WHITE PAPER

Network Digital Twin

The Key Catalyst for Autonomy

KEY TAKEAWAYS

Strategy First
Successful autonomous journeys depend on a clear strategic vision and robust foundational capabilities, ensuring CSPs are AI-ready from the outset.

Strong Data Foundations
Break data silos without breaking the bank, by standardising formats and integrating multiple data sources with efficient data storage strategies. A unified data environment enables advanced AI operations in real-time.

Incremental Autonomy
Enable CSPs to progressively achieve autonomy – from establishing data readiness to unlocking full ecosystem monetisation – with experienced partners like Celfocus guiding each step of the journey.

WHO SHOULD READ THIS DOCUMENT

- Head of Network Engineering
- Head of Network Operations
- Head of Orchestration
- Head of Network Domain
- Head of Network Virtual Infra
- Network Automation Managers
- Network Operations Managers
- Production/OSS Architecture Teams
- Chief Technology Officer
- Chief Information Officer

CELFOCUS

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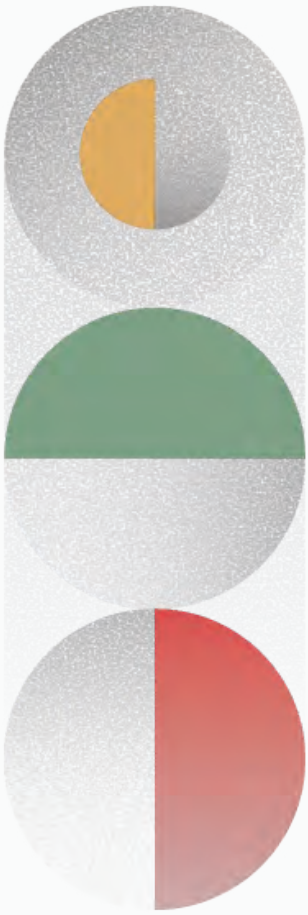
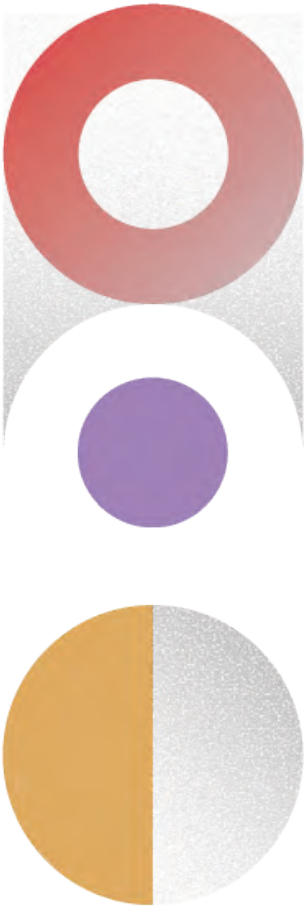


Executive Summary



The telecommunications industry is undergoing a profound transformation, with the move toward AI-native networks driving the need for greater efficiency, agility, and resilience. However, most Communication Service Providers (CSPs) remain constrained by siloed domains, fragmented data, and reactive operations that limit their ability to evolve.

Network Digital Twin (NDT) emerges as a critical enabler of this transition, offering a dynamic, near real-time digital replica of network ecosystems. By unifying data across domains, NDTs provide comprehensive end-to-end visibility, accelerate fault detection and resolution, and support predictive analytics for smarter investment and capacity planning. They unlock a step change in operational efficiency and pave the way towards fully autonomous, zero-touch networks.

The value of an NDT extends well beyond troubleshooting. By correlating events across multiple layers and domains, CSPs can significantly reduce incident duplication, Mean Time to Detect (MTTD), and reliance on domain-specific tools. Proactive impact assessments minimise customer disruption, while holistic insights optimise resource usage, improve resilience, and ensure sustainable growth in a 5G and cloud-native context. Agents play a pivotal role in operationalising the NDT, leveraging its contextual intelligence to autonomously monitor, recommend, and execute actions in real time. Together, digital twins and agents form the foundation of intent-based, AI-driven operations, **shifting CSPs from reactive to predictive and prescriptive models.**

Realising the full potential of NDTs requires more than technology. It demands robust data foundations, scalable frameworks, and experienced partners. With a proven track record, Celfocus helps operators define strategic roadmaps, integrate open and cloud-native platforms, and harness the power of automation and analytics. The result is not only **operational excellence** but also the ability to **monetise ecosystem opportunities** and maintain a **sustainable competitive edge** in an increasingly complex landscape.

