

Digital Media and Social Networks

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<https://minoskt.github.io>

WEEK 3: CENTRALITY MEASURES

**SOME SLIDES COPYRIGHT CECILIA MASCOLO (CAMBRIDGE)
AND HAMED HADDADI (QMUL)**



IN THIS LECTURE

- We will introduce the concept of centrality and the various measures which have been associated to this concept.
- We will show an application.

CENTRALITY

Spoken about important nodes...

Weak ties, bridges, local bridges...

CENTRALITY

Spoken about important nodes...

Weak ties, bridges, local bridges...

All about maintaining graph connectivity

Centrality

CENTRALITY

Spoken about important nodes...

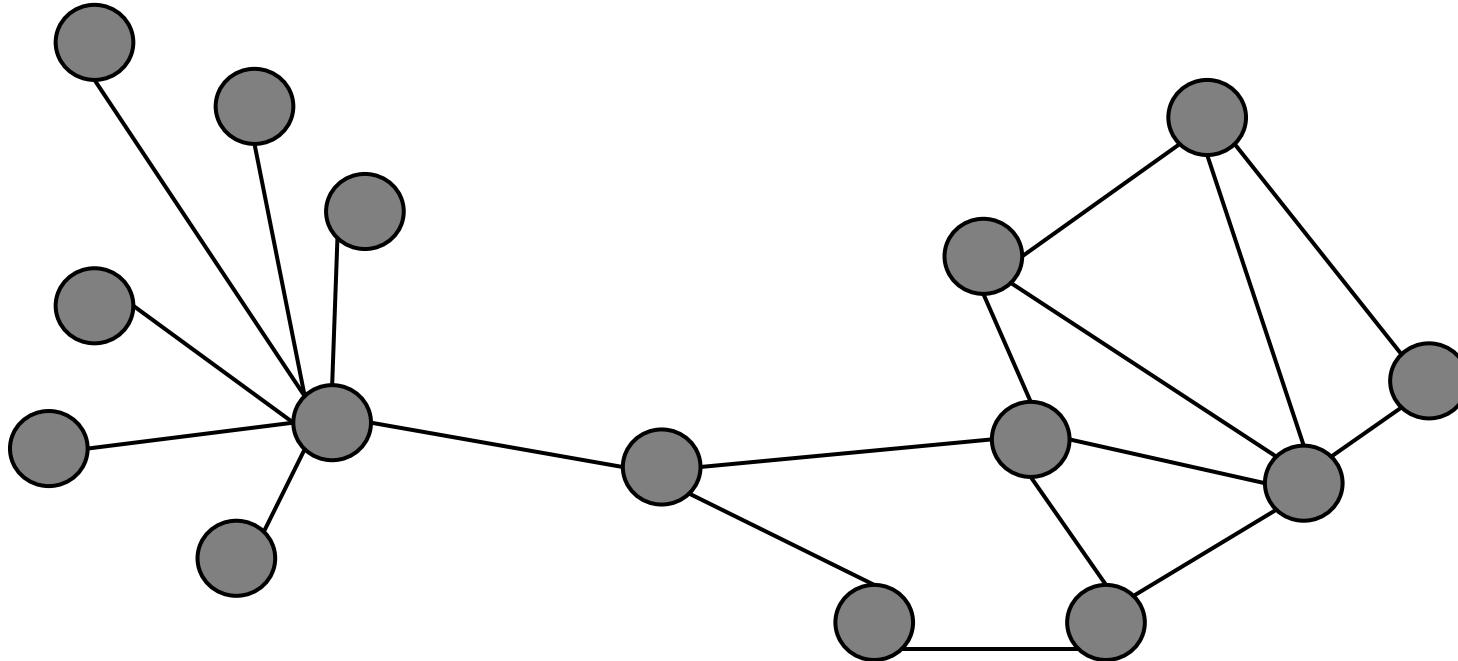
Weak ties, bridges, local bridges...

All about maintaining graph connectivity

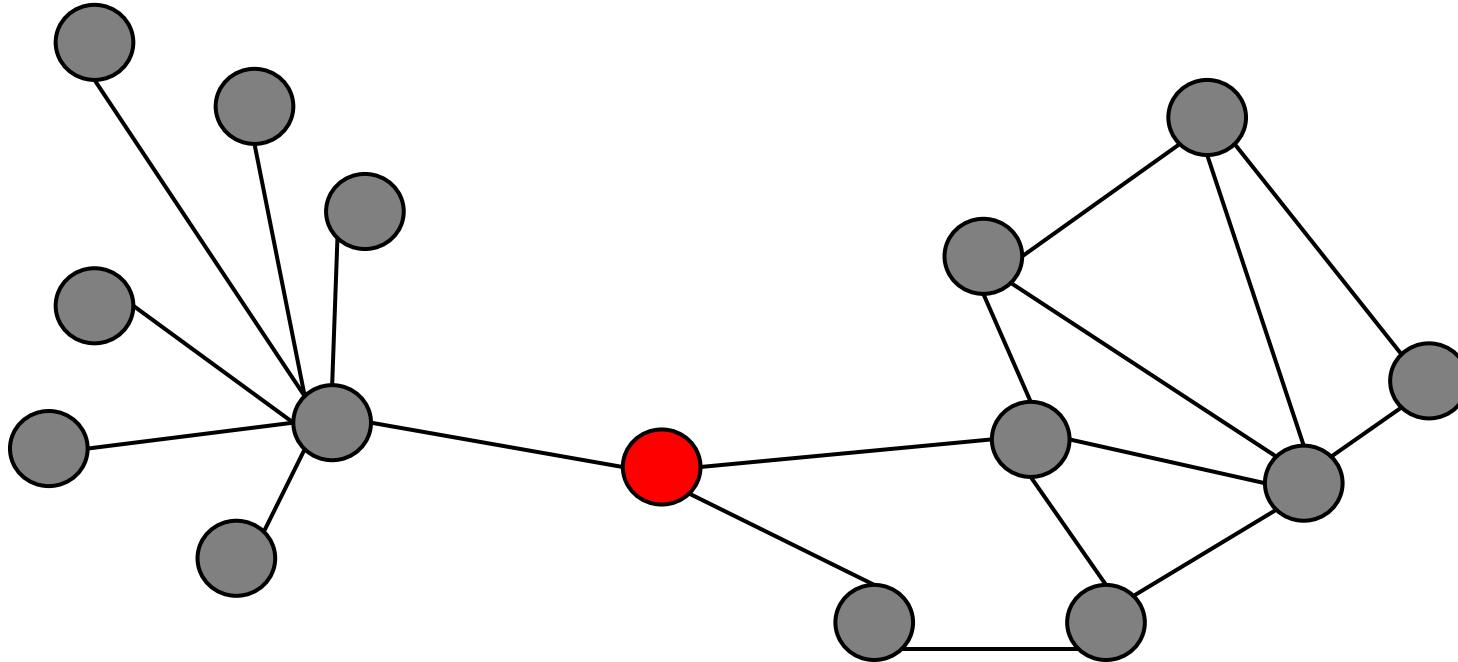
Centrality

All about finding the most “important” node

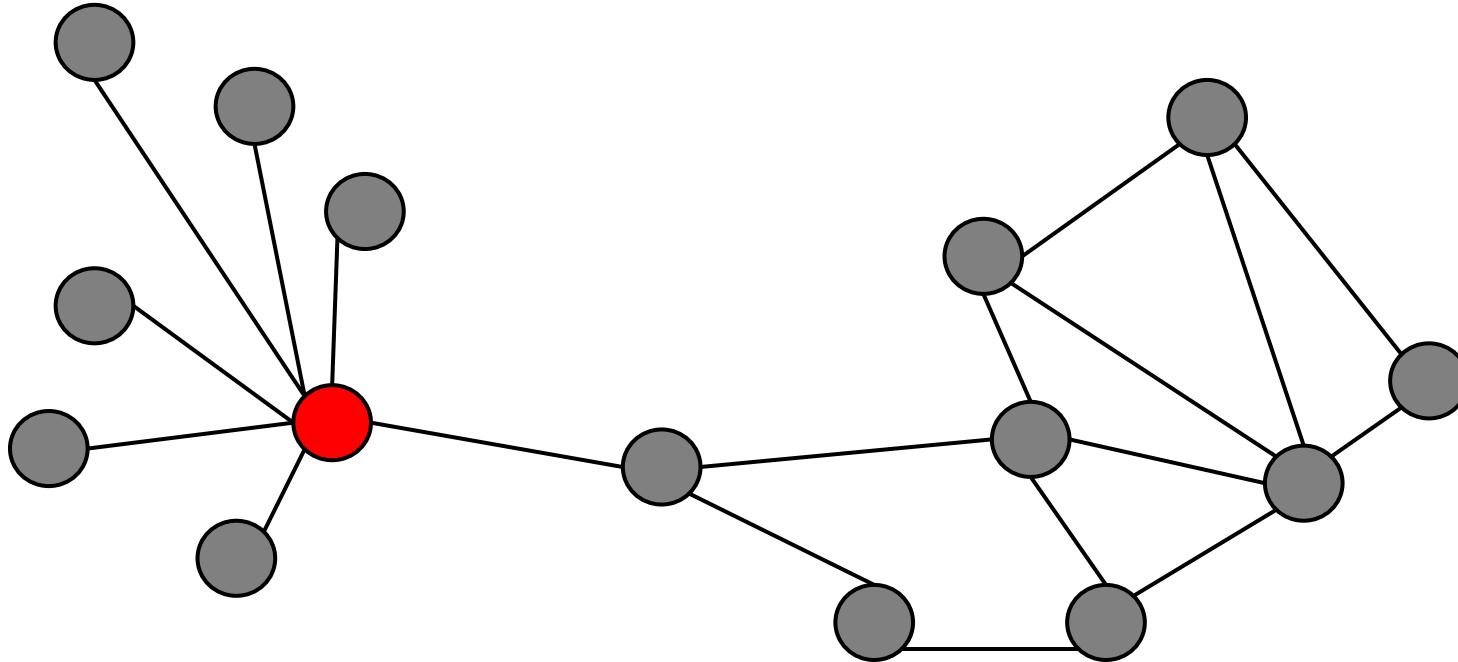
CENTRALITY



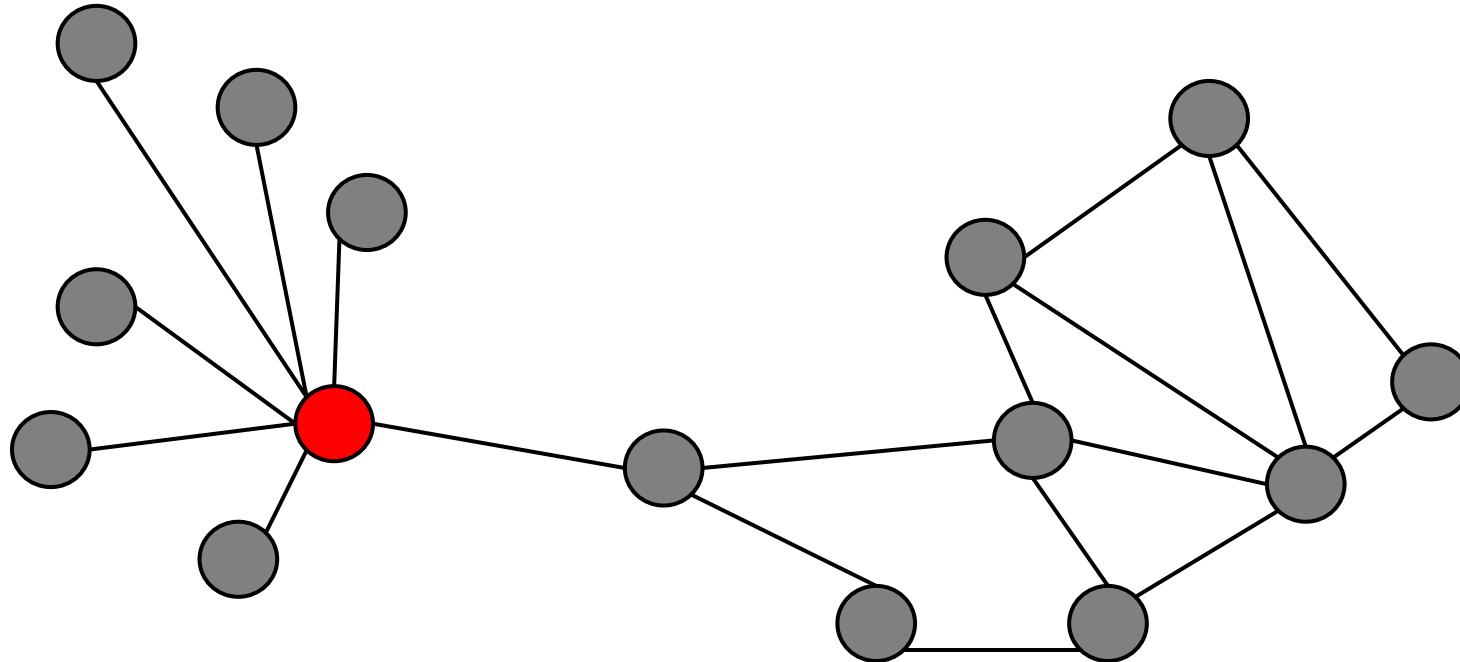
CENTRALITY



CENTRALITY

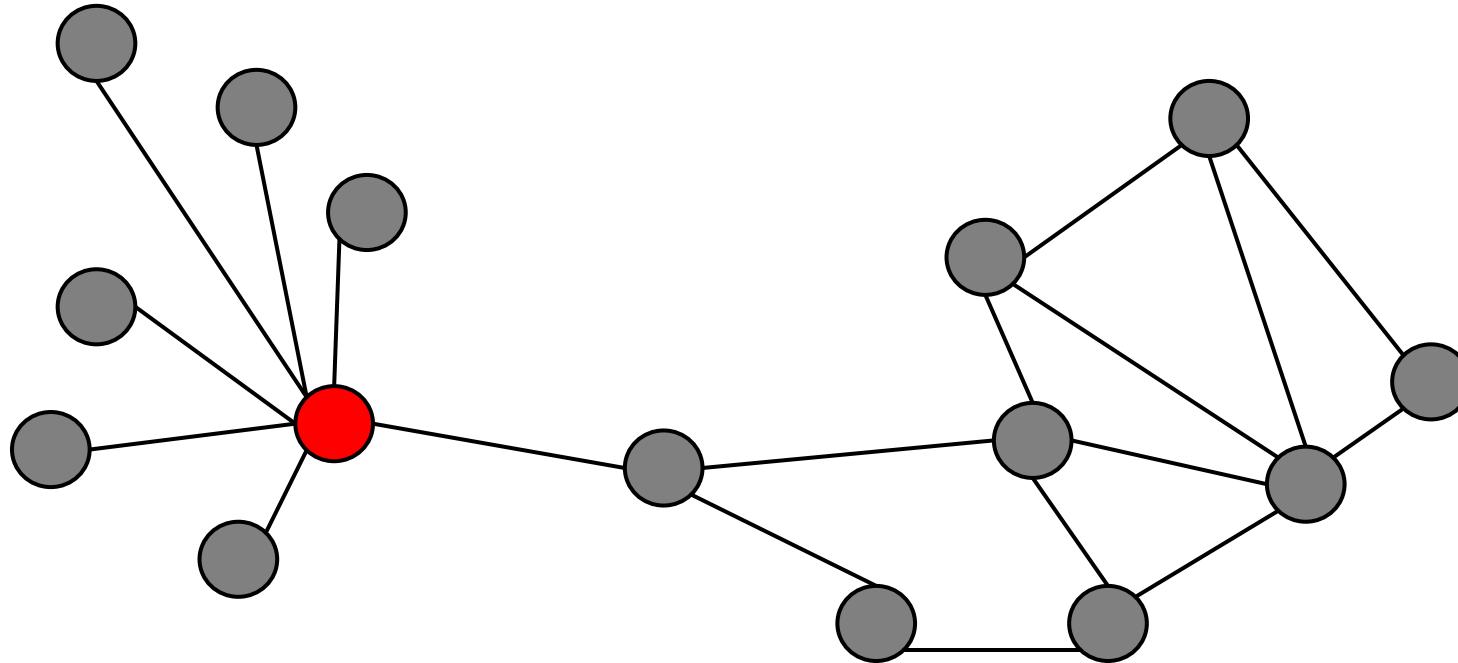


CENTRALITY



We can use multiple types of centrality

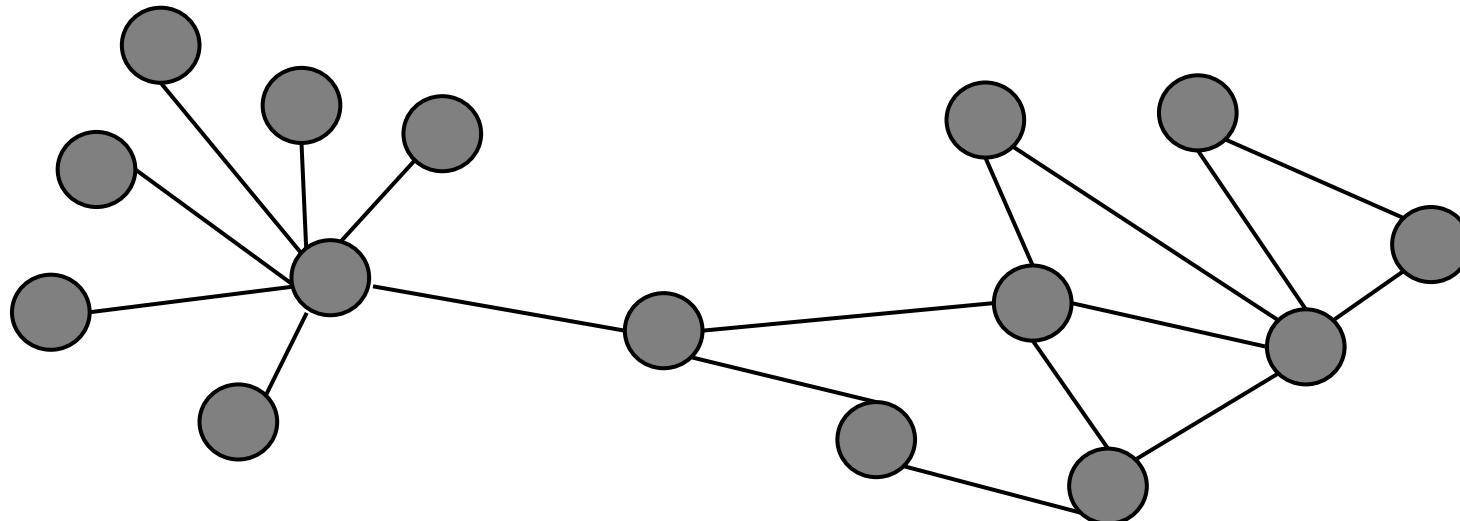
CENTRALITY



**We can use multiple types of centrality
Important to understand where to use them**

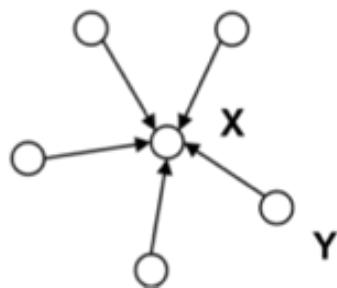
CENTRALITY

- Finding out which is the most **central node** is important:
 - It could help disseminating information in the network faster
 - It could help stopping epidemics
 - It could help protecting the network from breaking

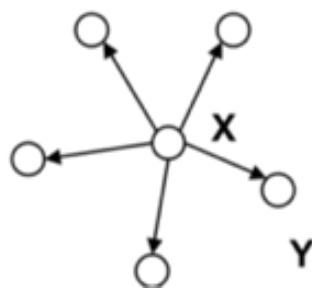


CENTRALITY: VISUALLY

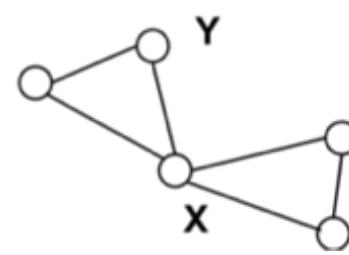
Centrality can have various meanings:



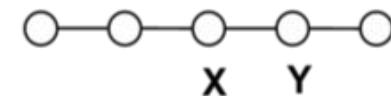
indegree



outdegree



betweenness



closeness

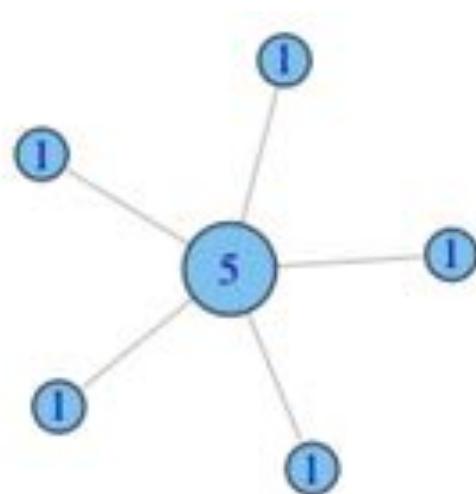


DEGREE CENTRALITY

DEGREE CENTRALITY

When is the number of connections the best centrality measure?

