GÉANT Project Network Development WP6 study:

Intelligent Networks - The Rise of Generative AI in Network Management

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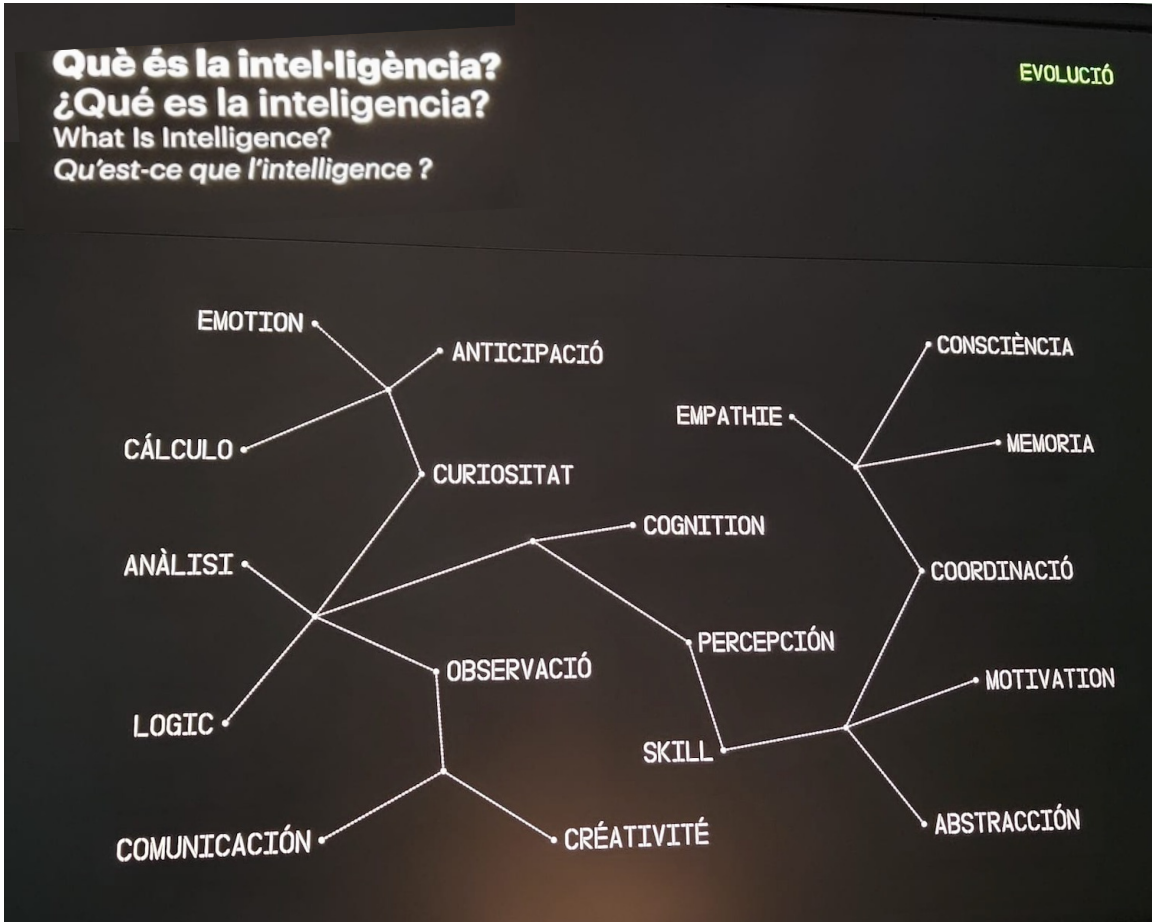
GÉANT Project Network Development Work Package (WP6) leaders

23th SIG-NOC, Barcelona, Spain, 14-15.10.2025.


CosmoCaixa


Què és la intel·ligència?
¿Qué es la inteligencia?
What Is Intelligence?
Qu'est-ce que l'intelligence ?
EVOLUCIÓ
EMOTION
ANTICIPACIÓ
CÁLCULO
CURIOSITAT
ANÀLISI
COGNITION
OBSERVACIÓ
LOGIC
COMUNICACIÓN
CRÉATIVITÉ
PERCEPCIÓN
SKILL
EMPATHIE
CONSCIÈNCIA
MEMORIA
COORDINACIÓ
MOTIVATION
ABSTRACCIÓN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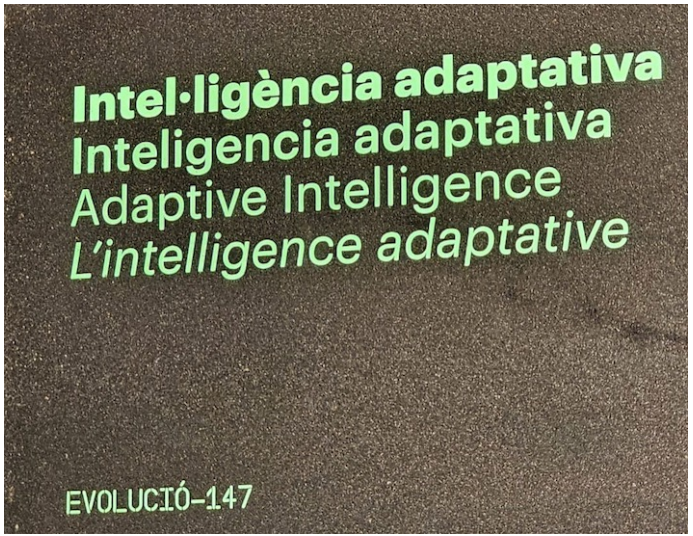
Intel·ligència adaptativa
Inteligencia adaptativa
Adaptive Intelligence
L'intelligence adaptative
EVOLUCIÓ-147