Autonomous Networks Start with Data

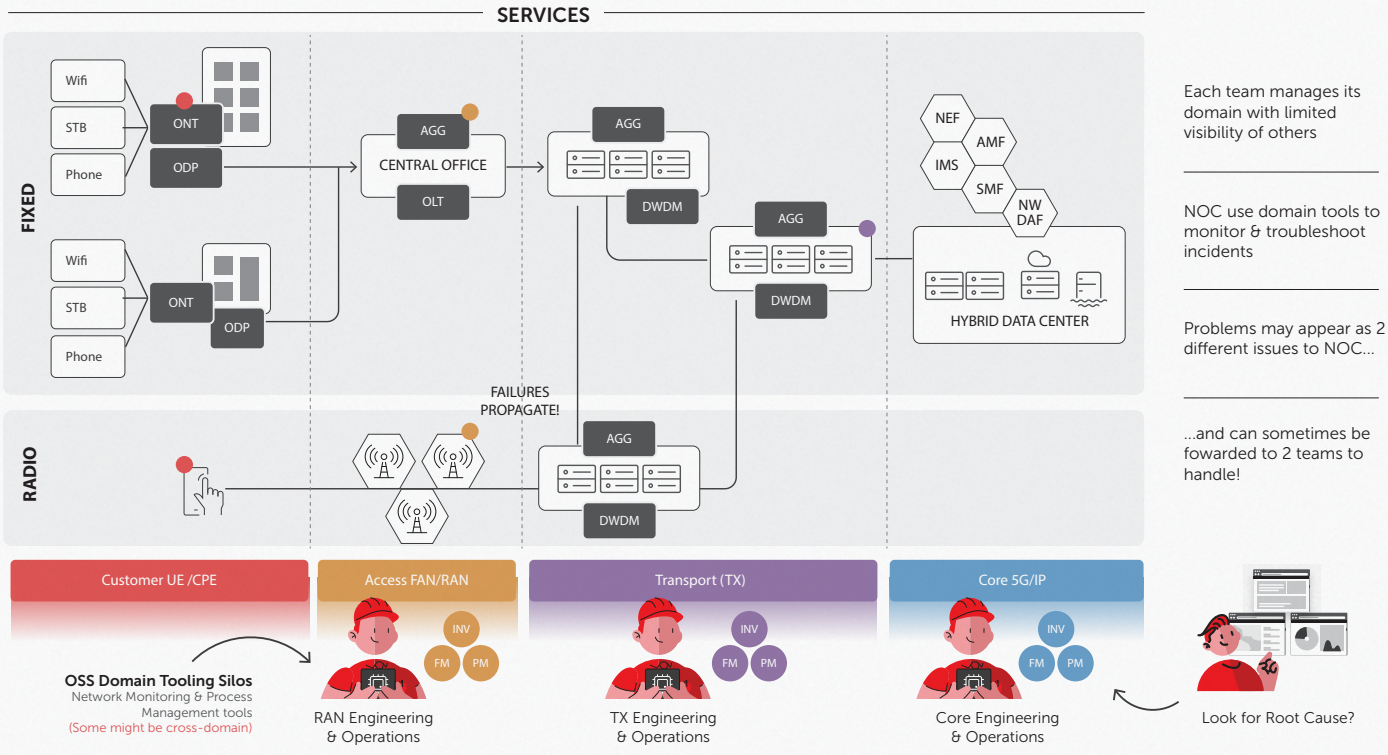
In our previous White Paper - "Telecom Gets Smart: How AI-Native Networks Are Redefining the Industry" -, we explored the paradigm shift toward AI-native networks and highlighted their importance for the long-term sustainability and success of operators. In this document, we will focus on how establishing a robust data foundation – one that provides real-time visibility of the entire network ecosystem – and progressively adopting autonomous capabilities can simplify operations, reduce complexity, and ultimately drive greater service reliability and monetisation. Expert partners play a crucial role in guiding operators through this transformative journey.

Today's Challenge
Siloed Network Domains

What we frequently observe in client operations is that network domains typically function in isolation, managed by dedicated teams relying on domain-specific tools. While this enables specialised attention, it creates blind spots and fragmented visibility when incidents occur.

