Network Dynamics: Introduction

Introduction to Network Science

Instructor: Michele Starnini — https://github.com/chatox/networks-science-course

upf. Universitat Pompeu Fabra Barcelona

Content

- Introduction to network dynamics
- Spreading phenomena

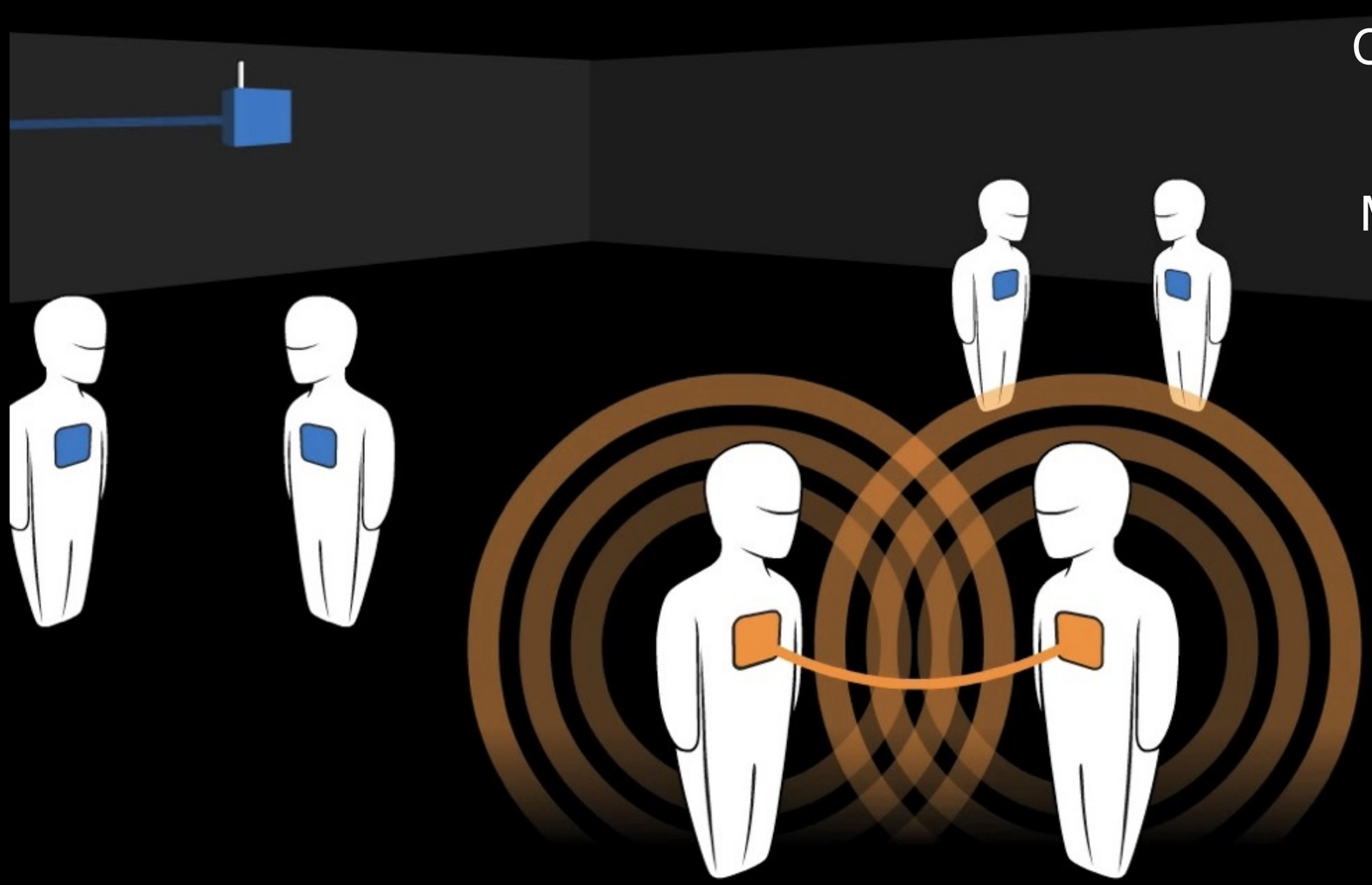
Network dynamics

- Dynamics OF networks: time-evolving (temporal) networks
- Dynamics ON networks: stochastic processes on static networks
- Dynamics ON & OF networks: stochastic processes on temporal networks

