An interdisciplinary approach to studying long-term social resilience to ICT hardware limitation

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Who are we?

- I'm a 2^{nd} year PhD candidate.
- Background in computer science.
- My doctoral training includes a doctoral training course in Science and Technology Studies (STS) together with STS PhD candidates.
- Interdisciplinary supervising team: two Information and Communication Technologies (ICT) researchers interested in socio-environmental issues of ICT and a sociologist of Science and Technologies.

Dependencies to ICT

A normal day in my lab...

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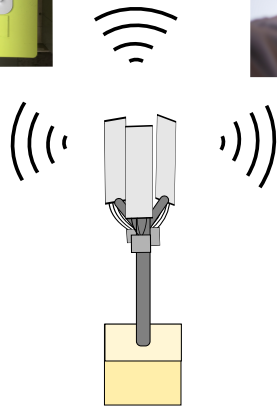
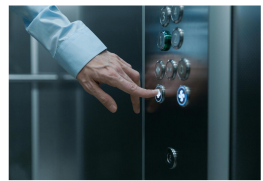
In cellular networks. . .





Dependencies to ICT

- Digital uses are multiplying and intensifying
  → global increase in our dependency on digital technologies (ICT)

- Current development of ICT based on a limitlessness assumption
  → Environmental and social impacts make it unsustainable.

- This raises the question of a possible lack of resilience of our digital uses.

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→ Research agenda *'in the abundant present for use in the future of scarcity'*[1]

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- We focus on the resilience issues related to mobile networks.

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Resilience viewed by ICT communities (1/2)

Resilience is the ability of a system to provide and maintain an acceptable level of service in the face of various faults and challenges to normal operation [Sterbenz et al., 2010].

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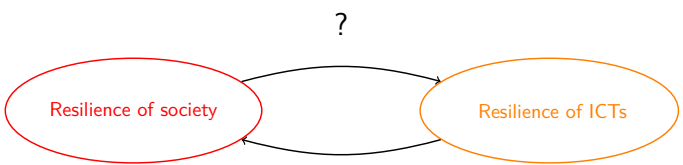

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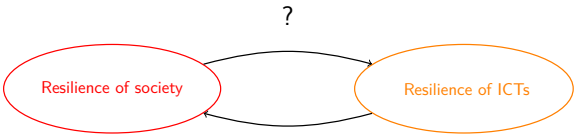

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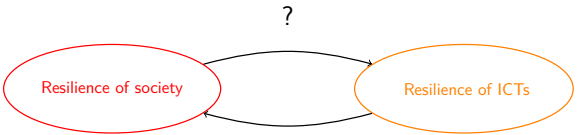

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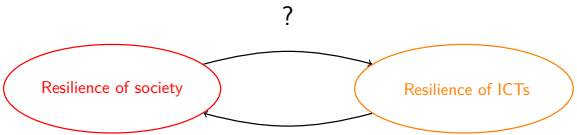

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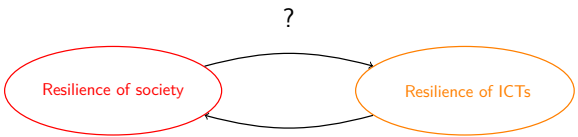

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Research on this topic is mainly organized around *collapse informatics* [Tomlinson et al., 2012] and the *Computing within LIMITS* workshop.

We study the long-term resilience of societies depending on unsustainable ICT.

Our case study on long-term resilience of ICT infrastructures applied to cellular networks facing hardware limitation [Courtillat--Piazza et al., 2025]

Approach: using *well-known methods* to cover research questions grounded in *heterodox assumptions* in ICT communities.

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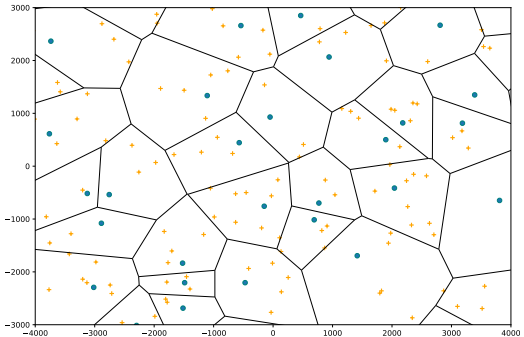

- Formal frame: stochastic geometry
- Base stations (BS) are modeled by a set of random points
  (an *homogeneous Poisson point process*)
- Users are modeled by another set of random points
- A user connects to the nearest base stations
  → The cells form a *Voronoi tesselation*.

