Some research topics and challenges at Alcatel-Lucent Bell Labs

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Alcatel·Lucent

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2. Research in Alcatel-Lucent Bell Labs worldwide
3. Research in Alcatel-Lucent Bell Labs France
4. Some research activities
    1. IP Routing: Next Generation Edge, Content Router
    2. Optical Networks: Capacity increase with margin management
    3. Wireless: Smart Wireless Systems
    4. IP platforms: Mathematics
5. Conclusion

Alcatel-Lucent in brief

Alcatel Lucent at a glance

1000+ Customers (network operator)

500K+ Customers (enterprise)

1M+ Networks

-1.8% 2012 adjusted operating margin

72,000 Employees

TR100 MOST INNOVATIVE COMPANIES 2011 2012 2013

2,900+ Patents in 2012

DJSI 2012 & 2013 Industry Group Leader for Technology

€ 14 Bn 2012 revenues

7 Nobel Prizes

16.1% 2012 R&D/Sales

250+ Universities collaborating

30,000+ Active patents

400G IP | CloudBand™ | Motive customer experience | lightRadio™ | 400G photonic | XRS Core router | VDSL2 vectoring | nuagenetworks™ | Network DVR Emmy Award

Alcatel·Lucent

Alcatel-Lucent in brief
Fast facts

- **Alcatel-Lucent**
  - At the forefront of global communications, providing products and innovations in **IP and cloud networking**, as well as **ultra-broadband fixed** and **wireless access**
  - Serving service providers and their customers, as well as enterprises and institutions throughout the world
    - Headquarters in France
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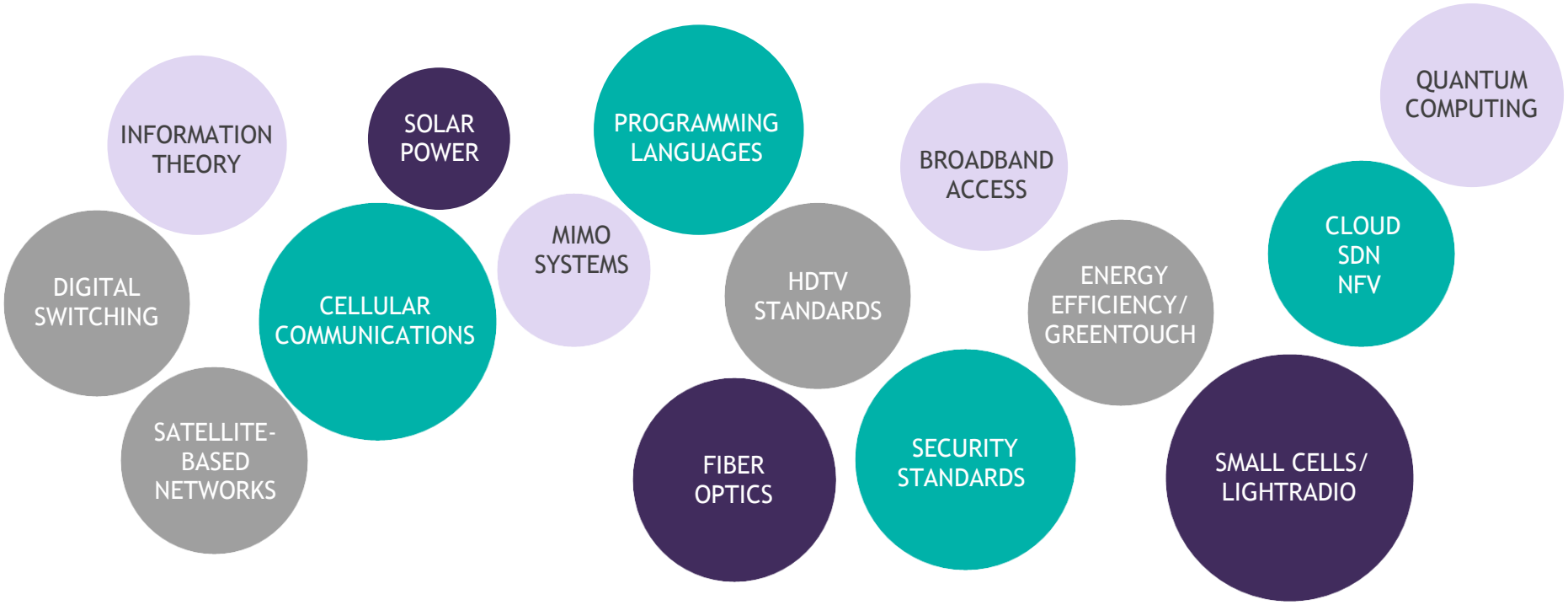
- **Research & Innovation**
  - € 2.3 billion in R&D investment (~16% of sales)
  - More than 30700 active patents, more than 2900 obtained in 2012
  - Research ("R") organization = **Bell Labs** (since 1925)

Research in Alcatel-Lucent Bell Labs worldwide

Bell labs – Foundation for our innovations



LEADERSHIP | **DEPTH AND BREADTH OF EXPERTISE** | **IMPACT**

15,000+	4	250+	7	12	4	30,000+
Patent Applications	Japan Prize Winners	Universities collaborating	Nobel Prizes	Nobel Prize Laureates	Turing Prize Winners	Active patents

Research in Alcatel-Lucent Bell Labs worldwide
Locations, Role & Research Programs

- Global presence: North America, Europe & Asia

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- **8 Research Programs:**
  - IP Routing
  - Optics (IP Transport)
  - IP Platforms
  - Wireless
  - Fixed Access
  - Internet of Thing
  - Multimedia
  - GreenTouch

Research in Alcatel-Lucent Bell Labs France

Location = Villarceaux, Nozay (~20 km south of Paris)

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EMPLOYEES: OUR HUMAN CAPITAL

- All development, research, and customer teams in one place
- Cross-fertilization, agility, mobility

Innovation city*

CUSTOMERS: OUR BUSINESS PRIORITY

- EBC: our innovations show room
- All ALU functions in one site for a unique customer experience
- Our platforms and Operations Centers: a sneak preview of your future networks

ECOSYSTEM: OUR CATALYST IN THE MARKET

- Our Bell Labs & research labs partners
- Competitiveness clusters
- Startups
- Academics

Research in Alcatel-Lucent Bell Labs France
Research Programs & Activities @ Villarceaux

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  Next Generation Edge + **Content Networking**

  + *other activities on optical components*

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  Intelligent Networks / Traffic Aware Optical Networking

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  Smart wireless systems + *Future mobile network*

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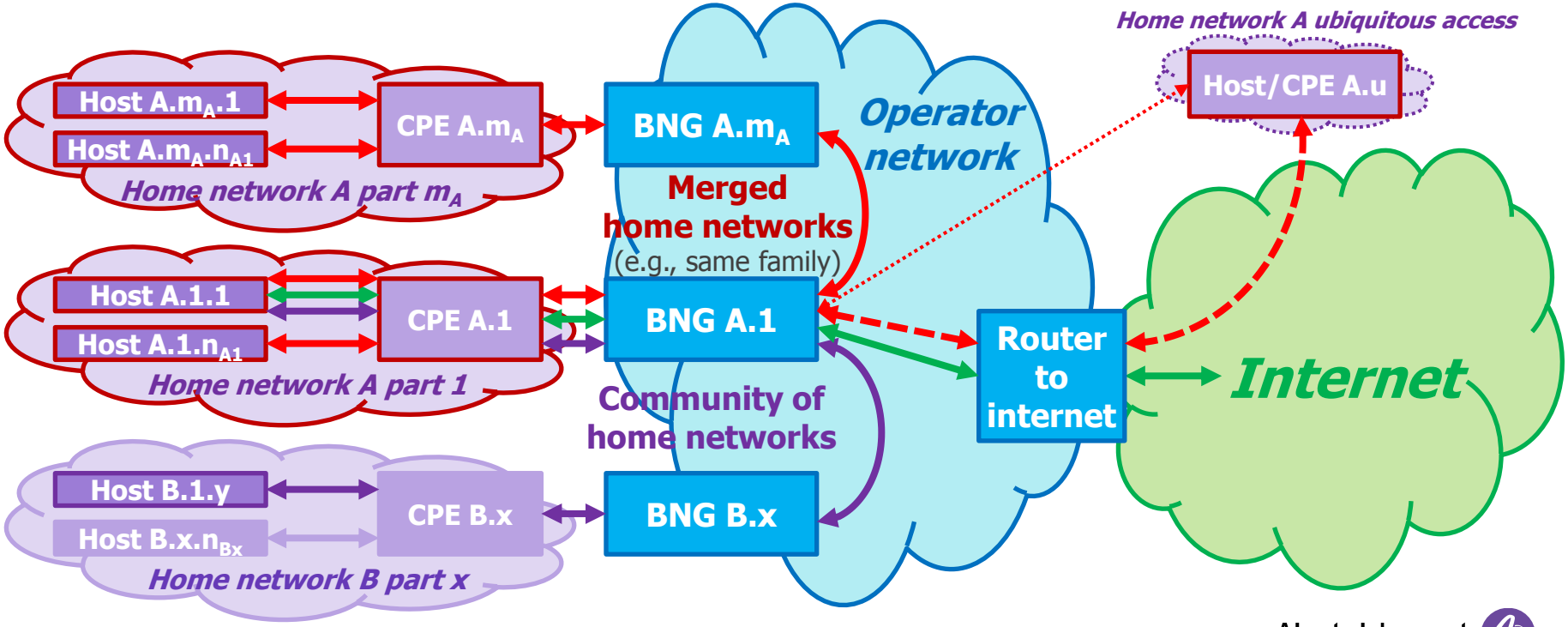
- **Internet of Thing:** *small activities related to Next Generation Edge (IP Routing)*
- **Multimedia:** *Advanced Multistream Communication*
- **GreenTouch:** *small activities related to Optics & Wireless*

IP Routing - Next Generation Edge
Context

- Main objective = **Home networks managed by the operator "edge" (~BNG)**
  - BNG = Broadband Network Gateway (usually implemented in Service Edge Router)
  - CPE = Customer Premise Equipment (e.g., home gateway)
  - Host = Any device / connected objects (IoT aspects)



IP Routing – Next Generation Edge
Some challenges

1. How to implement the management of the home networks by the operator?
   - The end-user should not be involved in any technical aspect!
   - Scalability issue, easy handling by human operators, visibility for the user, …
   - Where? Edge Routers or servers connected to them? Distribution over many routers?