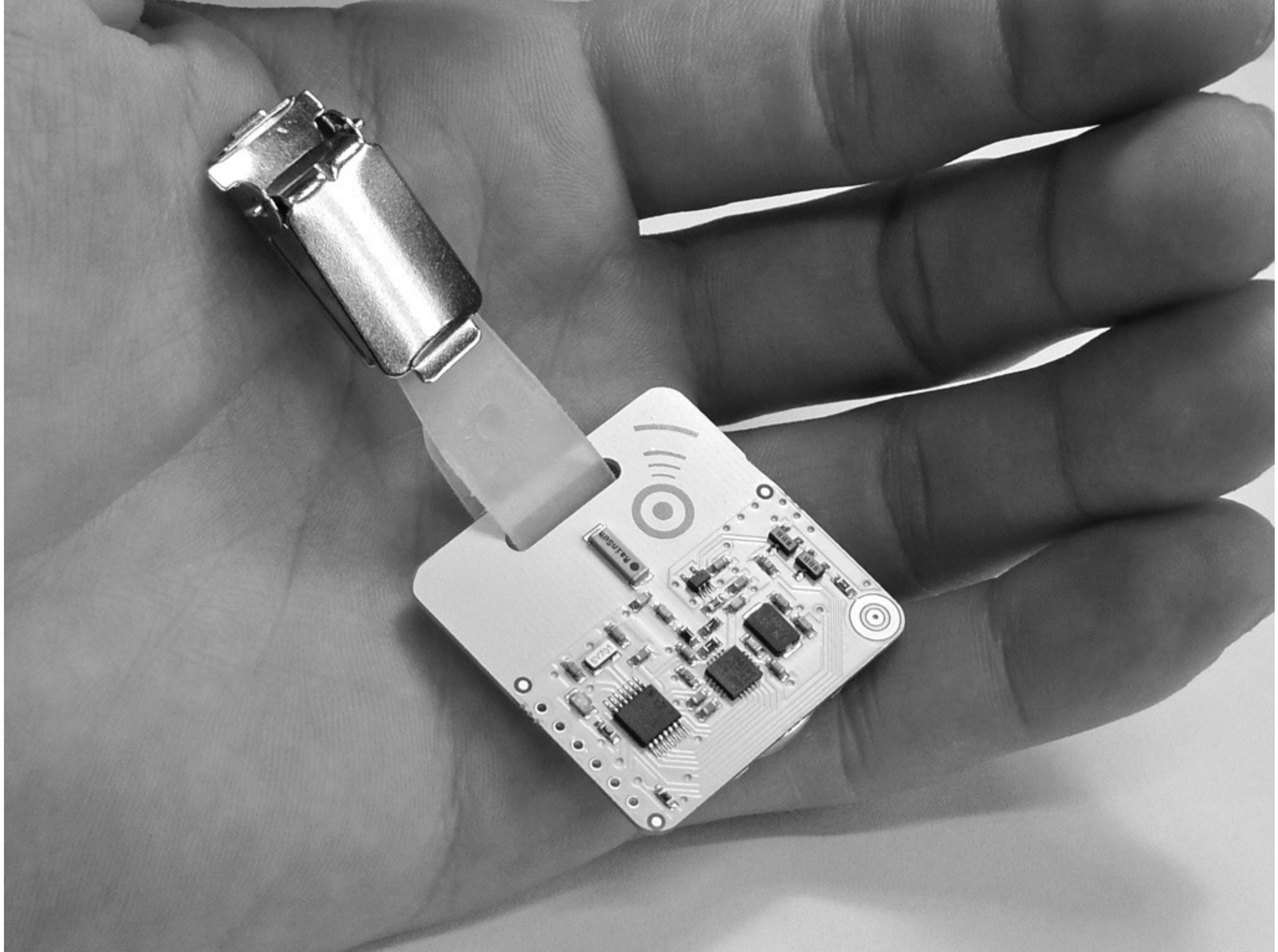
Temporal networks

- Temporal networks: links (and nodes) appear/disappear in time
- Online social networks: friendship created/removed, new users join/leave
- Contact networks: two persons interact for a while, then separate
- Communication network: each link (email) has instantaneous duration
- Transportation network: bus/train at a certain time
- Financial networks: financial transactions at a certain time

