Artificial Intelligence for Network and Service Automation Standards Enablers and Research Directions

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Main drivers…

Technology

Major breakthroughs. (backpropagation algorithms, convolutional neural networks, generative adversarial networks, high-dimensional word embeddings…)

Continuous advances in techniques and algorithms (e.g. graph and adversarial neural nets)

Ethical and regulatory considerations (e.g. differential privacy, explainable AI) becomes integral parts of the technology development

Data

Transformation from CSP* to DSP*, in-line with holistic digitization

Data collection platforms becomes intelligent, agile and with expanded application space

Increased use of data lakes

Techniques and tools available for synthetic data generation

Compute

Moore's law and continuous evolution of HW specialization e.g. CPU, GPU, TFU, ASICS…

Compute continuum: spanning from devices/sensors, through the edge to core DC

Tools

Maturing ecosystem of platforms, languages and libraries (TensorFlow, SageMaker, scikit-learn, PyTorch, Keras…)

Progress and availability of pipeline automation (e.g. AutoML)

Business

Embracing the industry evolution and new opportunities with the adoption of AI technologies and practices across CSP and NPN scenarios

Web-scale actors driving the main AI technology building blocks and steering their development

Attracting DSP data and increasing collaborations between DSP and web-scale partners – with/without telco vendors

(*)
- CSP: Communication Service Provider
- DSP: Digital Service Provider

… and gaps

AI mainstream is myopic about other AI realms

Heavily focused on Deep Learning, for human perception tasks

Semantic learning, knowledge representation/embedding, common sense reasoning… still minority but highly needed to support the full cycle of network and service automation

AI-based solutions working in isolation and case-tailored

Necessary coordination between multiple AI solutions for coherent decisions

Generalization and automation methodologies are needed to streamline AI pipelines

Radical re-thinking how to apply AI for the design and operation of network and service automation; go beyond simple replication of the usual problem-solution design process with AI

Application of AI technologies in NPN scenarios less investigated than for CSP

Limited use or reliance on standards

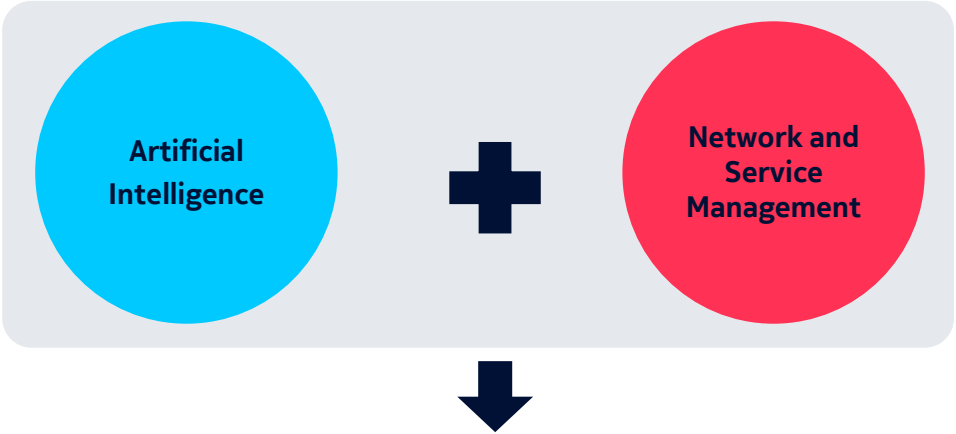
Still in the Infancy age of Networks AI and Networks AI standards

Standards needed to allow value creation with AI in multi-vendor and open solutions

No or limited interoperability and re-usability of de-facto standards driven by software development

AI technologies are developing and expanding fast, however some gaps must be overcome to fully exploit the potential of AI technologies

Scope



Advanced integration and embedding capabilities needed to maximize the use and efficiency of AI-assisted and AI-enabled management and automation

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High potential areas

Network planning

e.g. accelerate planning decisions by transferring knowledge/models learned in other operational domains

Service/slice provisioning

e.g. service/slice creation and deployment based on automated descriptor checking, fetching and completion

Operator experience

e.g. transform the operator experience by taking advantage of machine learning and reasoning in adapting control and supervision interactions

Security

e.g. AI-powered threat detection and mitigation, data integrity assurance

Network optimization

e.g. leverage real-time analytics to dynamically select optimal routes and steer traffic in multi-technology and cross-domain/cross-layer topologies

Service/slice and network assurance

e.g. reduce high volume of incidents to meaningful situations (e.g. outage and congestion prediction, SLA assurance…) by predicting, detecting and correlating events

