Network Theory: Universal Properties of TV Shows

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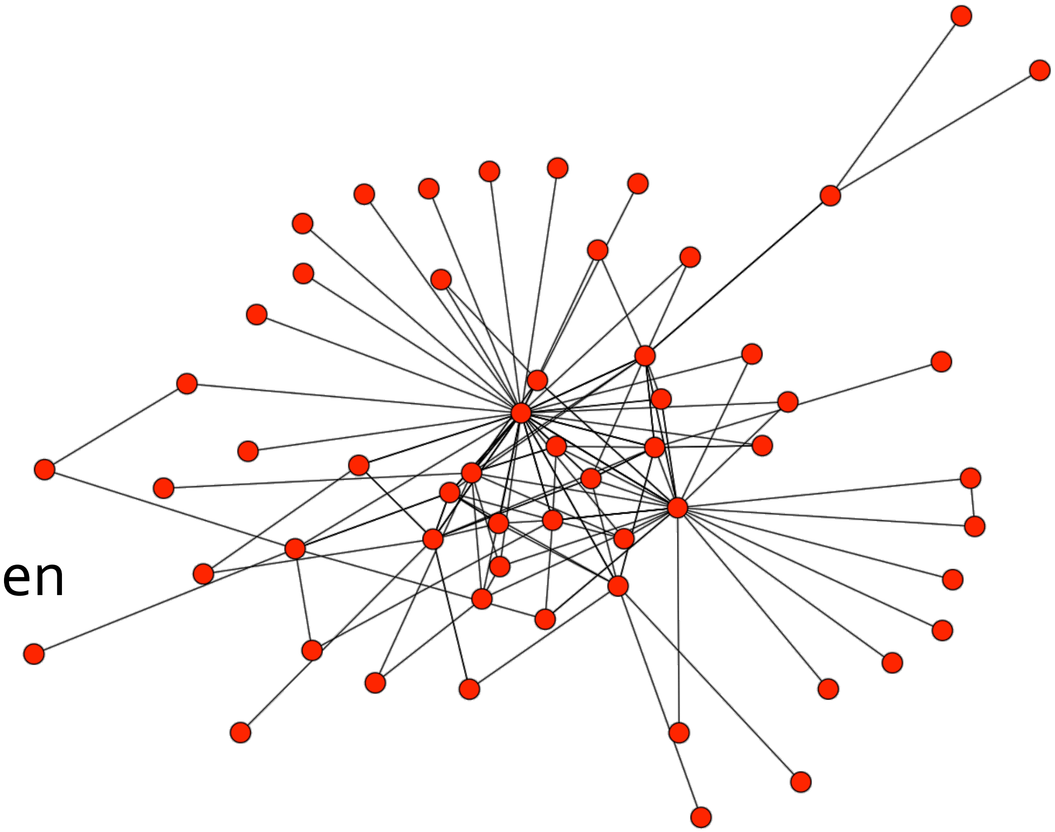
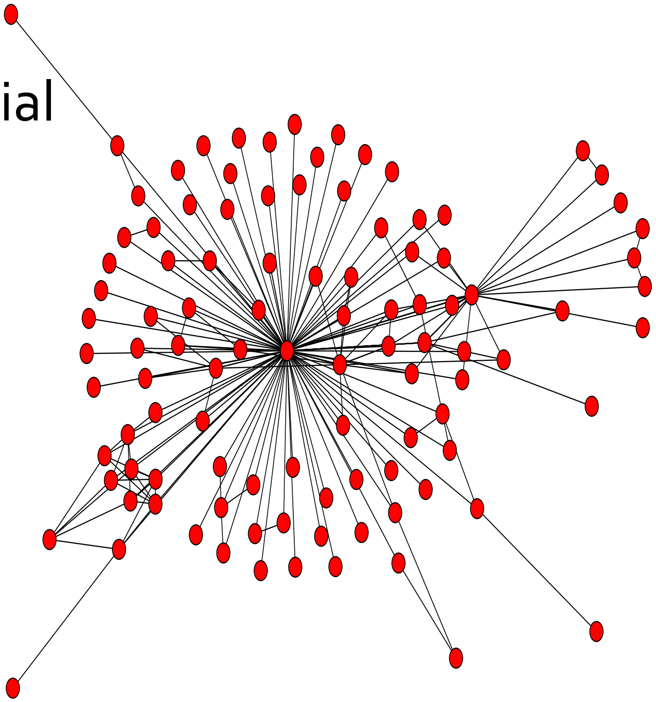
Introduction

- In this project, the first seasons of five television programs were analyzed using network theory.
- Each show's network is comprised of every character-to-character interaction, which was then graphed and analyzed.



Scientific Description

- The properties of the networks were compared to those of purely fictional networks and nonfictional social networks.
- The analysis reveals whether or not the social networks found in the television shows resemble real-life social networks.



Methodology

1. Collected the character-to-character interaction from five different TV shows; The Tudors, House of Cards, Keeping Up With The Kardashians, Cops, and Deadbeat.

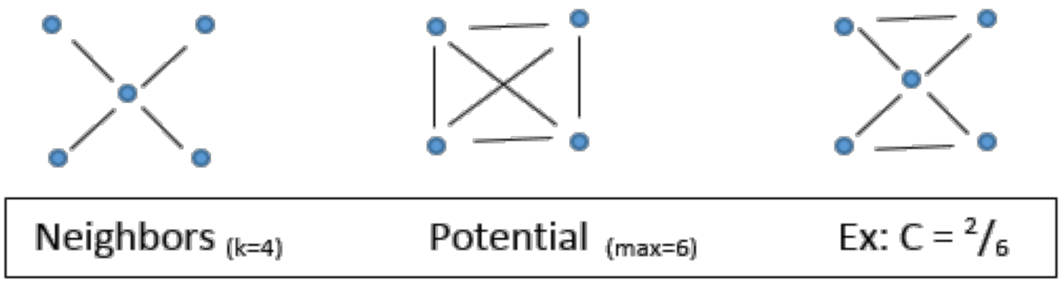
2. Used NetworkX in Python to develop individual networks.

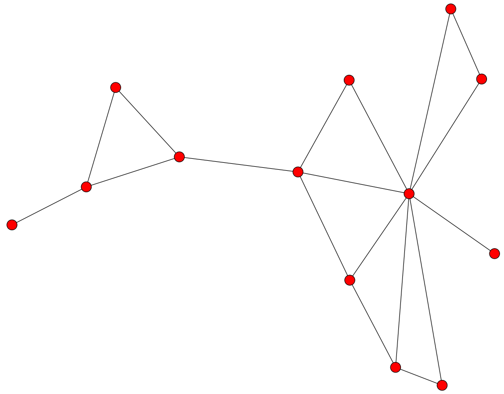
3. Analyzed each network using the universal properties described by Carron and Kenna [1].
   Universal Properties Examined:
   - Average path length
   - Clustering Coefficient
   - Hierarchical Network
   - Degree Distribution
   - Scale Free
   - Giant Component
   - Betweenness Centrality
   - Small World
   - Assortativity Coefficient
   - Structural balance
   - Target Attack

4. Based upon the data calculated we were able to determine whether or not each network resembled a real social network or fictitious network.