- People who will do favours to you
- People you can talk to / have a beer with

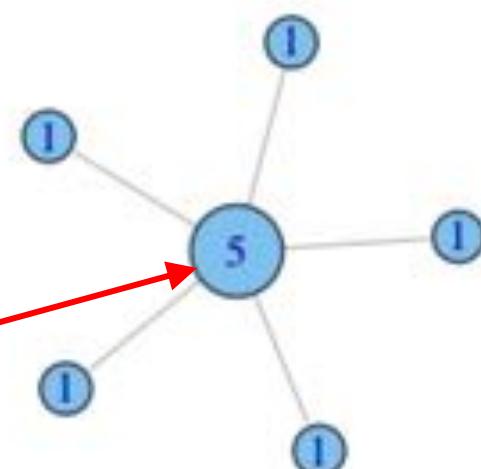


DEGREE CENTRALITY

When is the number of connections the best centrality measure?

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Centrality is 5

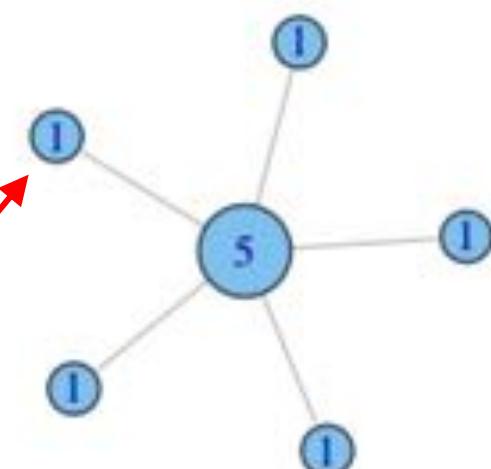


DEGREE CENTRALITY

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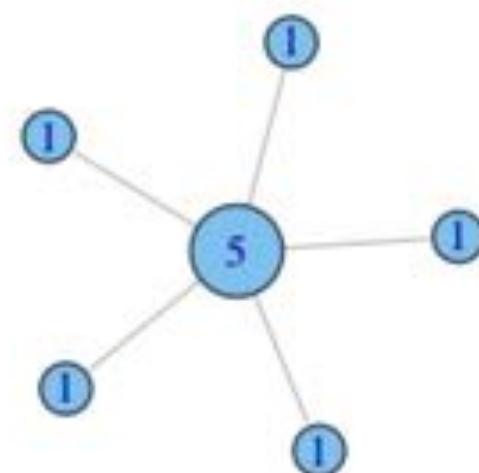
Centrality is 1



DEGREE CENTRALITY

When is the number of connections the best centrality measure?

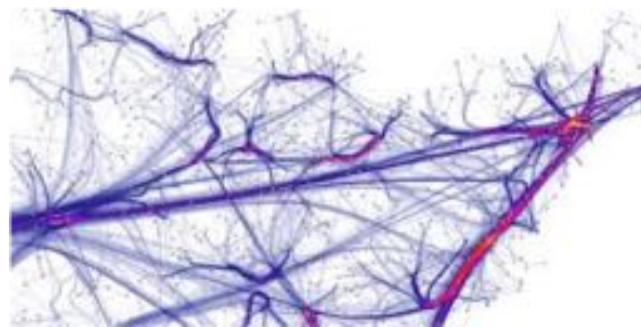
- People who will do favours to you
- People you can talk to / have a beer with



Who is most powerful?

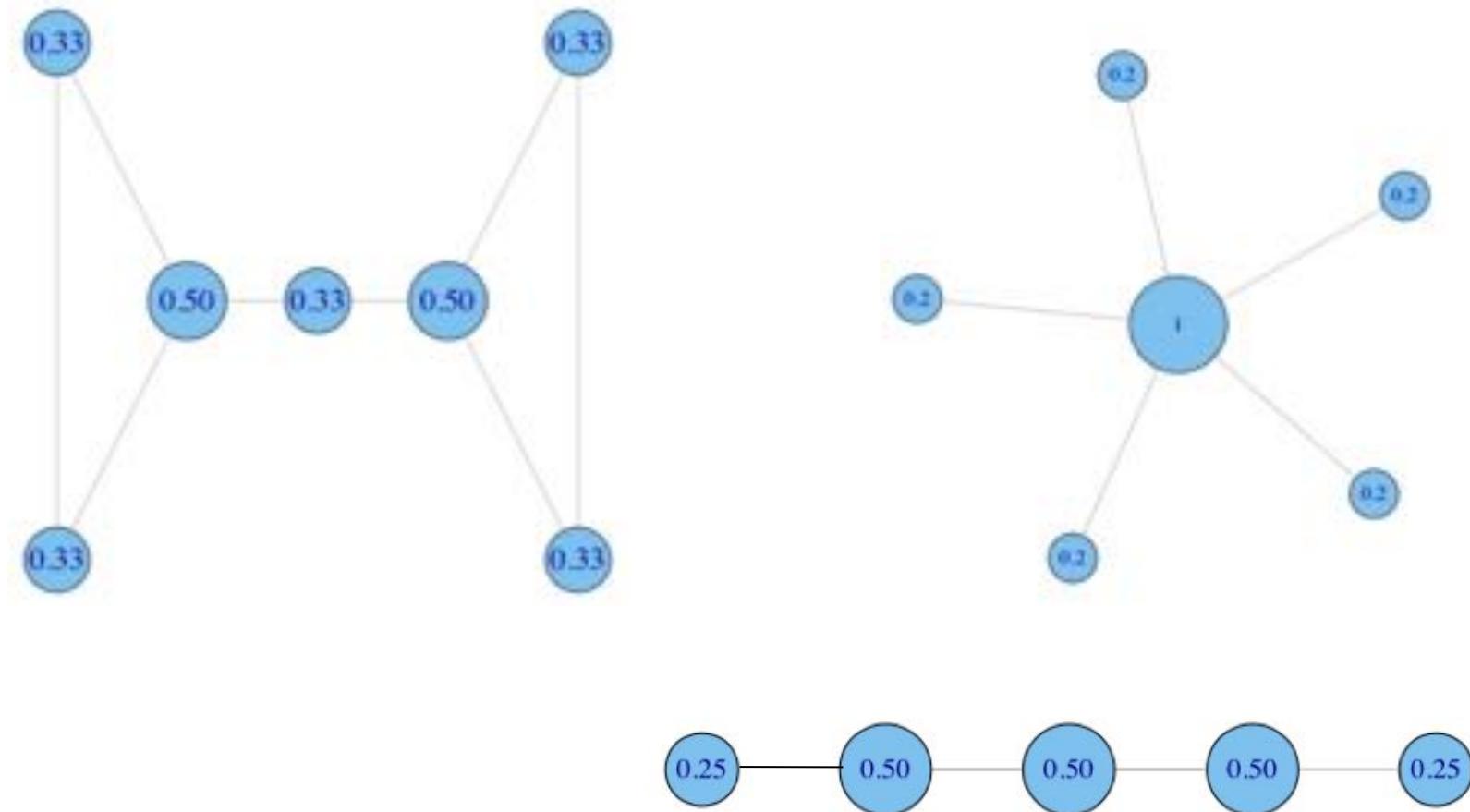
NORMALISATION

What if we want to compare multiple graphs?



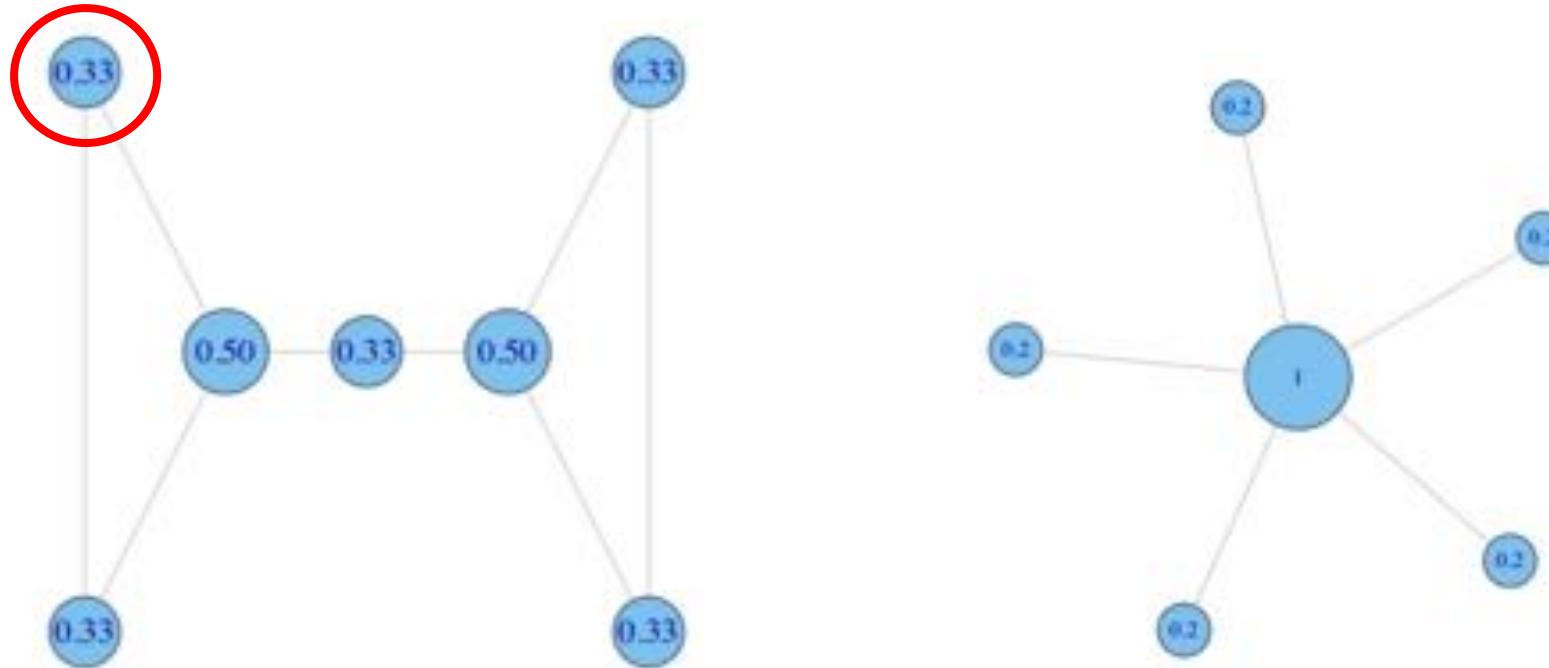
NORMALISATION

Divide for the max number of nodes ($N-1$)



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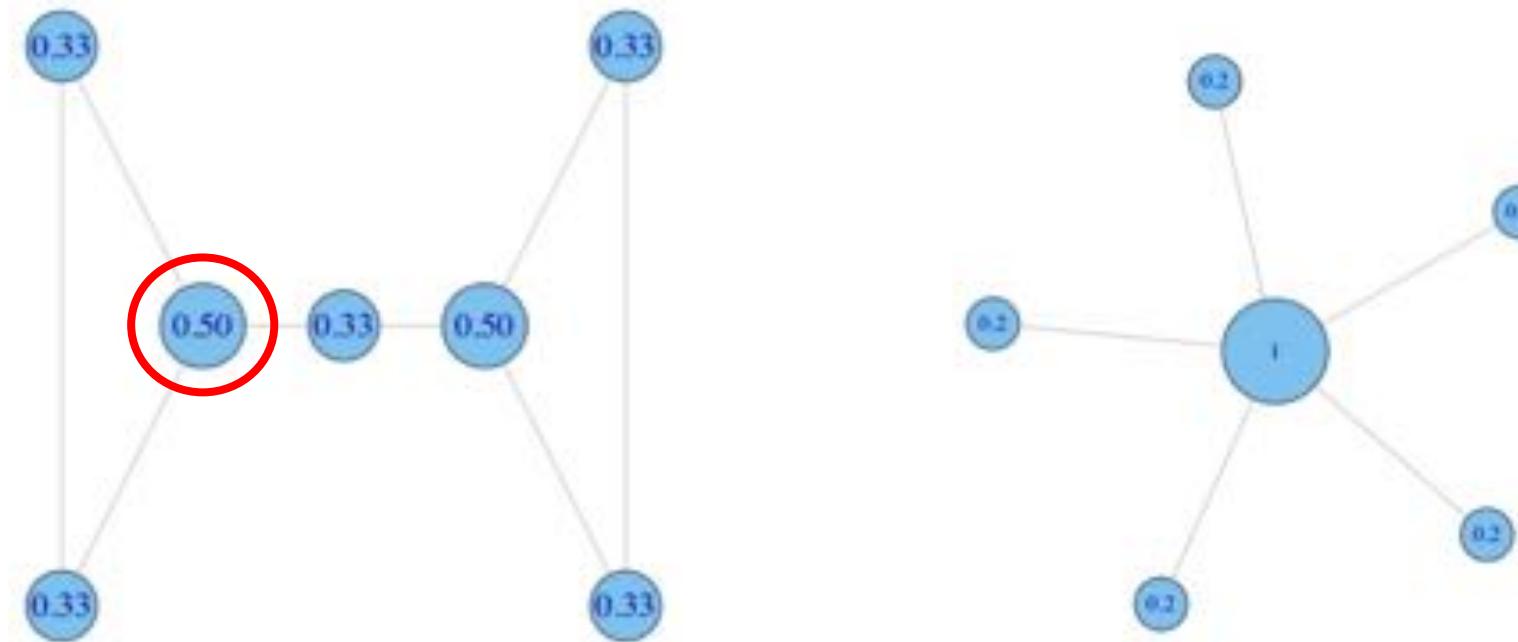


2 / 6



NORMALISATION

Divide for the max number of nodes ($N-1$)

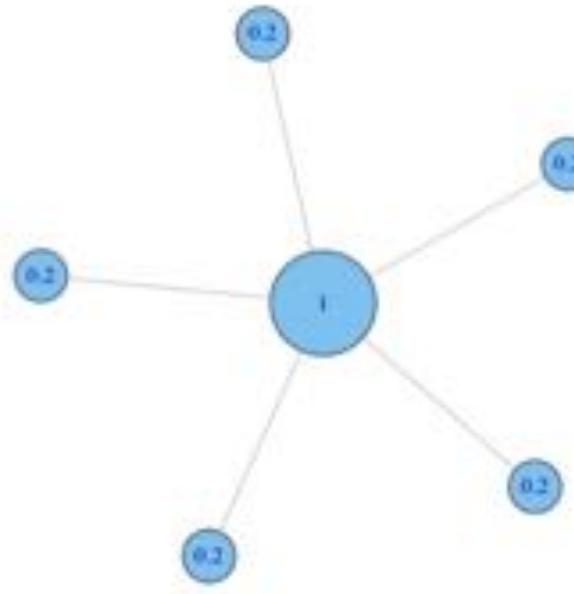
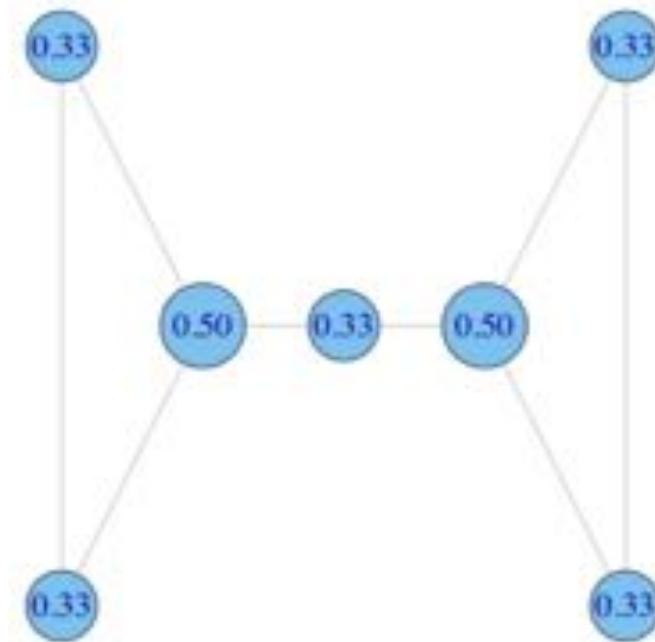


3 / 6

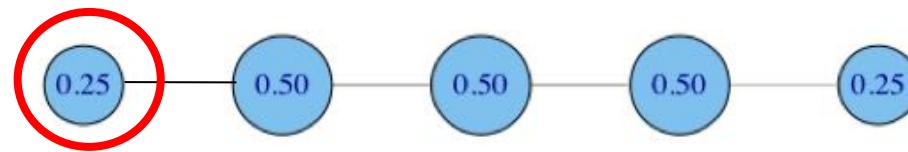


NORMALISATION

Divide for the max number of nodes ($N-1$)



1 / 4



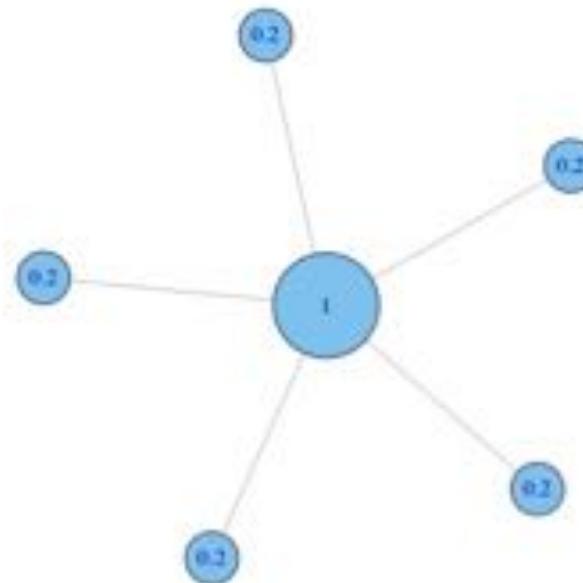
FREEMAN'S NETWORK CENTRALITY

What's the most uneven type of graph?



FREEMAN'S NETWORK CENTRALITY

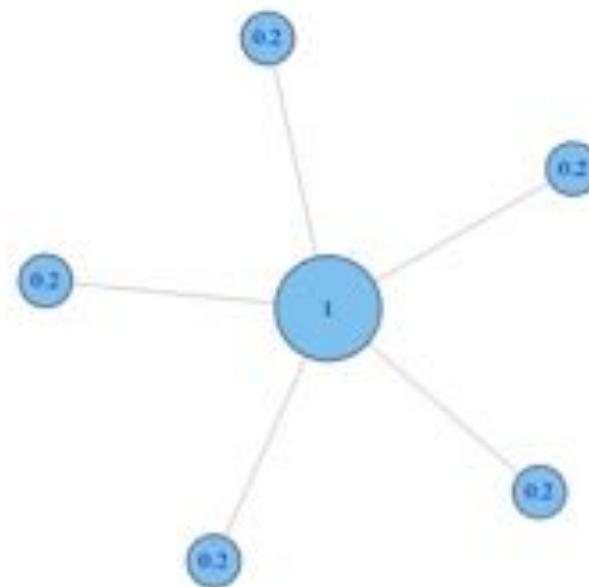
What's the most uneven type of graph?



FREEMAN'S NETWORK CENTRALITY

What's the most uneven type of graph?

We can judge how uneven other graphs are by comparing it to this one!



FREEMAN'S NETWORK CENTRALITY

How do we calculate the value of centrality of the network

To check how much variation there is among the nodes (heterogeneity?)

$$C_D = \frac{\sum_{i=1}^g [C_D(n^*) - C_D(i)]}{[(N-1)(N-2)]}$$

FREEMAN'S NETWORK CENTRALITY

How do we calculate the value of centrality of the network

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Max value of Degree
Centrality in the Network

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Degree of node i

FREEMAN'S NETWORK CENTRALITY

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FREEMAN'S NETWORK CENTRALITY

How do we calculate the value of centrality of the network

To check how much variation there is among the nodes (heterogeneity?)

If value is high, then
there is high
heterogeneity

E.g. Node A has
degree 10, Node B
has only degree 1...

$$C_D = \frac{\sum_{i=1}^g [C_D(n^*) - C_D(i)]}{[(N-1)(N-2)]}$$

FREEMAN'S NETWORK CENTRALITY

How do we calculate the value of centrality of the network

To check how much variation there is among the nodes (heterogeneity?)

Max value of the above:
when network is a star: 1
node has $C=N-1$ and all
others ($N-1$) have 1.

