Infectious disease spread on a data-driven dynamic contact network: an application for nosocomial infections

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- Introduction
- Rationale
- Experiment during a medical convention
- Experiment in a school
- Perspectives

Introduction

- Most infections are transmitted during close contacts (patients, health care workers, visitors or environment)
- Measuring contacts is important:
  - To understand the spread of pathogens
  - To improve the prevention and control of infections
- Little is known about the contact patterns underlying the spread of infections
- Using questionnaires for contacts measurments is difficult in practice and has limitations (observational bias)
- RFID technology allows studying dynamical contacts networks

Rationale

The start of the story

Chapter 1

Risk of Influenza-Like Illness (ILI) in an Acute Health Care Setting during the Community Influenza Epidemics in 2004-2005, 2005-2006 and 2006-2007

ICAAC 2009, In press

Objective

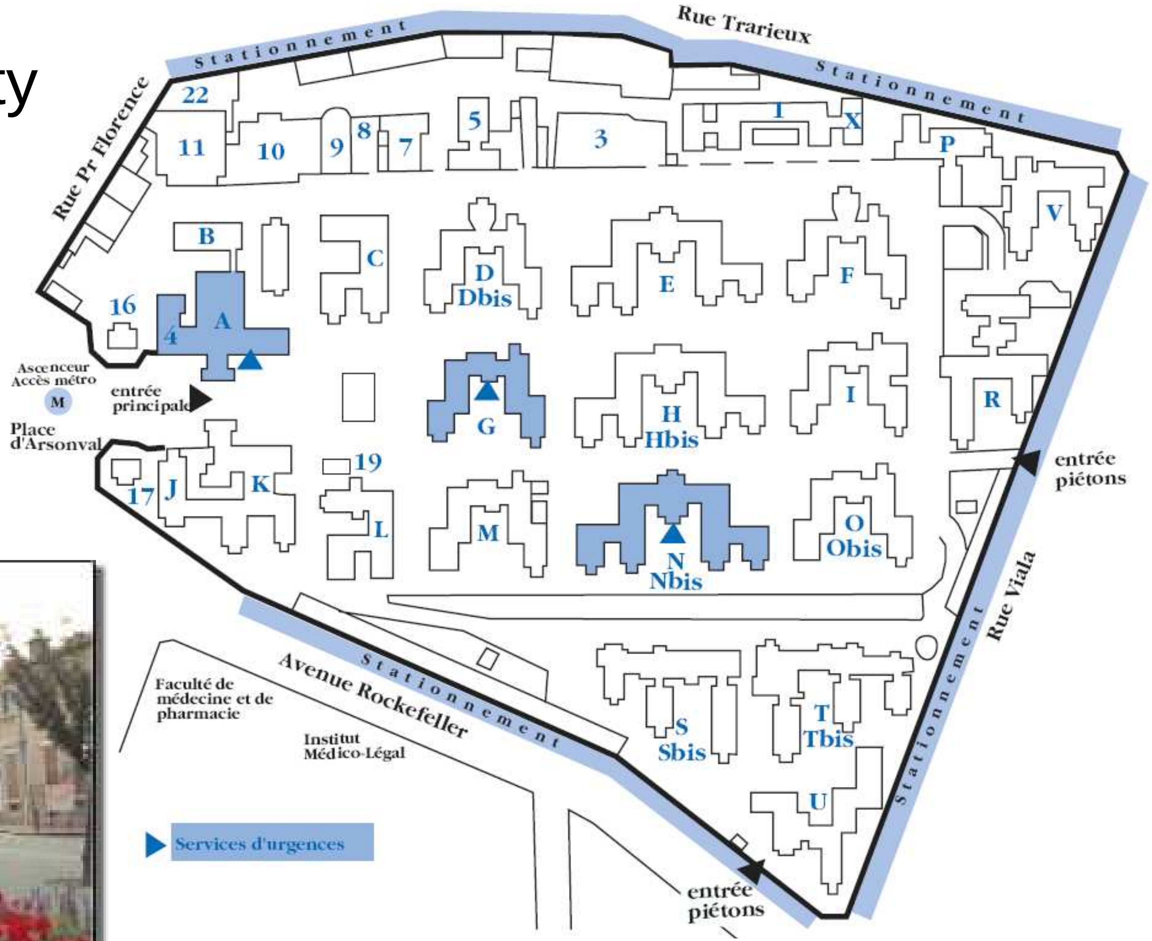
- To estimate prospectively the risk of ILI for hospitalized patients compared to the community in short stay units by level of exposure inside the hospital.

OR

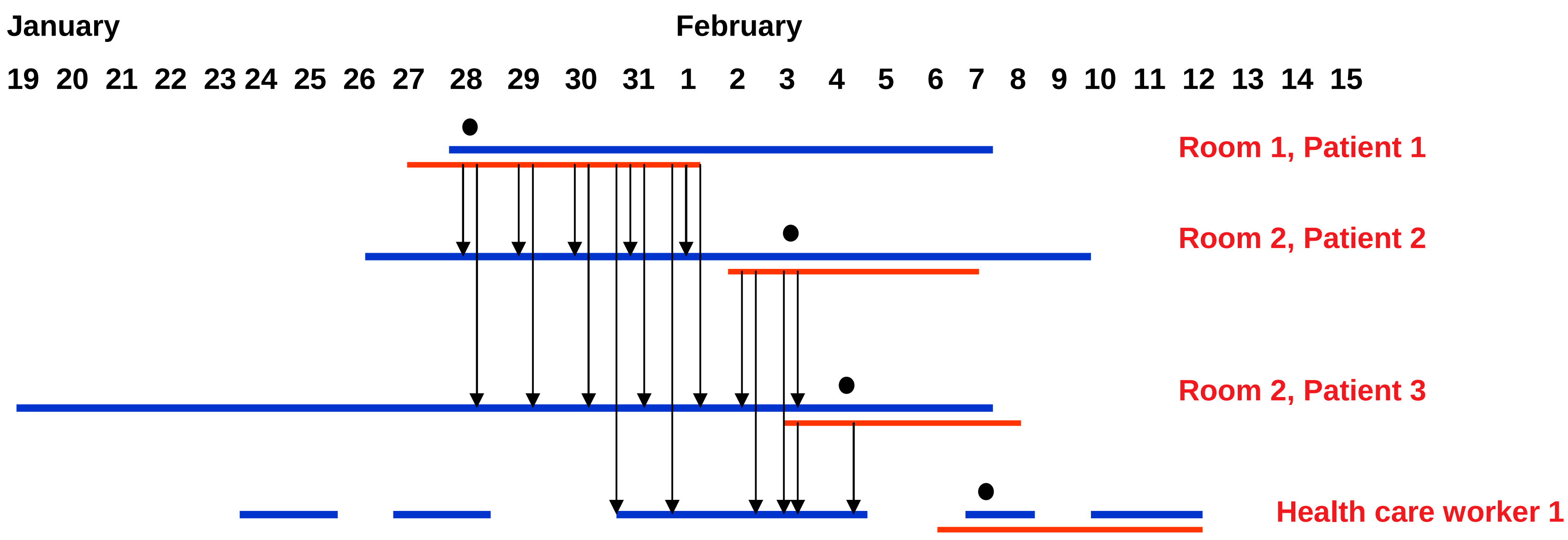
- Is the hospitalization a risk factor for ILI?
- Can we stratify this risk by level of exposure?

