Chair « *Risk and Resilience of Complex Systems*»

Centralesupelec

Annual Seminar - September 28, 2023
Anne Barros
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« Resilience analysis and optimization for interconnected or distributed systems: use cases and methodological contributions from the chair RRCS – 2019-2024 »

ESREL 2023 – Southampton UK
Keynote

September 4, 2023
Anne Barros
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Etienne Briere, Laurent Billet - Direction scientifique

- **Orange**

Thierry COUPAYE, Direction du Domaine de Recherche Software Infrastructure ORANGE

Bertrand Decocq, Responsable du projet « Risks and Resilience of Complex Systems »,

- **SNCF**

David DE ALMEIDA, Direction Innovation & Recherche SNCF

Cyril Cappi

Sécurité Système

DIRECTION TECHNOLOGIES, INNOVATION, PROJETS GROUPE

INNOVATION & RECHERCHE

Département Physique du Système Ferroviaire

- **EDF**
  - Carole Duval
  - Patrick Coudray
  - José Marques Lopes
  - Anthony Legendre
  - Emmanuel Rémy
  - Elias Fekhary
  - Yves Thermes
  - Mohamed Hitbi
- **Orange**
  - Benoit Lemoine
- **SNCF**
  - Marc Sango
  - Fabien Letourneaux
  - Alain Noyon
  - Philippe de Laharpe
  - Juliette Pouzet

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Chair RRCS

- 3 permanent members: Anne Barros, Yiping Fang, Zhiguo Zeng
- 3 PHD : Andrea Bellè, Matthieu Roux, Zehui Xuan

Team R3: Risk Resilience and Reliability

- + 3 permanent members: Adam Abdin, Guillaume Lamé, Jakob Puchinger
- + 7 PHD: Youba Nait Belaid (EDF), Rui Li (Orange), Khaled Sayad (Orange), Yang Sun (SNCF), Xihe Ge (ANR), Pascal Quach (ANR), Matthieu Dutel (Resallience),…
- Master Students – CS third year program: ***Operation Research and Risk Analytics***

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Introduction

Resilience definition?

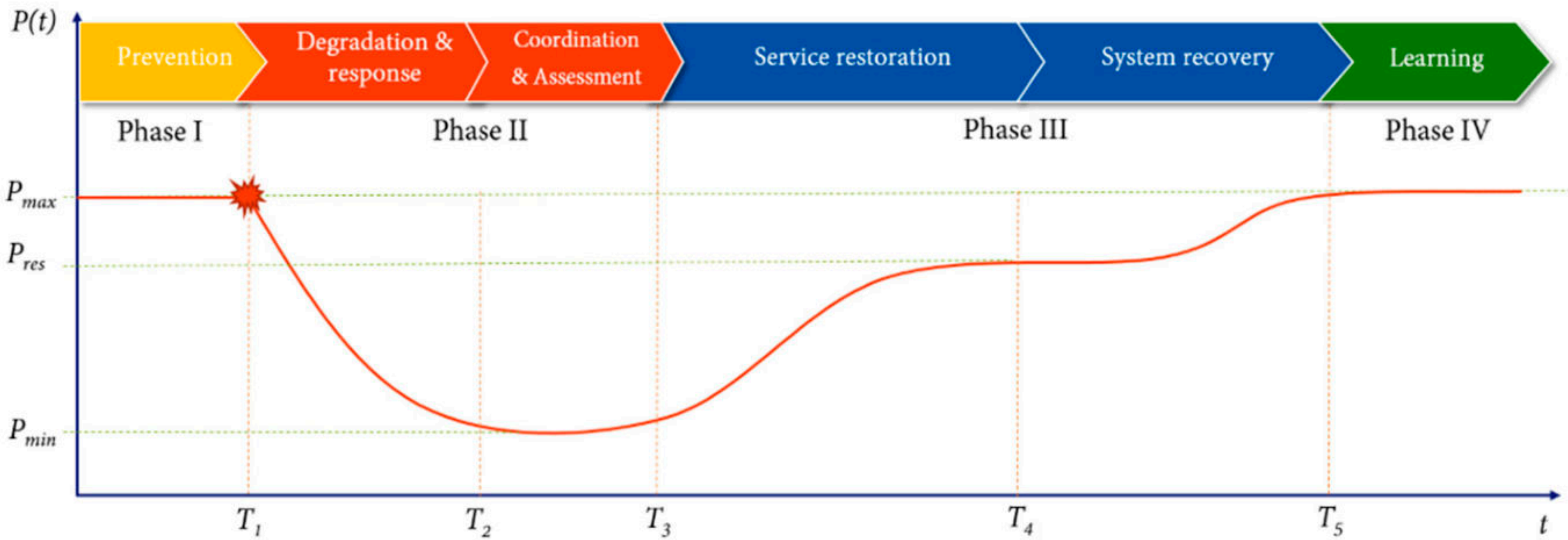
- « Resilience is the ability to
  - prepare and plan for,
  - absorb, recover from or more successfully adapt to

  actual or potential adverse events »

  N. R. Council, *Disaster Resilience: A National Imperative*. 2012.

- Importance of different phases

Performance curve



energies MDPI

Review

Resilience Quantification of Smart Distribution Networks—A Bird's Eye View Perspective

Youba Nait Belaid [1,2], Patrick Coudray [1], José Sanchez-Torres [1], Yi-Ping Fang [2,*], Zhiguo Zeng [2] and Anne Barros [2]

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Research axes elaborated with EDF, Orange, SCNF

- Axis 1: Modeling systems of systems with their interdependences for risk management and resilience between several operators

- Axis 2: Modeling and optimisation of maintenance phases to reduce their impact on service continuity intra-operators.

Axis 1

Modeling of Systems of Systems
with their interdependences
for risk management
and resilience between several operators

Interdependent critical infrastructures

- Physical: infrastructure A is dependent on infrastructure B through the flow of physical quantities, such as energy commodities, equipment, or goods.
- Cyber: infrastructure A is dependent on infrastructure B through the flow of data and information.
- Geographic: infrastructure A and infrastructure B (or some of their components) share the same geographical location, and a change in the local environment can impact both the infrastructures.
- Logic: infrastructure A is dependent on infrastructure B through a relationship that does not belong to the previous categories: human factors, regulations, policies, or financial markets.

S. Rinaldi, J. Peerenboom, and T. Kelly, "Identifying, understand- ing, and analyzing critical infrastructure interdependencies," *IEEE Control Systems Magazine*, vol. 21, no. 6, pp. 11–25, 2001. doi: 10.1109/37.969131.

Axis 1.1 : Identification and modeling of interdependences between systems, identification of possible external «attacks/failures»

- Modeling the effects of attacks/failures, their propagation within a complex system or a system of systems
- Overall vulnerability assessment

Axis 1.2 : Optimization of resilience in design

- Prediction and anticipation of attacks/failures, their propagation within a complex system or a system of systems
- Optimization of the coupling interfaces/implementation of barriers/mitigation actions in the long term

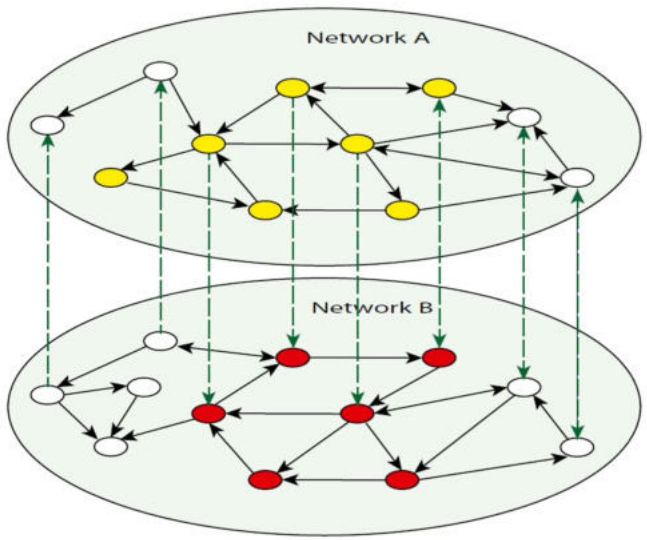
Axis 1.3 : Optimization of resilience in the operational phase

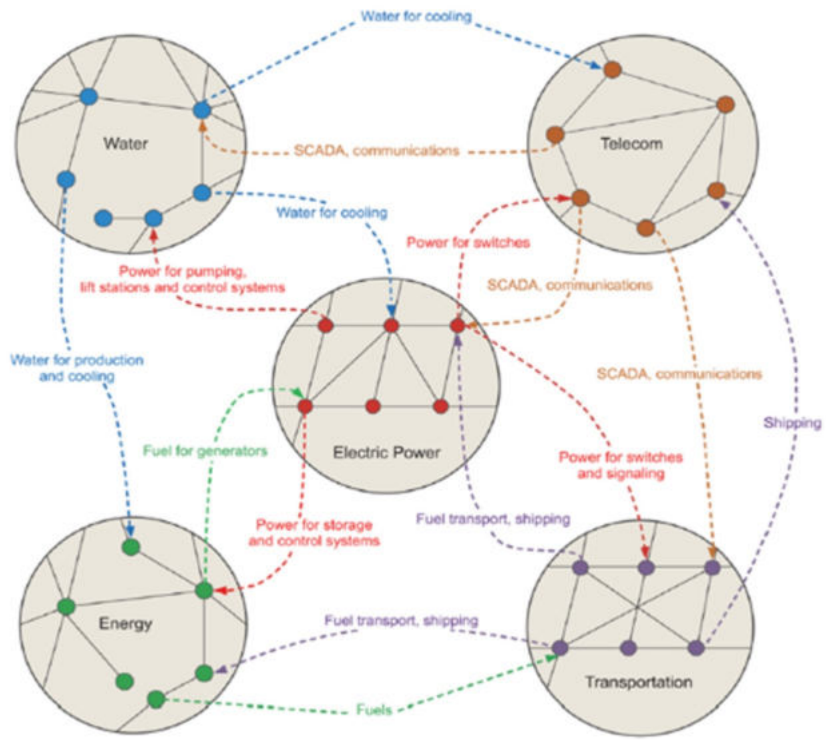
- Detection and early detection of attacks/failures, their propagation within a complex system or a system of systems
- Optimization of the implementation of barriers/mitigation/reconfiguration actions in the short term