Face-to-face interaction networks



Conferences
Schools
Hospitals
Museums…



Temporal networks

1:00 - 2:30 PM

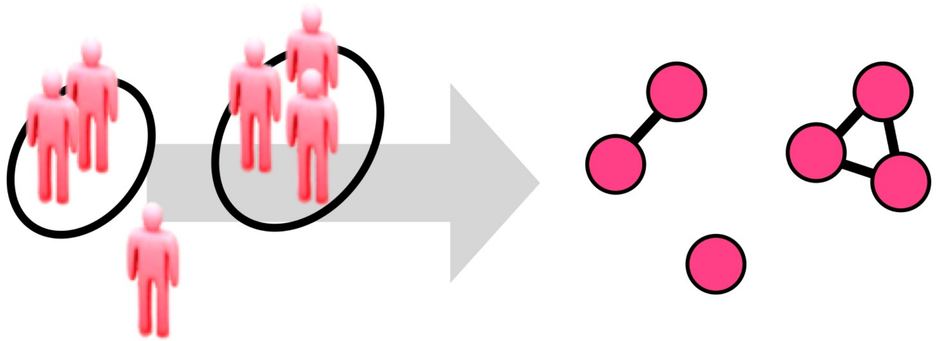
lunch, coffee and start of 3rd session

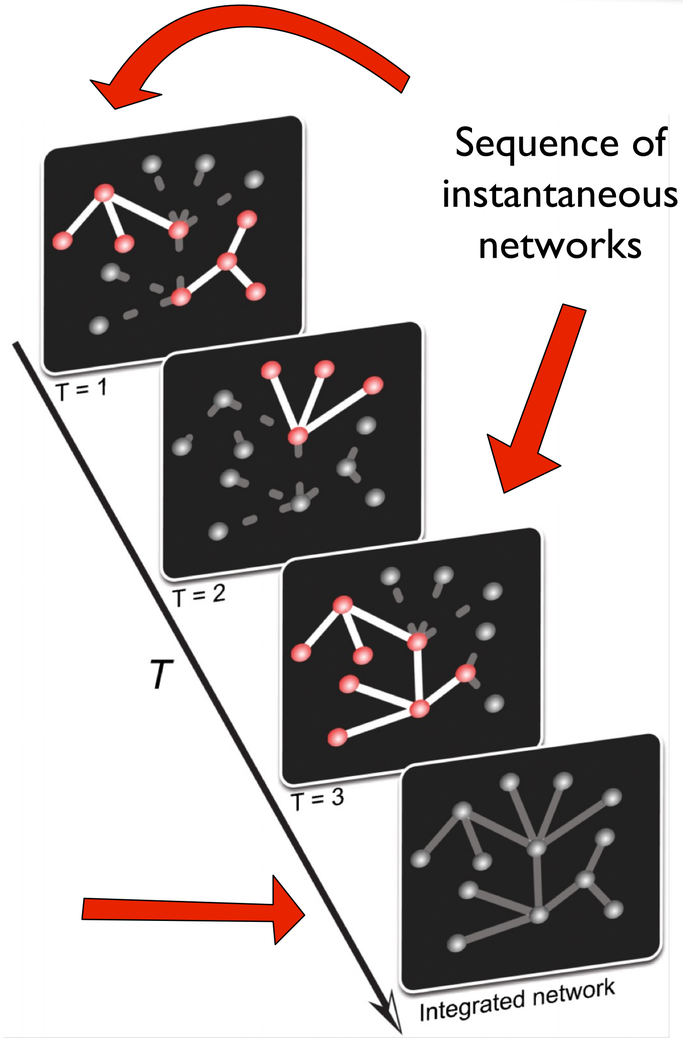
SocioPatterns

https://www.youtube.com/watch?v=ObtVS547lu4

From f2f interactions to temporal networks

Temporal resolution → Aggregation time window





Dynamics on networks: Stochastic processes

- Information diffusion
- Epidemic spreading
- Opinion dynamics
- Sychronization

Stochastic processes on networks

- Each node i has a certain state x_i
- Such a state changes in time according to some rules, $x_i(t)$
- Random walk: x_i=1 if random walker is on node i, 0 otherwise
- Epidemics: x_i=1 if node i is infected, 0 otherwise
- Info diffusion: x_i=1 if node i knows a certain piece of info, 0 otherwise
- Opinion dynamics: x_i=1 if node holds opinion A (left), 0 otherwise (right)