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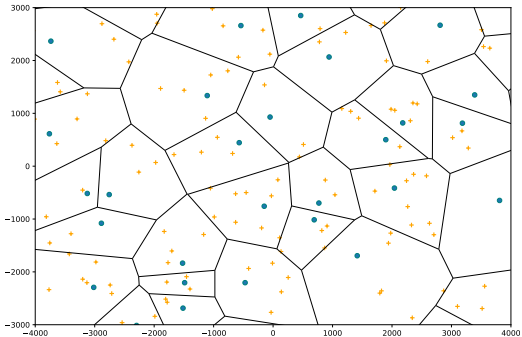

Metric of quality of service: coverage probability

= Probability of a quality metric q being greater than a threshold Γ

$$\gamma(u) = \mathbb{P}(q(u) > \Gamma) \tag{1}$$

Our case study [Courtillat--Piazza et al., 2025]

- We add an aging process on base stations.

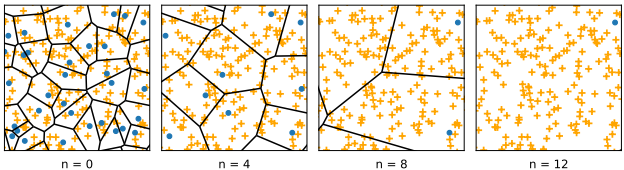

Figure: Remaining BS after n years when applying aging

- Resilience to aging is defined as the ratio of the remaining quality of service over time.

$$R^a_\Gamma(\Delta t) = \frac{\mathbb{P}(q(u) > \Gamma,\ t = t_0 + \Delta t)}{\mathbb{P}(q(u) > \Gamma,\ t = t_0)} \qquad (2)$$

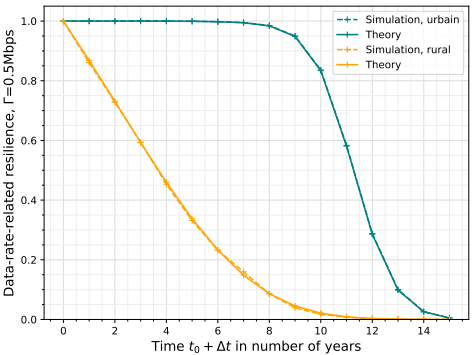

Figure: Resilience to aging.

Limitations of this cellular network modeling

- This research allows exploring long-term resilience to hardware limitation, in contrast to research focused on punctual disasters and built on limitlessness assumptions.

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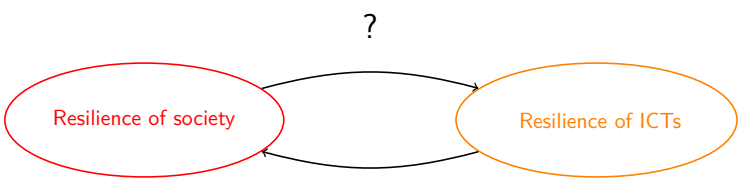
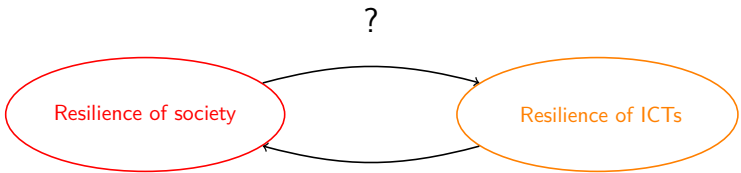
- However, resilience regarding quality of service does not inform on the social consequences of such a service loss.



Enriching our model with STS



- Resilience issues involve a variety of institutions, people, practices, technologies, standards, metrics that are intertwined that can be clarified through STS research.

- We thus initiated a sociological survey through interviews for complementing, and also iteratively modifying, our cellular network modeling and metrics.

STS literature: knowing and acting in a finite world

1. 'Knowing and acting in a finite world' literature [Joly, 2024]:
   How to organize the closure of socio-technical systems seen as unsustainable in the long term [Monnin, 2023, Joly et al., 2022]
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2. Literature on failures and risk management.

3. Literature on maintenance, care and broken world.

STS literature on failures and natural risk management

- Failures are studied in STS as ways of revealing cascading dependencies between entities [Bourrier and Nova, 2019, Latour, 1993].
- Studying crisis management thus allows understanding some of the current dependencies to socio-technical systems like ICT infrastructures.
  → For example, cellular networks are considered as critical as they support emergency calls with rescue departments.
- Studying crisis management also allows understanding what actually matters for stakeholders.
  → Example of *Operators of Vital Importance* in France.

