Addressing Threats and Vulnerabilities in Critical Interconnected Systems

Jon Kleinberg

Cornell University


RD
Glenmont
Wheaton
Forest Glen
Silver Spring
Takoma
Shady Grove
Rockville
Twinbrook
White Flint
Grosvenor-Strathmore
Medical Center
Bethesda
Friendship Heights
Tenleytown-AU
Van Ness-UDC
Cleveland Park
Woodley Park
Zoo/Adams Morgan
Dupont Circle
Farragut North
Fort Totten
Brookland-CUA
Rhode Island Ave
Brentwood
NoMa-Gallaudet U
Union Station
GR
Greenbelt
College Park-U of Md
Prince George's Plaza
West Hyattsville
Georgia Ave-Petworth
Columbia Heights
U St
African-Amer Civil War Mem'l/Cardozo
Shaw-Howard U
Mt Vernon Sq
7th St-Convention Center
Gallery Place
Chinatown
McPherson Sq
Judiciary Sq
SV
Wiehle-Reston East
Spring Hill
Greensboro
Tysons Corner
McLean
OR
Vienna
Fairfax-GMU
Dunn Loring
Merrifield
West Falls Church
VT/UVA
East Falls Church
Ballston-MU
Virginia Sq-GMU
Clarendon
Court House
Rosslyn
Foggy Bottom-GWU
Kennedy Center
Farragut West
National Mall
Metro Center
Federal Triangle
Smithsonian
National Mall
Archives
Navy Memorial-Penn Quarter
L'Enfant Plaza
Arlington Cemetery
Pentagon
Pentagon City
Crystal City
Potomac River
Ronald Reagan Washington National Airport
Braddock Rd
King St-Old Town
Eisenhower Ave
Huntington
YL
BL
Franconia-Springfield
Van Dorn St
Alexandria
Fairfax Co
Capital Beltway
Waterfront
Navy Yard-Ballpark
Anacostia River
Anacostia
Congress Heights
Southern Ave
Naylor Rd
Suitland
Branch Ave
Federal Center SW
Capitol South
Eastern Market
Potomac Ave
Stadium-Armory
Benning Rd
Capitol Heights
Addison Rd
Seat Pleasant
Morgan Blvd
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Landover
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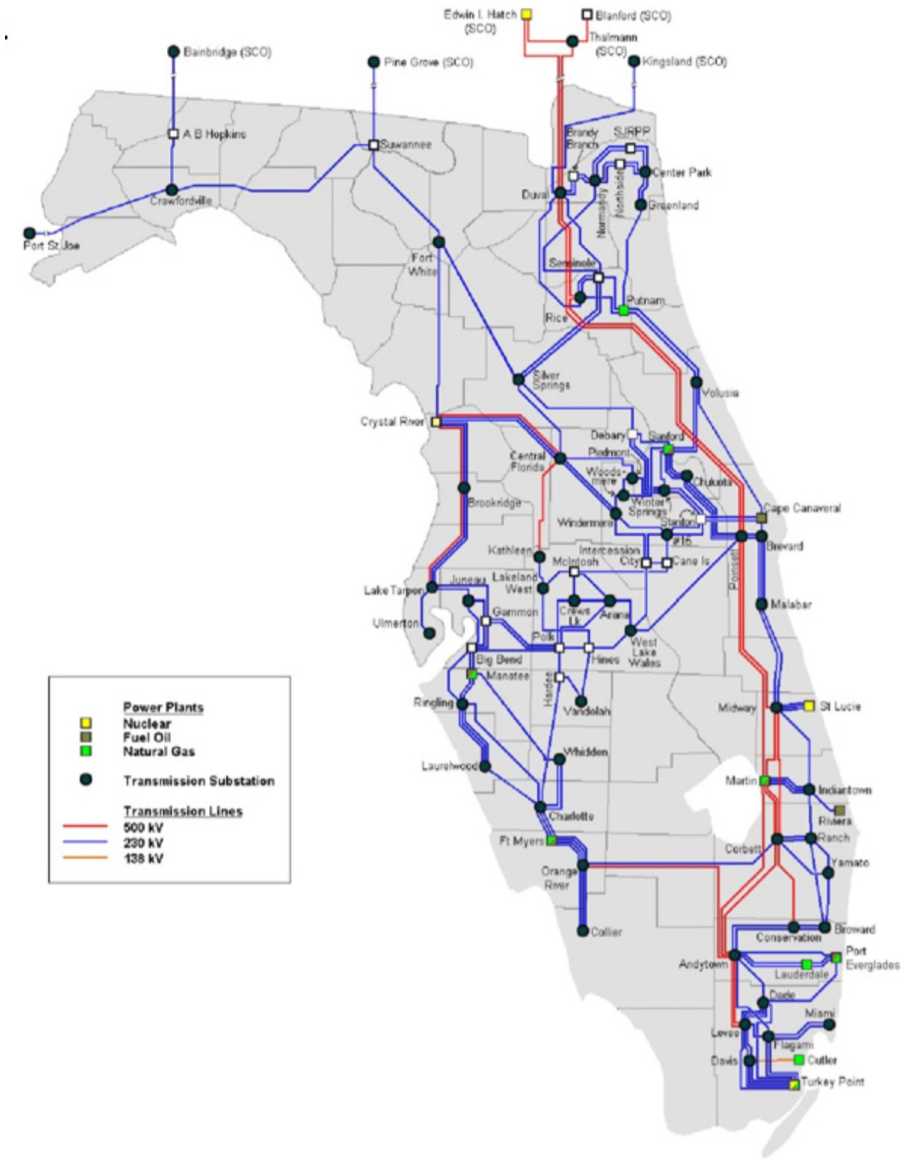
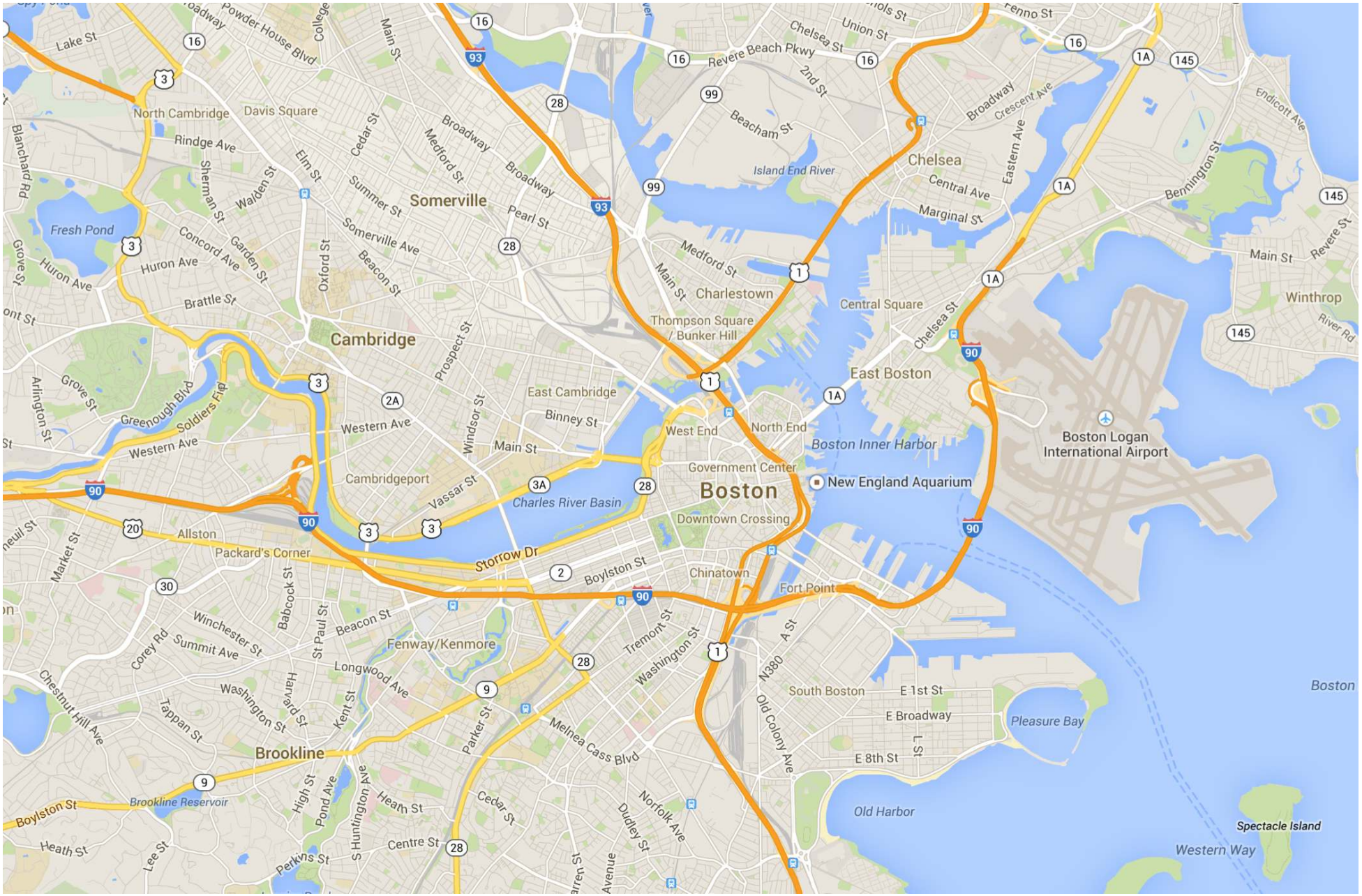
Map is not to scale