Clustering Coefficient (C_i, C)

- Density of neighbor connections of node
  - Given as percentage of actual over potential ($C_i \in [0, 1]$)
- Potential connections: max = $k_i(k_i-1)/2$
  - Where k_i is the number of neighbors of i^{th}-node ("degree")
  - Actual number, n_i divided by maximum: $C_i = 2n_i/k_i(k_i-1)$
- Global average yields probability two neighbors of a node are connected

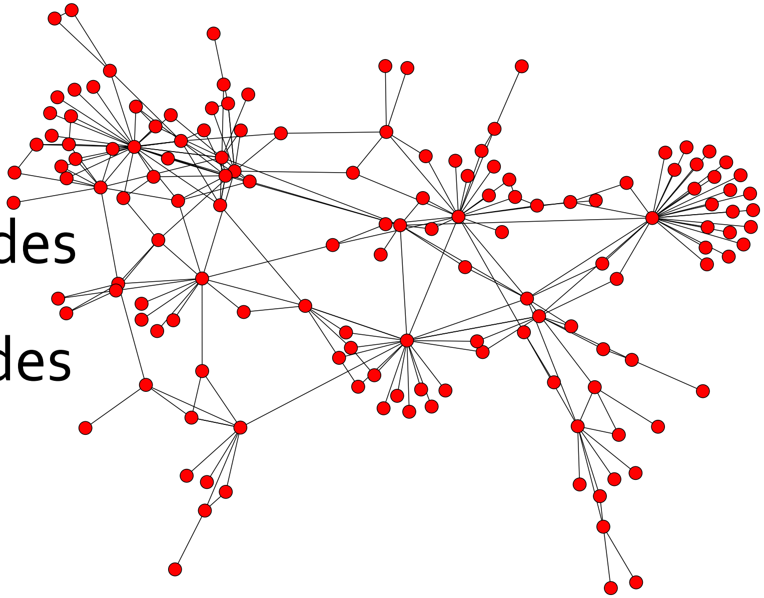




Hierarchical Networks

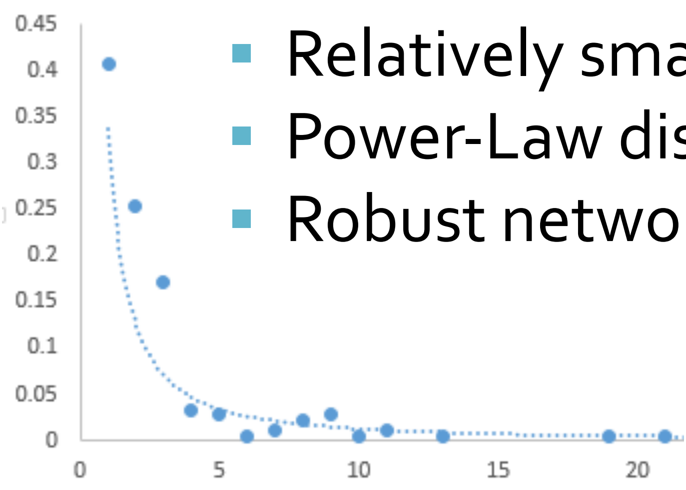
- Type of complex networks in which increasingly large groups form modular structures
- Clustering Coefficient is power-law dependent on node degree
  - C(k) ~ 1/k
  - Predominately low- degree nodes
  - Few high-degree structural nodes
  - Indicates dense sub-graphs