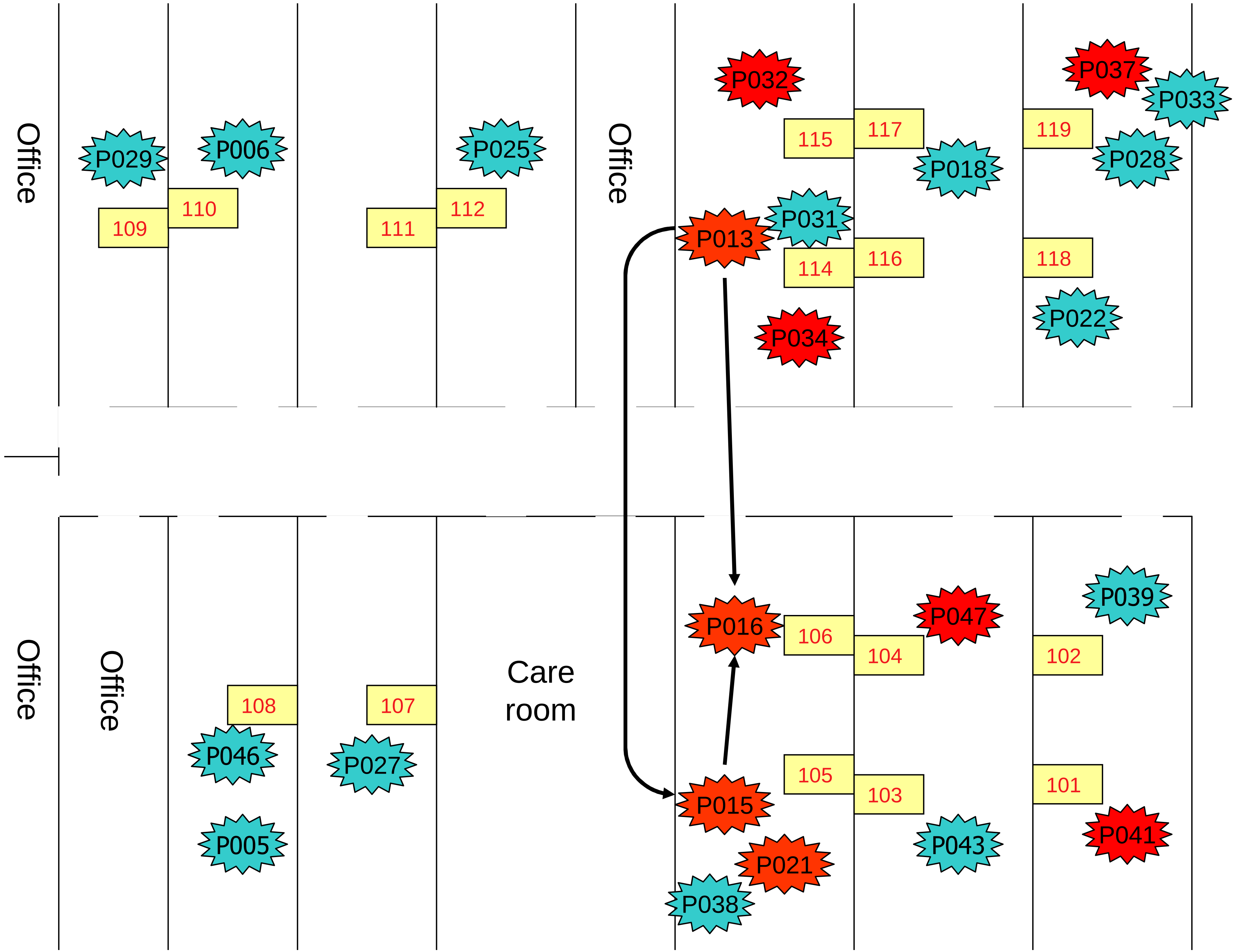
Methods (1)

Edouard Herriot University Hospital (Lyon, France)
Tertiary medical centre
1,100 beds,102 units
32 blocks



Exemple of flu transmissions in one unit (2004-2005)





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P031
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116
118
P022
P034
Office
Office
108
P046
P005
107
P027
Care room
P016
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P047
P039
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P015
P021
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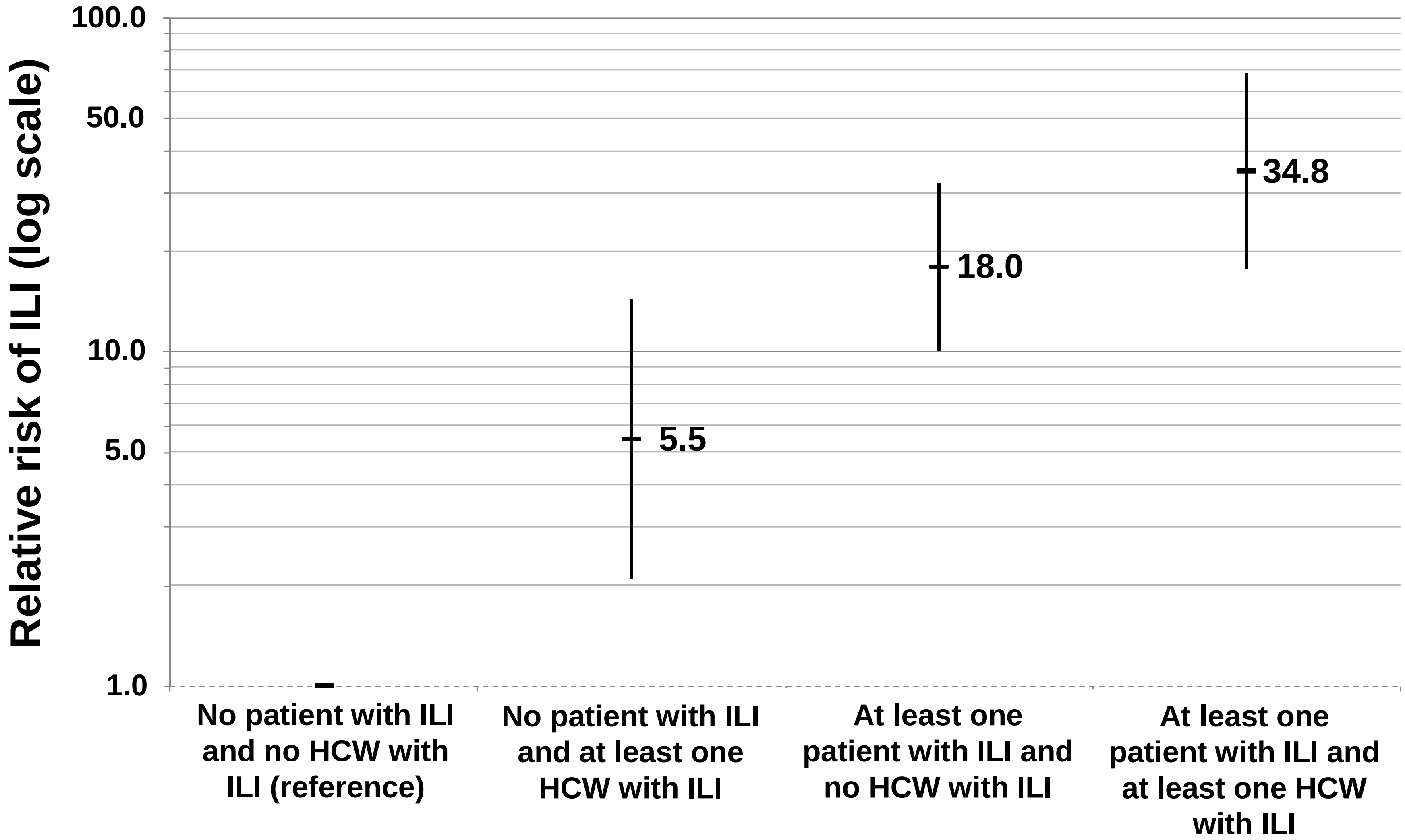
P041

Relative risk of HA-ILI by level of exposure



The story is going on…

Chapter 2

ENS LYON
LABORATOIRE DE PHYSIQUE

ISI
INSTITUTE
FOR SCIENTIFIC INTERCHANGE
FOUNDATION

CENTRE DE PHYSIQUE THÉORIQUE
DE MARSEILLE

Can we do better?

How can we improve the data collection and the data quality regarding time and place of flu transmission in the hospital?

↓

Measurement of individual contacts in the real life for epidemic modelization and evaluation of control interventions

↓

Measurement of contacts between individuals with electronic tools

From « conventional » epidemiology to computational epidemiology

New field in the clinical epidemiology specialty

A need of strong interactions with scientists from other domains such as physics, computer sciences, mathematics, etc.

Start of a collaborative project with ENS (Lyon), IPT (Marseille) and Institute for Scientific Interchange Foundation (Turino)

Objectives

- Comparing the spread of an infection between:
  - A static network of homogeneous contacts (HOM)
  - A static network of heterogeneous contacts (HET)
  - A dynamical network of heterogeneous contacts (DYN)
- Discussion on the use of this tool for exploring the transmission of nosocomial infections

Methods

Electronic tags

At low power level, the packet is received only by neighbouring tags

i.e. tags worn by persons in a close proximity within a 1-2 meters radius

This radius can been defined in order to reflect a close-contact situation during which infections can be transmitted