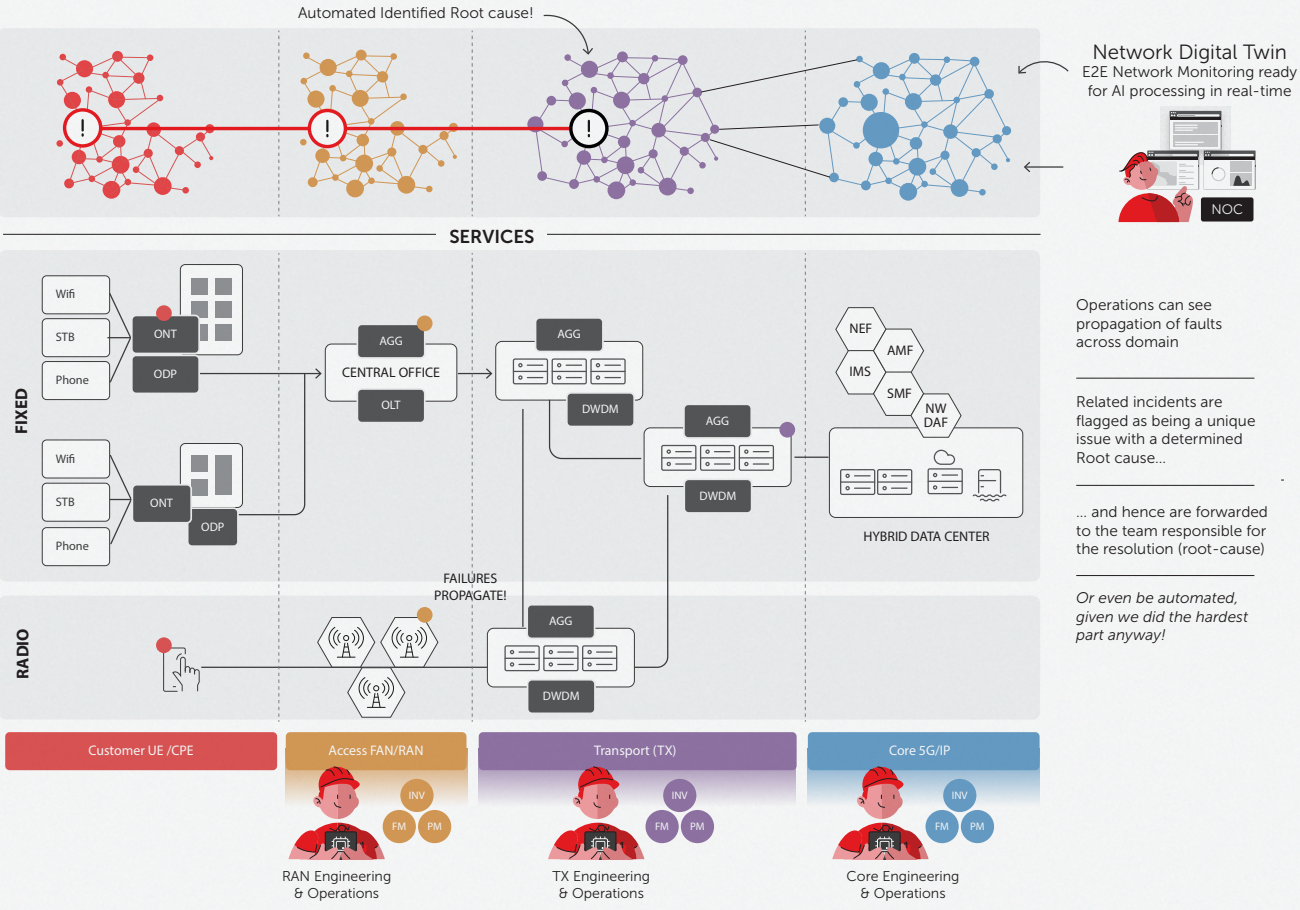
A single fault within one domain can easily cascade into adjacent areas, generating multiple alarms and misleading noise. Consequently, Network Operation Centers (NOCs) often perceive a single underlying issue as several unrelated incidents, assigning them separately to multiple teams.

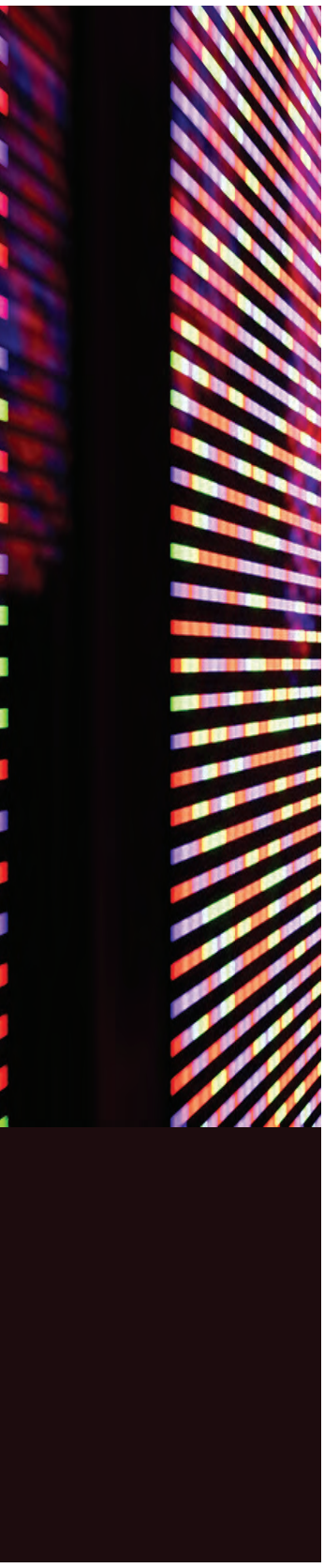
This fragmented approach results in duplicated efforts, prolonged troubleshooting, and delayed identification of the true root cause.