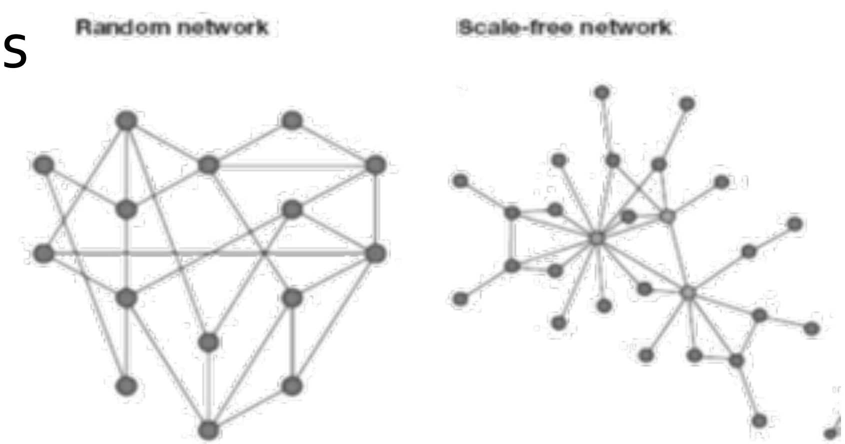
    of low-degree nodes



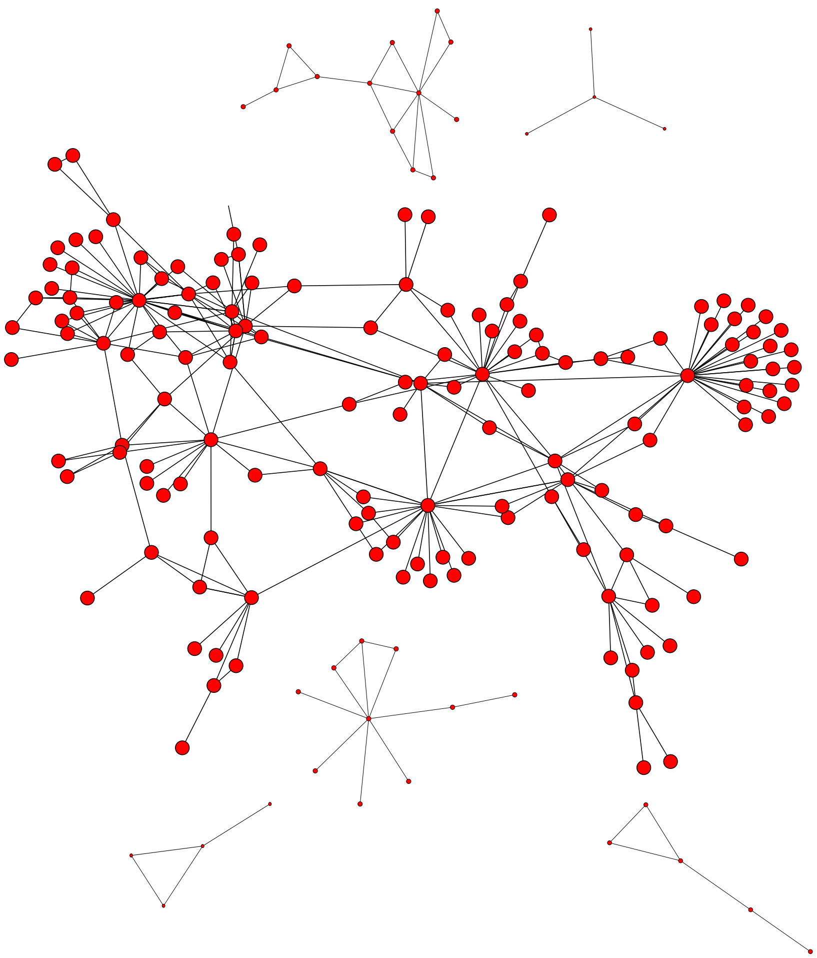
Degree Distribution
Scale-Free Networks

- Probabilistic distribution for degrees of each node
- Frequently:
  - $p(k) \sim k^{-\gamma}$ ← "probability that a node has degree, k"
  - for $\gamma > 0$
- Scale-Free Network Characteristics
  - Relatively small geodesics
  - Power-Law distribution
  - Robust networks





Giant Component

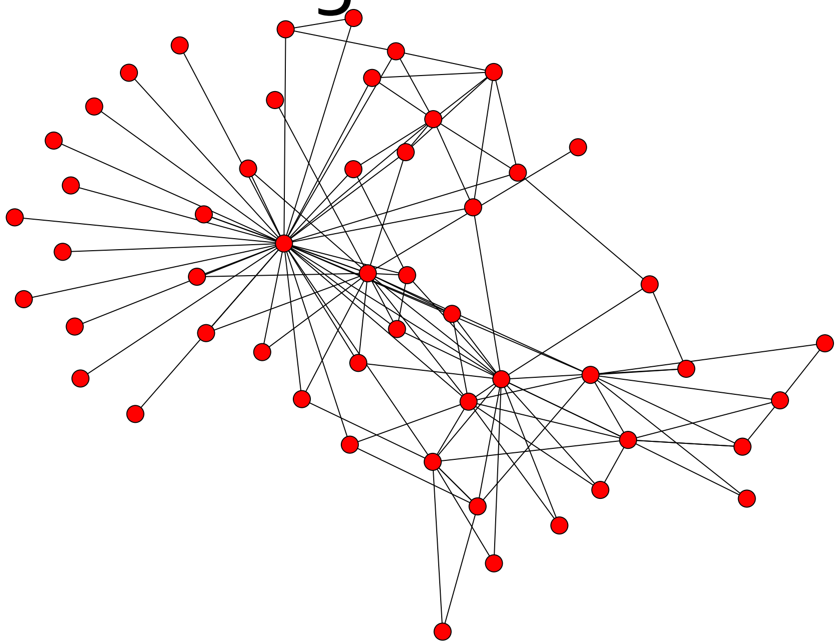


- Connected components: linked sections of any network
- Giant component is the largest of these
  - Size being a measure of connectivity of the network
- Scale-Free Networks: removing influential nodes collapses Giant Component
  - removing random nodes leaves intact

Betweenness Centrality (g_l)

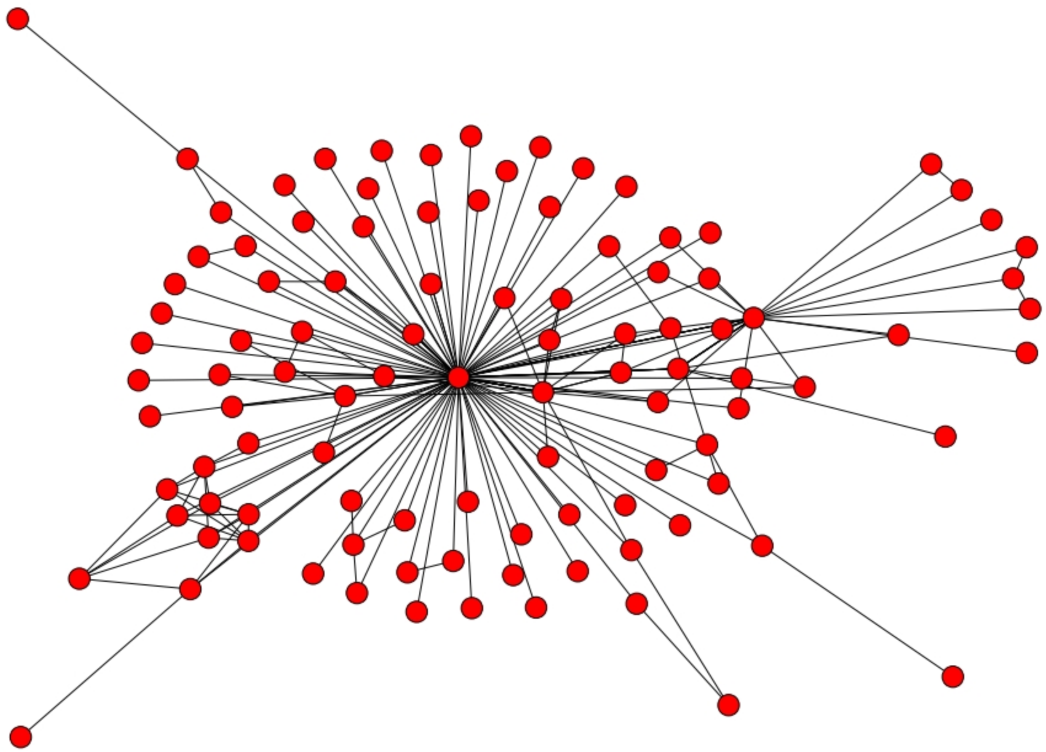
- Measure of network connectivity – influence of nodes in terms of flow
- Percentage of geodesics through a node

$$g_l = \frac{2}{(N-1)(N-2)} \sum_{i \neq j} \frac{\sigma_l(i,j)}{\sigma(i,j)}$$



Small World

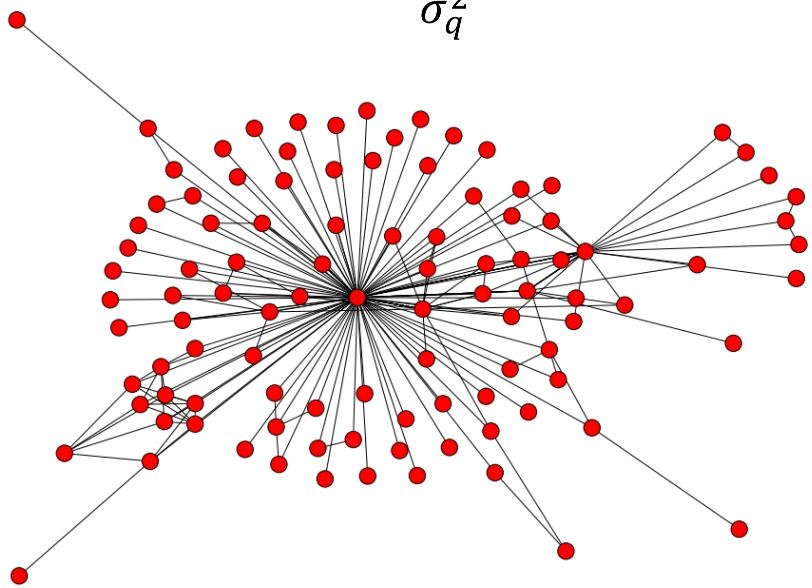
- Average path length (L)
- Clustering coefficient (C)
- Number of Nodes (N)
- Mean Degree (k)
- Random Network with same N and k
- $L \approx L_R$
- $C >> C_R$



