

# Centrality Measures

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Measures of the “importance” of a node in a network

The Oracle of Bacon

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Kevin Bacon to Charles Chaplin Find link More options >

```

    graph TD
      A[Charles Chaplin] --> B[Picture People No. 3: Hobbies of the Stars (1941)]
      B --> C[John Doolittle]
      C --> D[The Firm (1935)]
      D --> E[Margo Martindale]
      E --> F[Reels & Ties (2007)]
      F --> G[Kevin Bacon]
  
```

The screenshot shows a web browser window with the title "The Oracle of Bacon - Mozilla Firefox". The address bar contains a URL starting with "http://www.theoracleofbacon.org". The page features a header with a classical statue on the left and a portrait of a man on the right. The main content area displays a vertical search path from "Kevin Bacon" to "Charles Chaplin". The path consists of the following nodes: Charles Chaplin (green box), Picture People No. 3: Hobbies of the Stars (1941) (blue box), John Doolittle (green box), The Firm (1935) (blue box), Margo Martindale (green box), Reels & Ties (2007) (blue box), and Kevin Bacon (green box). Arrows indicate the direction of the search path. Below the path, there is a search bar with "Kevin Bacon" in the first field and "to Charles Chaplin" in the second field, followed by "Find link" and "More options >" buttons. The browser's taskbar at the bottom shows several open applications, including "The Oracle of Bacon".

# Hollywood Revolves Around

Click on a name to see that person's table.

[Steiger, Rod](#) (2.678695)

[Lee, Christopher \(I\)](#) (2.684104)

[Hopper, Dennis](#) (2.698471)

[Sutherland, Donald \(I\)](#) (2.701850)

[Keitel, Harvey](#) (2.705573)

[Pleasence, Donald](#) (2.707490)

[von Sydow, Max](#) (2.708420)

[Caine, Michael \(I\)](#) (2.720621)

[Sheen, Martin](#) (2.721361)

[Quinn, Anthony](#) (2.722720)

[Heston, Charlton](#) (2.722904)

[Hackman, Gene](#) (2.725215)

[Connery, Sean](#) (2.730801)

[Stanton, Harry Dean](#) (2.737575)

[Welles, Orson](#) (2.744593)

[Mitchum, Robert](#) (2.745206)

[Gould, Elliott](#) (2.746082)

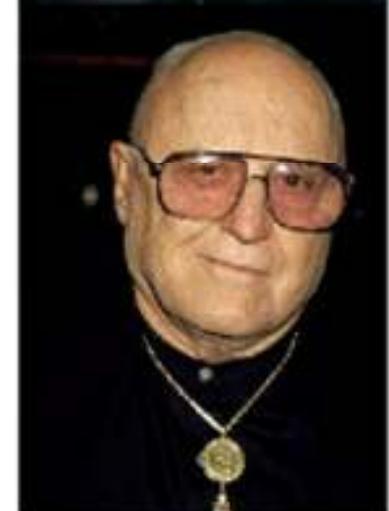
[Plummer, Christopher \(I\)](#) (2.746427)

[Coburn, James](#) (2.746822)

[Borgnine, Ernest](#) (2.747229)



