Département
D3: Networks, Systems and Services

Équipe LORELEY

Large Scale Trustworthy Distributed Collaborative Systems

Loria

Laboratoire lorrain de recherche en informatique et ses applications

Rapport d'activité 2025

cnrs UNIVERSITÉ DE LORRAINE

En partenariat avec

Inria CentraleSupélec

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Project-Team LORELEY

Creation of the Project-Team: 2025 August 01

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Computer sciences and digital sciences

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1 Team members, visitors, external collaborators

Research Scientist

- Claudia-Lavinia Ignat [Team leader, INRIA, Senior Researcher, HDR]

Faculty Members

- Khalid Benali [UL, Associate Professor, HDR]
- François Charoy [UL, Professor, HDR]
- Jean-Philippe Eisenbarth [UL, Associate Professor, from Sep 2025]
- Thomas Lambert [UL, Associate Professor]
- Gerald Oster [UL, Associate Professor]
- Olivier Perrin [UL, Professor, HDR]

Post-Doctoral Fellow

- Arthur Rauch [INRIA, Post-Doctoral Fellow, from Oct 2025]

PhD Students

- Quentin Acher [INRIA]
- Clélie Amiot [INRIA, until Nov 2025]
- Victor Henrique De Moura Netto [INRIA]
- Lisa Formentini [INRIA]
- Haoyue Liu [INRIA, from Nov 2025]
- Ludovic Paillat [INRIA, CIFRE]

Technical Staff

- Habibatou Ba [INRIA, Engineer, from May 2025 until Aug 2025]
- Jean-Philippe Eisenbarth [INRIA, Engineer, from Apr 2025 until Aug 2025]
- Georgy Ishmaev [INRIA, Engineer, from Dec 2025]
- Haleema Khan [INRIA, Engineer, from Dec 2025]
- Adrien Ludwig [Inria, Engineer, until Jan 2025]

Administrative Assistants

- Sophie Drouot [INRIA]
- Delphine Hubert [UL]

Visiting Scientists

- Dharun Rajkkumar Anandayuvaraj [Purdue University, USA, from Feb 2025 until May 2025]
- Diana Berbecaru [Univ Torino, from Sep 2025]

2 Overall objectives

2.1 Context

Advancement in mobile and ubiquitous communication have made computer-mediated collaboration an integral part of both our professional and personal lives. The rise of remote working has further increased reliance on these tools for work, education, and entertainment. This dependence is expected to grow with ongoing digitalization and the need to limit travel in response to climate change. At the same time, the rapid proliferation of Artificial Intelligence (AI) technologies has led to the emergence of systems in which humans increasingly collaborate with intelligent agents, jointly performing tasks, making decisions, and coordinating activities within shared digital environments.

While existing tools effectively support small groups (tens of users) collaborating in an orderly fashion on simple tasks, they fall short when handling large-scale (hundreds of users), heterogeneous groups engaged in complex, long-term projects. In such contexts, issues arise concerning: **trust** among stakeholders and agents, the platform, and produced artifacts; **security** for the involved organizations; **scalability** and **resilience** of the collaborative system.

Most of the platforms hosting collaboration services rely on **centralized authorities**, which introduces several limitations. One of the primary concerns is **privacy**, as users must relinquish control over their data and trust service providers to handle their information securely. In many cases, terms of service allow these providers to access and analyze user data, reducing privacy assurances.

Another significant limitation is **scalability**. Centralized systems often struggle to efficiently support a large number of simultaneous modifications, leading to performance bottlenecks and degraded user experience. They generally rely on **costly infrastructures** and do not allow sharing of infrastructure and administration costs [22].

Additionally, **data sovereignty** is a crucial issue, particularly in contexts such as crisis management or federated organizations, where stakeholders may be unwilling to store sensitive information on third-party servers. Organizations and institutions often need to maintain full control over their data, making centralized solutions less desirable for applications that require strict confidentiality and autonomy.

2.2 Objectives

The vision underlying LORELEY is to move away from centralised authority-based collaboration towards large scale trustworthy peer-to-peer collaboration where *control over the data is given to users* who can share it directly only with the users they trust and without having to store it at a central authority. The *risk of privacy breaches is decreased* in this peer-to-peer collaboration. If a node is attacked only their data is compromised and not the whole data stored in the system as in the case of an attack on a centralised architecture. These systems *enhance resilience* to faults and security attacks as to attack or shut down a peer-to-peer system, an attacker must target a large proportion of the nodes simultaneously. Moreover, peer-to-peer systems feature *high scalability* and a low deployment barrier for new services. Participating nodes are owned and operated by independent individuals and therefore *administration costs of the system are shared.*

LORELEY is structured around three research axes:

- Collaborative data management referring to the design and evaluation of various approaches related to the management of distributed shared data including replication mechanisms and data placement techniques.
- Security mechanisms for distributed collaborative systems without a central authority.
- Trustworthy collaboration referring to evaluation of trust in collaborators/agents and in collaboration platforms.

3 Research program

3.1 Replication mechanisms and architectures for complex data

According to the CAP theorem [20], distributed systems cannot ensure both high availability and strong consistency under network partitions; thus, consistency is often relaxed. Eventual consistency [23] allows replicas to temporarily diverge before converging once updates are received. Two main approaches support this model: operational transformation (OT) [19] and commutative replicated data types (CRDT) [24]. Members of LORELEY contributed and pioneered research on the design of OT and CRDT algorithms with WOOT [21] being the first CRDT algorithm in the domain of collaborative editing. We aim to further advance the design of CRDTs for complex and composite data, including sequences with reduced metadata overhead [3] and data structures that require the preservation of global invariants [2]. Beyond data structures, we investigate architectural aspects of replication, moving from full replication toward partial replication and replica placement strategies that account for data locality, network heterogeneity, and communication costs, particularly in peer-to-peer and edge environments. The methods that we generally use for the evaluation of various approaches are: theoretical analysis of algorithmic complexity, simulation, evaluation against collaboration traces and user studies.

3.2 Security mechanisms for distributed collaborative systems without a central authority

We seek to establish principled, usable, and fully distributed foundations for secure and robust collaborative systems, focusing on environments where users collaborate at scale under frequent membership changes and concurrent updates.