PHD Andrea Bellè – Axis 1.1. – Coupling Interface modeling & vulnerability assessment

$P(t) = P$

$P = P_A$

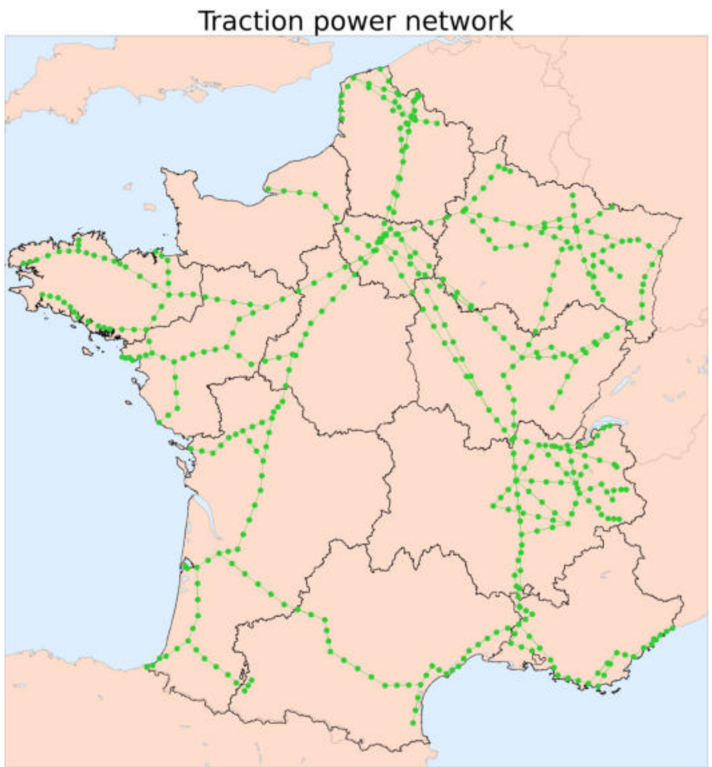


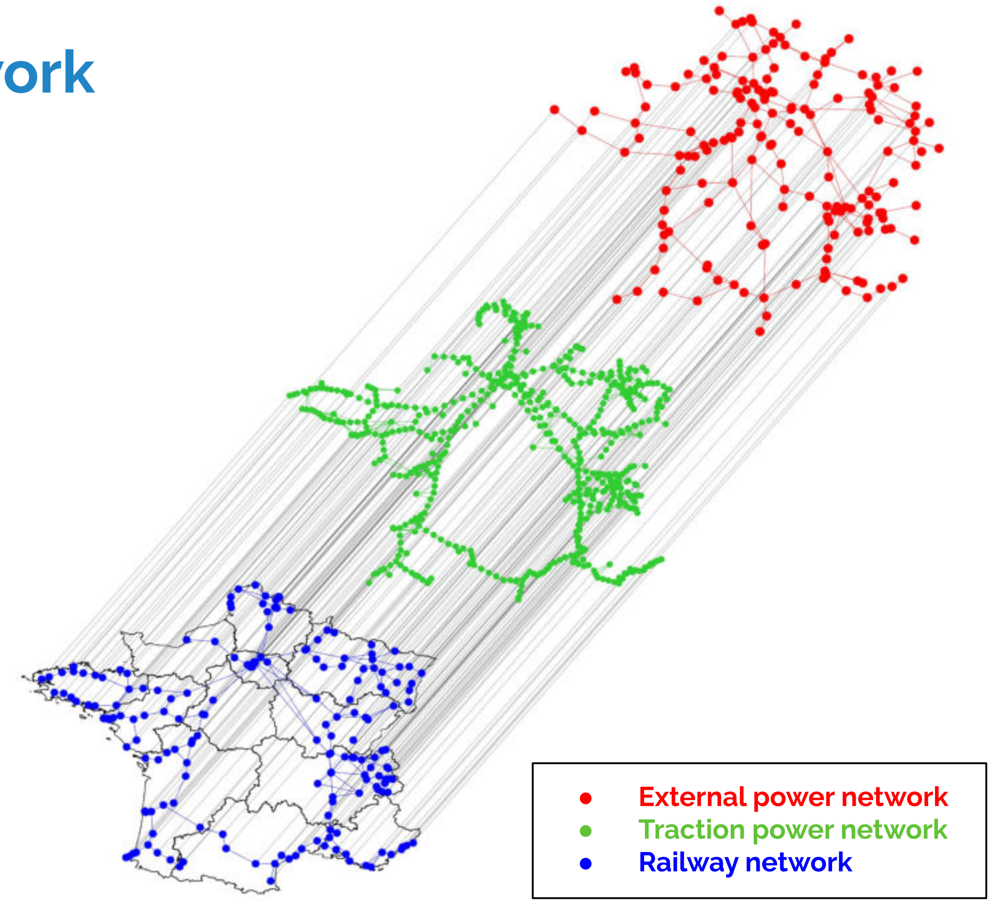


Liu, Xueming, H. Eugene Stanley, and Jianxi Gao. "Breakdown of interdependent directed networks." *Proceedings of the National Academy of Sciences* 113, no. 5 (2016): 1138-1143.
Smolyak, Alex, Orr Levy, Louis Shekhtman, and Shlomo Havlin. "Interdependent networks in Economics and Finance—A Physics approach." *Physica A: Statistical Mechanics and its Applications* 512 (2018): 612-619.

PHD Andrea Bellè – Axis 1.1. – Coupling Interface modeling & vulnerability assessment