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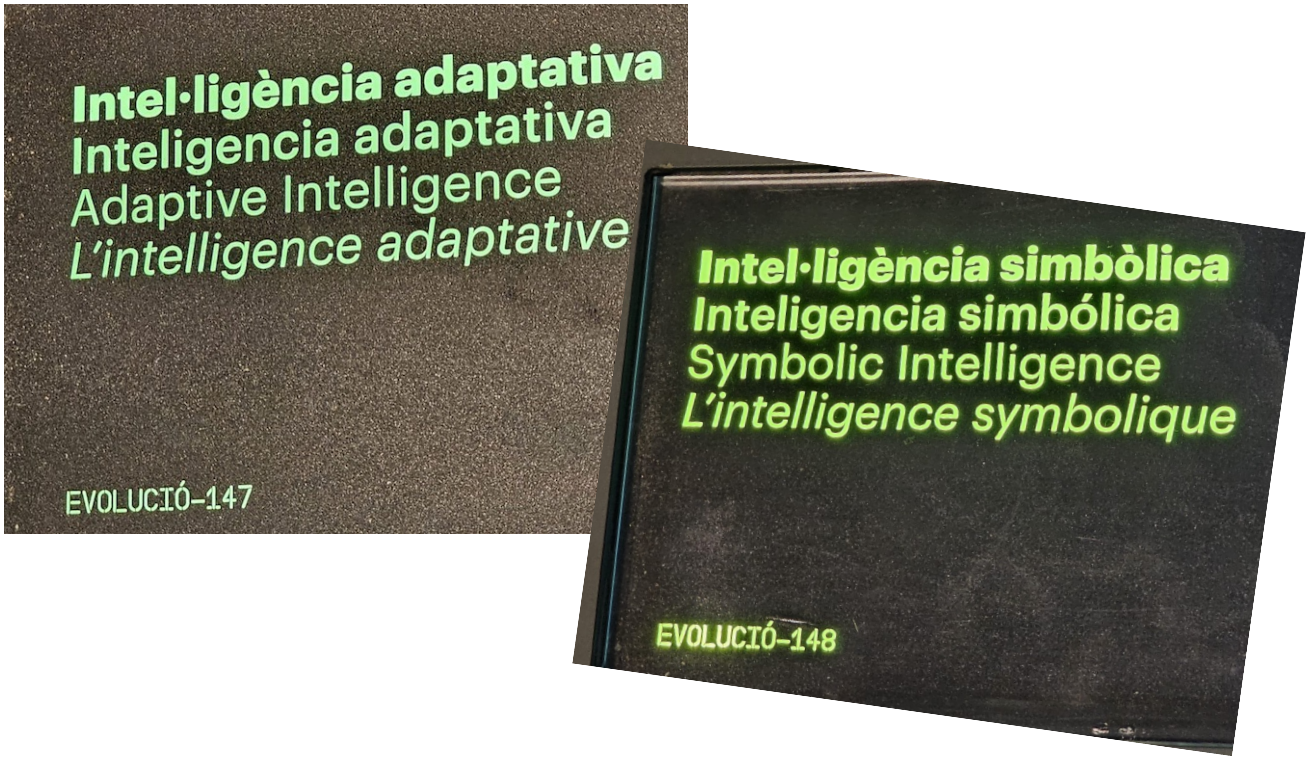
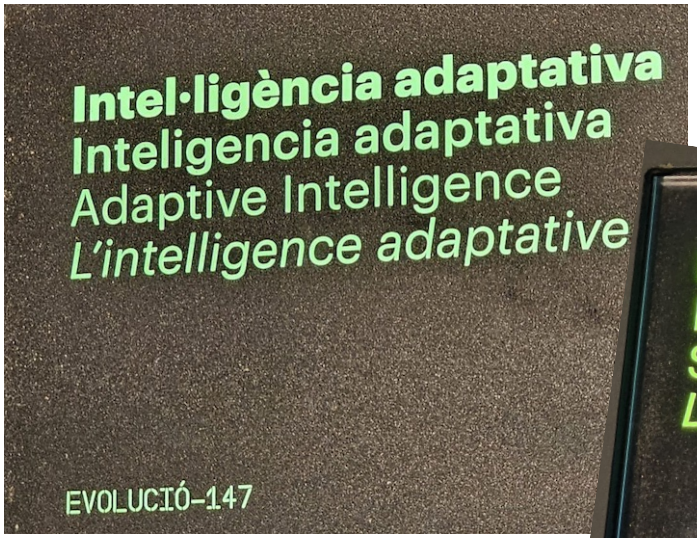

Intel·ligència adaptativa
Inteligencia adaptativa
Adaptive Intelligence
L'intelligence adaptative
EVOLUCIÓ-147
Intel·ligència simbòlica
Inteligencia simbólica
Symbolic Intelligence
L'intelligence symbolique
EVOLUCIÓ-148