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   - To share some common resources (communities of home networks)

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3. How to handle lot of connected objects in lot of home networks?
   - Identification, management, addressing and awareness of all the connected devices in all the home networks (IoT involved here!)

IP Routing – Next Generation Edge
Potential topics for internships

1. **Software-Define Network** (SDN) / **Network Function Virtualization** (NFV): analysis of existing solutions, new solution design, development on lab prototype, performances analysis…

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4. *Other ideas may come in the next weeks*

Contact: Ludovic Noirie

IP Routing – Content Networking
Context

- Hundreds of millions of new devices and people are coming online every year
- Data demand is exponentially skyrocketing:
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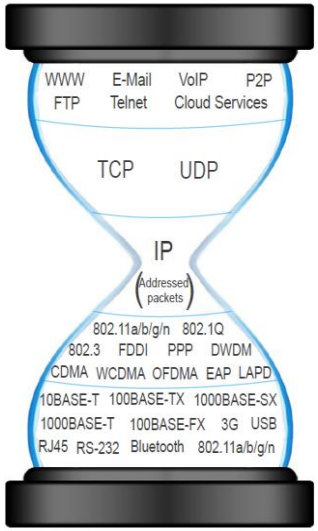
THE LIMITATIONS of CURRENT SOLUTIONS

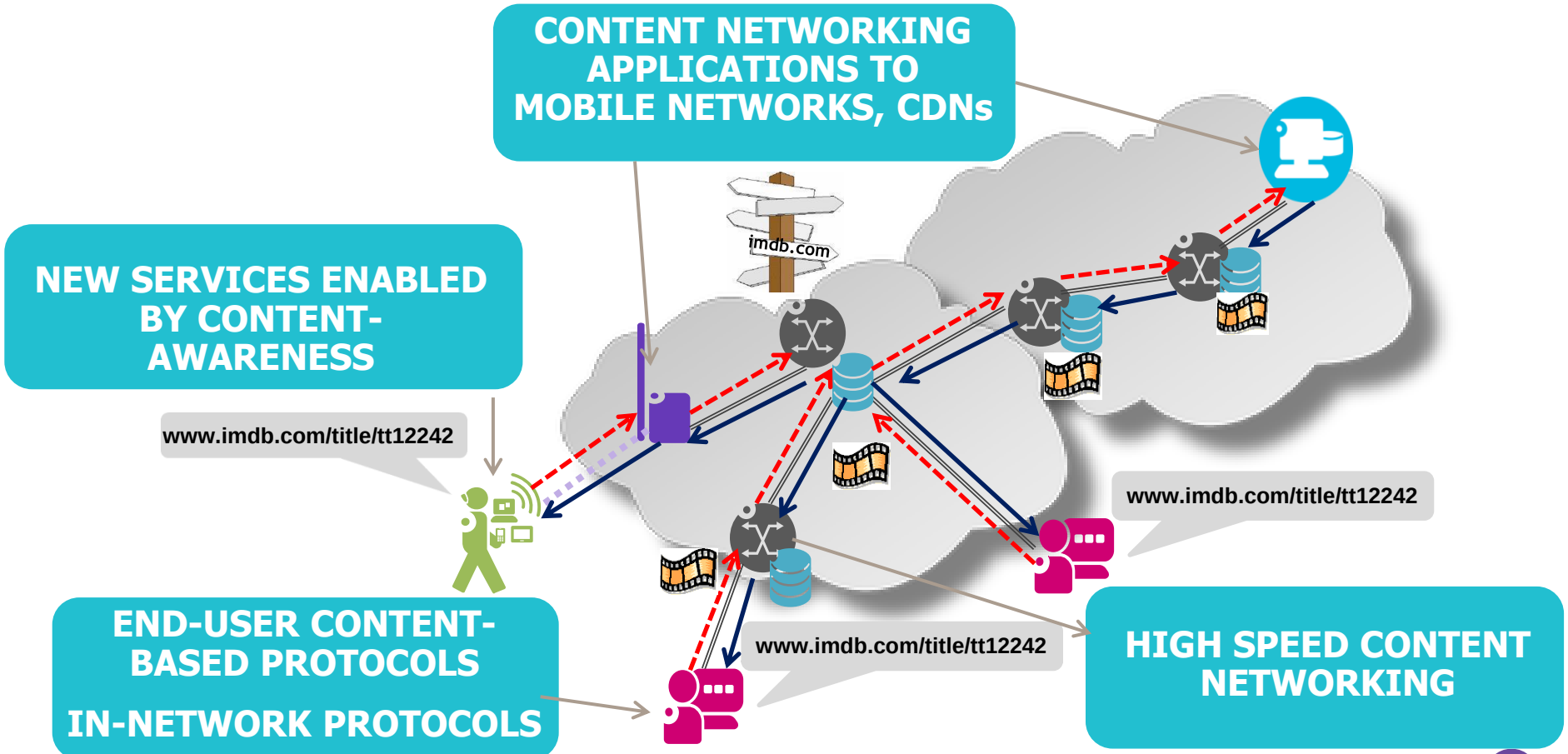
- Multiple stakeholders with different business interests: Content Providers (CP), CDN operators, ISPs
- Puzzle of technologies, difficult to manage and to interconnect
- Inefficiency of overlay approach in resource allocations/costs
- Inadequate communication model not meant to support information



INNOVATION AT NETWORK LAYER IS NEEDED TO SUPPORT CONTENT REVOLUTION

IP Routing - Content Networking Challenges

Design and Evaluation of an end-to-end **Information-Centric Networking** solution via analytical modeling, simulations, experiments, software/hardware prototypes



IP Routing – Content Networking
Potential topics for internships

1. **Optimized Content Delivery**: We work on the introduction of ICN mechanisms/protocols in CDN (Content Distribution Networks): the goal is to propose deployment options, analyze their feasibility and quantify performance gains compared to today's CDNs.

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Contact: Giovanna Carofiglio

Optics – Capacity increase with margin management
Context

- Current networks are dimensioning in a static way: a connection is set up at the beginning of the network life (BoL) and remains unchanged until the end of network life (EoL)
  - Network dimensioning: how to deploy equipment for a given a traffic matrix and a network topology so as to minimize the whole network cost

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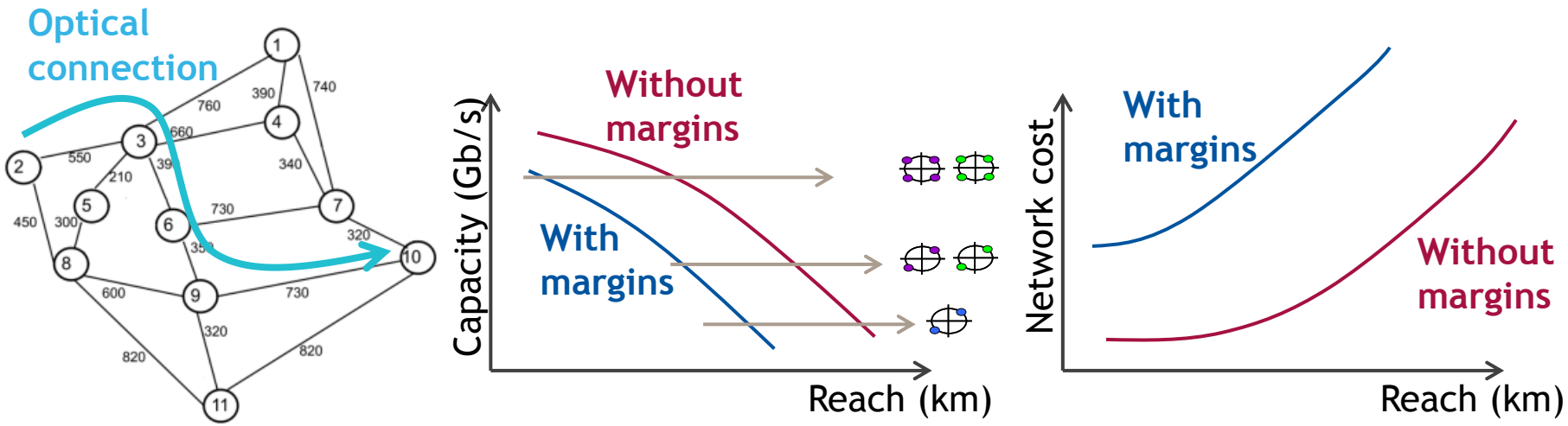
- This strategy takes into account an amount of physical margins that provide an initial over-cost of the network



Optics – Capacity increase with margin management
Challenges

1. How to postpone the deployment of optoelectronic devices during the network life so as to reduce the whole network cost?

→ By exploiting the following trade-off:

- Most of the deployed margins are unexploited, above all at the beginning of the network life
- The cost of optoelectronic devices decrease during the network life
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2. Various network strategies allowing the reduction of the whole network cost have to be proposed and compared

- Optimal solutions → minimum cost but high computational complexity
- Sub-optimal solutions → reduced computational complexity but the minimum cost is not ensured

Optics – Capacity increase with margin management
Potential topics for internships

1. **Traffic/Margin/Cost aware dimensioning of Optical Networks**: Research of new network strategies and the corresponding algorithms allowing the minimization of the whole network cost when traffic/margins/cost evolutions are taken into account

- Analysis of existing and proposed strategies have to be provided
- The development of such algorithms will be done on an already existing network dimensioning tool, coded in Java
- The optimal solution has to be implemented using CPLEX
- The host team has extensive experience on the understanding of both underlying physical phenomena driving margin-capacity-reach trade-off and the dimensioning tools
- This preliminary work could be extended as PhD topic

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Contacts: Annalisa Morea, Yvan Pointurier

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Context & Challenges

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  5. How to manage a large network in a self organized and optimized manner so that individual nodes can cooperate autonomously?
     - Supporting for example inter-cell interference coordination and mobility management

Wireless – Smart Wireless Systems
Potential topics for internships

1. **Future mobile network architectures** and **4G/5G systems**
   i. Next generation air interface design (wireless access), e.g. TDMA, CDMA, OFDMA, …
   ii. Next generation system design: 4G/5G, small cells, massive MIMO, mmWave, intelligent wireless networking, VLC, …
   iii. Spectrum and energy efficiencies, green radio
   iv. Device-to-device communications: machine-to-machine, ultra-low end-to-end latency, …

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2. **Radio resource management and optimization**
   i. Intelligent operation and management of mobile networks: LTE/LTEA/5G, heterogeneous cellular network (macro-small), WiFi (data offload), user centric, …
   ii. Advanced signal processing and new transmission techniques
   iii. Design of new optimization algorithms and mathematical tools: Inter-cell interference management, network utility maximization, capacity expansion, …

