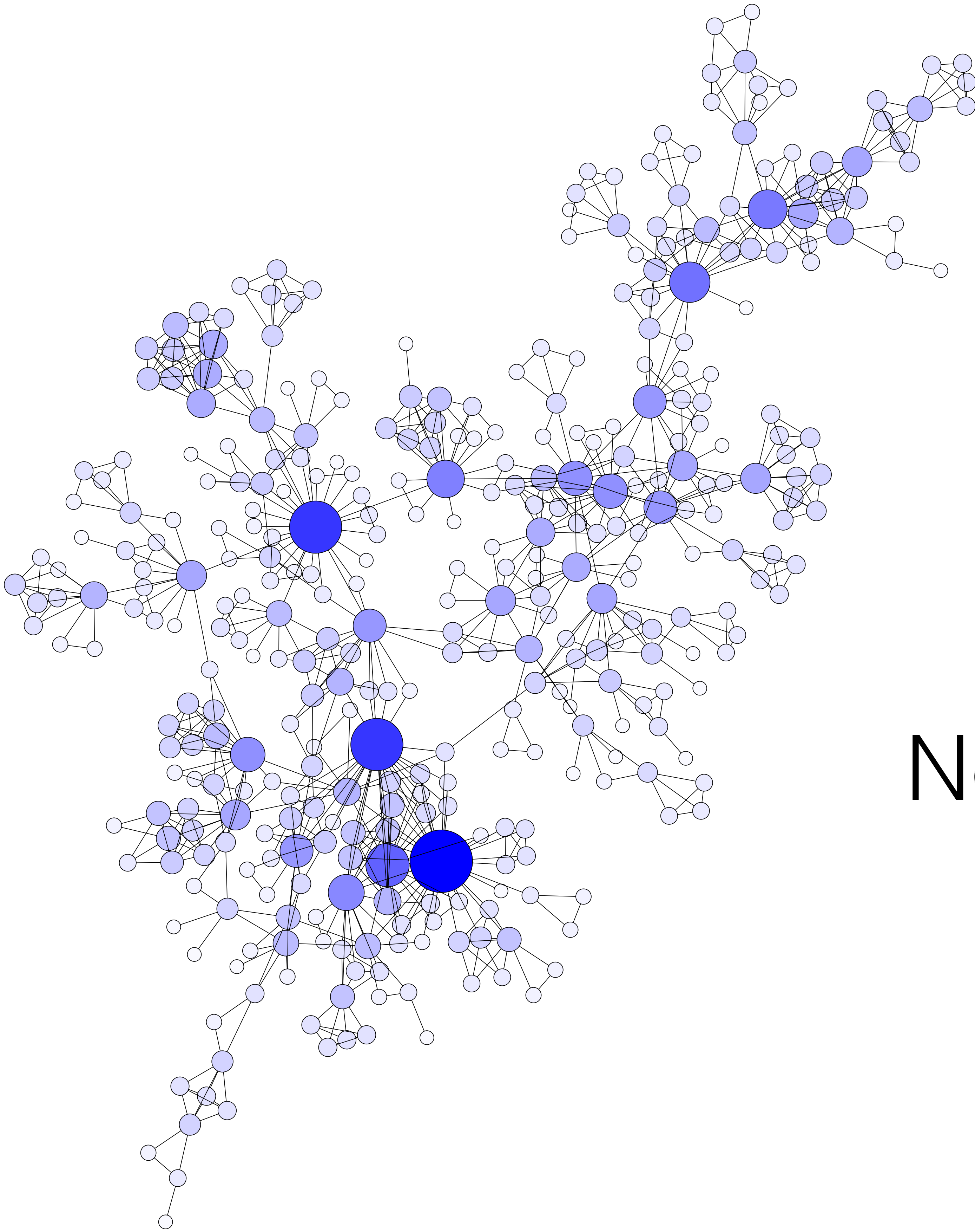


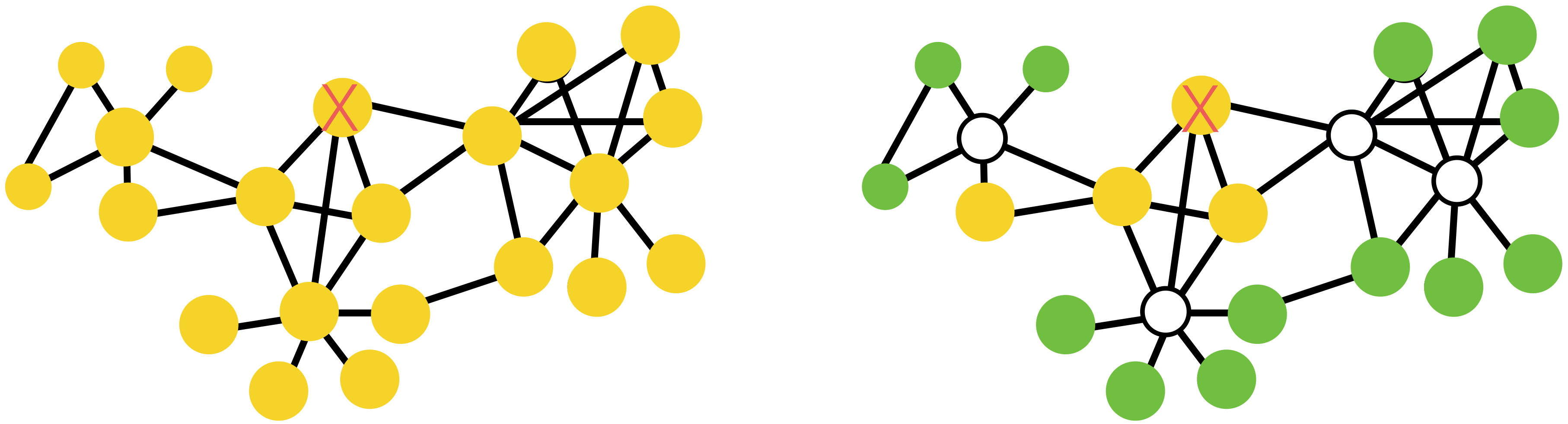
Network Resilience

Network Resilience

Removing nodes can have a number of effects:

- Path length ↑
- Average degree ↓
- Size of largest connected component ↓

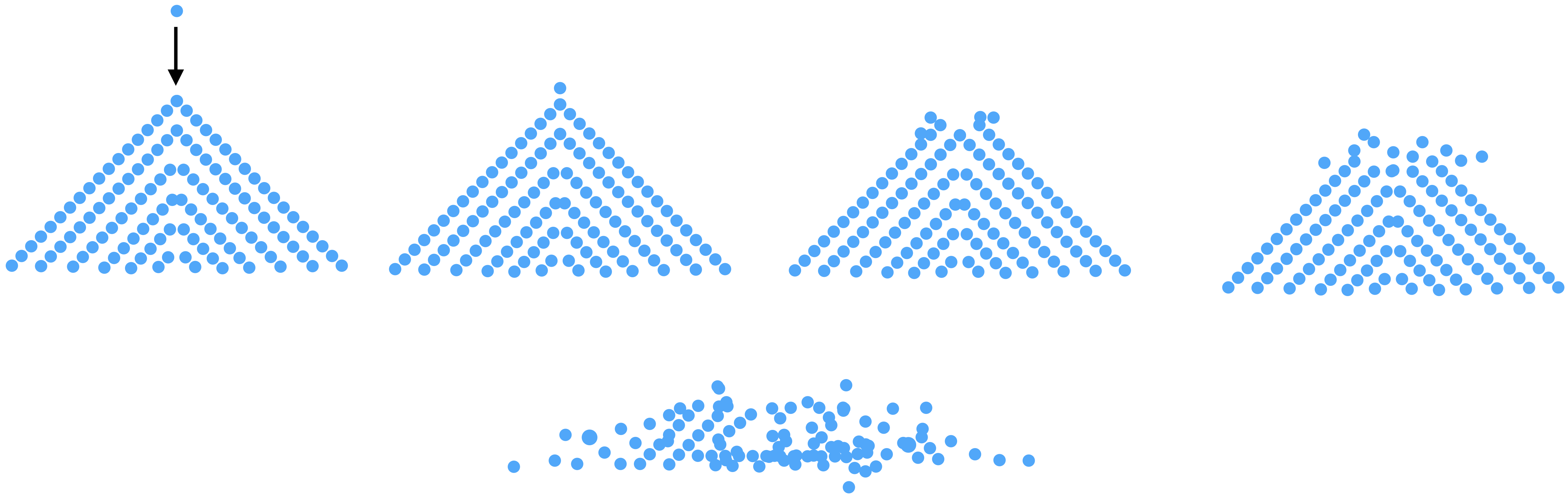
This should sound familiar from when we looked at vaccinating individuals to prevent the spread of disease: "removing" nodes fragments the network