Electronic tags

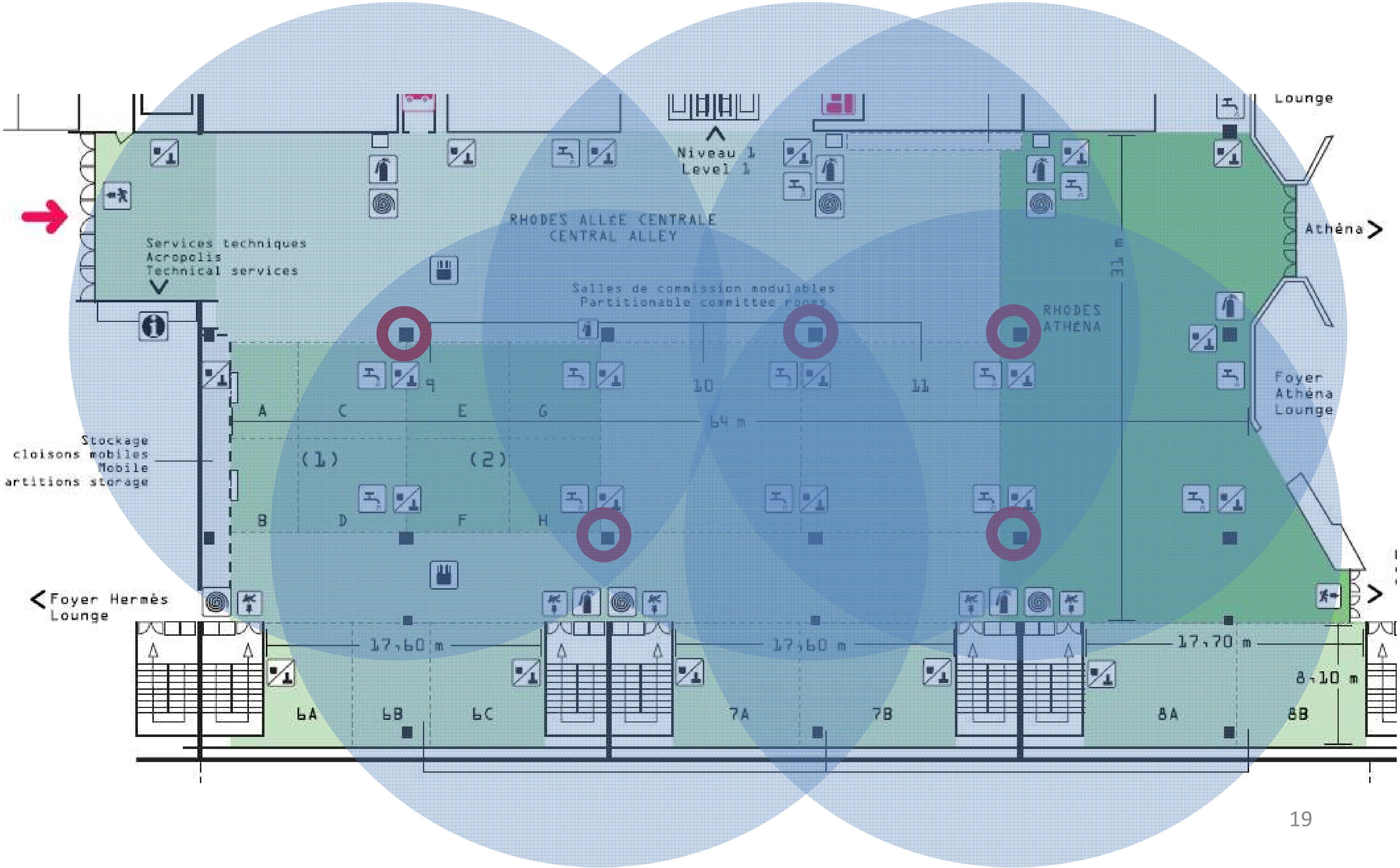
Methods

Emissions at large power are recorded by fixed antennas which can be used to estimate the location of the tag

Antennas transmit information about location of tags and contacts between tags on a server where data are stored

Annual congress of the French society of nosocomial infections - Nice Acropolis

Nice - Rhodes (2,000 m²)



Networks

- **DYN**amical : real (i.e. observed) temporal dynamic of contacts with their duration
  - A →→ B then B →→→→ C
- **HET**erogeneous: deleting temporal sequence of contacts but keeping contacts durations
  - A →→ B
  - B →→→→ C
- **HOM**ogeneous : deleting temporal sequence of contacts and **average contacts duration**
  - A →→→ B
  - B →→→ C

Epidemiological model

S → E → I → R

	Incubation	Contagiousness
Scenario 1	short	long
Scenario 2	long	long
Scenario 3 : flu	**short**	**short**
Scenario 4	long	short

Outcomes

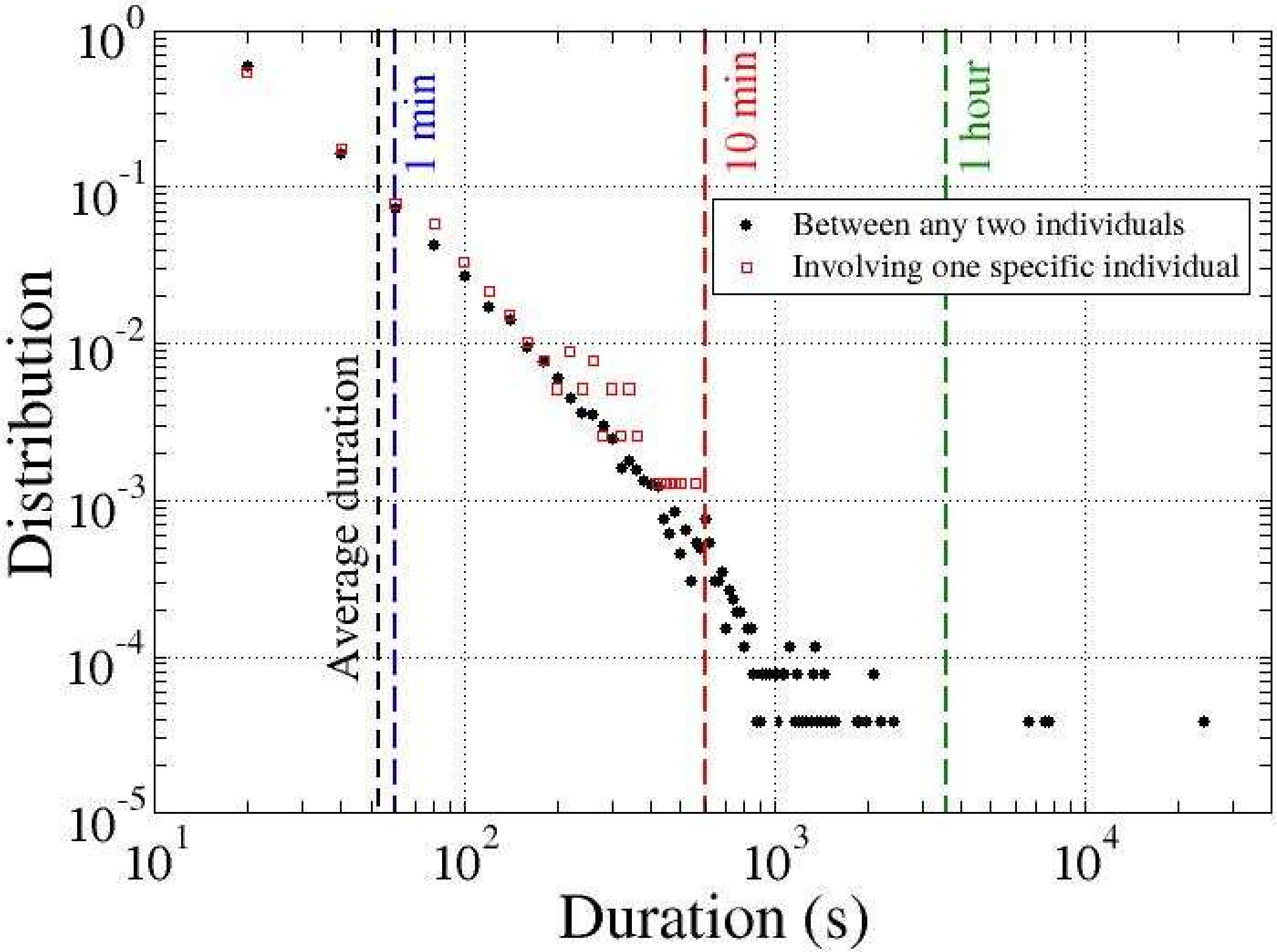
Comparison between networks:

– Final size of the epidemic
– Time of the epidemic peak
– R_0

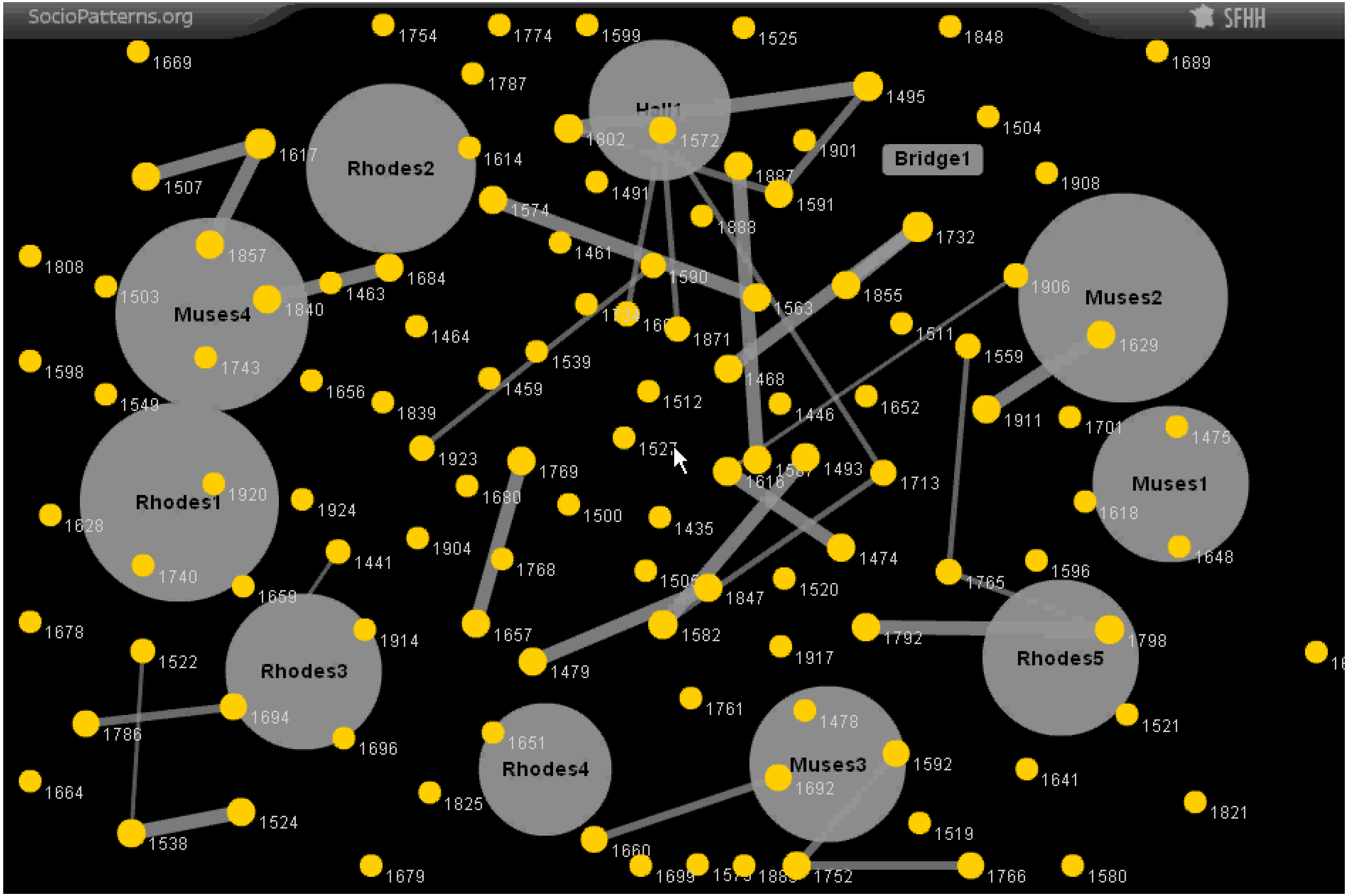
Results

- Individuals attending the 20th congress of the SFHH from 3rd to 4th June 2009 were asked to participate
- Face-to-face interactions between **402 individuals** out of 1,200 were collected during 2 days
- **26,040 contacts**
- Average duration: **54 seconds (20s – 2h max)**
- Large number of contacts of short duration
- Few contacts of high duration

Results (2)



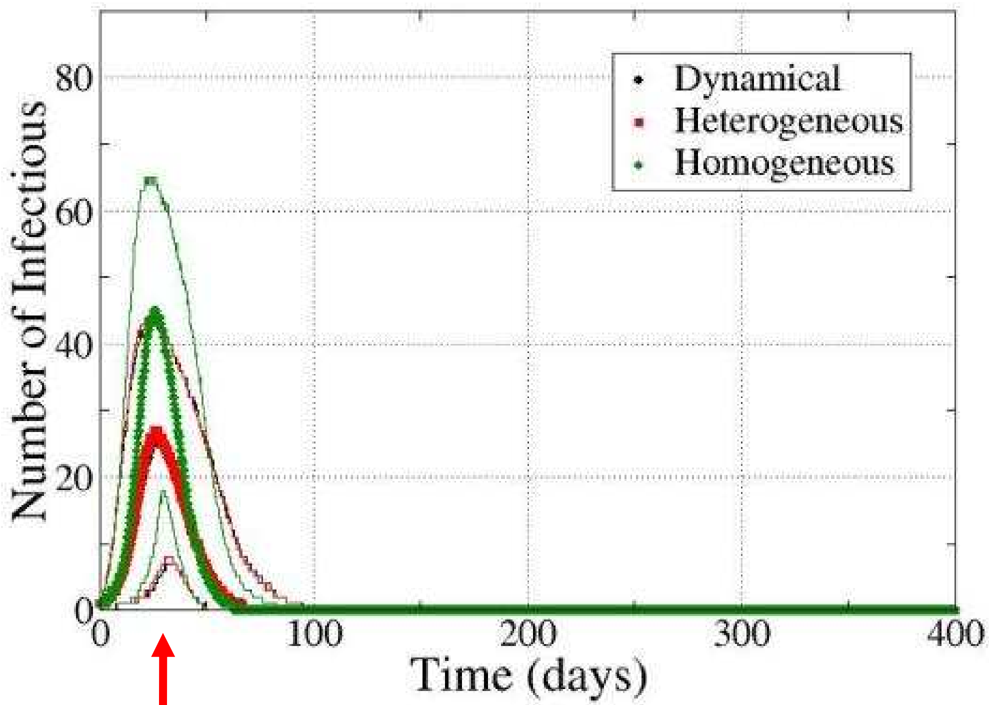
Distribution
Duration (s)
Average duration
1 min
10 min
1 hour
Between any two individuals
Involving one specific individual
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^1
10^2
10^3
10^4



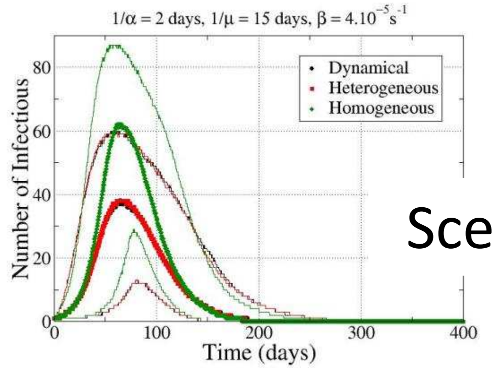
SocioPatterns.org
SFHH
Hall1
Rhodes2
Bridge1
Muses4
Muses2
Rhodes1
Muses1
Rhodes3
Rhodes5
Rhodes4
Muses3

Epidemic curves

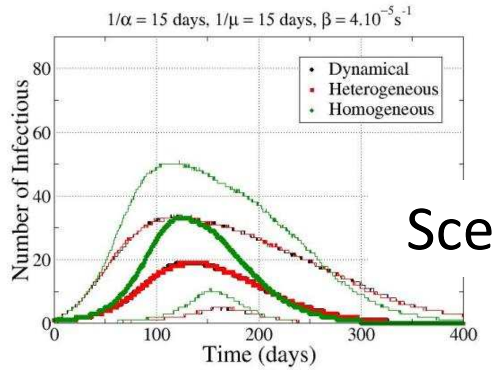
Scenario #3 (influenza)