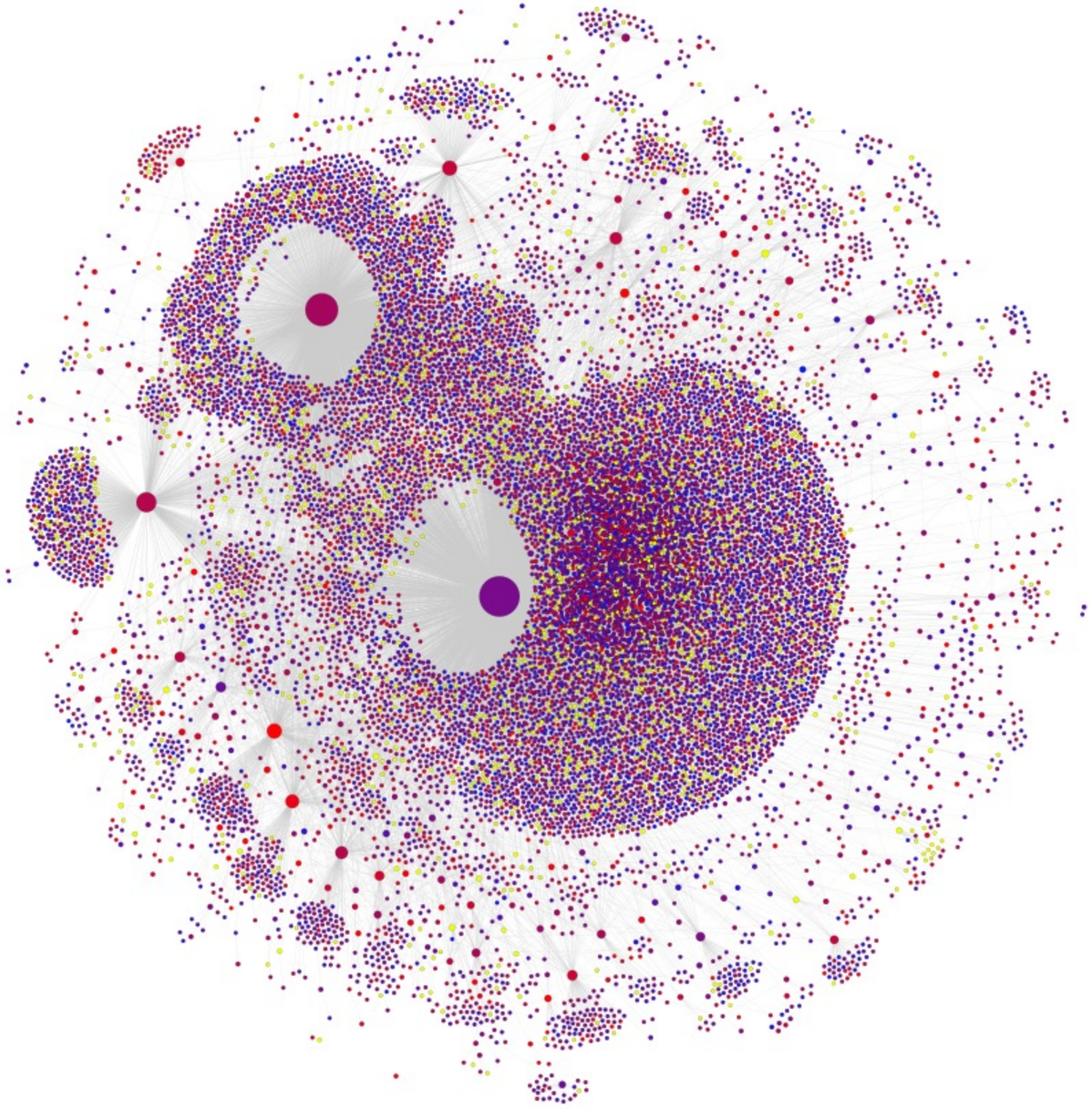
Stochastic processes on networks

- Each stochastic process is defined by the update rules
- How does state of node i changes in time, $x_i(t+1) = F(x_i(t), x_j(t), x_k(t), \ldots)$?
- On networks, the state of node i only depends on the previous state of its neighbors: $x_i(t+1) = F(x_i(t), x_{j1}(t), \ldots. x_{jk}(t), \mid j1, \ldots jk$ neighbors of node i)
- Random walk: $x_i(t+1) = 1$if the RW was at some neighbour at time t
- Epidemics: $x_i(t+1) = 1$ (infected) if some neighbor was infected at time t
- Opinions: $x_i(t+1) = 1$ (opinion A) if the majority of neighbors hold opinion A

Spreading phenomena: fake news

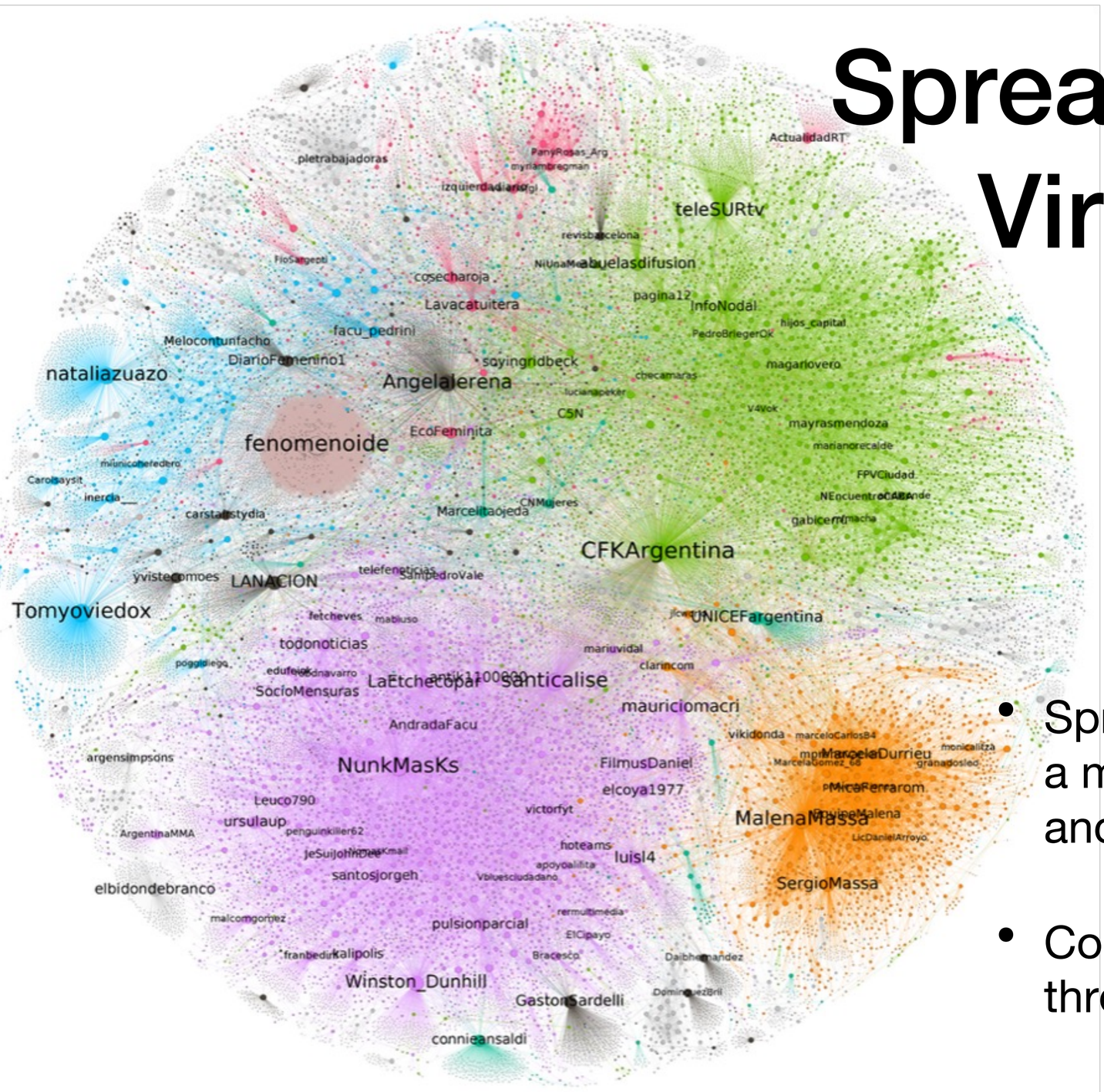
A fake news article spreading via Twitter during 2016 US presidential campaign