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Contact: Calvin Chung Shue Chen

IP Platform – Mathematics
Basic research approach

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   i. The art of making simple complex systems
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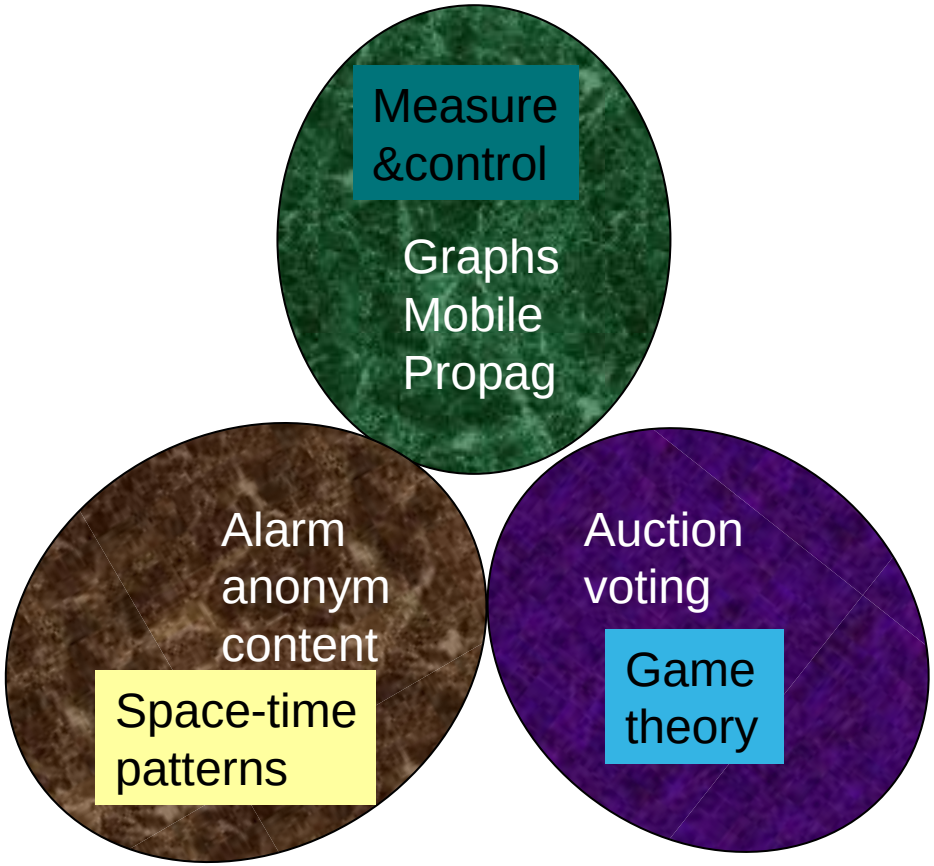
2. **Approach in the Maths Team**
   i. Input: a messy, complex system
   ii. Output: understand/predict/control what happens

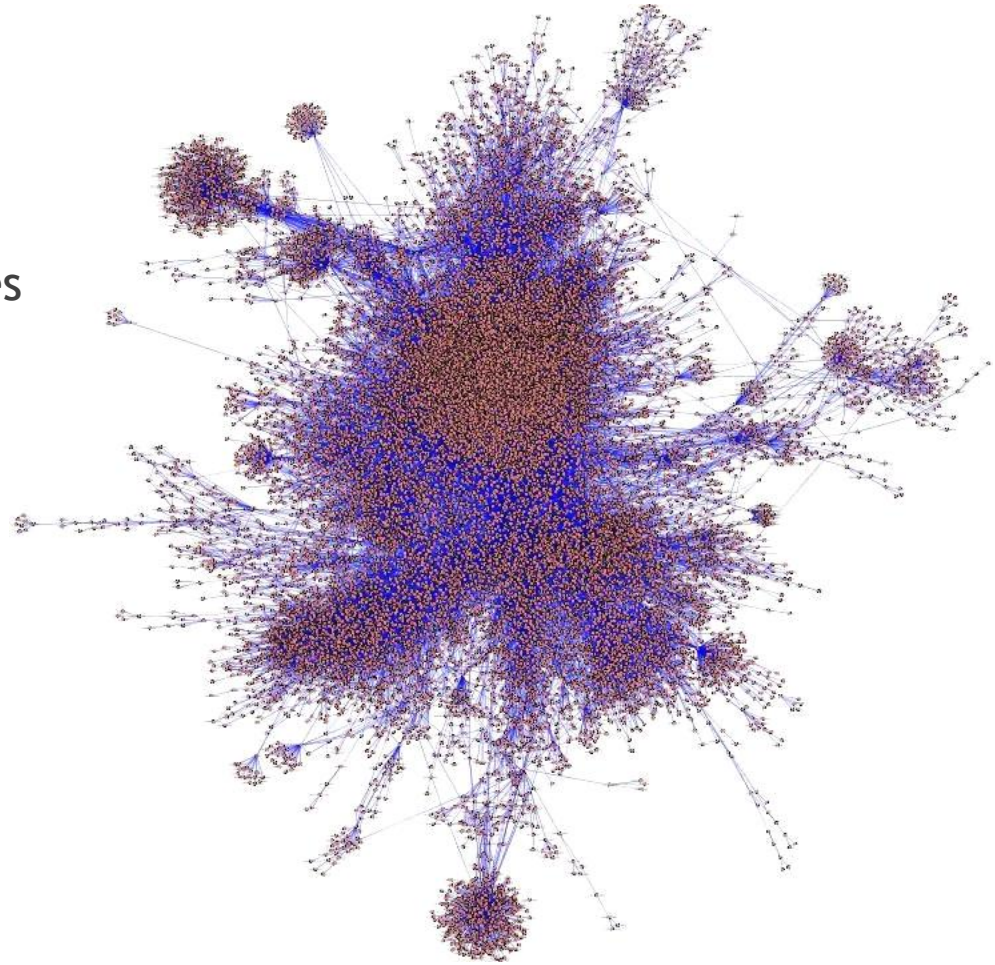
IP Platform – Mathematics

Our fields: models and algorithms



IP Platform – Mathematics
Example of spatial mess: large graphs

1. Lot of structure to process
2. How to extract relevant data?
3. A solution: centrality measures
   - Degree
   - Closeness
   - Betweenness
   - PageRank



IP Platform – Mathematics
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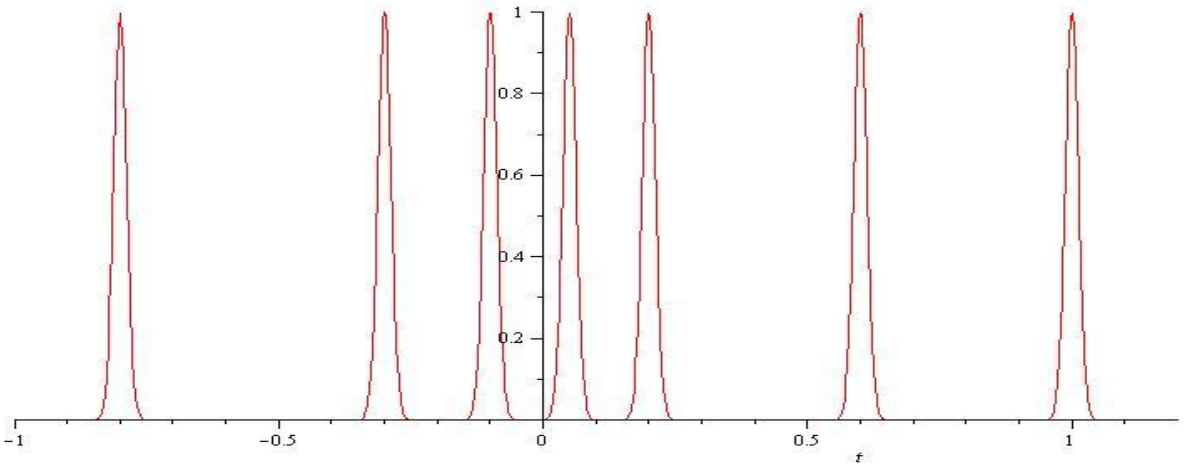
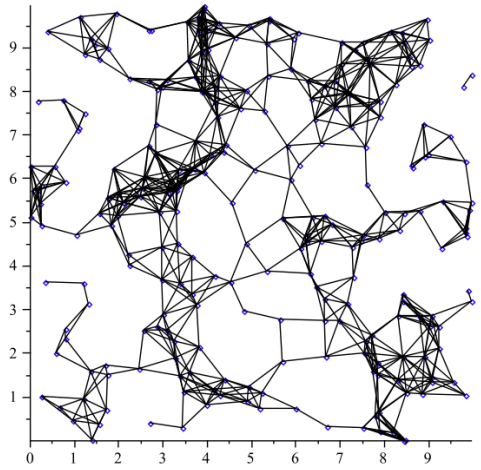
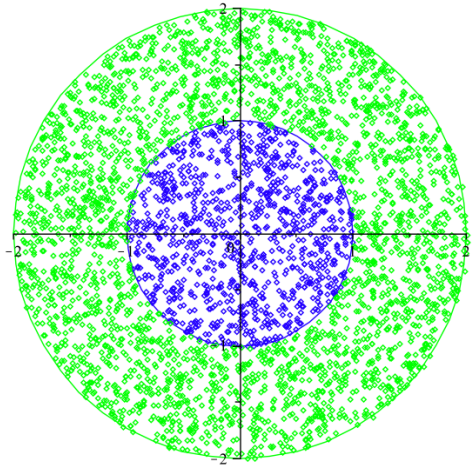
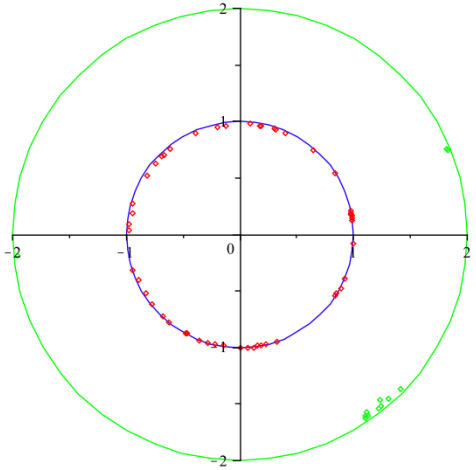
- Classic **PageRank** recursive algorithm gives main eigenvector
- Holy Grail: full spectral decomposition (in finite time)
- How to generalize PageRank ideas to get the spectrum?