Network Resilience

If nodes depend on each other, then there may be a chain reaction: removing one node may lead to others being removed as well

This process is called a *cascade*



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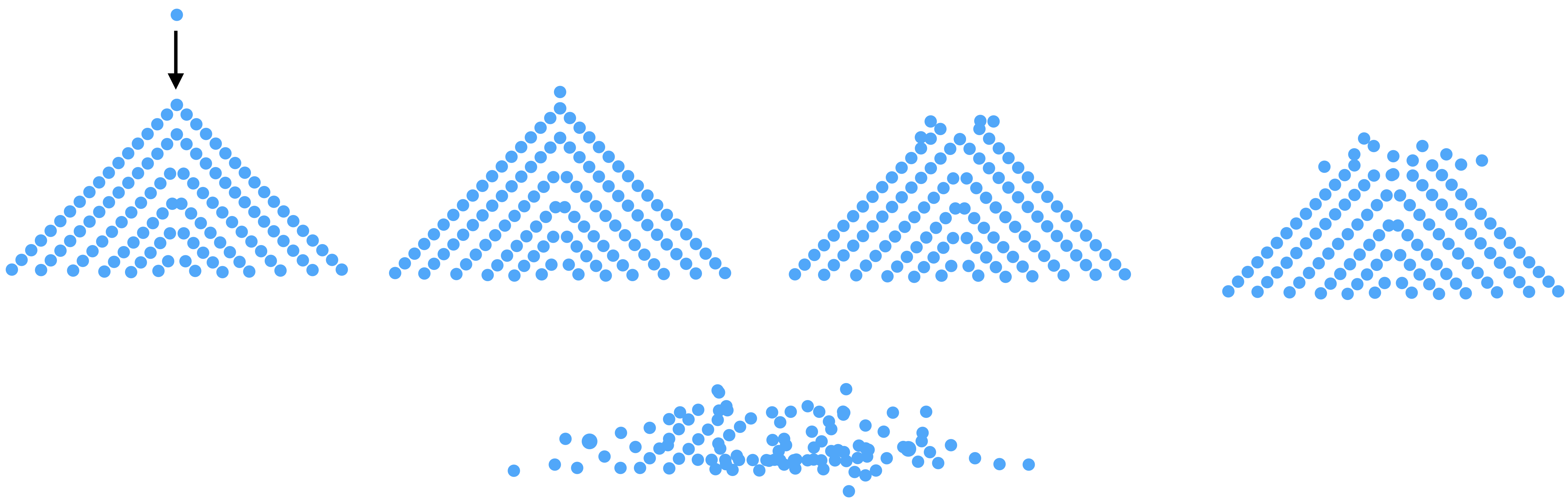
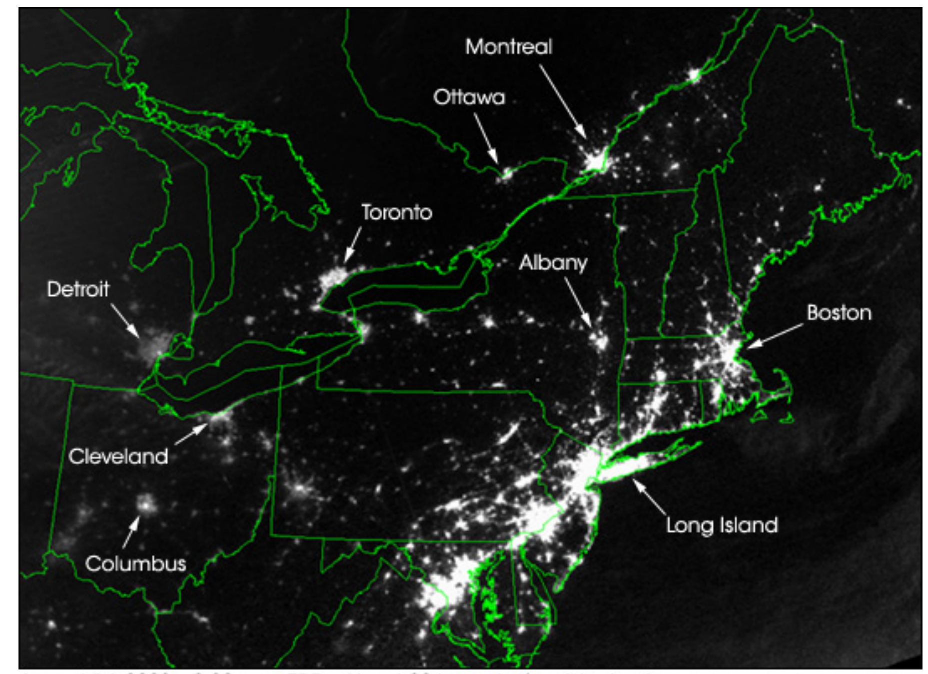


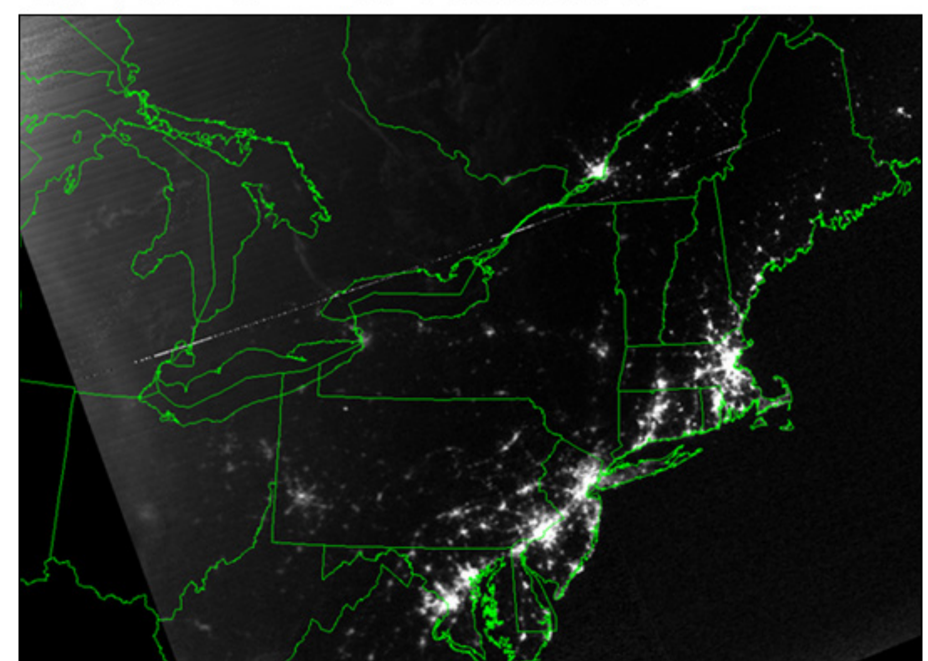
Network Resilience

Cascading failure is important in many contexts:

- Servers
- Financial Systems
- City Traffic
- Power Grids
- Ecosystems
- Airline Traffic