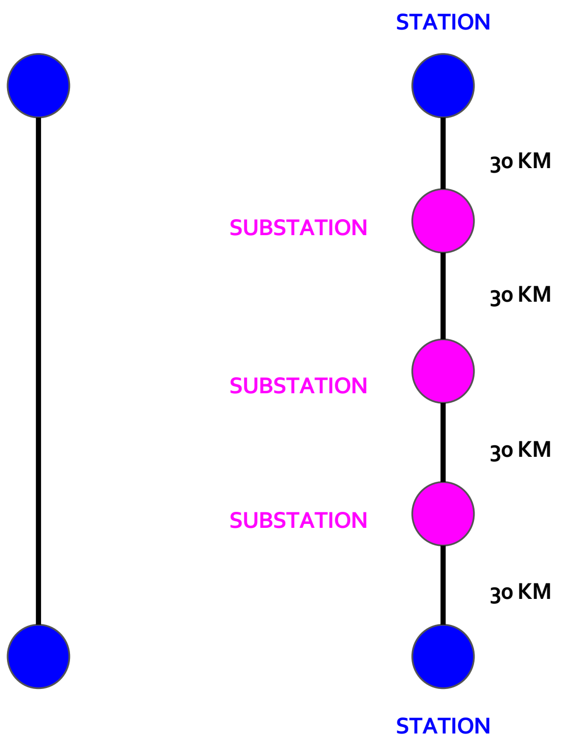
Traction power network

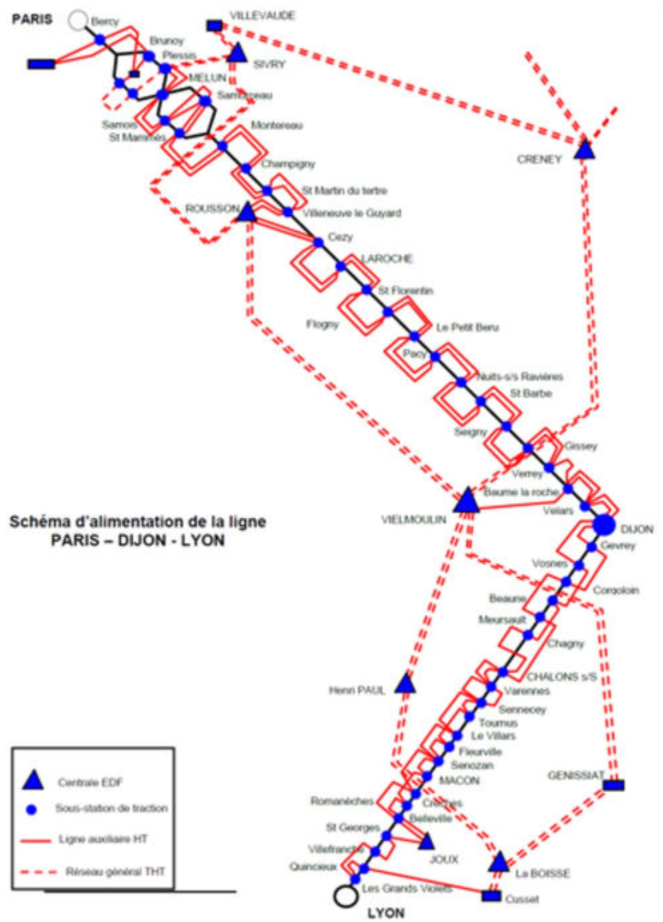




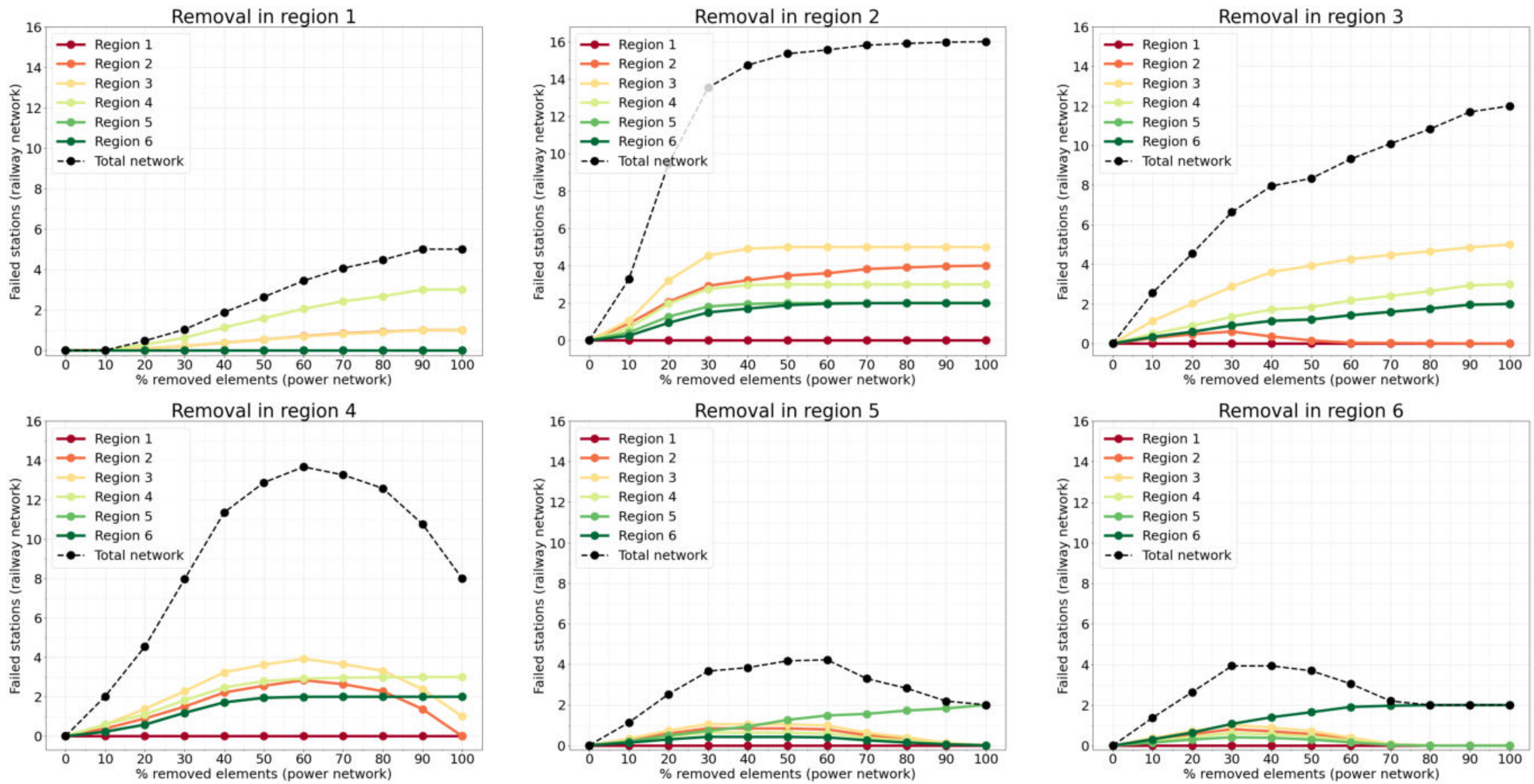
Belle Andrea, Zeng Zhiguo, Duval Carole, Sango Marc and Barros, Anne. "Modeling and vulnerability analysis of interdependent railway and power networks: Application to British test systems", Reliability Engineering & System Safety 2022.

Coupling interface modeling





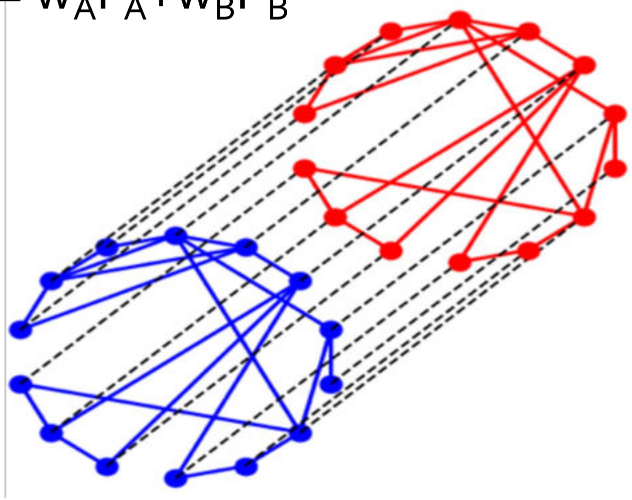
PHD Andrea Bellè – Axis 1.1. – Coupling Interface modeling & vulnerability assessment



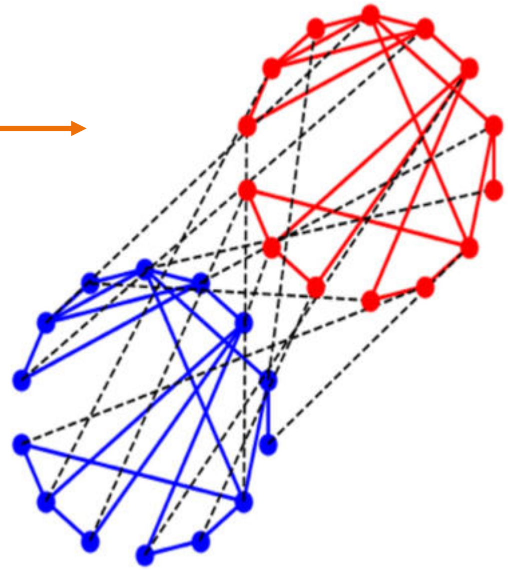
Bellè Andrea, Zeng Zhiguo, Sango Marc and Barros, Anne. "Towards a realistic topological and functional modeling for vulnerability analysis of interdependent railway and power networks", In 31st European Safety and Reliability Conference, ESREL 2021.

$P(t) = P$

$P = w_A P_A + w_B P_B$



DIFFERENT BEHAVIOURS

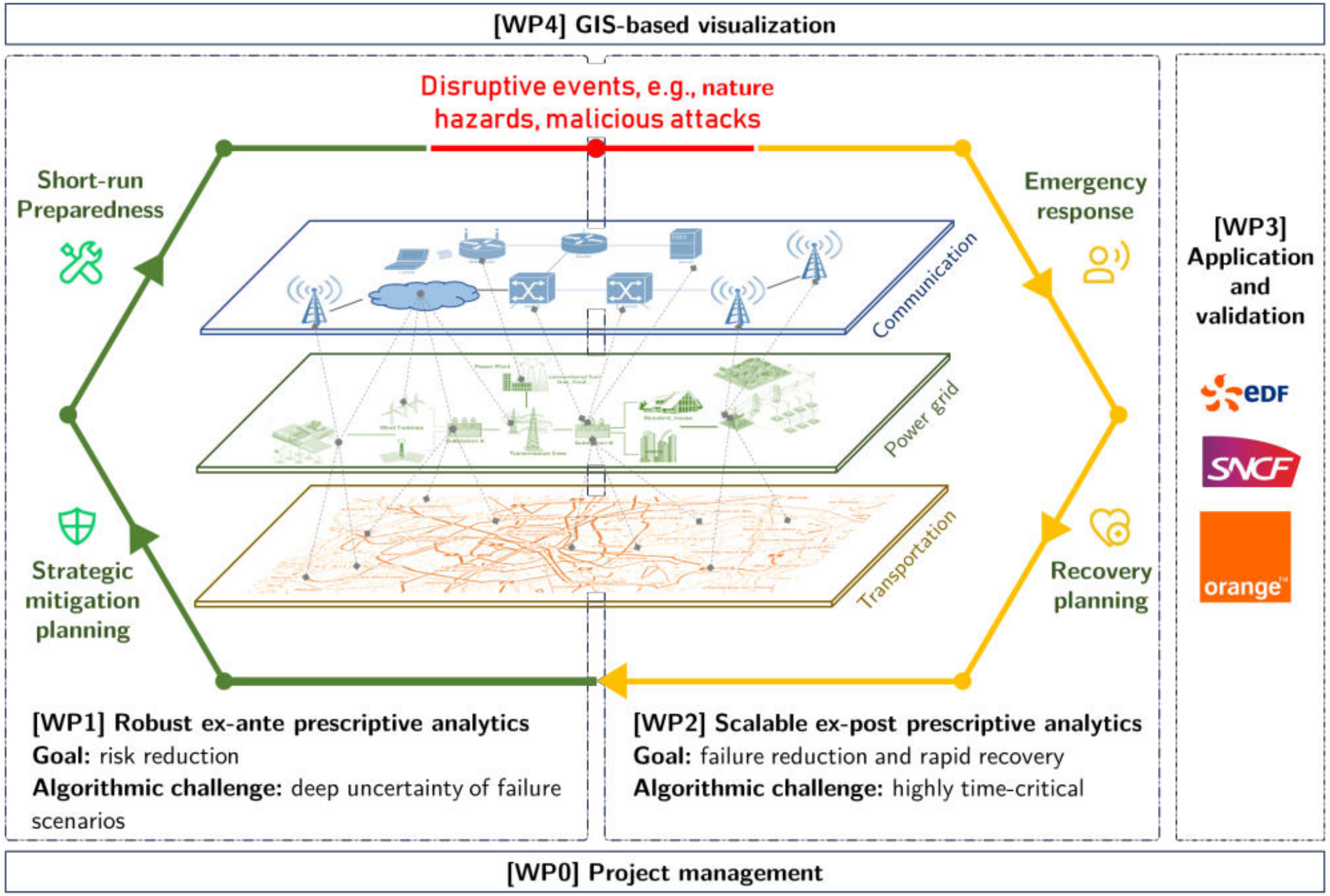


Bellè Andrea, Abdin F. Adam, Zeng Zhiguo, Fang Yi-Ping and Barros Anne, "A resilient-based framework for the optimal coupling of interdependent critical infrastructures", Reliability Engeneering and Systems Safety, 2023

