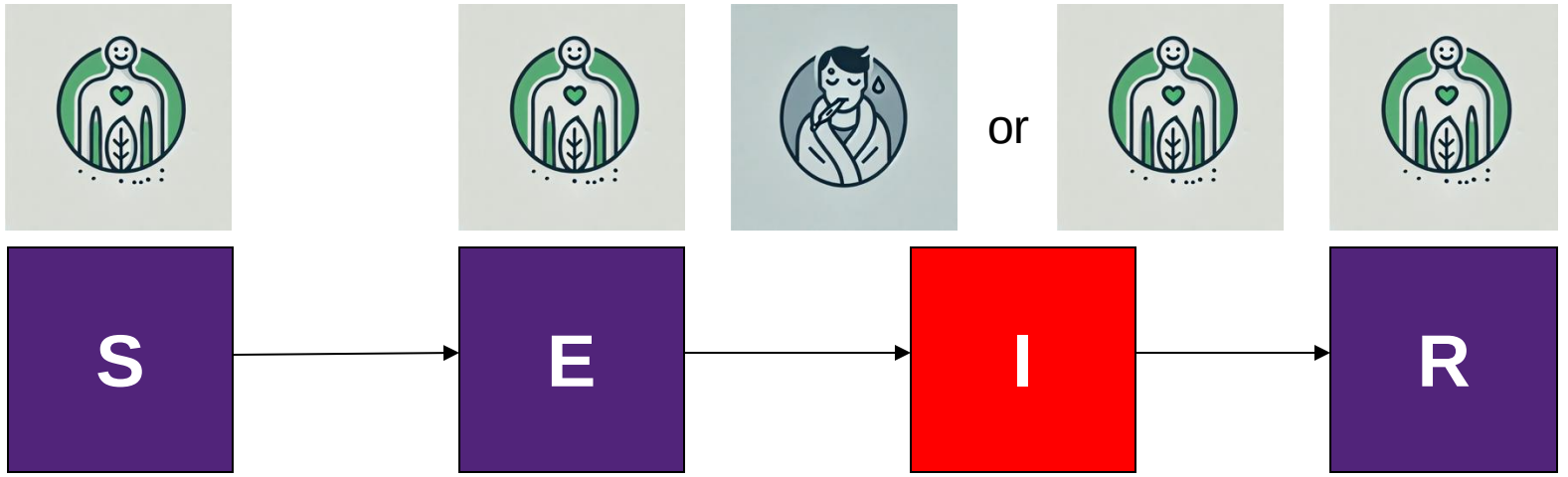
THE UNIVERSITY OF QUEENSLAND
AUSTRALIA
CREATE CHANGE

Principios y aplicaciones del análisis de redes en la vigilancia y epidemiología de enfermedades infecciosas: exemplos con influenza A en el Sudeste Asiático y China

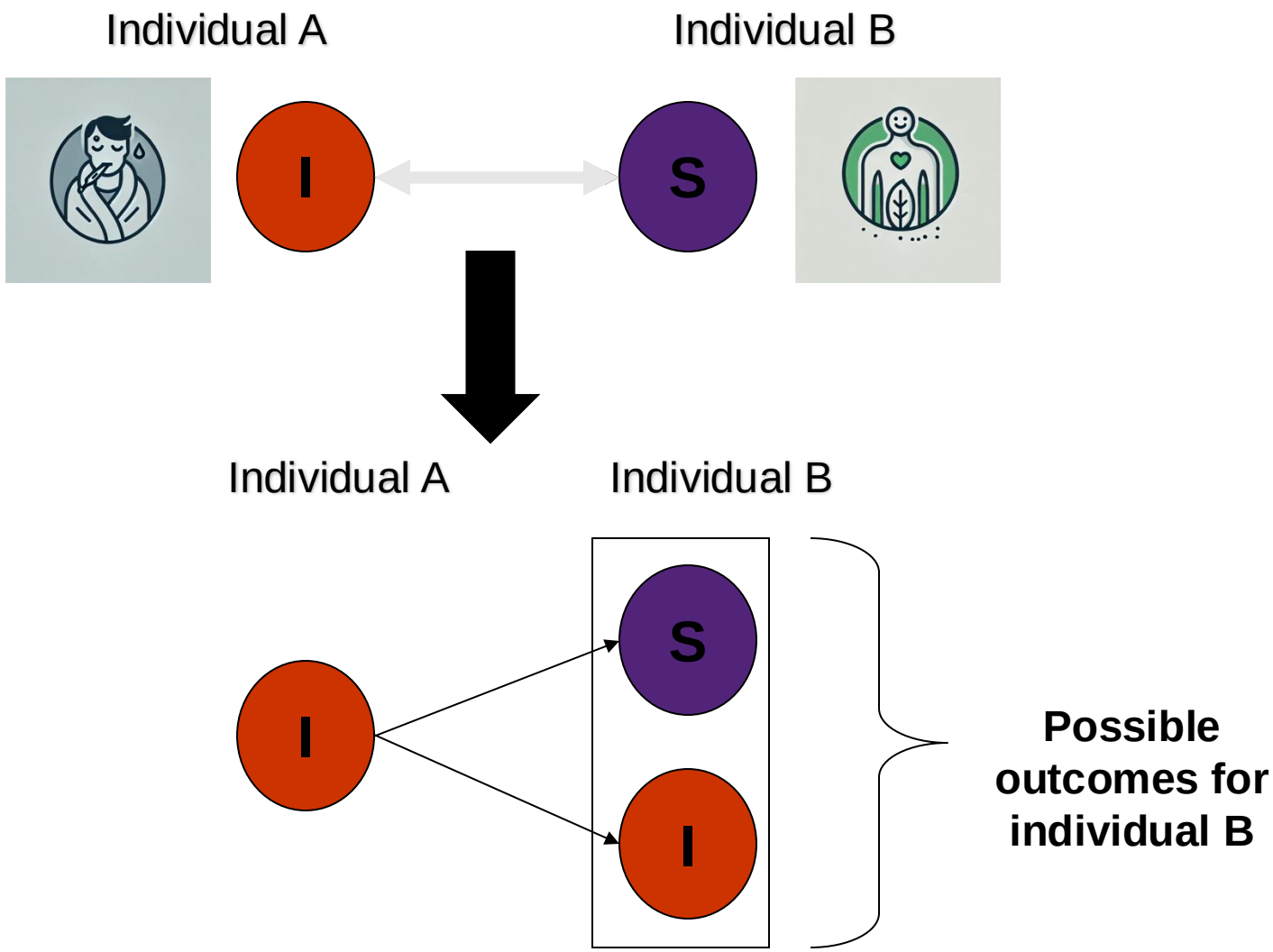
Prof. R.J. Soares Magalhães
Professor Titular de Enfermedades Zoonoticas y Bioseguridad
Queensland Alliance for One Health Sciences, University of Queensland
r.magalhaes@uq.edu.au; www.spatialepilab.com