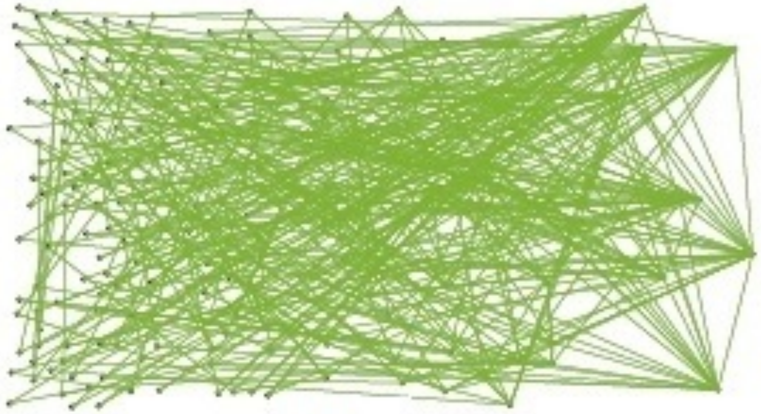
Assortativity coefficient (r)

- The assortativity coefficient is the Pearson correlation coefficient of degree between pairs of linked nodes

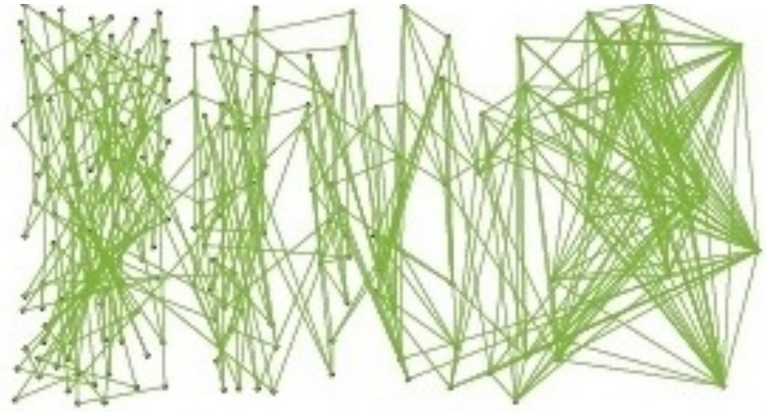
$$r = \frac{\sum_{jk} jk(e_{jk} - q_j q_k)}{\sigma_q^2}$$



r=-0.41



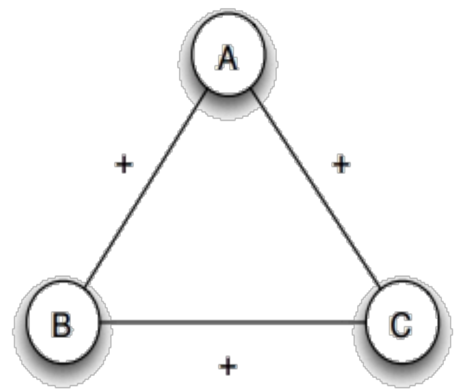
r=0



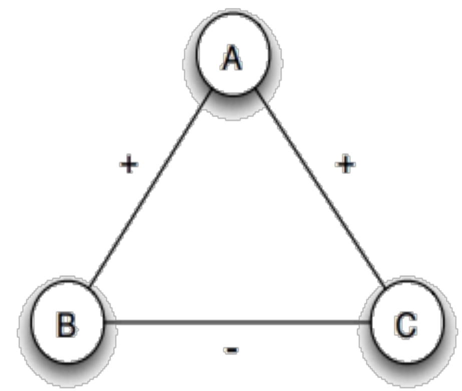
r=0.43

Structural Balance

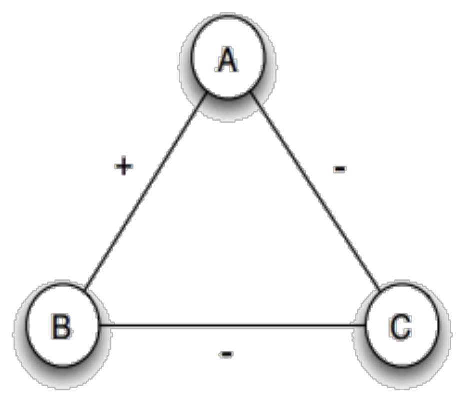
- Closed Triads
- Friendly/Hostile



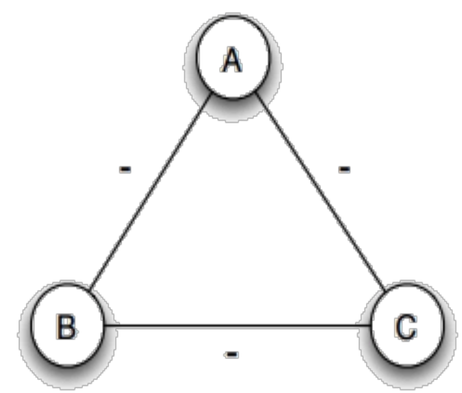
(a) *A, B, and C are mutual friends: balanced.*



(b) *A is friends with B and C, but they don't get along with each other: not balanced.*