Rod Steiger



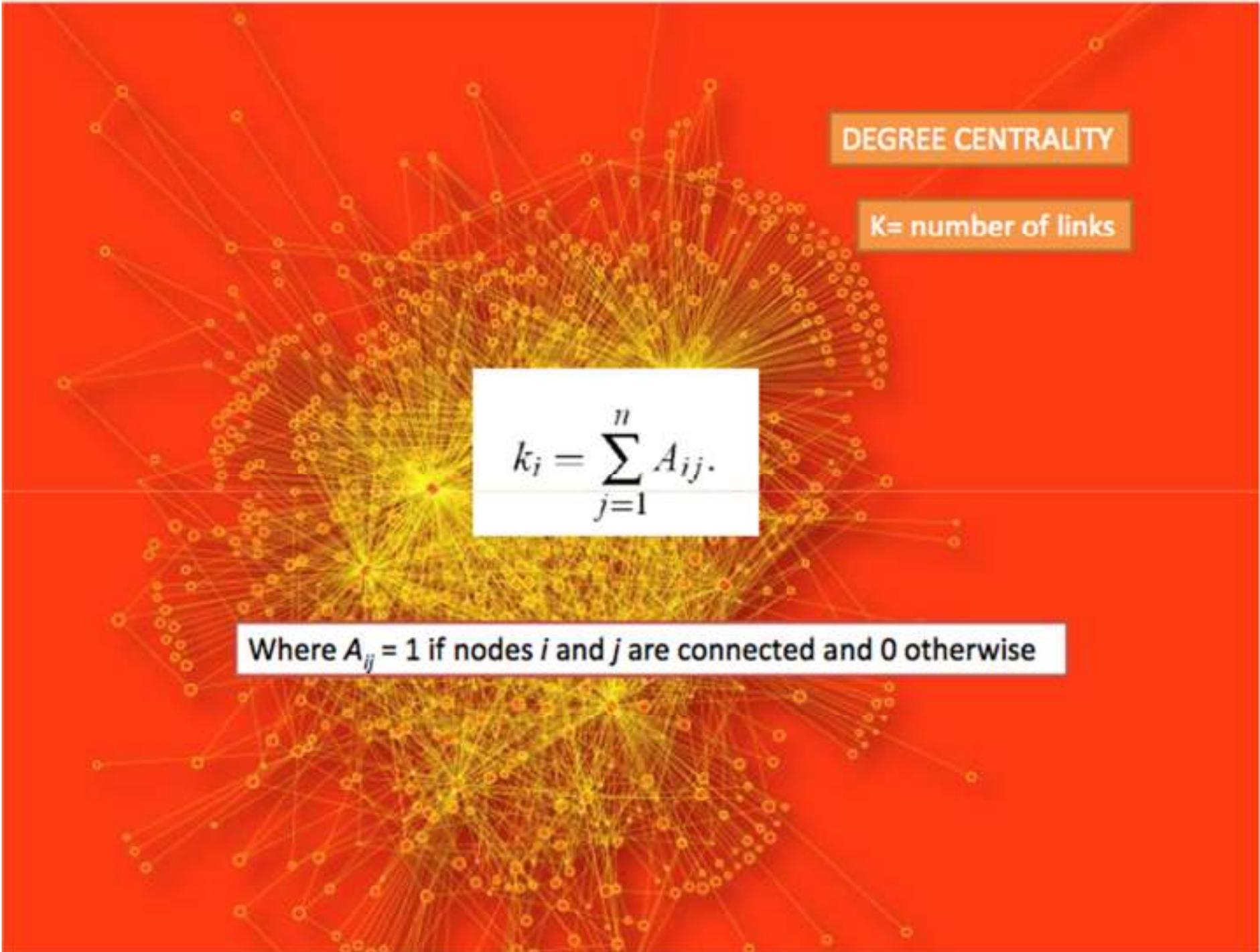
# Most Connected Actors in Hollywood

(measured in the late 90's)

Mel Blanc 759
Tom Byron 679
Marc Wallice 535
Ron Jeremy 500
Peter North 491
TT Boy 449
Tom London 436
Randy West 425
Mike Horner 418
Joey Silvera 410



