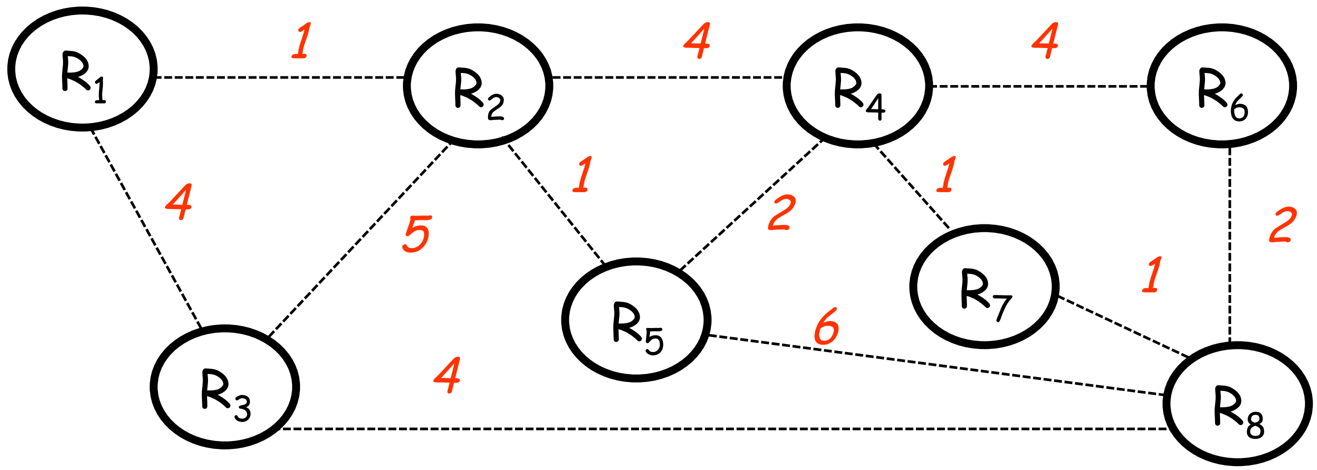
Vector $\underline{C}=(C_1, C_2,\ldots C_7)$ is the *distance vector* to R_8.

Initially, set $\underline{C} = (\infty, \infty, \ldots \infty)$.

1. After T seconds, R_i sends C_i to its neighbors.
2. If R_i learns lower cost path, update C_i.
3. Repeat.

Natural extension to calculate tree for $R_1 – R_7$.

An example



R_1	∞
R_2	∞
R_3	∞
R_4	∞
R_5	∞
R_6	∞
R_7	∞

R_1	∞
R_2	∞
R_3	4
R_4	∞
R_5	6
R_6	2
R_7	1

R_1	8, R_3
R_2	7, R_5
R_3	4
R_4	2, R_7
R_5	6
R_6	2
R_7	1

R_1	8, R_3
R_2	6, R_4
R_3	4
R_4	2, R_7
R_5	4, R_4
R_6	2
R_7	1

R_1	7, R_2
R_2	5, R_5
R_3	4
R_4	2, R_7
R_5	4, R_4
R_6	2
R_7	1

R_1	6, R_4
R_2	5, R_5
R_3	4
R_4	2, R_7
R_5	4, R_4
R_6	2
R_7	1

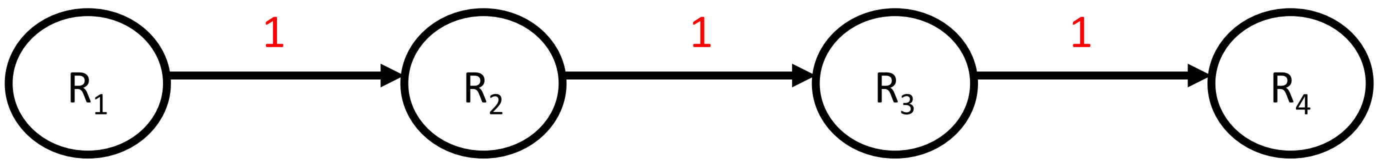
Distributed Bellman-Ford Algorithm

Questions:

1. What is the maximum run time of the algorithm?
2. Will the algorithm always converge?
3. What happens when link costs change, or when routers/links fail?

A Problem with Bellman-Ford

"Bad news travels slowly"



Consider the calculation of distances to R_4:

Time	R_1	R_2	R_3
0	3,R_2	2,R_3	1, R_4
1	3,R_2	2,R_3	3,R_2
2	3,R_2	4,R_3	3,R_2
3	5,R_2	4,R_3	5,R_2
…	"Counting to infinity"		…

Link $R_3 \longrightarrow R_4$ fails

Counting to Infinity Problem

Solutions

1. Set infinity = "some small integer" (e.g. 16).
   Stop when count = 16.
2. Split Horizon: Because R_2 received lowest cost path from R_3, it does not advertise cost to R_3.
3. Split-horizon with poison reverse: R_2 advertises infinity to R_3.
4. There are many problems with (and fixes for) the Bellman-Ford algorithm.

Bellman Ford in practice

Bellman-Ford algorithm is an example of a Distance Vector algorithm.

It was used in the first Internet routing protocol, called Routing Information Protocol (RIP).

It requires very little computation on the routers, is distributed, and will eventually converged.

Over time it was replaced by algorithms that calculate the entire spanning tree at each router.