

Networks Structure and Dynamics

13. Dynamics of links in contact networks

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Dynamical aspect of networks

Motivation

- Development of wireless devices
- A lot of new open dataset
- Dynamics ON and **OF** the network
- New structural properties
- Redefining usual metrics (graphs)

Issues

- How acquire knowledge from this object? (**measure**)
- Which notable properties? (**analyze**)
- *Which models best capture those properties? (**modelling**)*

Outline

- 1 Object under investigation
 - Mobile Networks
 - Markovian models
 - Dataset
- 2 Analyzing the dynamics
 - Methodology
 - Dynamics of the links
 - Impact of the markovian model
- 3 Conclusions and perspectives

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Mobile Networks

The networks under investigation

- Mobile equipments → moving entities
- Link = proximity between nodes of the network
- Creation and deletion of links over time

⇒ A good tool to describe such an object: *evolving graphs*

Relying on properties of the dynamics

- Propose efficient communication protocols
- Secure the robustness of communication networks

⇒ Need of (new) tools to analyze, model, etc.

Goal

The existing :

- Studies analyzing mobile networks [CHA07, TOU09, ...]
- Few models but recently: [CLE08, CLE09]

Used to study diffusion protocols:

- *flooding* protocol [BAU09, CLE10]
- *push* protocol [CLE13]

In this course: is the model realistic?

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- *push* protocol [CLE13]

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Models for evolving graphs

Background :

- **Evolving graph** model: recent [FER02]
- Evolving graph = Succession of distinct graphs G_0, G_1, \dots with V given
- Capture all types of dynamics

Variant of edge-markovian evolving graph:

- Temporal dependency in the evolution of the graph
- G_{t+1} determined by G_t and 2 parameters:
 - p : probability of creation of a *non-existing* link
 - d : probability of deletion of an *existing* link

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Example

Example with 4 nodes, $p = 0.3$, $d = 0.2$ and 5 time steps.

1	3	2	3
1	4	1	3
2	3	1	2
2	3	3	3
2	4	1	2
2	4	4	4
3	4	1	3

- 1st and 2nd column : identifiers of nodes involved in the contact
- 3rd column : starting time of contact
- 4th column : ending time of contact

Advantages / drawbacks

Interest is twofold:

- $\forall G_0, p, d$: converge towards an Erdős Rényi graph with $\hat{p} = \frac{p}{p+d}$
- Few parameters \implies theoretical results

But it is also its weakness:

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But it is also its weakness:

- 2 parameters to rule **all** creations/deletions
- Suppose that those 2 values are representative for the l'**entire** evolution of the de network

Methodology

Goal of the course:

Conduct a study to see if it is true.

- Analyze properties of the dynamics as observed in several dataset
- Comparison with the markovian model

Elements of response

- Yes for [WH11] (and [VOJ11]) but ...
- ... study over 1 dataset
- ... the criteria is weak: time needed to flood the network

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Rollernet

- Rollerblade tour in Paris
- Date : August 2006.
- Duration : 3h with a break (30 min) covering approx. 30km,
- Location : street of Paris
- Technology : *iMotes* (bluetooth)
- Size : 62 participants
- Frequency : every 15s.

Infocom06

- Experiment made during Infocom conference at Barcelona.
- Date : April 2006
- Duration : 3 days
- Technology : *iMote*
- Size : 98 iMotes (78 participants, 17 static, and 3 in elevators)
- Frequency : every 120s.

Sociopattern

- Exhibition in at a gallery (deseases propagations).
- Date : 2009
- Duration : 3 months
- Technology : *radio bagdes*
- Size : 88 to 410 (depends on the day)
- Frequency : every 20s.