August 14, 2003 • 9:29 p.m. EDT • About 20 hours before blackout

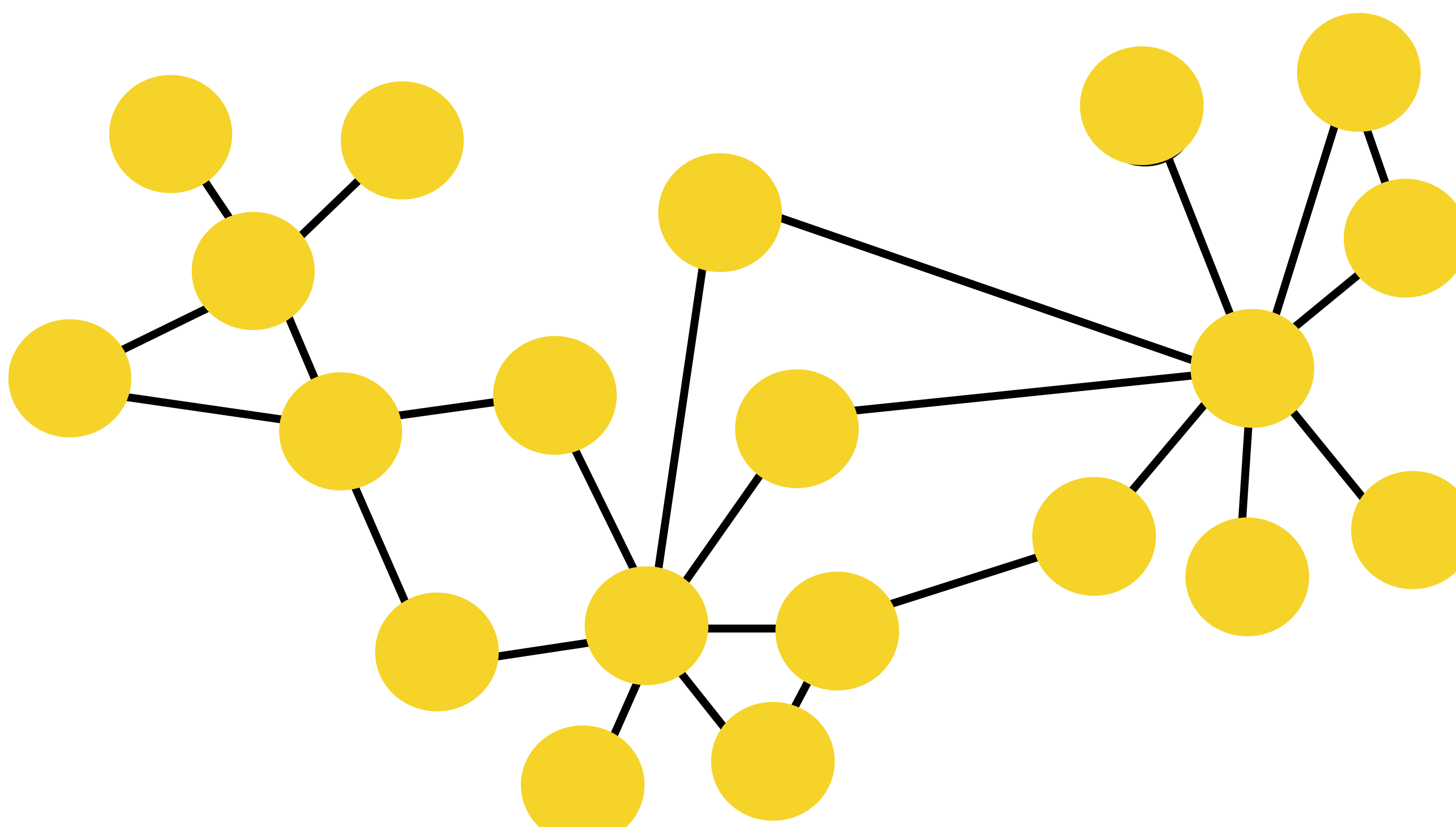

August 15, 2003 • 9:14 p.m. EDT • About 7 hours after blackout

ref: NASA

Network Resilience

A thought experiment: Suppose you have a network of banks, where A->B if A lends B money.

- If B fails, then they default on the loan to A
- If enough of A's investments fail, then they also default
- A default can spread through the network



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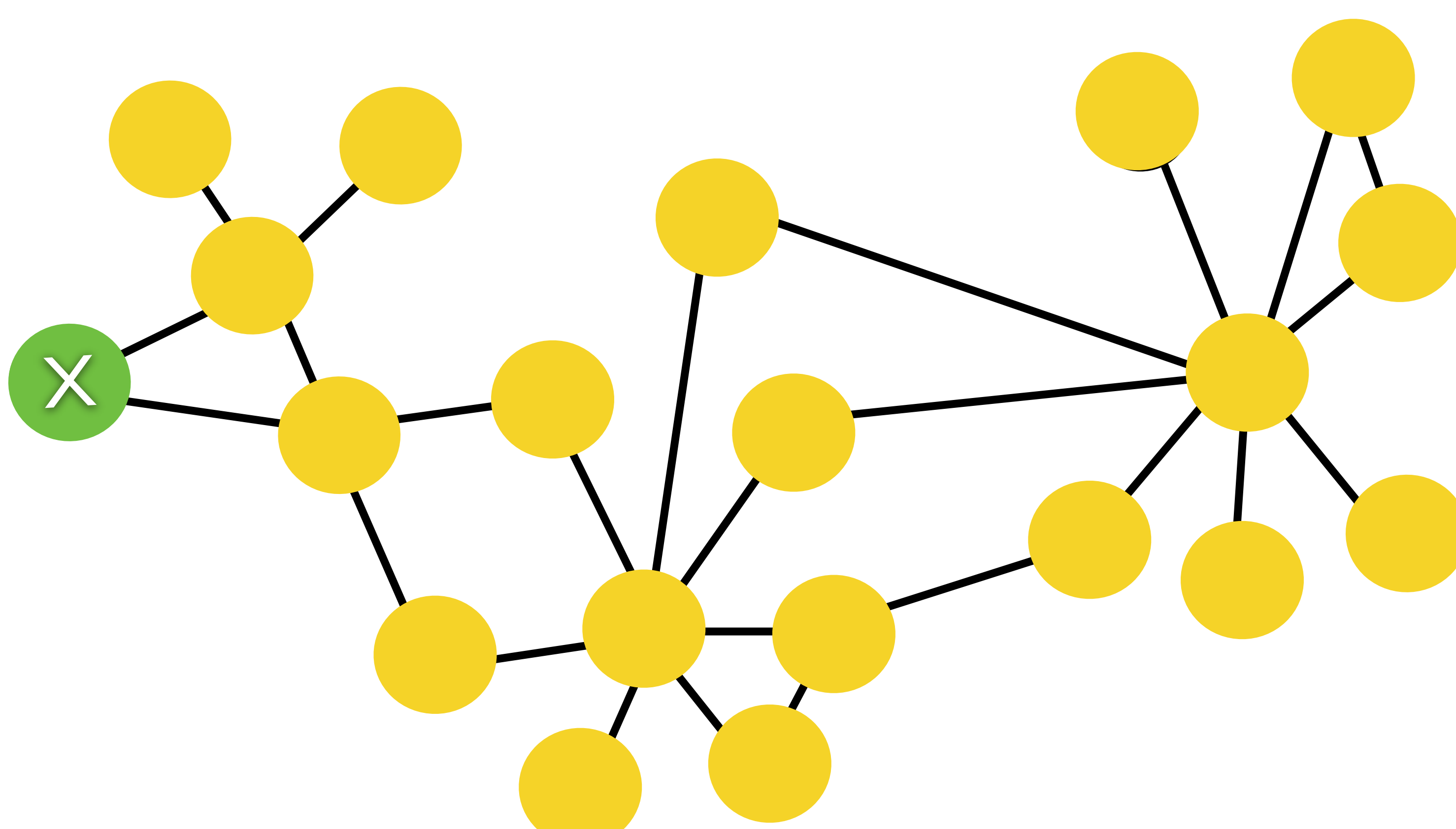