Historia natural de la infección: modelo SEIR para una infección inmunizante

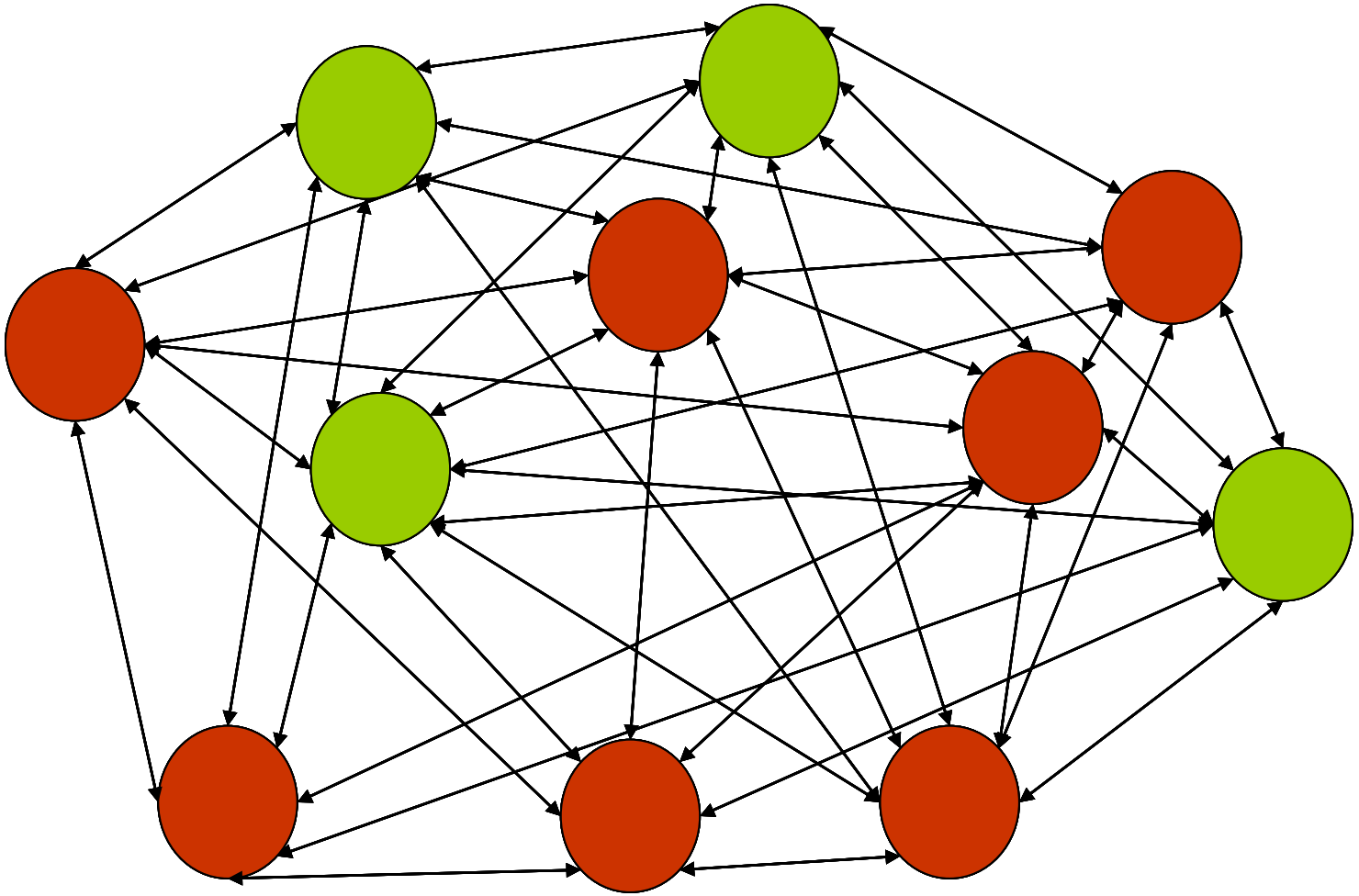


S – Susceptible
E – Exposed (infected)
I – Infectious
R –Recovered (Immune)

La probabilidad de que el contacto infeccioso resulte en infección (β)



Dinámica a nivel de población

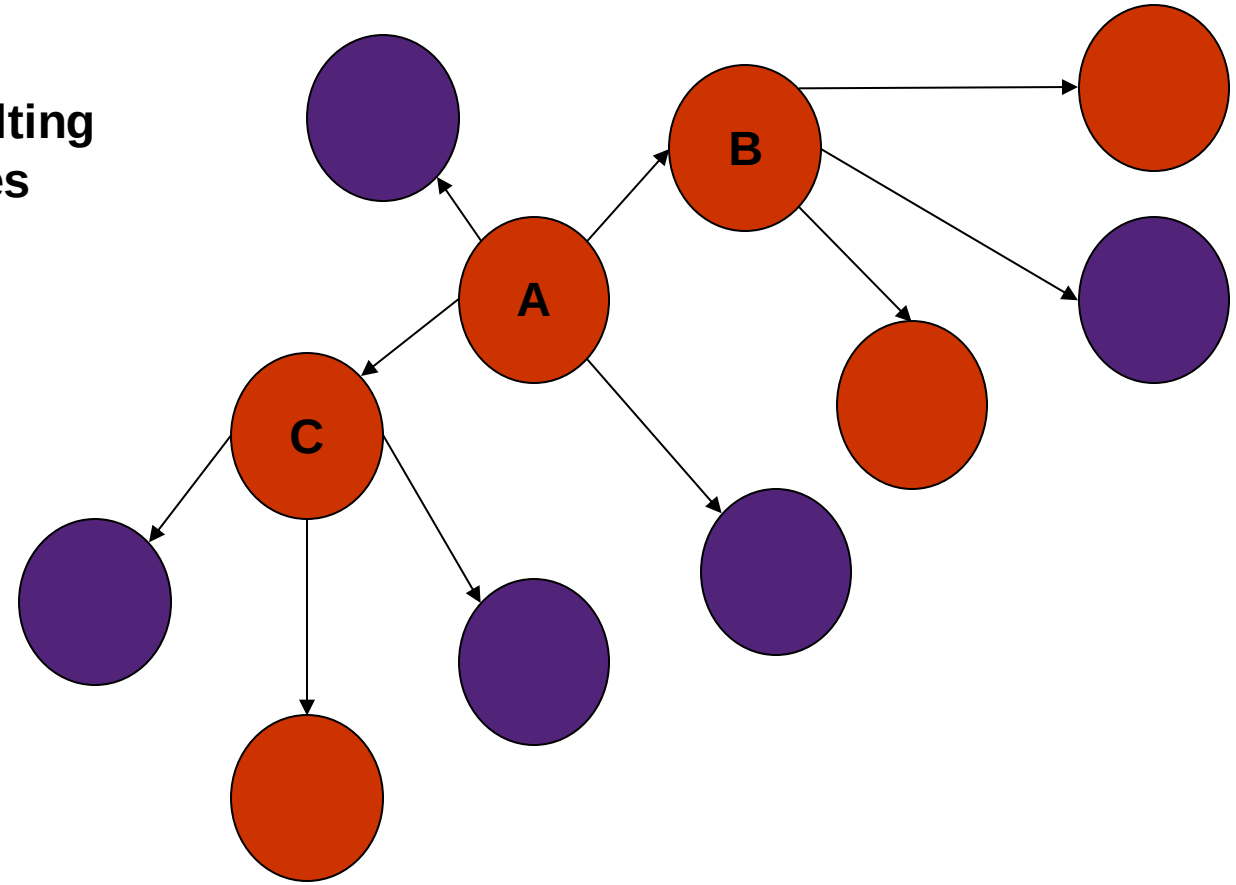


¿Cuál es el potencial de infección? – Tasa de reproducción (R0)

	N. resulting cases
Infectious A	2
Infectious B	2
Infectious C	1

Average

1,67



¿Pero qué determina si habrá un brote o no?