Many protocols for data and communication encryption exist in the literature. However, these solutions do not deal with mutable data that can be changed at any moment by a group of users and with dynamic groups where users can join and leave the group at any moment. Moreover, existing solutions are not suitable for a completely distributed environment without a central authority.

Access control in a purely distributed environment without a central authority is particularly challenging. We aim to combine optimistic replication mechanisms, notably CRDTs, with decentralized access control and group management, allowing data and access rights to be replicated consistently across peers. We aim to design CRDTs to manage dynamic access rights alongside shared data, ensuring convergence while preserving document integrity even in the presence of concurrent authorization changes [5]. We also aim to investigate scalable group key management for large, dynamic peer-to-peer groups for supporting secure collaboration without relying on centralized services [7]. Finally, we explore Sybil attacks in untrusted peer-to-peer environments.

3.3 Trustworthy collaboration

Technical solutions employed for a large-scale collaboration are not sufficient. Trust is very important in this collaboration and we need to understand how it is built and maintained. We adopt a cognitive definition of trust as "a learning process obtained from social experiences based on the consequences of trusting behaviors" [18], where trust is built based on observations in the past. We are interested in studying trust on collaborative platforms and services, trust between humans and trust between humans and agents in the large scale collaboration.

4 Application domains

4.1 Collaborative Editing

Collaborative editing systems allow users to collaborate on a set of shared documents, irrespective of the kind of documents, from different places, at any time and from different devices. Examples of collaborative systems are wikis, version control systems or GoogleDrive. Collaborative editing is an application of the replication mechanisms that we propose in distributed settings. Our replication algorithms allow the implementation of collaborative editors in a peer-to-peer manner, avoiding the need

for a central server and reducing the risk of data privacy breaches. The domain of collaborative editing requires us to consider the problem of access control of participants [5] and group key management [7].

4.2 Crisis Management

The realm of crisis management research delves into the multifaceted aspects of effectively handling unforeseen and catastrophic occurrences, such as floods, earthquakes, terrorist attacks, or pandemics. Every facet of crisis management, spanning from readiness to recovery, necessitates extensive cooperation among individuals representing various organizations. This context offers a unique opportunity to explore large-scale inter-organizational collaboration and to develop and assess mechanisms that guarantee a secure and dependable collaborative environment for all stakeholders involved.

Our primary objective is to analyze collaborative practices within civil security organizations, both during routine operations and in exceptional circumstances such as crises. We are currently analyzing crisis management practices and the technical environment that supports them within the PILOT project, with the goal of proposing methods to better introduce new tools that address these practices and their evolution. In the PhD thesis of Lisa Formentini [10] in collaboration with the Tech-CICO research team at LIST3N we are conducting interviews with the French firefighters of the Moselle region (SDIS 57) to explore their collaboration practices.

4.3 Peer-to-peer storage

Peer-to-peer storage systems use the combined capacity of the peers to provide storage functionality to end users. Peer-to-peer storage systems are designed to provide persistence and availability of the stored content despite unreliability of the individual autonomous peers in a decentralised environment. We started to apply our work on data replication, erasure coding and group key management [7] for IPFS (InterPlanetary File System) peer-to-peer storage and we will transfer it to Hivenet.

5 Social and environmental responsibility

The team is deeply aware of the environmental impact of its practices and research activities, with a shared commitment to reducing it.

5.1 Footprint of research activities

In terms of practices, since the Covid-19 pandemic, the number of flights for team members has significantly decreased. Remote participation is prioritized when appropriate, and train travel is favored whenever feasible. Additionally, we prioritize conferences within Europe and have shifted away from systematically accompanying PhD students presenting their work. Regarding hardware purchases, each team member uses a low-power consumption laptop as their primary device, which remains in use for at least the duration of its warranty (five years) and often beyond.

5.2 Impact of research results

Our research on large-scale distributed collaborative systems focuses on enabling remote work, thereby supporting the reduction of office space requirements. It also examines the social dimensions of remote collaboration and home-office setups, which can contribute to decreased energy consumption. These potential benefits are emphasized in the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report – Working Group III: Mitigation of Climate Change. Our work on distributed collaborative systems can be used to exploit the underused computer resources and thus reduce the energy overhead of datacenters, such as cooling whose costs represent about 40% of the total energy consumption of a datacenter.

6 Highlights of the year

The team LORELEY was created on August 1st, 2025.

7 Latest software developments, platforms, open data

7.1 Latest software developments

7.1.1 SR-DHT-Store

Keywords: DHT, Sybil attack, IPFS

Scientific Description: This repository presents a new active attack in which malicious nodes return semantically correct but intentionally false data. The attack leverages strategic Sybil placement to evade detection mechanisms and exploits an early termination behavior in Kubo, the main implementation of IPFS. Our approach is capable of fully eclipsing content on the real IPFS network. To address this vulnerability, we proposed a new mitigation called SR-DHT-Store, which enables efficient, Sybil-resistant content publication.

Functional Description: This repository contains the source code of an active Sybil attack on the IPFS DHT and its defense mechanisms described in the paper "Active Sybil Attack and Efficient Defense Strategy in IPFS DHT" (https://inria.hal.science/hal-05424411v1).

URL: https://gitlab.inria.fr/loreley-team/active-sybil-attack-and-efficient-defense-strategy-in-ipfs-dht

Publication: hal-05424411

Contact: Victor Henrique De Moura Netto

Participants: Victor Henrique De Moura Netto, Thibault Cholez, Claudia-Lavinia Ignat

7.2 Open data

COCCO 2 dataset and analyses
Web site: https://doi.org/10.5281/zenodo.16522610

Contributors: Clélie Amiot, François Charoy

Description: The dataset contains the data collected during the COCCO 2 experiment. The dataset contains the interaction traces of 36 participants working in pairs to collaboratively solve a series of logic puzzles using a shared interactive tabletop display. The dataset also contains the results of pre- and post-experiment questionnaires filled in by the participants, as well as the video recordings of the sessions. The dataset is anonymized and is available under CC BY-NC 4.0 license.