Intent fulfillment

e.g. learn what actions are more efficient and impactful to realize intents in given contexts with self-evaluation and self-measurement capabilities

And others such as…

- Testing
- What-if scenarios
- Tactical decision-making…

Problem-technique mapping (non-prescriptive)

AI type	AI task	Problems	Algorithms
Descriptive & Explanatory	Pattern or event detection and recognition	• Anomaly detection • Intrusion and Malware detection • Data protection breach • Abnormal, unexpected traffic detection	• Autoencoder • Clustering • (Semi-)Supervised learning • Statistical outlier detection
		• Recurring problem detection • Root cause analysis • Malware, traffic profiling • Routing and scheduling	• Feature extraction and classification • Deep Neural Networks • Supervised learning
Predictive & Exploratory	Prediction, search	• Predictive network optimisation and maintenance • Configuration parameters estimation • Mobile traffic forecasting	• Time series analysis • Predictive / forward modelling • Convolutional Neural Networks • Recurrent Neural Networks
Prescriptive	Decision making	• Countermeasure selection • Cognitive spectrum sharing • Shared resource allocation	• Structured learning • Reinforcement learning • Multi-agent system

Challenges

1

Networks are hard AI problems

- Networks are distributed, dynamic, heterogeneous, and encrypted
- Complexity in data sets and complexity in the algorithms that deal with them
- Network data are characterized by high-dimensional spaces
- Network data is heterogeneous and diverse
- Access to network data is difficult, lack of reference (labeled) data sets

Challenges

2

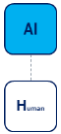
Confidence in AI

- AI technologies introduce new challenges and specificities such as
  - Performance degradation (re-training)
  - Data sensitivity: bias, adversarial inputs, governance (security, privacy)
  - Shift from deterministic/provable algorithms to stochastic/statistical paradigm
  - Explainability, accountability
- Need for a comprehensive framework to increase confidence in the use of AI

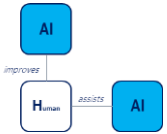
Challenges

3 Human – AI interaction

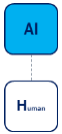
- Various levels of intelligence and support to human operator from assisted to empowered
  - Assist or extend human operator in service design, parametrization and operation
  - Adaptive intelligent automation based on dynamic levels of autonomy and supervision
- Different roles and interactions between the AI-based system and human operators
  - Introducing additional standardization requirements
  - Evolution of human operator's skills e.g. tune AI system, different forms of policies, and AI output interpretation
  - Adaptation of the AI output representation with the relevant domain knowledge and system abstractions



Independency
AI performs beyond immediate human operator control



Enablement
AI work with human operator in close cooperation



Replacement
AI does same task as human operator

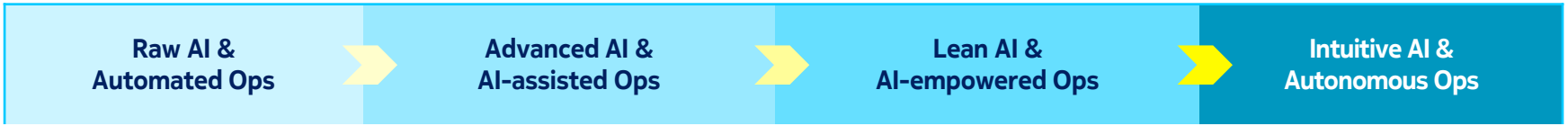
Challenges

4

AI diversity

- AI techniques have different requirements and standardization needs
- Overall design integrating and leveraging individual AI properties
- Coordination between distributed AI applications to ensure coherent e2e operation
- Additional (AI-specific) software diversity