Target State
Unified Multi-Domain Visibility

What we aim for is comprehensive, end-to-end, multi-domain visibility. When faults occur, operations teams should have a complete, real-time view across all network domains, enabling them to clearly track how incidents propagate. Related incidents are automatically correlated, identified as a single issue, and tagged with their root cause, significantly simplifying the trouble-shooting process. With clear identification, incidents can be swiftly directed to the appropriate team responsible for resolution – or better yet, resolved automatically, given that identifying the root cause is the most challenging step.





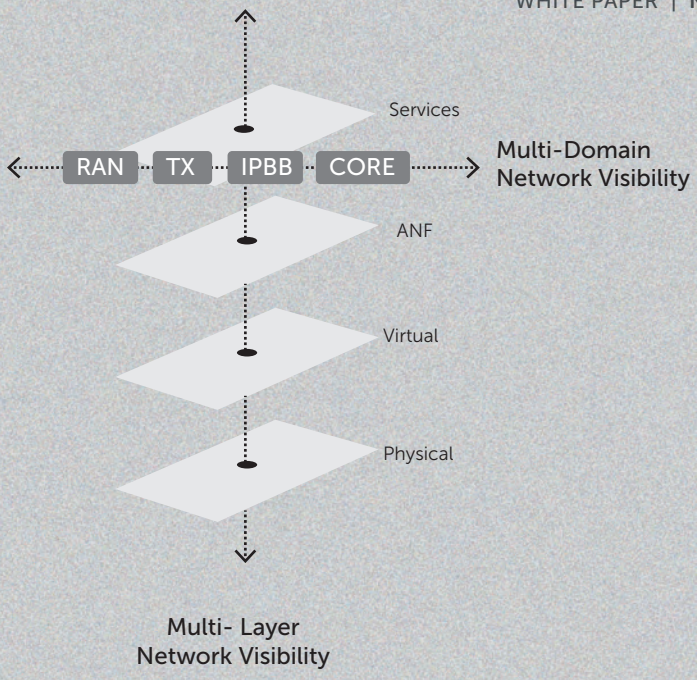
Furthermore, beyond operational efficiency, unified multi-domain visibility empowers strategic planning and smarter CAPEX decisions. By leveraging predictive analytics and what-if scenario modelling, CSPs can proactively assess the impact of potential network investments, anticipate capacity bottlenecks, and optimise resource allocation. This forward-looking approach allows providers to strategically prioritise their investments, mitigate risks, and ensure network readiness, ultimately driving long-term sustainability and growth.

Towards Network Digital Twin: Supporting real-time decisioning

As we have seen, operational data is typically sparse. This takes us to the need of a virtual near real-time dynamic representation of network ecosystems mimicking their real counterpart that simultaneously un-siloes critical data and enables simulation, prediction, and optimisation of performance.

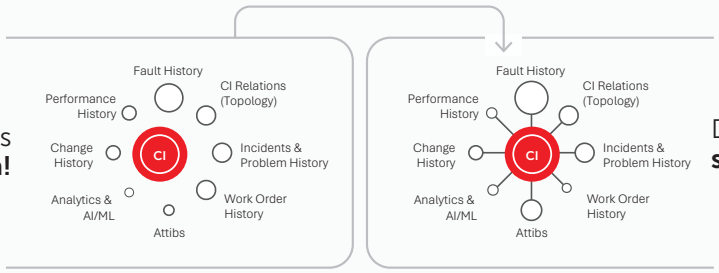
Any AI application's success relies on speed, quality, and relevance of the data feeding its algorithms. A robust data readiness framework and well-structured data model are therefore essential for rapidly querying, extracting, and processing information tailored to each targeted use case.

A well-designed data readiness framework addresses these issues by breaking down data silos, standardising formats, and enabling correlation across diverse sources. This paves the way for more efficient troubleshooting, streamlined operations and, ultimately, better AI outcomes and restoring visibility to virtualised networks from an E2E perspective.



Implementing a robust **digital twin data ecosystem** involves adopting a hybrid federated data ecosystem employing different storage technologies while balancing cost efficiency and performance where each component plays a specific technological role:

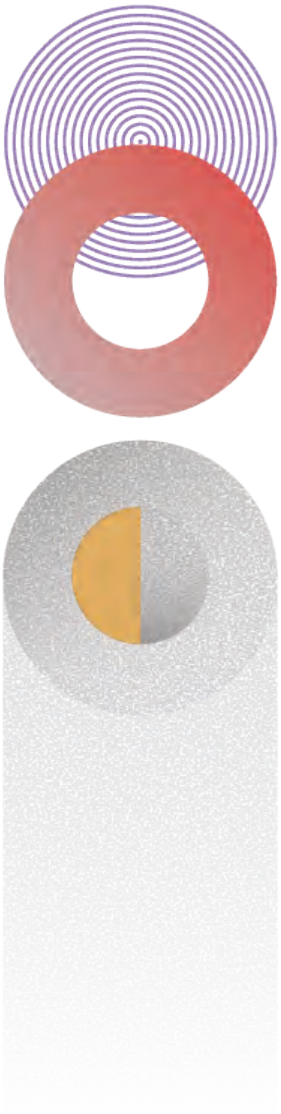
Operations
Sparse Data!