IP Platform – Mathematics
Example of spatial mess: geometric spanners

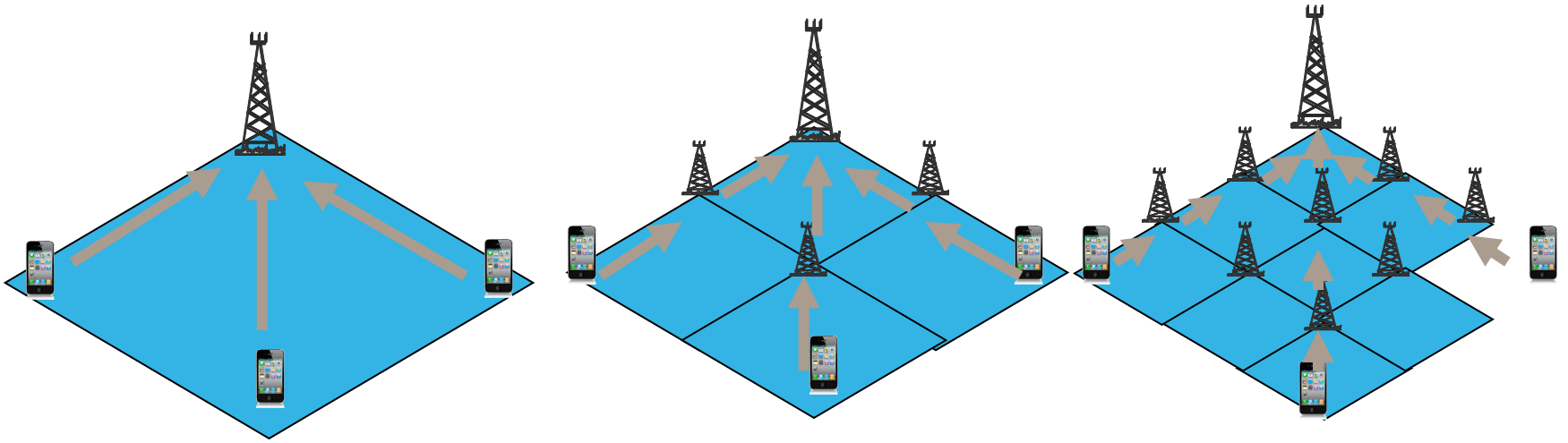
1. **Topology compression**
   i. Lossless compression (preserves shortest paths)
   ii. Lossy compression (with stretch factors)
2. **Remote spanners**
   i. Theoretical compression rate: at most $O(\frac{1}{n})$ (spanning trees)
   ii. Achievable MPR lossless compression in geometric graphs: $O\left(\frac{\log(n)}{n}\right)$

IP Platform - Mathematics

Example of spatial mess: to mesh or not to mesh?

Mesh is energy efficient

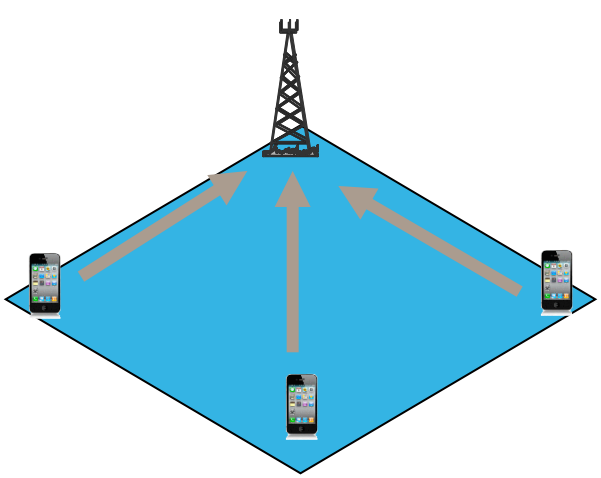


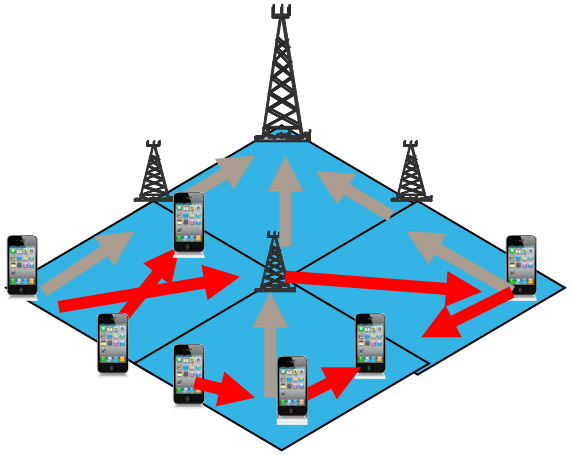
$$E_1 \qquad E_2 = \frac{1}{2^{\alpha-1}} E_1 \qquad E_h = \frac{1}{h^{\alpha-1}} E_1$$

IP Platform - Mathematics

Example of spatial mess: to mesh or not to mesh?

Mesh saves radio resources





Assumes 3 radio resources per “cell”

- Mesh allows $N_1 = 3, N_2 = 12, N_h = 3h^2$ resources
- In the end, $3h^2 - 3h$ additional resources available

IP Platform – Mathematics

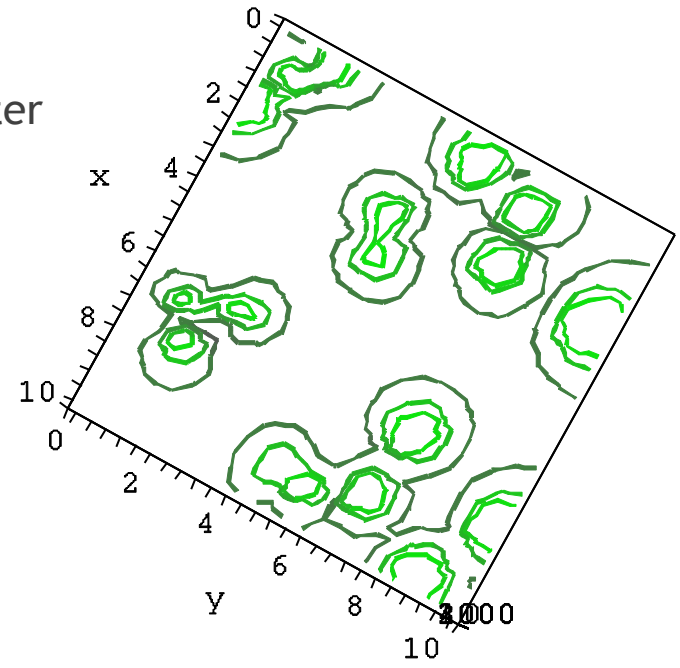
Example of time mess: dynamic resource allocation

Frequency re-use in multi-cells scenarios

1. How sub-optimal is random allocation?

$$\mathrm{sinc}\left(\frac{2\pi}{\alpha}\right)\mathrm{SNR}^{-2/\alpha} \approx 0.2$$

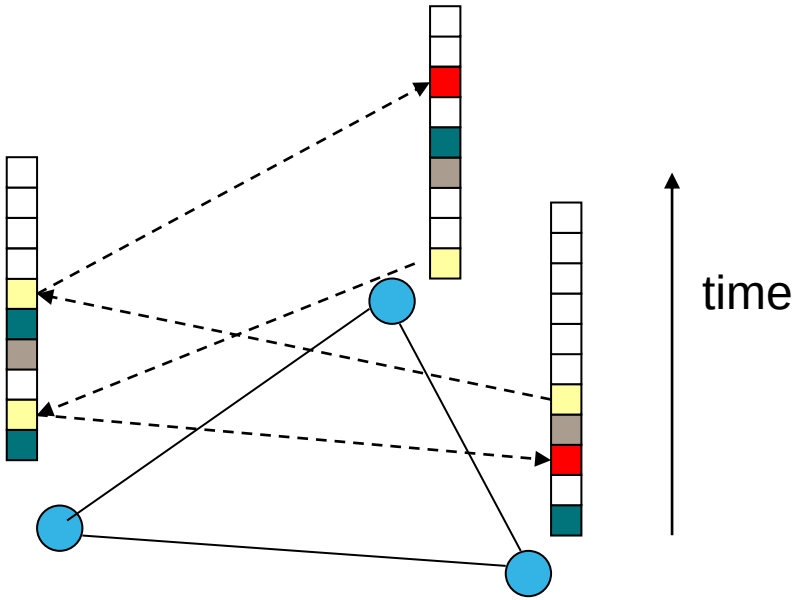
2. Optimal (static) cannot do more than 50% better



IP Platform – Mathematics

Example of space-time mess: network prediction

Some events (failures) may come from a space-time pattern

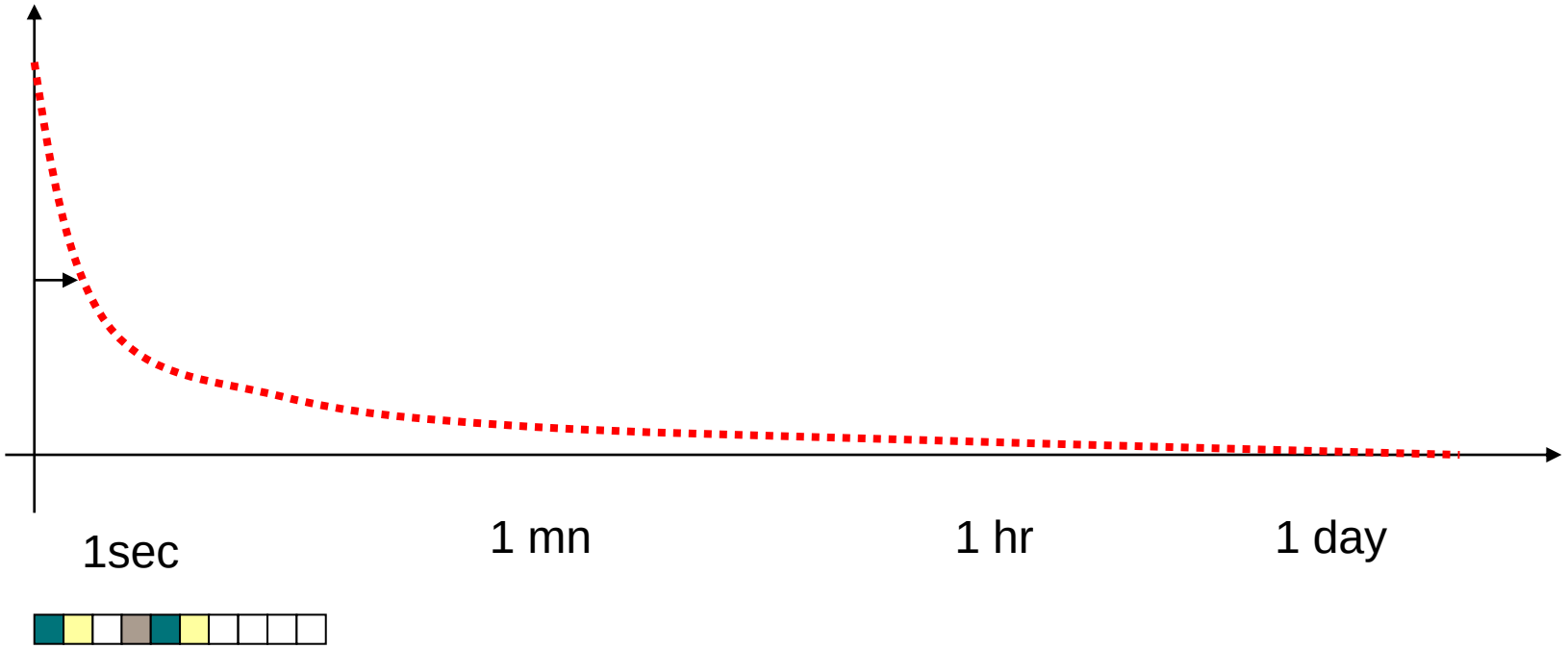


Alarm root cause sequence: 

IP Platform – Mathematics

Example of space-time mess: network prediction

Can space-time correlations extend the chaotic horizon?