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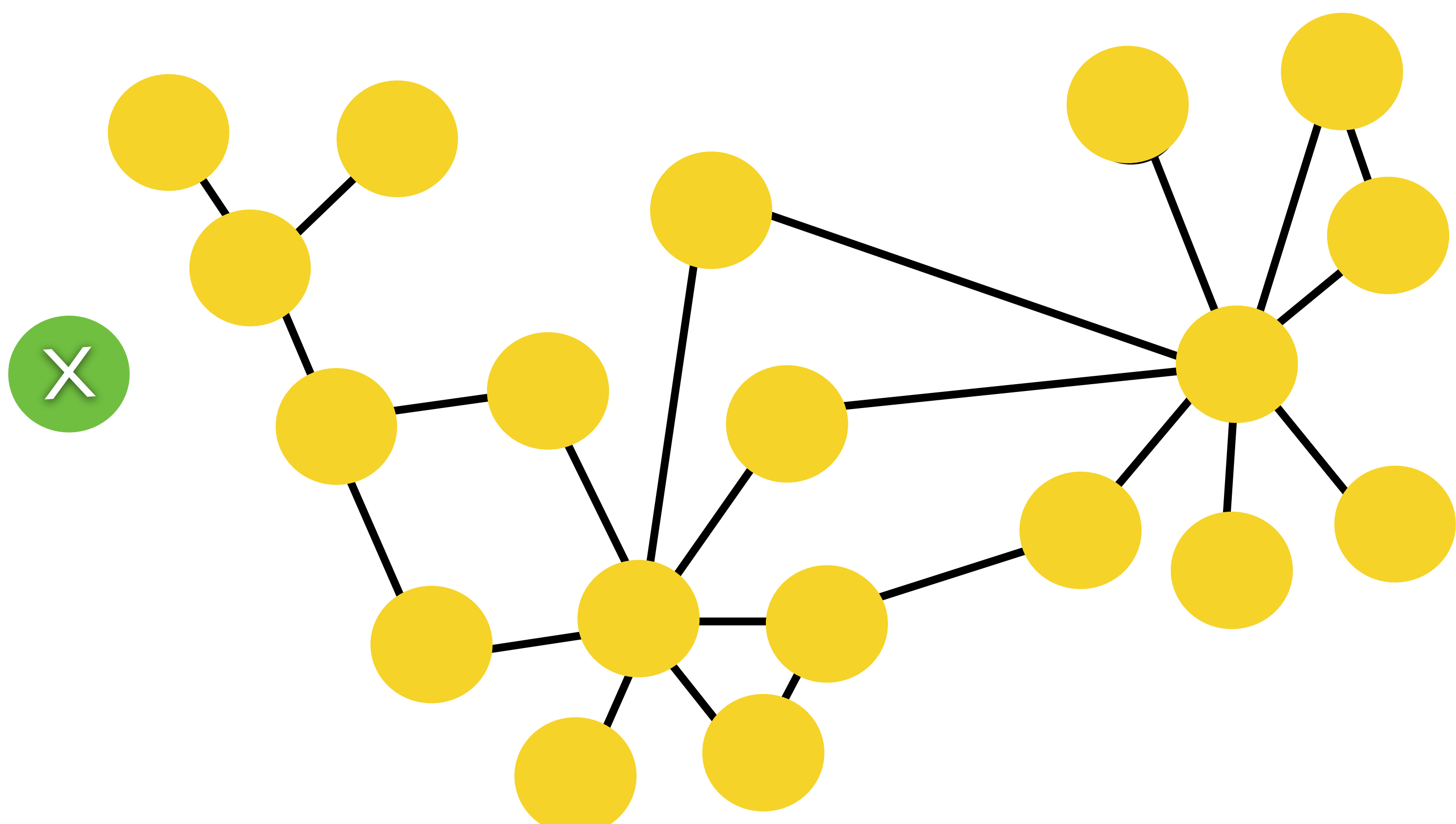

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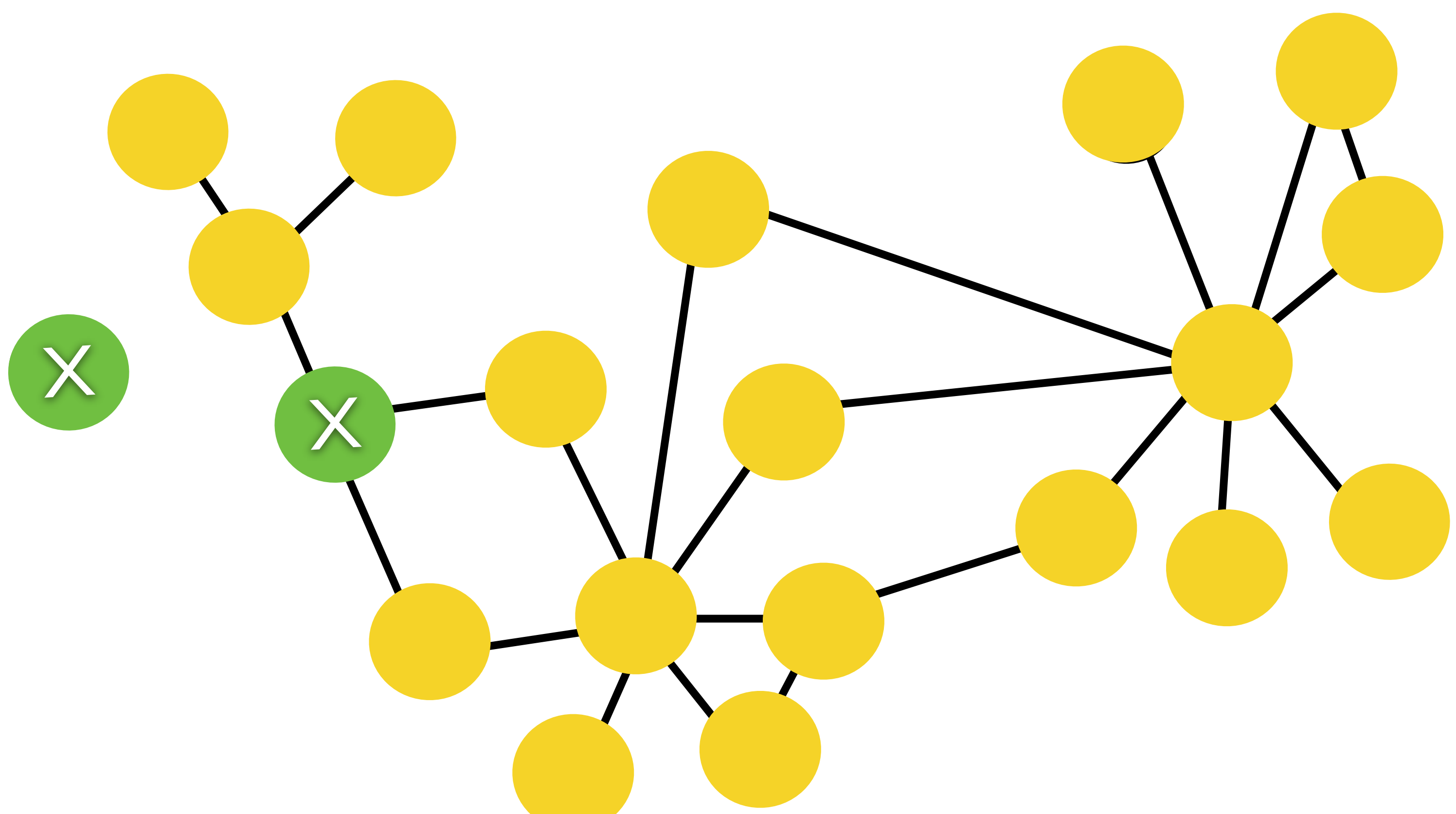