Publications: [6]

8 New results

8.1 Distributed Delivery Service for Group Key Agreement Protocols

Participants: Davide Frey *(WIDE team)*, Claudia-Lavinia Ignat, Amine Ismail *(Hivenet)*, Ludovic Paillat *(Hivenet)*, Mathieu Turuani *(PESTO team)*.

End-to-end encrypted messaging applications such as Signal and Whatsapp became widely popular thanks to their capability to ensure the confidentiality and integrity of online communication. While the highest security guarantees were long reserved to two-party communication, solutions for n-party communication remained either inefficient or less secure until the standardization of the MLS Protocol (Messaging Layer Security). The MLS protocol relies on a Group Key Agreement Protocol that allows members of a group to derive a common secret called group key which serves as a basis to secure group communications. It is scalable in terms of the number of operations modifying the group such as adding/removing members and it supports periodic group-key renewals preventing compromised communication. The MLS Protocol offers an efficient solution to guarantee the confidentiality and integrity of communication. However, the availability of the protocol depends on the centralized Delivery-Service component. The centralization of this component makes it an ideal target for attackers who wish to disrupt communication. Notably, with the help of a compromised Delivery Service, an attacker can prevent group members from refreshing their keys and resolving the compromise.

In order to overcome these limitations we proposed DiSCreet (Distributed delIvery Service with Context-awaRE coopEraTion), a fully distributed Delivery Service [7]. It combines two distributed communication mechanisms adapted to the need of the messages exchanged by the protocol. We used a Probabilistic Reliable Broadcast mechanism to reliably deliver messages allowing users to propose changes to the group (i.e. Proposal messages) and a Cascade Consensus Protocol to deliver the messages that actually modify the group (i.e. Commit messages) and thus require an agreement between members. Our solution strengthens the availability of the MLS Protocol without compromising its security. We showed that our approach is relevant in the context of dynamic groups by conducting a theoretical study comparing DiSCreet with DCGKA, another distributed group key agreement protocol. We implementated DiSCreet based on an open source implementation of MLS.

8.2 Active Sybil Attack and Efficient Defense Strategy in IPFS DHT

Participants: Thibault Cholez *(Resist team)*, Victor de Moura Netto, Claudia-Lavinia Ignat.

The InterPlanetary File System (IPFS) is a decentralized peer-to-peer (P2P) storage that relies on Kademlia, a Distributed Hash Table (DHT) structure commonly used in P2P systems for its proved scalability. However, DHTs are known to be vulnerable to Sybil attacks, in which a single entity controls multiple malicious nodes. Recent studies have shown that IPFS is affected by a passive content eclipse attack, leveraging Sybils, in which adversarial nodes hide received indexed information from other peers, making the content appear unavailable. Fortunately, the latest mitigation strategy coupling an attack detection based on statistical tests and a wider publication strategy upon detection was able to circumvent it. In this work, we present a new active attack, with malicious nodes responding with semantically correct but intentionally false data, exploiting both an optimized placement of Sybils to stay below the detection threshold and an early trigger of the content discovery termination in Kubo, the main IPFS implementation. Our attack achieves to completely eclipse content on the latest Kubo release. When evaluated against the most recent known mitigation, it successfully denies access to the target content in approximately 80% of lookup attempts. To address this vulnerability, we propose a new mitigation called SR-DHT-Store [15], which enables efficient, Sybil-resistant content publication without relying on attack detection but instead on a systematic and precise use of region-based queries, defined by a dynamically computed XOR distance to the target ID. SR-DHT-Store can be combined with other defense mechanisms, resulting in a defense strategy that completely mitigates both passive and active Sybil attacks at a lower overhead, while allowing for an incremental deployment.

8.3 Impact of Chatbots on Virtual Teamwork Dynamics and Performance

Participants: Clélie Amiot, François Charoy.

We studied the role of chatbots as a pivotal element in enhancing virtual teamwork. We delved into the effects of chatbots on group dynamics and performance within an online collaborative setting. To this end, a unique collaborative online activity was developed, completed with an integrated platform and a custom-designed chatbot assistant. The study involved 72 participants, systematically arranged into teams of four. These teams were further allocated into four distinct experimental conditions based on the nature of chatbot assistance provided: no assistance, private chat assistance, group chat assistance, or a combination of both.

The core findings of this investigation revealed a pronounced enhancement in team performance metrics attributable to the chatbot intervention. Teams with chatbot assistance exhibited not only improved performance but also experienced a notable reduction in response times for information requests during the collaborative activity. This improvement underscores the efficacy of chatbots in streamlining communication and information dissemination within team settings.

A particularly compelling aspect of our findings was the significant correlation observed between the chatbot's communication capabilities and the cognitive workload of team members. Teams interacting with chatbots demonstrating higher communication proficiency reported reduced cognitive strain, suggesting that the quality of chatbot interaction plays a crucial role in the overall team experience [6].

8.4 Dynamics of Digital Collaborative Tools in Civil Security's Ecologies of Artifacts

Participants: François Charoy, Lisa Formentini.

Introducing new digital collaborative tools in civil security is a recurrent issue in crisis informatics research. Our work aims to understand key dynamics in the introduction of the tools used for collaboration by civil security through the lens of the concept of ecology of artifacts (EoA). We identified multiple evolutionary movements based on real-life tool's cases inside the EoA of French firefighters of the Moselle region (SDIS57). Our research method is based on qualitative data collection through inter-service training observations and semi-directive interviews with active professionals. A thematic analysis revealed a dense, sometimes redundant and inter-connected EoA, constantly evolving through at least six movements: four related to the introduction of a new digital collaborative tool (personal-to-organizational, bottom-up, top-down and horizontal), one related to the realignment of an adopted tool and one related to a tool's replacement. Our research aims to facilitate the introduction of future digital collaborative tools for civil security and to guide the design of crisis management systems and policymakers toward working with pre-existing EoA rather than replacing it [10], [13], [14] [11].