IP Platform – Mathematics

Example of space-time mess: network prediction

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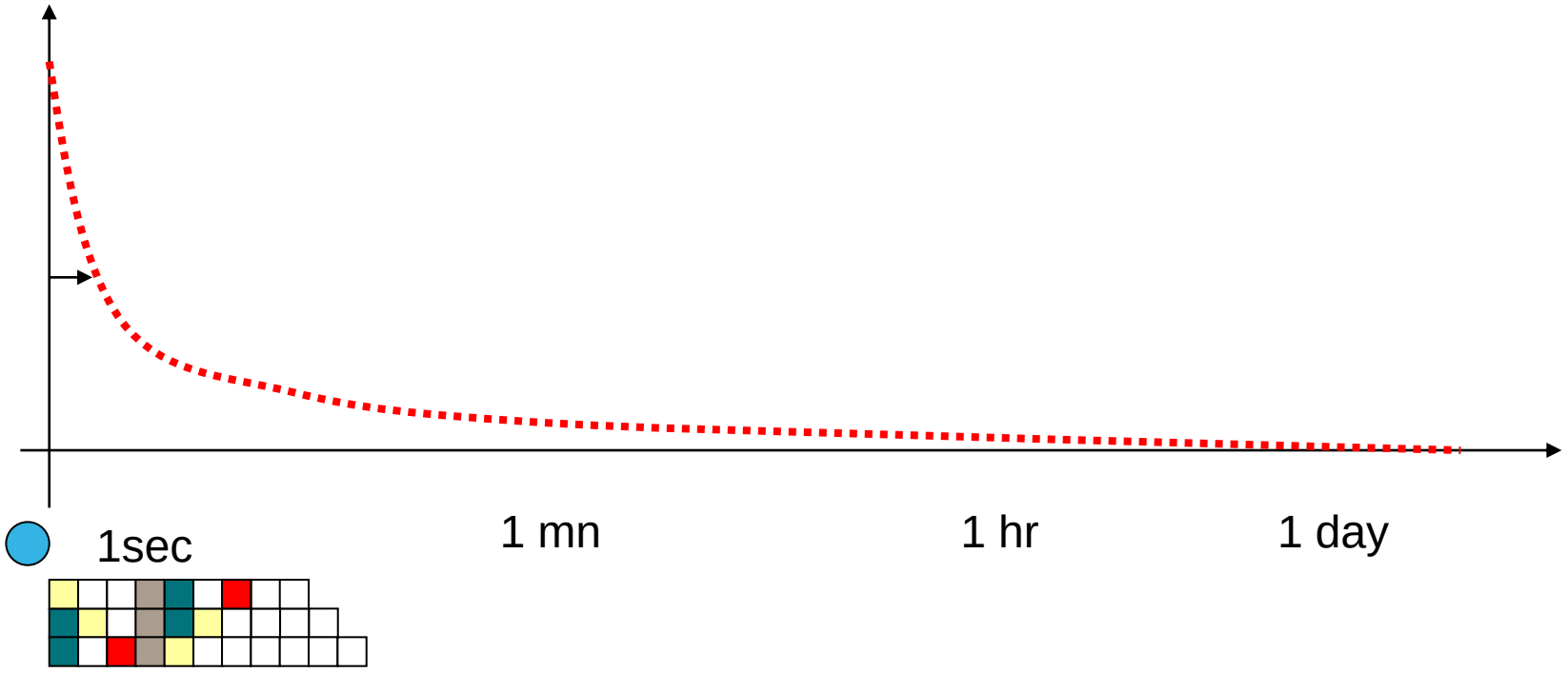

IP Platform – Mathematics

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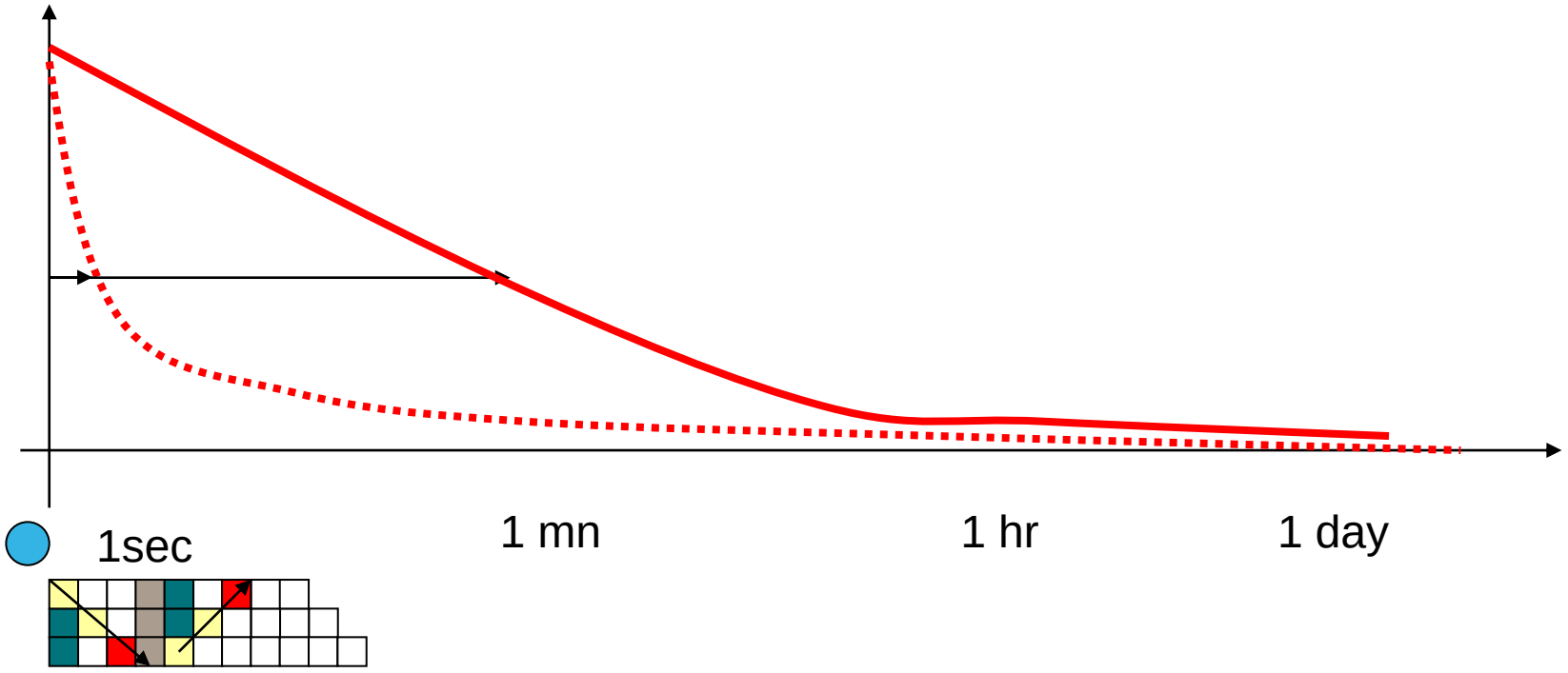
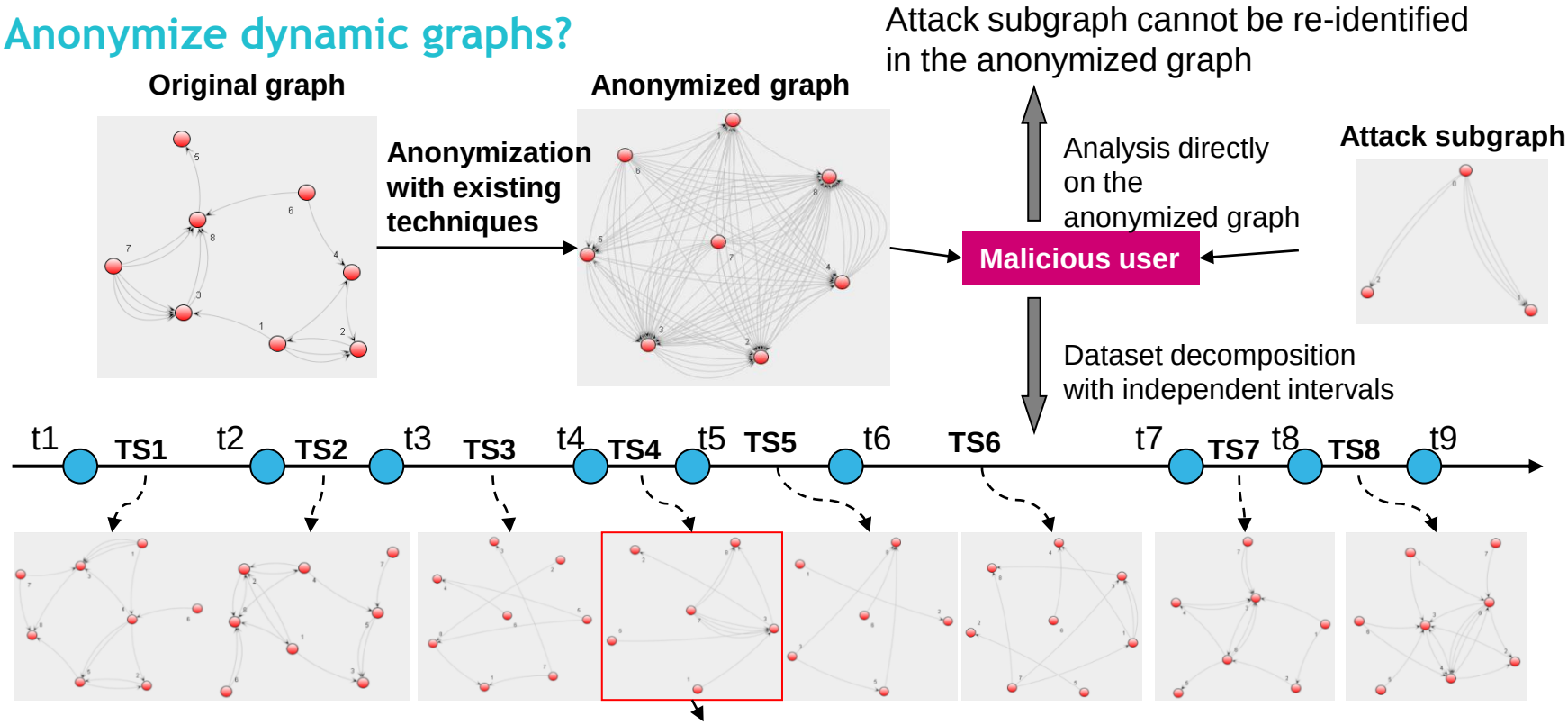