Power Grid

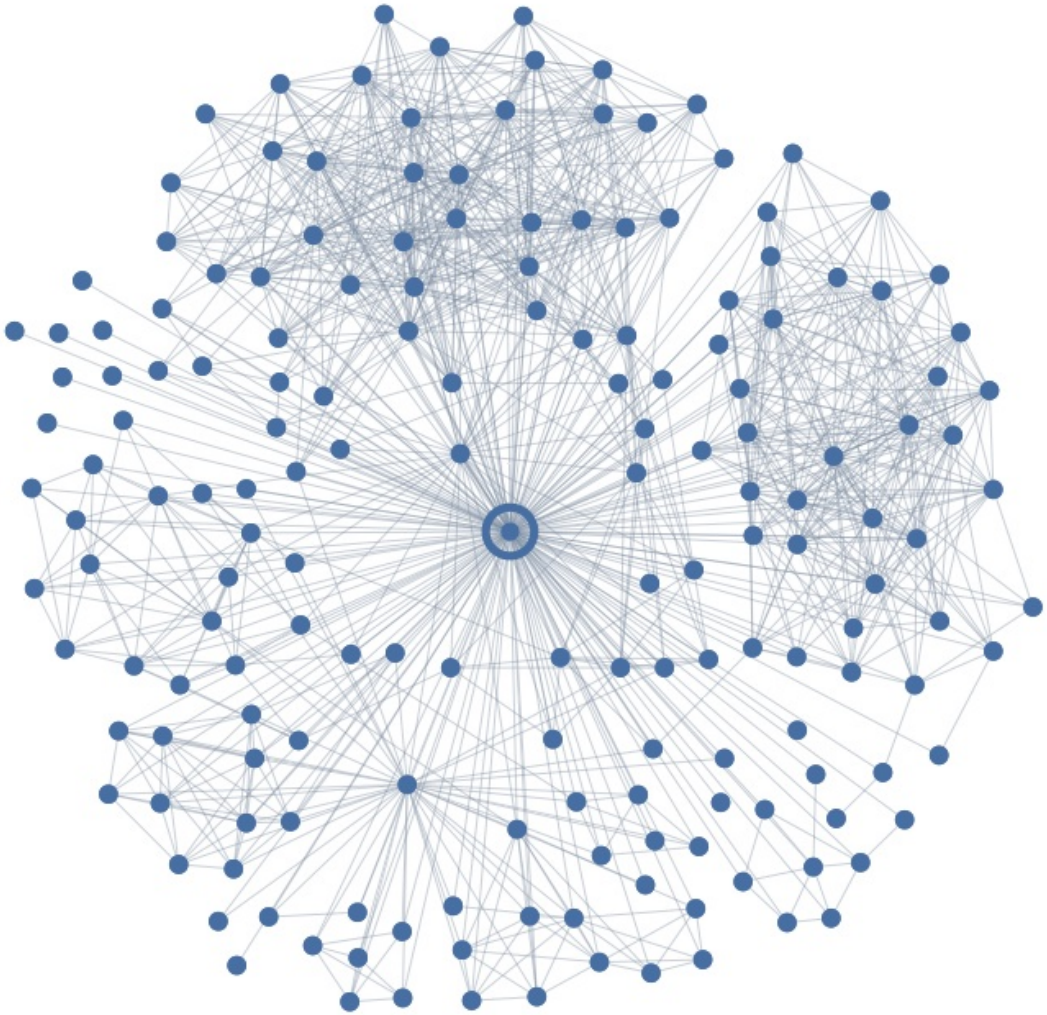


Florida Power Grid *(Dale et al, Xu et al)*



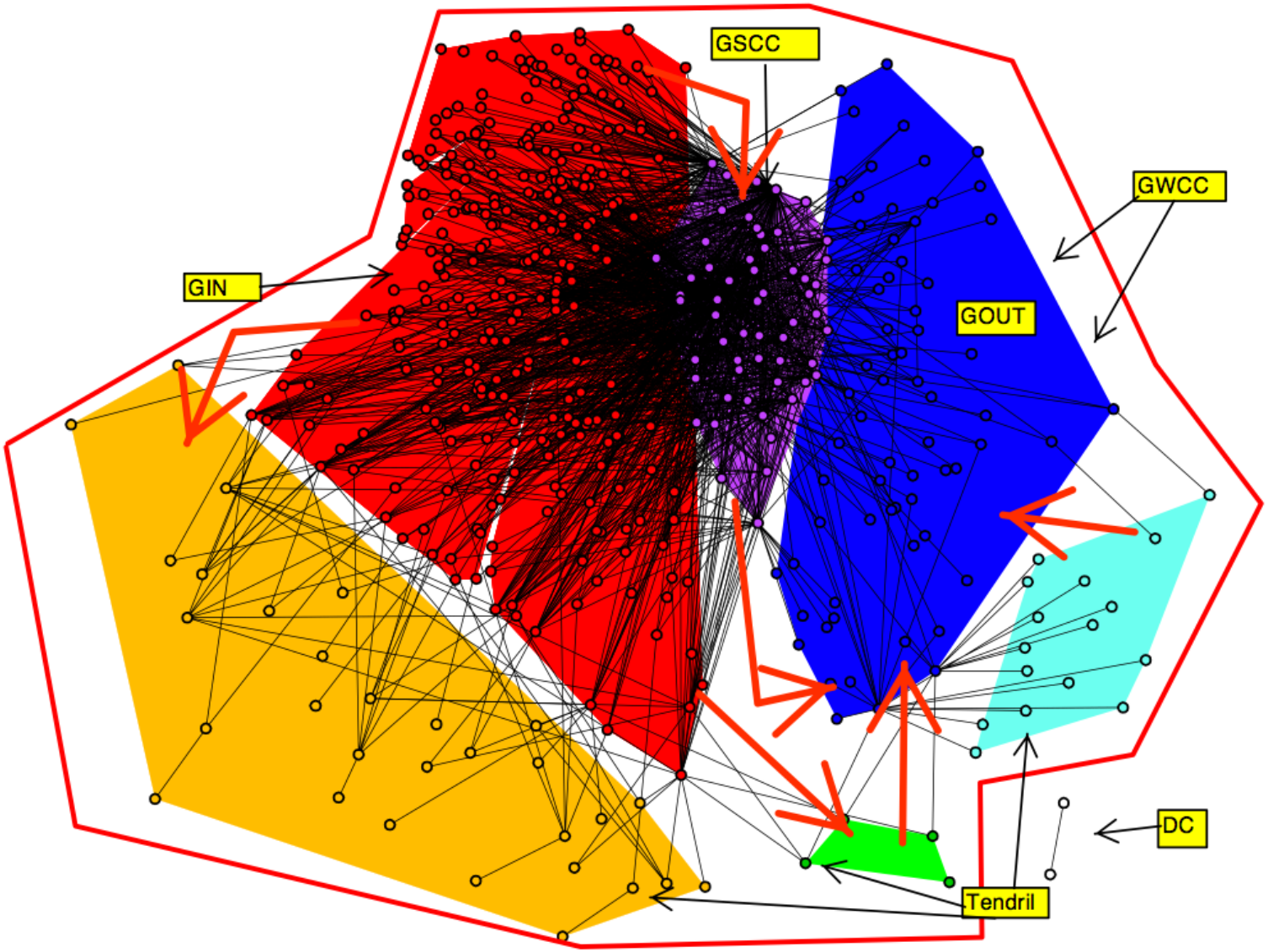
Boston, Google Maps

Social Network



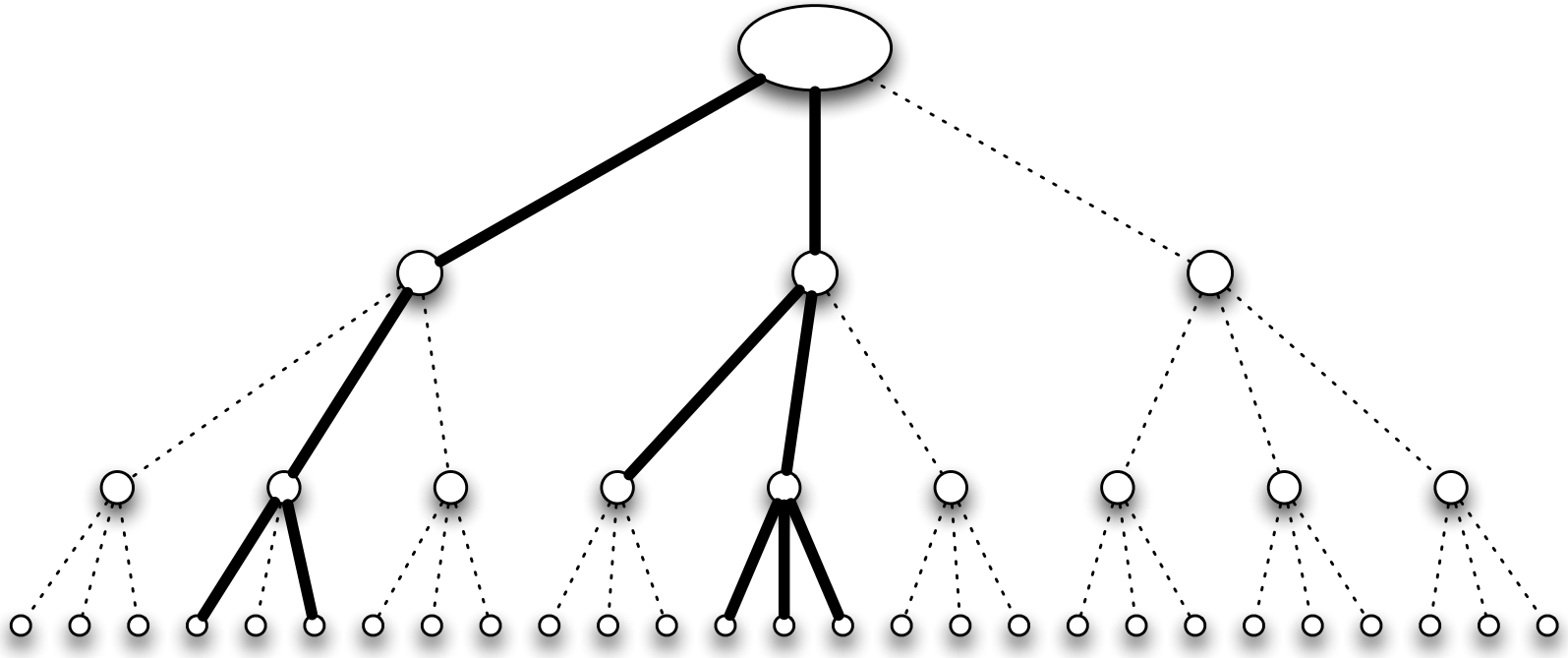
Facebook user's friends *(Marlow et al)*