Digital Twin
structure!

Data Lakes: Ideal for handling large-scale, unstructured data with minimal overhead, enabling both cost-effective storage and broad availability for operational processing and analytics.

Graphs: They perfectly mimic real network topology by capturing relationships between entities, making it simpler to visualise and analyse how components interact in a live environment. They also enable and facilitate



graph-related problem resolution using graph-native algorithms which applies perfectly to network challenges (e.g.: what is the most critical node in the network).

Time-Series Data: Designed to store recurrent, historical alarms, metrics and more - crucial for monitoring trends and events over time at high ingestion speeds. These metrics always stay connected to components of the topology within the graph.

Tabular Datasets: Best suited for knowledge arranged in the form of tables with rows and columns, simplifying the process of reading, understanding, and manipulating information. Tabular data is essential for organising datasets, running queries, and producing reports efficiently.

Vectorisation: Specially designed to store, manage, and query data represented as numerical vectors, also known as embeddings. These represent unstructured data like text, images, or audio, enabling efficient similarity searches and contextual understanding in AI and Machine Learning applications.

By combining specialised storage technologies, we ensure data from diverse sources is efficiently ingested, readily retrievable, and accurately reflects the complex interdependencies of modern network systems, both physical and virtual.

Key Functional Capabilities Enabled by the Digital Twin

A network digital twin serves as a powerful enabler for next-generation operations by providing **a dynamic, real-time replica of the network's physical and logical structure across multiple domains.**

This digital representation unlocks several key capabilities that enhance both operational efficiency and strategic planning. From visualising and analysing multi-domain topologies to pinpointing root causes of faults and predicting service impacts, the digital twin transforms how CSPs manage complexity.

It not only supports faster incident resolution and improved reliability but also enables proactive decision--making through scenario analysis and network optimisation, ultimately driving better customer experiences and more efficient use of resources.

Multi-domain Topology

Model physical & logical topology of multiple interconnected network domains.

Benefits
Multi-domain root cause analysis, and full E2E visibility of domain interactions

Root Cause Analysis

Identify dependencies and fault propagation paths within the network.

Benefits
Faster incident resolution, reduced downtime, and improved service reliability

Service Impact Assessment

Assess how changes (maintenance, upgrades, etc.) impact connected nodes

Benefits
Minimise service disruption, improve planning, manage customer expectations