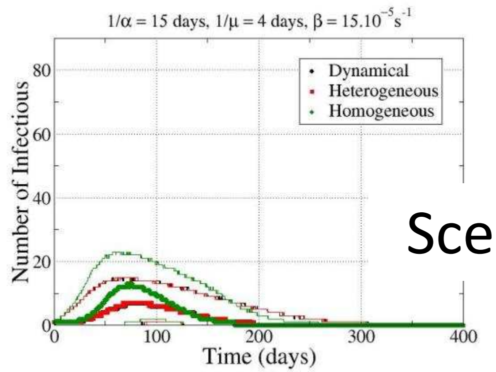
Peak: d29



Scenario #1



Scenario #2



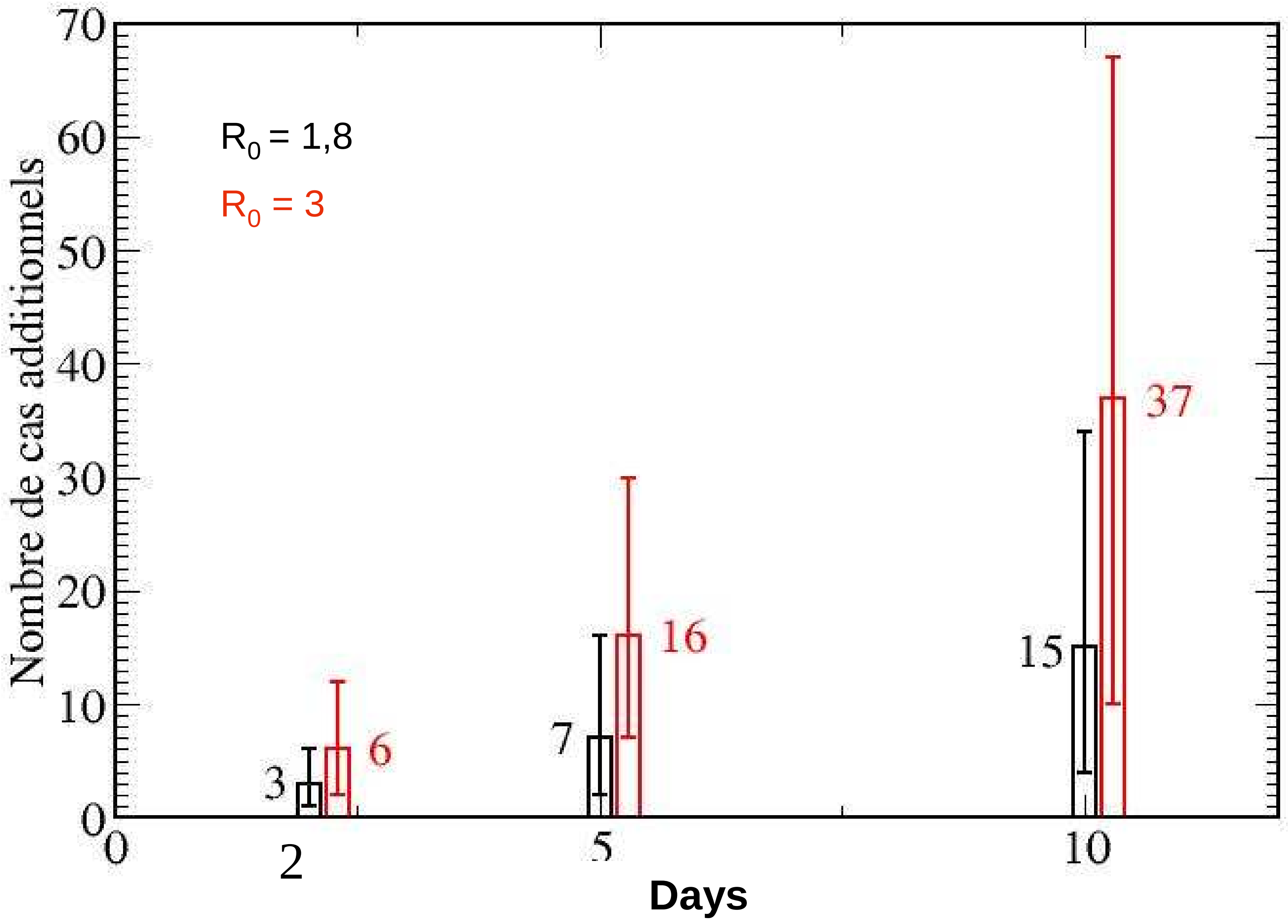
Scenario #4

Results

Scenarios	Network	% extinctions	1 - 10 cases (AR*≤2.5%) % of simulations	1 - 10 cases (AR*≤2.5%) # cases average	11 - 40 cases (2.5%<AR≤10%) % of simulations	11 - 40 cases (2.5%<AR≤10%) # cases average	40 cases (AR>10%) % of simulations	40 cases (AR>10%) # cases average
		Extinction					**Epidemic**	
#1	DYN	43.3	17.4	2.4	0.6	16.7	38.8	210
	HET	44.5	17.4	2.3	0.8	16.3	37.3	211
	HOM	39.0	11.1	2.0	0.1	13.8	49.8	287
#2	DYN	45.3	16.6	2.3	0.8	17.2	37.2	212
	HET	43.7	17.6	2.2	0.6	16.0	38.1	211
	HOM	37.8	11.5	2.1	0.2	15.6	50.5	287
#3 (flu)	DYN	44.8	18.2	2.4	0.8	15.8	36.2	209
	HET	44.7	17.2	2.3	0.7	16.0	37.5	210
	HOM	38.7	11.3	2.1	0.2	14.0	49.9	287
#4	DYN	45.3	16.7	2.4	0.5	15.4	37.4	210
	HET	45.1	16.4	2.4	0.8	17.0	37.7	212
	HOM	39.3	11.2	1.9	0.1	16.0	49.4	288

5,000 simulations

Estimation of H1N1 cases with 10 prevalent cases



Discussion

- In the 3 networks, an extinction of the infection is as frequent as an evolution toward an outbreak.
- A large difference of the disease spread was observed between HOM and the 2 HET and DYN networks with a systematically higher number of cases in the HOM network (i.e. assuming homogeneuous contact durations)
- Heterogeneities of contact durations between individuals was associated with a reduction of spread

Discussion

- The comparison of the spread between HET and DYN networks gives an idea of the effects of temporal constraints of contacts on disease propagation

- Application for health care situations facilitating transmission of infection : frequency, duration, and sequence of care

High resolution measurements of face to face proximity of children in a primary school : descriptive results

Chapter 3

Introduction

- Children are supposed to act as a reservoir for seasonal and pandemic respiratory infections or other infection (bronchiolitis, gastroenteritis)
- School closure has been proposed as an effective physical intervention in case of pandemic
- Collecting data on activities and interactions of children at school could help to better
  - describe contacts between children at school
  - understand the role of children in the transmission of respiratory infections

Methods (1)

- The study was conducted in a primary school in Lyon, France. October 1-2, 2009.
- 233 children in 10 classes. Each class has an assigned room and an assigned teacher. Age from 6 to 10 year old.
- A common playground outside the main building
- Lunches served in a common canteen

Methods (2)

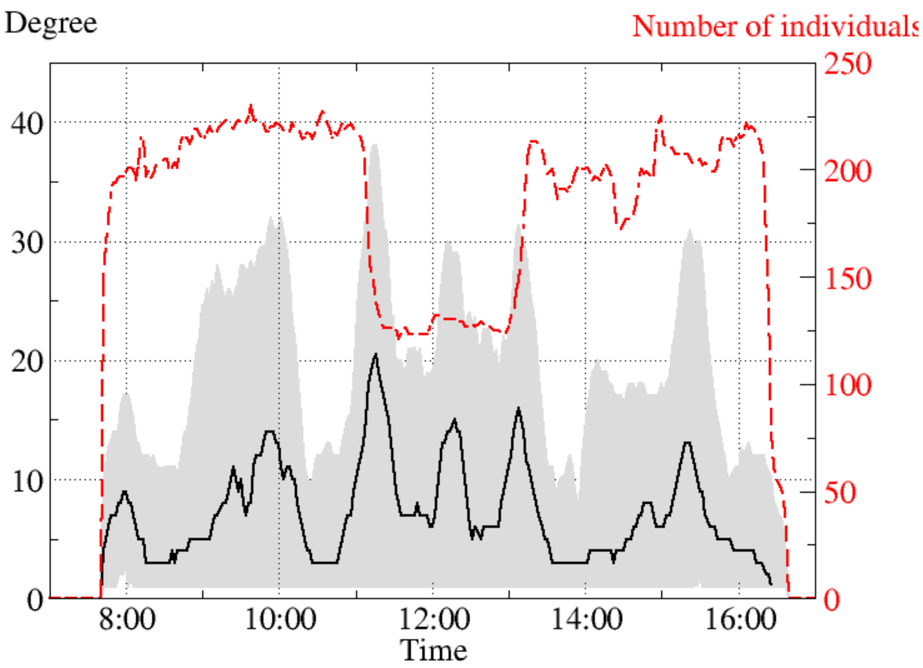
- From 08:45 to 17:20 on the first day and from 08:30 to 17:05 on the second.
- Contacts were not recorded outside of these time periods.
- RFID readers were installed in the various classrooms, in the canteen, the stairs and the playground, in order to collect the information about contact between RFID badges occurring in all these places.
- No information on contact events taking place outside the school was gathered.