6 case studies

Dataset	RollerNet	Infocom05	Infocom06	HT09	Socio	PMTR
Duration	3 hours	4 days	4 days	2,5 days	1 day	10 days
Participants	62	41	98	113	151	44
Contacts	60 146	17 682	148 784	9 865	2 051	11 895
Frequency (sec.)	15	120	120	20	20	1

For each:

- "Physical" contact network among individuals
- Each individual is equipped with a sensing device
- Detection between devices if proximity between individuals (2 to 10 m.)
- Frequency of detection varies, as well as duration of the experiments

In the rest of the presentation, 3 dataset only:

- RollerNet
- Infocom06: **similar to** Infocom05
- SocioPattern: **similar to** HT09 **and** PMTR

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Methodology

For each dataset and for each time step

- Fraction of created links (over possible new links)
- Fraction of deleted links (over existing links)

Corresponds to the parameters p and d of the model

Analyze :

- Evolution over time
- Distribution of the values
- Generation of artificial graphs according to the markovian model
- Comparison between real/artificial graph

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Created links

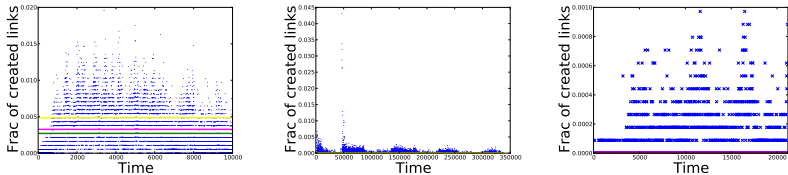


Figure : Evolution of the proportion de created links over time

Results

Created links

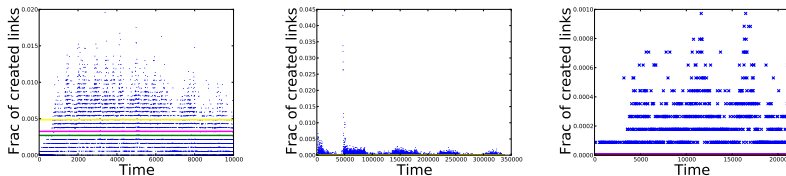


Figure : Evolution of the proportion de created links over time

Results

- RollerNet: notion of average is relevant
- Infocom06, SocioPattern: wide range of values
- Infocom06, SocioPattern: average, median and 75th percentile overcome by weak values
- \implies Infocom06, SocioPattern: non realistic

Deleted links

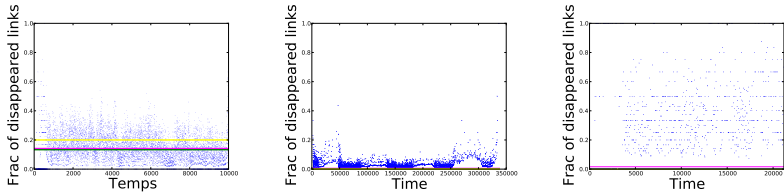


Figure : Evolution of the proportion of deleted links over time

Results

Deleted links

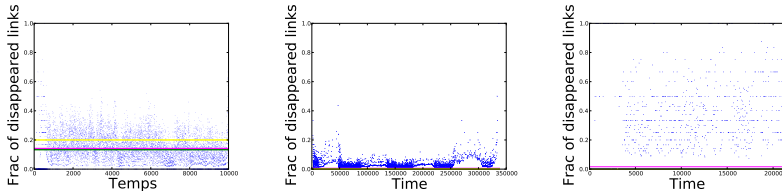


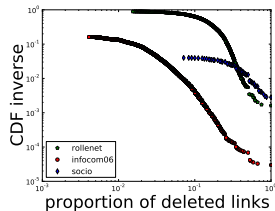
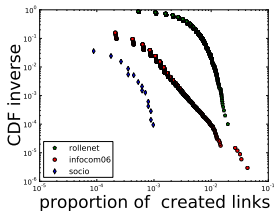
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Results

- Same observation but amplified
- Range of values is covered ($[0 : 1]$)
- Particular case for $d = 1$

Distribution of p and d values

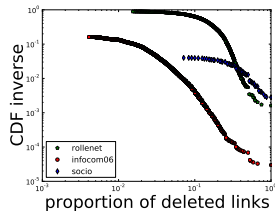
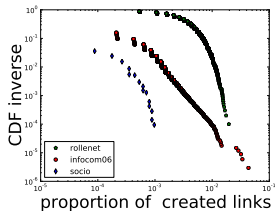
Dataset	RollerNet	Infocom06	Socio
Fractions of created links (average)	3.2 (10^{-3})	9.5 (10^{-5})	9 (10^{-6})
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Results

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Results

- Clearly heterogeneous for Infocom06
- and on several order of magnitudes
- RollerNet: sudden slope around the average value

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Methodology

So far:

- Studied the dynamics related to creation and delation of links
- Provided evidences that the models *is probably not suited* to particular dataset

How to demonstrate that the model is not pertinent?