Axis 1

Supporting projects

Prof. Yiping Fang – ANR JCJC– 2023-2027 – « Robust and Scalable Prescriptive Analytics for the Resilience of Critical Infrastructure Networks » 270kEuros



Prof. Anne Barros – AMI PEPR TASE – 2024-2029 – « Strategic Power Systems Development for the Future» 2.5 millions d'Euros

Research Lab	Research Institute/Faculty
Industrial Engineering Lab.	CentraleSupélec
Bordeaux Mathematic Institute	INRIA Centre Bordeaux Sud-Ouest
UMI Sustainability and Resilience	UVSQ
Climate and Environment Sciences Lab.	CNRS
Electrical Eng. Lab.	Grenoble INP - Université Grenoble Alpes

Objective
Simulate, characterize and analyze the scenario of a blackout & Optimize the resilience of Power Systems with Massive Renewable Energy

Research Questions

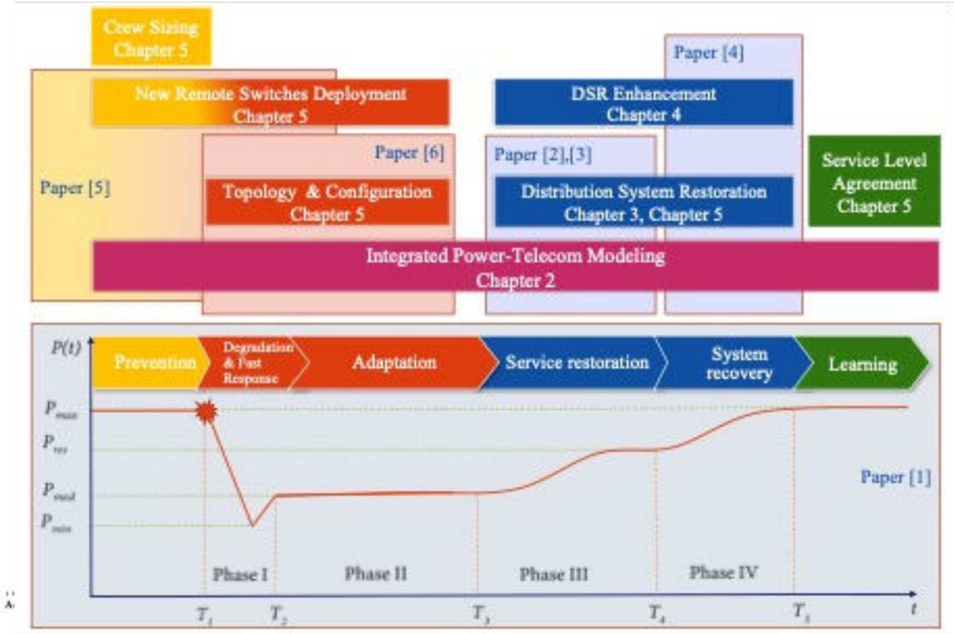
- Climate change scenarios must be considered
- Cascading failures must be analyzed with proper integration of renewable energy sources and climate change
- Societal and economic value chain must be considered
- Resilience must be optimized through proper decisions in operation and in design
- Multidisciplinary and complementary consortium plus a strong scientific integration is required

Axis 1

Team R3 – Dedicated Models for Use Cases

PHD Candidate Youba Nait Belaid– EDF - « Integrated Power-Telecom Modeling for Resilience Quantification and Optimization in Smart Distribution Grids» 2020-2023

- Power Flow model and Graphs for regional distribution networks with tele-operated circuit-breakers
- Optimisation of reconfiguration and mitigation with repair ressources allocation
- PHD Defense on September 18, 2023 – PHD soon available



- Paper [1]: Youba Nait Belaid, Patrick Coudray, José Sanchez-Torres, Yiping Fang, Zhiguo Zeng, Anne Barros. "Resilience Quantification of Smart Distribution Networks—A Bird's Eye View Perspective". In: Energies 14.10, MDPI, Jan. 2021.
- Paper [2]: Youba Nait Belaid, Yiping Fang, Zhiguo Zeng, Anthony Legendre, Patrick Coudray, Anne Barros. "Resilience Optimization of Wide-Area Control in Smart Distribution Grids". In: IFAC-PapersOnLine, 2405-8963, Jan. 2022.
- Paper [3]: Youba Nait Belaid, Yiping Fang, Zhiguo Zeng, Patrick Coudray, Anne Barros. "Optimal Allocation of Resilience Resources for Strategic Communication-aware Restoration of Smart Distribution Grids". Submitted to: IEEE Transactions on Industrial Informatics, Feb. 2023.
- Paper [4]: Youba Nait Belaid, Yiping Fang, Enrique Kremers, Zhiguo Zeng, Patrick Coudray, Anne Barros. "On the Implementation and Enhancement of Optimal Deterministic Crew Schedules during Smart Distribution Grid Restoration". Under submission to: International Journal of Electrical Power & Energy Systems, Jul. 2023.

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PHD candidate Rui Li – Orange - « Modeling of a 5G (or B5G) network to estimate its ability to meet the resilience requirements of verticals» - 2023

Dedicated modeling with discrete event simulation

P(t)= Latency or Availability – Stochastic – Time dependent or steady state

Axis 1.1: Coupling interface between 5G-Telecom network and Electrical-Teleoperation/Train equipements

- Modeling of Telecom network at the right level of abstraction
- Modeling of virtualisation layer
- Vulnerability: effect of failures and traffic on latency

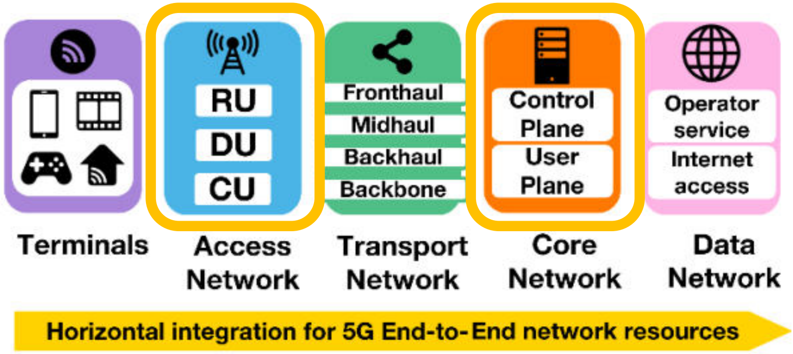
Axes 1.2 : « Optimization » of the resilience in the design phase

- Self healing

Axes 1.3: « Optimization » of the resilience in the operational phase

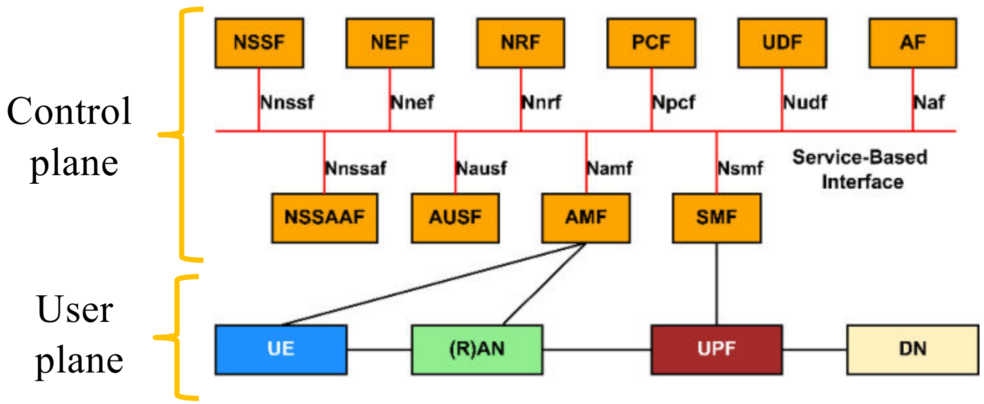
- Auto scaling

PHD Rui Li – Orange - « Modeling of a 5G (or B5G) network to estimate its ability to meet the resilience requirements of verticals» - 2023



5G End-to-End Architecture

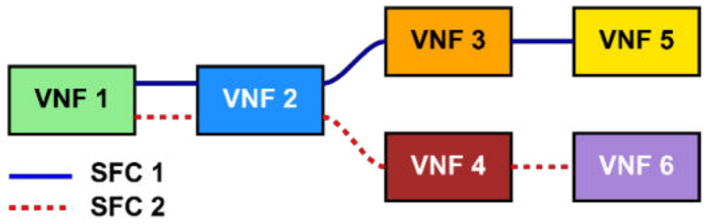
5G Service-Based Architecture



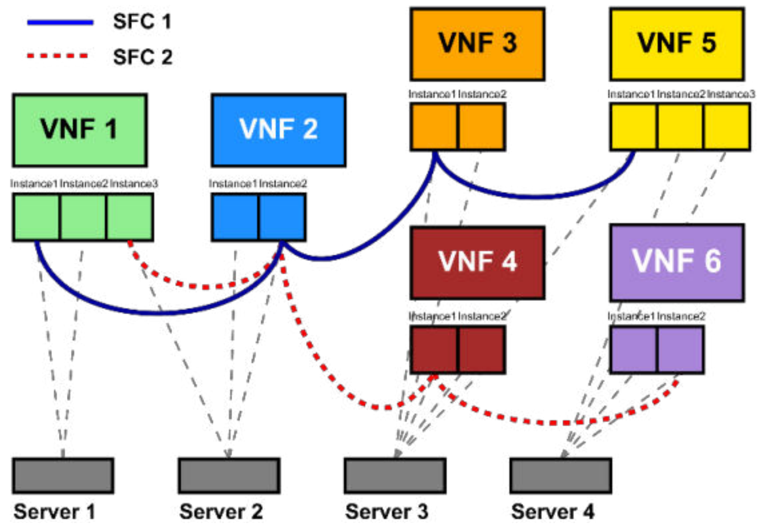
- Authentication Server Function (AUSF).
- Access and Mobility Management Function (AMF).
- Data Network (DN), e.g. operator services, Internet access or 3rd party services.
- Network Exposure Function (NEF).
- Network Repository Function (NRF).
- Network Slice Specific Authentication and Authorization Function (NSSAAF).
- Network Slice Selection Function (NSSF).
- Policy Control Function (PCF).
- Session Management Function (SMF).
- Unified Data Management (UDM).
- Unified Data Repository Function (UDF).
- Application Function (AF).