XXX



DEGREE CENTRALITY

$K$  = number of links

$$k_i = \sum_{j=1}^n A_{ij}.$$

Where  $A_{ij} = 1$  if nodes  $i$  and  $j$  are connected and 0 otherwise

## BETWEENNESS CENTRALITY

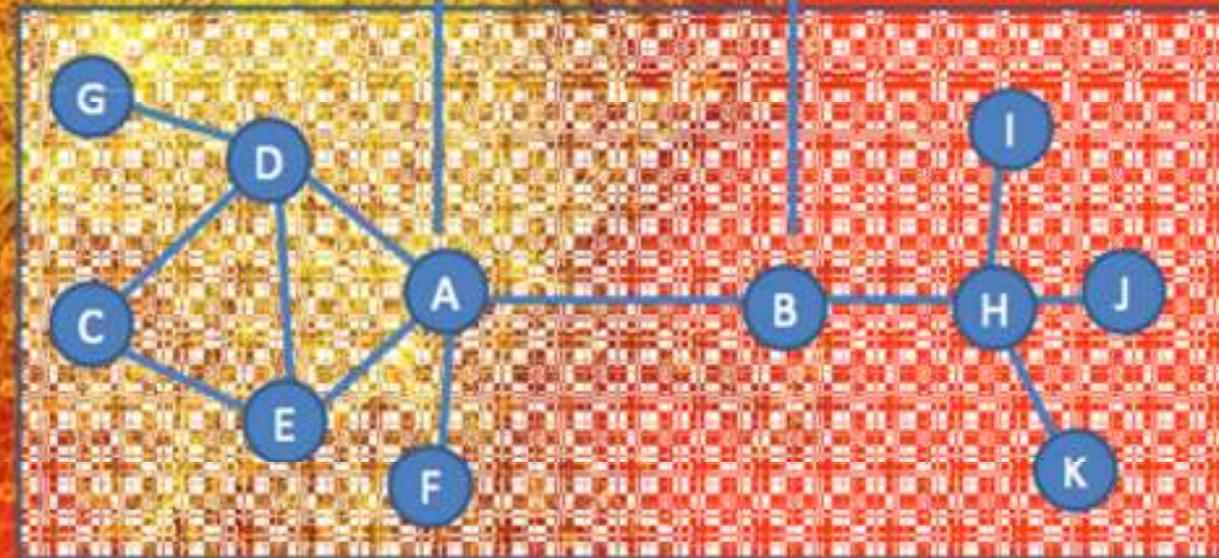
BC= number of shortest Paths that go through a node.

$$BC(G)=0$$

$$BC(D)=9+7/2=12.5$$

$$BC(A)=5*5+4=29$$

$$BC(B)=4*6=24$$



N=11

A set of measures of centrality based on  
betweenness

LC Freeman - Sociometry, 1977 - jstor.org

$$C(G) = \frac{1}{10}(1 + 2 \cdot 3 + 2 \cdot 3 + 4 + 3 \cdot 5)$$
$$C(G) = 3.2$$

$$C(A) = \frac{1}{10}(4 + 2 \cdot 3 + 3 \cdot 3)$$
$$C(A) = 1.9$$

### CLOSENESS CENTRALITY

C = Average Distance to neighbors



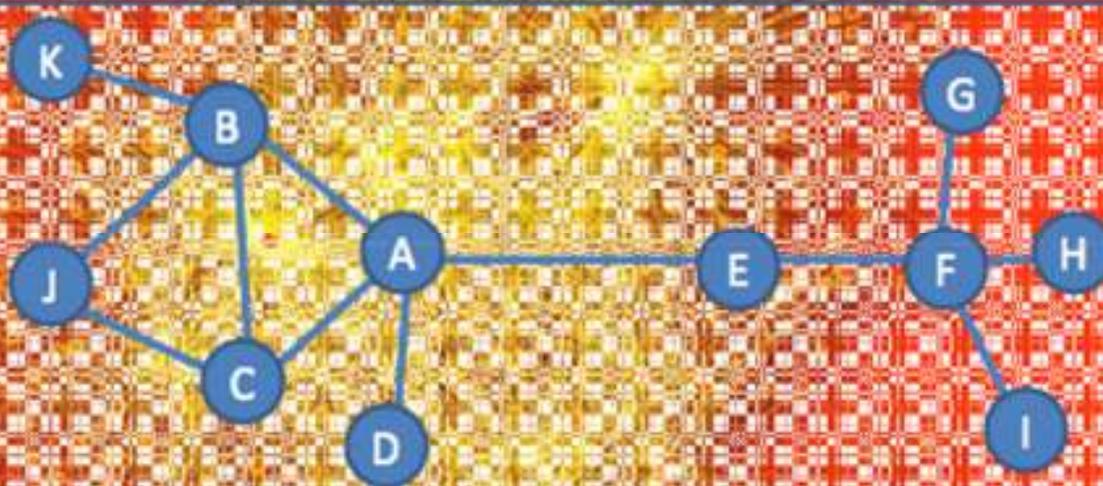
$$C(B) = \frac{1}{10}(2 + 2 \cdot 6 + 2 \cdot 3)$$
$$C(B) = 2$$