IP Platform – Mathematics

Example of space-time mess: anonymization

Anonymize dynamic graphs?



Only 1 candidate detected for the attack graph => **privacy broken**

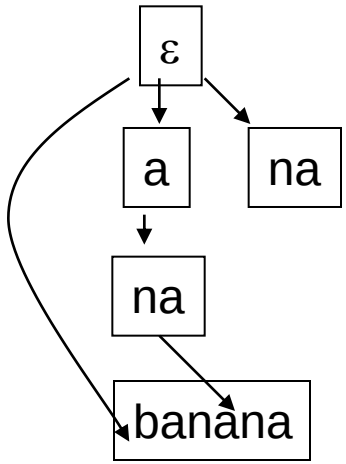
Learning methods for graph anonymization:

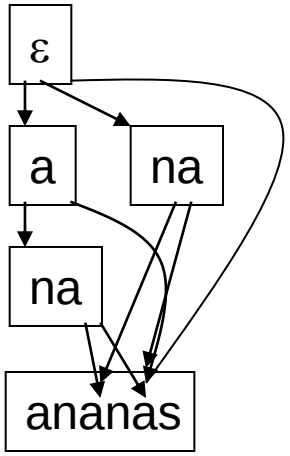
- Measure and privacy evaluation are blackboxes
- Use learning algorithms to determine the noise quantity to optimize privacy/utility trade-off

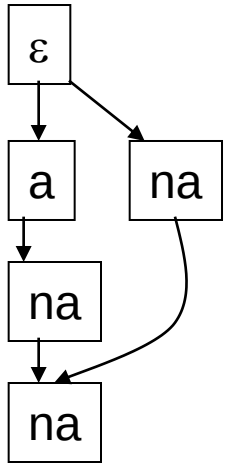
IP Platform - Mathematics
Example of random mess: Twitter content tracking

Use of joint complexity

- Comparison of suffix trees
- Minimal algorithm, minimal memory
- No grammar, no database







IP Platform – Mathematics

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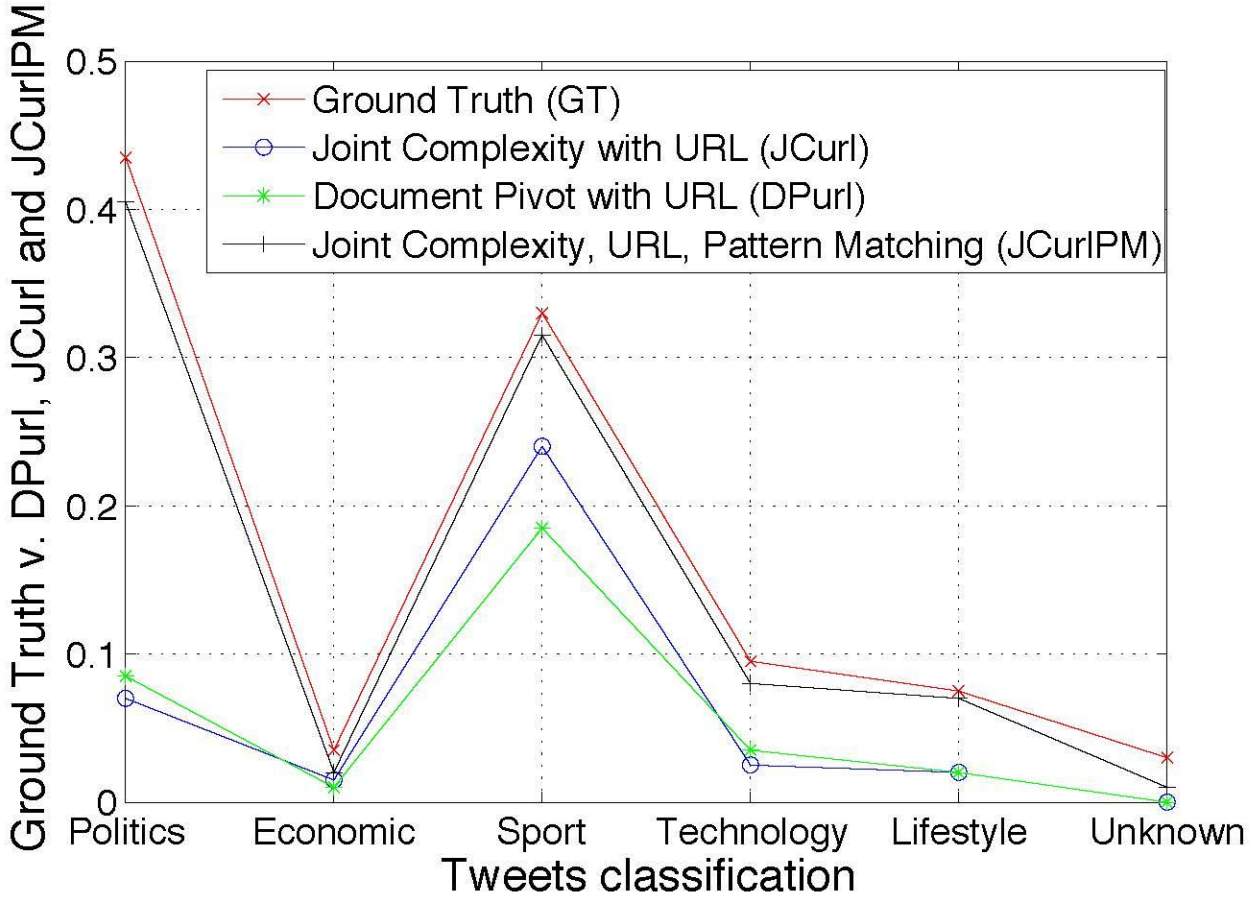
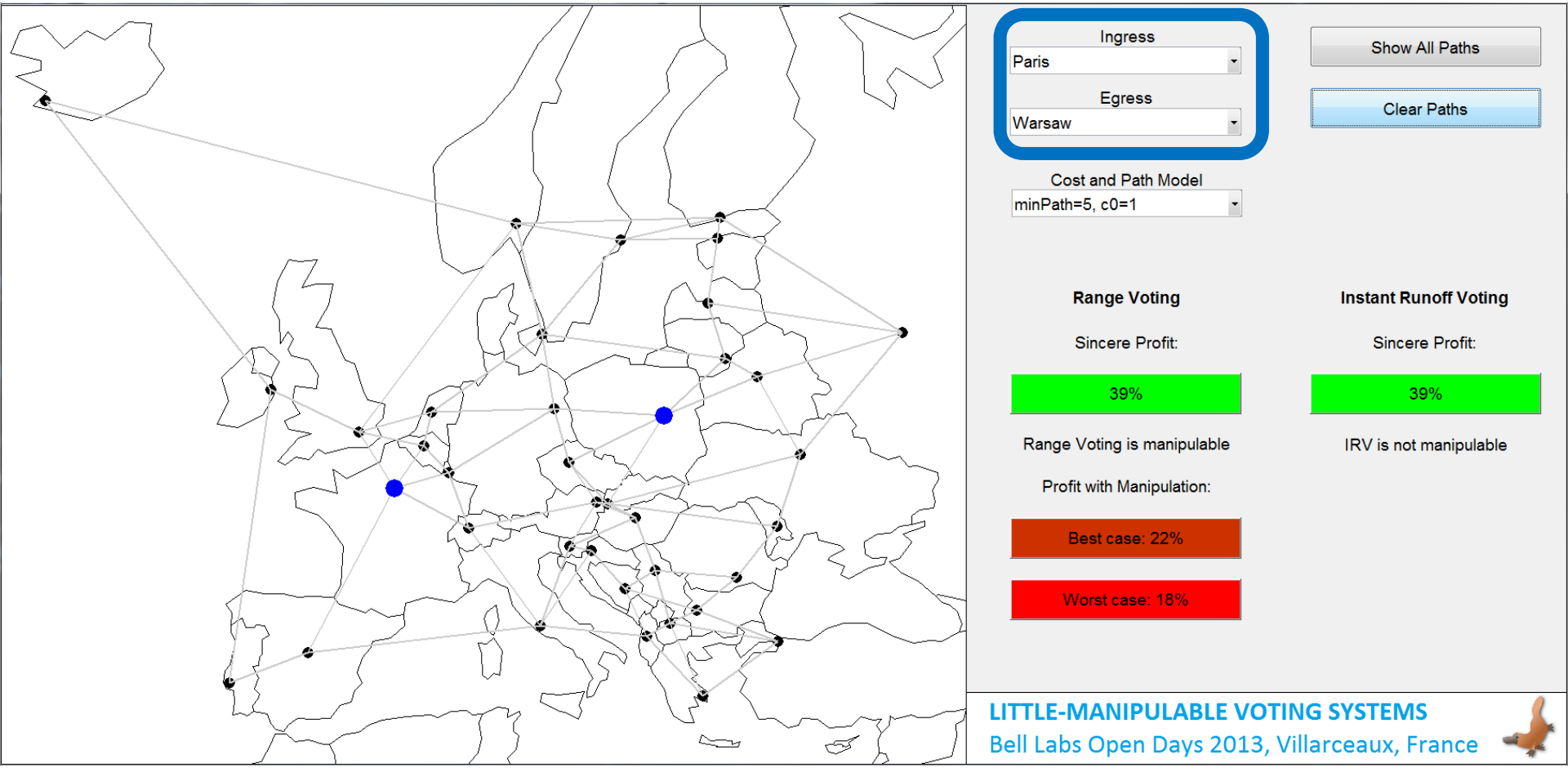