8.5 Causal Analysis of GossipSub Mesh Parameters Over the XRP Ledger

Participants: Jean-Philippe Eisenbarth, Jorge Augusto Meira *(SnT, University of Luxembourg)*, Flaviene Scheidt de Cristo *(SnT, University of Luxembourg)*, Radu State *(SnT, University of Luxembourg)*.
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Several distributed systems based on unstructured peer-to-peer networks, such as blockchains, rely on underlying protocols to disseminate messages in a fast and reliable way. As the state of the art for message dissemination in blockchains, GossipSub guarantees delivery and resilience against attacks and Byzantine faults by scaling publish and subscribe dissemination without exceeding bandwidth or overloading peers. Although GossipSub relies heavily on the way its mesh is constructed, there is little insight into how different configuration parameters impact the overall performance of the system. In [9] we analyzed the relationships between the configuration and the performance of GossipSub from a causal point of view using the concrete case of the XRP Ledger, a decentralized, open-source blockchain designed primarily for fast, low-cost payments and asset transfers. Using graphical causal methods to assess connection strength, our study aims to identify optimal GossipSub configurations across domains while reducing the need for extensive empirical testing.

9 Bilateral contracts and grants with industry

9.1 Bilateral contracts with industry

Hivenet - Hive Computing Services SAS (Cannes, France)

Participants: Alexandru Dobrila *(Hivenet)*, Davide Frey *(WIDE team)*, Claudia-Lavinia Ignat *(contact)*, Hua Junrui *(Hivenet)*, Gérald Oster, Ludovic Paillat *(Hivenet)*, François Taiani *(WIDE team)*, Mathieu Turuani *(PESTO team)*.

- Ludovic Paillat, CIFRE PhD Student, is supervised by Claudia-Lavinia Ignat, Davide Frey (WIDE team), Mathieu Turuani (PESTO team) and Alexandru Dobrila (Hivenet) on *Security for peer-to-peer cloud storage without central authority* since October 2023.
- Hua Junrui, CIFRE PhD Student, is supervised by Gérald Oster, François Taiani (WIDE team), and Alexandru Dobrila (Hivenet) on *Advanced techniques for efficient DHT with fault tolerance against Byzantine faults in large-scale distributed systems* since October 2024.

10 Partnerships and cooperations

10.1 International research visitors

10.1.1 Visits of international scientists

Invited professors

Diana Berbecaru

Status Associate Professor

Institution of origin: Politecnico di Torino

Country: Italy

Dates: September 25, 2025 - October 4, 2025

Context of the visit: Lecture teaching in the Master programme SIRAV at Université de Lorraine and discussion on possible collaborations with LORELEY team on cybersecurity attacks and defenses.

Type of mobility: Teaching and Research stay, Invited Professor at Université de Lorraine

Invited PhD students

Dharun Rajkkumar Anandayuvaraj

Status PhD student

Institution of origin: Purdue University

Country: USA

Dates: February 1, 2025 - May 31, 2025

Context of the visit: Collaboration with teams LORELEY and Synalp on the automation of the post-mortem process using language models.

Type of mobility: Chateaubriand programme

10.2 European initiatives

10.2.1 Other european programs/initiatives

IPCEI-CIS (Important Project of Common European Interest – Next Generation Cloud Infrastructure and Services) DXP between Inria and Amadeus

Title: Data Exchange Platform

Dates: 2024-2029

Inria coordinator: Claudia-Lavinia Ignat

Inria teams: CEDAR, LORELEY, MAGELLAN

Participants: François Charoy, Jean-Philippe Eisenbarth, Claudia-Lavinia Ignat *(contact)*, Thomas Lambert, Gérald Oster, Arthur Rauch.

This project aims to design and develop an open-source management solution for a federated and distributed data exchange platform (DXP), operating in an open, scalable, and massively distributed environment (cloud-edge continuum). In collaboration with Amadeus and the Cedar and Magellan teams, we will contribute to the design of solutions for data interoperability, access, and usage control, as well as to the development of a decentralized public/private key infrastructure and mechanisms for data placement and replication.

10.3 National initiatives

10.3.1 Inria Challenge

Alvearium between Inria and Hivenet

Title: Large Scale Secure and Reliable Peer-to-Peer Cloud Storage

Dates: 2022-2026

Inria coordinator: Claudia-Lavinia Ignat

Inria teams: LORELEY, COATI, MAGELLAN, PESTO, WIDE

Participants: Claudia-Lavinia Ignat *(contact)*, Thomas Lambert, Gérald Oster.

The project aims to propose an alternative peer-to-peer cloud which provides both computing and data storage via a peer-to-peer network rather than from a centralised set of data centers. Hivenet proposes to exploit the unused capacity of computers and to incentivize users to contribute their computer resources to the network in exchange for similar capacity from the network and/or monetary compensation. By exchanging similar computer resources and network capacity users can benefit from all cloud services. Peers store encrypted fragments of the data of other peers. This proposed peer-to-peer cloud solution addresses users concerns about the privacy of their data and the dependency on centralised cloud providers. In this collaboration with Hivenet we will apply our work on data replication and placement, Byzantine fault tolerance and security mechanisms in peer-to-peer environments.

Cupseli between Inria and Hivenet

Title: Collaborative Unified Platform for a Scalable and Efficient Learning Infrastructure

Dates: 2025-2029

Inria coordinator: Olivier Beaumont

Inria teams: ARGO, COATI, LORELEY, MAGELLAN, MIMOVE, NEO, OCKHAM, STACK, TADAAM, TOPAL, WIDE

Participants: Claudia-Lavinia Ignat, Thomas Lambert *(contact)*.

The project aims to demonstrate that it is possible to run complex applications (particularly in the field of machine learning) on heterogeneous, distributed, and volatile resources, while achieving strong parallel efficiency and preserving both accuracy and confidentiality. Building on the combined expertise of Hivenet and Inria in storage technologies illustrated in Alvearium, this strategic partnership explores algorithmic and system solutions to optimize computation, memory, and communications, while ensuring security and fault tolerance.