Financial Network



Loans among banks *(Bech and Atalay)*

First Mechanism: Transmission



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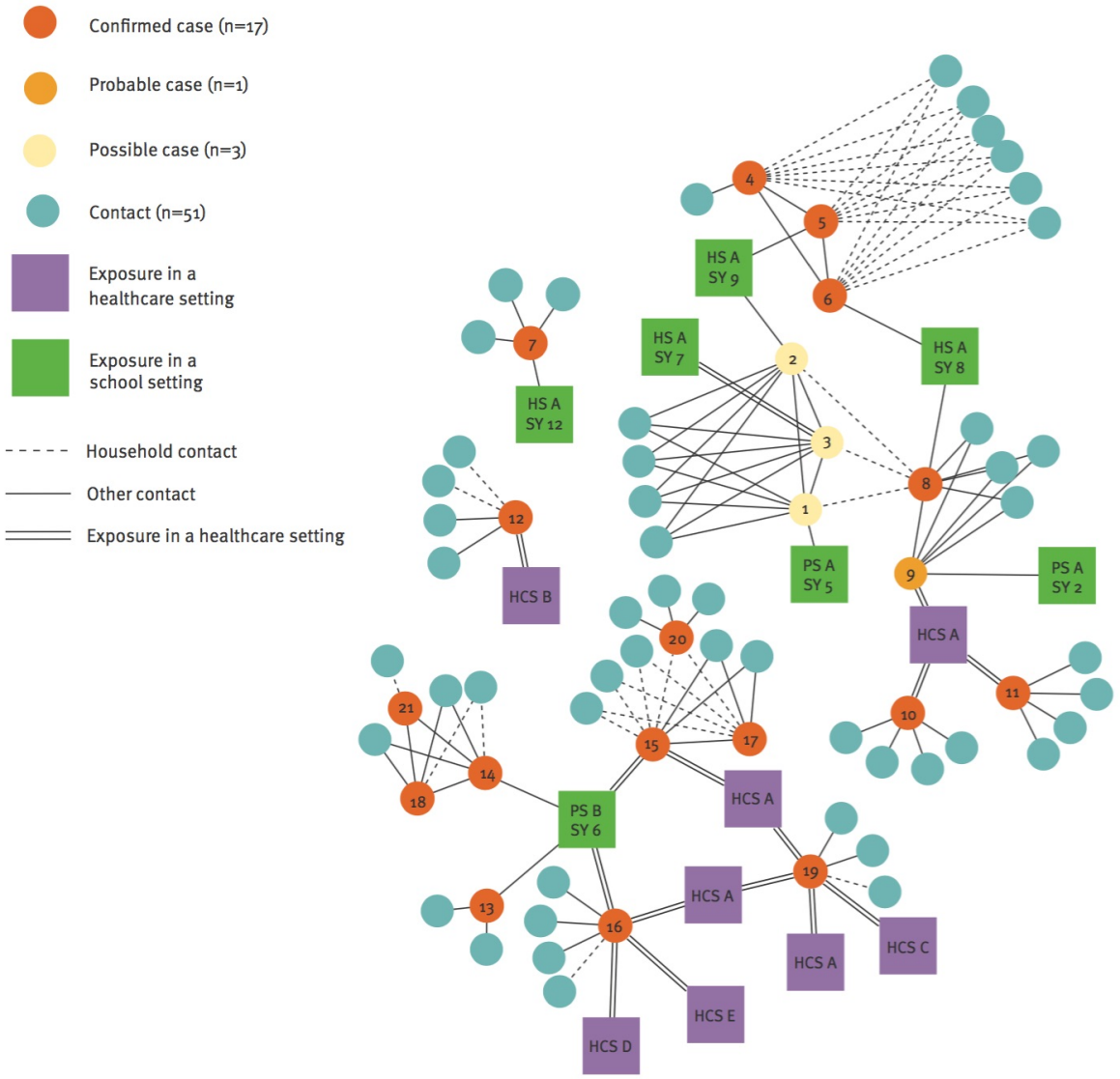
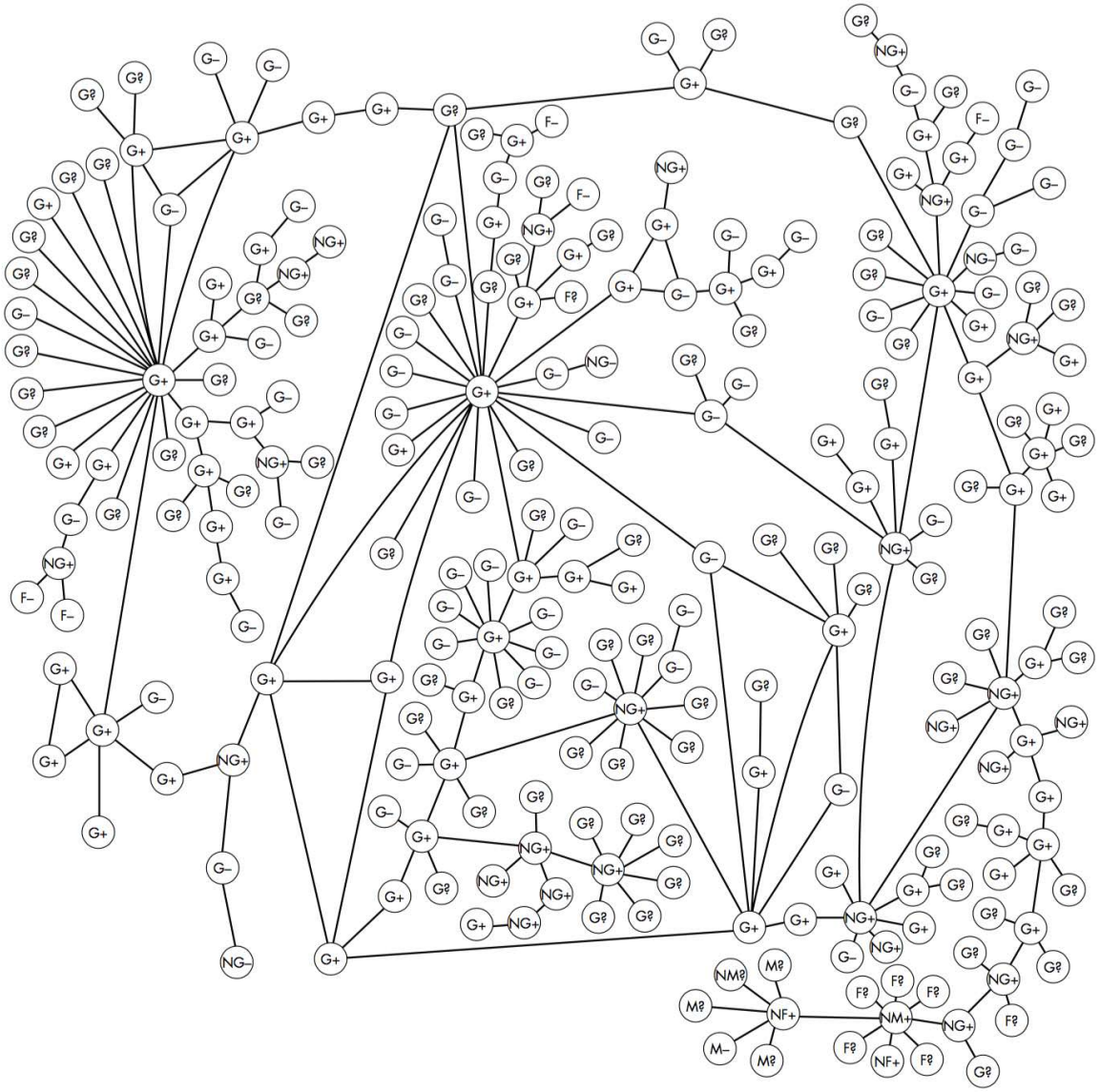


Measles transmission *(Currie et al)*

First Mechanism: Transmission



HIV transmission *(Potterat et al)*

COMPUTING

The wireless epidemic

Jon Kleinberg

As wireless communication technologies spread, so the potential for viruses to exploit them grows. Biological models of virus transmission will assume new relevance for assessing the emerging threat.

Ever since the first appearance of computer viruses on the digital landscape, our understanding of them has drawn on parallels with biology. Analogues of mutation, phylogenetic reconstruction and computational 'immune systems'[1] have all been investigated. But the central analogy has come from the use of epidemiological models to track how a computer virus spreads. A crucial ingredient in these models is a description of the contact network through which the epidemic propagates, where the links represent who has the potential to infect whom. Traditionally, computer viruses have propagated on networks that bear little resemblance to the networks of physical contact through which their biological counterparts spread. But a growing body of research[2–8] shows that the increasing use of short-range wireless communication networks might cause the two models to converge.

Accurately modelling the network through which a disease epidemic spreads is difficult in almost any setting. Diseases in plant populations, or animal diseases such as rabies, are heavily constrained by geographical proximity and the relatively fixed physical locations of the infected individuals[9]. Models of these diseases have been extended using detailed data on patterns of travel within cities[10,11] and by air worldwide[12] in attempts to analyse disease outbreaks in human populations.

Epidemics on the Internet are even more diverse. At the most general level, there is a distinction between computer viruses, which 'piggyback' on data exchanged between users, and computer worms, which more actively direct their own transmission through a network[13]. The networks on which these types of malicious code spread are based on patterns of file transfer or e-mail communication, or even on structures that evolve implicitly as a computer worm scans the Internet for targets.