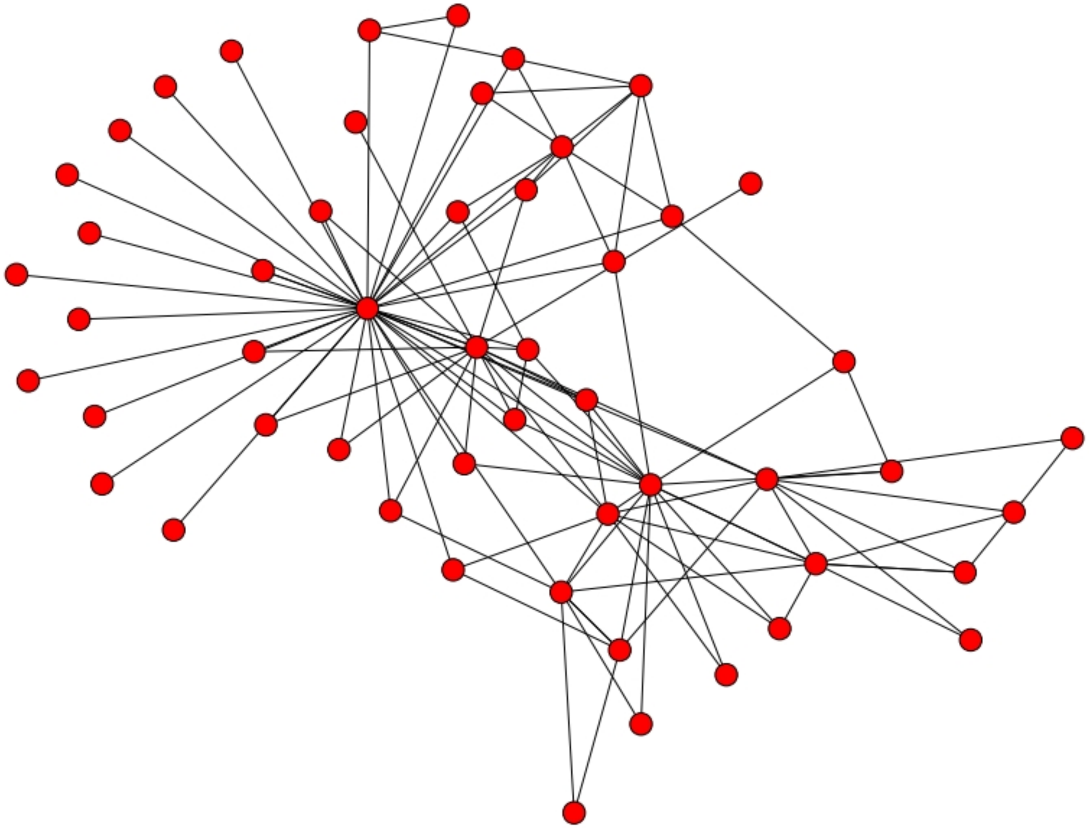
(c) *A and B are friends with C as a mutual enemy: balanced.*