10.3.2 PEPR

PILOT project of PEPR eNSEMBLE (Future of digital collaboration)

Title: Practices and infrastructure lor Long-term collaboration

Dates: 2023-2030

Coordinators: François Charoy (Université de Lorraine), Claudia-Lavinia Ignat (Inria), Myriam Lewkowicz (Université de Technologie de Troyes)

Partners: Inria (coordinator), CNRS, Université Grenoble Alpes, Université Paris-Saclay, Sorbonne Université, IMT, Université de Technologie de Troyes, INSA Lyon, Université Claude Bernard, Nantes Université, ENSAM, Université de Lille, Université de Toulouse III

Participants: François Charoy, Lisa Formentini, Claudia-Lavinia Ignat *(contact)*, Haoyue Liu, Gérald Oster, Olivier Perrin.

The project aims to design and engineer collaborative platforms that build upon regulatory challenges, organizational theories, and field descriptions. The project seeks to anticipate technological and societal evolutions and enable a French (or European) exception on digital platforms that guarantee individual actors' autonomy and foster care, trust, and digital well-being. The project's key challenges stem from revisiting the socio-technical stack, which includes novel conceptual models and design frameworks for long-term collaborative practices and enabling fluid collective experiences that support interoperability and evolution.

TRUSTINCloudS project of PEPR Cloud

Title: Cybersecurity of cloud infrastructures

Dates: 2023-2030

Coordinator: CEA (Aymen Boudguiga)

Partners: AMU, IMT, UL, EURECOM, UT3, CEA, INRIA

Participants: Victor Henrique De Moura Netto, Claudia-Lavinia Ignat *(contact)*.

The TRUSTINCloudS project develops solutions for major cybersecurity challenges specific to Cloud environments, in order to ensure the confidentiality, integrity and availability of data, applications and services. The work carried out in this project aims at adapting traditional security mechanisms to the characteristics of the Cloud in order to address the specific threats of the different types of Clouds (IaaS, PaaS,...). The main objective of TRUSTINCloudS is to study and develop new methodologies to strengthen Cloud security and implement them in platforms in order to build a sovereign and trusted Cloud. In the context of this project, LORELEY team will work on the security of peer-to-peer clouds for storage.

10.4 Public policy support

10.4.1 Collaboration with SDIS 57

Participants: François Charoy *(contact)*, Lisa Formentini.

The PhD thesis of Lisa Formentini investigates the collaborative practices within civil security organizations. Specifically, she examines whether emergency services (firefighters, police officers, paramedics, etc.) have changed their collaborative digital tools and practices since the Covid-19 pandemic and how best to address their evolving needs. Her research involves conducting interviews and observational studies with SDIS 57 (the firefighters of Moselle).

11 Dissemination

Participants: Quentin Acher, Khalid Benali, François Charoy, Victor De Moura Netto, Jean-Philippe Eisenbarth, Lisa Formentini, Claudia-Lavinia Ignat, Thomas Lambert, Gérald Oster, Olivier Perrin, Arthur Rauch.

11.1 Promoting scientific activities

11.1.1 Scientific events: selection

Member of conference steering committees

- Claudia-Lavinia Ignat was member of the Steering Committee of International Conference on Intelligent Computer Communication and Processing (ICCP) in 2025.

Member of conference program committees

- Claudia-Lavinia Ignat was a PC member of the International Symposium on Reliable Distributed Systems (SRDS) in 2025
- Gérald Oster was a PC member of the International Conference on Intelligent Computer Communication and Processing (ICCP) 2025.
- François Charoy was Senior PC Member of the ICSOC Conference in 2025 and PC Member of the following conferences: ICWS 2025, Coopis 2025, Business Information Systems Conference 2025 and Inforsid 2025.
- Jean-Philippe Eisenbarth was a PC member of the Conference on Blockchain Research & Applications for Innovative Networks and Services (BRAINS) and the ACM International Symposium on Blockchain and Secure Critical Infrastructure (BSCI) in 2025

- Thomas Lambert was a PC member of the Workshop on Challenges and Opportunities of Efficient and Performant Storage Systems (CHEOPS) and the International Conference on Big Data (IEEE BigData).
- Khalid Benali was a PC member of the World Conference on Information Systems and Technologies (WorldCist'25), the ACM International Conference on Management of Digital EcoSystems (MEDES 2025), the International Conference on Cloud Computing and Artificial Intelligence Technologies and Applications (CloudTech'25), the International Symposium of ISKO-Maghreb Society on "Digital Sciences: Impacts and Challenges on Knowledge Organization" (ISKO-Maghreb 2025), the Organization of Knowledge and Advanced Technologies (OCTA 2025) and the Workshop on Service oriented Enterprise Architecture for Enterprise Engineering (SoEA4EE'2025) in conjunction with EDOC 2025.

Reviewer

- In 2025 Thomas Lambert reviewed papers for Super Computing and CLUSTER conferences.

11.1.2 Journal

Member of editorial boards

- Claudia-Lavinia Ignat has been an associate editor of Computer Supported Cooperative Work (CSCW): The Journal of Collaborative Computing and Work Practices since 2011
- Claudia-Lavinia Ignat was an editor of the ACM Conference of Computer Supported Cooperative Work and Social Computing (CSCW) 2025 in charge of 150 submissions across two submission cycles [12]
- François Charoy is a member of the editorial board of Service Oriented Computing and Applications (Springer).

Reviewer - reviewing activities

- Claudia-Lavinia Ignat reviewed papers for Future Generation Computer Systems journal
- Arthur Rauch reviewed a paper for IEEE Transactions on Computers
- Jean-Philippe Eisenbarth reviewed a paper for Springer's Journal of Network and Systems Management
- Thomas Lambert reviewed papers for Transactions on Distributed Systems, Future Generation Computer Systems, Journal of Parallel and Distributed Computing and Transactions on Cloud Computing journals

11.1.3 Invited talks

- Claudia-Lavinia Ignat and Gérald Oster were invited to give the presentation "Working together remotely: solutions and challenges of distributed collaborative systems" ("Travailler ensemble à distance : solutions et défis des systèmes collaboratifs distribués") at Rendez-vous de l'informatique du Programme National de Formation 2024-2025 du Ministère de l'Éducation Nationale, de l'Enseignement Supérieur et de le Recherche and at NSI journey (Numérique et Sciences Informatiques) – SNT (Sciences Numériques et Technologie), on April 2025, Nancy, France [17]
- Claudia-Lavinia Ignat was invited to give the presentation "Peer-to-Peer Architectures for Scalable Storage and Efficient Distributed Learning" at Smart Diaspora 2025, on November 2025, Cluj-Napoca, Romania
- Lisa Formentini was invited to present her research work during the Tech-Cico seminar at UTT, Troyes on Septembre 2025

11.1.4 Leadership within the scientific community

- Claudia-Lavinia Ignat and François Charoy organized monthly online animation seminars and bi-annual meetings in the context of PILOT project of PEPR eNSEMBLE involving 14 research institutions and more than 25 research teams in France.