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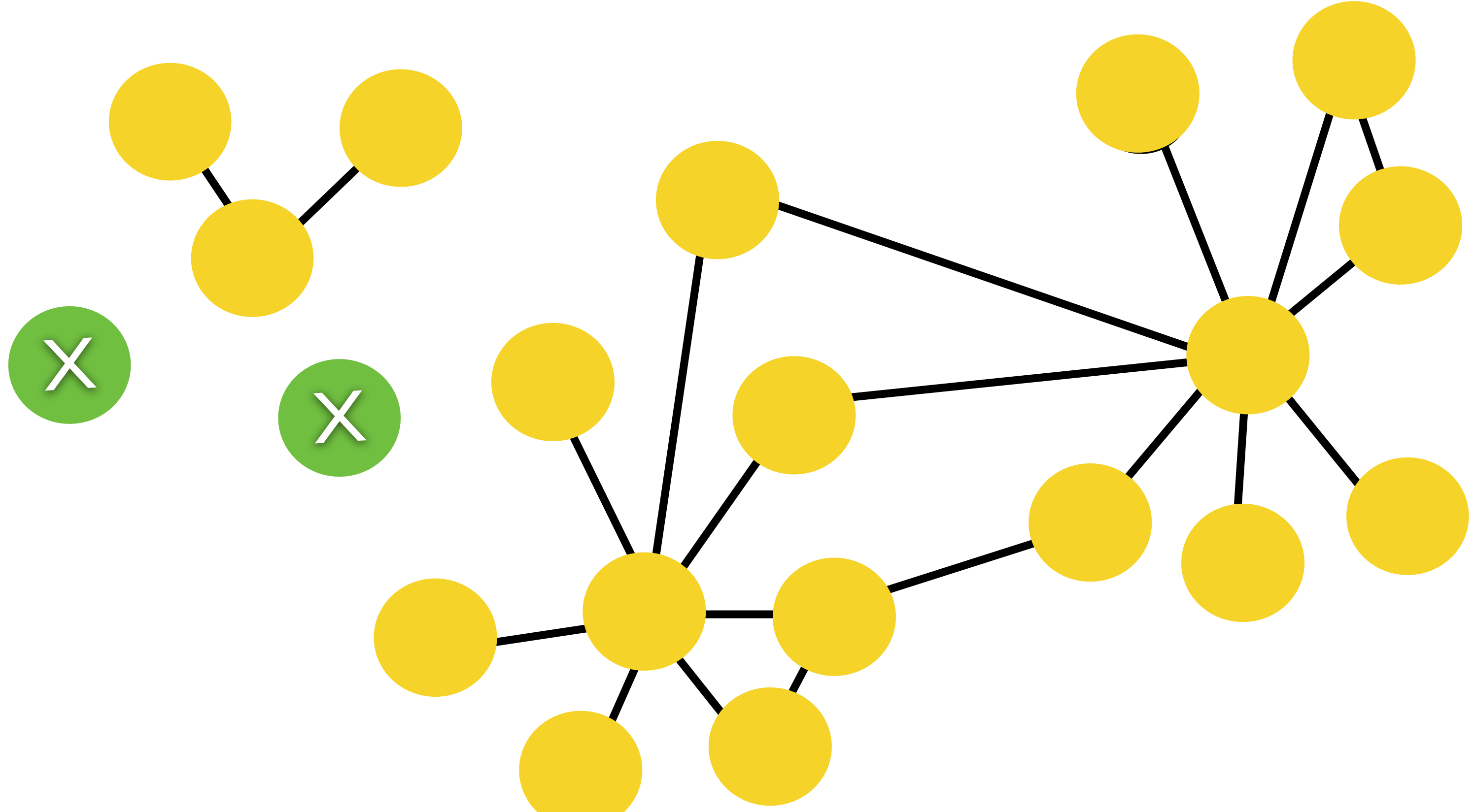

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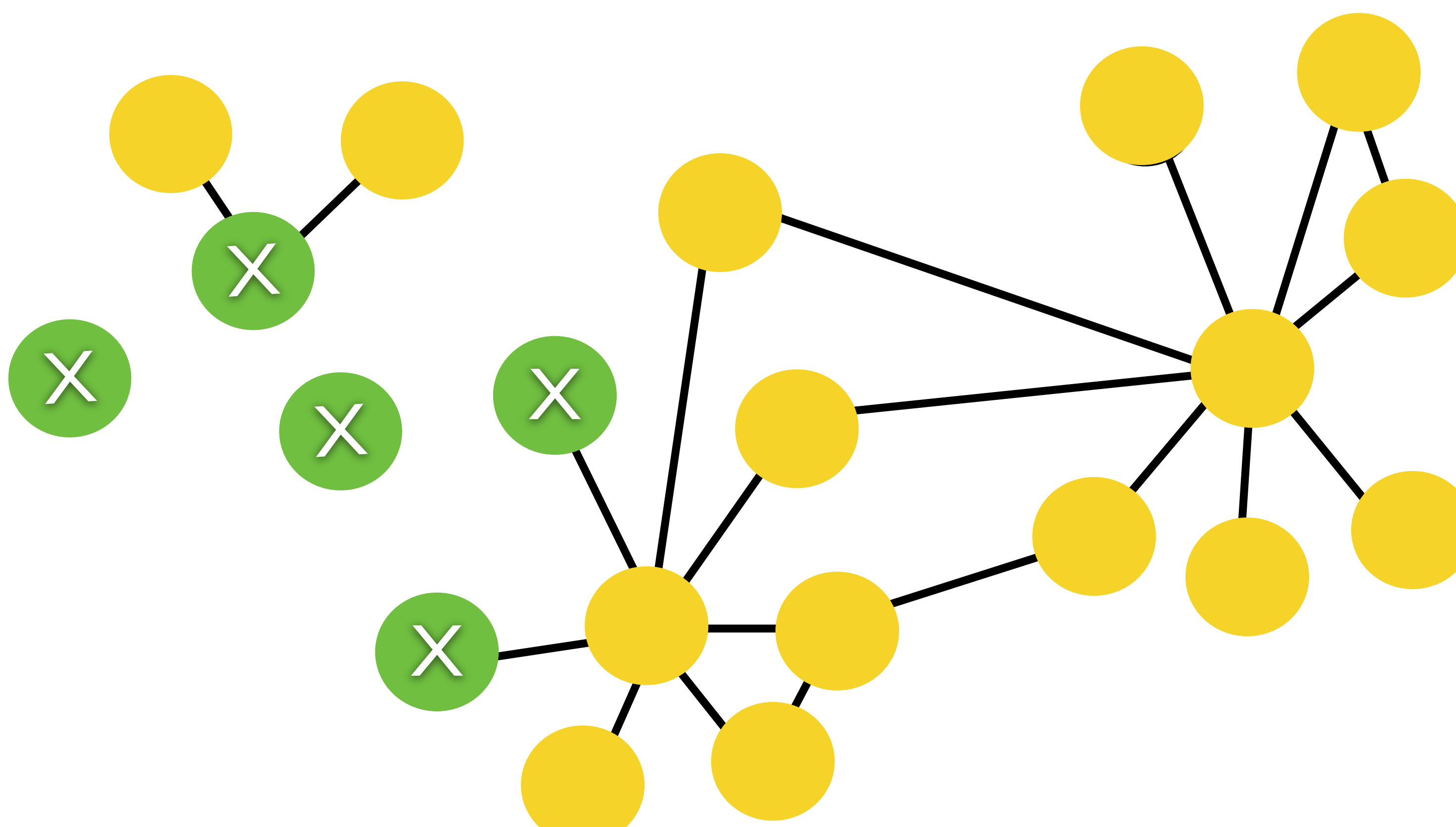

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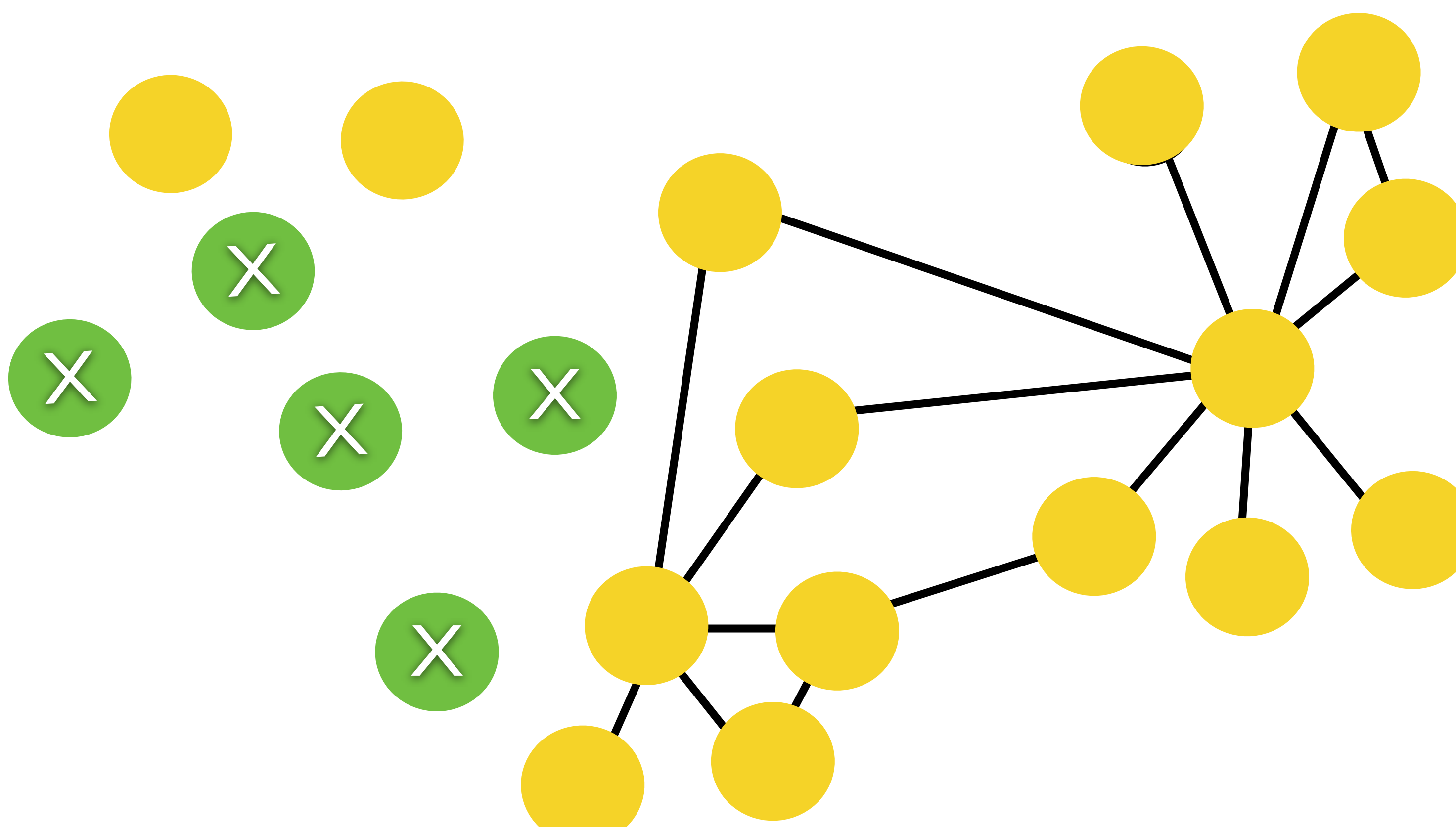