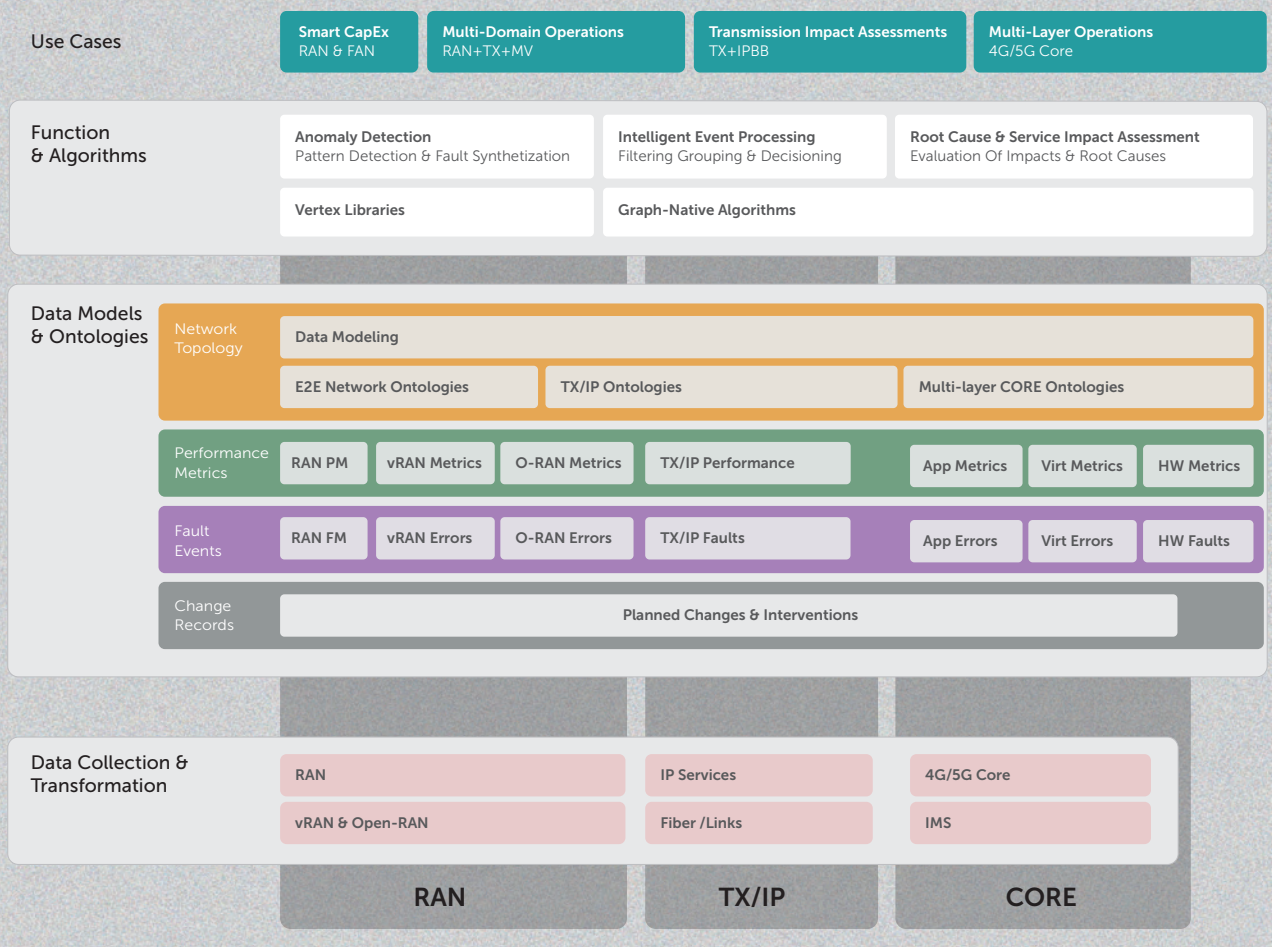
Network Optimisation

Optimise data flow, reroute traffic dynamically, and enhance resilience

Benefits
Reduces congestion, improves latency, and ensures efficient resource utilisation

Where to Start

Celfocus's Network Digital Twin framework is built on a modular foundation that integrates key capabilities across multiple levels, ensuring scalability, adaptability, and real-world applicability. At its core, the framework combines advanced functions and algorithms for analytics and automation, robust data models and ontologies to standardise and represent complex network relationships, and flexible data collection and transformation pipelines that ingest and harmonise information from diverse sources. This layered architecture enables CSPs to accelerate their digital twin adoption, ensuring **accurate, real-time insights and supporting a wide range of use cases** – from operational intelligence to strategic planning.

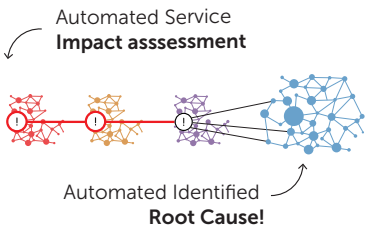


Making it real
Examples of value delivered by the NDT

The implementation of a Network Digital Twin (NDT) delivers tangible outcomes across several critical operational domains, helping CSPs transition from **reactive, fragmented processes to intelligent, data-driven operations**. Here's some results we were able to achieve:

Multi-Domain Operations
RAN + TX + MW

Combine events from multiple domains to perform anomaly detection, perform root cause analysis and provide recommendations to engineers.



- Inter and Intra domain network fault correlation
- Proactive real-time anomaly detection on metrics
- Automated Root Cause & Service Impacts
- Correlation with change management occurrences
- Recommendations for next steps
- Agentic based resolution procedures

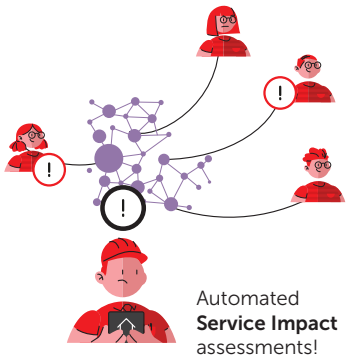
VOLUME
-50%
Less duplication of effort between teams

RESOLUTION
-60%
Mean time to detect and resolve

LICENSING
-60%
Less OSS/Network Tooling and licences

Impact Assessments
TX + IPBB

Ability to infer service and customer impacts from planned interventions or incidents occurring in a given network node.



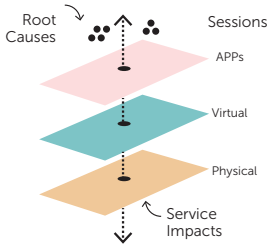
From multiple days to a couple of hours
Calculating service impacts on TX/IP networks upon planned interventions

-60%
MTTD/MTTR

-30%
TOOLS & LICENSING

Multi-Layer Operations
4G/5G Core

Combine physical, virtual, and application layers to enable anomaly detection, root cause analysis (RCA), and recommendation engines.