However, studying risk management provides insights on the current critical uses of systems but not into the long term.

STS literature on maintenance, ruins, broken world thinking

- The organization of society around aging, fragile and sometimes failing infrastructures can be informed by STS literature related to maintenance, care, ruins and *broken world thinking* [Denis and Pontille, 2022][Tsing, 2015] [Jackson, 2014].
- A different view on the notions of 'failure' and 'disaster', which can be slow and diffuse, as in the case of pollution [Takahashi, 2024].
- Focus on micro-crisis and micro-repair that are part of the mundane and normal functioning of systems [Kocksch and Jensen, 2024].
- Grounded in the everyday life of systems, while also making aging and long-term evolution visible.

Approach relevant for studying what could be done, with the infrastructures we already have, in case of ICT hardware limitation.

STS survey

- Interviews with mobile network stakeholders, mostly high-level engineers.

Topics of interest in interviews:

On dependencies and resilience issues of mobile networks:

- De-commissioning
- Critical uses

On the practical functioning of mobile networks:

- Quality of service definition
- Maintenance and aging

- Example of preliminary result — on base stations' lifetime:
  - Current replacement of base stations is mainly driven by software obsolescence.
    $\rightarrow$ However, a survey on maintenance may reveal information on practical functioning and fragilities of mobile networks that are not necessarily visible for high level network engineers.

Conclusion

- We presented our approach for studying long-term social resilience to ICT hardware limitation.
- We use a well-known method (stochastic geometry) to study a scenario of hardware limitation and open the question of closure of cellular networks to the mobile network community.
- We use a sociological survey through interviews to study the social consequences of quality of service loss in mobile networks, and investigate hardware aging.

Question

How can studying current socio-technical systems in a world based on growth inform a future in a limited world?

- Example: can studying maintenance of software-obsolescent mobile networks inform the theoretical lifetime of aging networks with compatible software?

References I


Bourrier, M. and Nova, N. (2019).
(en) quête de pannes.
Techniques & culture.


Courtillat--Piazza, L., Coupechoux, M., and Quinton, S. (2025).
Multi-techno-band cellular network resilience to shocks and aging: a stochastic geometry approach.
First Workshop on Resilience in Next-Generation Networks (NGResNet 2025), IEEE International Conference on Computer Communications (INFOCOM).
https://doi.org/10.1109/INFOCOMWKSHPS65812.2025.11152902.


Denis, J. and Pontille, D. (2022).
Le soin des choses: Politiques de la maintenance.
La Découverte.


Jackson, S. J. (2014).
Rethinking repair.
Media technologies: Essays on communication, materiality, and society, pages 221–39.


Joly, P.-B. (2024).
Sciences et techniques en sociétés, chapter 1 STS, histoire française d'une (in)discipline, pages 8–33.
Iste Editions.

References II


Joly, P.-B., Barbier, M., and Turnheim, B. (2022).
Gouverner l'arrêt des grands systèmes sociotechniques.
Goulet, F., Vinck, D.(Eds.), Faire sans, Faire Avec Moins. Les Nouveaux Horizons de l'innovation. Presses des Mines, Paris.


Kocksch, L. and Jensen, T. E. (2024).
The mundane art of cybersecurity: Living with insecure it in danish small-and medium-sized enterprises.
Proceedings of the ACM on Human-Computer Interaction, 8(CSCW2):1–17.


Latour, B. (1993).
Le groom est en grève. Pour l'amour de Dieu, fermez la porte.
La clef de Berlin et autres leçons d'un amateur de sciences.


Monnin, A. (2023).
Politiser le renoncement.
Éditions divergences.


Sterbenz, J. P., Hutchison, D., Çetinkaya, E. K., Jabbar, A., Rohrer, J. P., Schöller, M., and Smith, P. (2010).
Resilience and survivability in communication networks: Strategies, principles, and survey of disciplines.
Elsevier - Computer networks, 54(8):1245–1265.

References III

Takahashi, M. (2024).
Risk and disaster in STS.
Elgar Encyclopedia of Science and Technology Studies, page 264.

Tomlinson, B., Silberman, M. S., Patterson, D., Pan, Y., and Blevis, E. (2012).
Collapse informatics: augmenting the sustainability & ict4d discourse in hci.
In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, page 655–664, New York, NY, USA. Association for Computing Machinery.

Tsing, A. L. (2015).
Le champignon de la fin du monde: sur la possibilité de vivre dans les ruines du capitalisme.
Les Empêcheurs de penser en rond.