PHD Rui Li – Orange - « Modeling of a 5G (or B5G) network to estimate its ability to meet the resilience requirements of verticals» - 2023

Two VNF Chains in one network



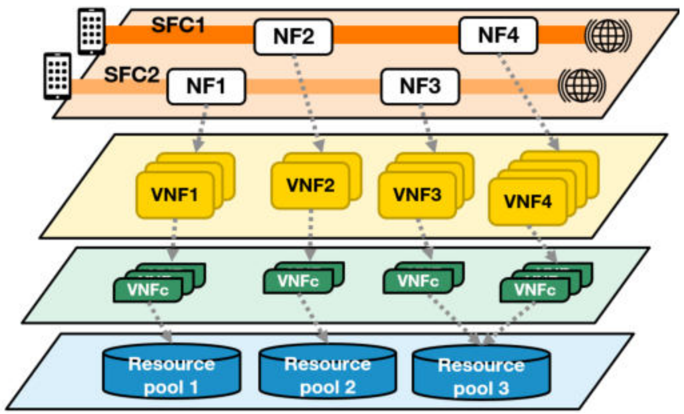
Deployment of two Service Function Chains.



Rui Li, Bertrand Decocq, Anne Barros, Yiping Fang, Zhiguo Zeng. Complexity in 5G Network Applications and use cases. 31st European Safety and Reliability Conference, Sep 2021, Angers, France. pp.3054-3061, 10.3850/978-981-18-2016-8_211-cd . hal-03363854v2

PHD candidate Rui Li – Orange - « Modeling of a 5G (or B5G) network to estimate its ability to meet the resilience requirements of verticals» - 2023

« To deliver an End-to-End service, 5G networks need to steer the traffic through a set of VNFs (Virtual Network Functions) distributed in RAN (Radio Access Network) and CN (Core Network), called SFC (Service Function Chaining). In the previous generations, these functions were implemented in the form of physical boxes. With NFV and SDN, these functions are virtualized, and further softwarized. »



NF1 and NF2 : RAN
NF3 and NF4: CN

VNFi with instances

Microservice /POD

Physical layer - servers

Fig. 1. 5G End-to-End service delivery model with SFC, VNF, VNF component and Resource layers.

Rui Li, Bertrand Decocq, Yiping Fang, Zhiguo Zeng, Anne Barros. A Petri Net-based model to study the impact of traffic changes on 5G network resilience. 32nd European Safety and Reliability Conference (ESREL 2022), Aug 2022, Dublin, Ireland. pp.3016-3023, 10.3850/978-981-18-5183-4_S28-02-493-cd . hal-03891448

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VNF modelling with Petri Nets

Table 1. Place and transition explanations of a microservice process Petri Net.

Element	Explanation
p_1	Packet(s) arriving at microservice
p_2	Packet waiting list for microservice
p_3	Packet rejected due to queue capacity
p_4	Pod replicas of microservice
p_5	Treated Packet(s)
t_1	Packet(s) inserting to waiting list
t_2	Pod selection based on workload
t_3	Packet processing

Resilience management modelling with Petri Nets

- Self Healing
- Auto Scaling

Table 2. Petri Net of Kubernetes autoscaling.

Element	Explanation
p_1	Kubernetes autoscaling probe
p_2	Increase pod number
p_3	Decrease pod number
p_4	Free resources
p_5	Running Pod replicas
t_1	Scaling-out decision
t_2	Scaling-in decision
t_3	No scaling decision
t_4	Create new replica(s)
t_5	Terminate replica(s)

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Fig. 1. VNFs and their microservices.

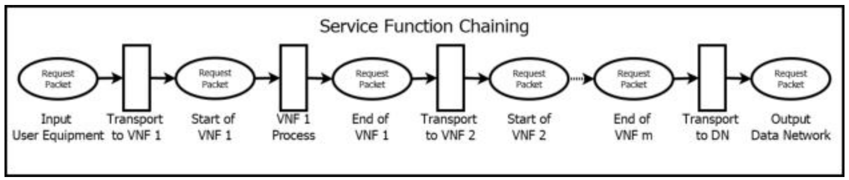


Fig. 2. Petri Net of SFC example.

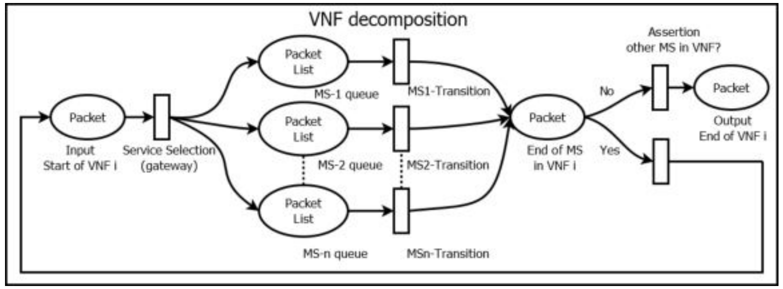


Fig. 3. Petri Net of VNF decomposition.

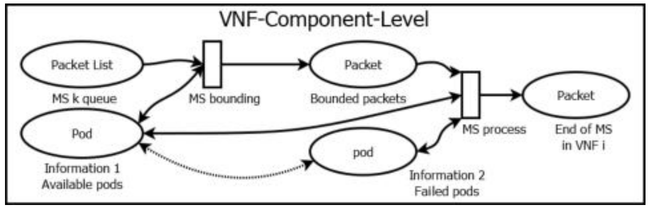


Fig. 4. Petri Net of Mirco-service treatment.

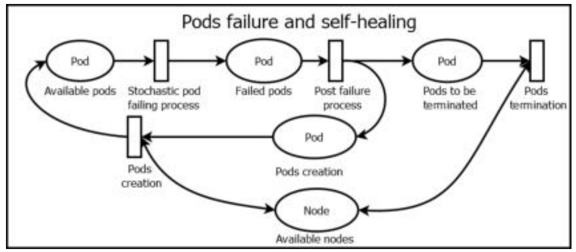


Fig. 5. Pod Self-healing process

Rui Li, Bertr Decocq, Anne Barros, Yiping Fang, Zhiguo Zeng. Petri Net-Based Model for 5G and Beyond Networks Resilience Evaluation. 2022 25th Conference on Innovation in Clouds, Internet and Networks and Workshops (ICIN), Mar 2022, Paris, France. pp.131-135, 10.1109/ICIN53892.2022.9758134 . hal-03648310

PHD candidate Rui Li – Orange - « Modeling of a 5G (or B5G) network to estimate its ability to meet the resilience requirements of verticals» - 2023

- « Reliability challenges of 5G and Beyond networks applications in high-speed trains »

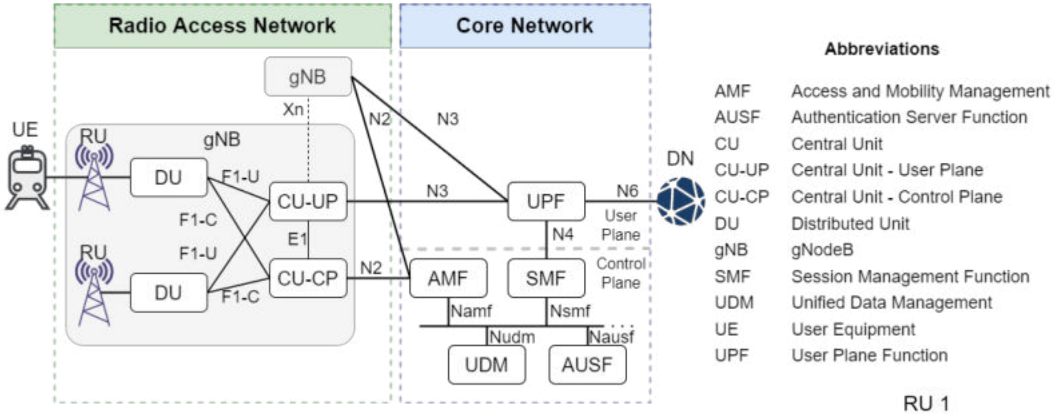
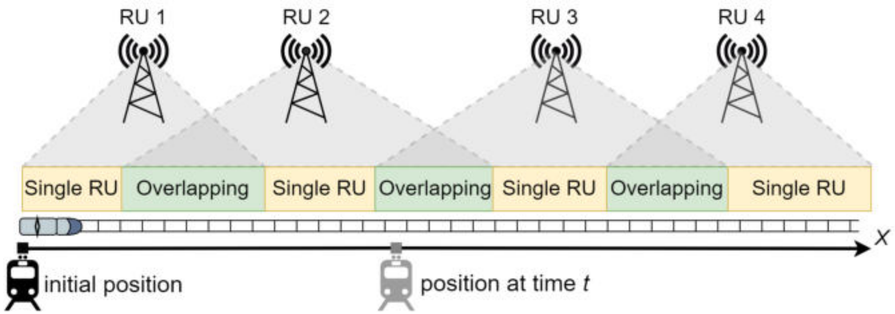
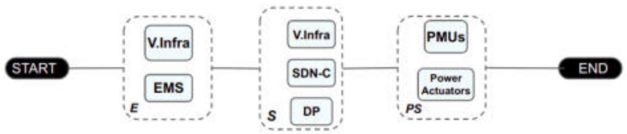


Fig. 1. 5G network architecture.