The threshold conditions for disease spread:

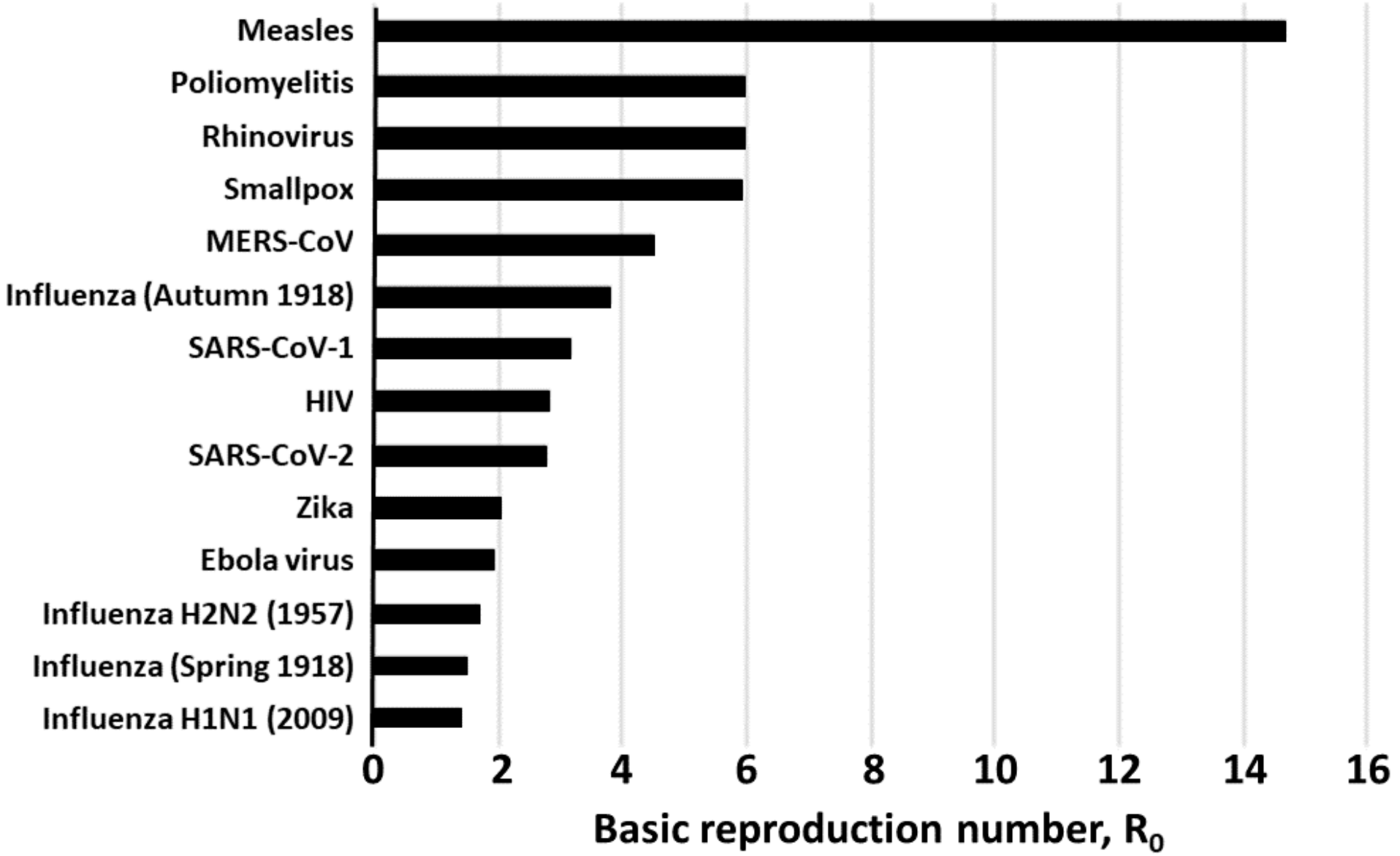
- Deterministic approach
  - R=1 (endemic situation)
  - R<1 – disease will not spread
  - R>1 – disease will spread

- Stochastic approach
  - R<1 – minor outbreaks may occur
  - R>1 – minor or major outbreak may occur

- Proportion of the population needed to be immunised to control transmission:
  - Herd immunity threshold = $1- (1/R_0)$

(Anderson and May, 1991)

R0 para enfermedades infecciosas seleccionadas



Source: The Centre for Evidence-Based Medicine, University of Oxford

¿Cuál es el potencial de infección? – Tasa de reproducción (R0)

Basic Reproductive ratio (R0) - Average number of secondary infections produced by the introduction of an infectious case in a homogeneously mixing, totally susceptible population during its entire infectious period.

$$R_0 = ecr \times \left(\frac{1}{r} \right)$$

R0 is related to the number of individuals effectively contacted by per unit time (effective contact rate) and the duration of the infectious period.

La fuerza de la infección (Force of infection)

- **The force of infection λ is the probability for a susceptible host to acquire the infection.**
- **In a simple model with homogeneous "mixing", it has 3 "factors":**

$$\lambda = m \times (I / N) \times t$$

- **m :** "mixing" rate (contact pattern using contact networks)
- **I / N** : proportion of contacts with infectious hosts

Effective contact rate (ECR)

- **t** : probability of transmission of the infection once a contact is made between an infectious host and a susceptible host

→ **Number of new infections = λ x S ("catalytic model")**

¿Qué es una red?

01

A network consists of “units of interest” that may be “linked” in some way (or not!)

02

Units of interest are NODES

03

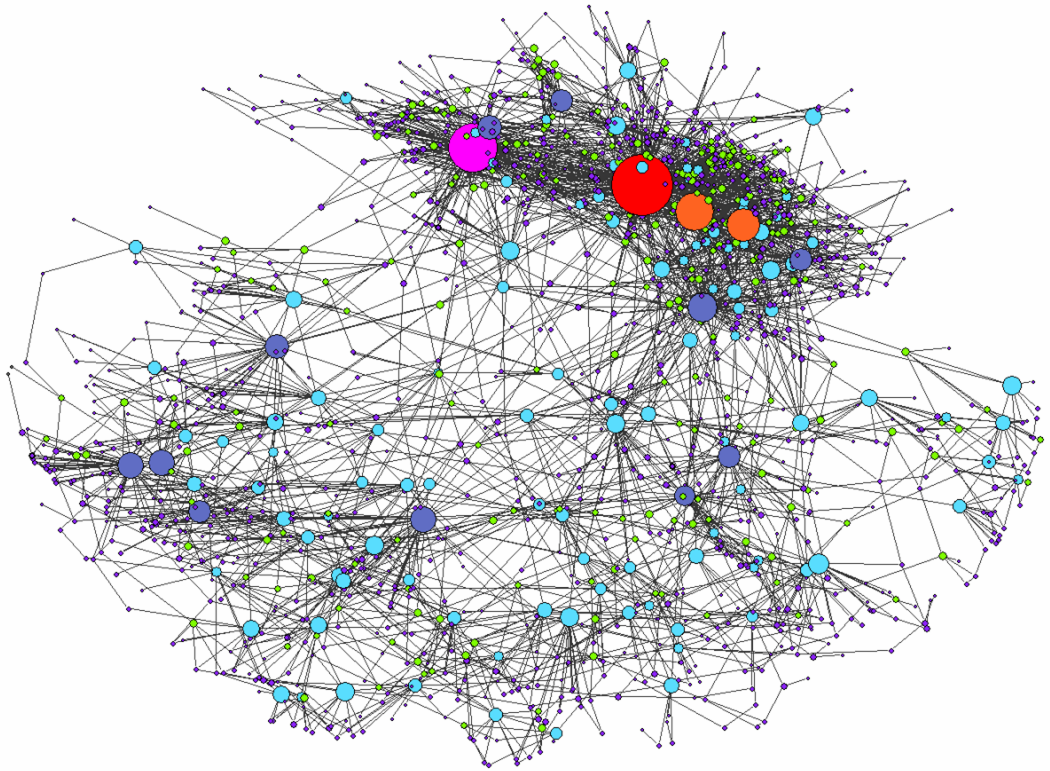
Links are EDGES and represent some form of “relationship”