N=11

## PAGE RANK

PR=Probability that a random walker with interspersed Jumps would visit that node.

PR=Each page votes for its neighbors.



$$PR(A) = PR(B)/4 + PR(C)/3 + PR(D) + PR(E)/2$$

A random surfer eventually stops clicking

$$PR(X) = (1-d)/N + d(\sum PR(y)/k(y))$$

## PAGE RANK

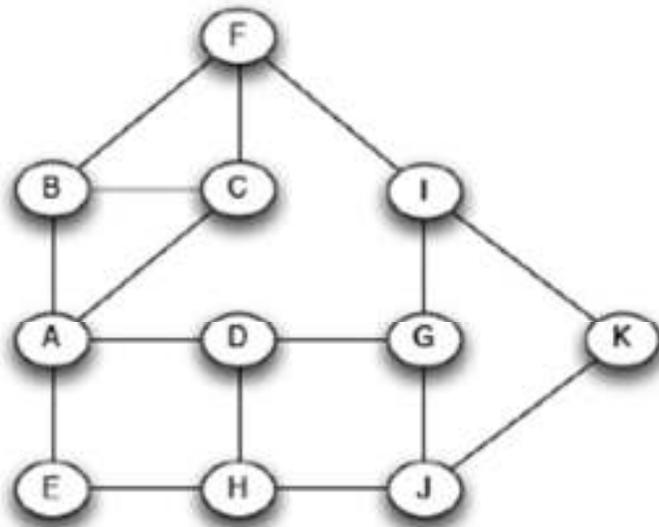
PR=Probability that a random Walker would visit that node.  
PR=Each page votes for its neighbors.

$$\mathbf{R} = \begin{bmatrix} PR(p_1) \\ PR(p_2) \\ \vdots \\ PR(p_N) \end{bmatrix}$$

$$\mathbf{R} = \begin{bmatrix} (1-d)/N \\ (1-d)/N \\ \vdots \\ (1-d)/N \end{bmatrix} + d \begin{bmatrix} \ell(p_1, p_1) & \ell(p_1, p_2) & \dots & \ell(p_1, p_N) \\ \ell(p_2, p_1) & \ddots & & \vdots \\ \vdots & & \ell(p_i, p_j) & \\ \ell(p_N, p_1) & \dots & & \ell(p_N, p_N) \end{bmatrix} \mathbf{R}$$