Mathematical models of these different net-

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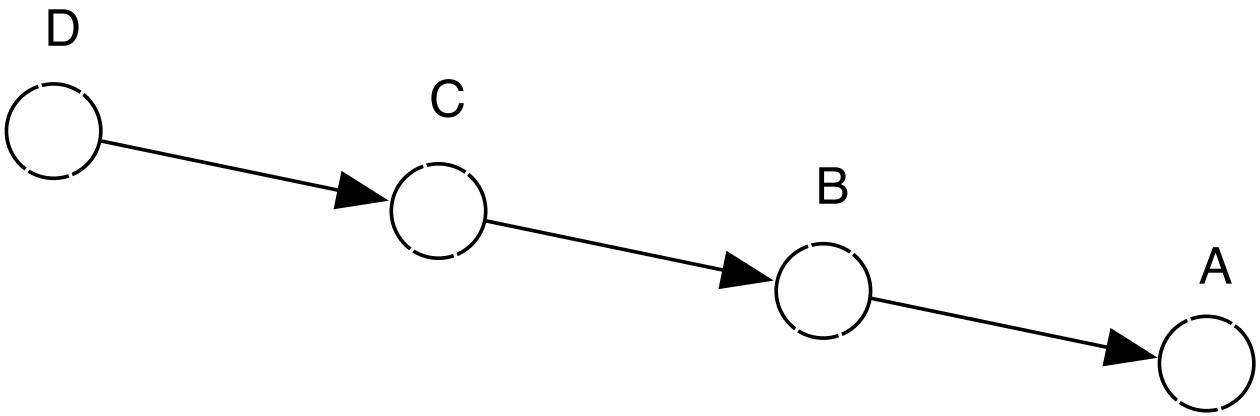
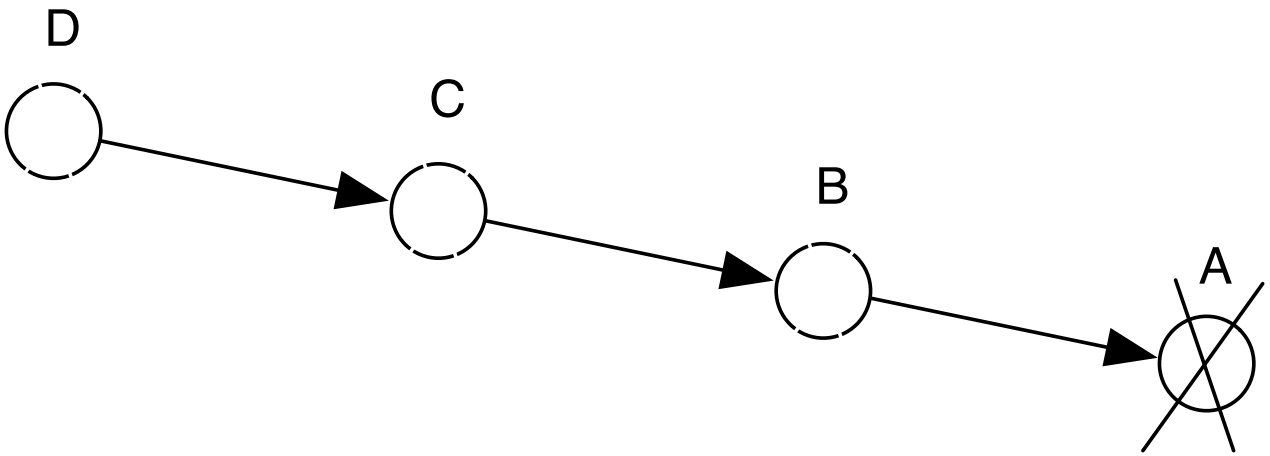
Second Mechanism: Unraveling



If node B depends on node A, and node A fails, then B may fail.

Second Mechanism: Unraveling



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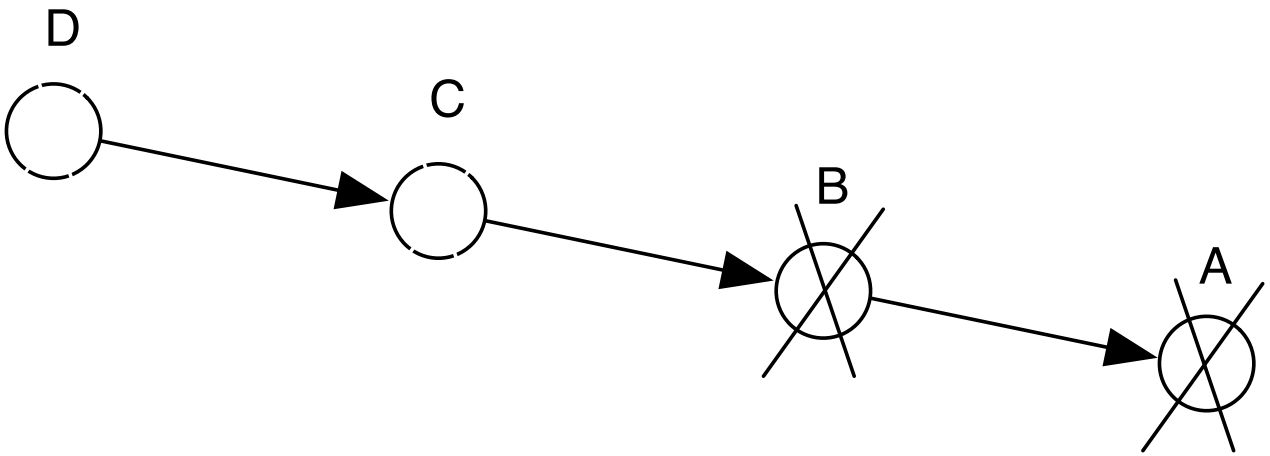

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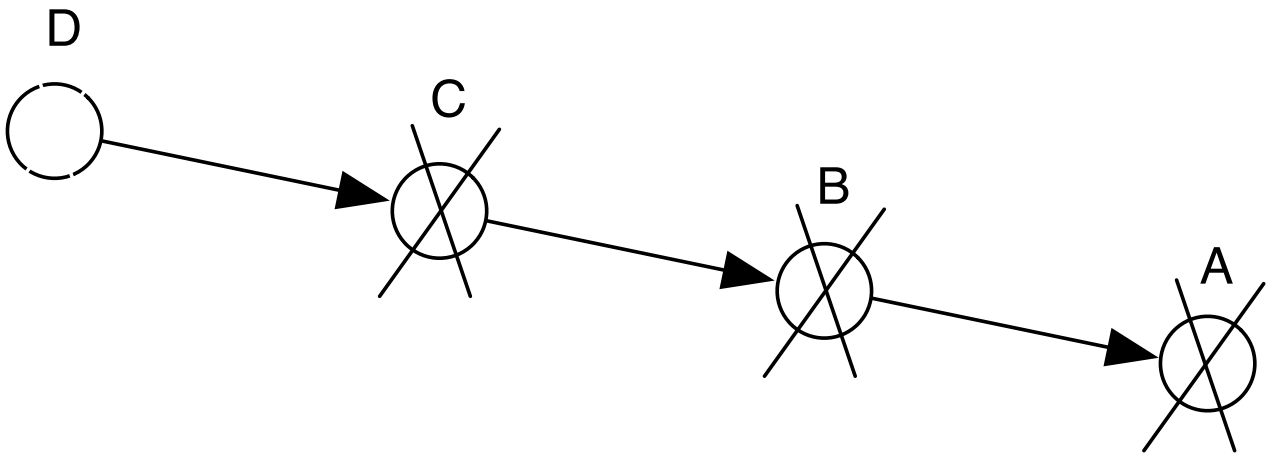

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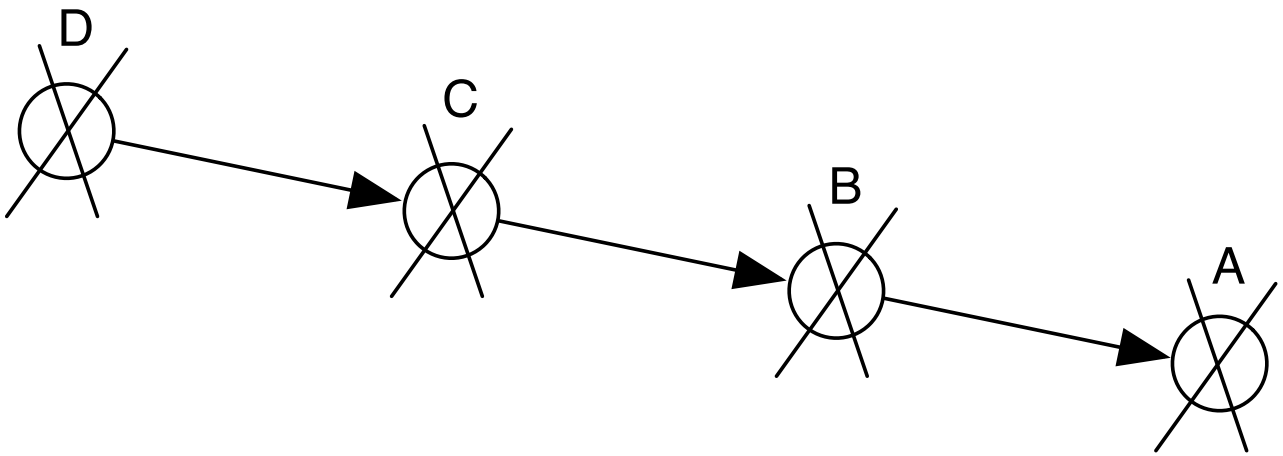