Red nodes are likely bots



"Influencers" and their sponsored posts

Spreading phenomena: Viral propagation



- Spread of the #NiUnaMenos hashtag: a movement against gender-based violence and femicide started in Argentina in 2015

- Colors based on communities detected through modularization optimization

Spreading phenomena: Non-trivial examples

- Back pain: spread from West to East in Germany after fall of Berlin Wall
- Suicide: well known to spread throughout communities on occasion
- Sexual “scripts”: expected sequences of behaviors during intimate situations
- Politics: the denser your connections, the more intense your convictions
- A wide array of phenomena spread through networks, not only viruses and information

Stochastic processes on temporal networks

- Both state of the nodes & presence/absence of links change in time
- The evolution of the process depends on the network dynamics

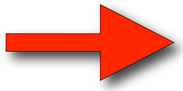
	Network	Process
Epidemic	Face-to-face contacts	Disease transmission
Information	Online social networks	News diffusion
Mobility	Transportation networks	Passengers flows

Stochastic processes on temporal networks

- The time scales of the network & process can be similar or very different
- Viral propagation on social media: viral propagation much faster (hours) than new connections on online social networks (weeks/months)
- Epidemic spreading: epidemic transmission (days) comparable with mobility (days)

Stochastic processes on temporal networks

- Process dynamics
- Time-varying network

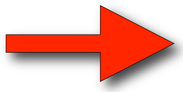


Time scales coupling

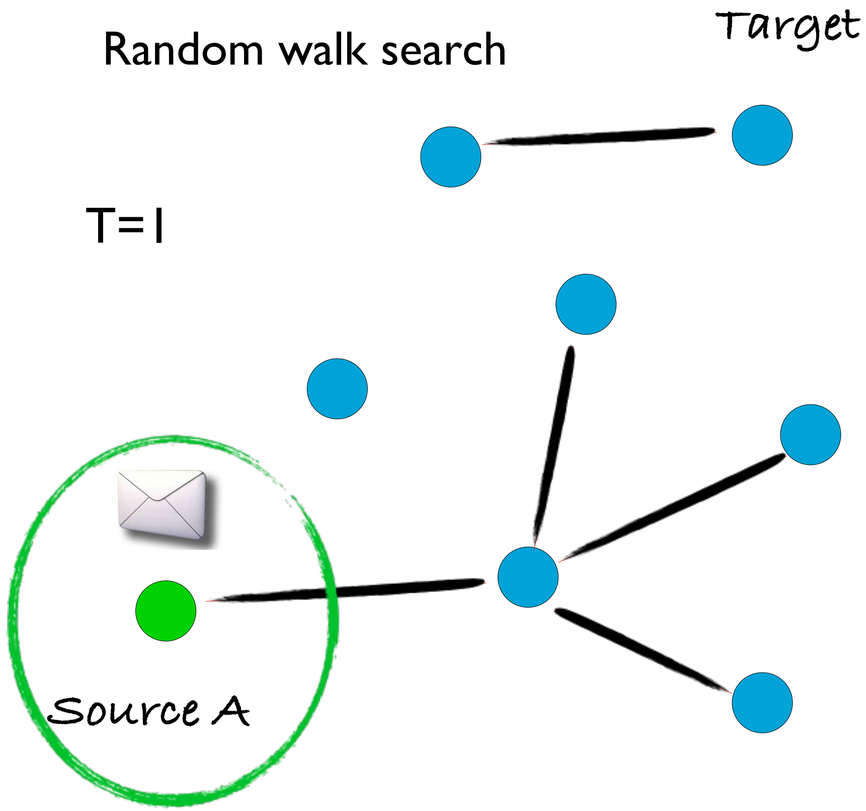
Random walk on a temporal network: At each time step, the letter takes one available link at random