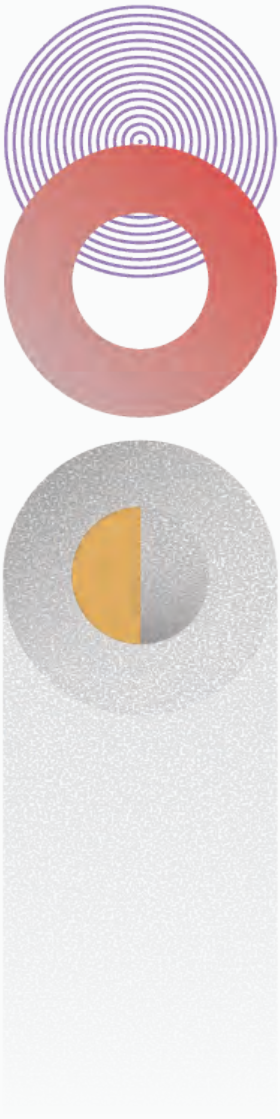
- Multi-layer network data correlation across physical, virtual, and application domains
- Real-time anomaly detection with proactive alerting
- Dynamic thresholds
- Automated Root Cause & Service Impacts
- Recommendations for next steps
- Agentic based resolution procedures

HARDWARE
-20%
Less hardware usage and energy consumption

LICENSING
-30%
Less OSS/network tooling and licences

CONSULTING
-20%
Consultancy spending with NW vendors

RESOLUTION
-60%
Mean time to detect and resolve



1. Multi-Domain Operations (RAN + TX + MW)

By correlating events across Radio Access, Transport, and Microwave domains, NDTs enable comprehensive fault detection, cross-domain root cause analysis, and unified incident visualisation.

Key Benefits

- **50%** less effort duplication across operational teams
- **60%** reduction in Mean Time to Detect (MTTD) and resolve incidents
- **30%** reduction in reliance on domain-specific tooling and silos

This results in faster resolution cycles and eliminates confusion when faults span multiple technology layers.

2. Impact Assessments (TX + IPBB)

NDTs can assess how planned interventions or unplanned faults impact customers and services by tracing dependencies through the transport and IP backbone.

Key Benefits

- Reduction from **days to hours** for impact analysis
- **-60%** fewer escalations to second-line technical teams
- **-30%** fewer customer complaints

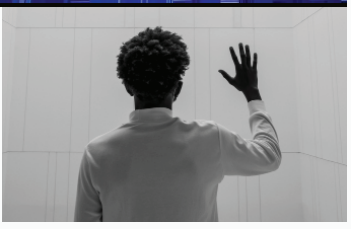
This proactive insight minimises customer impact, streamlines internal coordination, and reduces churn.

3. Multi-Layer Operations (4G/5G Core)

Digital twins integrate physical, virtual, application and session layers to enable full-stack visibility critical for modern cloud-native networks.

Key Benefits

- **20%** decrease in unnecessary resource usage (energy & capacity)



- **30%** reduction in tool fragmentation across OSS/NMS layers
- **20%** reduction in consulting/engineering dependency from NVI vendors
- **60%** faster root cause isolation and incident resolution

The result is improved operational agility, cost control, and a more resilient 5G-ready infrastructure.

What about Agents?