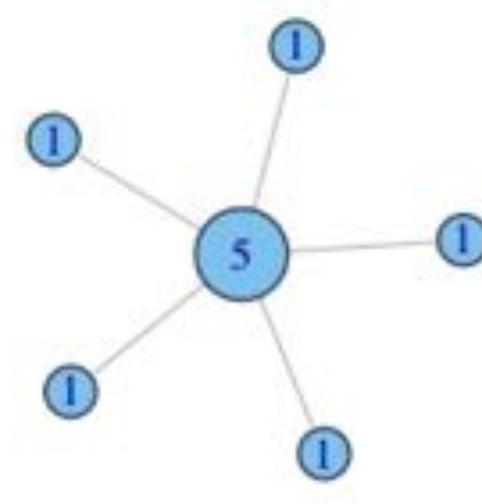
$$C_D = \frac{\sum_{i=1}^g [C_D(n^*) - C_D(i)]}{[(N-1)(N-2)]}$$

FREEMAN NETWORK CENTRALITY EXPLAINED

Explanation of the denominator:

In the star topology one node has degree $N-1$ and all other nodes have degree of 1:

$$0 + ((N-1)-1) * (N-1) = (N-2) * (N-1)$$

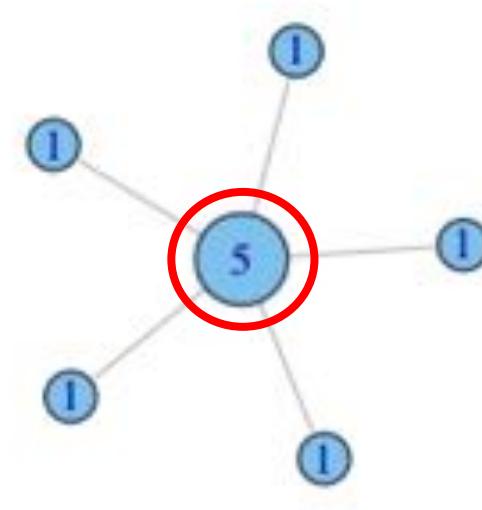


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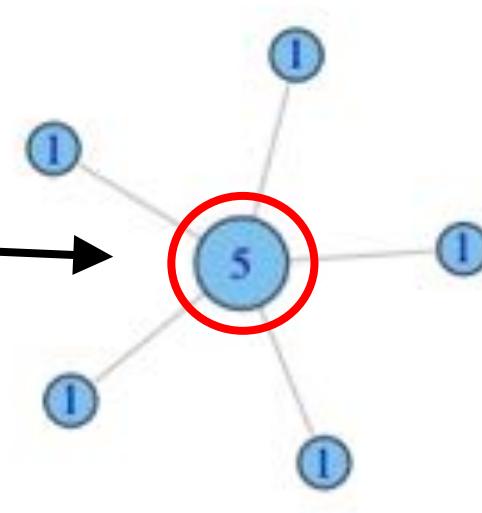


FREEMAN NETWORK CENTRALITY EXPLAINED

Explanation of the denominator:

In the star topology one node has degree $N-1$ and all other nodes have degree of 1:

$$\underline{0 + ((N-1)-1) * (N-1)} = (N-2) * (N-1)$$



I have $N-1$ (5) links:

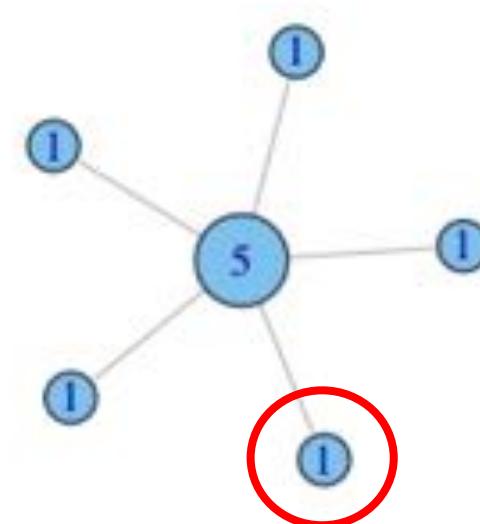
$$(N-1) - (N-1) = 5 - 5 = 0$$

FREEMAN NETWORK CENTRALITY EXPLAINED

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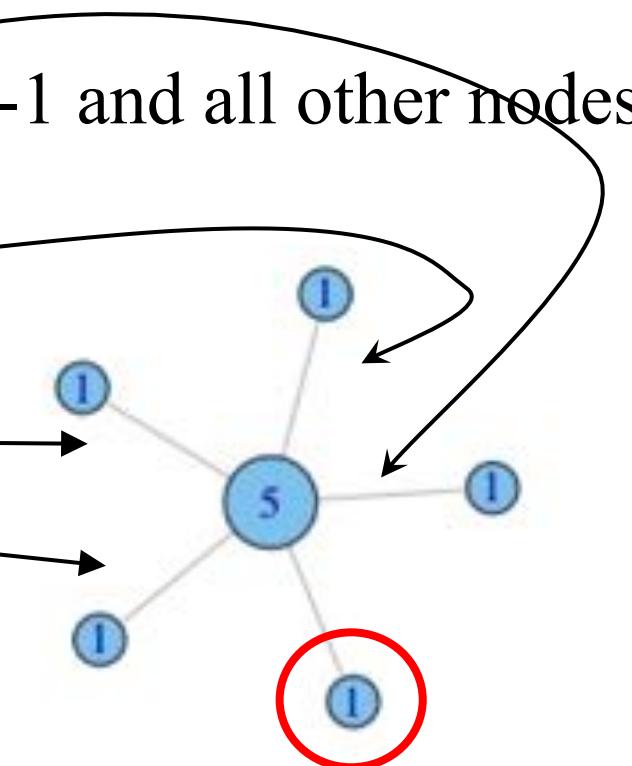
FREEMAN NETWORK CENTRALITY EXPLAINED

Explanation of the denominator:

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Hub has 4 more links than me

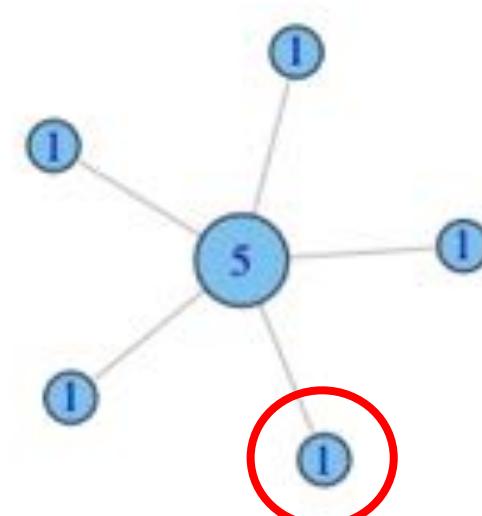


FREEMAN NETWORK CENTRALITY EXPLAINED

Explanation of the denominator:

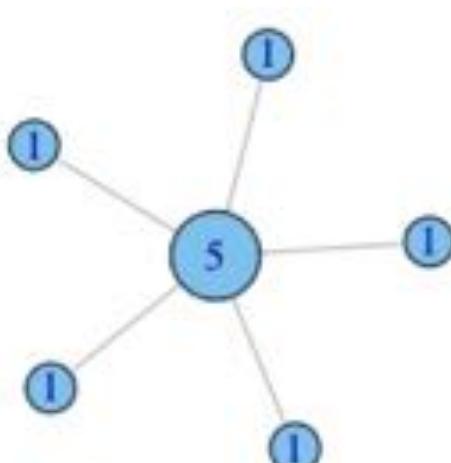
In the star topology one node has degree $N-1$ and all other nodes have degree of 1:

$$0 + ((N-1)-1) * (N-1) = (N-2) * (N-1)$$



Need to do the same for all nodes except the hub

FREEMAN'S NETWORK CENTRALITY



$$C_D = 1.0$$

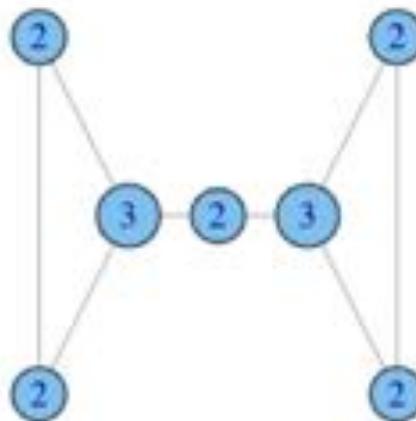


$$C_D = 0.167$$

4+4+4+4+4

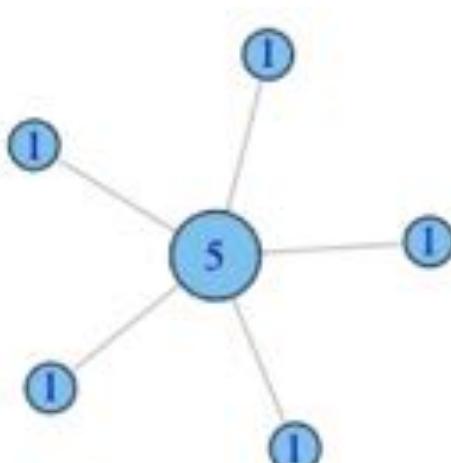
or **5*4**

$n-1$ $n-2$



$$C_D = 0.167$$

FREEMAN'S NETWORK CENTRALITY



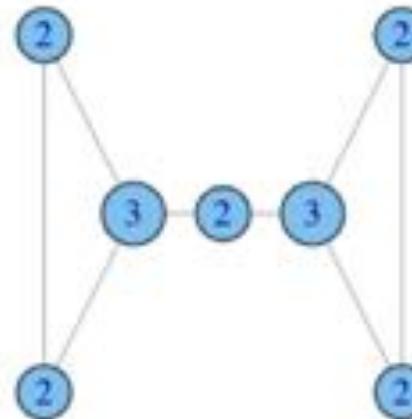
$$C_D = 1.0$$

$$(N=5) \quad 1+0+0+0+1$$

```
graph LR; 1 --- 2_1; 2_1 --- 2_2; 2_2 --- 2_3; 2_3 --- 1;
```

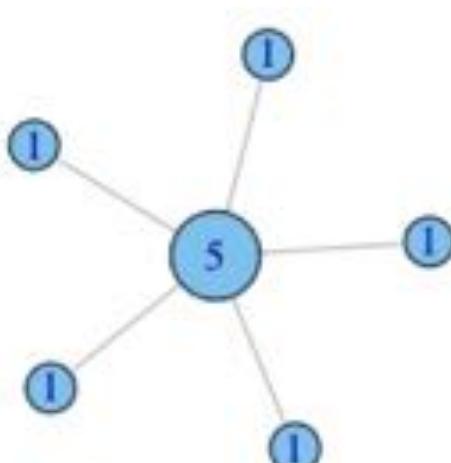
$$4*3 = 2/12 = 1/6$$

$$C_D = 0.167$$



$$C_D = 0.167$$

FREEMAN'S NETWORK CENTRALITY



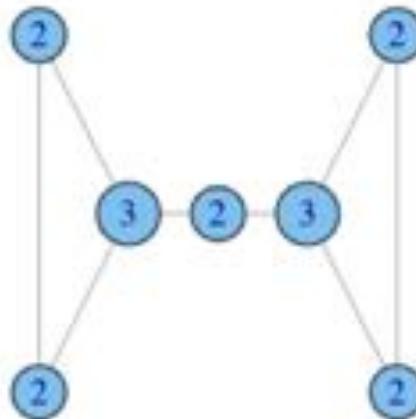
$$C_D = 1.0$$



$$C_D = 0.167$$

(N=7) 1+1+0+1+0+1+1

$$6 \times 5 = 5/30$$



$$C_D = 0.167$$

FREEMAN'S NETWORK CENTRALITY

How do we calculate the value of centrality of the network

To check how much variation there is among the nodes (heterogeneity?)

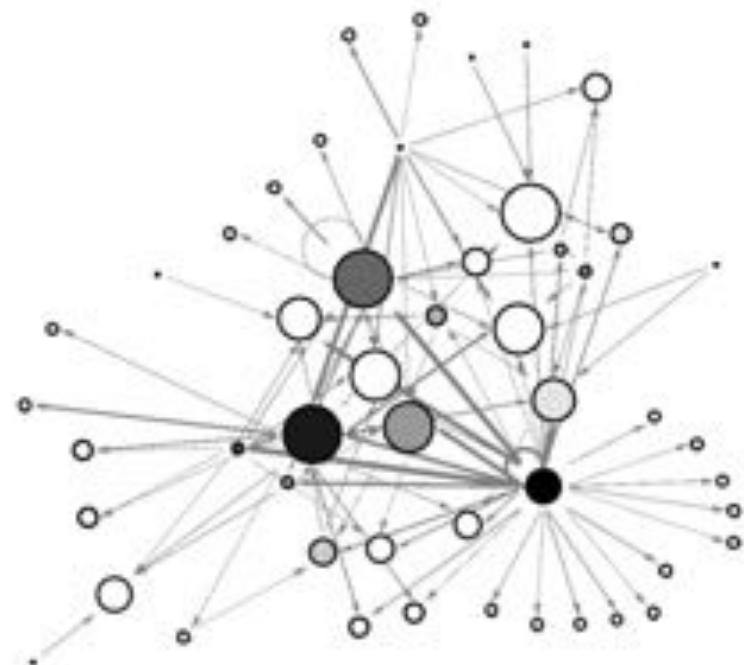
Graph heterogeneity

Worst case heterogeneity

$$C_D = \frac{\sum_{i=1}^g [C_D(n^*) - C_D(i)]}{[(N-1)(N-2)]}$$

EXAMPLES: FINANCIAL NETWORKS

First network is very heterogeneous



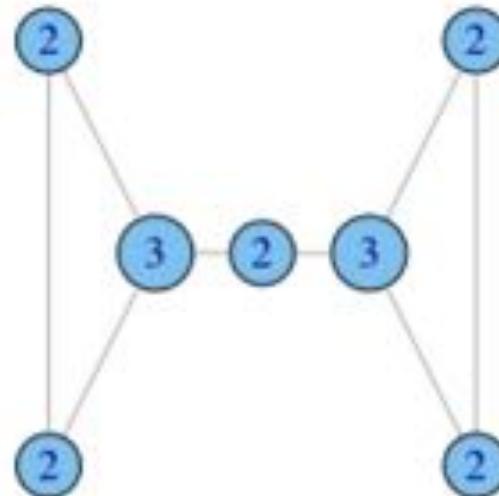
Second very homogeneous:
Many traders trading equally



WHEN IS DEGREE CENTRALITY NOT SO GOOD?



$$C_D = 0.167$$



$$C_D = 0.167$$

WHEN IS DEGREE CENTRALITY NOT SO GOOD (2)?

Ability to broker between groups

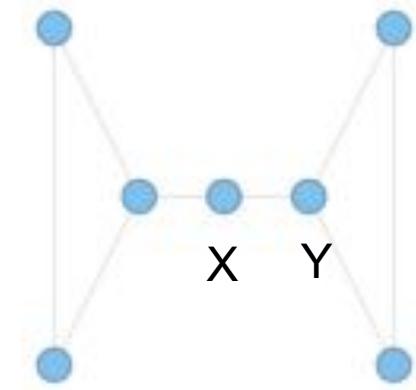
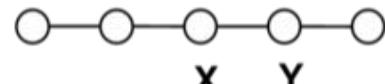
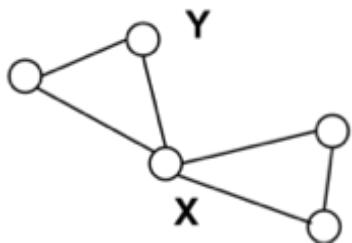
Likelihood that information originating anywhere in the network reaches you...

BETWEENNESS CENTRALITY



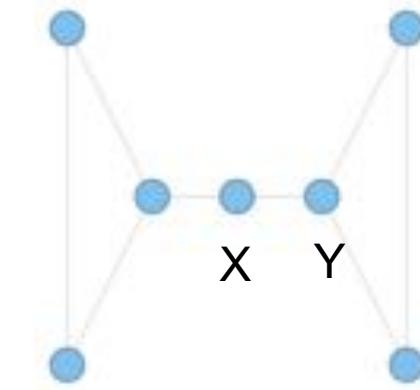
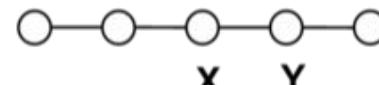
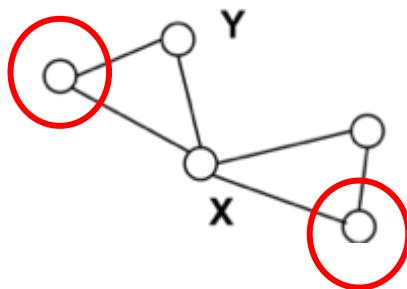
BETWEENNESS CENTRALITY

Intuition: How many pairs of individuals would have to go through you in order to reach one another in the minimum number of hops?
who has higher betweenness, X or Y?



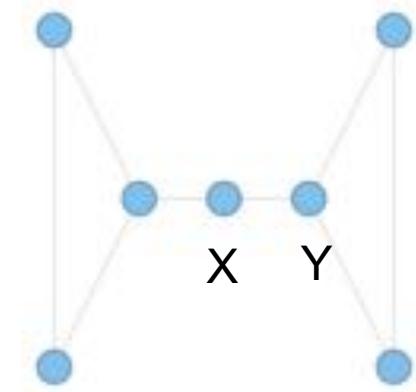
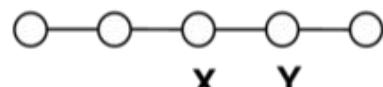
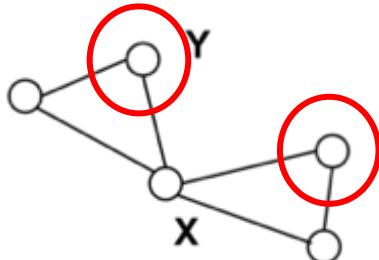
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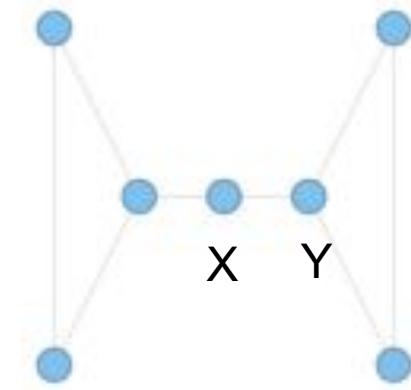
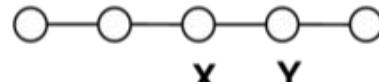
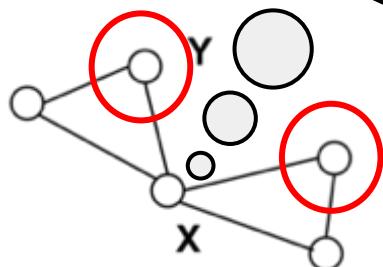
Intuition: How many pairs of individuals would have to go through you in order to reach one another in the minimum number of hops?
who has higher betweenness, X or Y?



BETWEENNESS CENTRALITY

Intuition: How many individuals would have to go through you in order to reach who else?

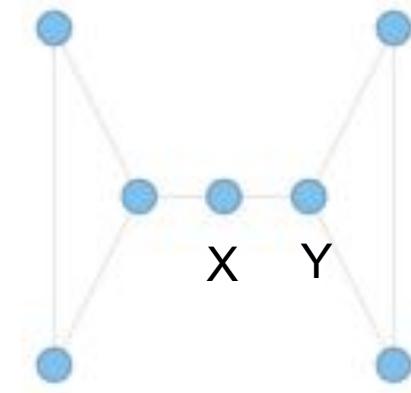
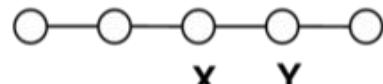
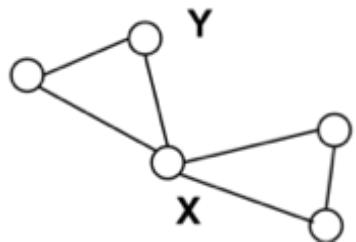
**Oh no, I'm
always stuck
between these
guys!**



BETWEENNESS CENTRALITY

Calculate shortest paths between all pairs

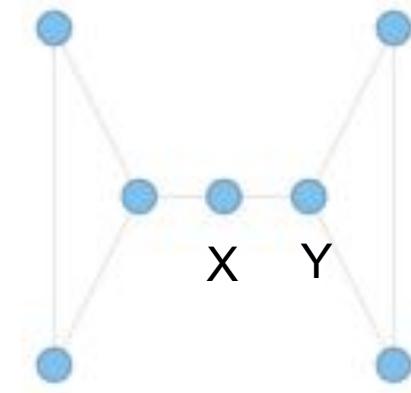
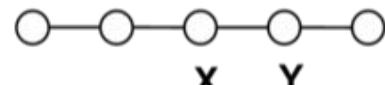
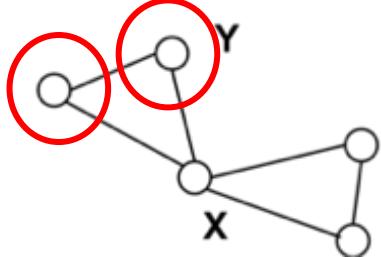
Find the node that exists on the most shortest paths



BETWEENNESS CENTRALITY

Calculate shortest paths between all pairs

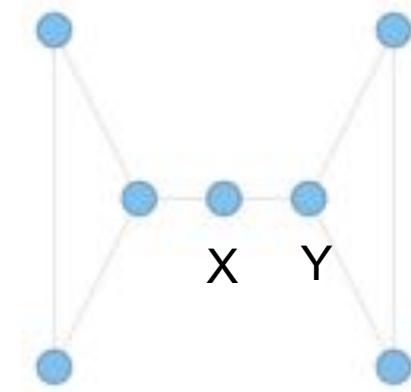
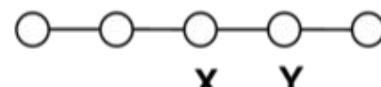
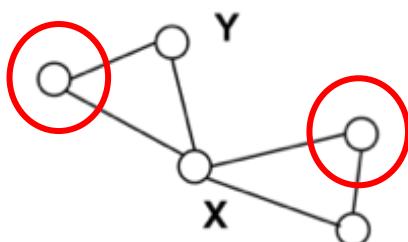
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BETWEENNESS CENTRALITY

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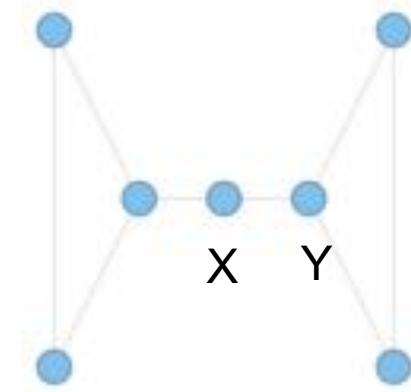
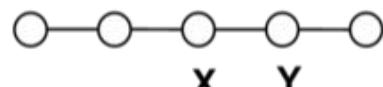
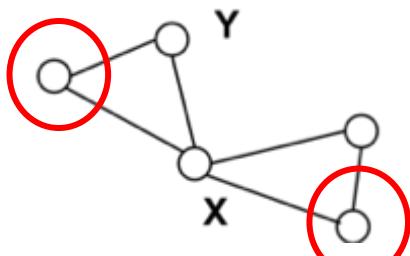
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BETWEENNESS CENTRALITY

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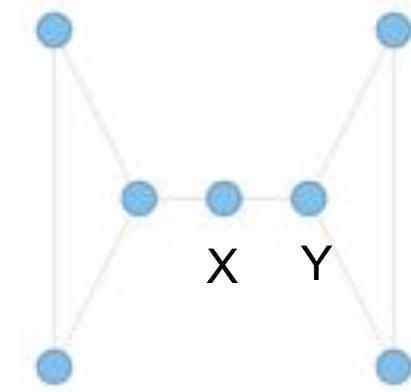
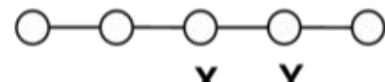
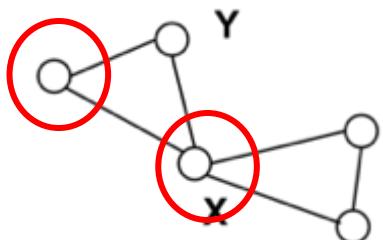
Find the node that exists on the most shortest paths



BETWEENNESS CENTRALITY

Calculate shortest paths between all pairs

Find the node that exists on the most shortest paths



BETWEENNESS (FORMALLY)

$$C_B(i) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$



BETWEENNESS (FORMALLY)

$$C_B(i) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$

What is the betweenness centrality of node i ?