Methodology

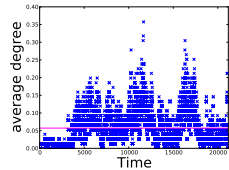
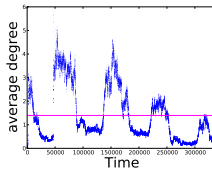
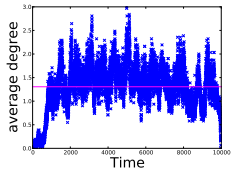
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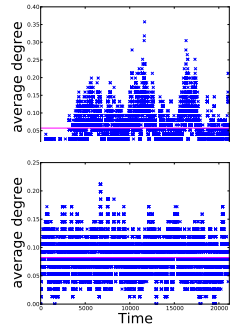
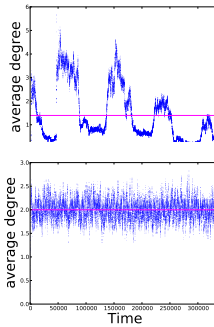
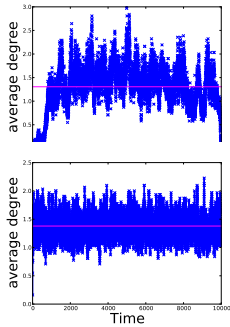
- Choose an external criteria (ie not the fraction of created and deleted links) ...
- ... but close enough the meaning of p and d (for fairness)
- Compute the value of the criteria for the real and the artificial graphs.
- Comparison between real/artificial graph.

Evolution of mean degree



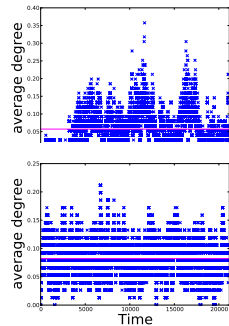
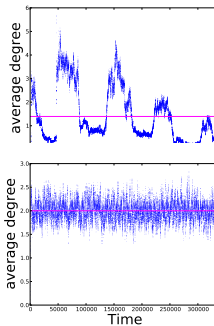
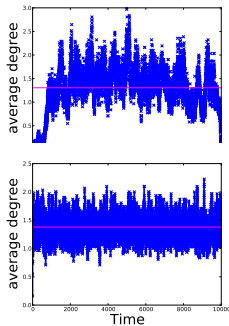
Results

Evolution of mean degree



Results

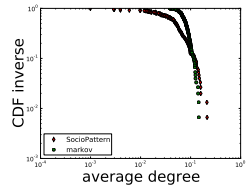
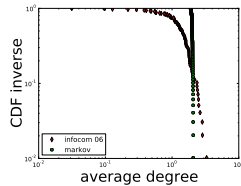
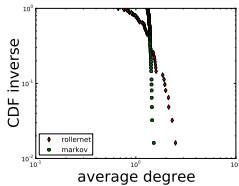
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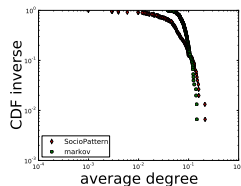
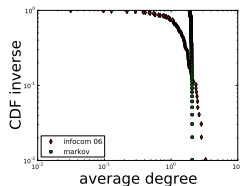
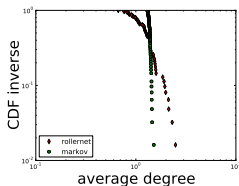
- "Uniformization" for Infocom06 and SocioPattern (not the same range of values!)
- Seems to have little impact on RollerNet
- Except at the beginning (expected)

Average degree distribution



Results

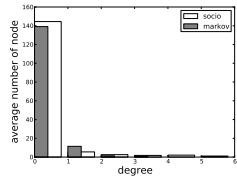
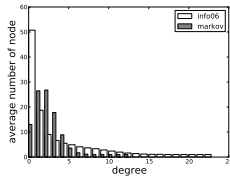
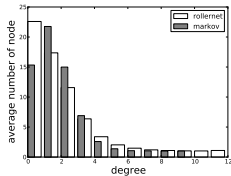
Average degree distribution