politics | sport | technology | economics | lifestyle

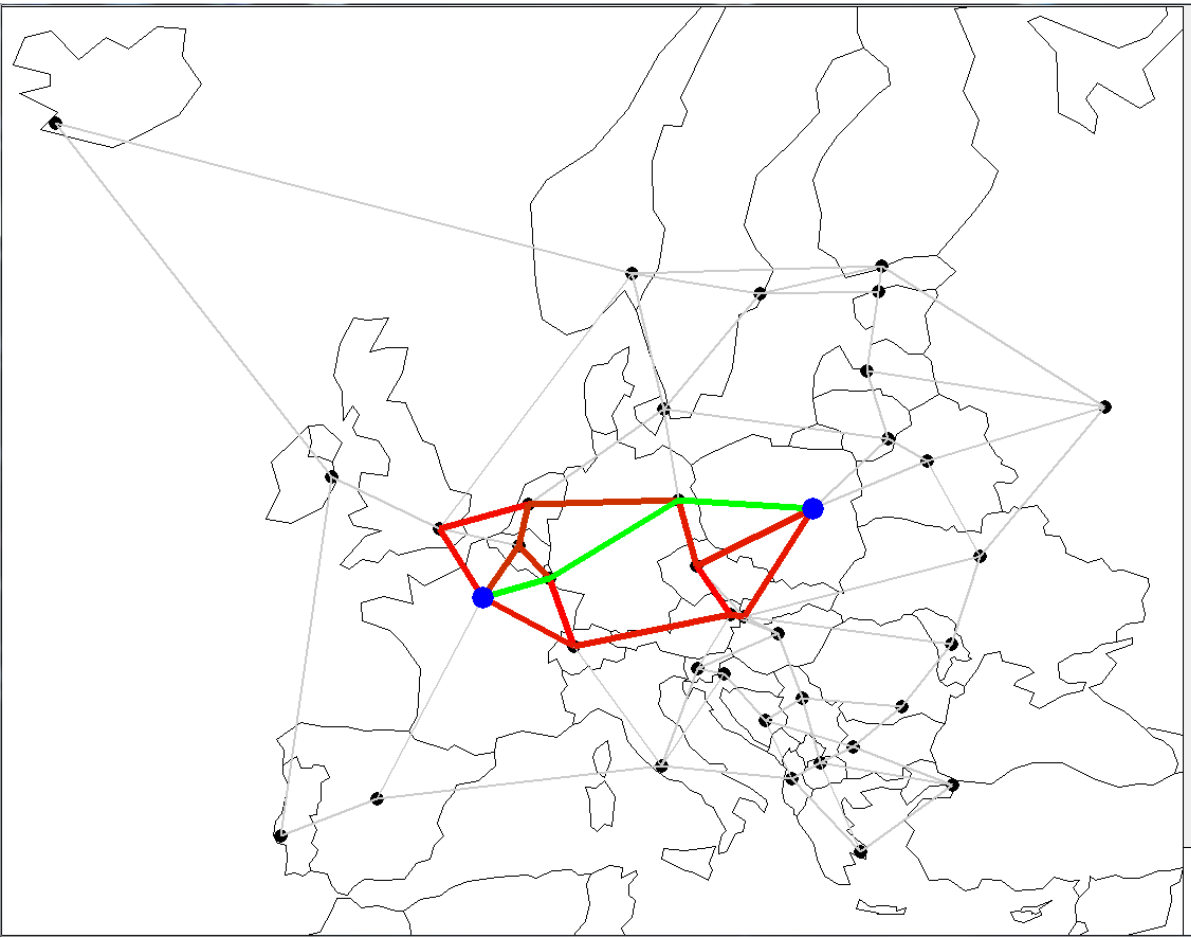
IP Platform - Mathematics

Example of game mess: voting processes



IP Platform - Mathematics

Example of game mess: voting processes



Ingress

Paris

Egress

Warsaw

Cost and Path Model

minPath=5, c0=1

Show All Paths

Clear Paths

<K> = 9.94

f = intermediate

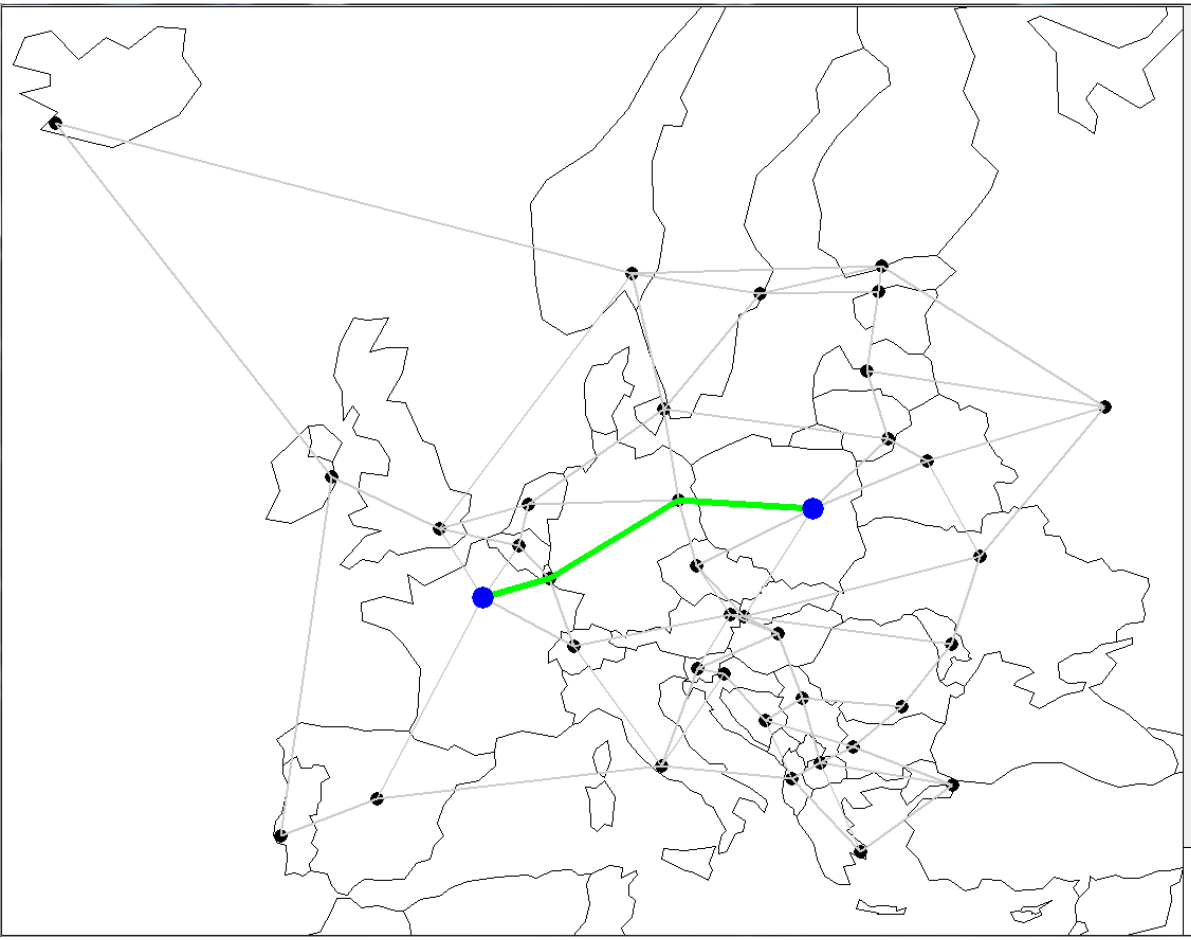
Range Voting	Instant Runoff Voting
Sincere Profit:	Sincere Profit:
39%	39%
Range Voting is manipulable	IRV is not manipulable
Profit with Manipulation:	
Best case: 22%	
Worst case: 18%	