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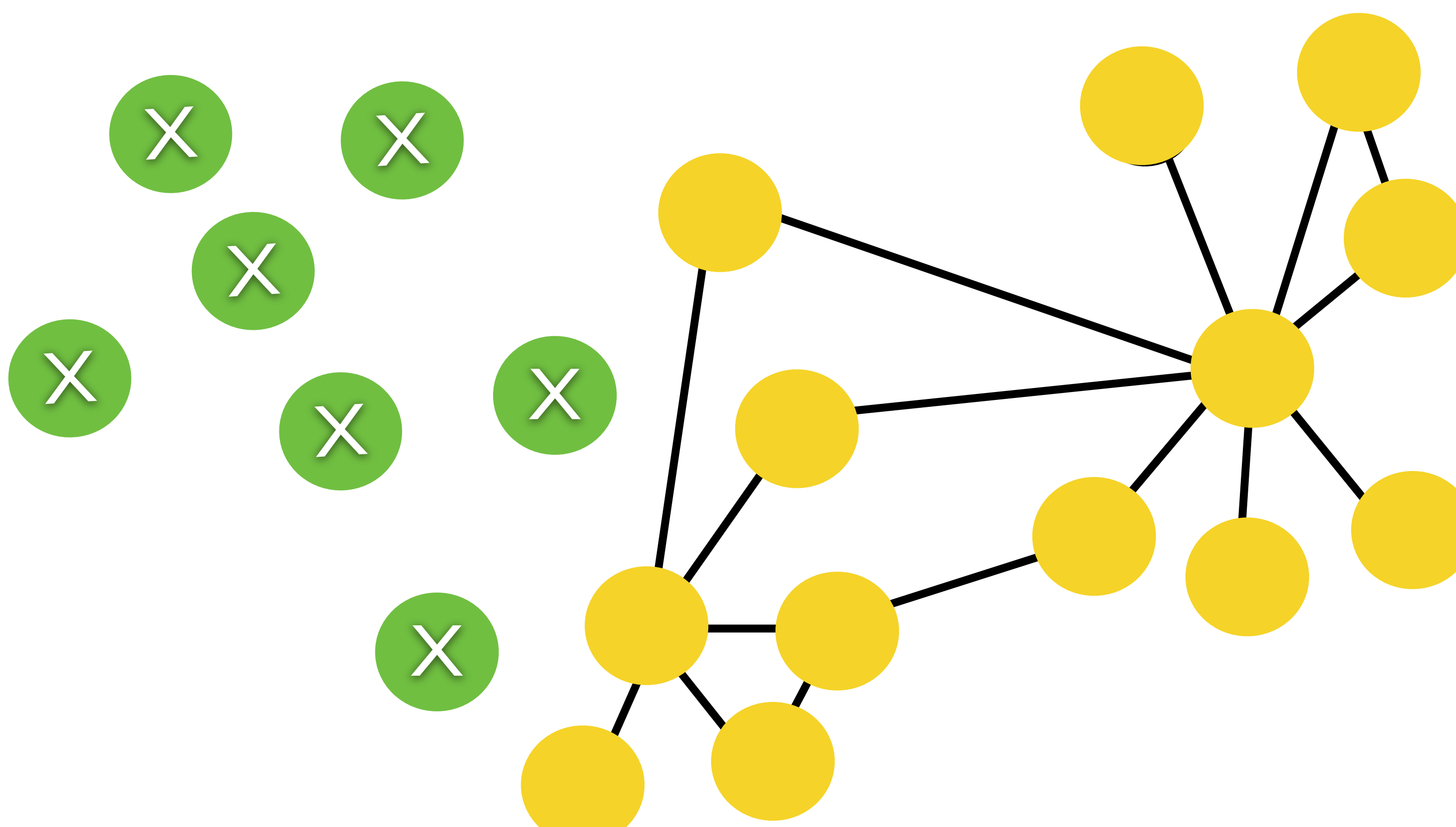
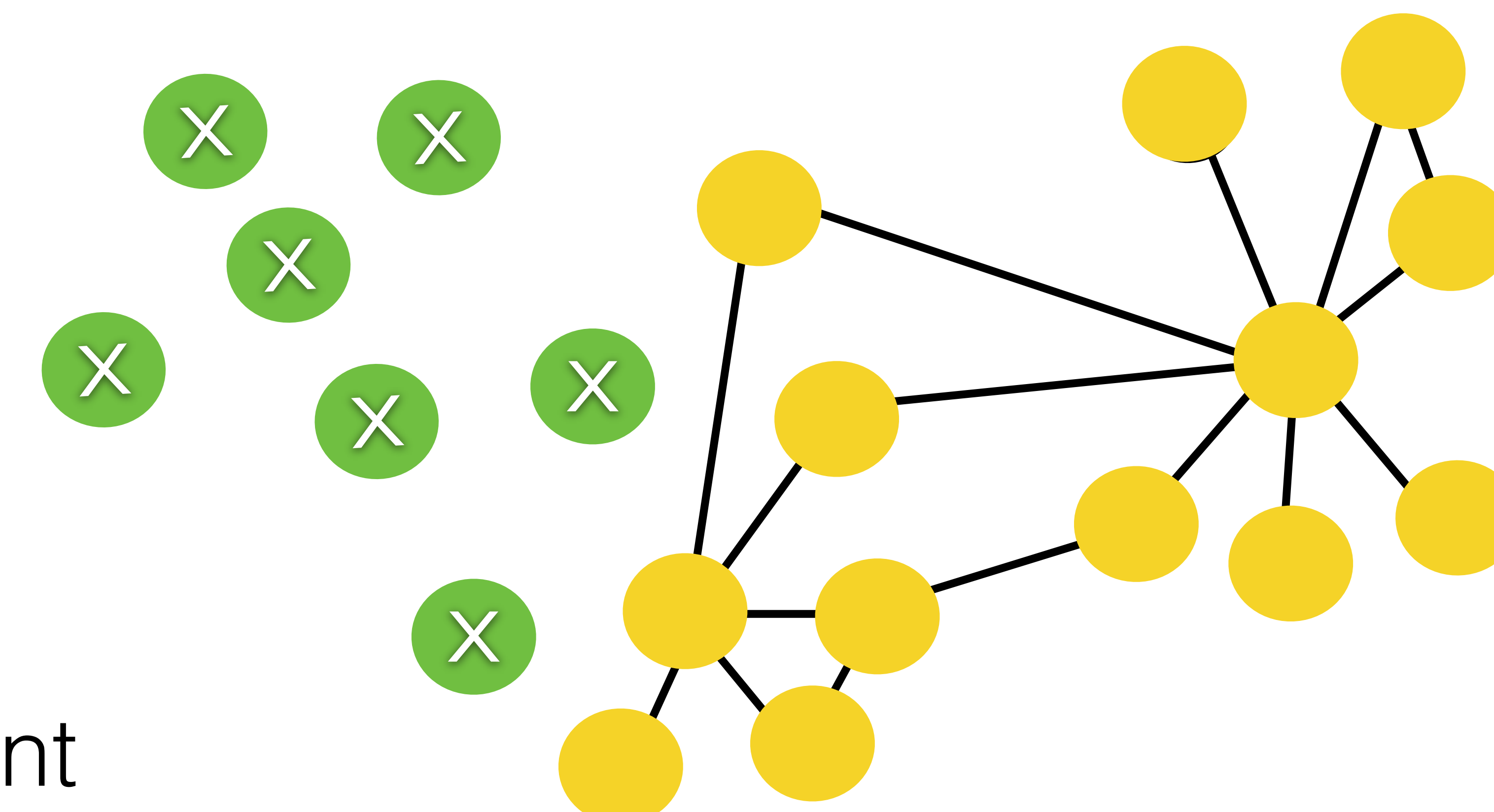