04

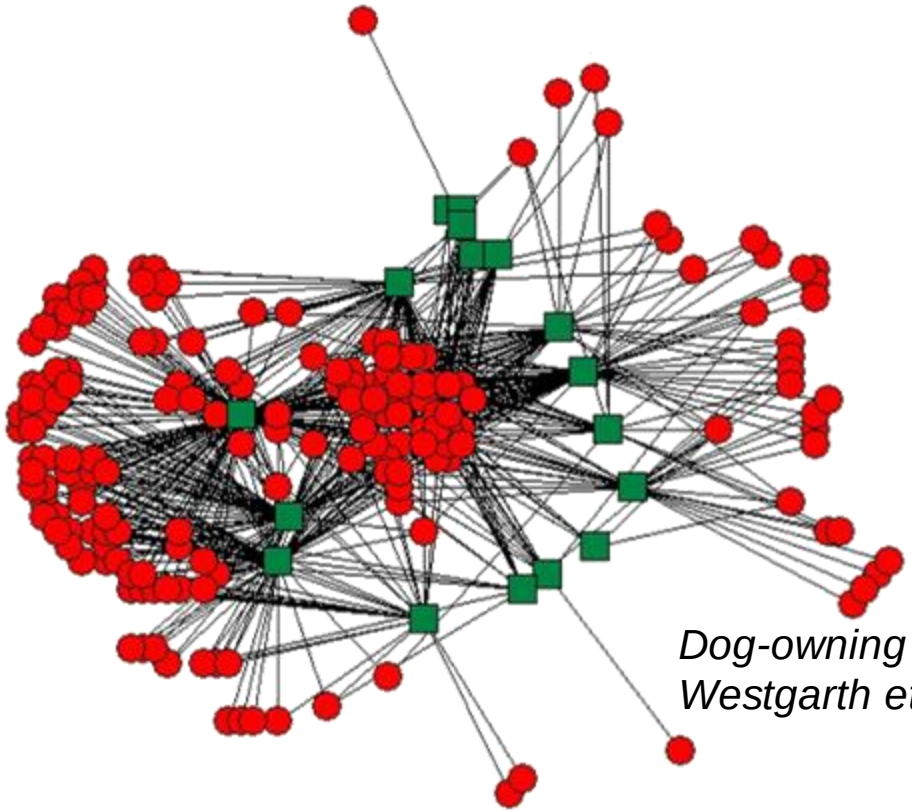
Each type of link defines a distinct network

- It may (or may not) be reasonable to amalgamate networks

Medición de patrones de contacto: ejemplos de redes de movimiento

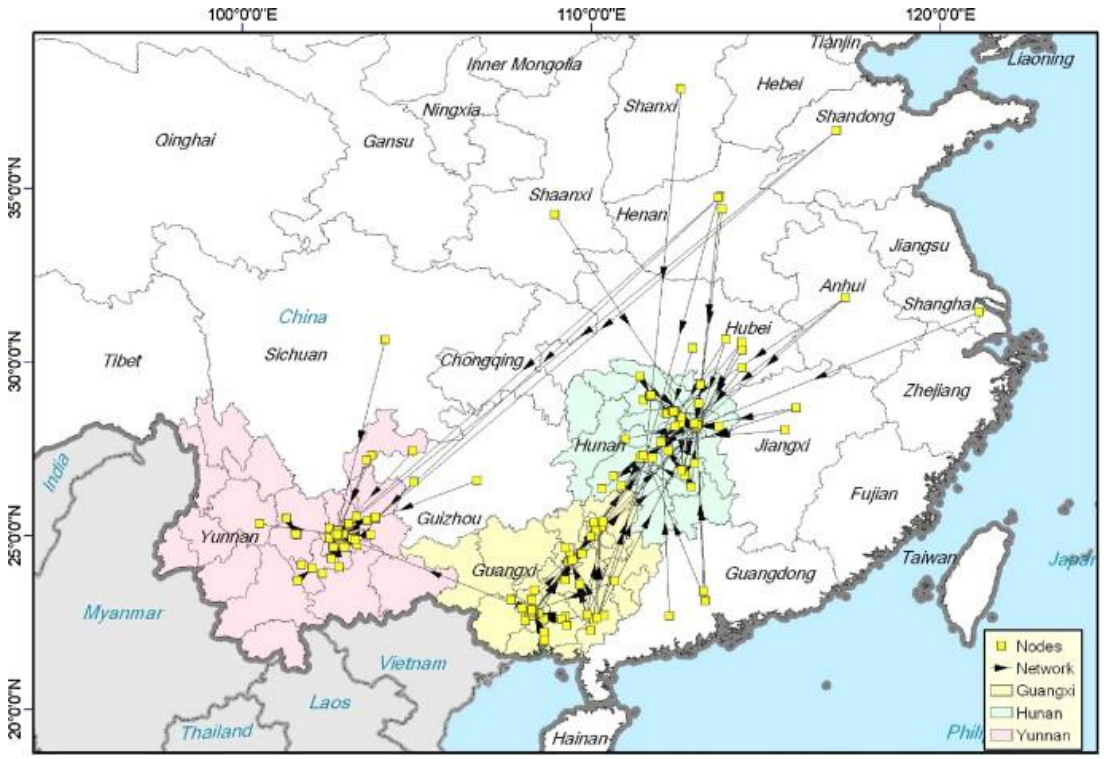


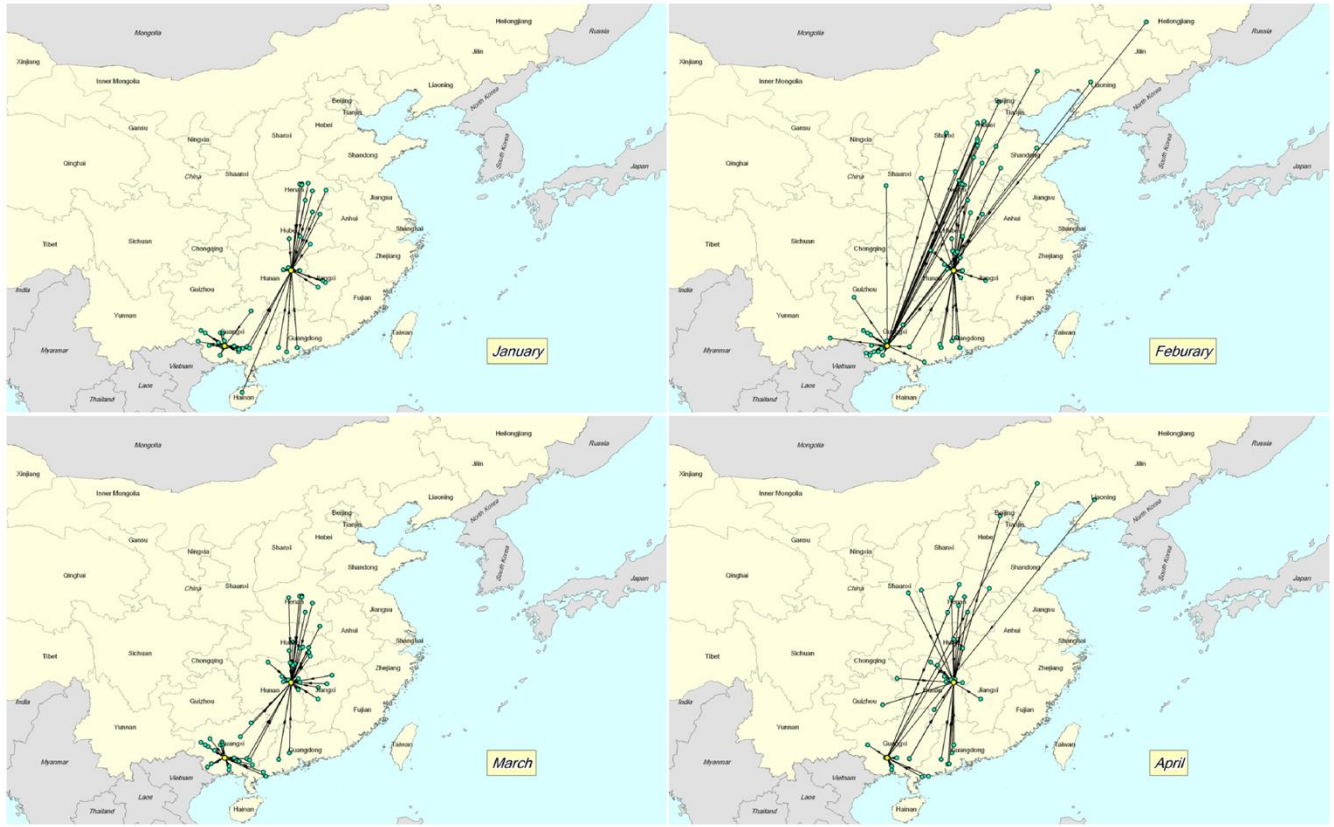
Cattle movement, UK, Feb 2002
Christley et al, SVEPM 2005