BETWEENNESS (FORMALLY)

$$C_B(i) = \sum_{j \neq k} g_{jk}(i) / \text{circled } g_{jk}$$

Calculate total number of shortest paths between node j and node k

BETWEENNESS (FORMALLY)

$$C_B(i) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$

**Calculate number of shortest paths
between node j and node k
...that pass through node i**

BETWEENNESS (FORMALLY)

$$C_B(i) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$

**Calculate number of shortest paths
between node j and node k
...that pass through node i**

This tells us what fraction of paths between j and k go through i

If outcome is 1, then *all* paths go through i

BETWEENNESS (FORMALLY)

$$C_B(i) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$

Add up the scores for every pair of nodes

BETWEENNESS (FORMALLY)

$$C_B(i) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$

Usually normalized by:

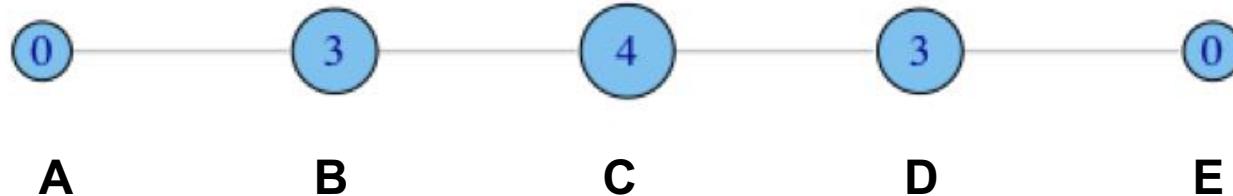
$$C'_B(i) = C_B(i) / [(n-1)(n-2)/2]$$

Number of pairs of vertices
excluding the vertex itself

BETWEENNESS: EXAMPLE

$$C_B(i) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$

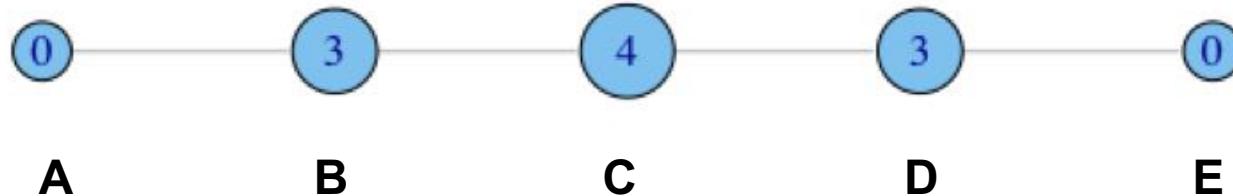
- A lies between no two other vertices
- B lies between A and 3 other vertices: C, D, and E
- C lies between 4 pairs of vertices (A,D),(A,E),(B,D),(B,E)
- Note that there are no alternative paths for these pairs to take, so C gets full credit



BETWEENNESS: EXAMPLE

$$C_B(\textcolor{red}{B}) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$

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- C lies between 4 pairs of vertices (A,D),(A,E),(B,D),(B,E)
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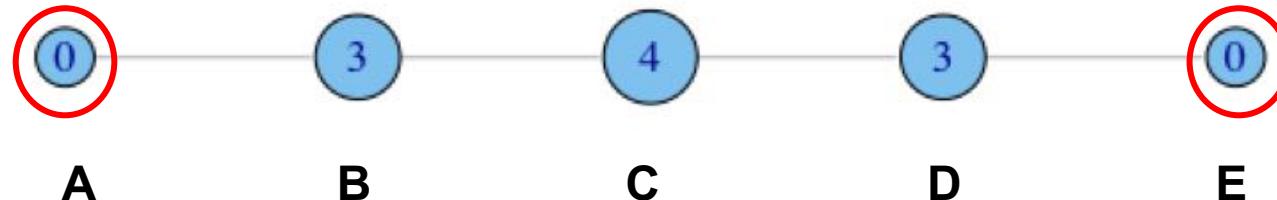


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-
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Calculate all paths between A and E

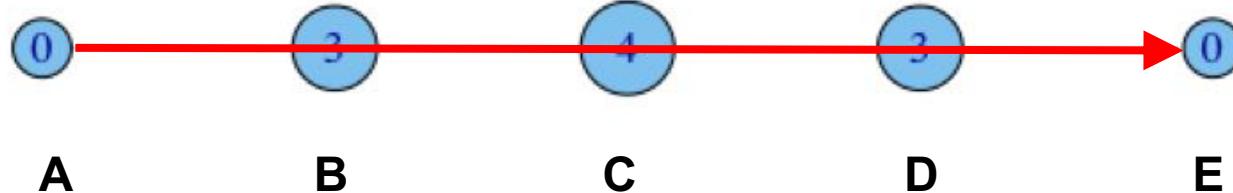


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$$C_B(\textcolor{red}{B}) = \sum_{j \neq k} g_{jk}(i) / g_{jk}$$

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 - C lies between 4 pairs of vertices (A,D),(A,E),(B,D),(B,E)
-
- Note that there are no alternative paths for these pairs to take, so C gets full credit

Okay, just 1 path

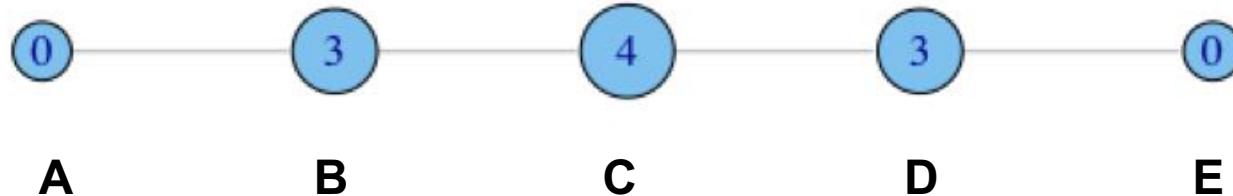


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$$C_B(B) = \sum_{j \neq k} g_{jk}(B) / g_{jk}$$

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-
- Note that there are no alternative paths for these pairs to take, so C gets full credit

How many of them pass through B?

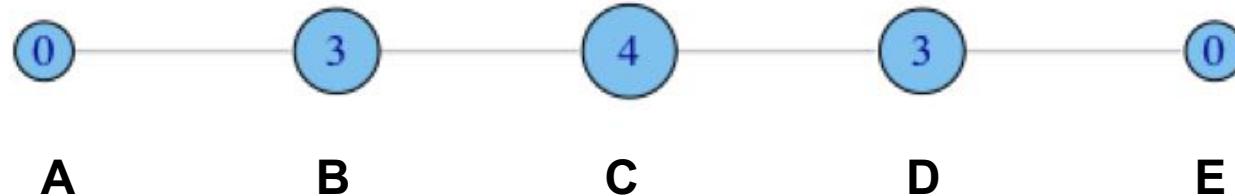


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-
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Okay, just 1

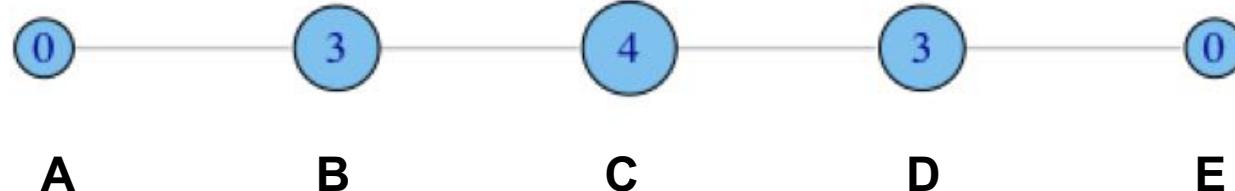


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-
- Note that there are no alternative paths for these pairs to take, so C gets full credit

$$\textcolor{red}{1 / 1 = 1}$$

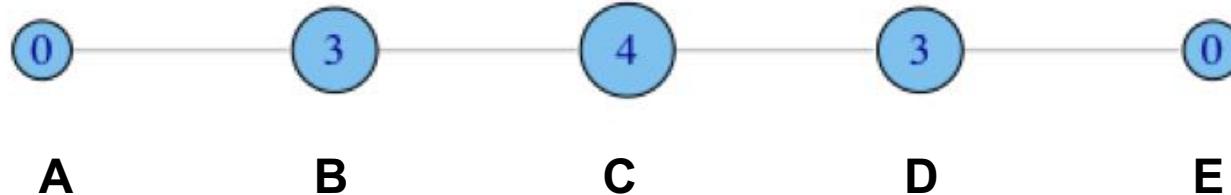


BETWEENNESS: EXAMPLE

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-
- Note that there are no alternative paths for these pairs to take, so C gets full credit

Repeat for all pairs of nodes (j,k) and add up the results

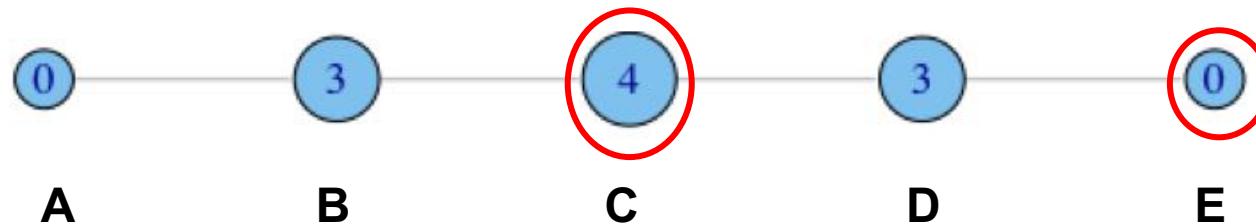


BETWEENNESS: EXAMPLE

$$C_B(B) = \sum_{j \neq k} g_{jk}(B) / g_{jk}$$

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-
- Note that there are no alternative paths for these pairs to take, so C gets full credit

So, let's set j=node C, and k=node E

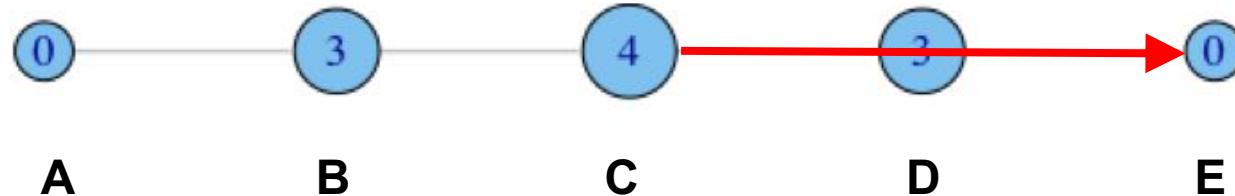


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-
- Note that there are no alternative paths for these pairs to take, so C gets full credit

There is 1 path from C to E

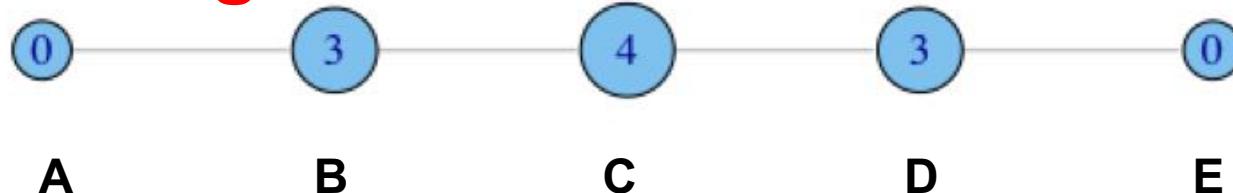


BETWEENNESS: EXAMPLE

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-
- Note that there are no alternative paths for these pairs to take, so C gets full credit

There are no paths from C to E that go through B

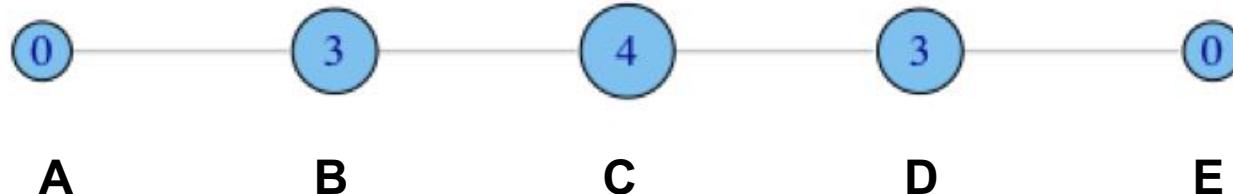


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-
- Note that there are no alternative paths for these pairs to take, so C gets full credit

$$0 / 1 = 0$$

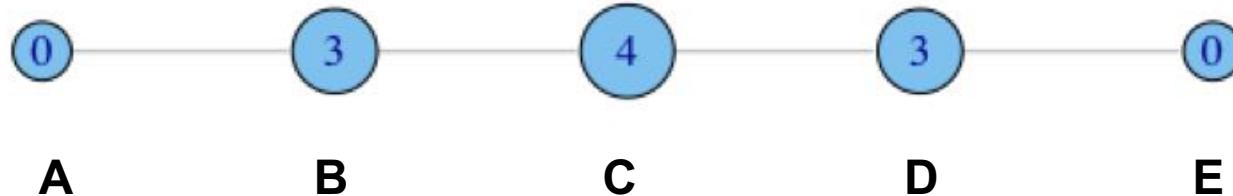


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So far, we have 1 + 0...



BETWEENNESS: EXAMPLE

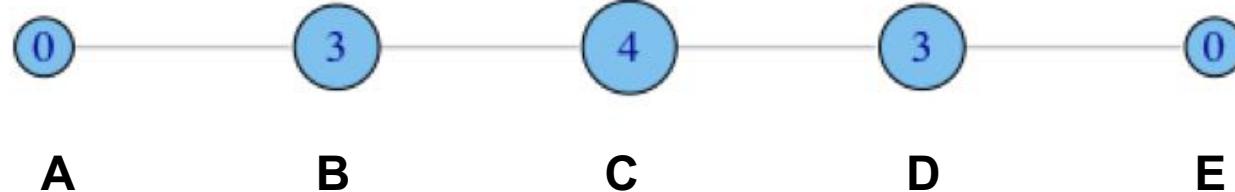
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- A lies between no two other vertices
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■ Note that there is a red dashed box around the text "Put simply, we count up all the paths between nodes that pass through B".

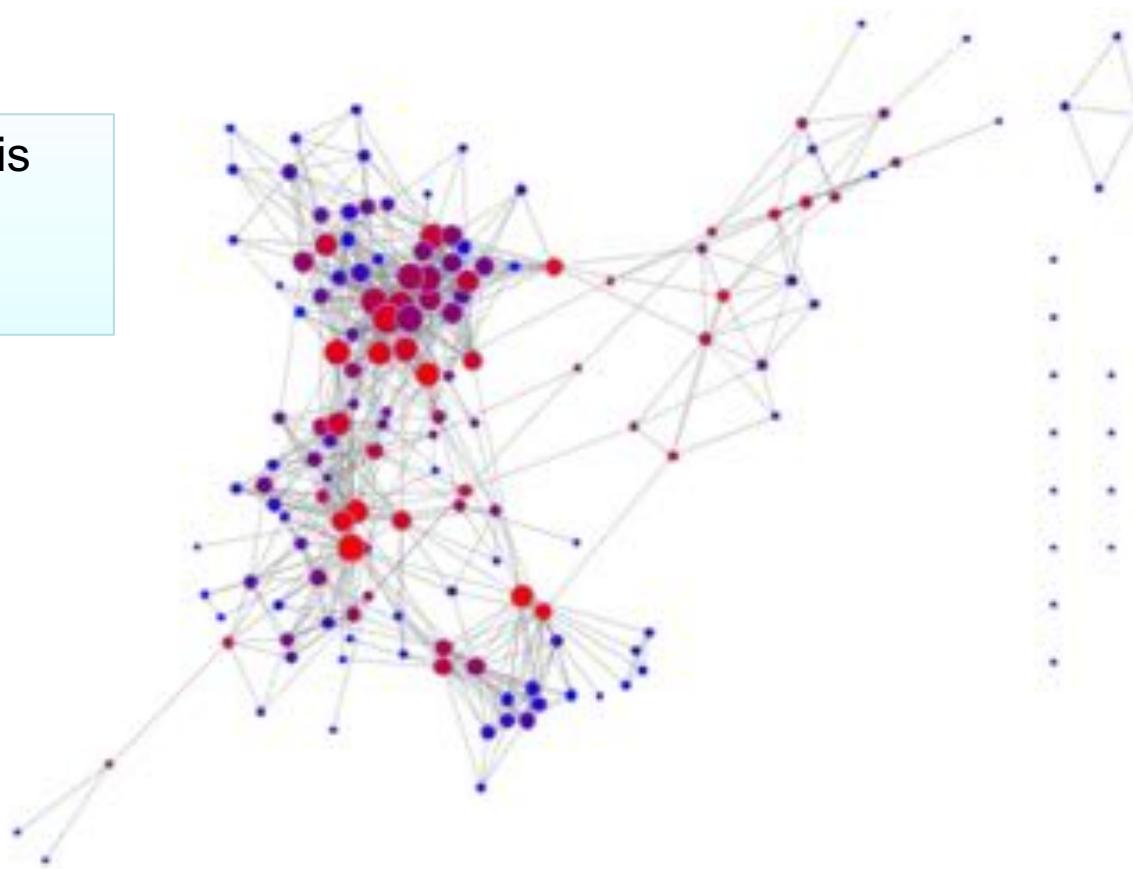
so C gets full credit

Put simply, we count up all the paths between nodes that pass through B



FACEBOOK EXAMPLE (ADAMIC)

Color(from blue to red) is
betweenness
Size is degree.



CLOSENESS CENTRALITY



CLOSENESS CENTRALITY

- What if it is not so important to have many direct friends?
- Or to be “between” others
- But one still wants to be in the “middle” of things, not too far from the center

CLOSENESS CENTRALITY

- What if it is not so important?
- Or to be “between” others
- But one still wants to be in the “middle” of things, not too far from the center

I'm sick of being
between people.

I want to be close to
people!



CLOSENESS CENTRALITY (FORMALLY)

Closeness is based on the length of the average shortest path between a vertex and all vertices in the graph

A low average shortest path value means that you're only a few hops away from everybody else!