11.1.5 Research administration

- Claudia-Lavinia Ignat is a member of the Scientific Committee of GDR Réseaux et Systèmes Distribués (RSD) since 2024. She is a member of “Bureau du Comité de Projets" (BCP) for Inria Centre at University of Lorraine since 2022. In 2025 she was responsible with leading the hiring committee for Junior Research Scientists (CRCN/ISFP) at Inria Grenoble.

- Thomas Lambert is scientific deputy for Nancy of Grid5000/SLICES-FR platform since 2023. He is also a member of the user’s committee for the Abaca platform and Abaca coordinator for the Contractual Plan between the State/Regions (Contrat de Plan Etat Région - CPER) Grand-Est Numérique Intensif - GENI. He was also part of a hiring committee for four ATER positions.

- Gérald Oster was the president of two hiring committees for a Professeur Agrégé (PRAG) position at Télécom Nancy in 2025.

- Quentin Acher, Lisa Formentini and Arthur Rauch are members of “Bureau des Doctorants" for Loria in charge of the organisation of students’ integration weekend and Coffee Time and Beer Time events since 2024.

11.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

Permanent members of the LORELEY project-team are leading teachers in their respective institutions. They are responsible of lectures in disciplines like software engineering, database systems, object oriented programming and design, distributed systems, service computing and more advanced topics at all levels and in different departments in the University. Most PhD Students have also teaching duties in the same institutions. Claudia-Lavinia Ignat teaches a course on data replication and consistency at Master level (M2 SIRAV) at Université de Lorraine. As a whole, the LORELEY team accounts for more than 2,500 hours of teaching. Members of the LORELEY team are also deeply involved in the pedagogical and administrative life of their departments.

- Khalid Benali is Associate Professor at IDMC. He heads the Master Master degree speciality "Distributed Information Systems" of MIAGE (Université de Lorraine). He teaches around 250 hours a year.

- François Charoy is Professor at TELECOM Nancy Engineering School. He is responsible for the software engineering speciality. He teaches around 250 hours a year.

- Jean-Philippe Eisenbarth is Associate Professor at IDMC. He is responsible for the first year of the “MIASHS" Bachelor’s degree at IDMC. He teaches around 200 hours a year.

- Claudia-Lavinia Ignat teaches a course of 32 hours a year on data replication and consistency at Master level (M2 SIRAV) at Université de Lorraine..

- Thomas Lambert is Associate Professor at the computer science department. He teaches around 250 hours a year.

- Gerald Oster is Associate Professor at TELECOM Nancy Engineering School and deputy director of this school since 2022. He is responsible for the 3rd (last) year of study and President of the jury of the Diploma at TELECOM Nancy. He teaches around 300 hours a year.

- Olivier Perrin is Professor at IUT Nancy. He teaches around 250 hours a year.

11.2.1 Supervision

- PhD defended: Clélie Amiot, Trust and Human/Chatbot collaboration, defended in November 2025, supervised by Jérome Dinet and François Charoy
- PhD in progress: Quentin Acher, Management of mutable data over P2P storage, started in September 2023, supervised by Claudia-Lavinia Ignat and Shadi Ibrahim (Magellan team)
- PhD in progress: Ludovic Paillat (Hivenet), Security for peer-to-peer cloud storage without central authority, started in October 2023, supervised by Claudia-Lavinia Ignat, Davide Frey (WIDE team) and Mathieu Turuani (PESTO team)
- PhD in progress: Lisa Formentini, Evolution of Ecology of Artefacts for Cooperation, the case for Civil Security, started in October 2023, supervised by François Charoy and Matthieu Tixier (UTT)
- PhD in progress: Mohammad Rizk (Magellan team), Reliable and cost-efficient data placement and repair in P2P storage over immutable data, started in November 2023, supervised by Shadi Ibrahim (Magellan team) and Thomas Lambert
- PhD in progress: Victor Henrique De Moura Netto, Improving security and performance of IPFS's DHT, started in October 2024, supervised by Claudia-Lavinia Ignat and Thibault Cholez (Resist team)
- PhD in progress: Hua Junrui (Hivenet), Advanced techniques for efficient DHT with fault tolerance against Byzantine faults in large-scale distributed systems, started in October 2024, supervised by François Taiani (Wide team) and Gérald Oster
- PhD in progress: Haoyue Liu, Evolution of agile development process in the Generative AI era, started in November 2025, supervised by François Charoy and Rebecca Deneckere (CRI, Paris)
- Postdoc: Arthur Rauch, started in October 2025, "Distributed PKI", supervised by Jean-Philippe Eisenbarth and Claudia-Lavinia Ignat
- Research engineer: Adrien Ludwig, till January 2025, "Collaborative File System", supervised by Claudia-Lavinia Ignat and Gérald Oster
- Research engineer: Jean-Philippe Eisenbarth, from April till August 2025, "Group key management", supervised by Claudia-Lavinia Ignat
- Research engineer: Habibatou Ba, from May till August 2025, "Collaborative File System" supervised by Claudia-Lavinia Ignat and Gérald Oster
- Research engineer: Haleema Khan, since December 2025, "CRDTs for distributed collaborative file system", supervised by Claudia-Lavinia Ignat and Gérald Oster
- Research engineer: Georgy Ishmaev, since December 2025, "Incentived for peer-to-peer storage systems", supervised by Claudia-Lavinia Ignat
- Intern: Dharun Rajkkumar Anandayuvaraj, from February 1, 2025 to May 31, 2025, "Automation of the post-mortem process using language models", supervised by Claudia-Lavinia Ignat and Cristophe Cerisara (Synalp team, Loria)