Network Resilience

So one failure can cause many failures—how many will depend on the structure of the network, and which node initially fails.

Question 1: what characteristics of the network affect it's resilience?



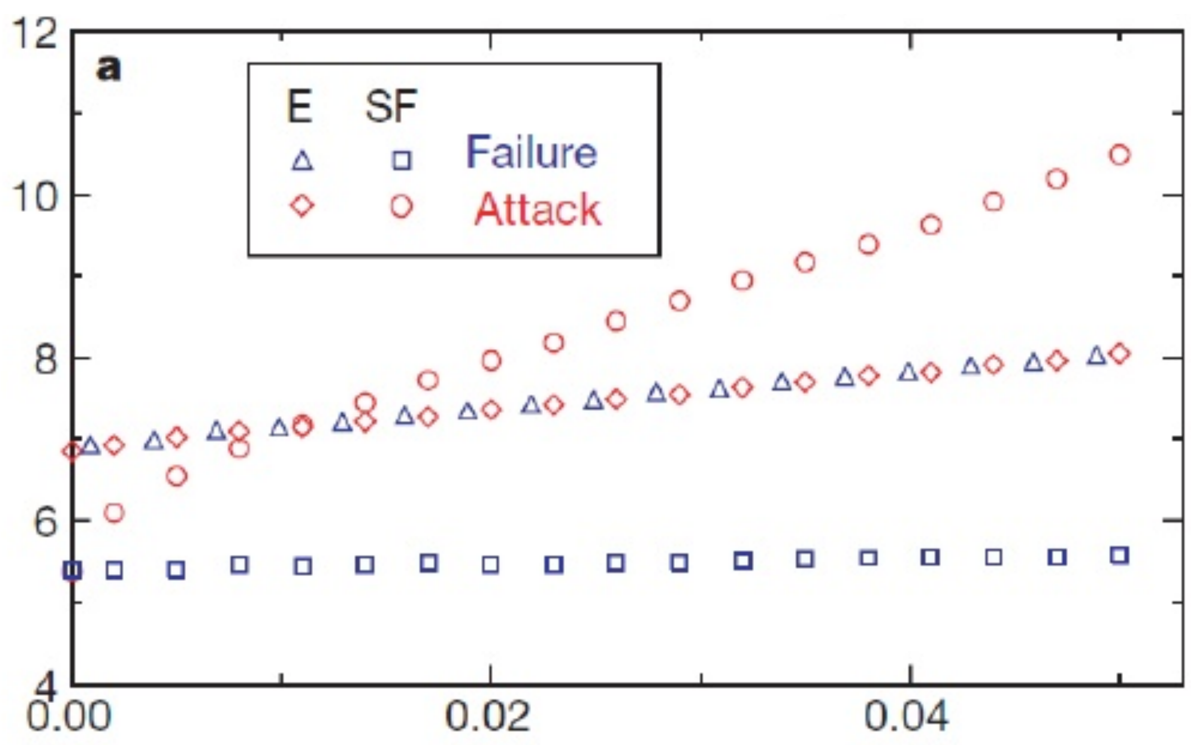
Question 2: how is a random failure different than a deliberate attack?

Network Resilience

Characteristic 1: Degree distribution

Higher average degree: less resilience to node deletion

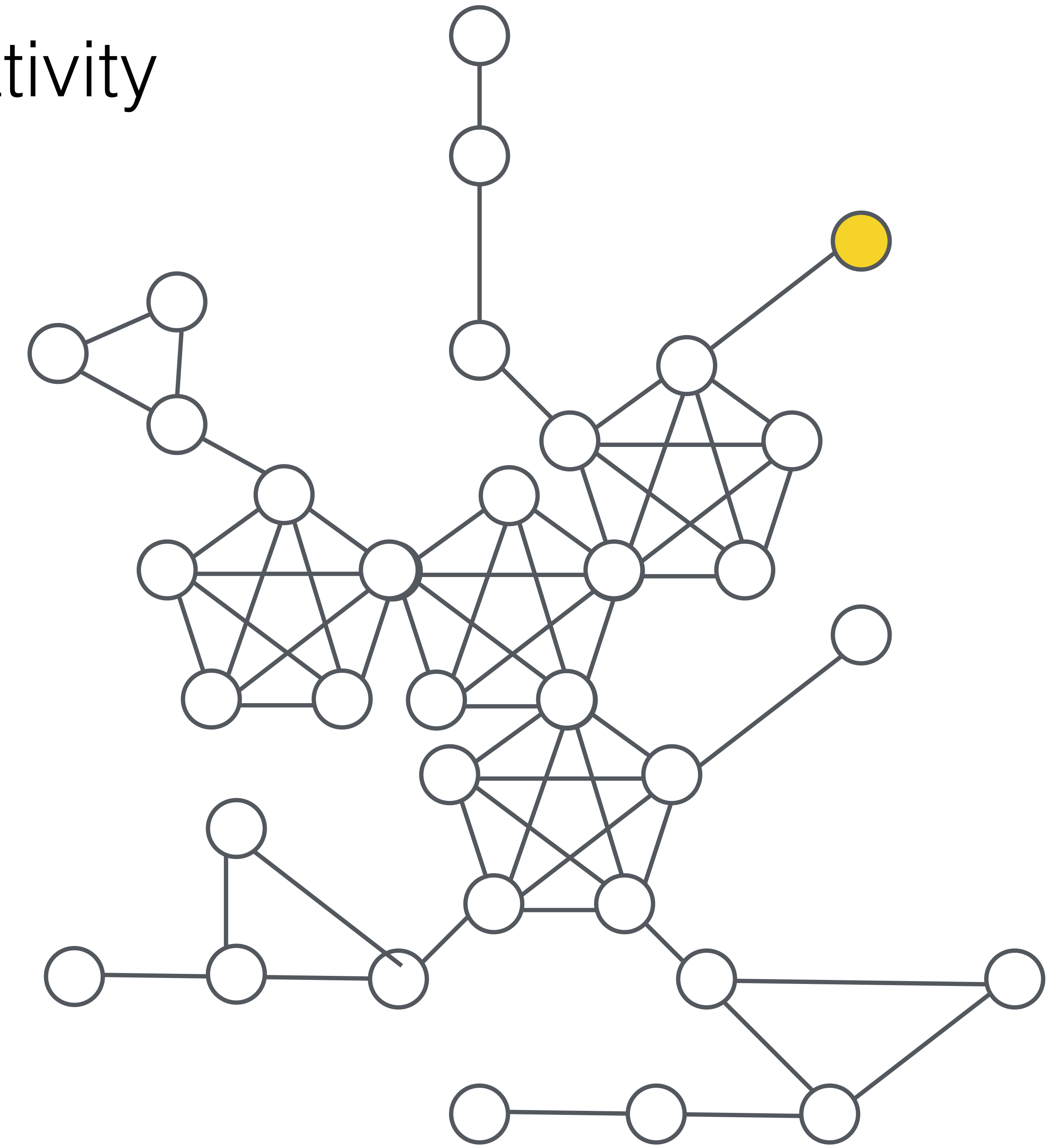
More skewed degree distribution: less resilience to node deletion (generally speaking)