CLOSENESS CENTRALITY (FORMALLY)

Closeness is based on the length of the average shortest path between a vertex and all vertices in the graph

$$C_c(i) = \left[\sum_{j=1}^N d(i,j) \right]^{-1}$$

CLOSENESS CENTRALITY (FORMALLY)

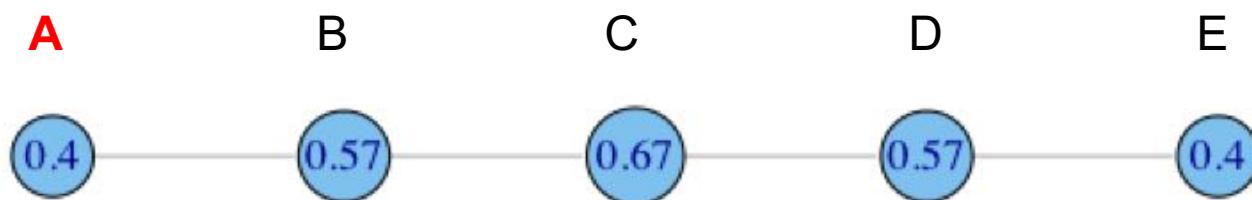
Closeness is based on the length of the average shortest path between a vertex and all vertices in the graph

$$C_c(i) = \left[\sum_{j=1}^N d(i,j) \right]^{-1}$$

$$C'_c(i) = (C_c(i)) / (N - 1)$$

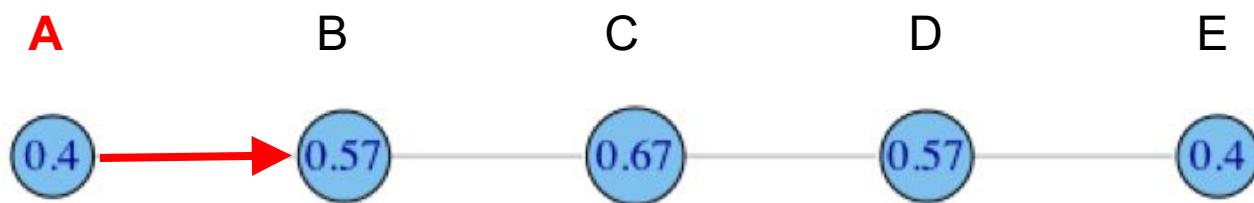


CLOSENESS: EXAMPLE



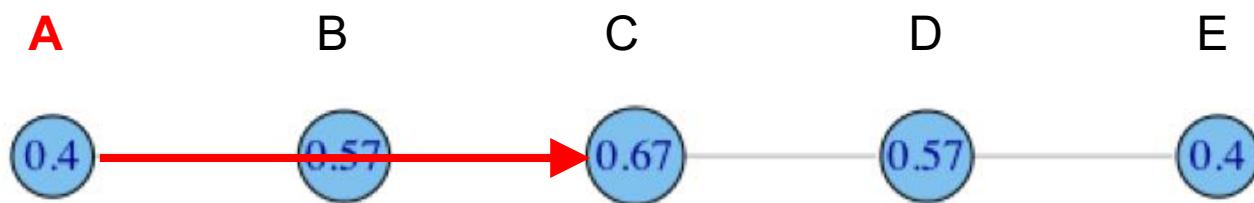
$$C_c(A) = \left[\frac{\sum_{j=1}^N d(A,j)}{N-1} \right]^{-1} = \left[\frac{1+2+3+4}{4} \right]^{-1} = \left[\frac{10}{4} \right]^{-1} = 0.4$$

CLOSENESS: EXAMPLE



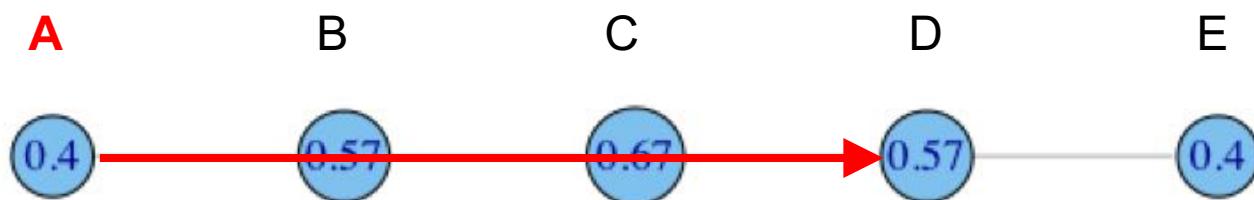
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CLOSENESS: EXAMPLE



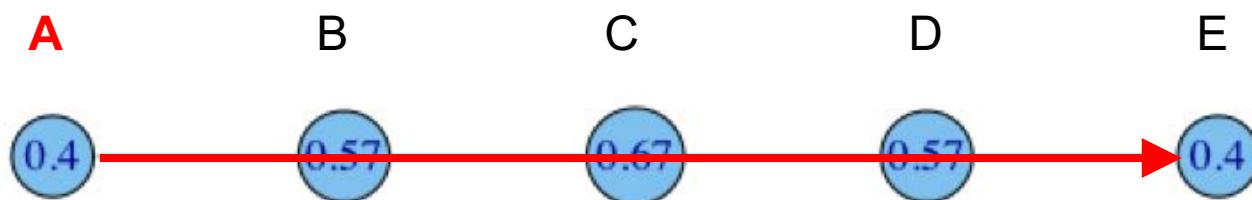
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CLOSENESS: EXAMPLE



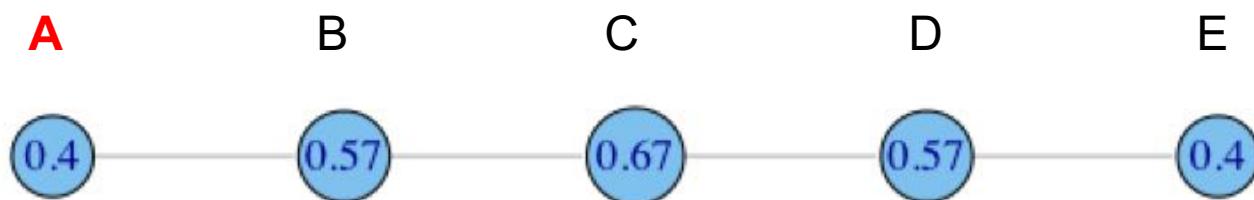
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CLOSENESS: EXAMPLE



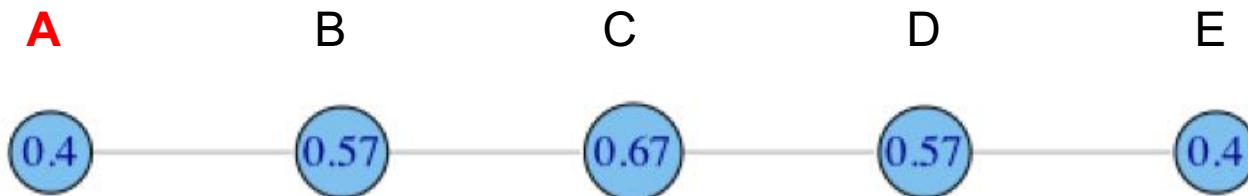
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CLOSENESS: EXAMPLE



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CLOSENESS: EXAMPLE

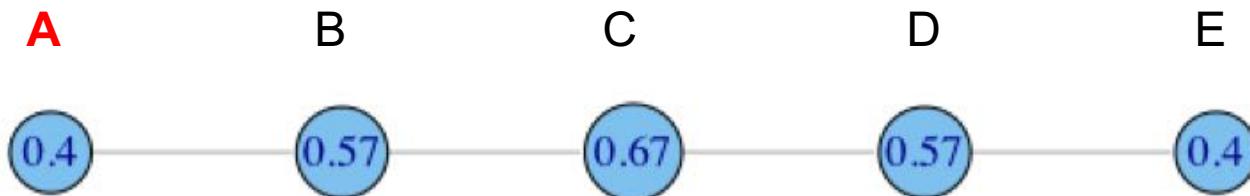


$$C_c(A) = \left[\frac{\sum_{j=1}^N d(A, j)}{N-1} \right]^{-1} = \left[\frac{1+2+3+4}{4} \right]^{-1} = \left[\frac{10}{4} \right]^{-1} = 0.4$$

Oh no! But That's 2.5
Lower number = higher centrality



CLOSENESS: EXAMPLE



$$C_c(A) = \left[\frac{\sum_{j=1}^N d(A,j)}{N-1} \right]^{-1} = \left[\frac{1+2+3+4}{4} \right]^{-1} = \left[\frac{10}{4} \right]^{-1} = 0.4$$

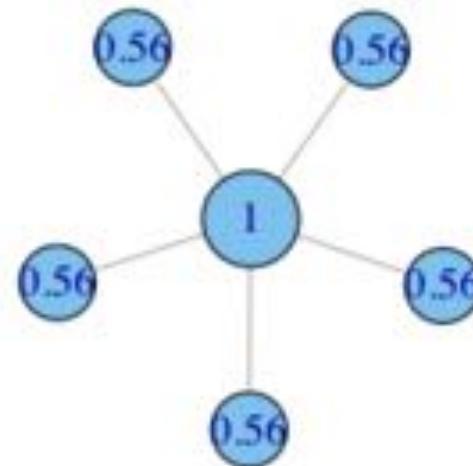
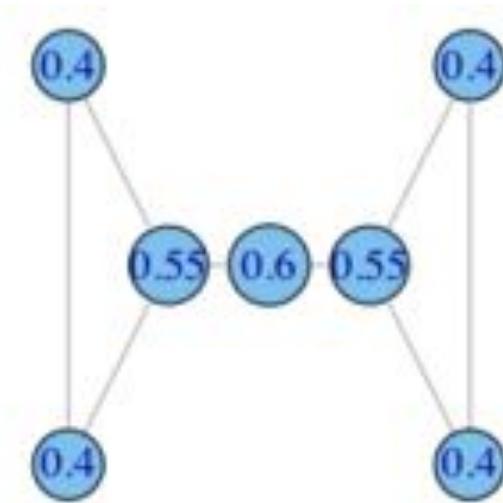


| So, we just take the reciprocal (i.e. 4/10)
| Higher value = greater centrality

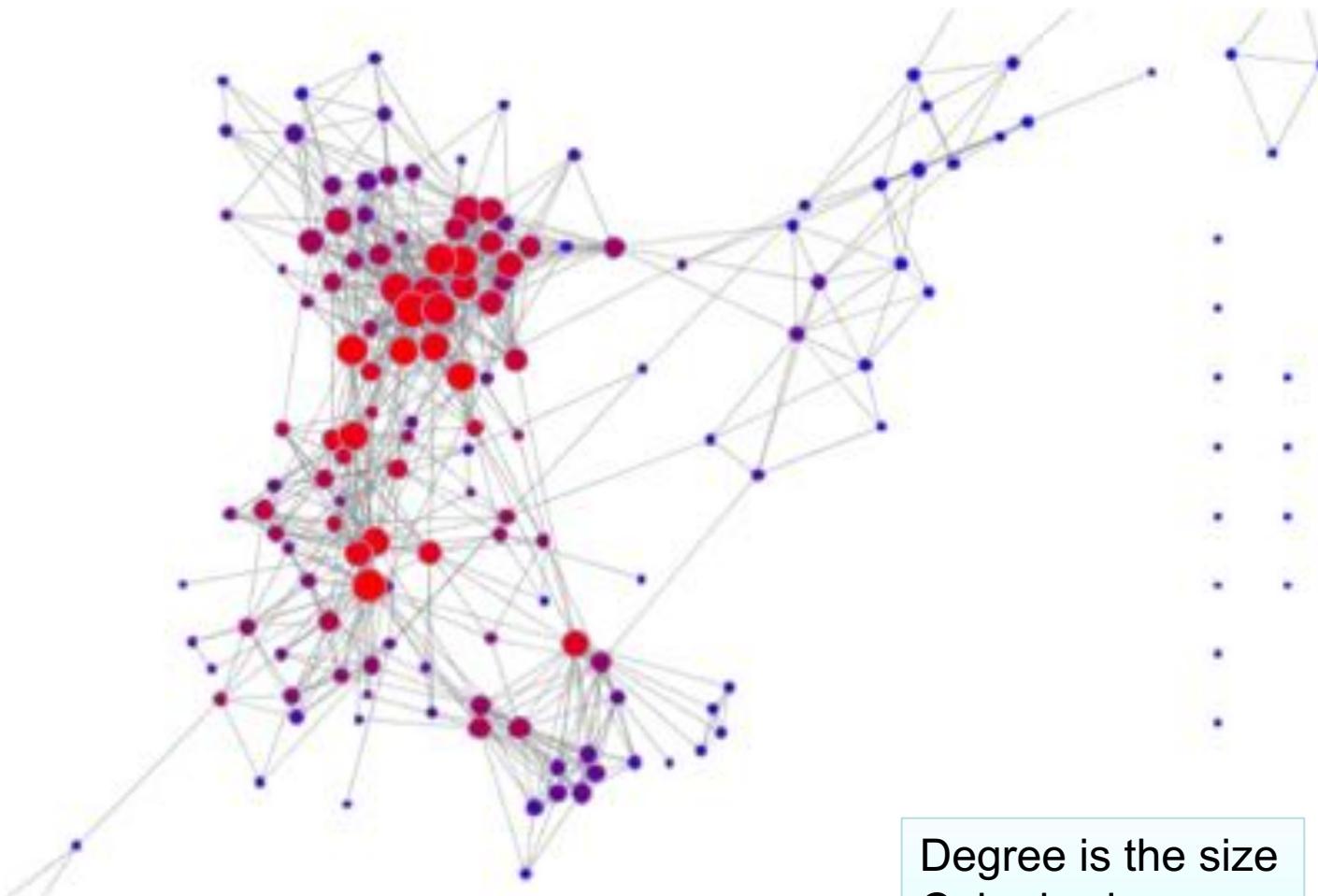


EXAMPLES

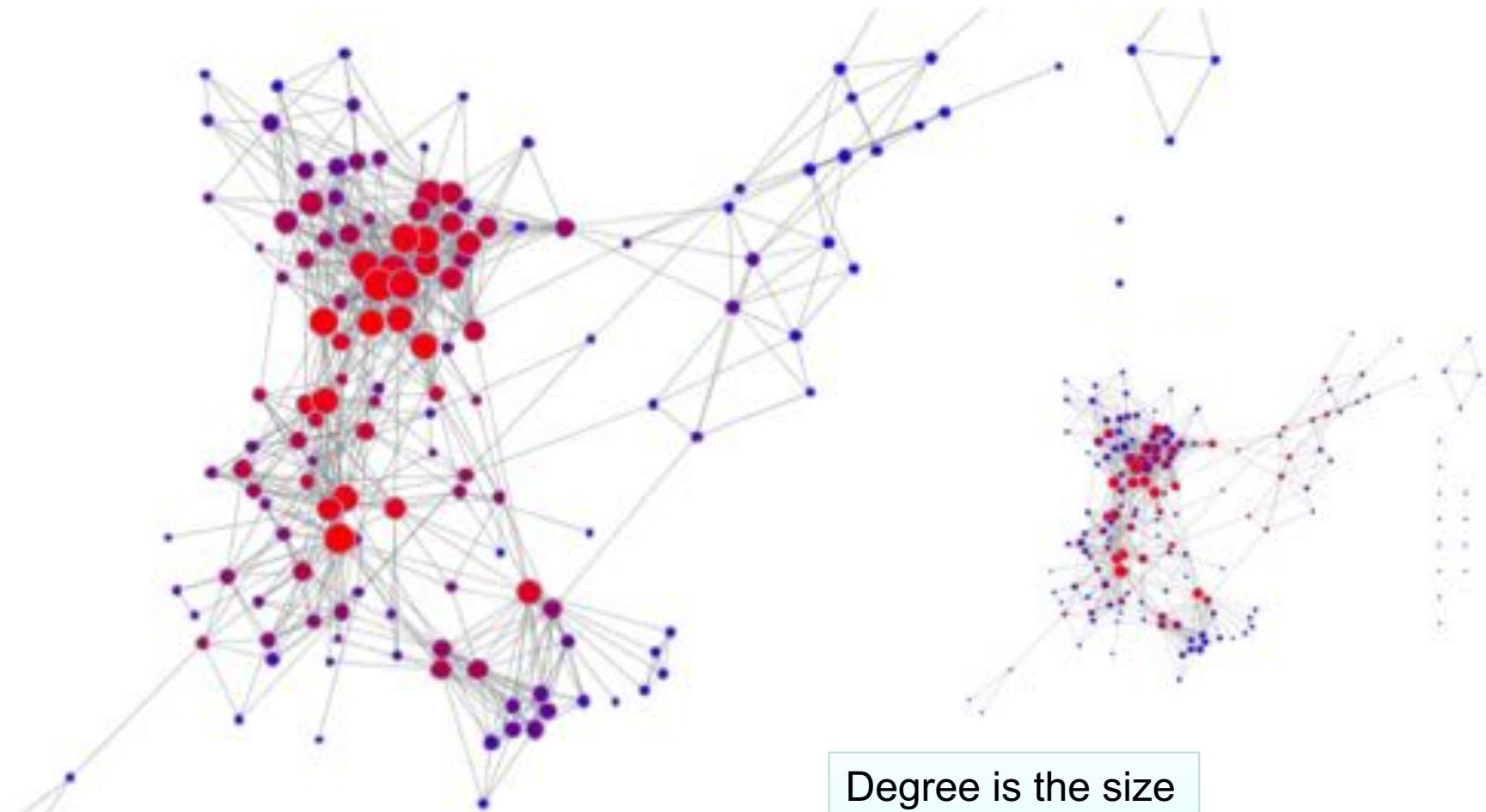
1 hop from the hub, and 2 hops
from everybody else



EXAMPLE: FACEBOOK (ADAMIC)



EXAMPLE: FACEBOOK (ADAMIC)



EIGENVECTOR CENTRALITY



EIGENVECTOR CENTRALITY

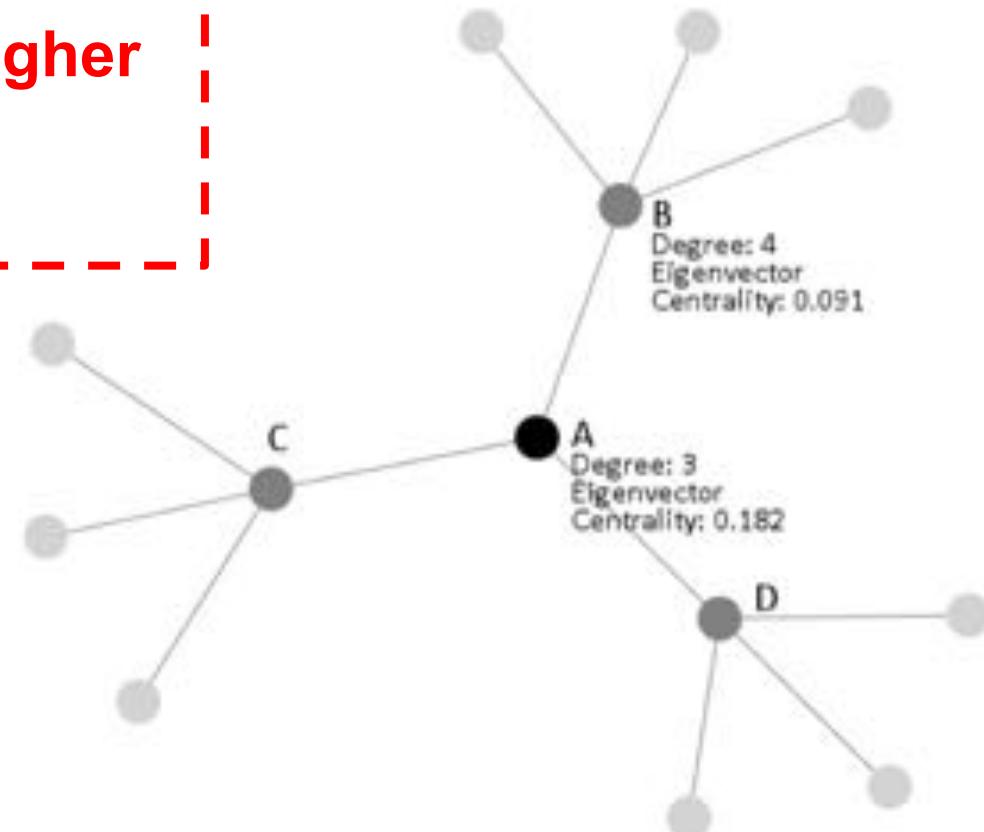
- How do you rank importance of nodes related to others?
 - Does degree centrality capture this?
- Need to consider characteristics of neighbours
 - More impressive to know Obama than know me!
- “Central” nodes should be connected to powerful nodes

EIGENVECTOR CENTRALITY

1. Assign centrality score of 1 to all nodes
2. Recompute scores of each node as weighted sum of centralities for all nodes in a node's neighbourhood
3. Normalise by dividing each value by the largest value
4. Repeat steps 2 and 3 until centrality values stop changing.