(d) *A, B, and C are mutual enemies: not balanced.*

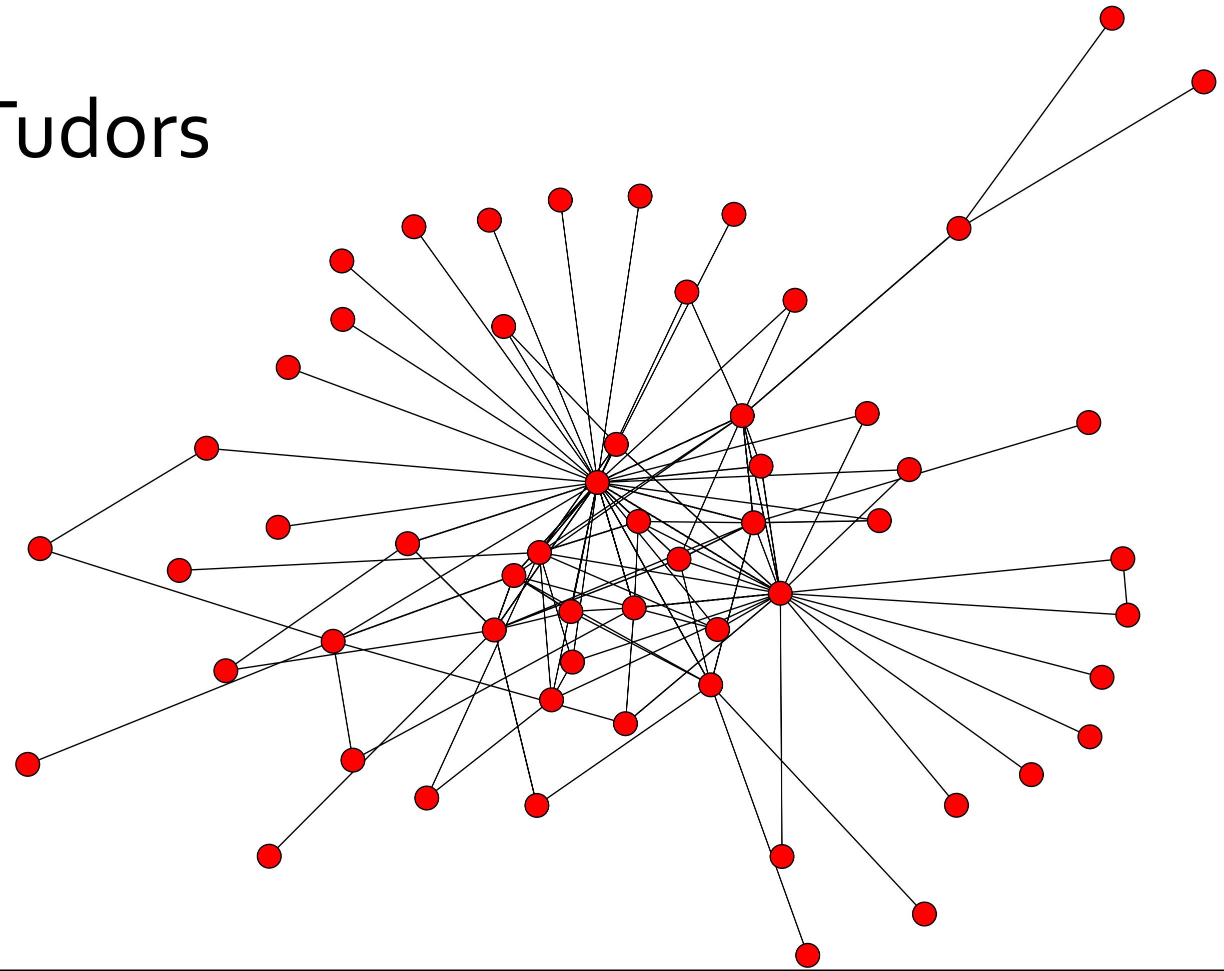
Target Attack and Random Attack

- Targeted attack
- Random attack
- Robustness
- Vulnerability



Results

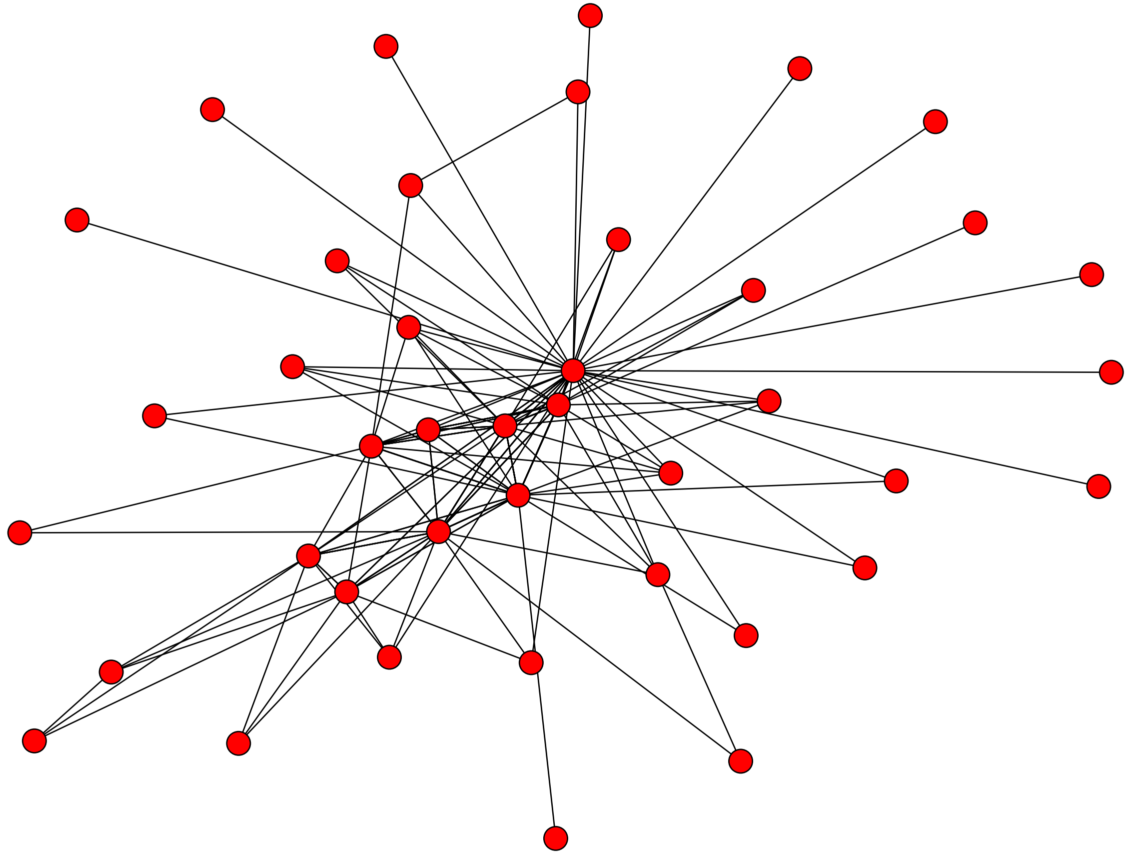
The Tudors



Network	*N*	*<k>*	*l*	*l*rand	*l*max	*C*	*C*rand	*G*c	*r*	gl
The Tudors	57	5.90	2.55	2.45	5	0.32	0.088	1.00	-0.29	0.0281

Results

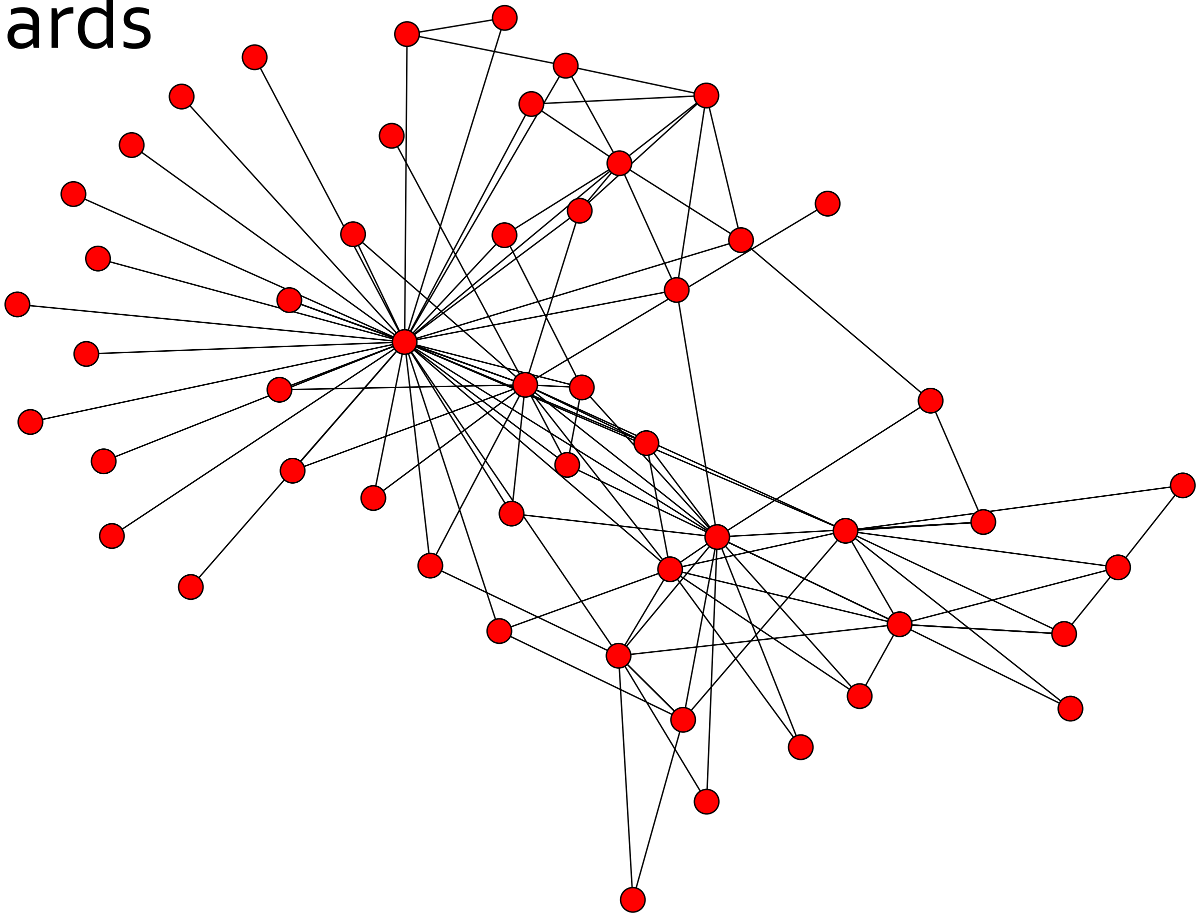
Keeping Up With The Kardashians



Network	*N*	*<k>*	*l*	*l*rand	*l*max	*C*	*C*rand	*G*c	*r*	gl
Keeping Up With the Kardashians	41	8.44	2.07	1.91	4	0.59	0.21	1.00	-0.28	0.0274