CosmoCaixa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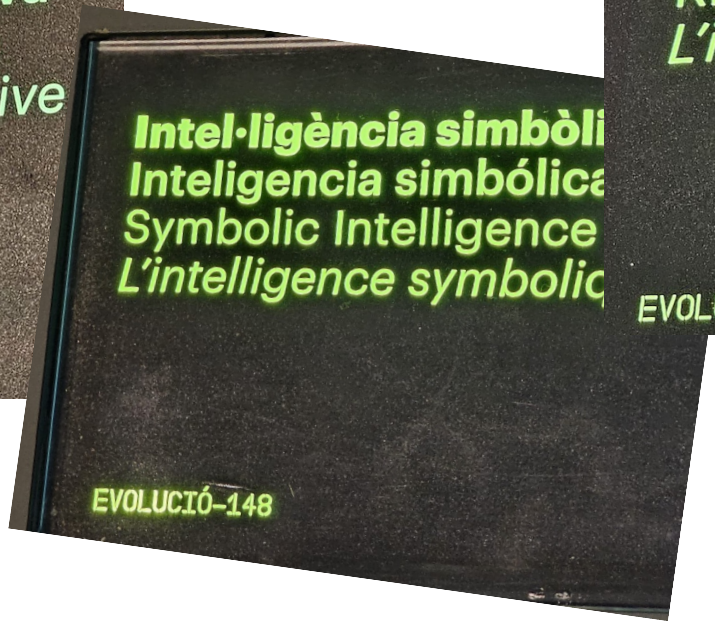
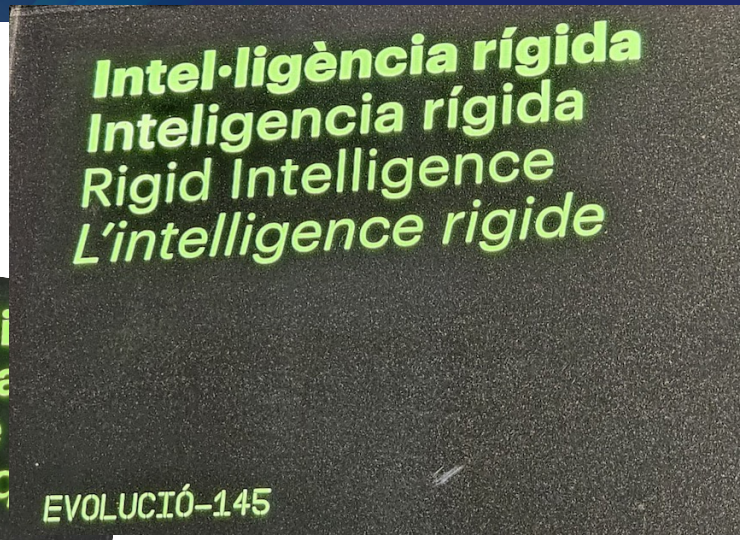
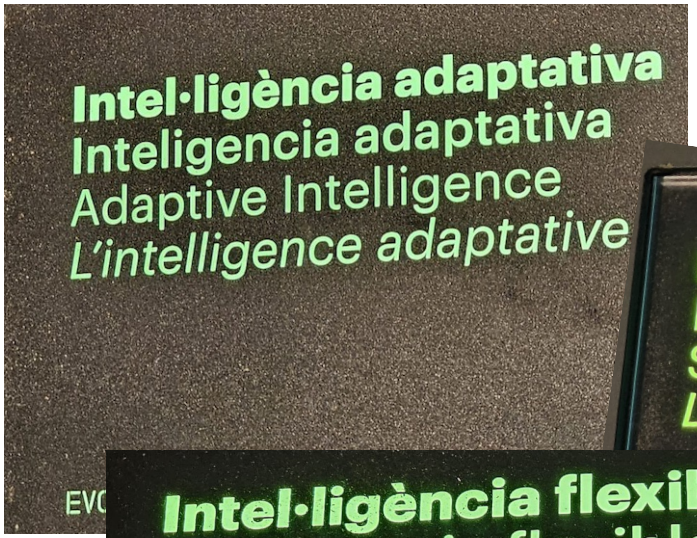

Intel·ligència simbòli
Inteligencia simbólica
Symbolic Intelligence
L'intelligence symbolic
EVOLUCIÓ-148


Intel·ligència rígida
Inteligencia rígida
Rigid Intelligence
L'intelligence rigide
EVOLUCIÓ-145


CosmoCaixa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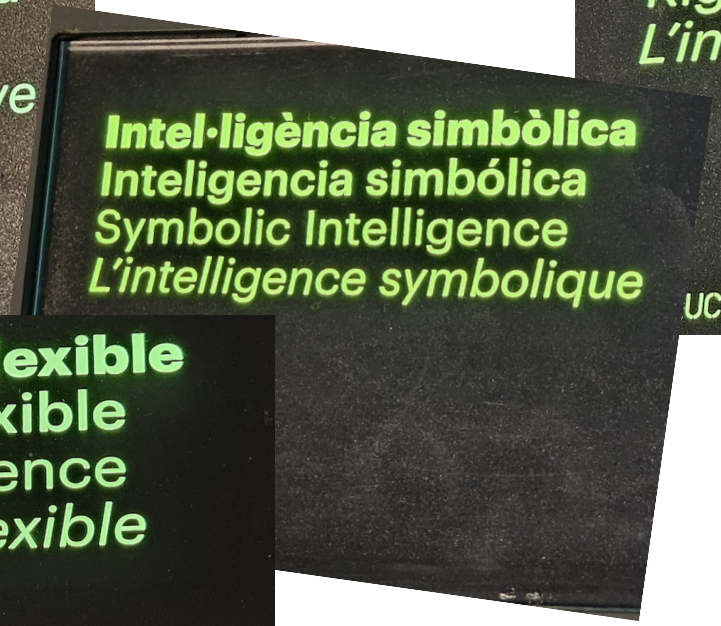
Inteligencia adaptativa
Adaptive Intelligence
L'intelligence adaptative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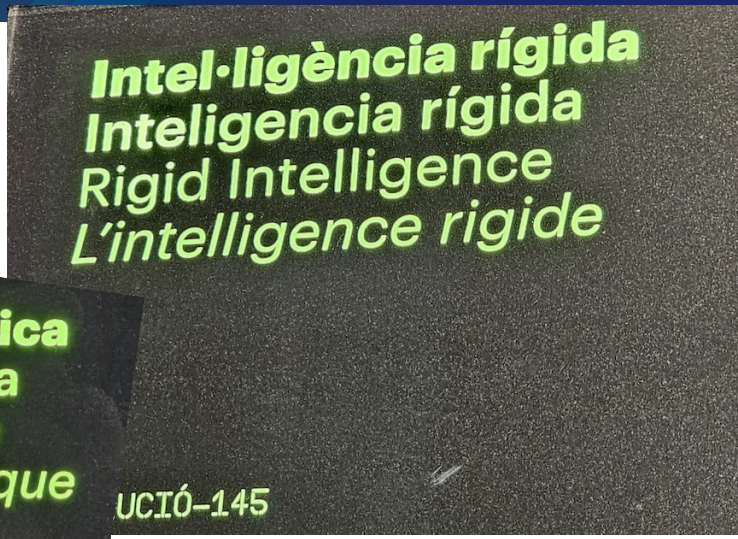
Inteligencia simbólica
Symbolic Intelligence
L'intelligence symbolique