EIGENVECTOR CENTRALITY

Even though B has a higher degree, A has a higher Eigenvector centrality



EIGENVECTOR CENTRALITY: PAGERANK

Algorithm used to rank search results in Google™

Based on Eigenvector centrality

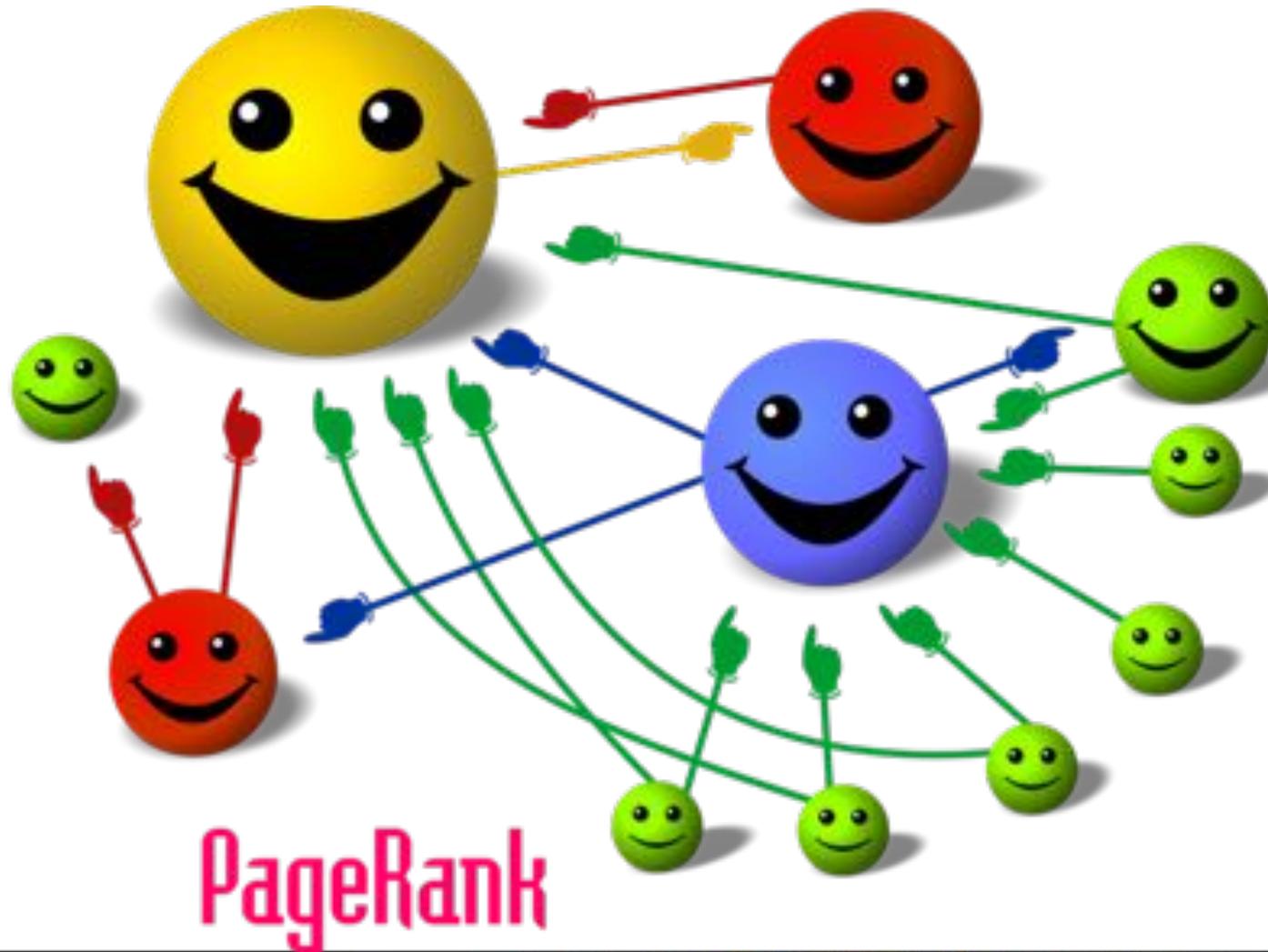
Uses graph of hyperlinks
between webpages

The screenshot shows a Google search results page. At the top, there's a snippet from a search result showing two identical links: "stop finishing my sentences". Below this, the text "About 16,300,000 results (0.22 seconds)" is displayed. The main search results area has a light gray background. The first result is a link titled "How to Stop Interrupting People and Finishing Sentences" with the URL "www.thesuburbanjungle.com/interrupt-people". Below it, there's a snippet of the page content: "18 Mar 2010 – Interrupting and **finishing** other people's **sentences** is ... many I don't **stop** talking, even if someone has tried to finish my t...". The second result is a link titled "Stop finishing my sentences. | Facebook" with the URL "www.facebook.com/group.php?gid=7858942140". Below it, there's a snippet of the page content: "Sign Up Stop finishing my sentences. is on Facebook Sign up for Fac... with Stop finishing my sentences. Stop finishing my sentences. ...".