Results

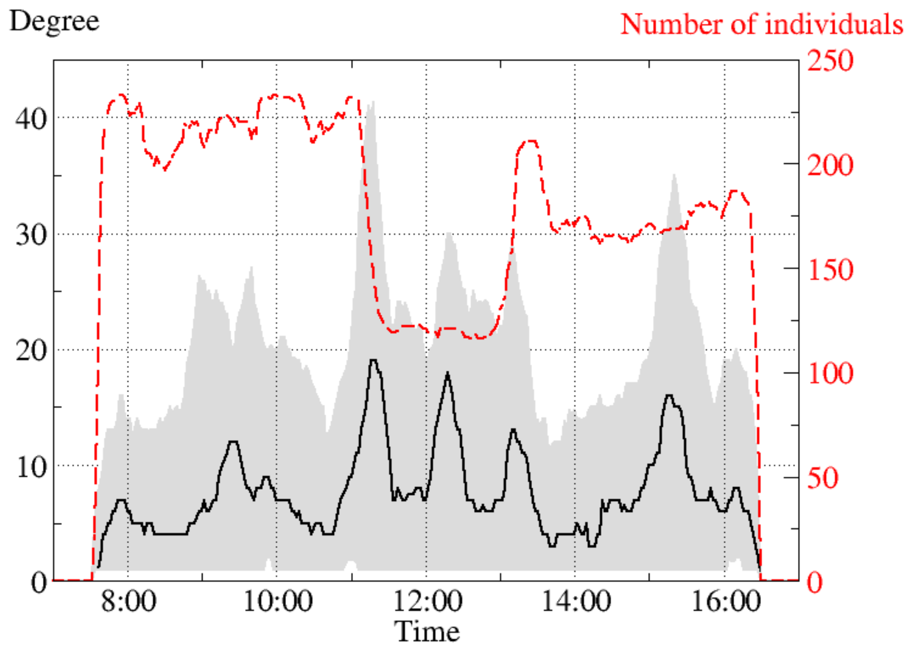
- Face-to-face interactions between 233 children of 10 classes and 9 teachers
- The collected data set is composed of **85,896** contact events between 242 individuals (42,115 contacts on Thursday and 43,781 on Friday) with an average of 177 contacts per individual per day
- The average duration of a contact is **33.6** seconds

Results

Day 1

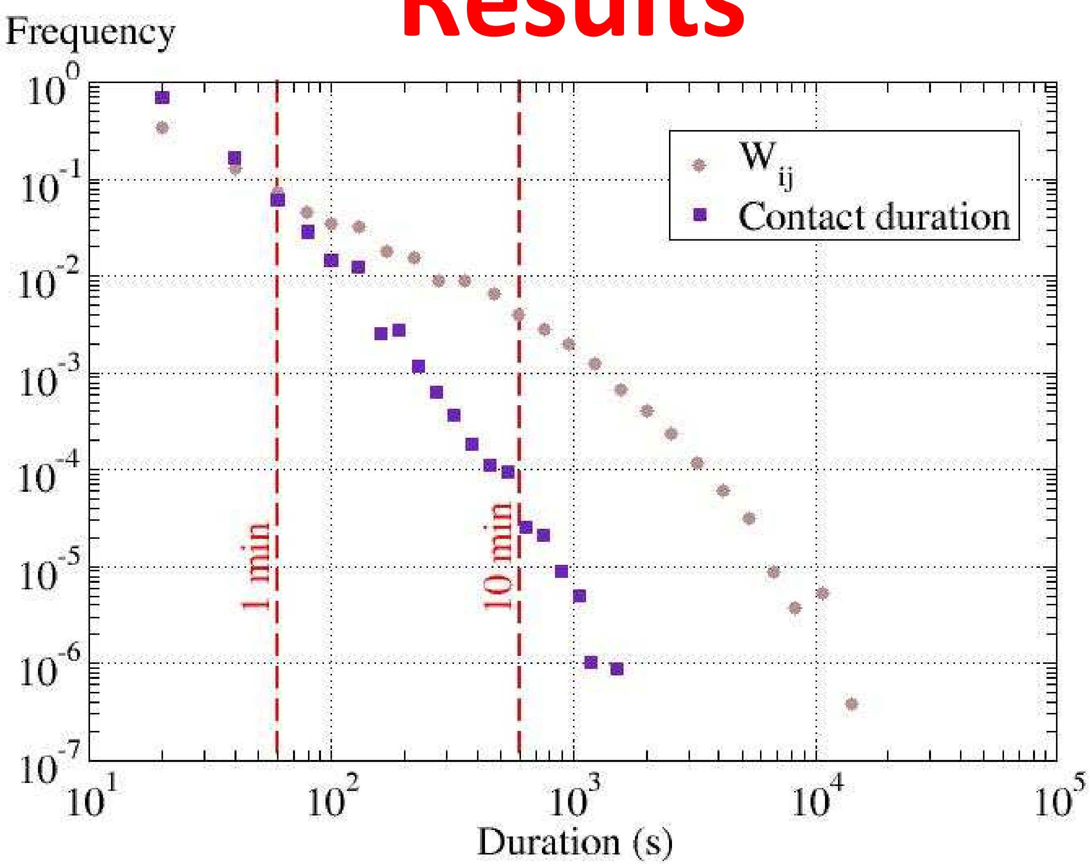


Day 2



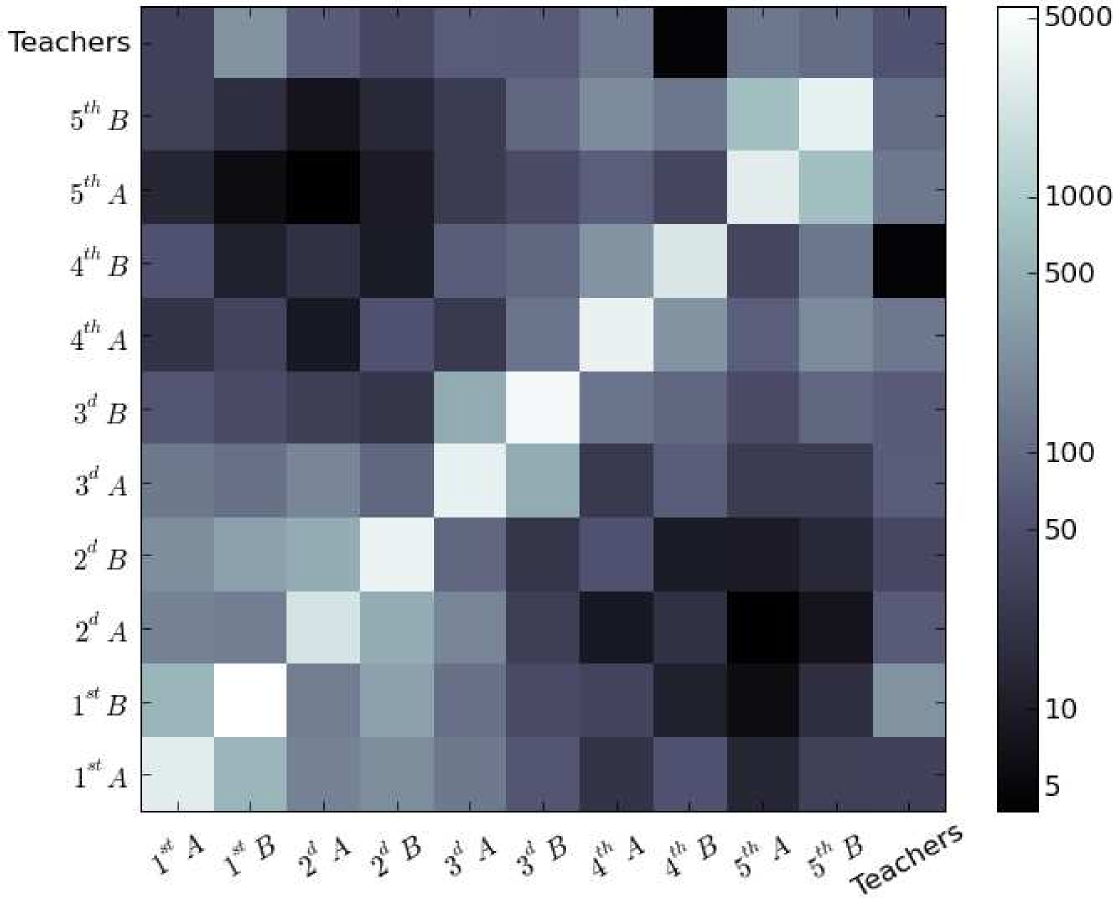
Number of children involved in contacts - Average number of contacts/child

Results



Log-log plot of the distribution of the contact durations and of the cumulated duration of all the contacts two individuals have over a day (W_{ij}). **82% of the contacts lasted less than 2 minutes, but more than 2% lasted more than 10 minutes.** For the cumulated durations, 62 % of the total duration of contacts between two individuals during one day last less than 2 minutes, but 12% last more than 10 minutes and 0.75% more than 1 hour.