Intel·ligència rígida
Inteligencia rígida
Rigid Intelligence
L'intelligence rigide
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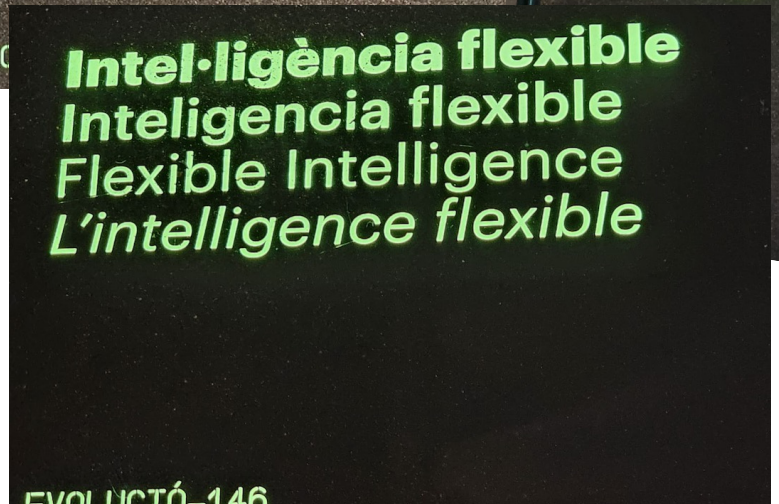
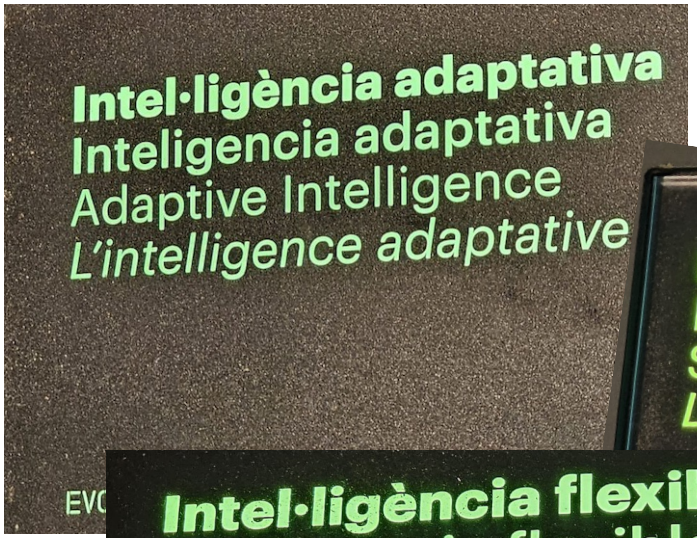

Intel·ligència flexible
Inteligencia flexible
Flexible Intelligence
L'intelligence flexible


CosmoCaixa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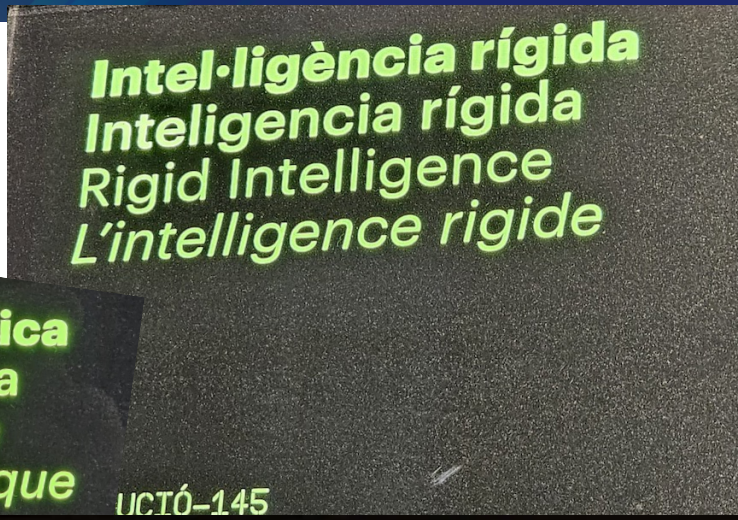
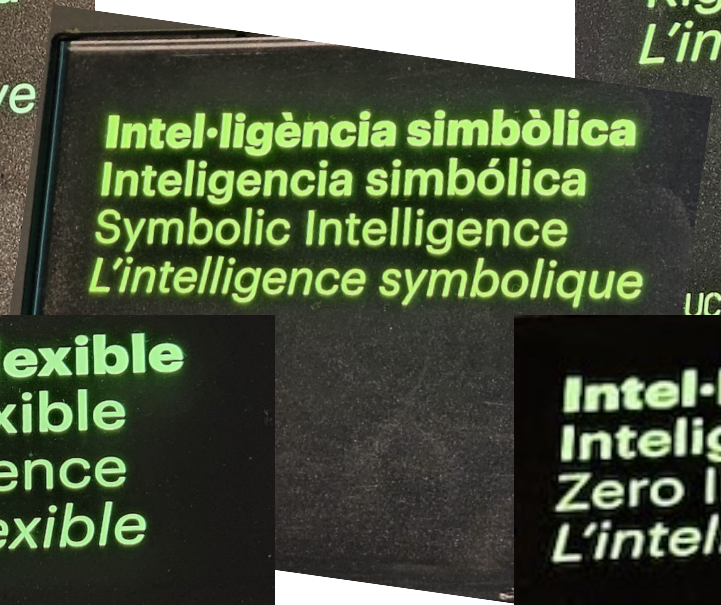