Results

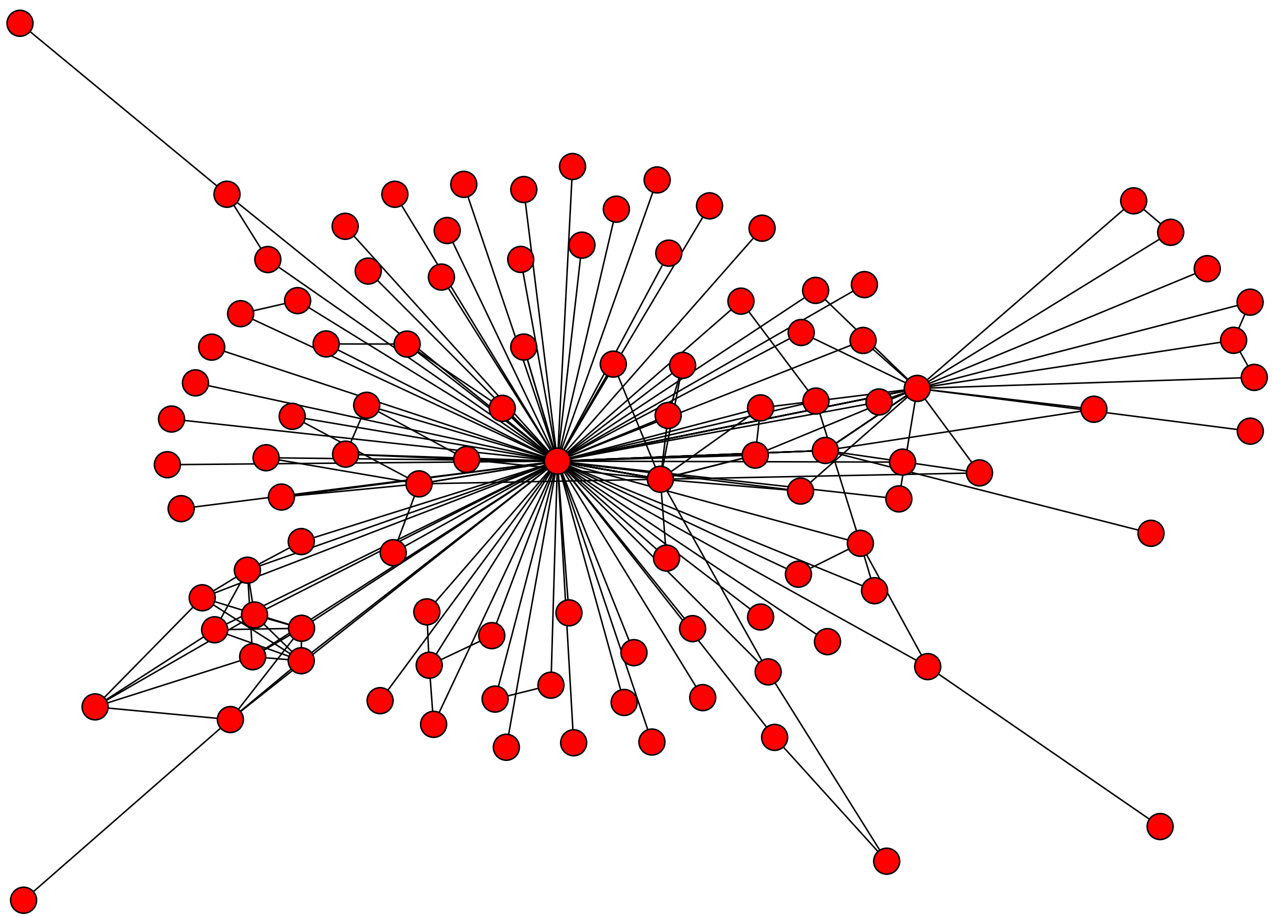
House of Cards



Network	*N*	<k>	*l*	*l*rand	*l*max	*C*	*C*rand	*G*c	*r*	gl
House of Cards	52	4.30	2.29	3.21	4	0.49	0.057	1.00	-0.43	0.0253