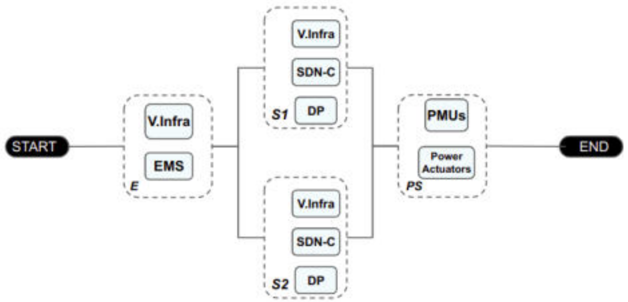


PHD Candidate Khaled Sayad – Orange - « Cross Domain Resilience in Cloud-native, Critical Cyber-Physical Systems Network: Availability modelling, Analysis and Optimisation of Critical Services Provisionning» 2020-2023

Towards Cross-Domain Resilience in Interdependent Power and ICT Infrastructures: A Failure Modes and Effects Analysis of an SDN-enabled Smart Power Grid



(a) Reliability Block Diagram of a CPS^{EPI} without redundancy.



(b) Reliability Block Diagram of a CPS^{EPI} with networking redundancy.

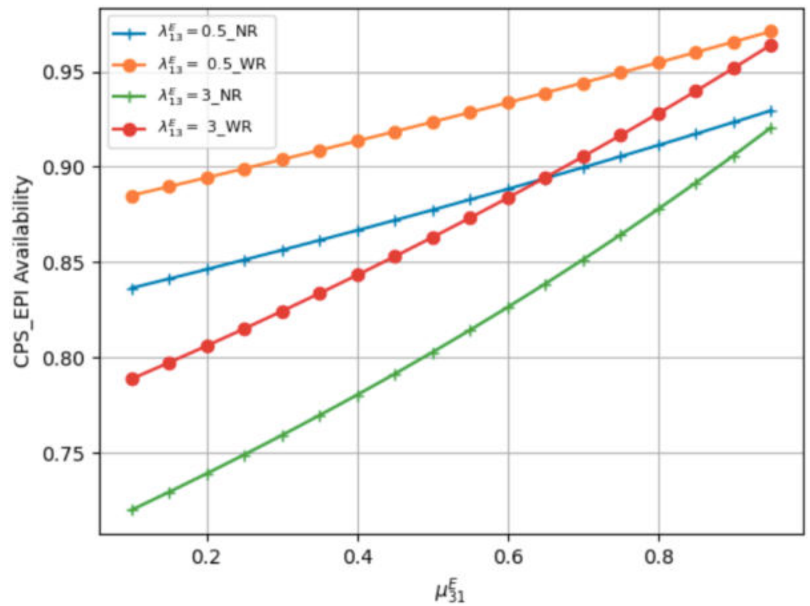


Fig. 9: Steady state availability of CPS^{EPI} in two scenarios: with redundancy (WR and without redundancy NR).

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Safety-Critical Scenario Analysis of Semi-Automated Train Operation

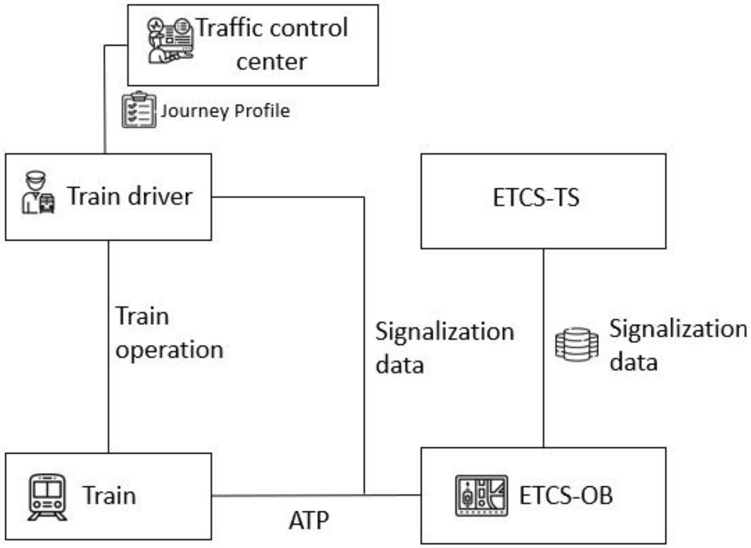

Fig. 1. ERTMS system architecture at GoA1 (adapted from [13]).

5

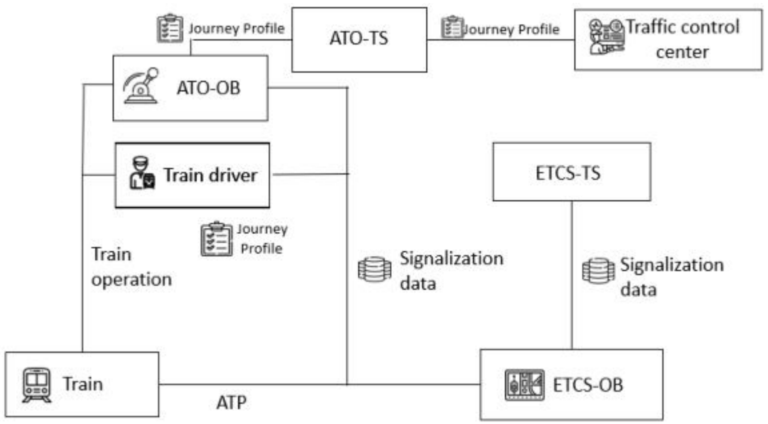

Fig. 2. ERTMS/ATO system architecture at GoA2 (adapted from [13]).

Y. Sun, G.A. Boy, M. Sango, A. Barros, « PRODEC-based task analysis for the design of semi-automated trains », CSDM 2023 China

Starting projects - Orange

- PHD Candidate Ikram Temericht – Orange – « Digital twin for 6G for measuring and improving resilience »

  « L'objectif scientifique principal de la thèse est de réaliser un jumeau numérique de tout ou partie du réseau 6G

  - pour mesurer sa résilience et sa capacité à répondre aux exigences des verticales. Les verticales sont en général des entreprises ou des domaines particuliers qui vont pouvoir bénéficier des apports de la 6G, et qui vont par conséquent exprimer leurs exigences en fonction des services, comme par exemple, un niveau de latence très faible quand on parle de services pour l'industrie, pour la santé ou pour des véhicules autonomes. Certaines de ces exigences concerneront la résilience.
  - pour anticiper et tester les actions qui pourraient être menées pour améliorer cette résilience »

- PHD project – Orange - « Placement of Virtual Network Functions Aware of Dependence on Electricity Distribution Networks »

  « Le sujet de thèse consiste à explorer et améliorer des techniques d'optimisation centralisée et distribuée de placement de Fonctions Réseau Virtuelles (VNF – Virtual Network Functions) sur de multiples sites pour minimiser le coût global des infrastructures tout en assurant le niveau de disponibilité requis par les services qui y sont hébergés »

Axis 2

Modeling and optimization of maintenance phases to reduce their impact on intra-operator service continuity

- Axis 2.1: Development of optimization models for preventive, conditional, and predictive maintenance of complex systems
    - Consideration of dependencies between subsystems
    - Development of efficient numerical algorithms to solve the maintenance optimization model
- Axis 2.2: Development of degradation models, diagnostic methods and prognostic methods for complex systems
    - Consideration of dependencies between subsystems
    - Integrate data of different kinds
    - Feed the optimization models of axis 2.1 (degradation models)
    - Allow the implementation of the optimal solutions found (diagnosis and prognosis are necessary for the implementation of any predictive maintenance strategy).
    - Digital Twins

PHD Matthieu Roux « Optimization of planned maintenance operations for complex industrial systems » 2021-2024

Axis 2.1 – Optimisation models for maintenance

P(t) is an expected discounted cost - To be improved and linked to the resilience curve

- Distributed system type systems, or fleets, which are very present in the use cases of our industrial partners
- Condition Based Maintenance – CBM
  - Impact of imperfect sensors (monitoring) on the CBM maintenance policy of a fleet.
  - To what extent the CBM policy sees its performance degraded by such monitoring errors
  - Before equipping a fleet of CBM sensors, assess the value that can be expected as a return on investment
- Complexity of the underlying industrial system.
  - Economic type dependencies, in a very large system (around 20 to 200 items in the fleet).
  - For reasons of resource constraints, availability constraints or opportunistic maintenance, the maintenance policy must necessarily be designed at system level

Fleets are complex distributed systems to maintain

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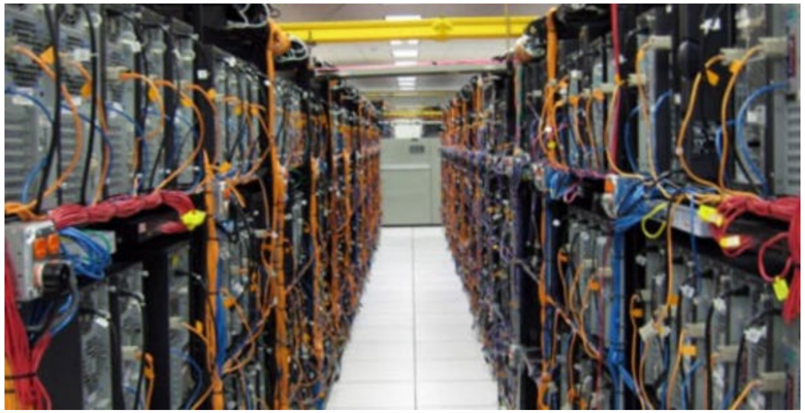
Objective: optimize **condition-based maintenance (CBM)** strategies