Dynamical processes on temporal networks

- Process dynamics
- Time-varying network



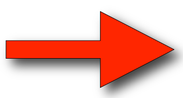
Time scales coupling



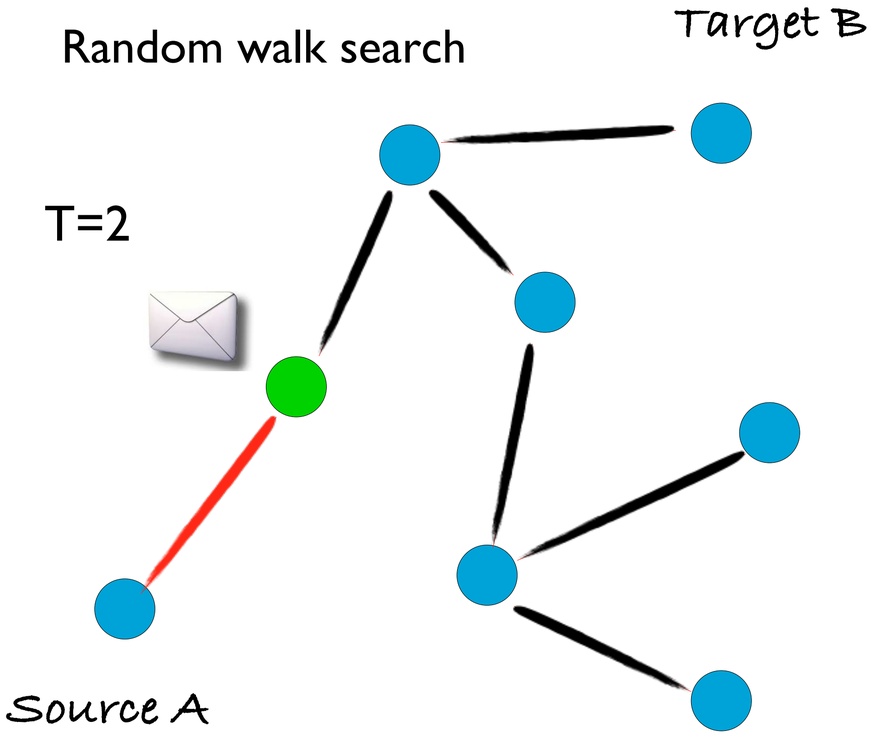
Random walk on a temporal network: At each time step, the letter takes one available link at random

Dynamical processes on temporal networks

- Process dynamics
- Time-varying network



Time scales coupling

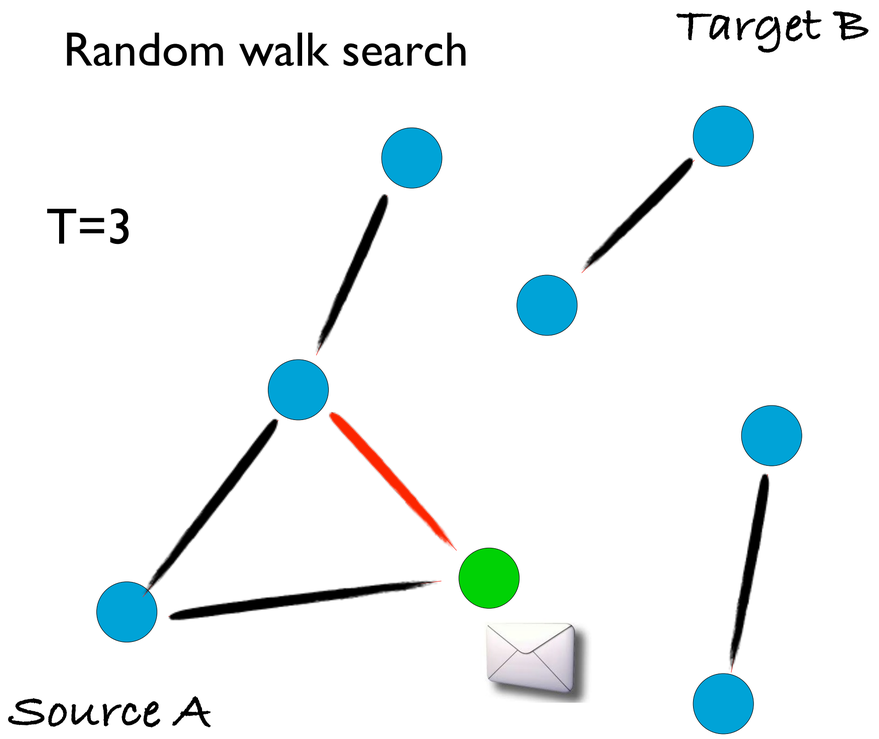


Random walk on a temporal network: At each time step, the letter takes one available link at random