EIGENVECTOR CENTRALITY: PAGERANK



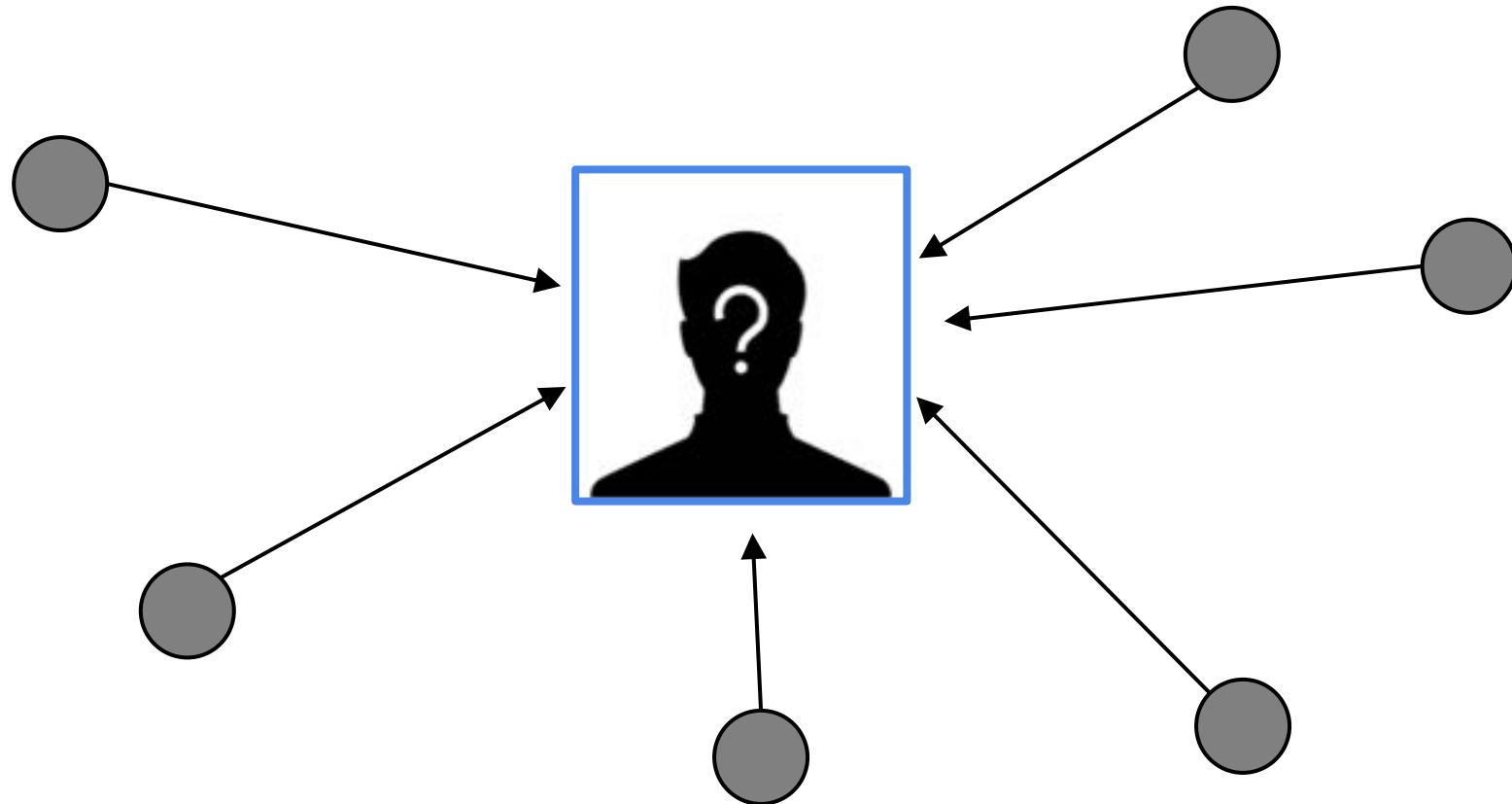
EIGENVECTOR CENTRALITY: PAGERANK



EIGENVECTOR CENTRALITY: PAGERANK



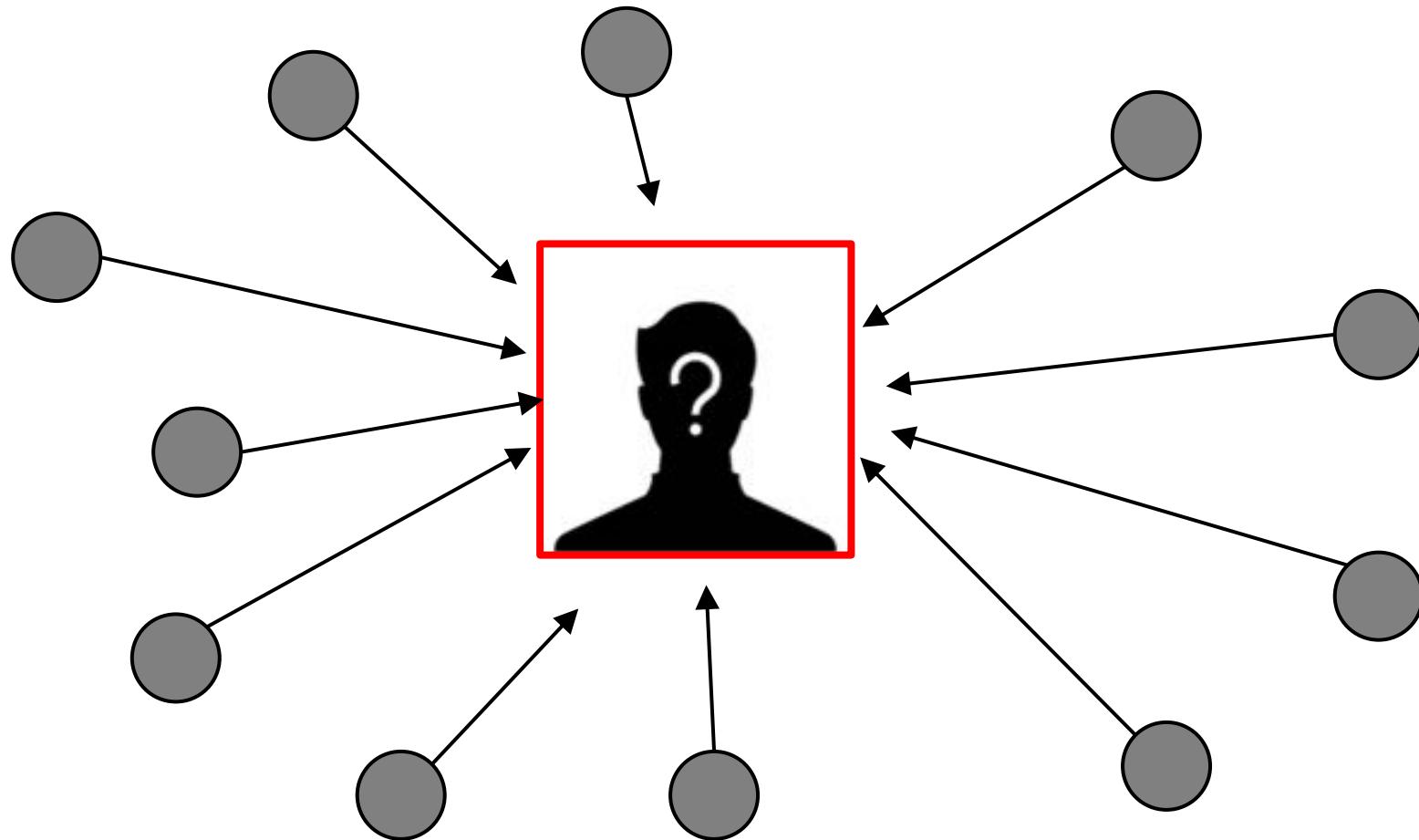
EIGENVECTOR CENTRALITY: PAGERANK



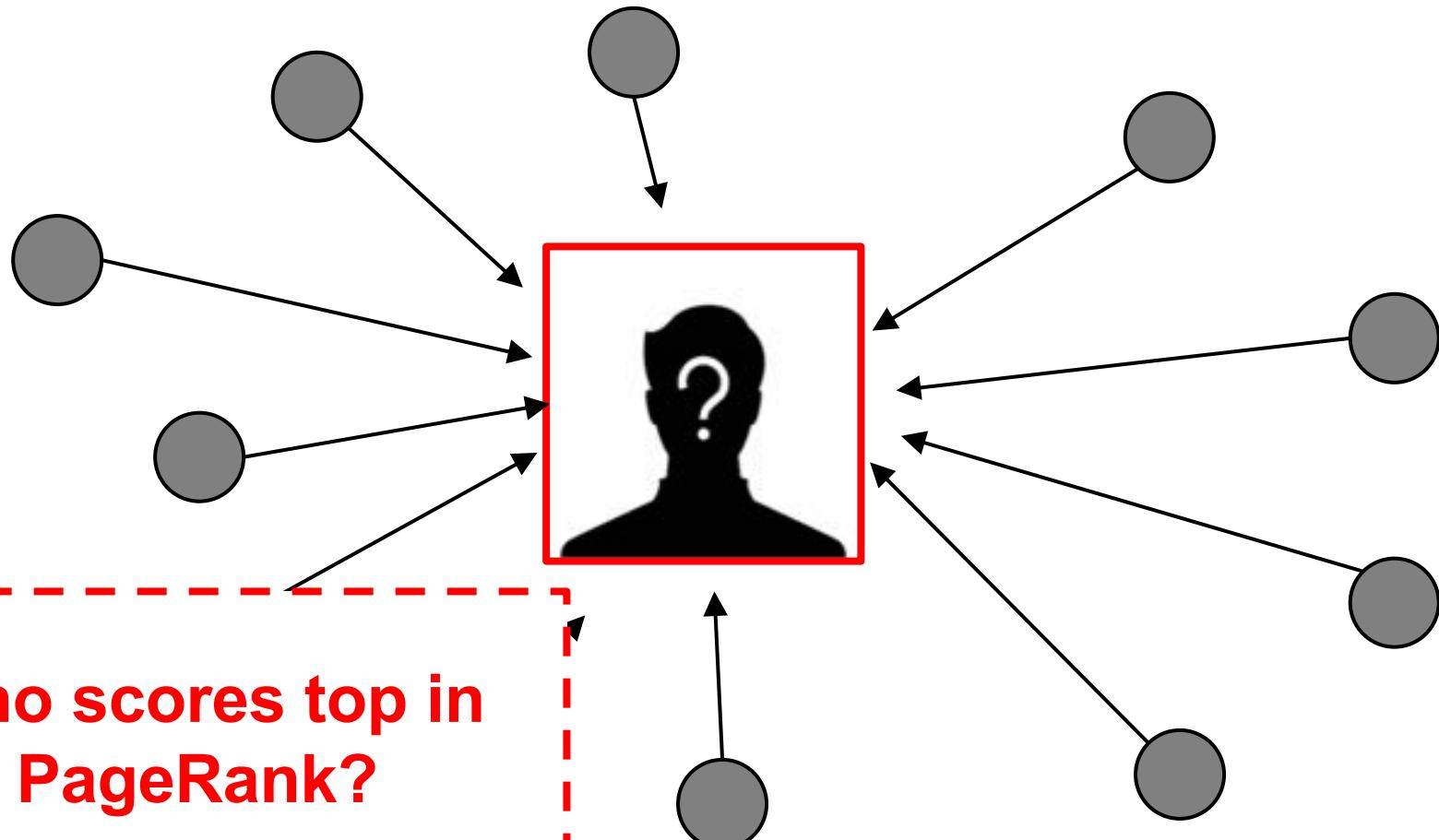
EIGENVECTOR CENTRALITY: PAGERANK



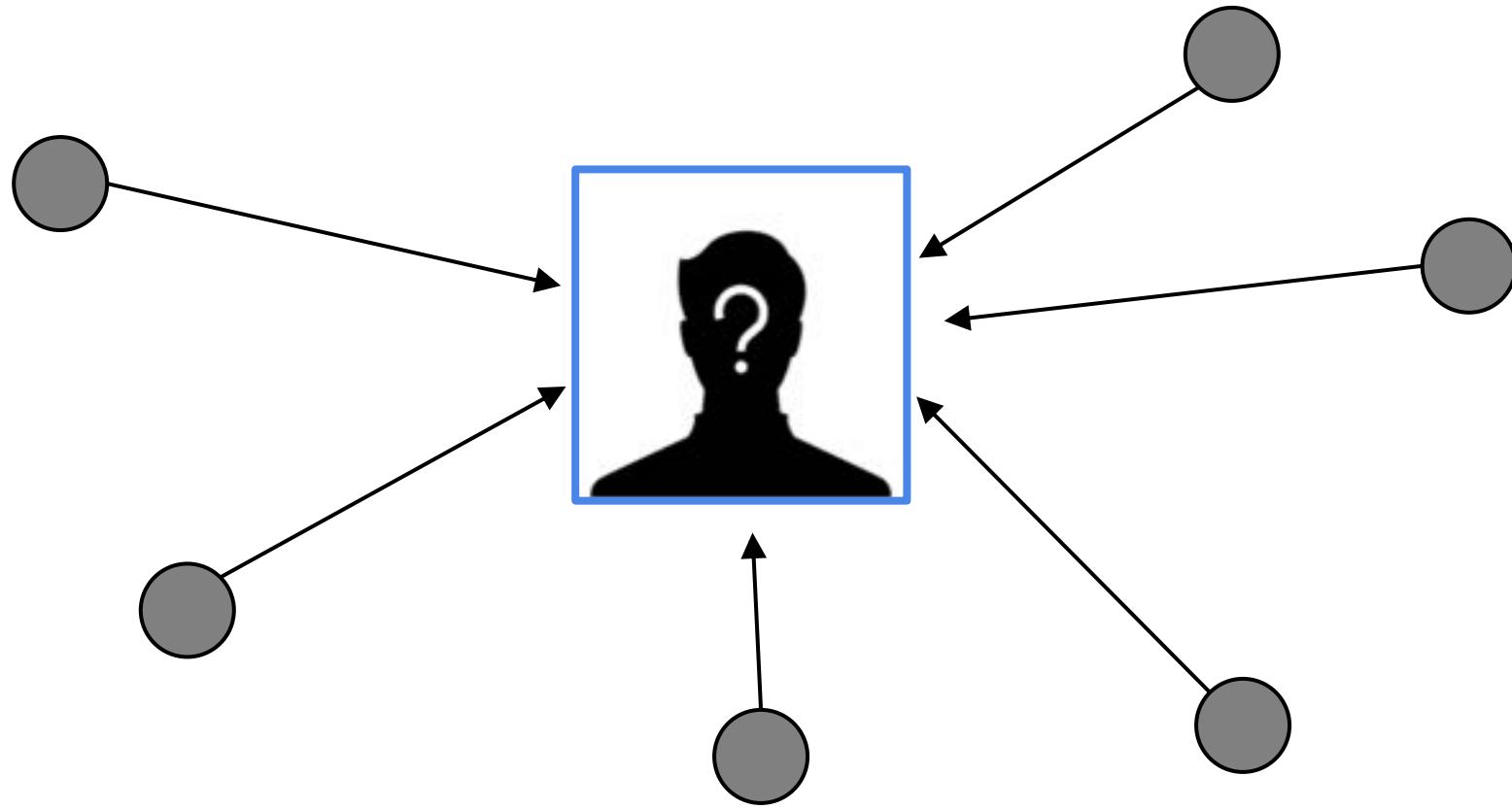
EIGENVECTOR CENTRALITY: PAGERANK



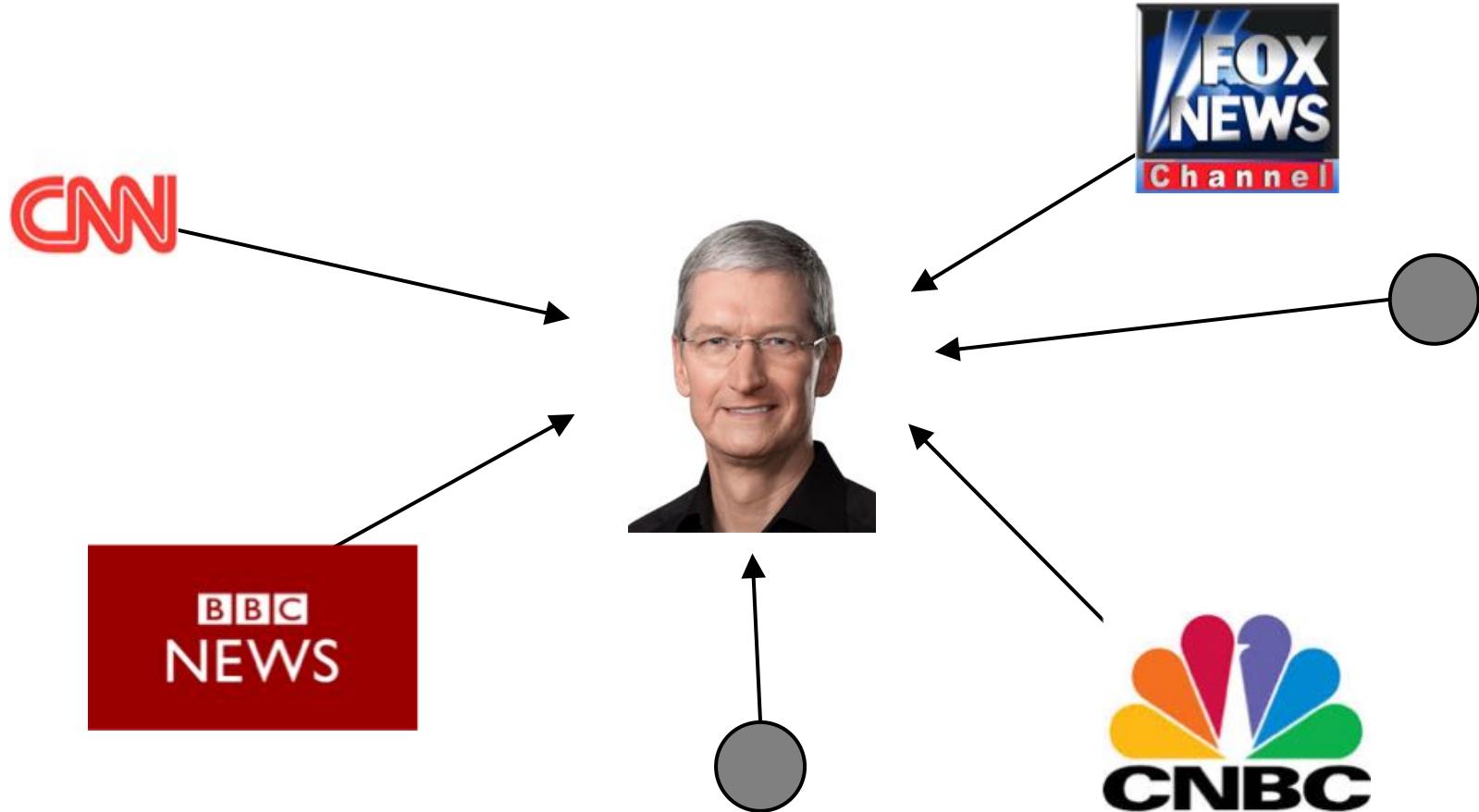
EIGENVECTOR CENTRALITY: PAGERANK



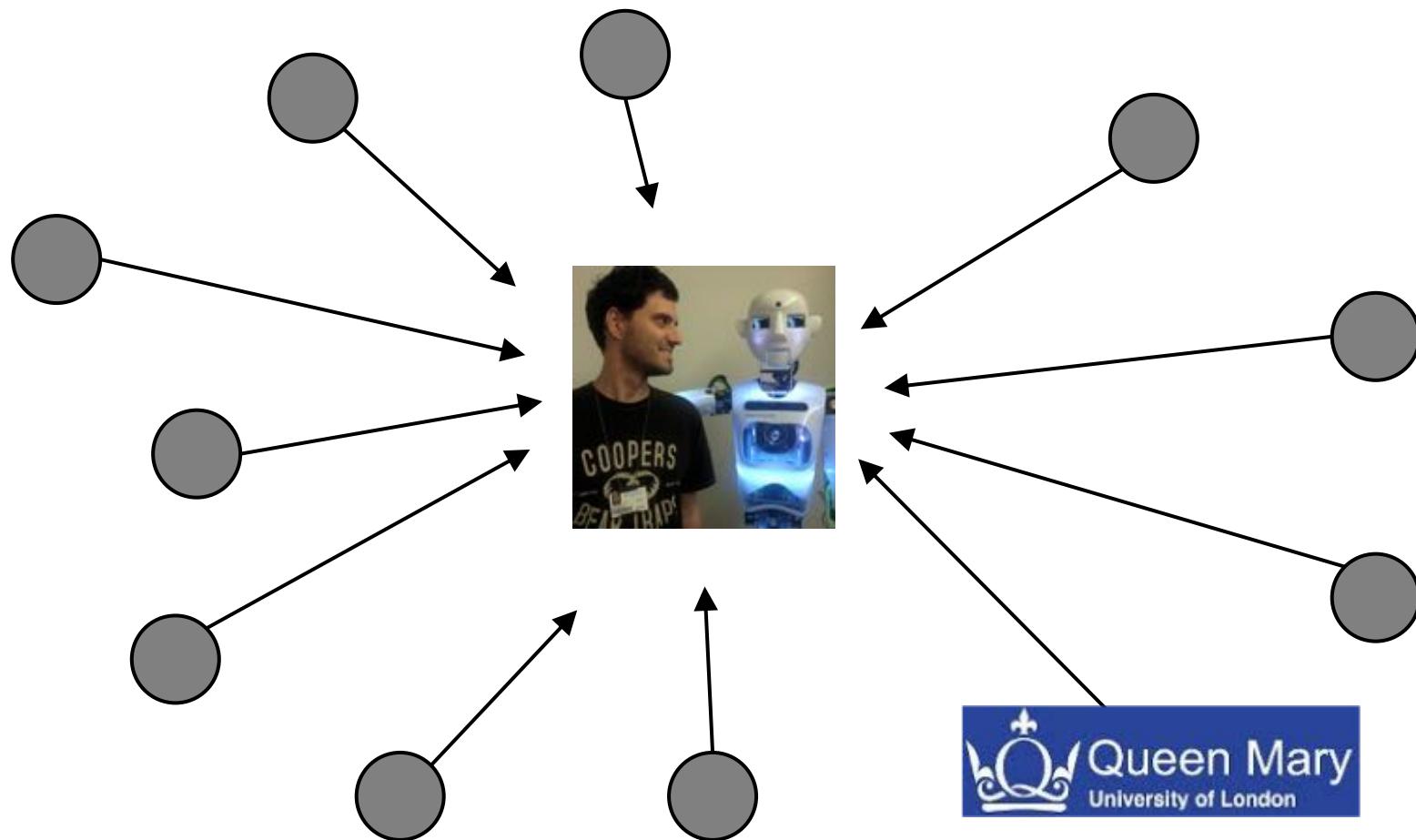
EIGENVECTOR CENTRALITY: PAGERANK



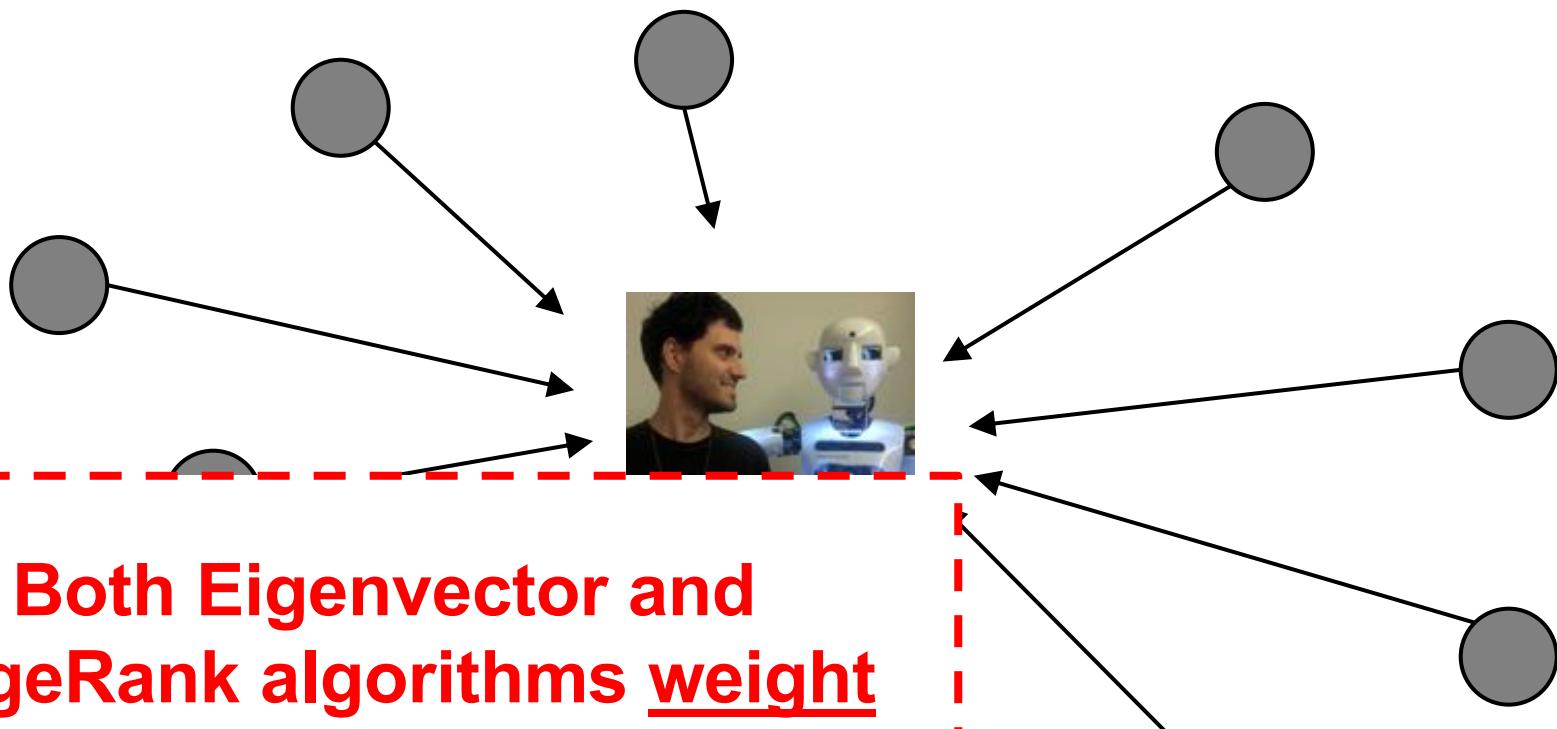
EIGENVECTOR CENTRALITY: PAGERANK



EIGENVECTOR CENTRALITY: PAGERANK



EIGENVECTOR CENTRALITY: PAGERANK



WHAT'S THE POINT IN CENTRALITY?



APPLICATION OF CENTRALITY MEASURES TO BIG DATA

The screenshot shows a video player interface for the "First 2008 Presidential Debate (Full Video)". The video frame displays a portrait of Barack Obama speaking. A subtitle at the bottom of the frame reads: "QUESTION: As President, what priorities will you have to give up to pay for the financial recovery plan?" Below the video frame, the progress bar shows "0:31:58 / 1:36:44". The video has received "4.8M+ ratings" and has "1,865,836 views". Below the video frame are buttons for "Favorite", "Shares", "Playlist", and "Flag". There are also links to "Send Email", "Twitter", "Facebook", and "More share options".

Statistics & Data

Video Responses (71)

Text Comments (20,414) Options

minimumgrade (2 hours ago)
Obama sure has fixed the economy! Thank God we got rid of capitalism!

Kingofgold42 (2 hours ago)
he won that is good

C-SPAN
September 27, 2008
[View info]
Sen. John McCain (R-AZ) and Sen. Barack Obama (D-IL) participate in the first 2008 Presidential debate.
Category: News & Politics
Tags: obama, mccain, debate, campaign, 2008, presidential

[Watch](#) [Share](#) [Email](#) [Print](#)

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Related Videos

More Popular News Videos

PEOPLE TWEET WHILE THEY WATCH

What are you doing? 140

|

Latest: max mind = -1 - (newer about 18 hours ago) update

 **Karatequilla @BigRed561** oh nah, where is dat?
less than 2d ago from web to reply to BigRed561.

 **tabligherooz** VPS made \$81/14p12,000 ↗ <http://t.co/6ahA8>
less than 2d ago from FriendFeed

 **jen_cohen @henryb35** no thanks.
less than 2d ago from web to reply to henryb35

 **AndreJayP @HASstyle420 @duecebigz26 @AndreJayP @gegoquedawg @rdafuture7 @silkybutmilky @climfuturistic #4thqtr- aint nuffn star.. @magicdoom04 ??**
less than 2d ago from Twitter

 **laurandempsey** don't forget, kids: throw your support behind @cirochelle tonight as she embarks on the world's first known #firstwitterdate. :)

less than 2d ago from web

 **easthawaiilarts** While sending tweets, always remembering words of early founder Mrs. F. Sherman: "Art is for EVERYBODY!!!" [#hawaii](http://www.ehcc.org/#art)



ANATOMY OF A TWEET

Repeated (retweet) content starts with RT

RT @jowyang If you are watching the debate you're invited to participate in #tweetdebate Here is the 411 <http://tinyurl.com/3jdy67>

ANATOMY OF A TWEET

Address other users with an @

RT: **@jowyang** If you are watching the debate you're invited to participate in #tweetdebate Here is the 411
<http://tinyurl.com/3jdy67>

ANATOMY OF A TWEET

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ANATOMY OF A TWEET

RT: @jowyang If you are watching the debate you're invited to participate in #tweetdebate Here is the 411
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Tags start with #

TWEET CRAWL

Three hashtags: **#current #debate08 #tweetdebate**

97 mins debate + 53 mins following = **2.5 hours** total.

3,238 tweets from **1,160 people**.

1,824 tweets from 647 people during the debate.

1,414 tweets from 738 people post debate.

577 @ mentions (reciprocity!)

266 mentions during the debate

311 afterwards.

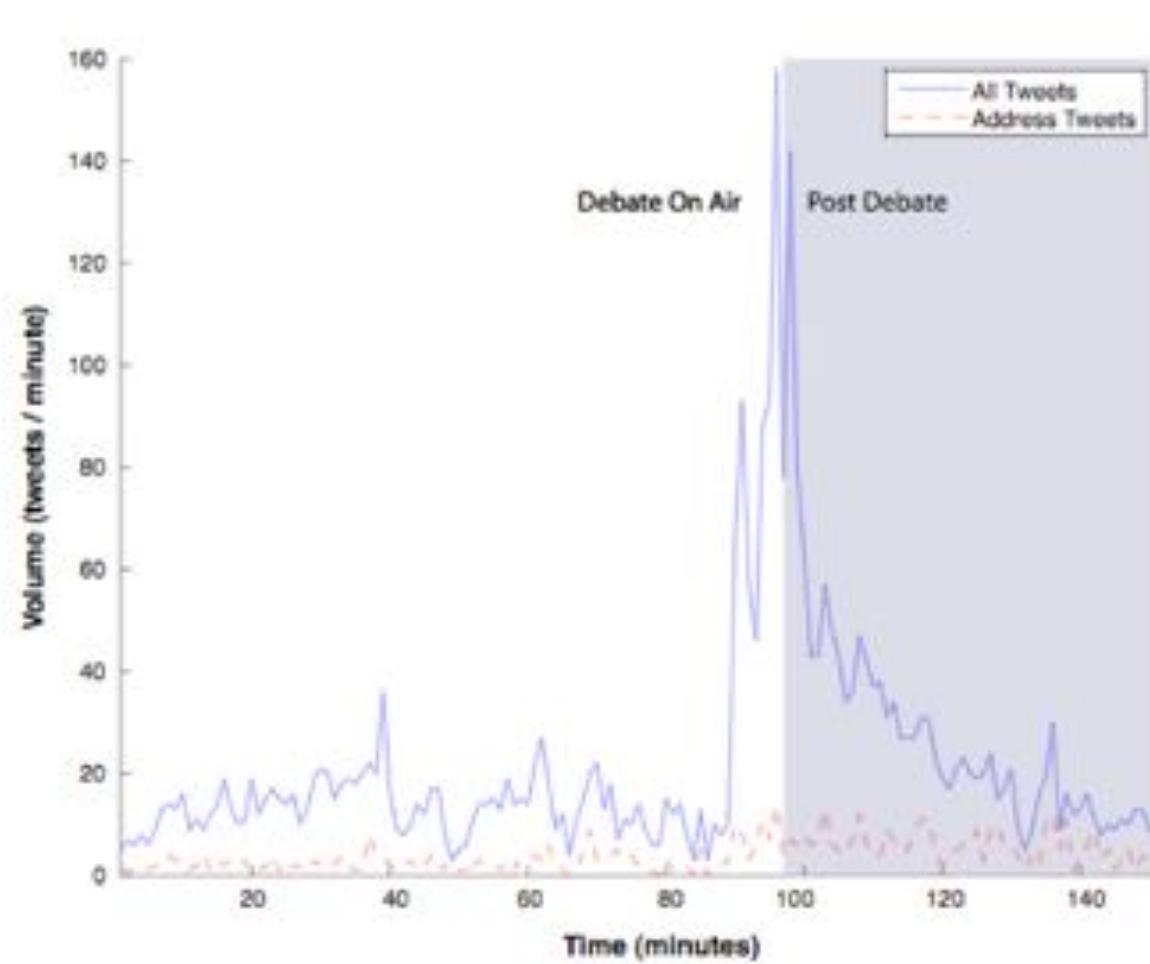
Low RT: **24 retweets** in total

6 during

18 afterwards.

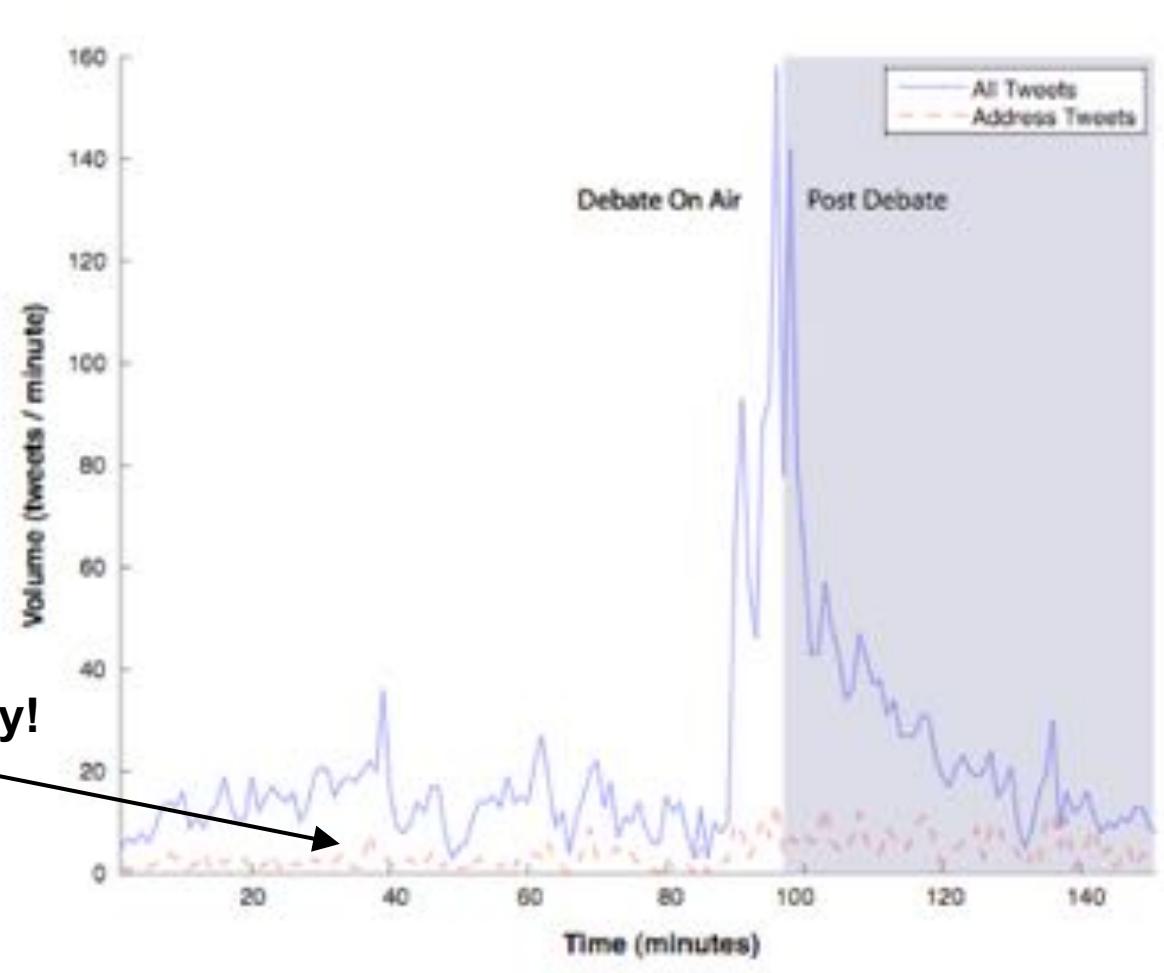
<http://www.ee.columbia.edu/~lyndon/pubs/wsm2009-twitter.pdf>

VOLUME OF TWEETS



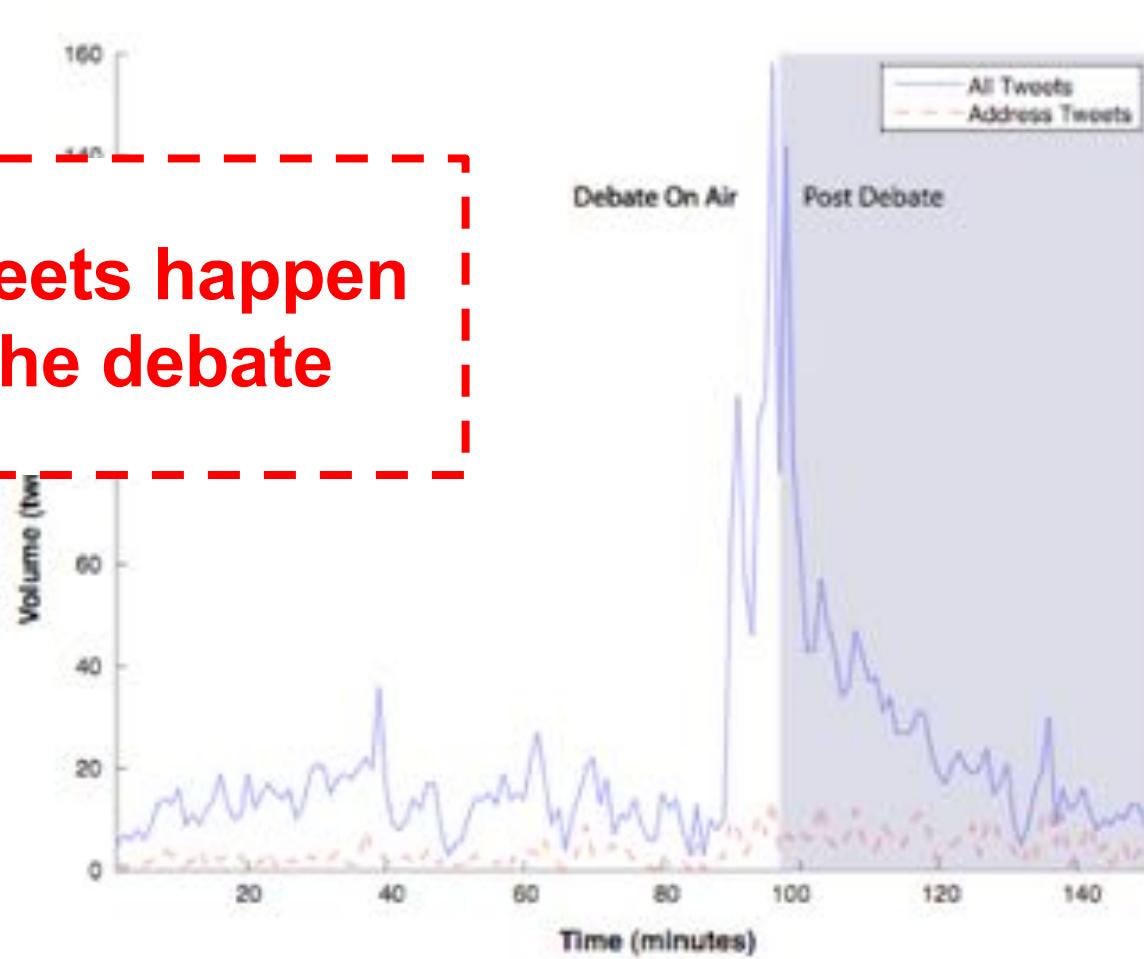
VOLUME OF TWEETS

@barackobama Hey!