11.2.2 Juries

- Joël Roman Ky, PhD defense jury, "Anomaly Detection and Root Cause Diagnosis for Low-Latency Applications in Time-Varying Capacity Networks", Université de Lorraine, April 2025 (Claudia-Lavinia Ignat, Invited member)
- Enzo d'Andrea, PhD defense jury, "Apprentissage machine réutilisable et adaptable pour la sécurité réseau", Université de Lorraine, December 2025 (Claudia-Lavinia Ignat, President)

- Elise Klein, PhD defense jury, "Formal Verification in Practice: Real-World Case Study and Enhanced Support for AC Operators in Tamarin", Université de Lorraine, December 2025 (Claudia-Lavinia Ignat, Examiner)
- Ali Nour Eldin, PhD defense jury, A Comprehensive Framework for Low-Code Data-Centric Process Management, Télécom Sud Paris, June 2025 (François Charoy, Rapporteur)
- Wissam Gherissi, PhD defense, Predictive Process Monitoring: improving predictive models using object-centric information, Université de Paris Dauphine, September 2025 (François Charoy, Rapporteur)

11.3 Popularization

11.3.1 Specific official responsibilities in science outreach structures

- Lisa Formentini was a member of Orion club on “Human Interact" and organised a pint of science and several lab visits
- Lisa Formentini was a member of "Bureau de l’association Sciences Cognitives Fresco" during one month, in Avril 2025

11.3.2 Productions (articles, videos, podcasts, serious games, ...)

- In Feburary 2025 Lisa Formentini gave an interview on "Combining computer science and psychology to support public safety"
- In July 2025 Lisa Formentini gave a video interview on an interdisciplinary profile in computer science
- In August 2025 Claudia-Lavinia Ignat gave a video interview on Alvearium, the peer-to-peer cloud project (Alvearium, le projet de cloud pair à pair)
- In October 2025 Claudia-Lavinia Ignat gave an interview on LORELEY: towards decentralised and secure collaborative systems
- In December 2025 Claudia-Lavinia Ignat realised a podcast on LORELEY research work
- In December 2025 Claudia-Lavinia Ignat gave an interview on "Data management: Amadeus and Inria are exploring decentralisation"

11.3.3 Participation in Live events

- In January and February 2025 Claudia-Lavinia Ignat presented her research works to several ninth-grade students (élèves en 3ème) while they were doing an internship at Inria Centre at Université de Lorraine
- In February 2025 Thomas Lambert supervised Julie Oster, a ninth-grade student (élève en troisième) at La Malgrange for a one-week internship at Inria Centre at Université de Lorraine, in the LORELEY team
- In June 2025 Gérald Oster supervised Maxence Quignard, a tenth-grade student (élève en seconde) at Henri Loritz high school for a one-week internship at Inria Centre at Université de Lorraine, in the LORELEY team
- In December 2025 Claudia-Lavinia Ignat supervised Achille Guéry, a ninth-grade student (élève en troisième) at Jacques Callot high school for a one-week internship at Inria Centre at Université de Lorraine, in the LORELEY team
- Victor de Moura Netto and Quentin Acher organised several Arduino tutorials for several high school students

- In September 2025, Lisa Formentini did a presentation at Jeudi de la Cardie organized by Académie Nancy-Metz in Nancy
- In June 2025, Lisa Formentini did a presentation during RESAIA club Orion IA in Metz
- In January 2025 Lisa Formentini presented her research work on "Computer science and psychology" during a Pizza time event at Loria/Inria Centre at Université de Lorraine dedicated for an exchange between young researchers around their research topics
- In February 2025, Lisa Formentini gave a presentation during “Sciences, un métier de femmes” to encourage high school girls to pursue a scientific career.

12 Scientific production

12.1 Major publications

[1] C. Amiot, F. Charoy and J. Dinet. ‘Chatbots in Collaborative Settings and their Impact on Virtual Teamwork’. In: *Proceedings of the ACM on Human-Computer Interaction* 9.2 (2nd May 2025), CSCW047. DOI: 10.1145/3710945. URL: https://hal.science/hal-04841009.

[2] C.-L. Ignat, V. Elvinger and H. Ba. ‘Synql: A CRDT-Based Approach for Replicated Relational Databases with Integrity Constraints’. In: *Lecture Notes in Computer Science*. DAIS 2024 - 24th IFIP International Conference on Distributed Applications and Interoperable Systems. Vol. LNCS-14677. Distributed Applications and Interoperable Systems. Groningen, Netherlands: Springer Nature Switzerland, 2024, pp. 18–35. DOI: 10.1007/978-3-031-62638-8_2. URL: https://inria.hal.science/hal-04969158.

[3] M. Nicolas, G. Oster and O. Perrin. ‘Efficient Renaming in Sequence CRDTs’. In: *IEEE Transactions on Parallel and Distributed Systems* 33.12 (1st Dec. 2022), pp. 3870–3885. DOI: 10.1109/TPDS.2022.3172570. URL: https://inria.hal.science/hal-03772633.

[4] L. Paillat, C.-L. Ignat, D. Frey, M. Turuani and A. Ismail. ‘Discreet: distributed delivery service with context-aware cooperation’. In: *Annals of Telecommunications - annales des télécommunications* 80.3-4 (Apr. 2025), pp. 357–374. DOI: 10.1007/s12243-024-01053-1. URL: https://inria.hal.science/hal-04829916.

[5] P.-A. Rault, C.-L. Ignat and O. Perrin. ‘Access control based on CRDTs for Collaborative Distributed Applications’. In: *Proceedings of the 22nd IEEE International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom-2023)*. The 22nd IEEE International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom-2023). Exeter, United Kingdom, 1st Nov. 2023. URL: https://inria.hal.science/hal-04224855.

12.2 Publications of the year

International journals

[6] C. Amiot, F. Charoy and J. Dinet. ‘Chatbots in Collaborative Settings and their Impact on Virtual Teamwork’. In: *Proceedings of the ACM on Human-Computer Interaction* 9.2 (2nd May 2025), CSCW047. DOI: 10.1145/3710945. URL: https://hal.science/hal-04841009.