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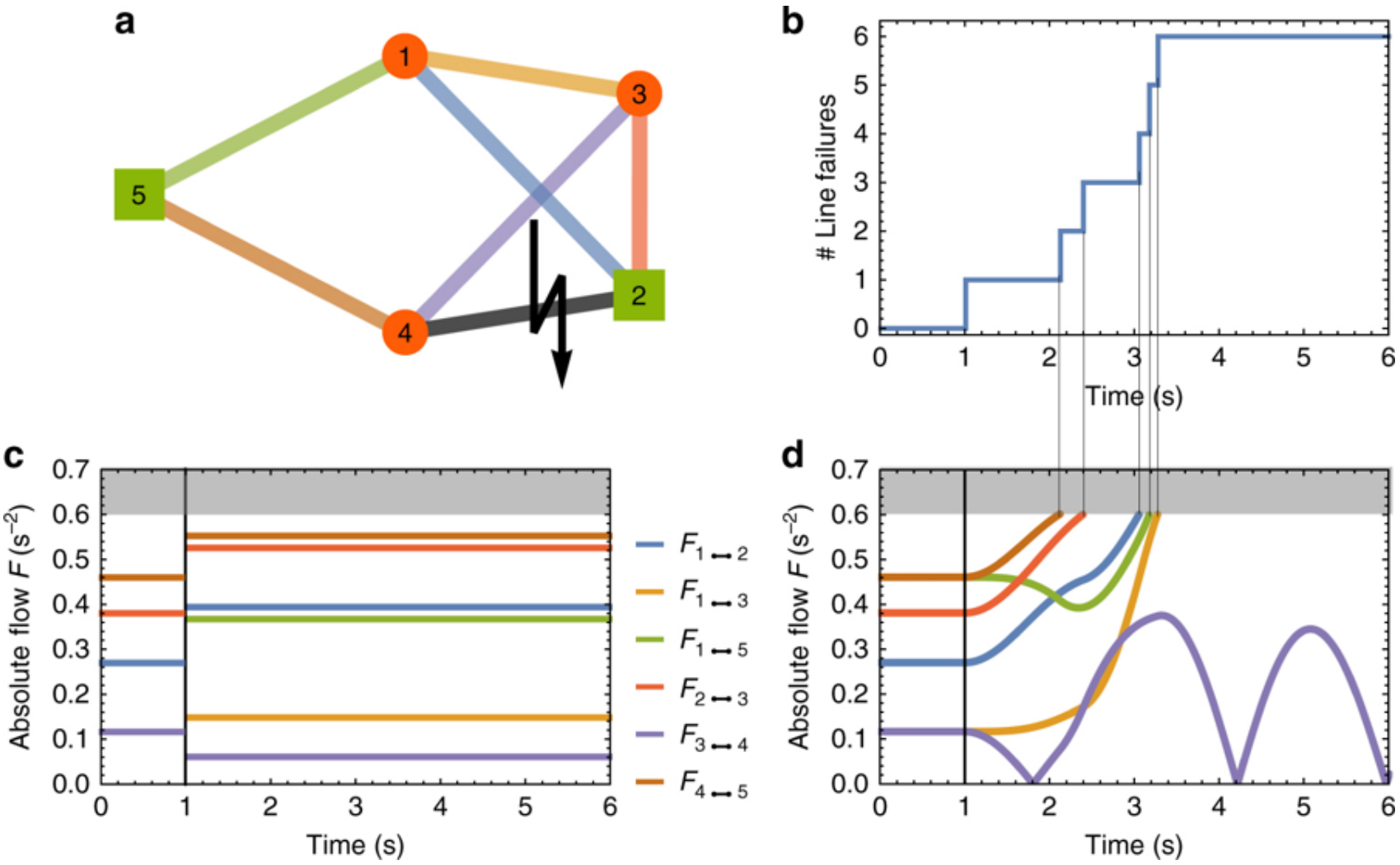
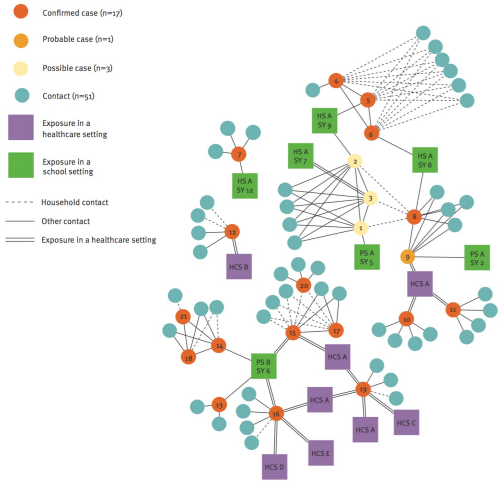
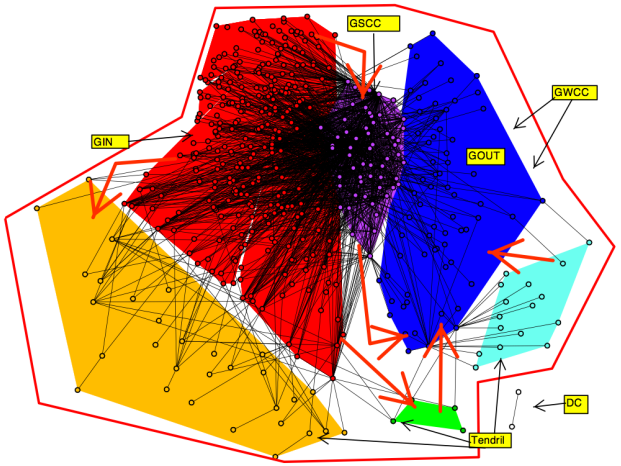
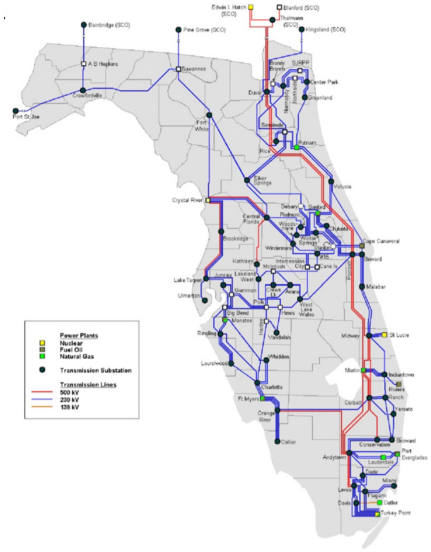


Power grid *(Schafer et al)*

Themes for Network Cascades







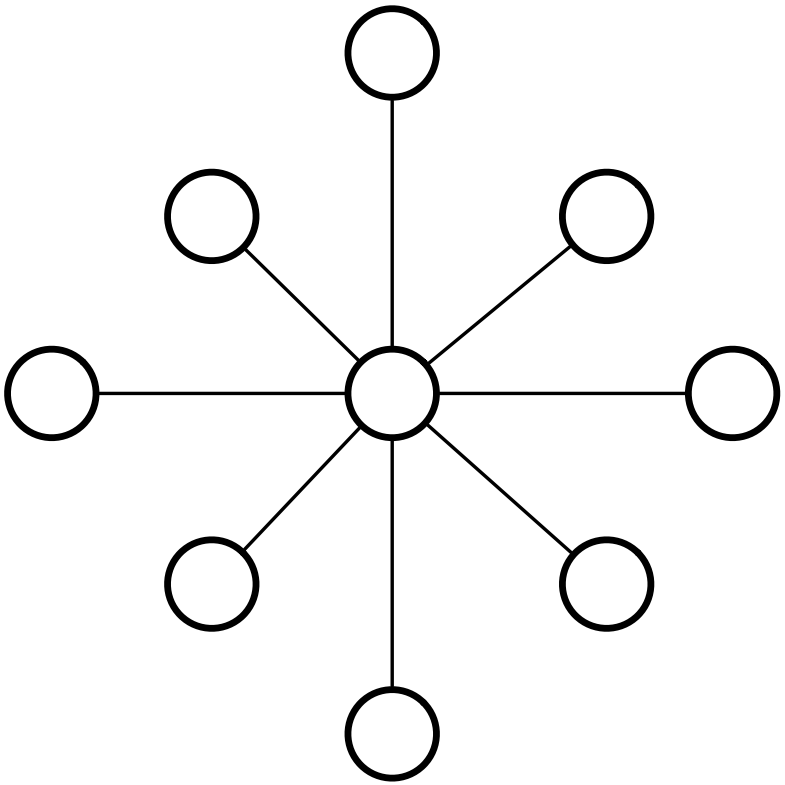
(1) Critical nodes

(2) Cascading behavior as a design goal

(3) Predictability

(4) Early-warning signals

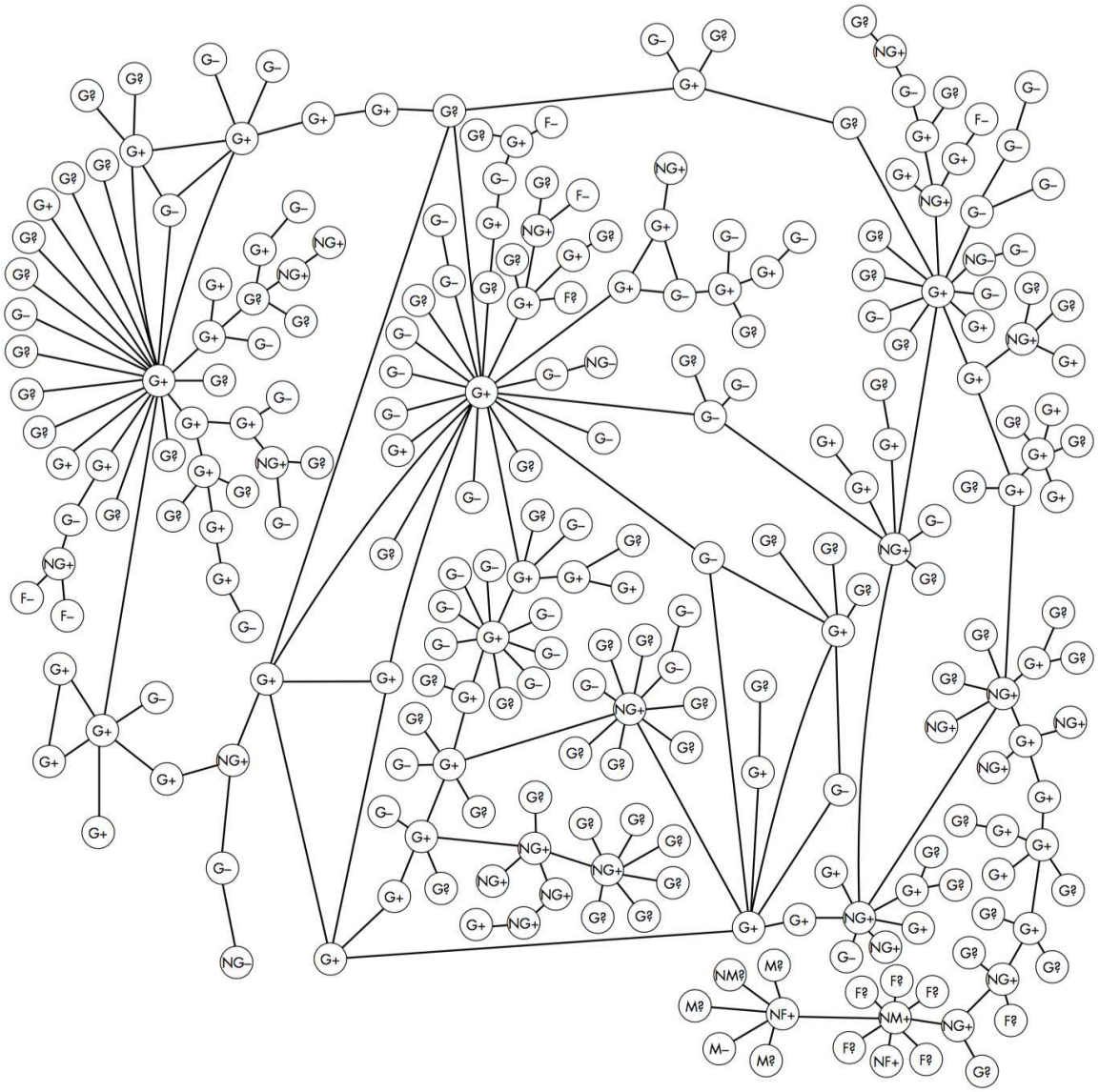
Critical Nodes



"Single point of failure"

- Can be either a good or a bad thing, depending on the objective.