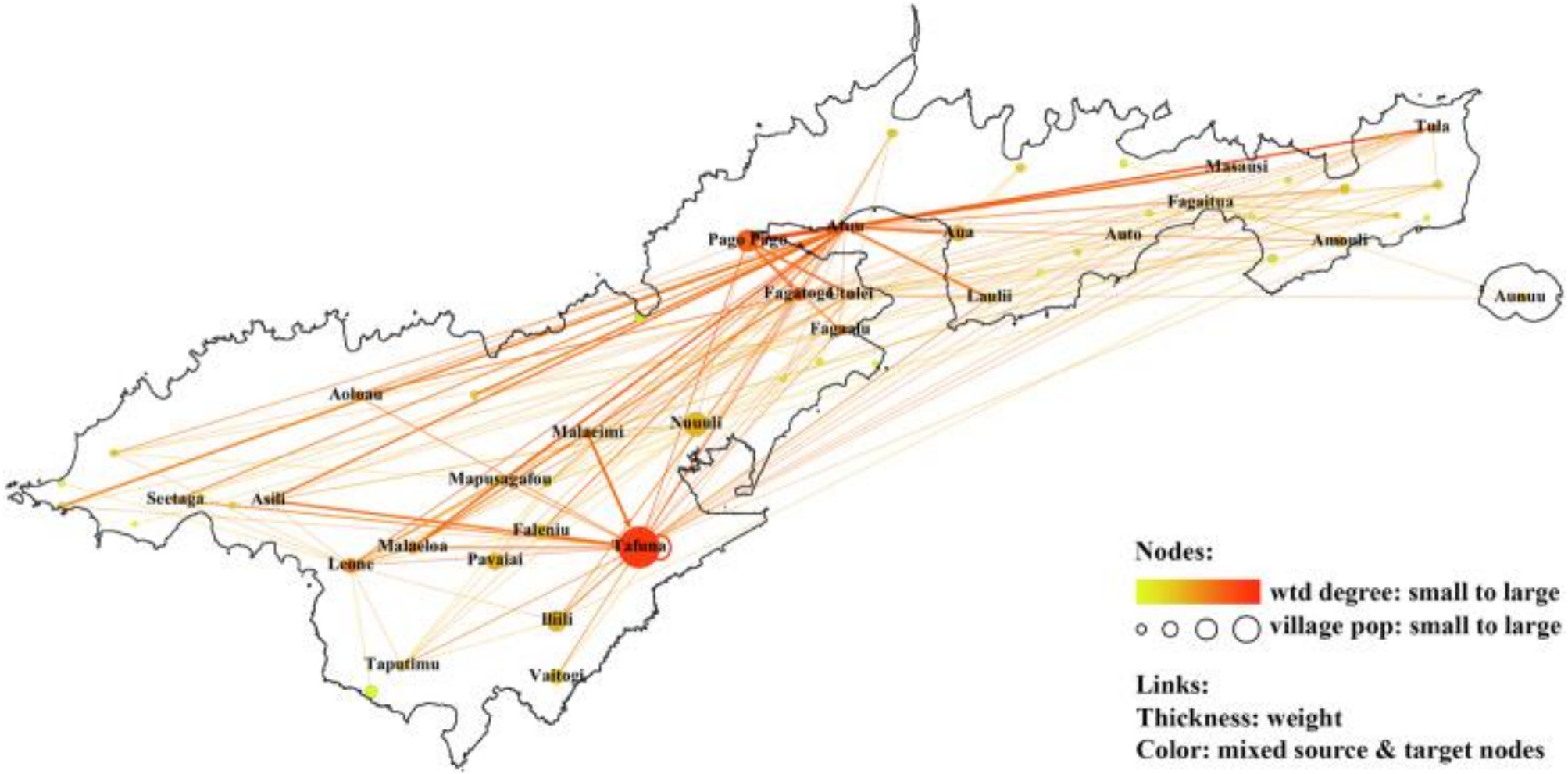
Dog-owning households
Westgarth et al, 2006

Redes de mercado de aves vivas en el sudeste de China





Redes de movimiento de individuos entre localidades de Samoa.



¿Qué es el análisis de red?

A toolbox of methods for:

- **Exploring** the topology of networks (i.e. relationship between individuals)
- **Identifying** subgroups
- **Statistical analysis** of network data
  - Characterising the **role** of individuals
- and more…

Research questions:

Size, duration and probability of an outbreak

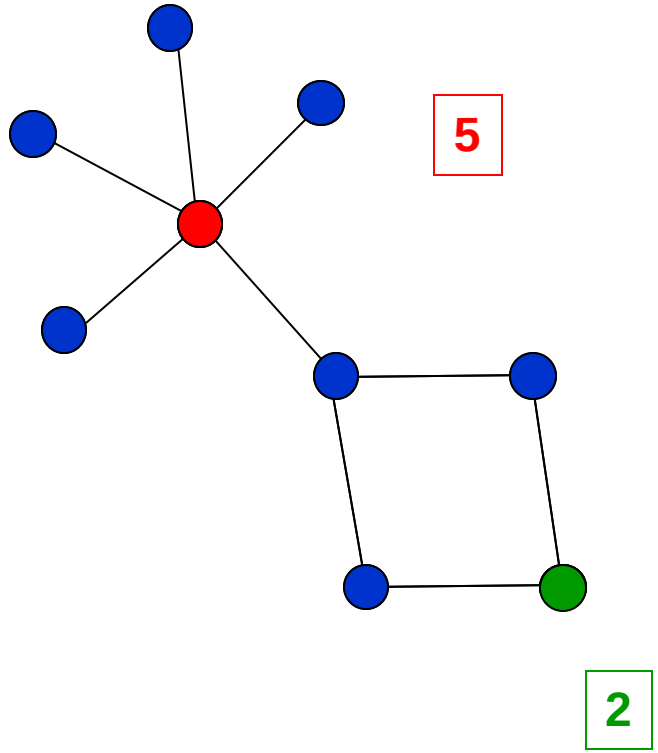
Network Centrality

- **Network centrality is a measure of an individuals "position" in a network**

- **Many centrality measures exist;**
  - Degree
  - Betweenness
  - Closeness
  - K-Core
  - Eigenvector
  - …