Intel·ligència rígida
Inteligencia rígida
Rigid Intelligence
L'intelligence rigide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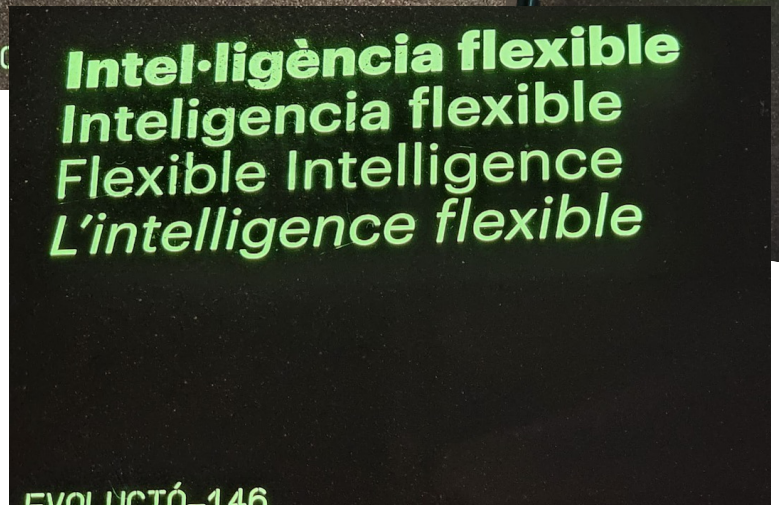
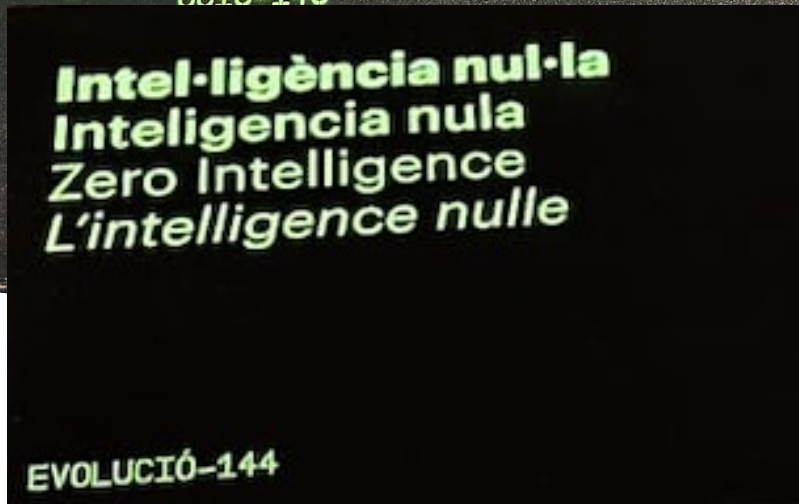
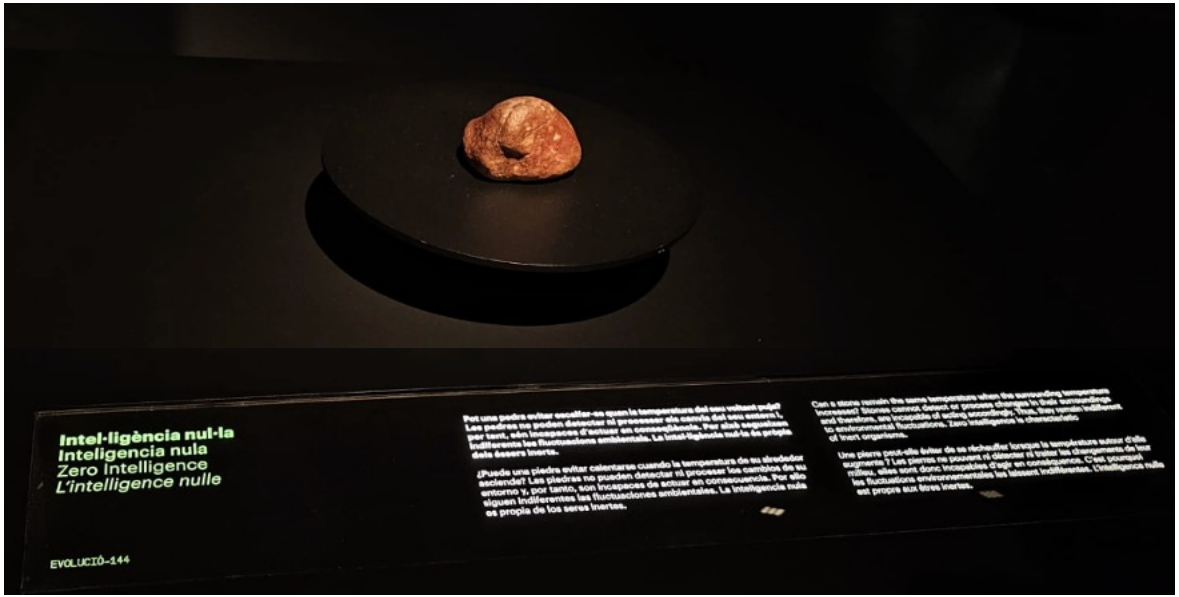

Intel·ligència flexible
Inteligencia flexible
Flexible Intelligence
L'intelligence flexible


Intel·ligència nul·la
Inteligencia nula
Zero Intelligence
L'intelligence nulle
EVOLUCIÓ-144

CosmoCaixa

Intel·ligència nul·la
Inteligencia nula
Zero Intelligence
L'intelligence nulle

EVOLUCIÓ-144



Can a stone remain the same temperature when the surrounding temperature increases? Stones cannot detect or process changes in their surroundings and therefore, are incapable of acting accordingly. Thus, they remain indifferent to environmental fluctuations. Zero intelligence is characteristic of inert organisms.