Critical Nodes



Critical Nodes

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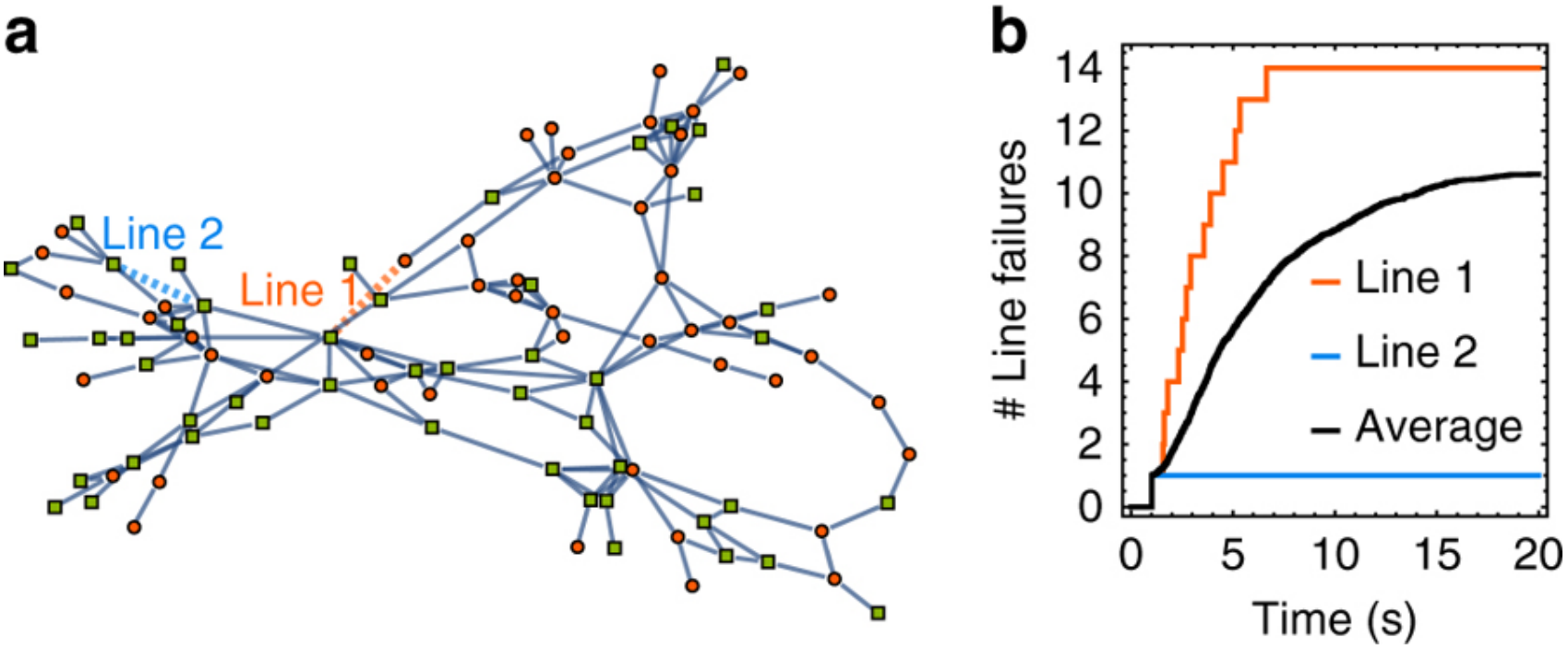
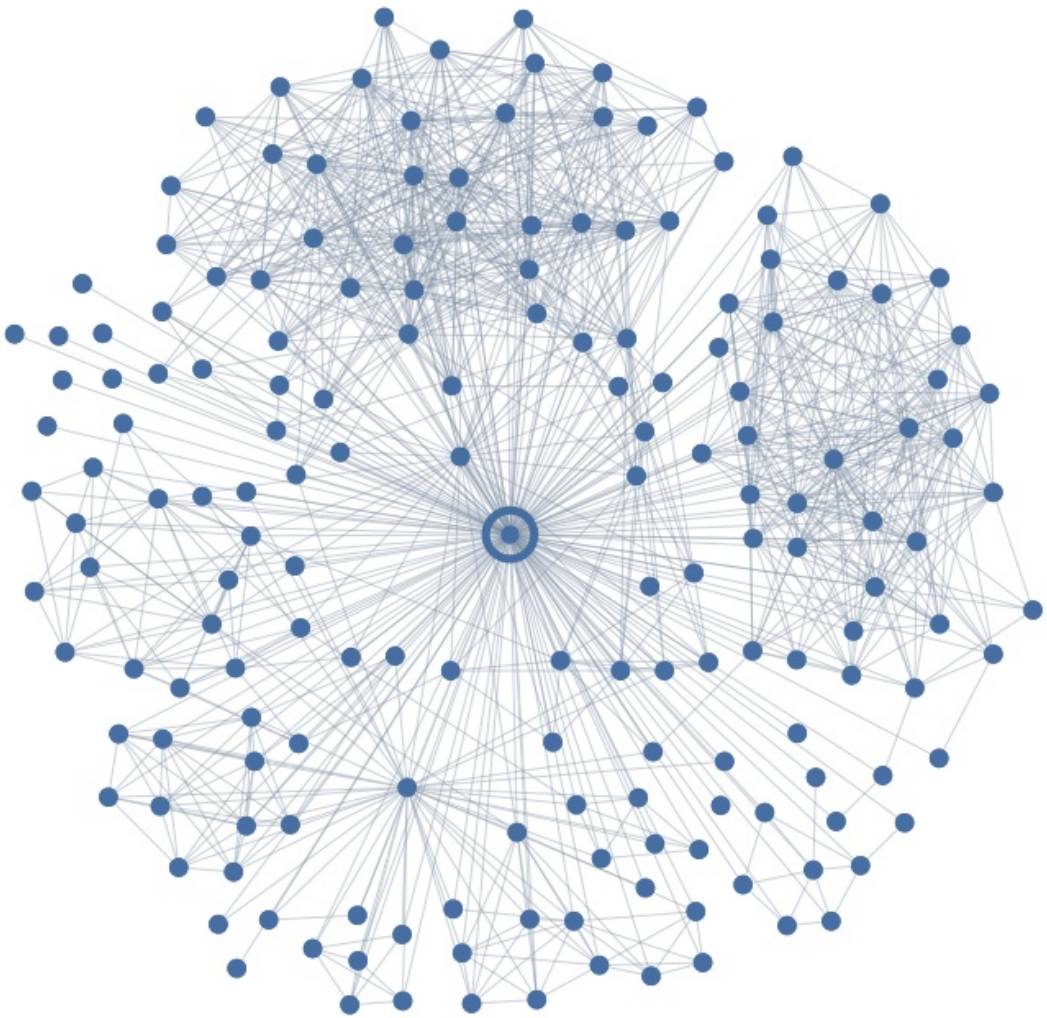
Critical Links for Unraveling



Power grid *(Schafer et al)*

Cascading Behavior as a Design Goal



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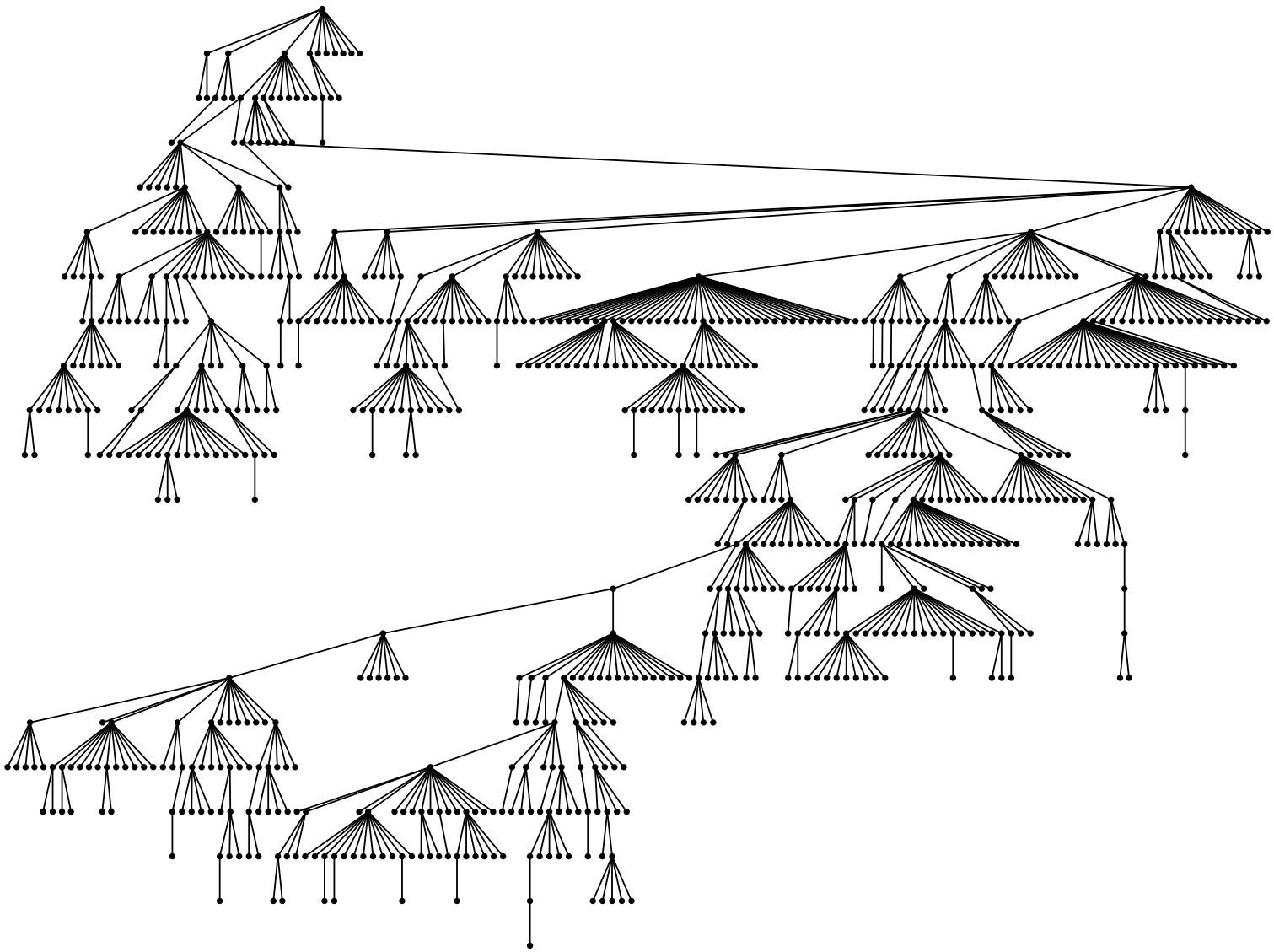
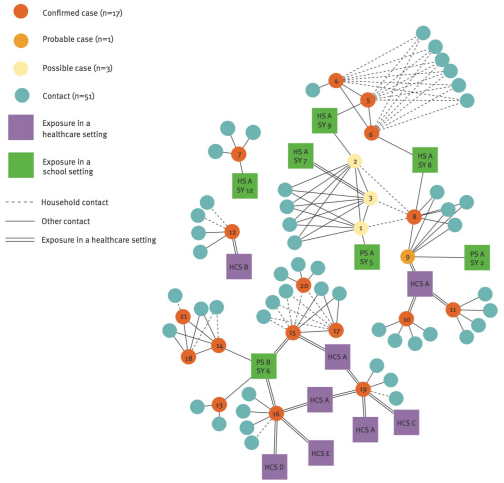
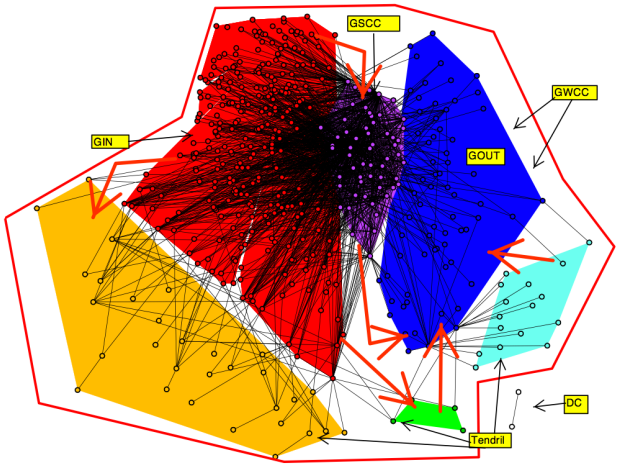
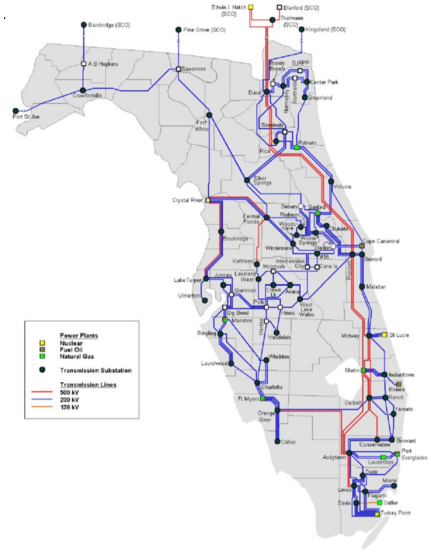