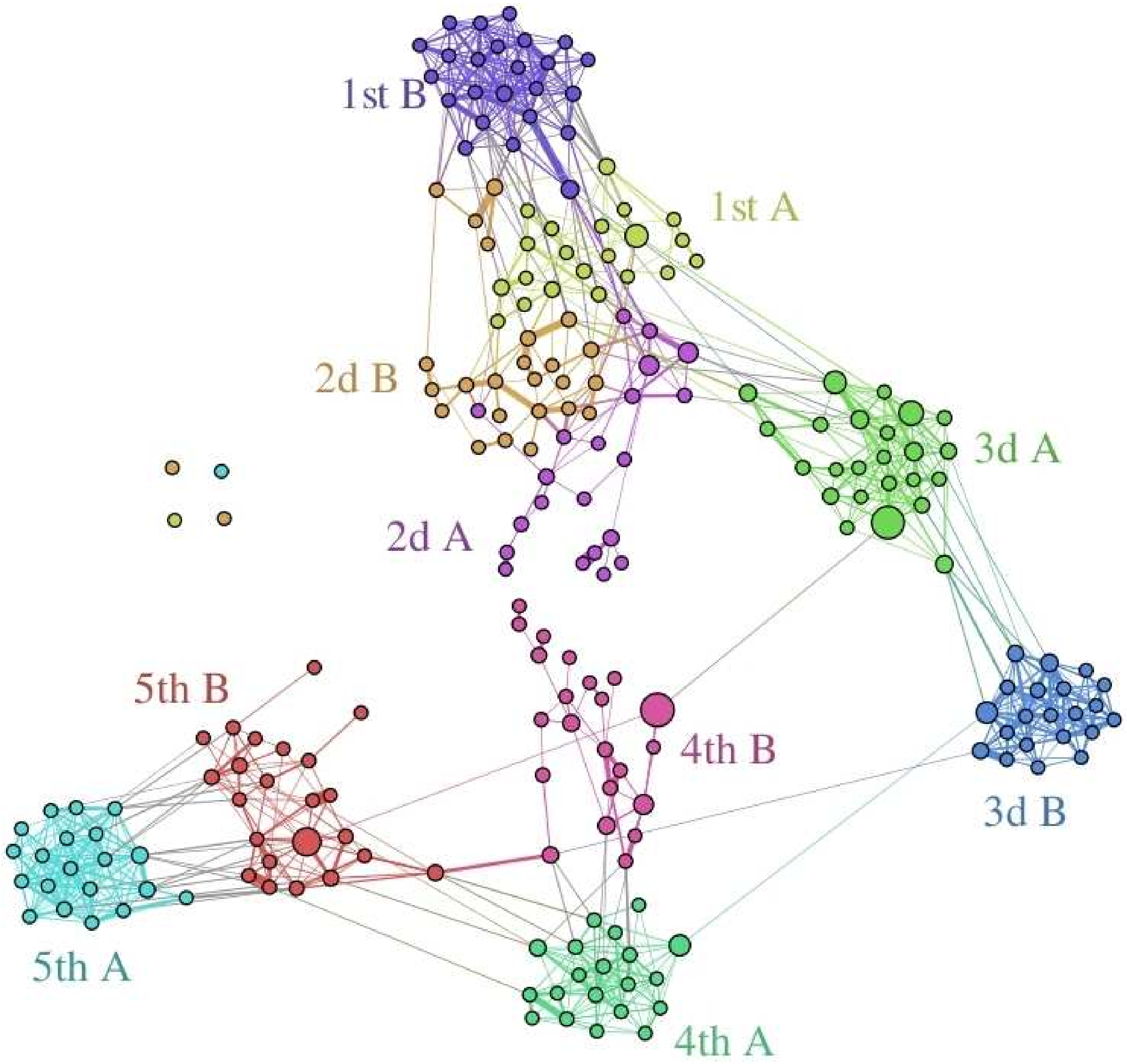
Results



Age : 6Y 7Y 8Y 9Y 10Y

Results

Network of contacts aggregated over the first day.



Time of epidemic peak (days)

	R_0 = 1.5	R_0 = 2.0	R_0 = 2.5
I_*=1	26	22	17
I=5	19	14	12
I=10	13	12	11

*** Number of prevalent cases**

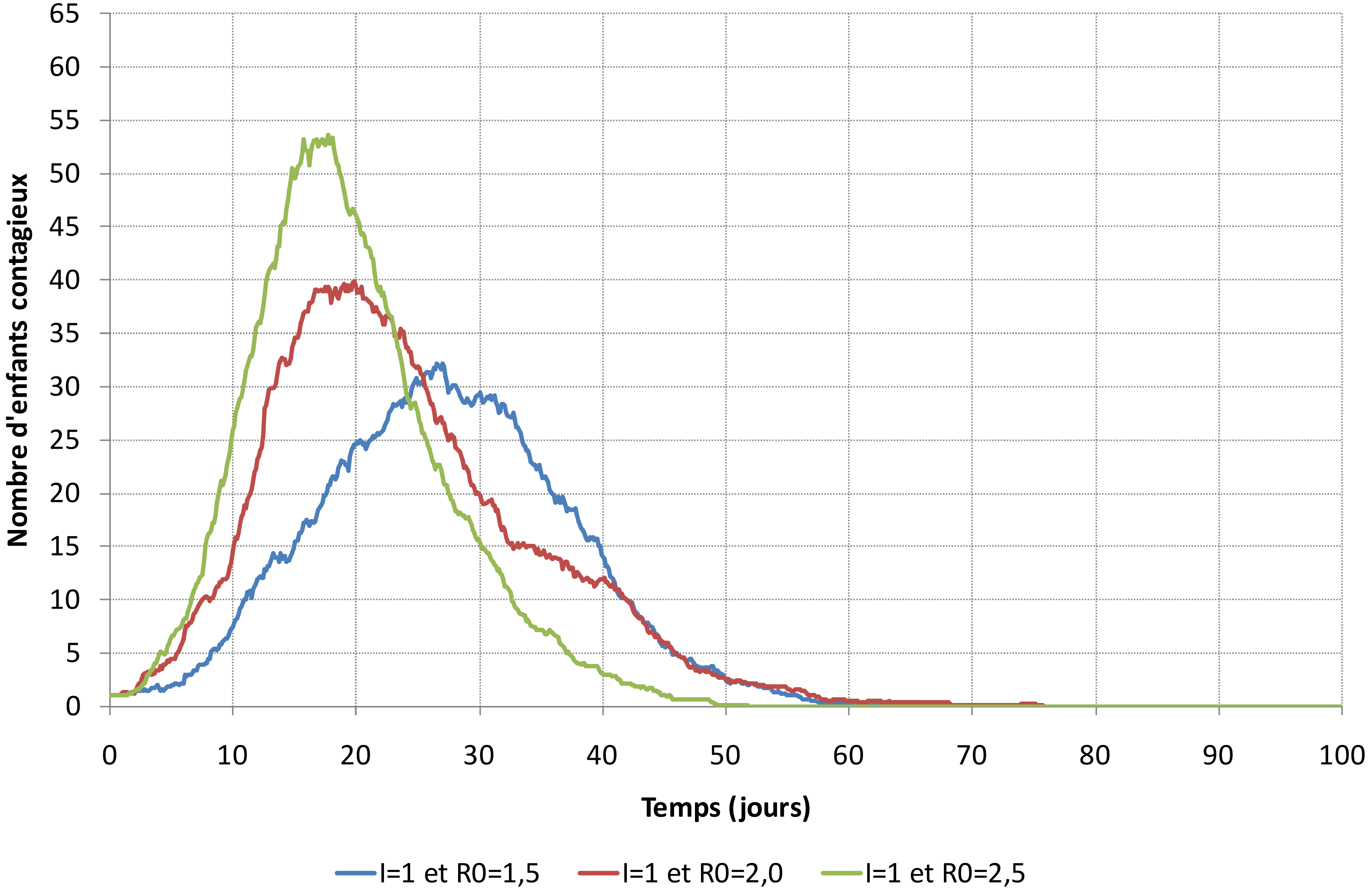
Number of infected children at the time of epidemic peak