LITTLE-MANIPULABLE VOTING SYSTEMS

Bell Labs Open Days 2013, Villarceaux, France

IP Platform - Mathematics

Example of game mess: voting processes



Ingress
Paris
Egress
Warsaw
Cost and Path Model
minPath=5, c0=1
Show All Paths
Clear Paths
Sincere Range Voting Path: Paris -> Luxembourg -> Berlin -> Warsaw
Profit = 39 %
Range Voting
Sincere Profit:
39%
Instant Runoff Voting
Sincere Profit:
39%
Range Voting is manipulable
IRV is not manipulable
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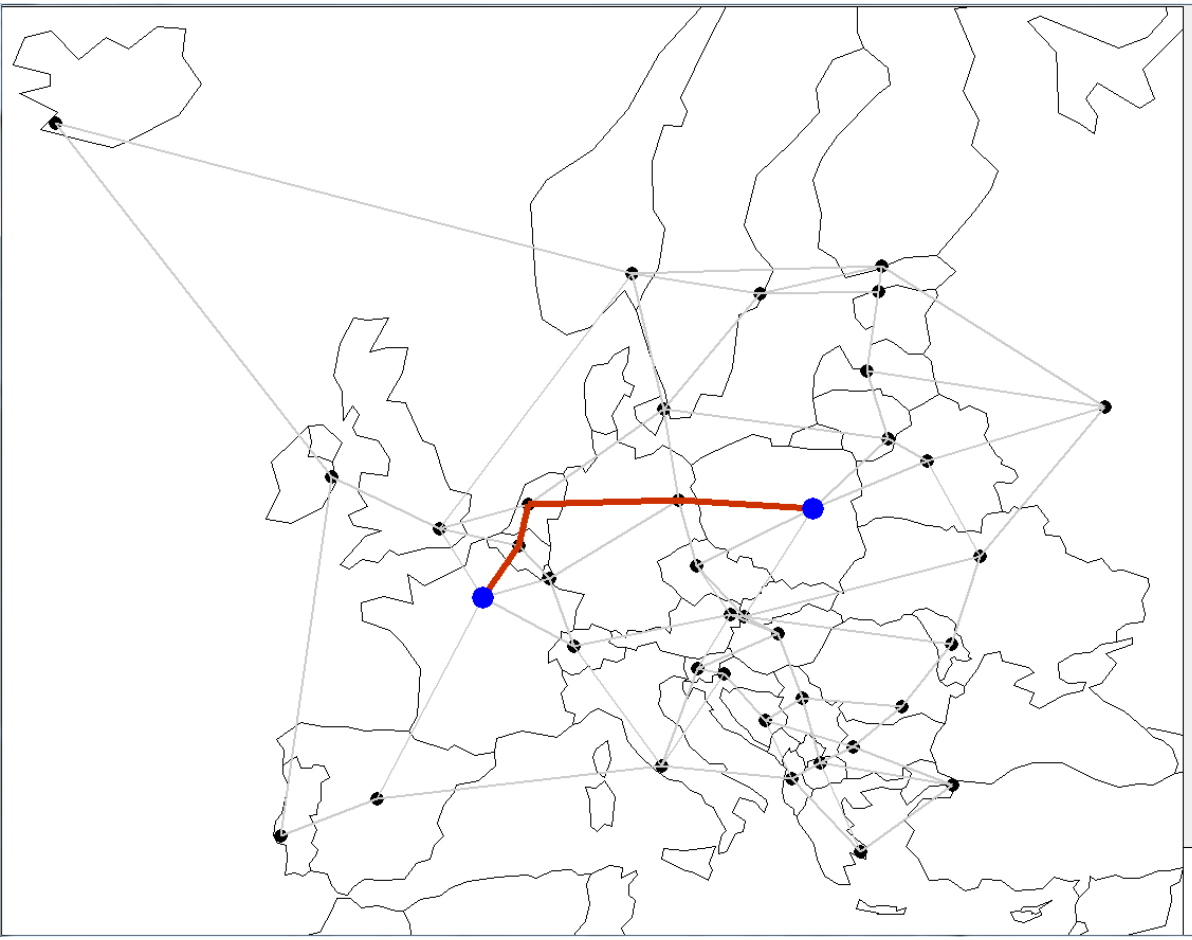


Ingress

Paris

Egress

Warsaw

Cost and Path Model

minPath=5, c0=1

Show All Paths

Clear Paths

Best Manipulated RV Path:
Paris -> Brussels ->
Amsterdam -> Berlin -> Warsaw

Range Voting

Sincere Profit:

39%

Range Voting is manipulable

Profit with Manipulation:

Best case: 22%

Worst case: 18%

Instant Runoff Voting

Sincere Profit:

39%

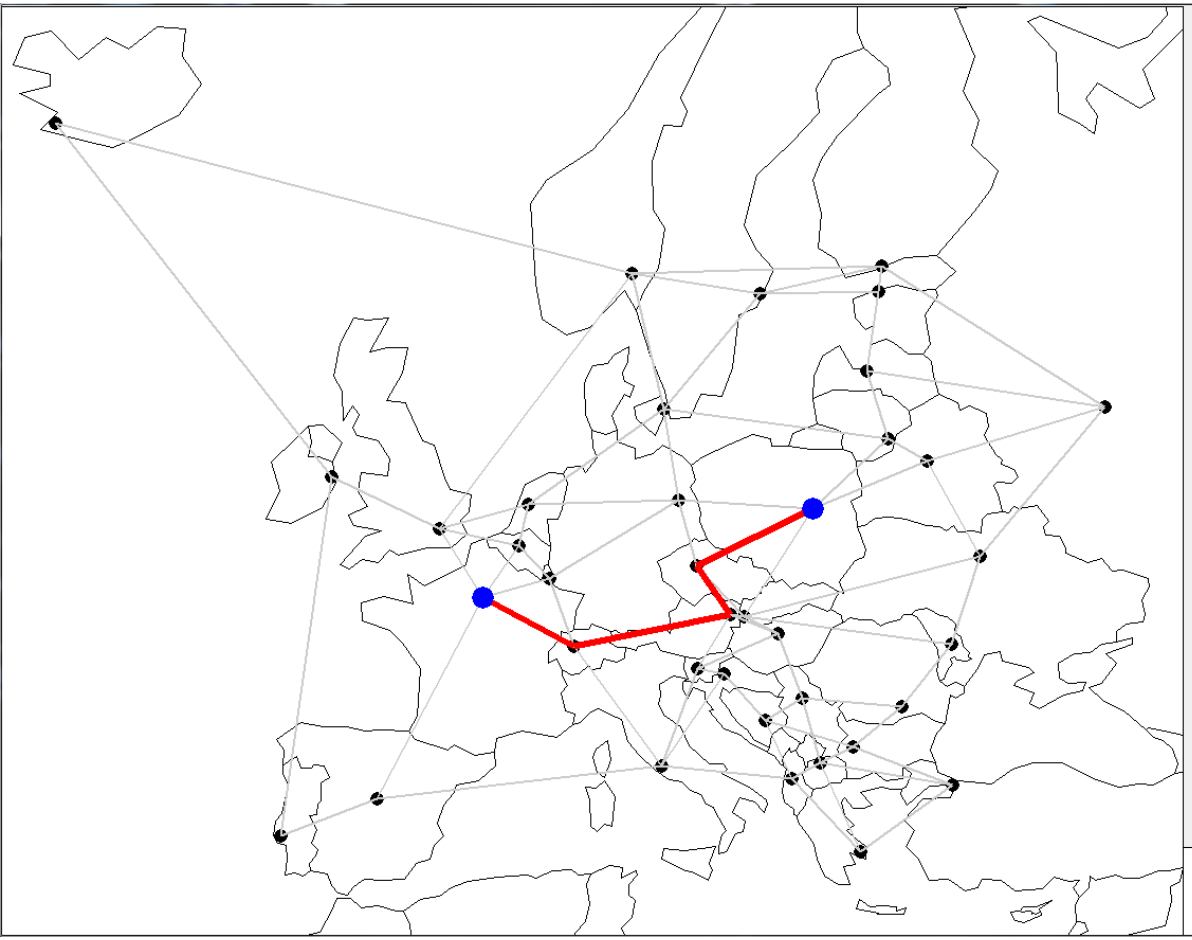
IRV is not manipulable

Profit = 22 %
⇒ divided by 1.8

LITTLE-MANIPULABLE VOTING SYSTEMS
Bell Labs Open Days 2013, Villarceaux, France

IP Platform - Mathematics

Example of game mess: voting processes



Ingress

Paris

Egress

Warsaw

Cost and Path Model

minPath=5, c0=1

Show All Paths

Clear Paths

Worst Manipulated RV Path:
Paris -> Bern -> Vienna ->
Prague -> Warsaw

Range Voting

Sincere Profit:

39%

Range Voting is manipulable

Profit with Manipulation:

Best case: 22%

Worst case: 18%

Instant Runoff Voting

Sincere Profit:

39%

IRV is not manipulable

Profit = 18 %
⇒ divided by 2.2

LITTLE-MANIPULABLE VOTING SYSTEMS
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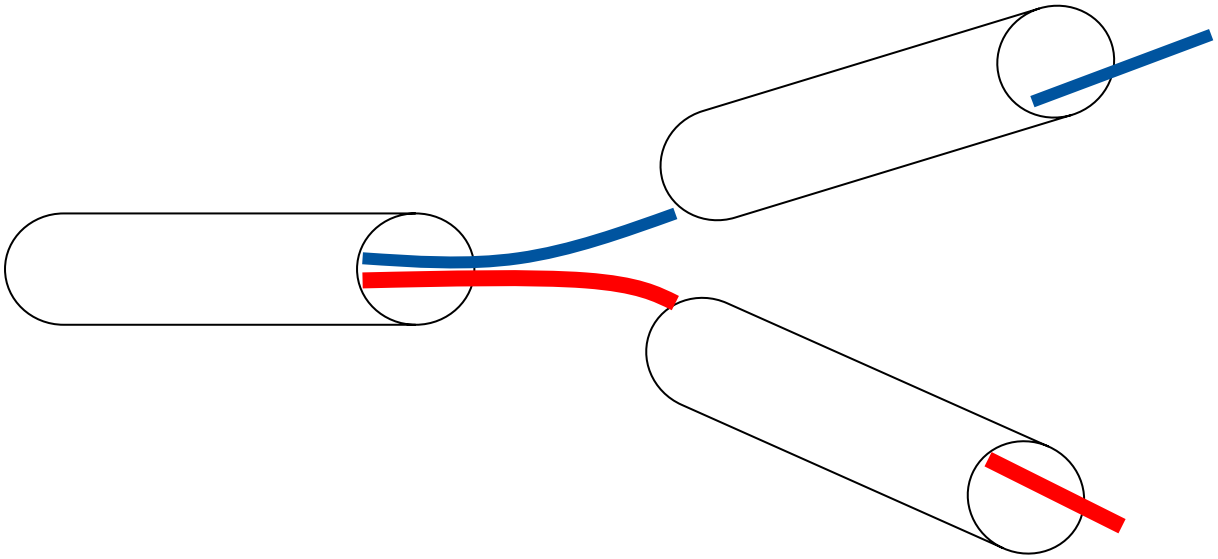
IP Platform – Mathematics

Example of game mess: bandwidth brokers



IP Platform – Mathematics
Potential topics for internships

- Presented topics are:
  - Representative of active subjects in the maths team
  - Related spontaneous applications will be considered
- Official internship topics will be delivered later

Contact: Fabien Mathieu

Research in Alcatel-Lucent Bell Labs France
Conclusion – LINCS

- Many internship possibilities within Alcatel-Lucent Bell Labs France

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Conclusion – LINCS

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- Some internships may be done totally or partly at the LINCS

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Laboratory of Information, Networking and Communication Sciences (LINCS)

- Location = 23 avenue d'Italie, 75013 Paris
- Joint lab between:
  - **Institut Mines-Télécom**
  - **Inria**
  - **UPMC Sorbonne Universités**
  - **Alcatel-Lucent Bell Labs France**
  - **SystemX (IRT)**

Research in Alcatel-Lucent Bell Labs France
Conclusion – Contacts

- How to know about Alcatel-Lucent internships?

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   - **Mathematics**: Fabien Mathieu
   - **Optics**: Annalisa Morea, Yvan Pointurier
   - **Wireless**: Calvin Chung Shue Chen (chung_shue.chen@...)

E-mails: first.last@alcatel-lucent.com

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3. **And your professors…**
   - They have contacts with several Alcatel-Lucent Bell Labs researchers…

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Questions ?

www.alcatel-lucent.com