Network Resilience

Characteristic 2: Assortativity

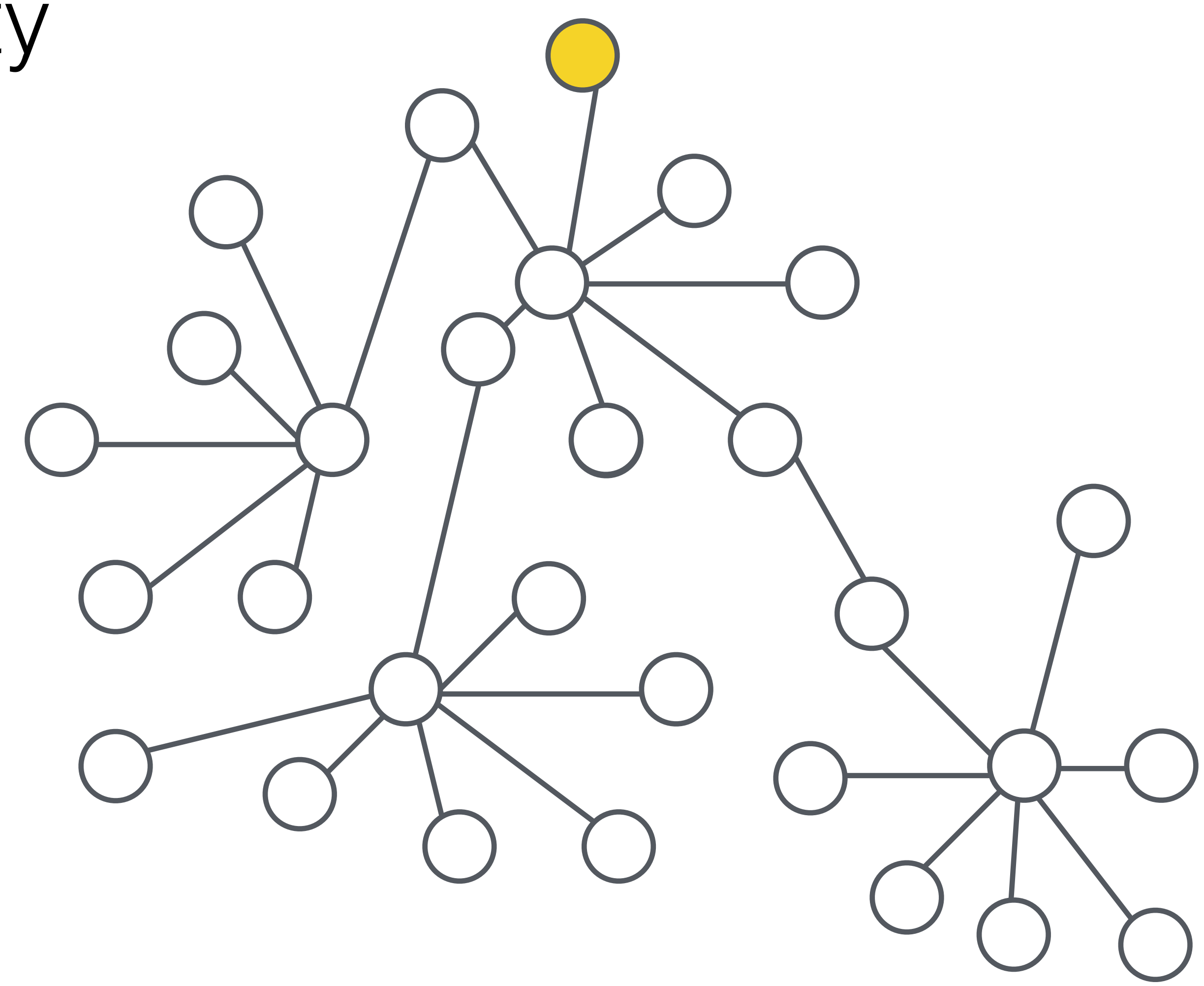
Assortative networks fail quickly, but the failure is not wide-spread



Network Resilience

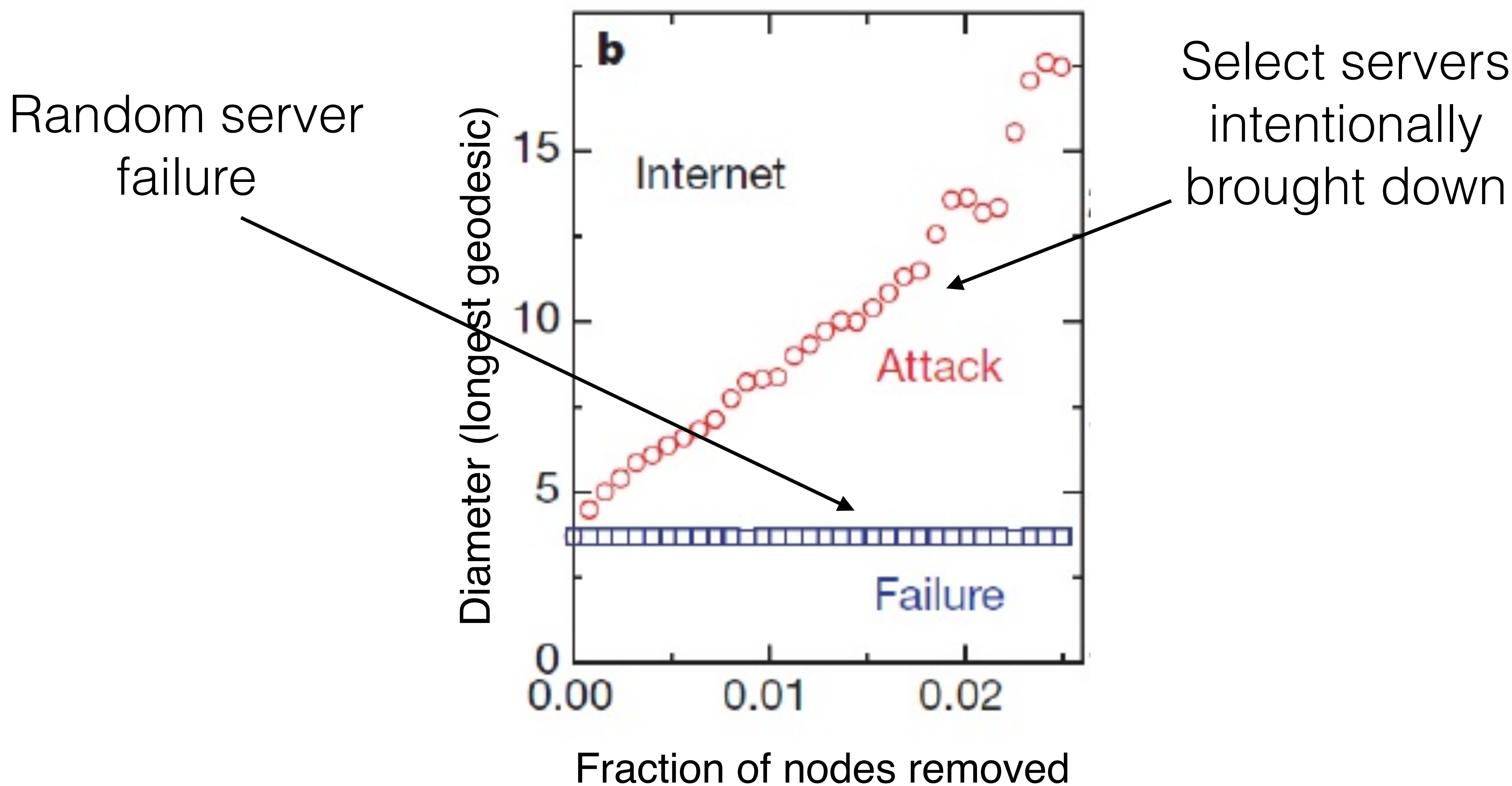
Characteristic 2: Assortativity

Disassortative networks fail slowly, but comprehensively



Network Resilience

It also depends on whether the failure was random, or a deliberate choice



Network Resilience

This has implications for how we should design power networks, airline routes, road systems, server networks, etc to prevent wide-spread failure due to terrorist attack

It also might have implications for how covert networks are formed to minimize the chances of the whole system going down at once