Dynamical processes on temporal networks

- Process dynamics
- Time-varying network

→ Time scales coupling



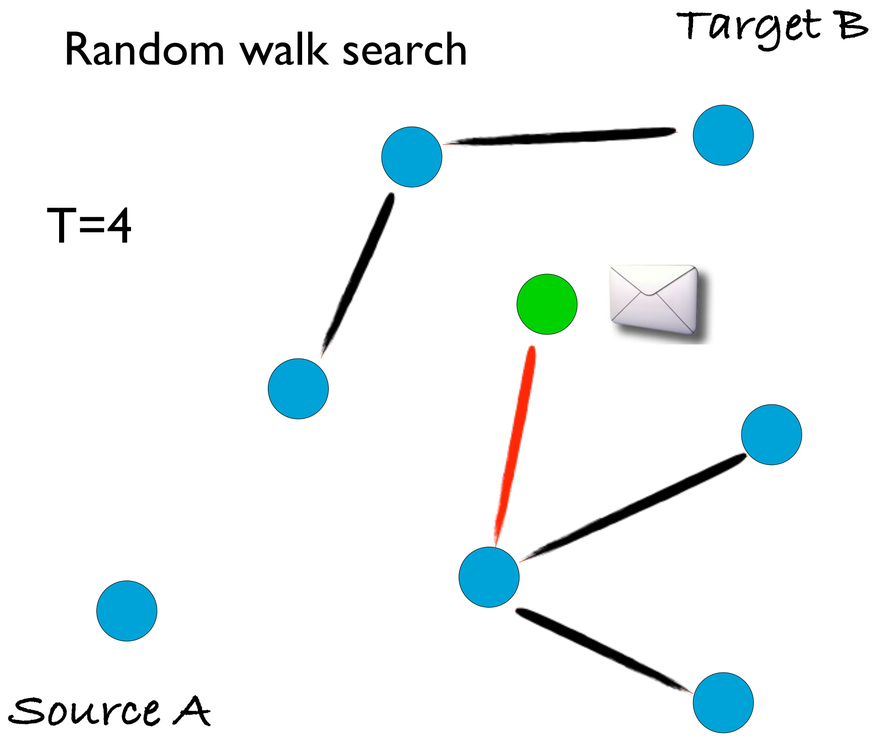
Random walk on a temporal network: At each time step, the letter takes one available link at random

Dynamical processes on temporal networks

- Process dynamics
- Time-varying network

→ Time scales coupling

Random walk search



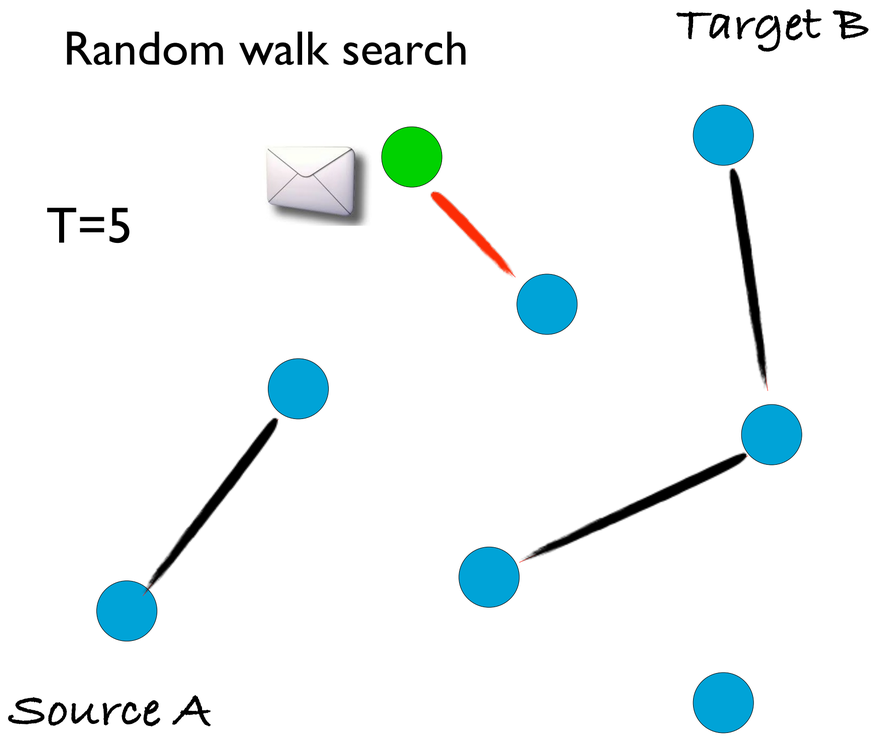
Random walk on a temporal network: At each time step, the letter takes one available link at random