Results

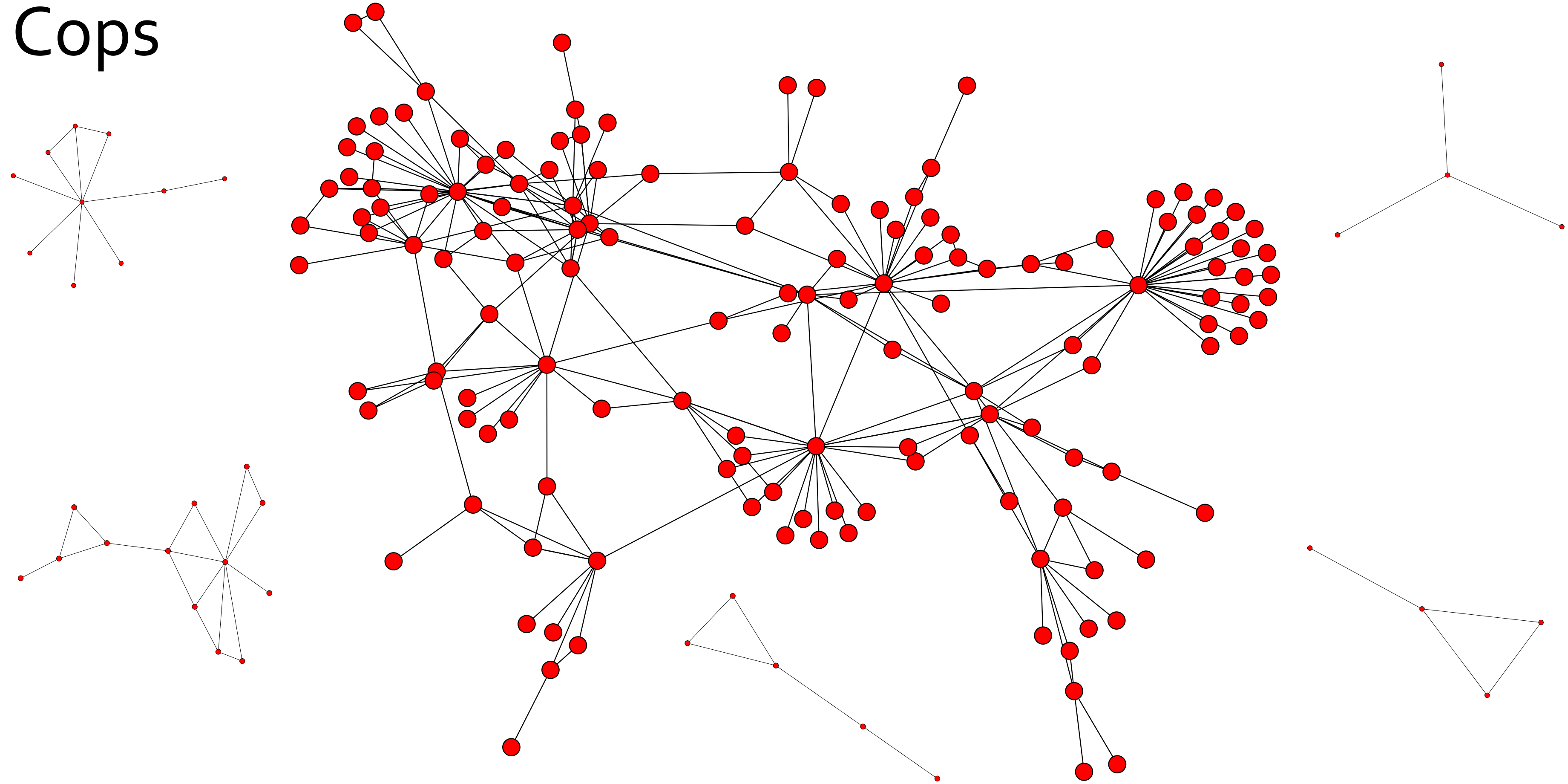
Deadbeat



Network	*N*	*<k>*	*l*	*l*rand	*l*max	*C*	*C*rand	*G*c	*r*	gl
Deadbeat	102	3.33	2.20	3.64	4	0.46	0.014	1.00	-0.41	0.012

Results

Cops



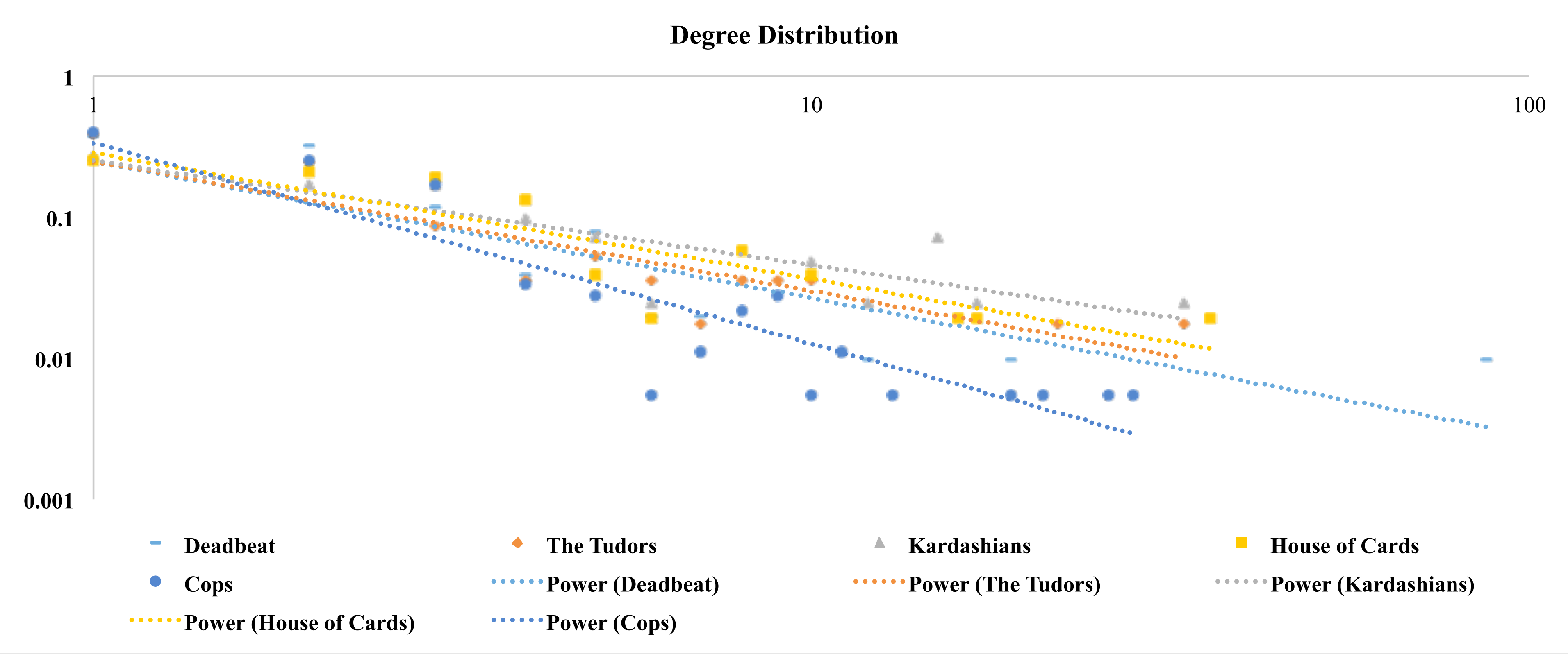
Network	*N*	*<k>*	*l*	*l*rand	*l*max	*C*	*C*rand	*G*c	*r*	gl
Cops	182	3.10	3.92	4.34	8	0.33	0.022	0.80	-0.30	0.0105

Results

Network	*N*	<*k*>	*l*	*l*rand	*l*max	*C*	*C*rand	*G*c	*r*	gl
Keeping Up With the Kardashians	41	8.44	2.07	1.91	4	0.59	0.21	1.00	-0.28	0.027
The Tudors	57	5.90	2.55	2.45	5	0.32	0.088	1.00	-0.29	0.028
House of Cards	52	4.30	2.29	3.21	4	0.49	0.057	1.00	-0.43	0.025
Cops	182	3.10	3.92	4.34	8	0.33	0.022	0.80	-0.30	0.011
Deadbeat	102	3.33	2.20	3.64	4	0.46	0.014	1.00	-0.41	0.012

- Small World
  - Want $L \approx L_R$
  - Want $C >> C_R$
- Assortativity *r*
  - [-1,1]
  - -1 is a fictitious network, 1 is a real social network

Results



Degree Distribution
1
0.1
0.01
0.001
1
10
100
Deadbeat
The Tudors
Kardashians
House of Cards
Cops
Power (Deadbeat)
Power (The Tudors)
Power (Kardashians)
Power (House of Cards)
Power (Cops)

Results

	Social	Fiction	Kardashians	The Tudors	House of Cards	Cops	Deadbeat
Small World	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hierarchy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
p(k)	Power Law	Exponential	Power Law	Power Law	Power Law	Power Law	Power Law
Scale Free	Yes	No	No	No	No	No	No
Gc	<90%	>90%	>90%	>90%	>90%	<90%	>90%
TA	Vulnerable	Robust	Robust	Robust	Robust	Robust	Vulnerable
Assortative	Yes	No	No	No	No	No	No

All five networks possess qualities of both social and fictitious networks. Of the five, Cops was the show that most closely resembled a real social network.

Columns 1 and 2 taken from [1].

Potential Application

- In the context of television, one can determine whether “historical” shows are in fact representative of real life networks.
- One of the many applications of applied network theory is uprooting corrupted law enforcement based on the network of their arrest patterns.
- Additionally, this type of network theory could be used to trace lobbyist money to certain pieces of legislation and the congressmen who sponsor them.

References

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Questions?