Network Centrality - Degree

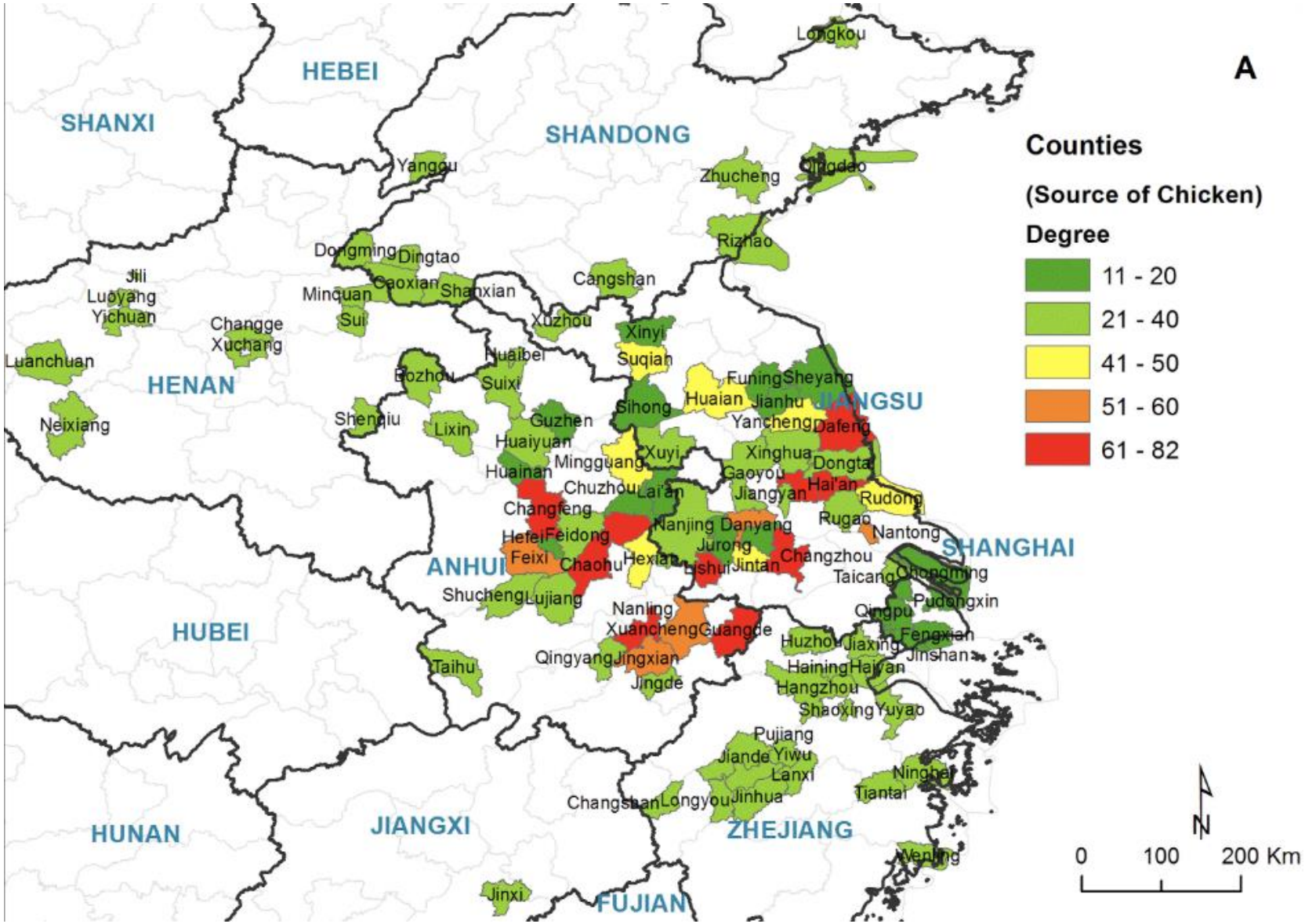
Definition: the sum of unique contacts made by a node to all other nodes.
Individual level measure of connectivity



Directed graphs, can describe the:

- **In-degree**: the number of ties connecting **to** a node
- **Out-degree**: the number of ties leaving a node

1 mode “source–source node” network of poultry movement in eastern China according to the degree value

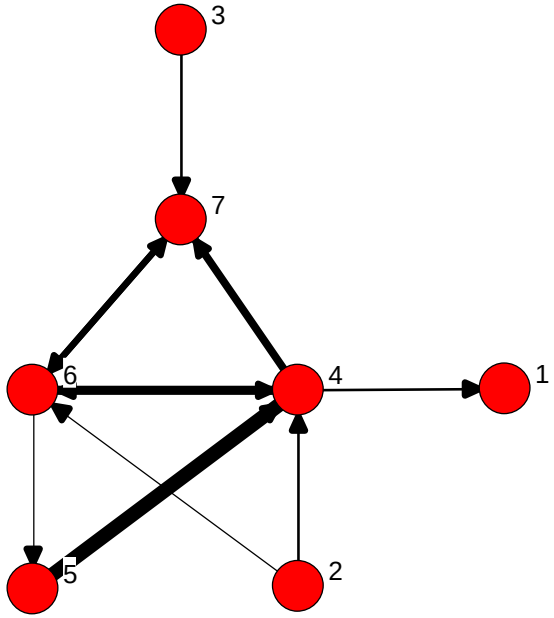


Disassortative network - nodes tend to connect to other nodes that have different degree.

Assortative network – nodes connected to other nodes that have similar degree.

Network Centrality in Valued and Directed Networks

Degree: the sum of unique contacts made by a node to all other nodes.



		On movements						
	ID	1	2	3	4	5	6	7
Off	1							
	2				2		1	
	3							2
	4	2					1	7
	5				12			
	6				8	1		5
	7						5	

ID	Out degree	In degree
1	0	1
2	2	0
3	1	0
4	3	3
5	1	1
6	3	3
7	1	3

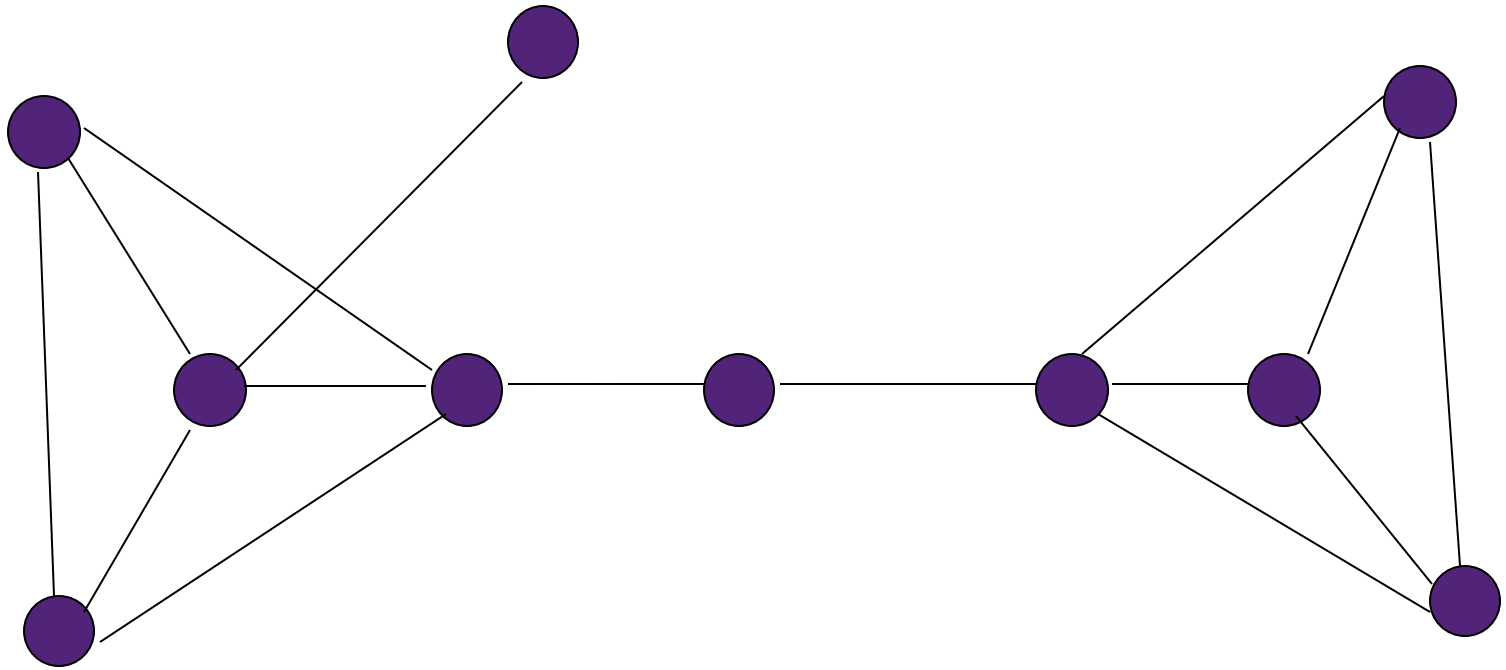
Network Centrality – K-core

Definition

Maximal subgraph (subgroup of nodes) in which each node has at least degree *k* within the subgraph (ie., 2-core, 3-core …..etc….)