	R_0 = 1.5	R_0 = 2.0	R_0 = 2.5
I=1	42	52	64
I=5	45	57	68
I=10	51	61	65

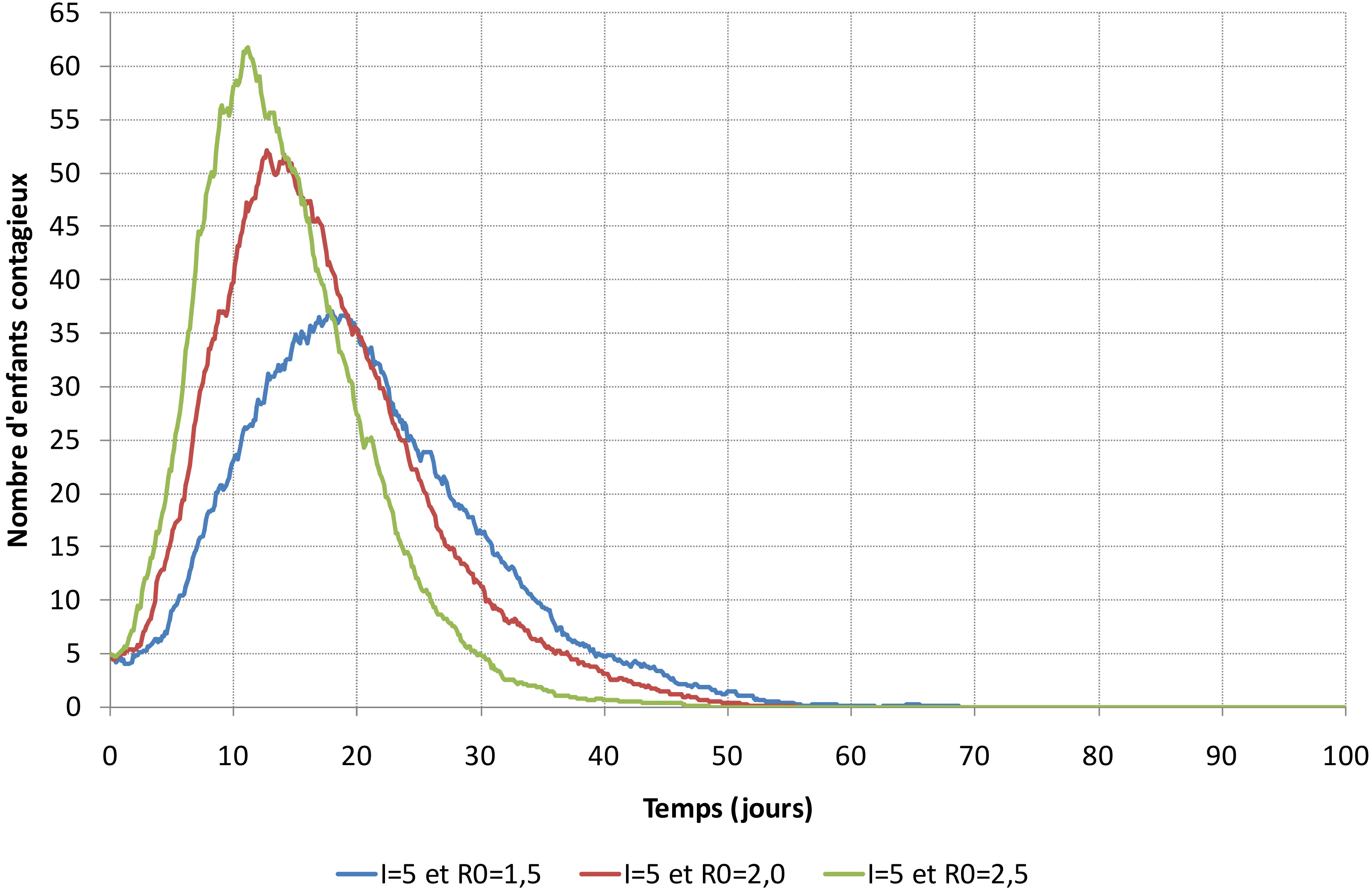
Duration of the outbreak (days)

	R_0 = 1.5	R_0 = 2.0	R_0 = 2.5
I=1	78	58	57
I=5	65	66	53
I=10	58	51	52

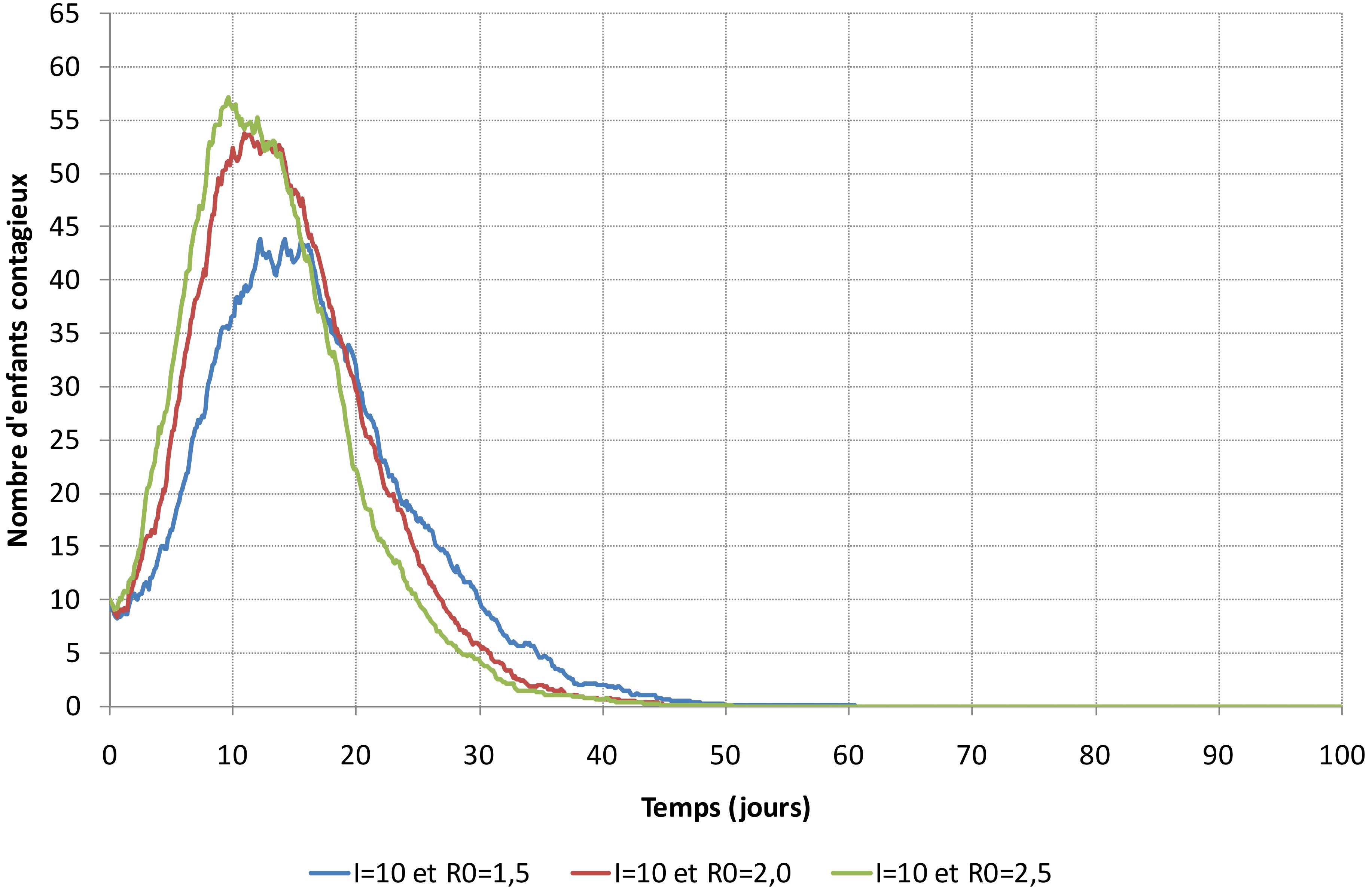
1 infected child at T0



5 infected children at T0



10 infected children at T0



Discussion

- Strong heterogeneity in contact duration between two individuals
- 62% of contacts between 2 individuals lasted less than 2 mn during a day
- Contact numbers and durations related to the class and age structure
- More numerous contacts among children of the same class or of close ages
- Simulations of outbreaks are planned taking into account vaccination coverage

Perspectives for nososocmial infections

Application in an university hospital

Strengths : geographic distribution known, characteristics of patients and HCW well documented (age, vaccination, underlying diseases, immunosuppression), nosocomial infection as a national priority, 6 years of ongoing flu surveilllance, adjusted analysis (?)

Limits : sample size, visitors, motivation of HCW, <u>validation of the contacts</u>

Experiment in a geriatric unit at
Edouard Herriot University Hospital

December, 6 to December 10, 2010

Chapter 4

Perspectives

- Such a data collection infrastructure could be highly effective.
- Strong and new collaborations between scientists: physicists, epidemiologists, computer scientists, and others.
- Application to other situations associated with a risk of infection where persons are in close interactions:
  - Schools , colleges, universities, etc.
  - **Hospitals (intensive care units, emergency units)**
  - Work places
  - …

Other fields than nosocomial infections : organisation of care, admission and hospitalisation of patients.

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Participants

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GOJO

Purell BRAND

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http://www.sociopatterns.org