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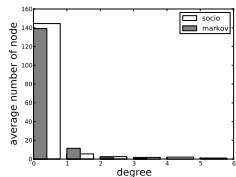
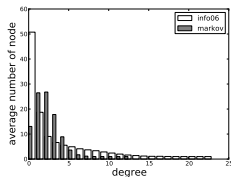
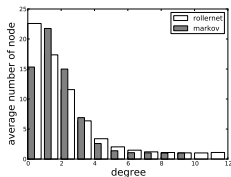
- Infocom06: clear differences between model and real data (expected)
- RollerNet and SocioPattern: also different, although less obvious

Degree distribution



Results

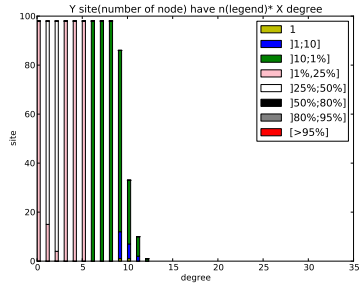
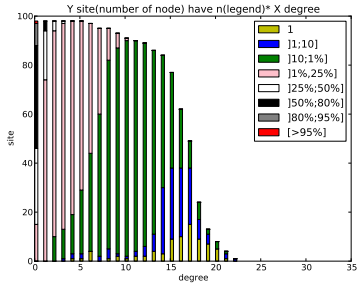
Degree distribution



Results

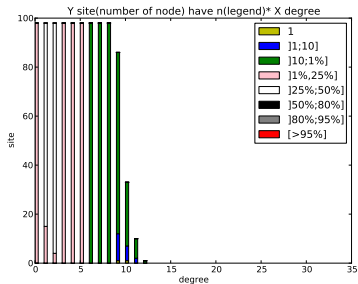
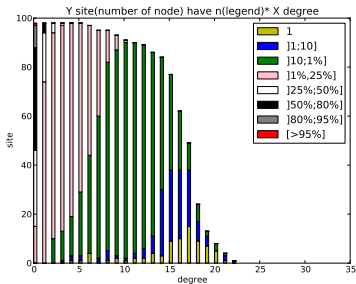
average value relevant \nrightarrow the model reproduces well the **global** properties of the networks

Distribution and frequency of the degrees (Infocom06)



Results

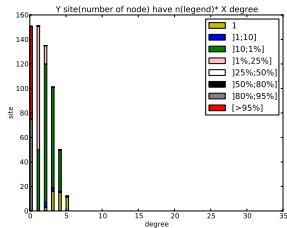
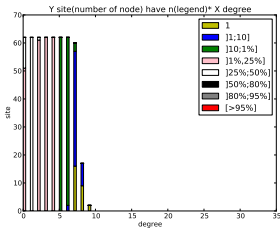
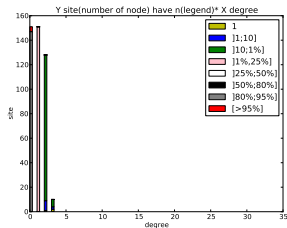
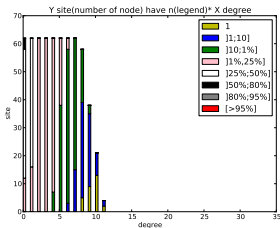
Distribution and frequency of the degrees (Infocom06)



Results

- Nodes are more degree-stable in real networks
- Small degrees are over-represented
- No node with the same degree more than 50 % of the time in the model*

Distribution and frequency of the degrees (RollerNet, SocioPattern)



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Conclusions and perspectives

Conclusions

- Confrontation markovian model vs. real data
- Hypothesis of homogeneity does not stand in most of the cases
- Even in favourable case, it **does not reproduce the dynamics**
- *Still remain useful* : cf [WH11, VOJ11]

Perspectives

- Consider other way to define p and d (following an heterogeneous distribution? different for each nodes? depending on the graph state? ...)
- Study refined properties (repartition of connexions)
- Analyze correlation between creations and deletions
- Take into account the local density
- Study *gossip* protocols of diffusion on **real data**

[WCdA11, CMM⁺08, CPMS09, CMM⁺10, CCD⁺13, TLB⁺09, VP11, CHC⁺07, Fer02, BCF09]



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