Motivation for the GenAI study

Network management path from manual -> OSS/BSS -> automation -> ML -> GenAI

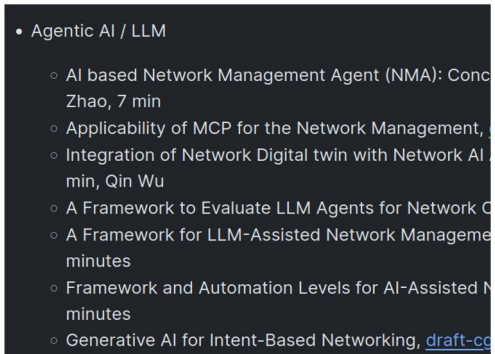
ChatGPT appeared in 2022, and became fastest-growing consumer software

How best to benefit from GenAI?

If it can write text or code, can it write network configurations, scripts?

Can it really help in other network management fields?

AI in network management is the key topic of different events in the last two years,



IRTF NMRG Interim meeting on AI 8.10.2025.

Conference theme: theme “AI for Management and Management for AI”

AI-related activities in the Network Development WP6

Chatbot for Network eAcademy (completed in the GN5-1 project)

perfSONAR/PMP data analysis

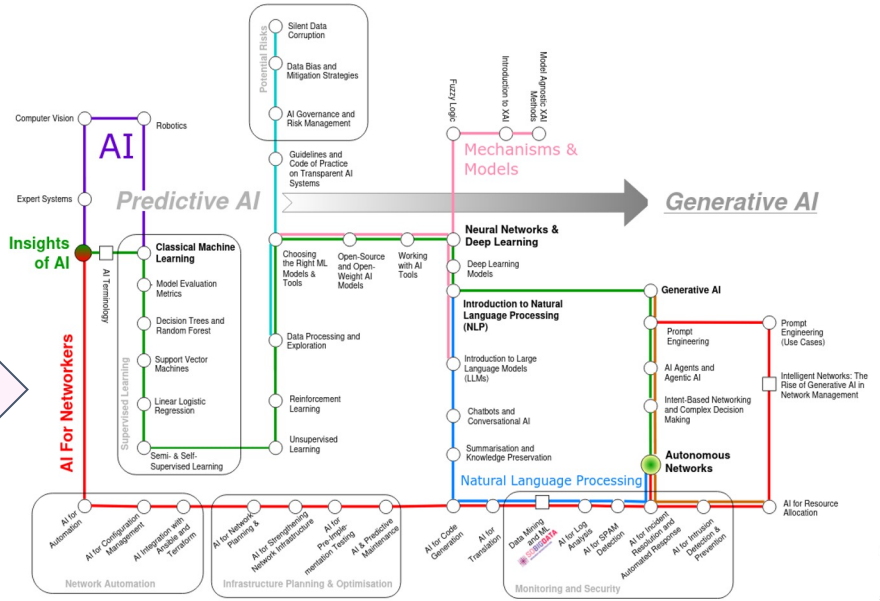
AI for network automation

New incubator projects:

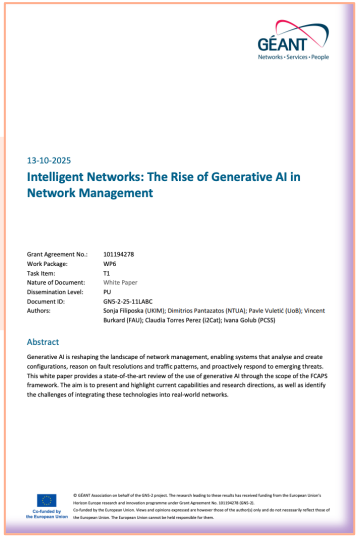
- LogLLM: Automated Log Analysis and Management based on LLMs
- AI module for Workflow Orchestrator

Network eAcademy AI track (not yet official)

Survey: Intelligent Networks - The Rise of Generative AI in Network Management



Survey: Intelligent Networks - The Rise of Generative AI in Network Management



The research team:

Sonja Filiposka (UKiM), Dimitris Pantazatos (NTUA), Vincent Burkard (FAU), Claudia Torres Pérez (i2Cat/UPC)

Two sections:

1. **Analysis of 57 peer-reviewed scientific papers**
   - Between 2018 and June 2025
   - Explicitly employ **generative models** for network-management tasks
   - Reported quantitative results on real or emulated networks
   - Offered code, data or methodological clarity sufficient for reproduction
   - Targeted at least one FCAPS function:
     - **F**ault, **C**onfiguration, **A**ccounting, **P**erformance, **S**ecurity
2. **Analysis of 39 open source and commercial tools**
   - Includes Artificial Intelligence for IT Operations (**AIOps**) and **network performance management**

The most widely explored families of generative models (1)

Large-Language Models (LLMs) - transform text or code sequences

- **Prompt engineering** - involving carefully crafted input queries that guide the model's behaviour without modifying its internal configuration.
- Using **fine-tuning**, one can retrain the model using domain-specific examples, including configurations, annotated incident logs, or policy documents.
- **Retrieval-Augmented Generation (RAG)**, which integrates the LLM with an external knowledge source, such as a network documentation repository, logs, tickets etc.