VOLUME OF TWEETS

Most tweets happen after the debate

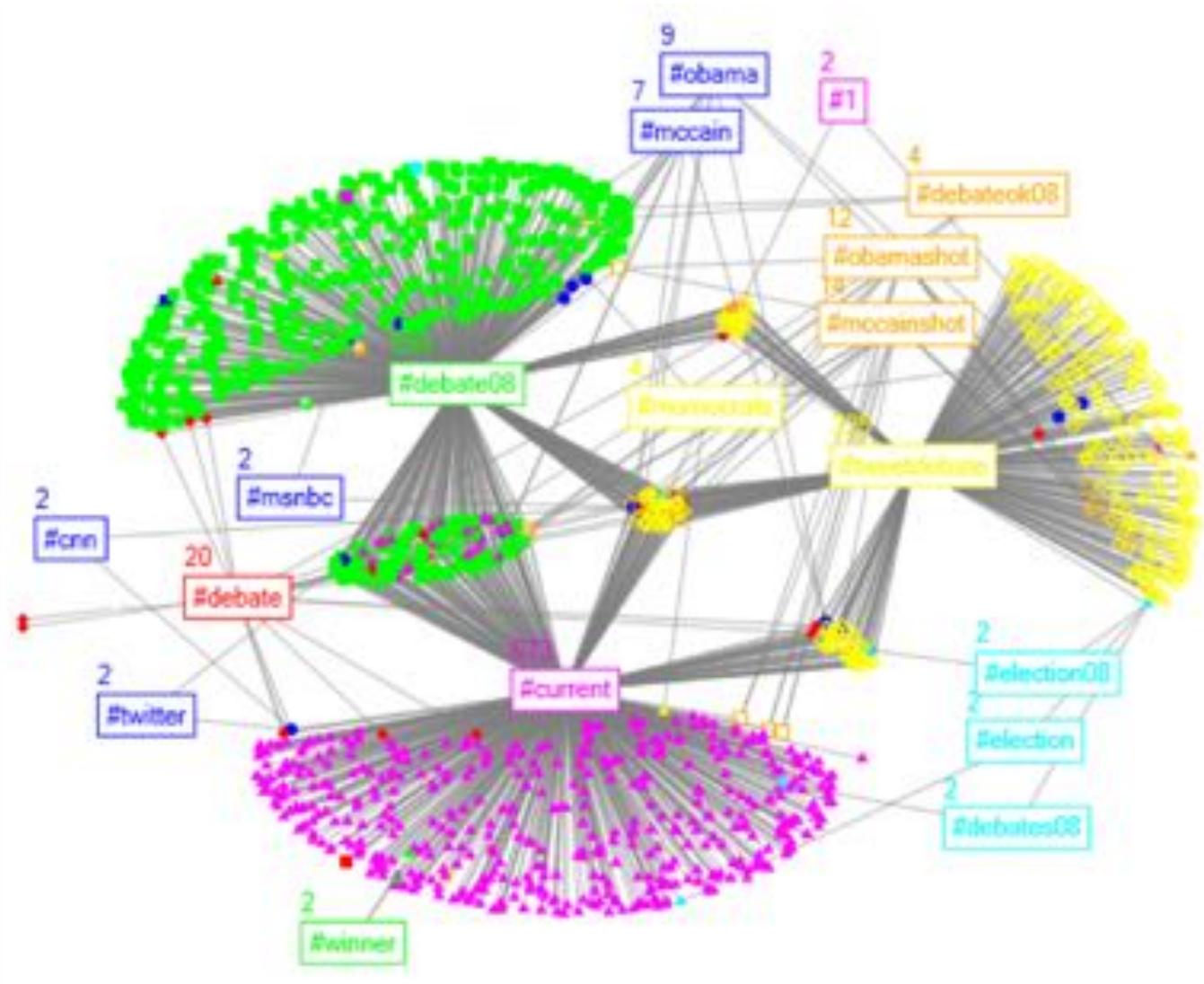


CLUSTER OF TAGS

We can treat the tags and users as a graph

“The betweenness centrality of **#current** is 1.0; **#debate08** and **#tweetdebate** scored 0.892 and 0.499 respectively”

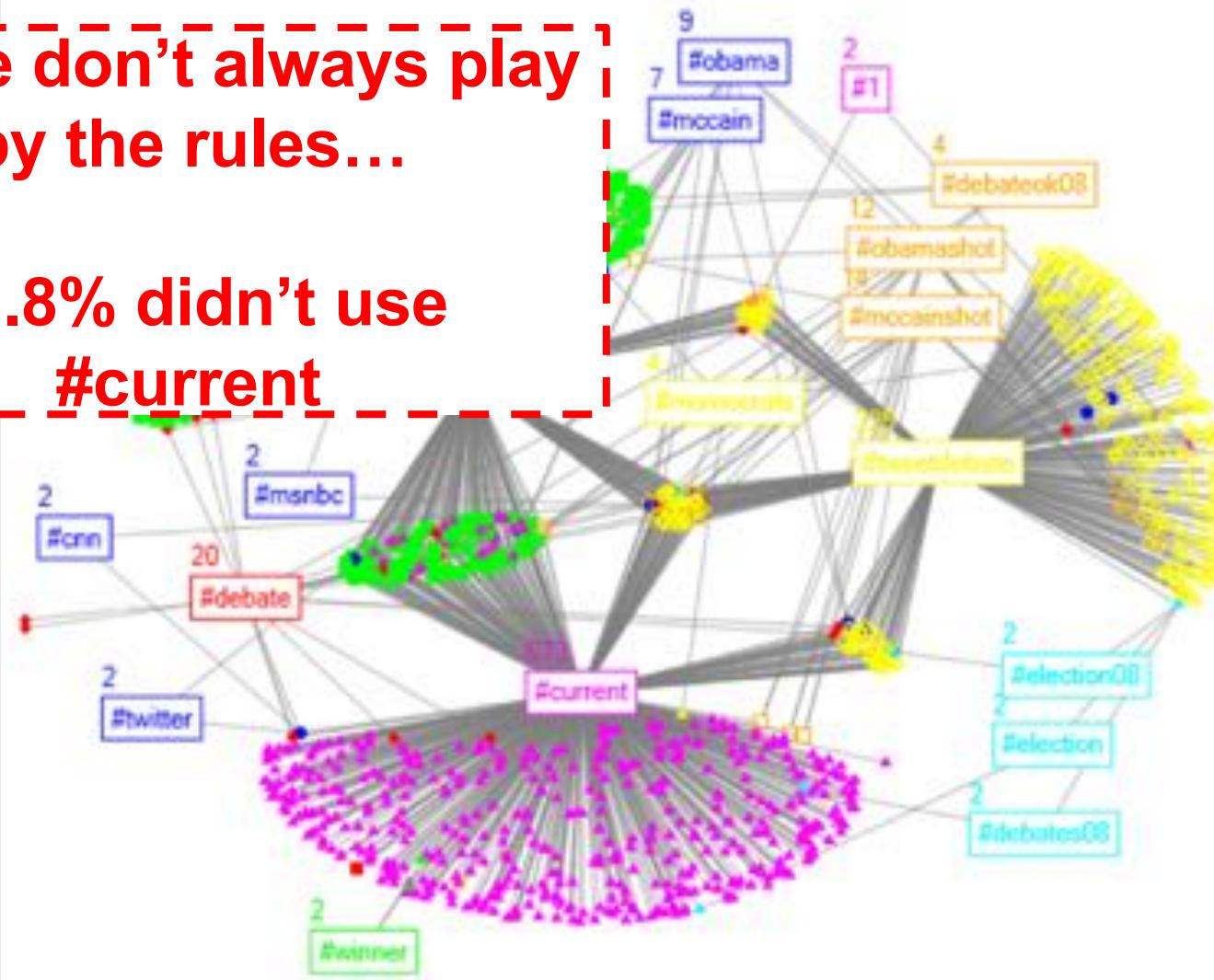
CLUSTER OF TAGS



CLUSTER OF TAGS

「People don't always play by the rules...」

48.8% didn't use #current



CENTRALITY

The network of 577 @user mentions is a directed graph of elicit call outs.

Only 10% were reciprocated

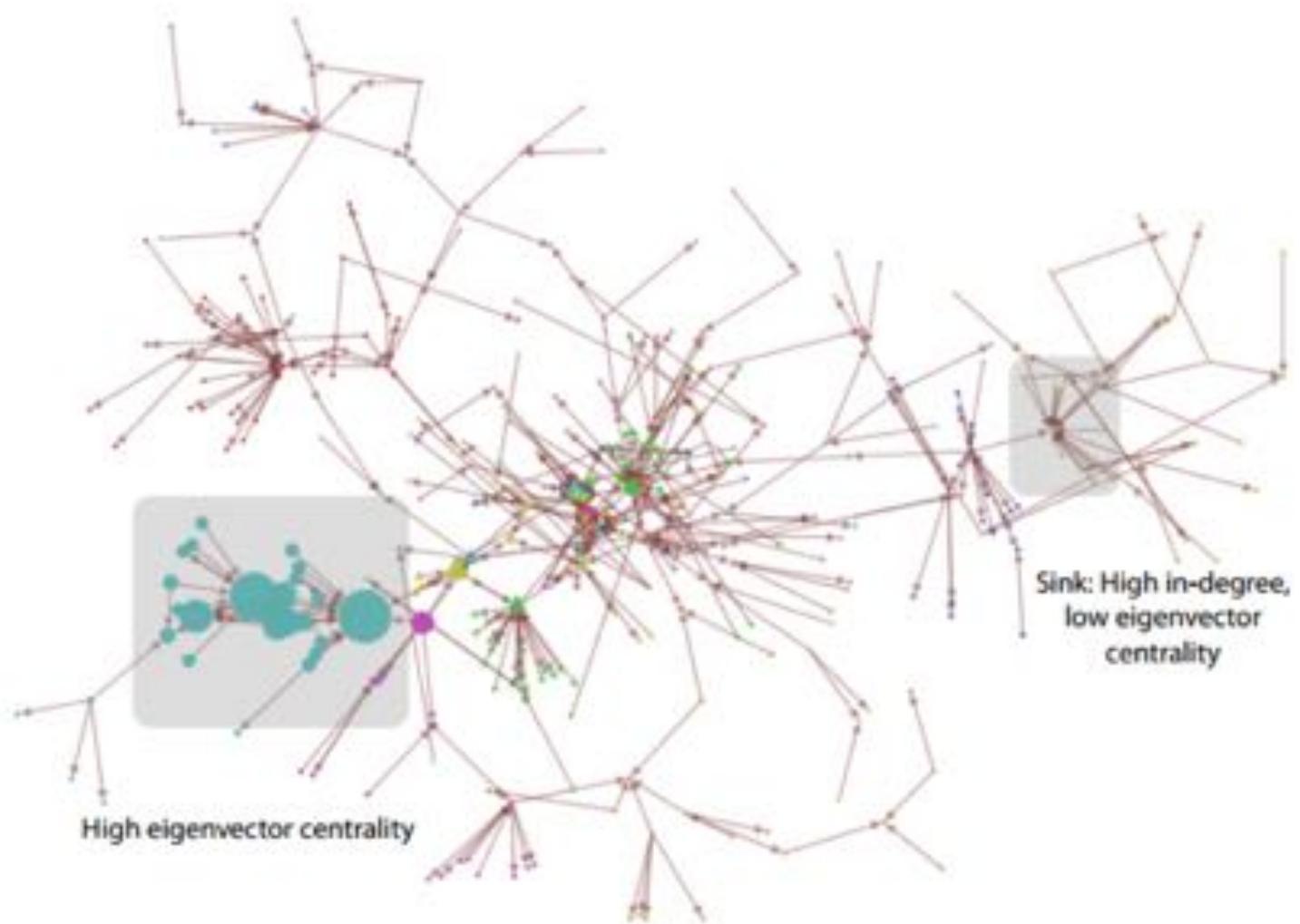


@barackobama Hey man!

CENTRALITY

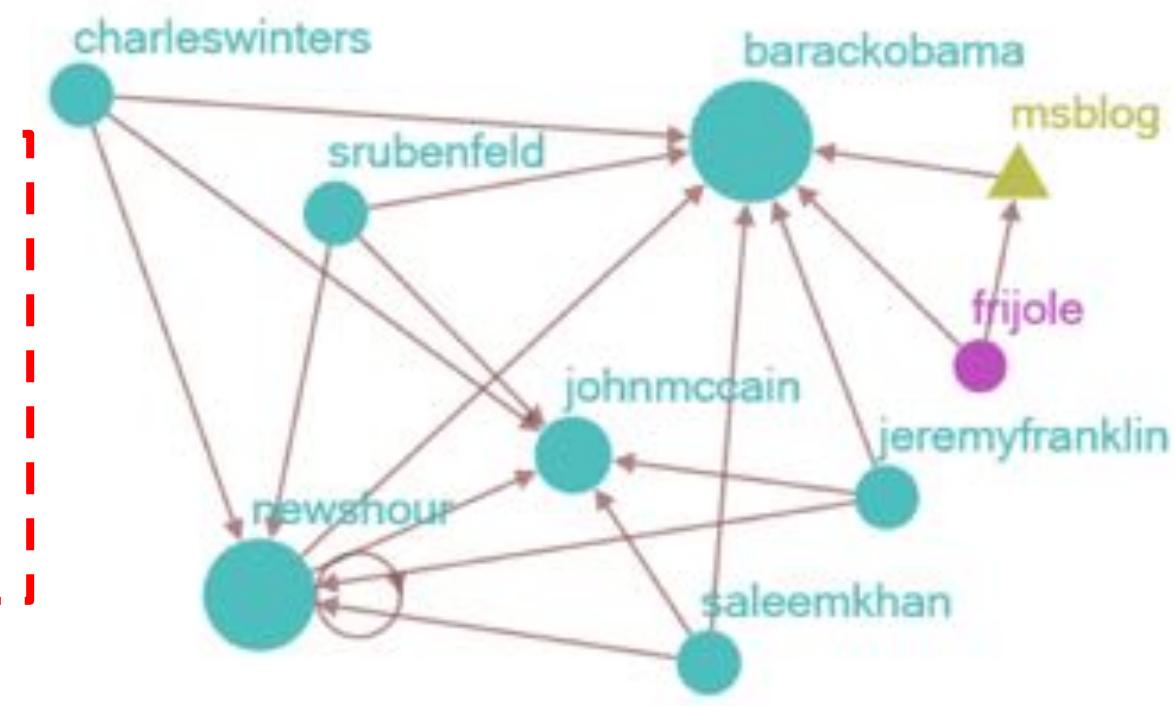
Twitter User	Eigenvector Centrality	In Degree	Out Degree
@barackobama	0.472	15	0
@newshour	0.427	11	5
@johnmccain	0.277	6	0
@charleswinters	0.223	0	3
@jeremyfranklin	0.223	0	3
@saleemkhan	0.223	0	3
@srubenfeld	0.223	0	3
@msblog	0.221	5	6
@frijole	0.175	0	7

TWITTER MENTIONS



AUTOMATIC DISCOVERY THROUGH CENTRALITY

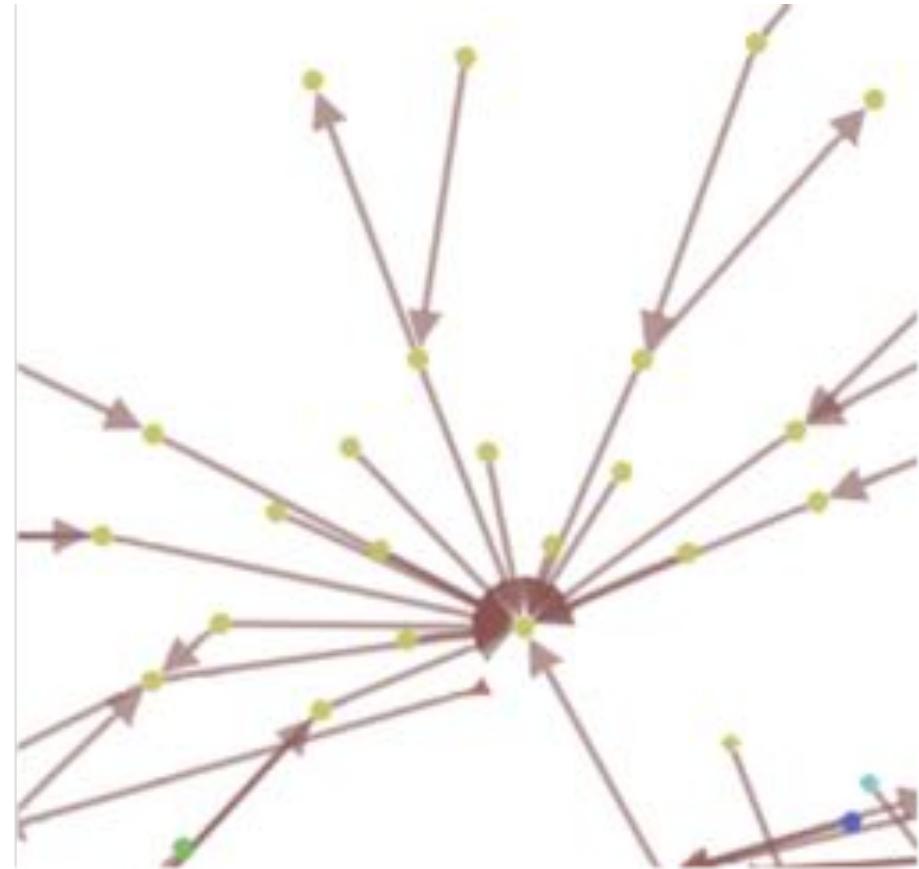
Can easily detect the
big players in the
debate



SINKS

High in-degree but poor centrality:

@current, who ran the Hack the Debate program, and @jowyang, an employee of Forrester Research who uses Twitter as a personal, not corporately related microblog.



TWEETS TO TERMS

Twitter	drinking candidates wins minute lehrer letting tv mccoains tweet moderator	kennedy plan hope hand comment moderator	cut earmarks compared tax tie home audience republicans	screen bailout energy joke bear dollars problems personal american	senate difference winning strategy iraq festooned nuclear giving freeze looked	puling pakistan understand republican strategy sounds coming telling story	lousy democracies lol government story wars league times <i>iran</i> -5	georgia video blog league russia ha lot condescending issue oil	security experience 9/11 safe country tactics attack video pakistan bringing
	presidential debates minutes eisenhower financial direct policy news mississippi university	street greed main how's house package accountable wall rewarded crisis	\$18 requests earmarks gateway loopholes \$5,000 pork-barrel employer business tax	programs medicare cost eliminate \$700 hard decisions agency rescue tom	funding winning leave timetable violence lessons baghdad surge succeed started	border taliban prepared supported muddle u.s bombing <i>pakistan</i> qaeda army	henry kissinger contacts preparation legitimize table <i>iranians</i> sanctions ahmadinejad precondition	georgia international putin ukraine russia world's offshore sanctions ahmadinejad nato	restore knowledge missile safer veterans terms focused earth billions challenges
	opening financial recovery	Solving Financial Crisis	Financial Recovery	Lessons of Iraq	Troops in Afghanistan	Threat from Iran	Relations with Russia	Terrorist Threat	
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	presidential debates minutes eisenhower financial direct policy news mississippi university	street greed main how's house package accountable wall rewarded crisis	\$18 requests earmarks gateway loopholes \$5,000 pork-barrel employer business tax	programs medicare cost eliminate \$700 hard decisions agency rescue tom	funding winning leave timetable violence lessons baghdad surge succeed started	border taliban prepared supported muddle u.s bombing pakistan qaeda army	henry kissinger contacts preparation legitimize table iranians sanctions ahmadinejad precondition	georgia international putin ukraine russia world's offshore aggression resurgent nato	restore knowledge missile safer veterans terms focused earth billions challenges

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Twitter									
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Debate	presidential debates minutes eisenhower financial direct policy news mississippi university	street greed main how's house package accountable wall rewarded crisis	\$18 requests earmarks gateway loopholes \$5,000 pork-barrel employer business tax	programs medicare cost eliminate \$700 hard decisions agency rescue tom	funding winning leave timetable violence lessons baghdad surge succeed started	border taliban prepared supported muddle u.s bombing pakistan qaeda army	henry kissinger contacts preparation legitimize table iranians sanctions ahmadinejad precondition	georgia international putin ukraine russia world's offshore aggression resurgent nato	restore knowledge missile safer veterans terms focused earth billions challenges

SUMMARY

- We have introduced various measures of centrality and explained the pros and cons
- We have illustrated one example of use of centrality in a Twitter related example



SUMMARY

- Degree centrality
- Freeman's centrality
- Betweenness centrality
- Closeness centrality
- Eigenvector centrality



References

- Kleinberg's book: Chapter 3.
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- M. Newmann. **Networks**. Oxford University Press. April 2010.
- David A. Shamma, Lyndon Kennedy, and Elizabeth F. Churchill. 2009. *Tweet the debates: understanding community annotation of uncollected sources*. In Proceedings of the first SIGMM workshop on Social media (WSM '09). ACM, New York, NY, USA