LinkedIn invitations *(Anderson et al)*

Themes for Network Cascades







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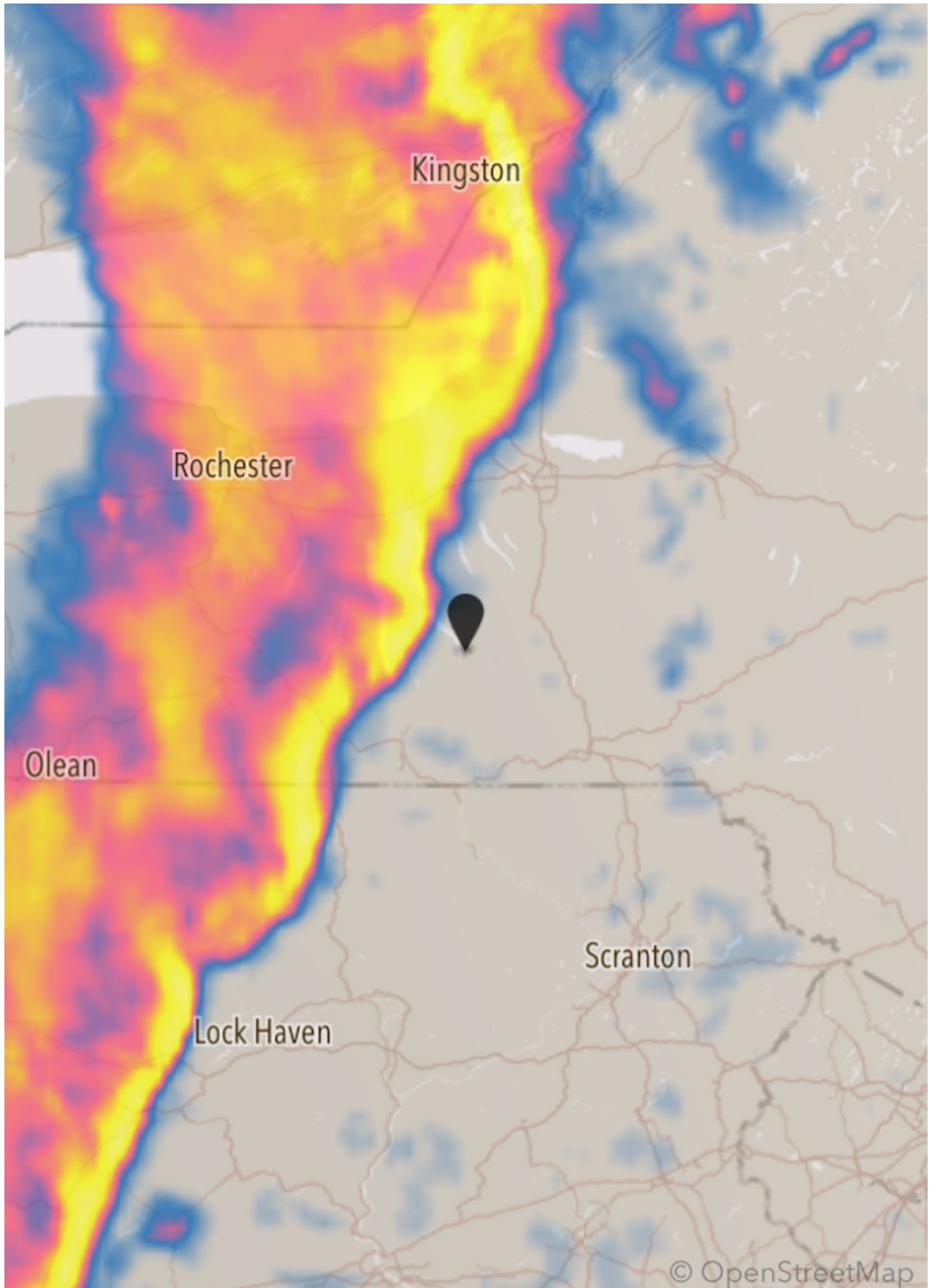
(4) Early-warning signals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Rochester
Olean
Scranton
Lock Haven
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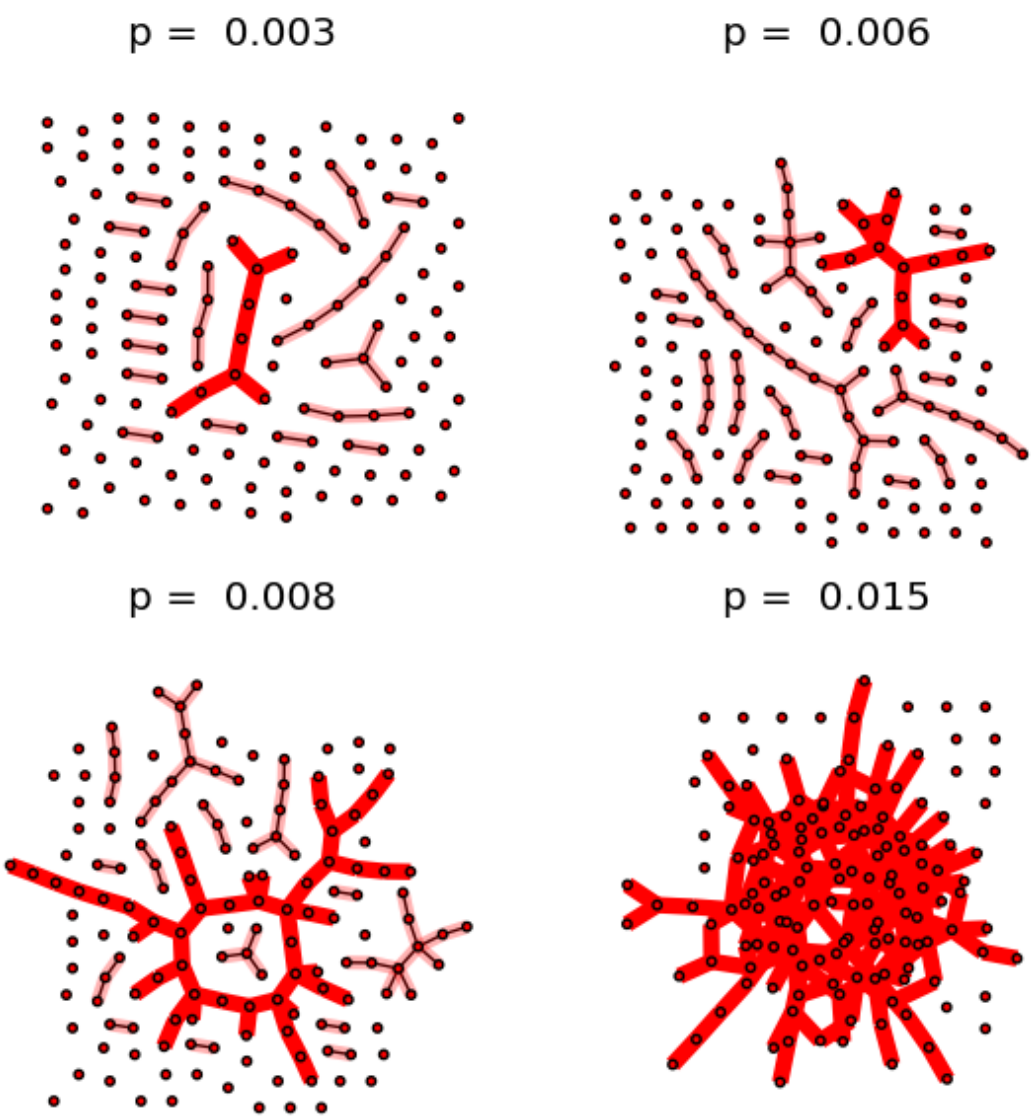
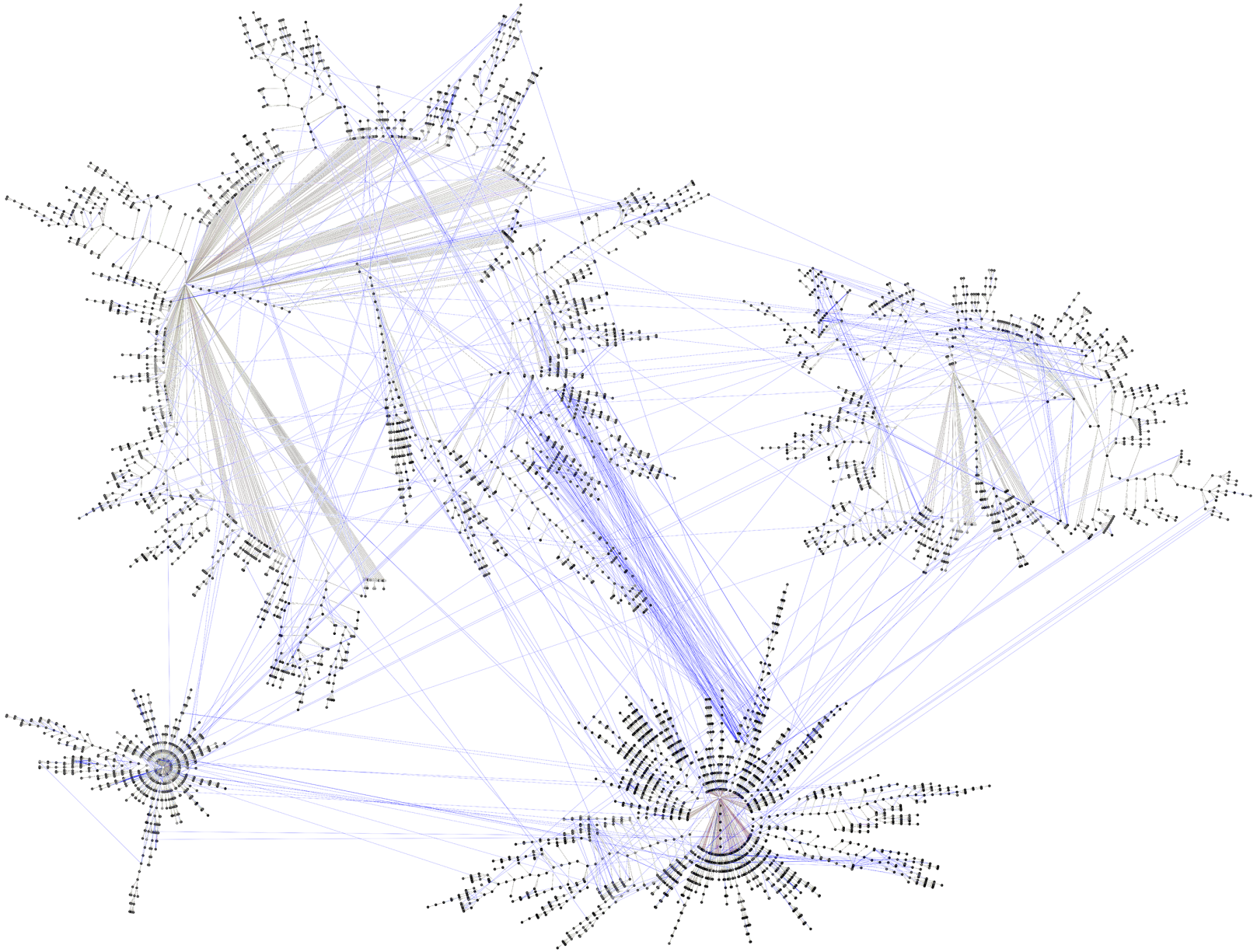
Sudden Onset