Generative Adversarial Networks (GANs)

- Includes **two neural networks**: a **generator** (produces synthetic data), and a **discriminator** (attempts to distinguish generated data from real examples).
- Widely used for **generating synthetic traffic data**, **simulating rare fault conditions**, and **producing labelled intrusion examples for training security systems**.

The most widely explored families of generative models (2)

Variational Autoencoders (VAEs)

- Used for anomaly detection or configuration search
- Useful for **modelling the distribution of valid configurations**, **detecting anomalies** and **generating intermediate network states** for smooth policy transitions

Diffusion Models

- Function by gradually adding noise to input data through multiple steps, then learning to reverse this process to generate structured outputs
- In network operations, diffusion models show promise in **synthesising configurations** that meet specific performance or QoS constraints and generating policies under operational constraints.
- **More computationally expensive than other models**

Hybrid pipelines

Research on the use of AI for Network Management

www.geant.org

Fault management

FCAPS

Fault management aims to detect, diagnose, and resolve problems with minimal impact on services.

Networks and systems are generating increasingly complex and multi-modal data, the ability to detect, diagnose and respond to faults quickly and accurately is essential to maintaining service reliability.

Opportunities for GenAI in fault management:

Semantic Log Interpretation

LLMs interpret and explain multi-modal logs to assist in identifying root causes

Predictive Fault Detection & Forecasting

Generative models anticipate faults and evaluate risk without affecting live systems

Synthetic Fault Pattern Generation

GANs generate rare or edge-case fault data for training robust detection models

Closed-loop Fault Management

AI-driven systems that detect, diagnose, and suggest remediation steps autonomously

Research papers - use cases

FCAPS

Examples:

1. **Transformer-based LLMs** used to **interpret unstructured log and telemetry data** for fault detection and explainability
2. **GANs and VAEs** used to **generate synthetic fault scenarios**.
   - Helps mitigate the problem of imbalanced fault datasets, improving the robustness of classifiers in low-frequency failure conditions.
3. GenAI integration with **simulation environments**, building **digital twin systems**

Reported **high anomaly detection accuracy**, **enhanced prediction** accuracy, **improved performance**

All use cases done **in simulated environments**, **not integrated in the operational workflows**.

Configuration management

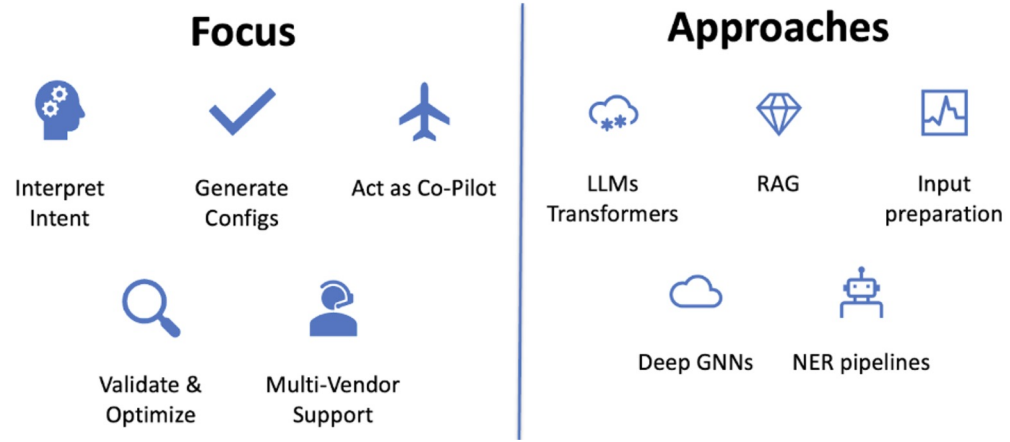
FCAPS

The largest number of research papers (apart from security)

Natural approach for GenAI (also seen in code development):

Interpreting high-level input such as natural language or policy intent and **Producing** accurate, consistent and standards-aligned configurations.

Opportunities for GenAI in configuration management



Research papers - use cases

FCAPS

Examples:

1. Use of LLMs with structured YANG models and natural language to **generate NETCONF-compliant XML configurations**
2. Use of LLMs with **standardised TM Forum and ETSI templates** to **transform high-level policy intent into complete configurations**
3. Use RAG to fetch examples or prior configurations from a knowledge base and then use the LLM to generate context-aware suggestions (**Co-pilot systems**)
4. Combination of **high-precision natural language prompts with post-generation validation**

A consistent and important design principle:

- **Keep humans in the loop** as a deliberate architectural choice.
- Incorporate **co-pilot models** that support, rather than replace, engineers

Accounting Management

FCAPS

Accounting

includes **monitoring, measuring and analysing resource usage** across a network,

for **billing**, **cost optimisation**, **auditing**, **and service-level enforcement**.

No peer-reviewed studies that explicitly focus on using GenAI for accounting tasks in a networking context have been identified.

There is some related work in:

- financial accounting,
- automated billing systems, and
- predictive analytics for revenue forecasting

LLMs, VAEs and GANs used for:

- generating synthetic transaction data,
- detecting anomalies,
- producing explainable summaries.

Performance Management

FCAPS

Performance management in networking systems focuses on ensuring the availability, responsiveness and efficiency of network resources.