- Identifies relatively dense subgraphs
- Uses degree to identify clusters
- Generally used on undirected networks
- A component always a 1-core

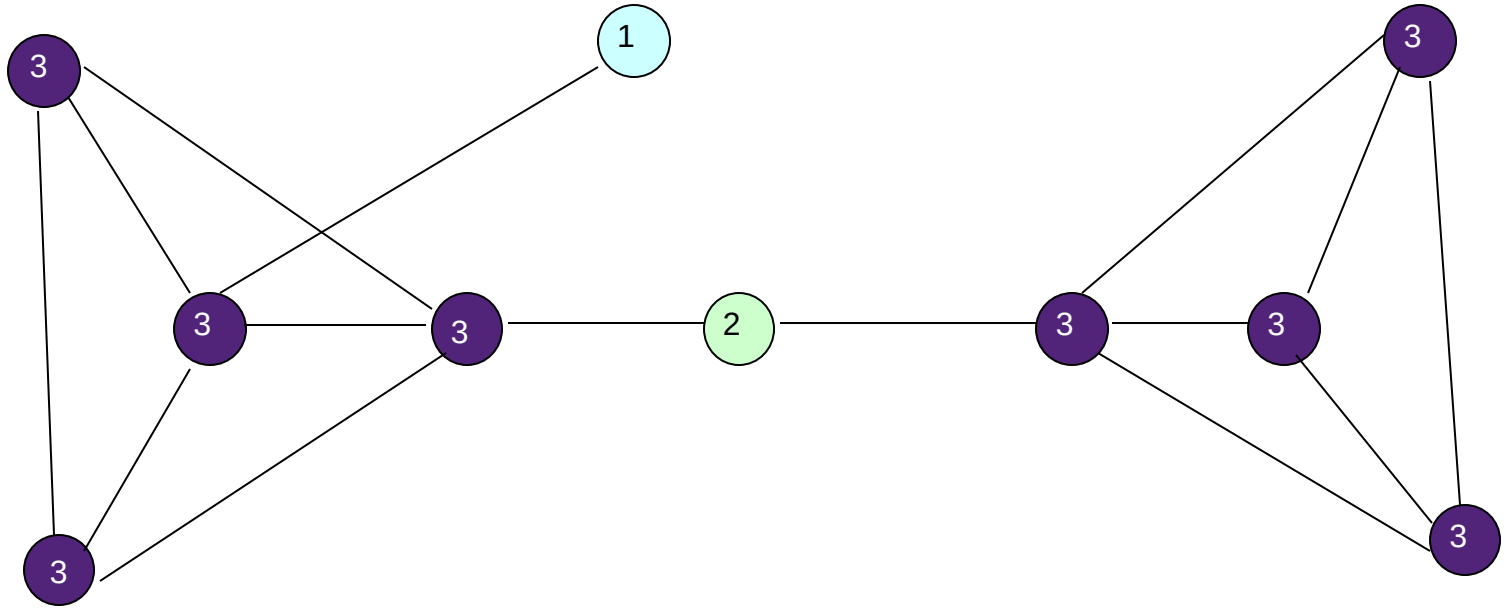
Útil para detectar subgrupos cohesivos de individuos dentro de una red.



Útil para detectar subgrupos cohesivos de individuos dentro de una red.

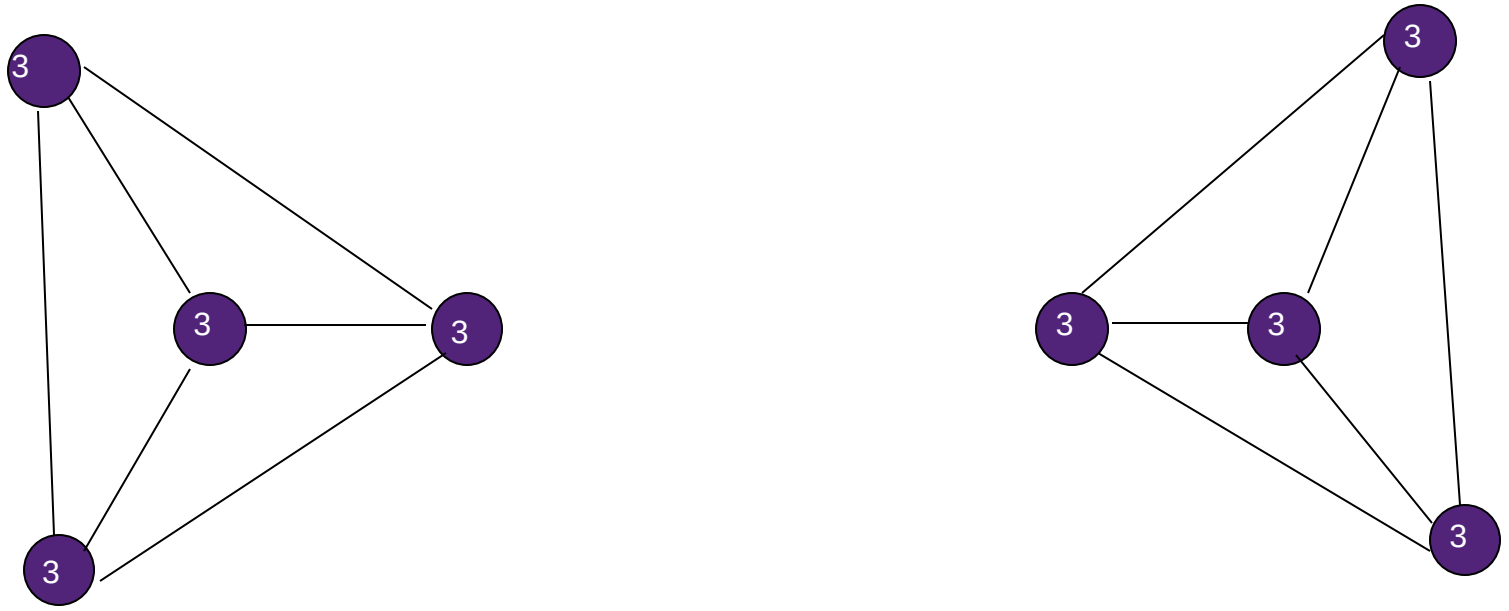
The University Of Queensland
AUSTRALIA

Remove lowest k-cores until the network breaks up into relatively dense components