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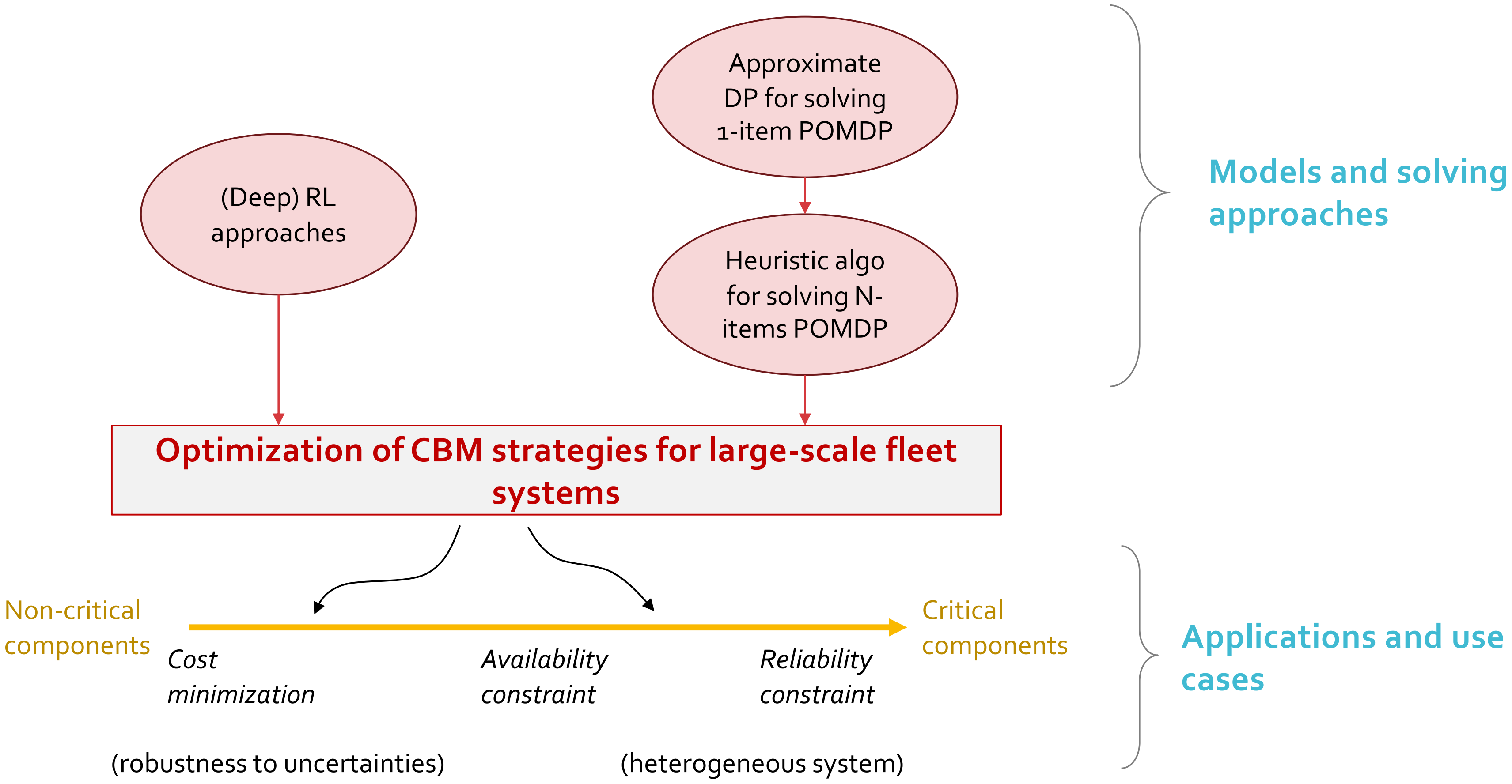
PHD Matthieu Roux « Optimization of planned maintenance operations for complex industrial systems » 2021-2024



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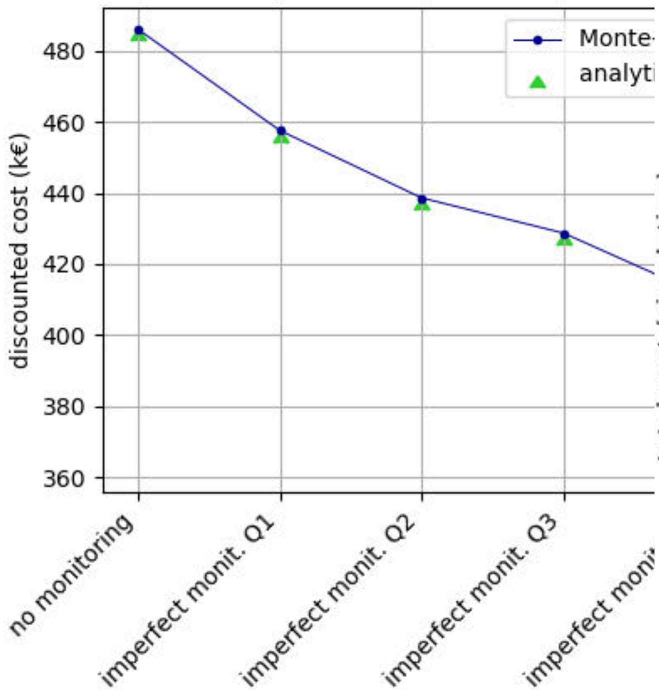
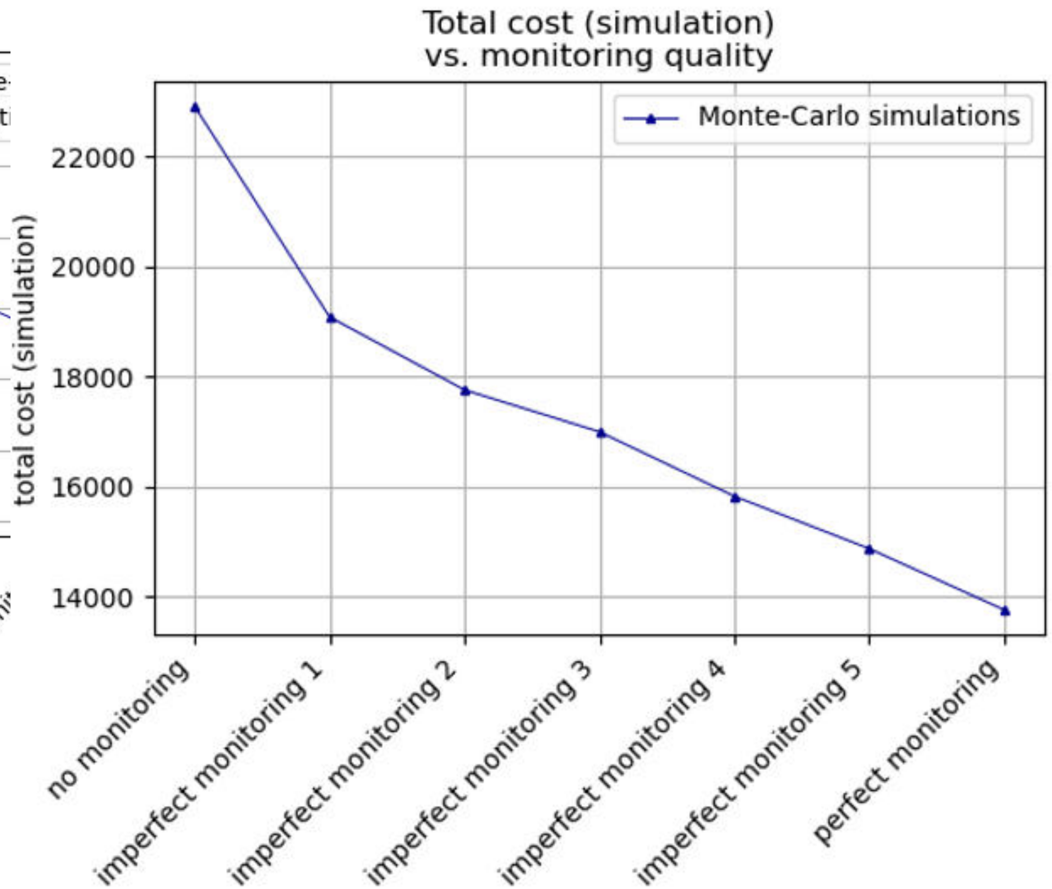
PHD Matthieu Roux « Optimization of planned maintenance operations for complex industrial systems » 2021-2024



ESREL 2022
1 item



ESREL 2023
50 items

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Axis 2

Supporting projects

Prof. Zhiguo Zeng « Axis 2.2 Development of degradation models, diagnostic methods and prognostic methods for complex systems »

- French National Project – 2023-2027 – «Digital Failure Twin for online reliability assessment and predictive maintenance of future manufacturing systems (DFT)»

Challenges to the reliability of future industrial systems:

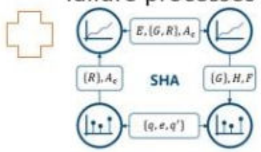
- Few failure data available. ⇨ New reliability model needed.
- Existing digital twin-based models only consider a single failure process. ⇨ Need to consider multiple dependent failure processes.

In this project, we intend to develop:

- Digital Failure Twin (DFT).
- Online reliability assessment methods based on DFT.
- Predictive maintenance models based on DFT.

Digital twin

Multiple dependent failure processes

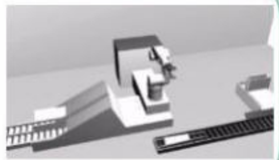


In order to:

- Improve the reliability.
- Reduce the operation costs of future manufacturing systems.

Use cases:

- An intelligent production line
- Supported by GE Healthcare and orange.