Opportunities for GenAI in network performance management

Traffic Forecasting

Predict traffic patterns using time-series generative models

Example: Avoid congestion before it occurs

QoS Metric Inference

Infer latency, jitter, throughput directly from traffic traces

Example: Auto-monitor SLA performance

Adaptive Resource Allocation

Use GANs in RL frameworks to recommend bandwidth/resource changes

Example: Real-time load balancing

Model Lifecycle Support

Trigger retraining based on GenAI-simulated drift

Example: Keep ML models tuned without constant re-labelling

Research papers - use cases

FCAPS

Examples:

- Use of diffusion models to **simulate mobile user behaviour** and **design contracts** that optimise wireless service delivery under QoS constraints
- *Deep-Q* - deep generative model to directly **infer QoS metrics** from raw traffic traces
- *GAN-powered Deep Distributional Reinforcement Learning* - **dynamic resource allocation in network slicing**. GAN-generated synthetic samples can accelerate policy learning, leading to faster convergence and more stable performance even under traffic fluctuation.
- *OpticGAI* targets optical networks, combining generative learning with deep reinforcement techniques to **optimise complex problems like routing and spectrum allocation**.

Security Management

FCAPS

Extensive use of AI/ML in cybersecurity for anomaly/attack detection

Opportunities for GenAI use in Security management:

- Synthetic attack generation
- Prompt-based rule generation (model can write rules that define protocols, offsets, byte patterns, flow direction, thresholds and metadata in Snort/Suricata engine's native, keyword-rich syntax)
- Data augmentation (using GANs)
- Unsupervised anomaly detection (using VAE)
- Similar uses like fault management

AI Tools for Network Management

www.geant.org

Vendor solutions

“All in one” approach - covering (almost) all FCAPS areas

Tailored for the products of the company

Common features:

- Natural language interaction,
- Configuration assistant
- Script generation
- Troubleshooting assistant
- Automated incident summarisation
- Anomaly detection

Cisco AI Network Analytics

MIST AI

watsonx

FortiAI

ServiceNow ITOM

XENONSTACK
A Stack Innovator

ATERA

NetBrain Chatbot

DX Operational Observability

Open-source solutions and frameworks

Not tailored for Network Management, can be used/adapted

Covering less FCAPS areas

Also analysed additional 15 security related AI tools

Common features:

- Script generation
- Natural language to device configuration
- LLM interface, Model Context Protocol (MCP)
- Autonomous problem-solving

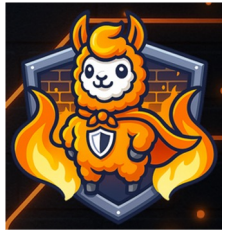
LangChain

Pydantic AI

AutoGen

CAI CYBERSECURITY AI Bug bounty-ready AI

Adversarial Robustness Toolbox



Agent Development Kit

Conclusions

Most advanced in adoption and capability

- Configuration, Security then Fault management

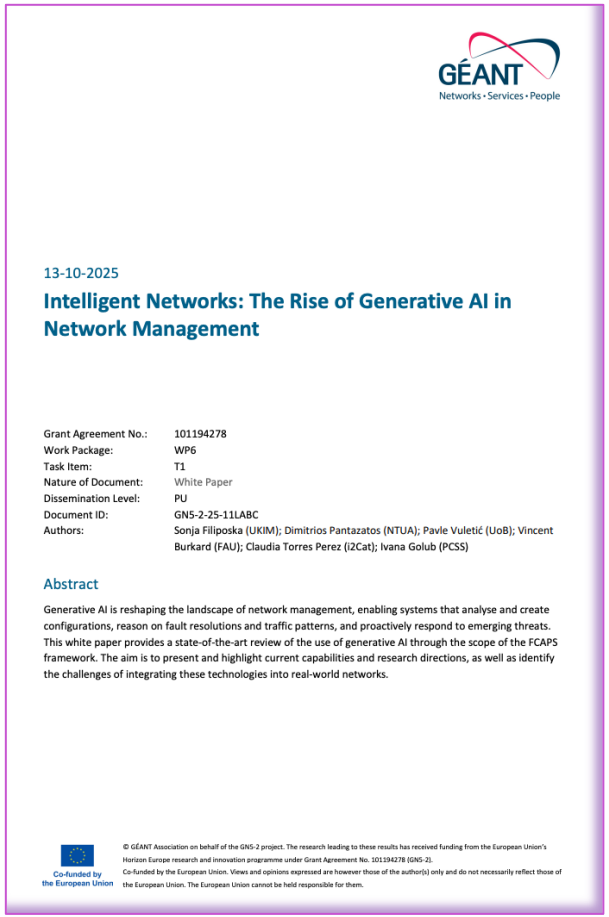
Commercial vs. Open-source solutions

- Commercial solutions provide dedicated vendor support and are closer to the agentic AI
- Open-source tools depend on community support and require more customisation.

Many promises, but some challenges remain:

- Validity and safety, Explainability
- Operational constraints: latency, integration with other systems, compliance
- How justified is to rely on synthetic data?

This study is the basis for further WP6 actions in the Network eAcademy and incubators



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13-10-2025

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Abstract

Generative AI is reshaping the landscape of network management, enabling systems that analyse and create configurations, reason on fault resolutions and traffic patterns, and proactively respond to emerging threats. This white paper provides a state-of-the-art review of the use of generative AI through the scope of the FCAPS framework. The aim is to present and highlight current capabilities and research directions, as well as identify the challenges of integrating these technologies into real-world networks.

Thank You

Any questions?

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Full paper available at:

NETDEV Wiki: https://wiki.geant.org/download/attachments/212303969/GN5-2-White-Paper_Gen-AI-in-Network-Management.pdf?api=v2

Zenodo: https://zenodo.org/records/17349004

GÉANT project website: https://resources.geant.org/wp-content/uploads/2025/10/GN5-2-White-Paper_Gen-AI-in-Network-Management.pdf