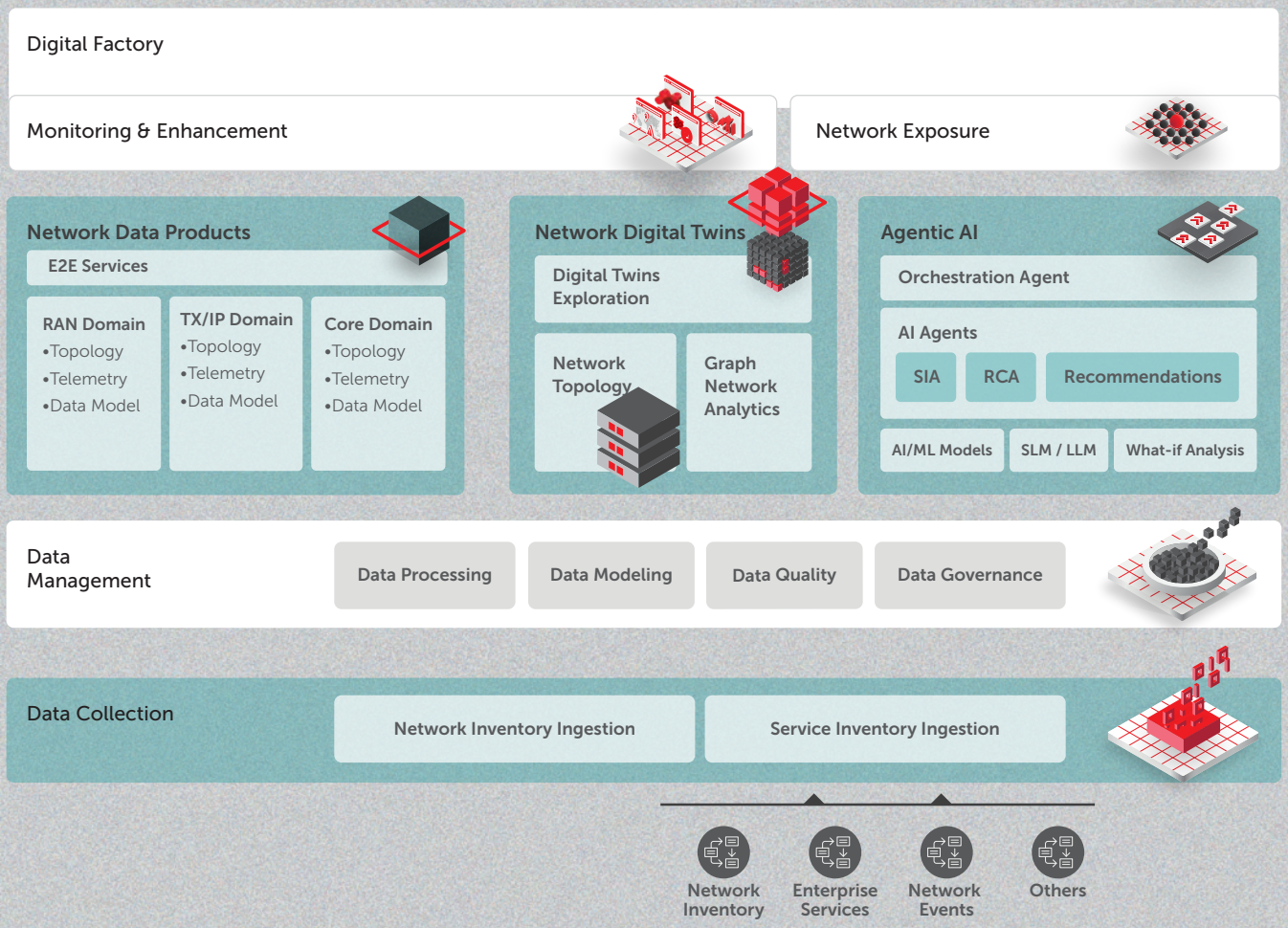
While a Network Digital Twin provides the foundational data environment and simulation capabilities, agents act as the execution layer that leverages this intelligence. Agents – whether AI-based or rule-driven – can act autonomously or semi-autonomously to:

- Continuously monitor for anomalies or threshold breaches

- Trigger automated remediation workflows

- Recommend optimal reconfigurations to operations teams

- Execute closed-loop actions, such as rerouting traffic, restarting network functions, or provisioning additional resources



Agents become especially powerful when embedded within an intent-based operations framework. The digital twin supplies the context; agents act on it – bringing about true zero-touch operations. This human-out-of-the-loop paradigm enables CSPs to shift from reactive to predictive and prescriptive network management.

Conclusion

Network Digital Twins are not just a technical enhancement – they are a strategic enabler for AI-native operations. By offering a unified, real-time, and contextualised view of multi-domain network infrastructure, they empower CSPs to transition from fragmented and reactive operations toward **intelligence-driven, autonomous networks.**

Realising the full value of NDTs requires more than technology – it requires a shift in mindset, strong data foundations, and the right ecosystem of tools and partners. With the right strategy, CSPs can unlock operational efficiency, service excellence, and strategic agility, ultimately ensuring a sustainable competitive advantage in a rapidly evolving telecom landscape.

Furthermore, as part of the journey toward autonomy, **intelligent agents** play a critical role in operationalising the insights derived from the digital twin. These agents – AI-powered or rule-based – can proactively trigger actions, automate routine responses, and close the loop on fault management or service optimisation scenarios. In essence, agents transform situational awareness into situational response, enabling truly autonomous operations that scale with the complexity of modern networks.

Why Celfocus?

Remove uncertainty from your path. Celfocus is a systems integrator with over 20 years of experience in CSP transformations, guiding clients from strategy to implementation and operation. We help our clients solve some of the most complex challenges in telecom by answering critical questions such as:

- How to define and execute a roadmap for AI-native evolution?
- How to implement scalable, cloud-native platforms that support automation across network domains?
- How to set up effective data governance frameworks and unlock the full value of existing infrastructure?
- How to ensure end-to-end visibility and service assurance in hybrid, virtualised environments?

We leverage the existing ecosystem and strategic CSP investments to deliver integrated, future-ready solutions. Our platforms are based on proven, pre-built assets that align with open standards and are designed to work seamlessly in complex multi-vendor technology landscapes.

Celfocus draws insights from large-scale data operations and open-source innovation, as well as hyperscaler frameworks, to accelerate delivery, reduce complexity, and maximise impact. Our reference projects demonstrate a consistent ability to deliver outcomes at scale, enabling telecom leaders to turn strategy into execution, and vision into value.

For more information about CELFOCUS,
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www.celfocus.com

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