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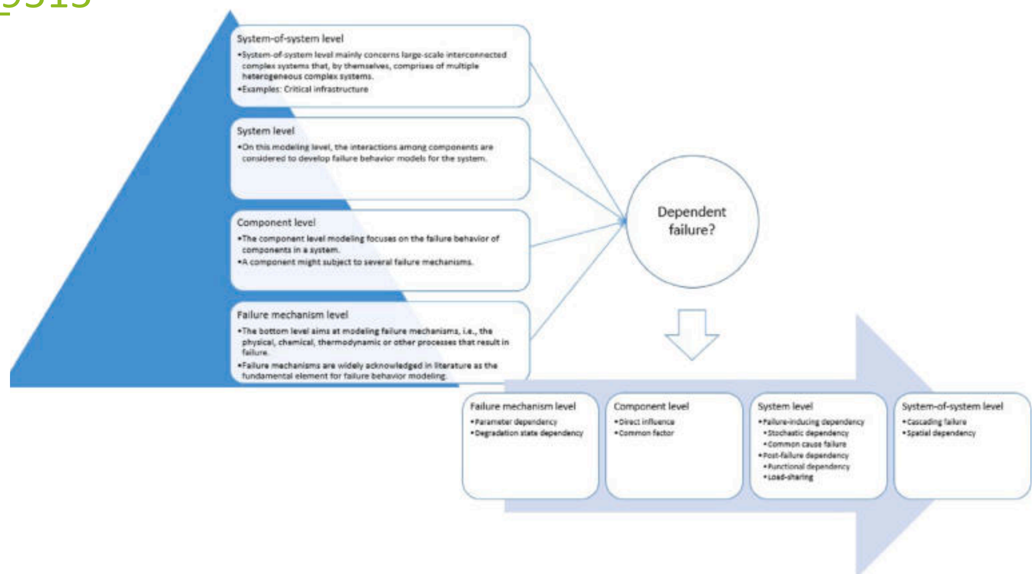
Prof. Zhiguo Zeng « Axis 2.2 Development of degradation models, diagnostic methods and prognostic methods for complex systems »

- PHD project – 2023-2027 « AI-based text analytics for assessing and optimizing the resilience of infrastructure and complex systems »

- Zhiguo Zeng, Anne Barros, David Coit, Dependent failure behavior modeling for risk and reliability: A systematic and critical literature review, RESS 2023
- https://doi.org/10.1016/j.ress.2023.109515



Axes 1 & 2

Integrated Machine Learning and Optimization for Dynamic Decision-Making in Continuously Monitored Systems

- PHD starting: Zehui Xuan
- Continuation of Matthieu Roux PHD and Andrea Bellè PHD (resilience optimisation in operation)

The focal dynamic operation and maintenance planning problems are essentially about the sequential allocation of the limited resources, corresponding to the classical *restless multi-armed bandit problem* (RMABP) which is often studied in the framework of Partially Observable Markov Decision Processes (POMDP)

This thesis aims to develop credible models and efficient algorithms for data-driven operation and maintenance optimization of large-scale multi-unit industrial systems. From the modeling perspective, we will focus on strongly coupled RMABP by considering system-level reliability/availability constraints.

International Collaborations
Associate Members

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Associate Membership

- John Andrews
    - Resilience Engineering Research Group
    - Nottingham University - Llyod’s Register Foundation
    - https://www.nottingham.ac.uk/engineering/people/john.andrews

- David Coit
    - Department of Industrial System Engineering
    - Rutgers University
    - https://www.davidcoit.net/home

- Hiba Baroud
    - Associate Chair, Civil and Environmental Engineering
    - Vanderbilt University
    - https://engineering.vanderbilt.edu/bio/hiba-baroud

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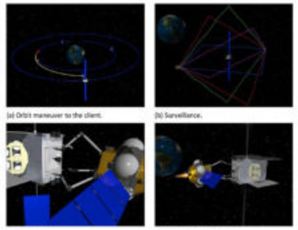
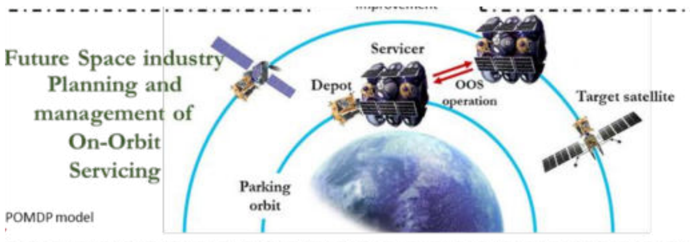
Summary

- The budget allocated to the chair scientifif project is doubled with public founding
- Citations of papers related to interdependences and associate members
- Recruitment

- IA
- Stochastic optimisation
- Digital Twins and Digital Failure Twins
- Human Factor



- Climate change
- Systèmes d’information – Cyber securité



- New partners

- New members in Team R3: Adam Abdin, Guillaume Lamé, Jakob Puchinger

Teams R3

	Optimization Determinist and Stochastic	Stochastic modelling	Data analytics	Socio Economics and Ergonomics / Human factor integration	Simulation (MC and discrete event, Dig.Twin)
Terrestriel Infrastructure	X	X	X	X	X
Industrie 4.0 Predictive Maintenance	X	X	X		X
Spatial Infrastructure	X	X	X		X
Health systems			X	X	X
Transport systems / Smart cities	X				X

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Our Website: http://r3.centralesupelec.fr/

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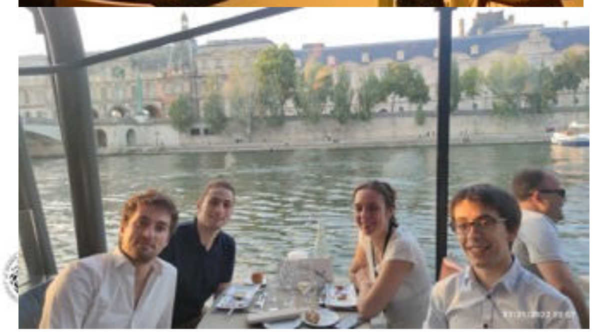

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Publications – Axis 1

1. Bellè A., Abdin A., Fang Y.-P., Zeng Z., Barros A., A data-driven distributionally robust approach for the optimal coupling of interdependent critical infrastructures under random failures, Accepted for publication, 2023, European Journal of Operational Research
2. Fang C., Chu Y., Fu H., Fang Y., On the resilience assessment of complementary transportation networks under natural hazards, 2022, Transportation Research Part D: Transport and Environment
3. Bellè A., Fang Y.-P., Zeng Z., Barros A., A distributionally robust approach for the optimal protection of power networks with endogenous uncertainty, 2022, IFAC-PapersOnLine
4. Belaid Y.N., Fang Y.-P., Zeng Z., Legendre A., Coudray P., Barros A., Resilience Optimization of Wide-Area Control in Smart Distribution Grids, 2022, IFAC-PapersOnLine
5. Wang H., Fang Y.-P., Zio E., Resilience-oriented optimal post-disruption reconfiguration for coupled traffic-power systems, 2022, Reliability Engineering and System Safety
6. Wang H., Abdin A.F., Fang Y.-P., Zio E., Resilience assessment of electrified road networks subject to charging station failures, 2022, Computer-Aided Civil and Infrastructure Engineering
7. Yin Z., Fang C., Yang H., Fang Y., Xie M., Improving the resilience of power grids against typhoons with data-driven spatial distributionally robust optimization, 2022, Risk Analysis
8. Li R., Decocq B., Barros A., Fang Y., Zeng Z., Petri Net-Based Model for 5G and beyond Networks Resilience Evaluation, 2022, Proceedings of the 25th Conference on Innovation in Clouds, Internet and Networks, ICIN 2022
9. Bellè A., Zeng Z., Duval C., Sango M., Barros A., Modeling and vulnerability analysis of interdependent railway and power networks: Application to British test systems, 2022, Reliability Engineering and System Safety
10. Rui Li, Bertrand Decocq, Anne Barros, Yiping Fang, Zhiguo Zeng, Modélisation d'un réseau 5G par des réseaux de Pétri pour estimer sa résilience, 2022, 24èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications(AlgoTel 2022)
11. Rui Li, Bertrand Decocq, Yiping Fang, Zhiguo Zeng, Anne Barros, A Petri Net-based model to study the impact of traffic changes on 5G network resilience, 2022, 32nd European Safety and Reliability Conference (ESREL 2022)

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Publications – Axis 2

1. Matthieu Roux, Yiping Fang, A Barros, Maintenance Planning under Imperfect Monitoring: an Efficient POMDP Model Using Interpolated Value Function, 2022, IFAC-PapersOnLine
2. Matthieu Roux, Yi-Ping Fang, Anne Barros, Impact of imperfect monitoring on the optimal condition-based maintenance policy of a single-item system, 32nd European Safety and Reliability Conference (ESREL 2022)
3. Matthieu Roux, Anne Barros, Yi-Ping Fang, Maintenance planning under imperfect monitoring: two POMDP approaches to quantify the value of information, 23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision
4. Wang J., Zeng Z., Zhang H., Barros A., Miao Q., An hybrid domain adaptation diagnostic network guided by curriculum pseudo labels for electro-mechanical actuator, 2022, Reliability Engineering and System Safety
5. Ding Y., Hu Y., Lin Y., Zeng Z., Reliability Analysis of Multiperformance Multistate System Considering Performance Conversion Process, 2022, IEEE Transactions on Reliability
6. Xiahou T., Liu Y., Zeng Z., Wu M., Remaining useful life prediction with imprecise observations: An interval particle filtering approach, 2022, IISE Transactions
7. Wang J., Zeng Z., Zhang H., Barros A., Miao Q., An Improved Triplet Network for Electromechanical Actuator Fault Diagnosis Based on Similarity Strategy, 2022, IEEE Transactions on Instrumentation and Measurement
8. Lee S., Barros A., Lundteigen M.A., Paltrinieri N., A Risk Aspect of Periodic Testing on Pressure Relief Valves, 2022, Chemical Engineering Transactions
9. Khaled Sayad, Anne Barros, Yiping Fang, Zhiguo Zeng, Benoît Lemoine, Interdependency-Aware Resource Allocation for High Availability of 5G-enabled Critical Infrastructures Services, 2022, 32nd European Safety and Reliability Conference (ESREL 2022)
10. Youba Nait Belaid, Anne Barros, Yiping Fang, Zhiguo Zeng, Anthony Legendre, Patrick Coudray, 2022, Enhanced Power and Communication Modeling in Cyber-Physical Distribution Grids for Resilience-based Optimization, 32nd European Safety and Reliability Conference (ESREL 2022)

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