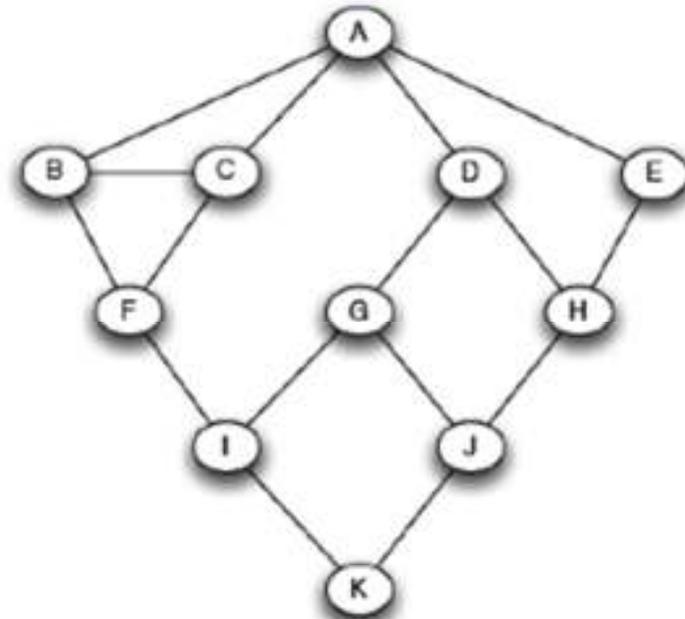
$$\sum_{i=1}^N \ell(p_i, p_j) = 1,$$

# How to compute betweenness?



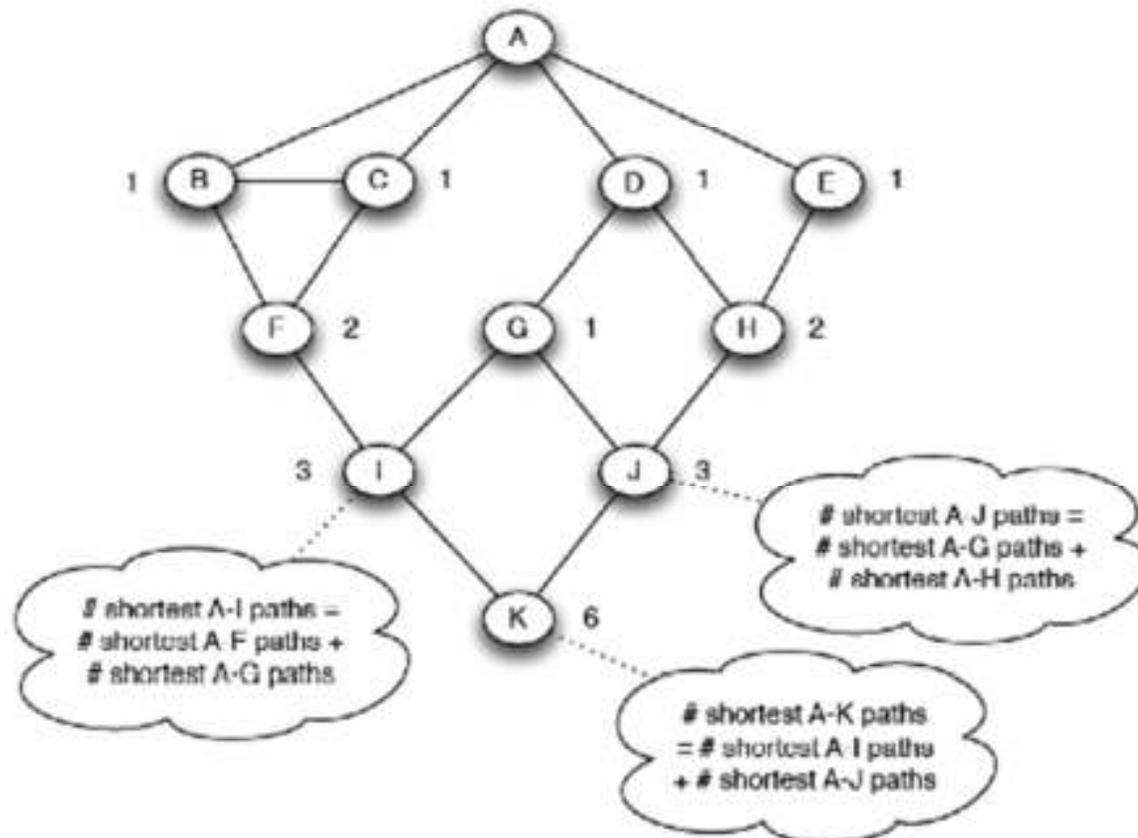
- Want to compute betweenness of paths starting at node A

- Breath first search starting from A:



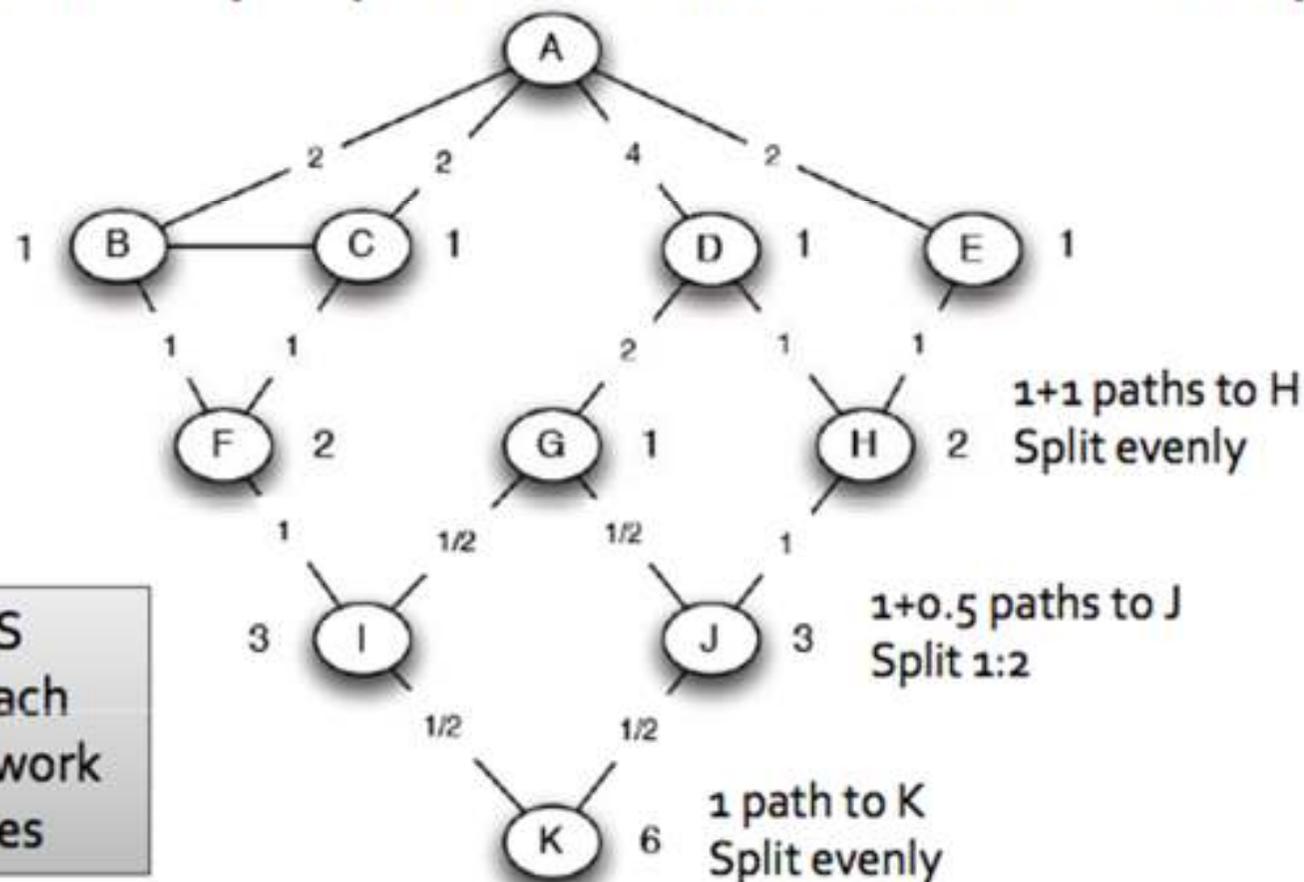
# How to compute betweenness (2)

- Count the number of shortest paths from A to all other nodes of the network:



# How to compute betweenness (3)

- Compute betweenness by working up the tree: If there are multiple paths count them fractionally



- Repeat the BFS procedure for each node of the network
- Add edge scores