Dynamical processes on temporal networks

- Process dynamics
- Time-varying network

→ Time scales coupling

Random walk search



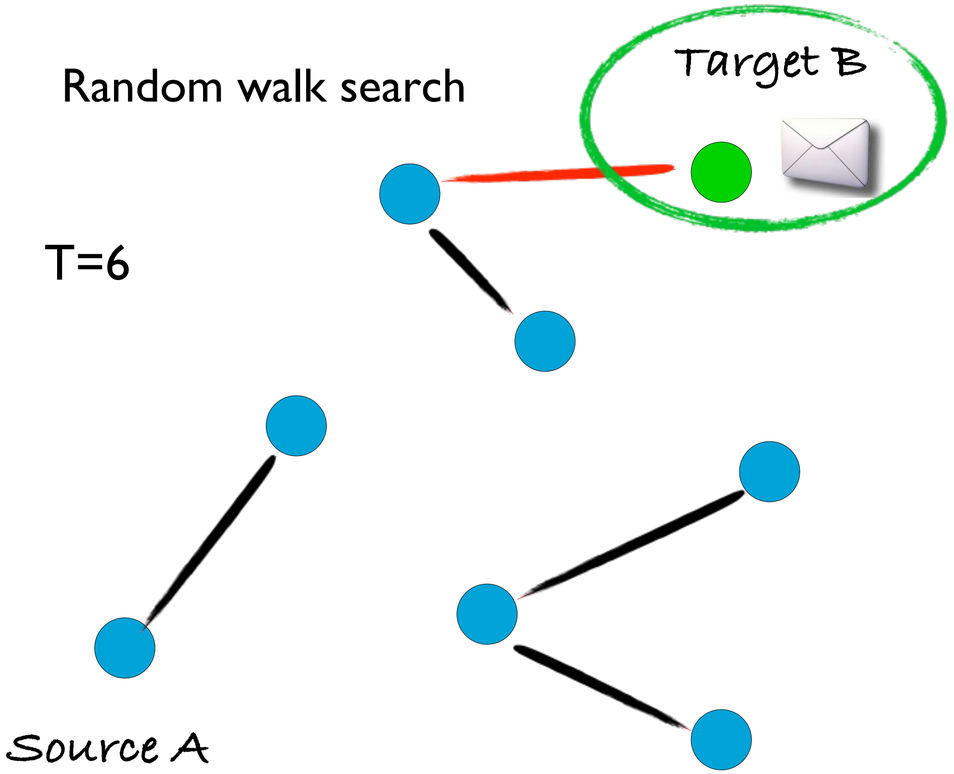
Random walk on a temporal network: At each time step, the letter takes one available link at random

Dynamical processes on temporal networks

- Process dynamics
- Time-varying network

→ Time scales coupling

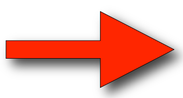
Random walk search



Random walk on a temporal network: At each time step, the letter takes one available link at random

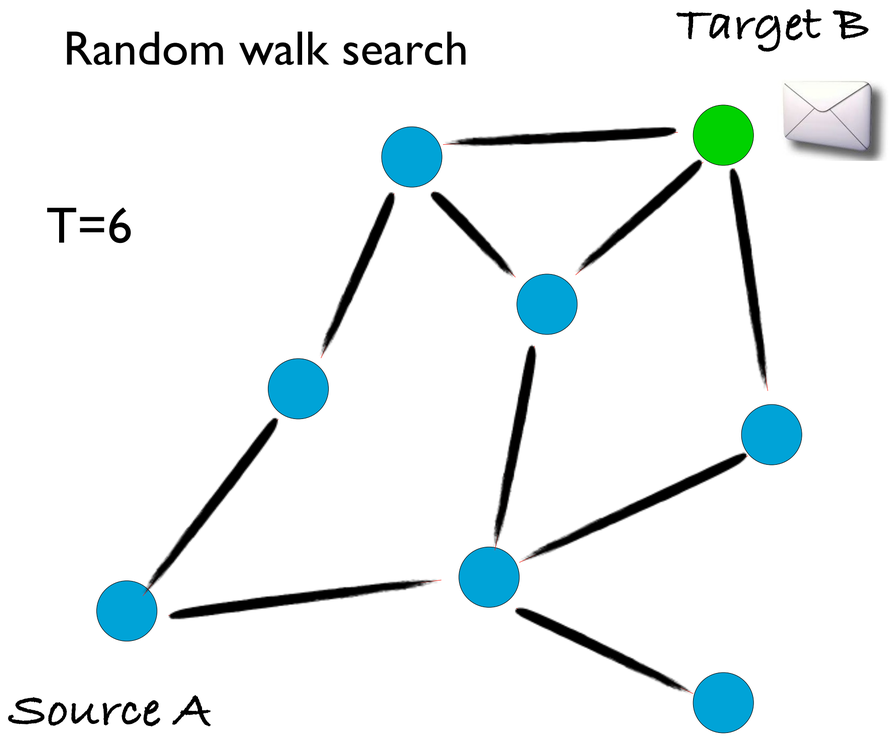
Dynamical processes on temporal networks

- Process dynamics
- Time-varying network



Time scales coupling

Random walk search



On a static network,
more links are available:
Very different process

Things to remember:

- Difference between dynamics ON and OF networks
- Definition of stochastic process on networks
- Examples of spreading phenomena, temporal networks
- How a stochastic process unfolds on temporal networks