[7] L. Paillat, C.-L. Ignat, D. Frey, M. Turuani and A. Ismail. ‘Discreet: distributed delivery service with context-aware cooperation’. In: *Annals of Telecommunications - annales des télécommunications* 80.3-4 (Apr. 2025), pp. 357–374. DOI: 10.1007/s12243-024-01053-1. URL: https://inria.hal.science/hal-04829916.

Invited conferences

[8] C.-L. Ignat. ‘Peer-to-Peer Architectures for Scalable Storage and Efficient Distributed Learning: Invited presentation’. In: Smart Diaspora 2025. Cluj-Napoca, Romania, 6th Nov. 2025. URL: https://hal.science/hal-05434615.

International peer-reviewed conferences

[9] F. S. de Cristo, J. A. Meira, J.-P. Eisenbarth and R. State. 'Causal Analysis of GossipSub Mesh Parameters Over the XRP Ledger'. In: *2025 IEEE/IFIP Network Operations and Management Symposium (NOMS 2025)*. NOMS 2025 - IEEE Network Operations and Management Symposium. Honolulu, United States: IEEE, 15th July 2025, pp. 01–09. DOI: 10.1109/NOMS57970.2025.11073650. URL: https://inria.hal.science/hal-05462849.

[10] L. Formentini, F. Charoy and M. Tixier. 'Changing Collaborative Tools: Introductory Dynamics of Digital Collaborative Tools in Civil Security's Ecologies of Artifacts'. In: *Proceedings of the 22nd ISCRAM Conference*. ISCRAM 2025- International Conference on Information Systems for Crisis Response and Management. Halifax, Canada, 20th May 2025. DOI: 10.59297/m1qksb05. URL: https://hal.science/hal-04992248.

[11] L. Formentini, M. Tixier and F. Charoy. 'Studying digitally supported collaboration through Artifact Ecologies: a State of art'. In: *ACM digital library Proceedings of IHM25*. Interactions Humain Machines 2025. Toulouse, France, 4th Nov. 2025. URL: https://hal.science/hal-05059264.

Edition (books, proceedings, special issue of a journal)

[12] A. Fabiano Pinatti de Carvalho, J. Vitak, X. Ma, X. Page, C. Rossitto, N. Makoto Su, L. Barkhuus, M. Divitini, A. Lee Hughes, J. Huh-Yoo, C.-L. Ignat, R. Kelly, K. Luther, S. Mccrickard, D. Mcdonald, J. Pater, H. Tellioglu, A. Vivacqua, H.-C. Wang, J. Cai, M. Jacobs and S. Koch Stigberg, eds. *CSCW Companion '25: Companion Publication of the 2025 Conference on Computer-Supported Cooperative Work and Social Computing*. CSCW Companion '25: Companion of the Computer-Supported Cooperative Work and Social Computing. Bergen, Norway: ACM, 17th Oct. 2025. DOI: 10.1145/3715070. URL: https://hal.science/hal-05434580.

Reports & preprints

[13] L. Formentini, F. Charoy and M. Tixier. *"We're not going to use them all". Evolutive Movements in the Ecologies of Artifacts of Civil Security populations*. 18th Feb. 2025. DOI: 10.18420/ecscw2025-to-be-added. URL: https://hal.science/hal-04992244.

[14] L. Formentini, M. Tixier and F. Charoy. *"They've given us so many tools". Movements in French civil security's collaborative Ecologies of Artifacts*. 27th Oct. 2025. URL: https://hal.science/hal-05372573.

[15] V. H. de Moura Netto, T. Cholez and C.-L. Ignat. *Active Sybil Attack and Efficient Defense Strategy in IPFS DHT*. 2nd May 2025. URL: https://inria.hal.science/hal-05424411.

Other scientific publications

[16] L. Formentini. 'Movements in collaborative tools. Evolutionary dynamics if civil security's artifact ecologies.' In: PePR eNSEMBLE annual day. Paris, France, 2025. URL: https://hal.science/hal-04904355.

Scientific popularization

[17] C.-L. Ignat and G. Oster. *Travailler ensemble à distance : solutions et défis des systèmes collaboratifs distribués*. Nancy, France, 2nd Apr. 2025. URL: https://inria.hal.science/hal-05170265.

12.3 Cited publications

[18] J.-H. Cho, K. Chan and S. Adali. 'A Survey on Trust Modeling'. In: *ACM Computing Surveys* 48.2 (Nov. 2015). DOI: 10.1145/2815595.

[19] C. A. Ellis and S. J. Gibbs. 'Concurrency control in groupware systems'. In: *SIGMOD Record* 18.2 (June 1989), pp. 399–407. DOI: 10.1145/66926.66963.

[20] S. Gilbert and N. Lynch. 'Brewer's Conjecture and the Feasibility of Consistent, Available, Partition-Tolerant Web Services'. In: *SIGACT News* 33.2 (June 2002), pp. 51–59. DOI: 10.1145/564585.564601.

[21] G. Oster, P. Urso, P. Molli and A. Imine. 'Data Consistency for P2P Collaborative Editing'. In: *Proceedings of the ACM Conference on Computer-Supported Cooperative Work - CSCW 2006*. Banff, AB, Canada, 2006, pp. 259–267. DOI: 10.1145/1180875.1180916.

[22] R. Rodrigues and P. Druschel. 'Peer-to-peer Systems'. In: *Communications of the ACM* 53.10 (Oct. 2010), pp. 72–82. DOI: 10.1145/1831407.1831427.

[23] Y. Saito and M. Shapiro. 'Optimistic Replication'. In: *Computing Surveys* 37.1 (Mar. 2005), pp. 42–81. DOI: 10.1145/1057977.1057980.

[24] M. Shapiro, N. M. Preguiça, C. Baquero and M. Zawirski. 'Conflict-Free Replicated Data Types'. In: *13th International Symposium on Stabilization, Safety, and Security of Distributed Systems, SSS 2011*. Oct. 2011, pp. 386–400. DOI: 10.1007/978-3-642-24550-3_29.