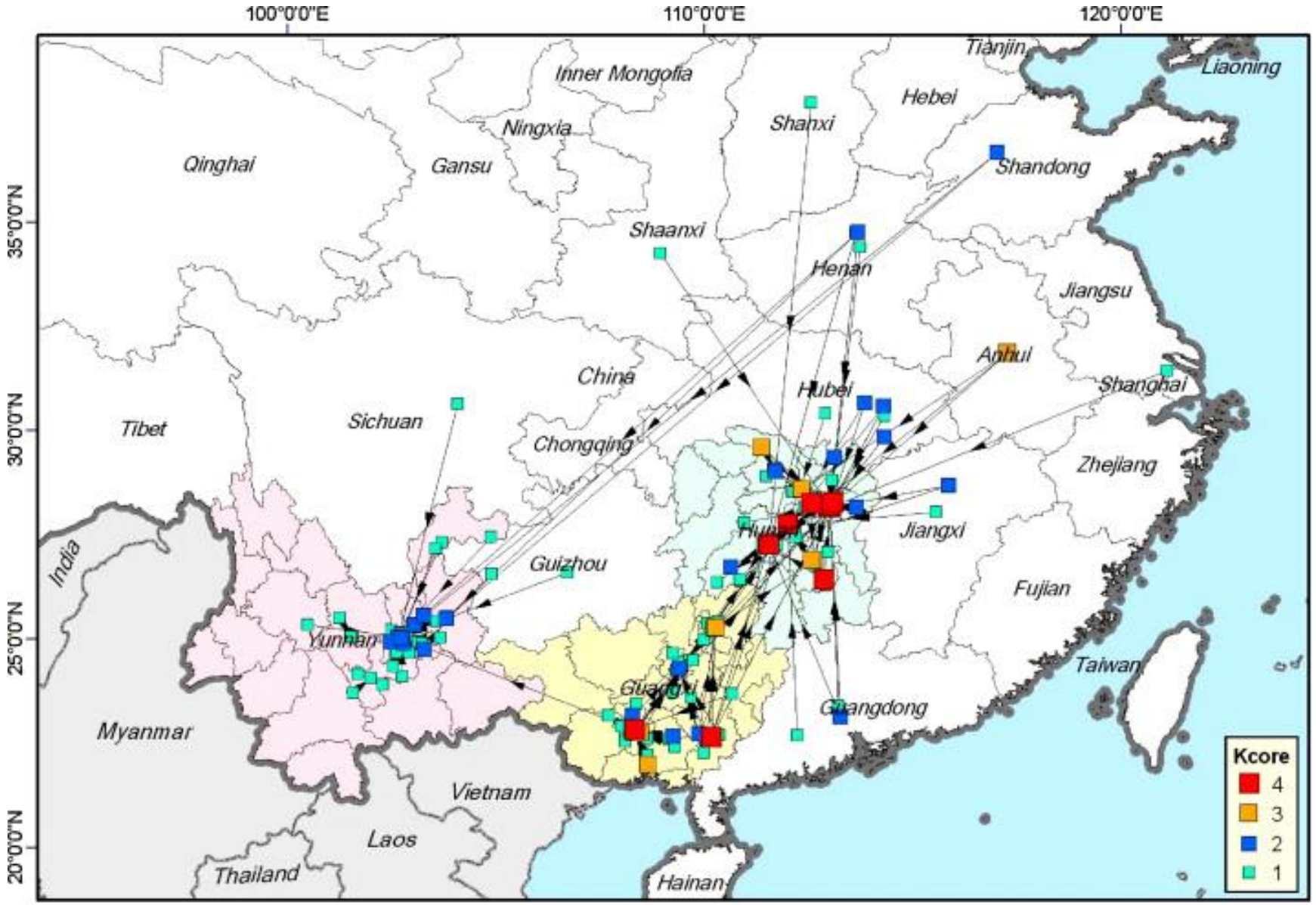


Útil para detectar subgrupos cohesivos de individuos dentro de una red.

Remove lowest k-cores until the network breaks up into relatively dense components



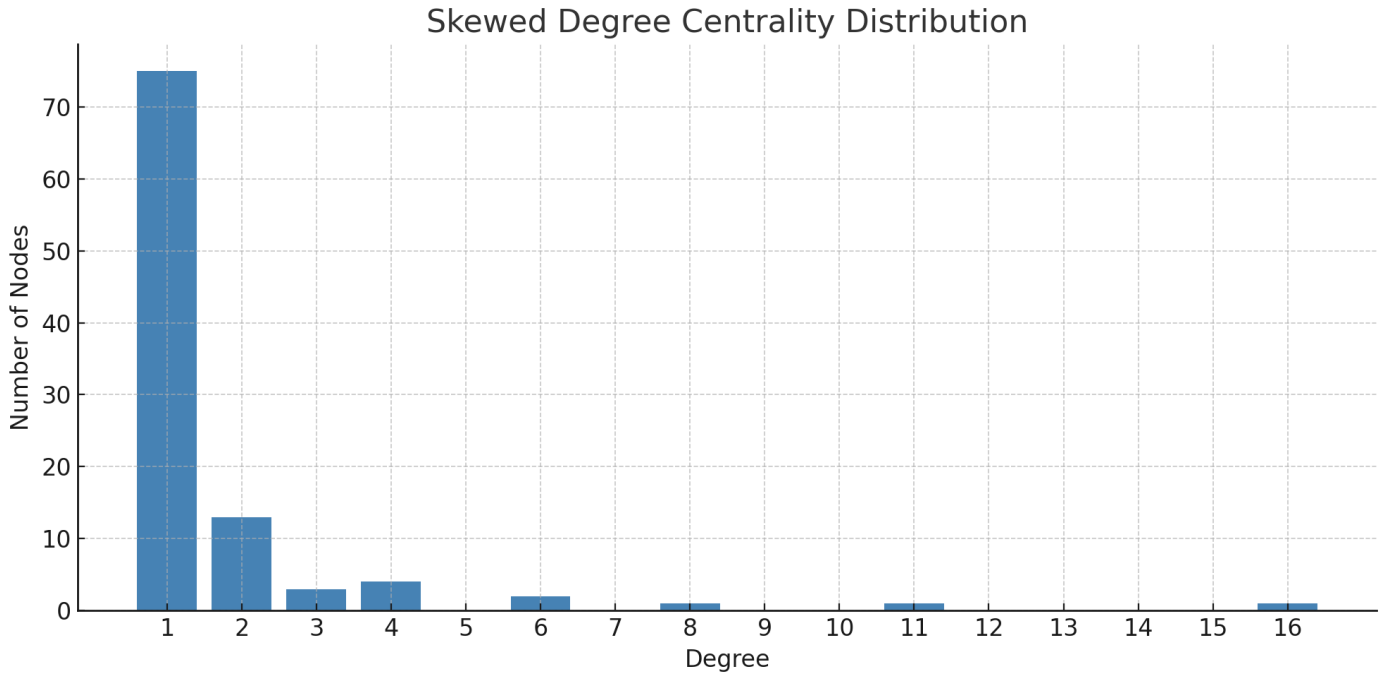
Red de movimiento de aves de corral de 2-mode “nodo de mercado-fuente” en el sur de China según el valor k-core



Network structure has important implications for infectious disease control

Networks with skewed degree distributions said to be:

- Resistant to random *control* programmes
- Susceptible to targeted *control* programmes



Albert, Jeong and Barabasi, Error and attack tolerance of complex networks. Nature 406, 378-382 (2000)

Implications for disease control and biosecurity:

- Random (elective) control/prevention/biosecurity may have little effect globally unless undertaken on a large proportion of nodes

- Targeting “high risk” nodes
  - More useful in disassortative networks (?biological)
  - May need to target more nodes in assortative networks (?social)
  - Requires identification of high-risk individuals
    - Difficult
    - Varies with time

Es importante destacar….
los factores de riesgo de infección también son factores que afectan la estructura de la red.

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Individual level factors

- Disease status
- Social status/age

Management factors

- Biosecurity indicators
- Housed v's pastured
- Stocking density

Geographic and Environmental factors

- Spatial location
- Climate/season
- Terrain

A diseased individual may have:

- ***Increased*** *contact rate*
  Early stages of on outbreaks

- ***Decreased*** *contact rate*
  Disease control interventions in place- e.g. movement restriction

Resumen de las pruebas de autocorrelación en el análisis de redes sociales

Use Case	Statistical Tests
Continuous variable similarity (e.g., income, score)	Moran's I, Geary's C or t-test
Categorical attribute clustering (e.g., gender, role)	Join Count or Assortativity
Testing relationship between attribute matrix and network ties	QAP or Mantel Test
Modeling influence or behavior diffusion	Network autocorrelation models or SAOM
Group or community-based clustering	Modularity / ERGMs

Diferencias estadísticas en “Degree” entre ubicaciones con diferentes patrones de infección en diferentes puntos temporales

Month/County infection status	Not-infected	Infected	Two-tailed t-test probability of the difference of the mean degree
January			
Poultry outbreaks	47	21	−0.203 (P = 0.933)
Market infection	43	25	0.577 (P = 0.768)
Human outbreaks	53	15	−6.974 (P = 0.001)
February			
Poultry outbreaks	61	24	4.561 (P = 0.018)
Market infection	59	26	5.475 (P = 0.001)
Human outbreaks	68	17	−1.941 (P = 0.202)
March			
Poultry outbreaks	57	20	5.325 (P = 0.076)
Market infection	57	20	5.325 (P = 0.078)
Human outbreaks	65	12	−8.559 (P = 0.011)
April			
Poultry outbreaks	41	19	1.972 (P = 0.324)
Market infection	40	20	2.100 (P = 0.281)
Human outbreaks	49	11	−5.187 (P = 0.018)

doi:10.1371/journal.pone.0049712.t002

The connectivity among counties experiencing human infection was significantly higher compared to counties without human infection for the months of January, March and April. Conversely, counties with poultry infections were found to be significantly less connected than counties without poultry infection for the month of February.

Gracias - preguntas?

Prof. R.J. Soares Magalhães
Professor Titular de Enfermedades Zoonoticas y Bioseguridad
Queensland Alliance for One Health Sciences, University of Queensland
r.magalhaes@uq.edu.au; www.spatialepilab.com