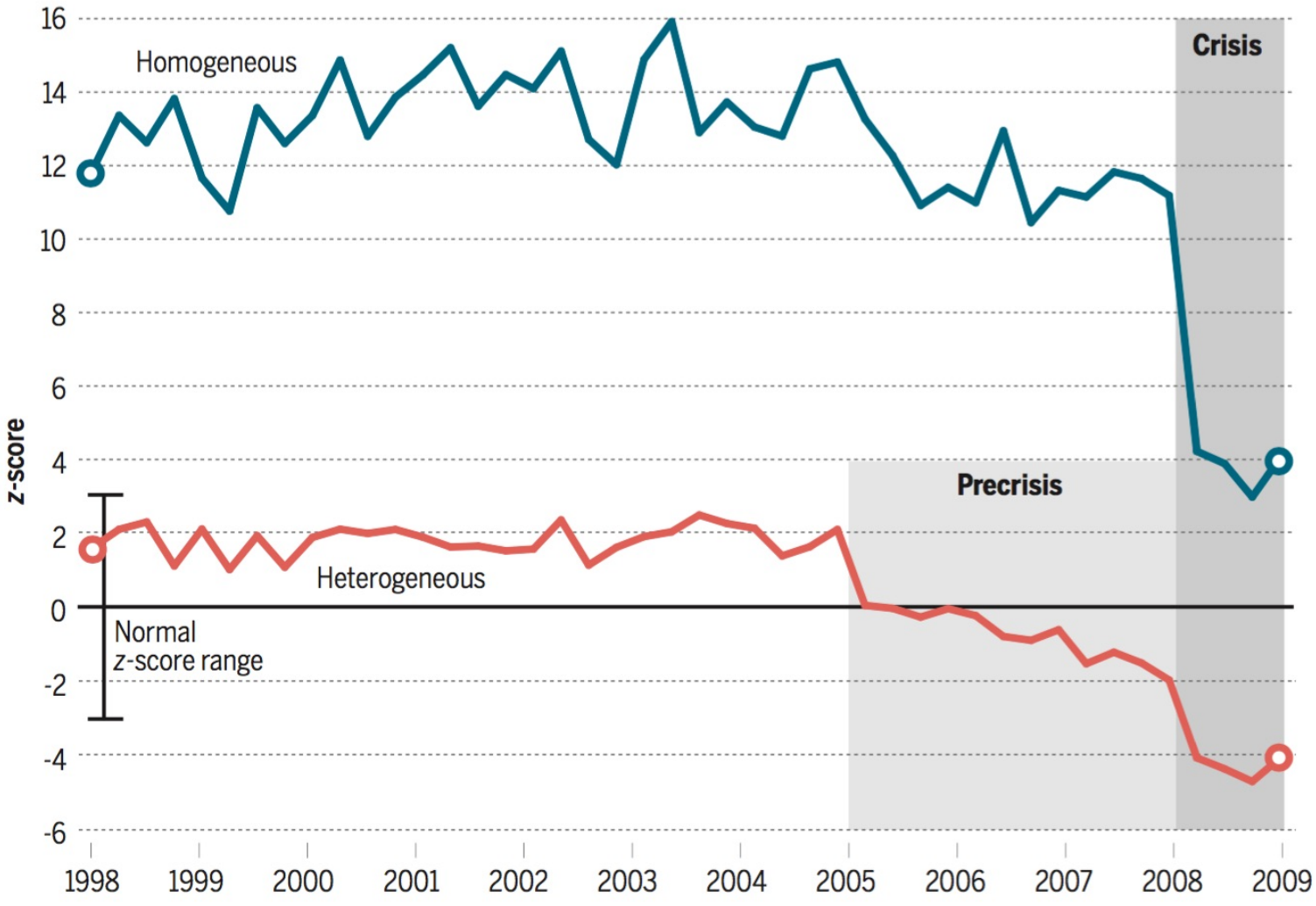
(Networkx, networkx.github.io)

Early-Warning Signals



Facebook reshares *(Cheng et al)*

Early-Warning Signals



Signals in financial network *(Battiston et al, Squartini et al)*

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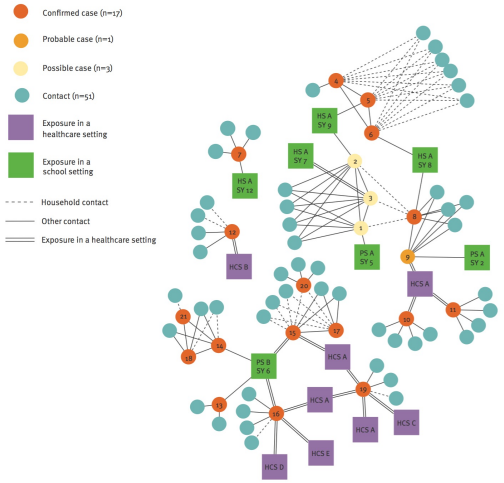

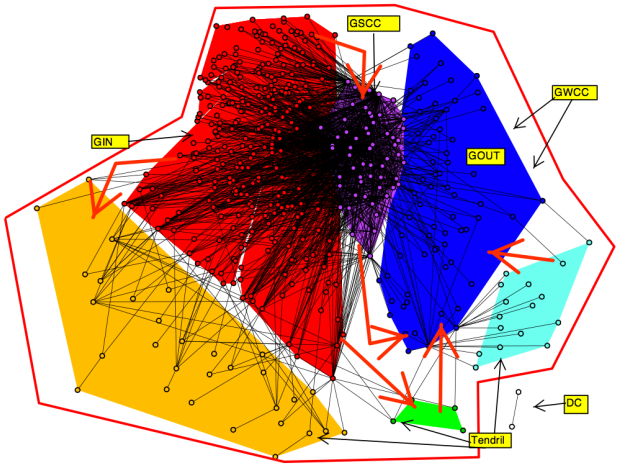

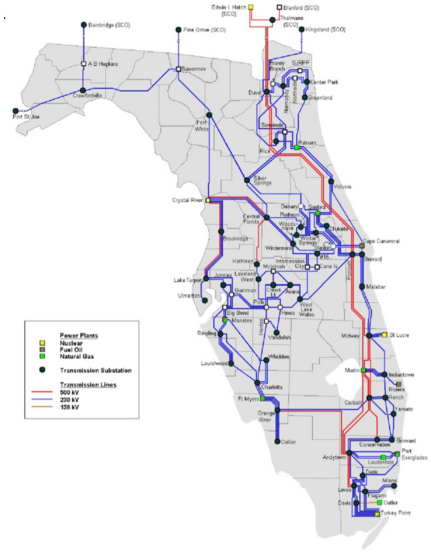

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