Understanding emergent behaviors
- Stacking up simple functionalities results in complex artifacts …

… whose behaviors and properties we need to understand and make statements about!

Let’s take an example
- How does the Internet “graph” or a social network “graph” grow over time?
  - What will it look like in 10 years?

- Important to find out to answer questions like
  - Are there vulnerabilities? What are the weakest links?
  - How to slow down virus propagation?
  - How to design marketing/political campaigns?
  - Who is the most influential blogger out there?

Let’s take an example
- How does the Internet “graph” or a social network “graph” grow over time?
  - What will it look like in 10 years?

- I have no idea, but I can make a wild guess
  - I can “imagine” a model of how such networks may form…
Attempt #1: Edges at Random

1. Pick the size of the graph you want – i.e., the number of nodes $n$ you want.

2. Pick the average number of neighbors (degree) for a node $d$.

3. For every pair of nodes in the graph – roll the dice and with probability $\sim \frac{d}{n}$ establish an edge between the pair of nodes.

What do we get? [demo]

"ER" Model due to Erdos-Renyi (circa 1959)

Observations for ER Graphs

- Graph disconnected when $d < 1$ and very "quickly" gets connected when $d > 1$.

- Not a natural way to explain how (Internet or social) networks develop because it is not an "evolutionary" graph.

- Need a "growth" model…

Attempt #2: Random Attachment

1. In the beginning, the network had a single node.

2. Then, came a new node which decided to link up to the network. To do so:
   - The new node selected one of the existing nodes in the network uniformly at random.
   - The new node establishes a link to that node.

3. Go to 2 until graph of desired size is reached.

What do we get? [Demo]

How does it compare?

Which one is my "real" Facebook graph?