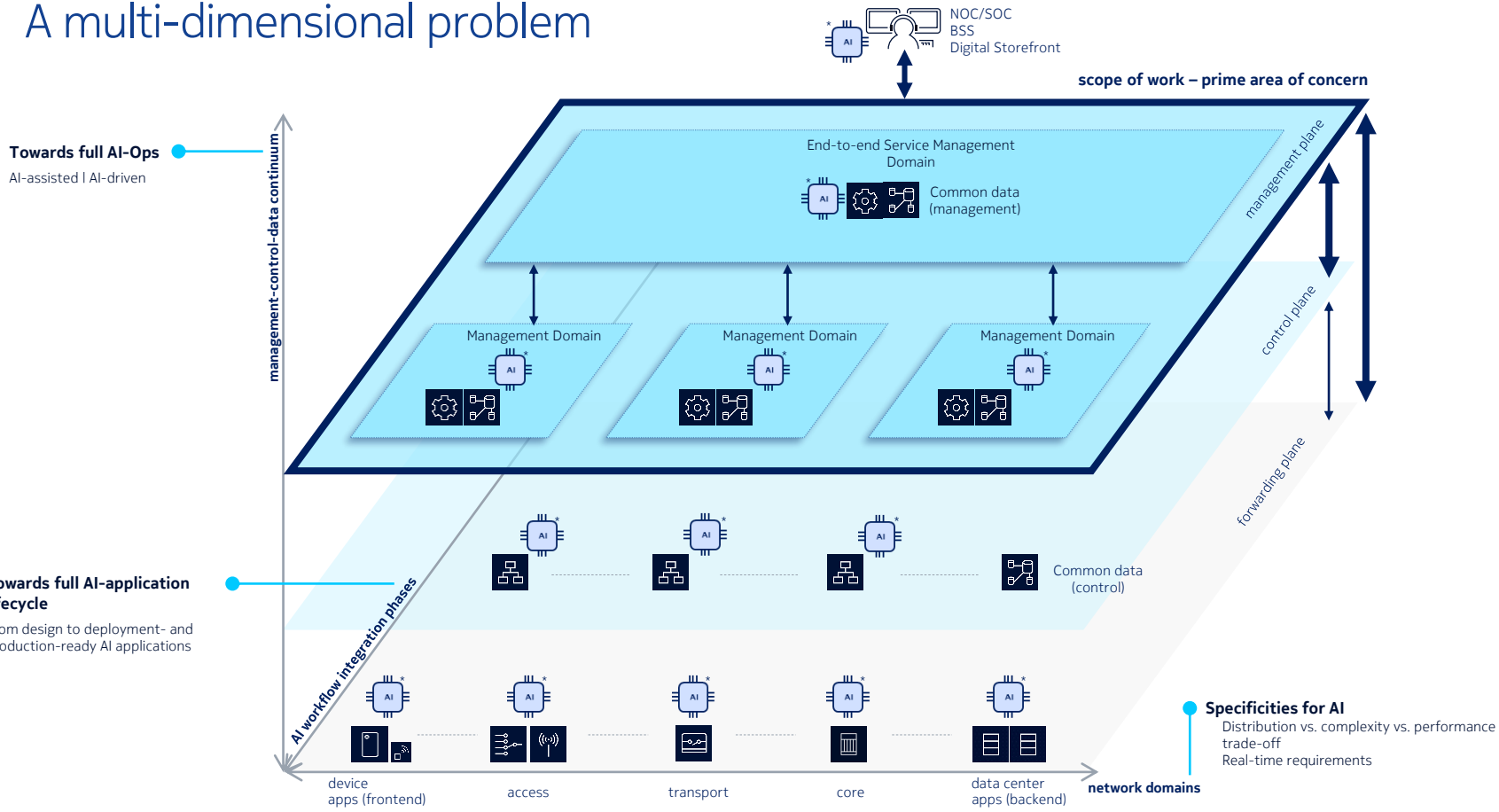
Joint evolution of AI and Ops



Joint evolution of AI and Ops

	Raw AI & Automated Ops	Advanced AI & AI-assisted Ops	Lean AI & AI-empowered Ops	Intuitive AI & Autonomous Ops
AI & Data	Limited view and use of AI potential Big dumb data	More diversified, network-adapted AI techniques Smarter data	Broad set of AI techniques for N&S environment Intelligent data	Zero-touch AI-Ops Machine Reasoning Symbiotic Human-AI interaction Mission autonomy Transparent, trusted, open AI Reliable, robust and distributed AI
Scale & Adoption	Use case-driven Isolated, small scale solutions with limited re-use	Cross use cases Large scale application and penetration of AI-based N&S automation solutions	"AI-as-a-Service" Full scale deployment and applicability of AI-enabled, plug-n-play solutions	
Practice & Integration	Retrofit ML technologies for N&S automation Manually-intensive integration	AI know-how is leveraged for N&S automation Semi-automated design and integration	Designed with AI Seamless design and integration	
Confidence & Security	Controlled autonomy and confined in scope No AI-specific security measures	Towards operation autonomy Trust framework safeguards AI-based solutions AI-specific security techniques protect N&S operations	Towards mission autonomy AI continuously and reliably delivers on the business targets Guaranteed AI functional safety	
Standards & Regulation	Lack of standards Consultations with authorities and stakeholders	Emerging standards and basic interoperability First compliant AI-based N&S automation solutions	Comprehensive standards and increased interoperability Fully embedded policies and principles	

A multi-dimensional problem



* potentially multiple AI instances

Standardization scope

Enable innovation and differentiation with AI in multi-vendor network and service management environment

Key enablers and functionality

Mediation between data sources and data processing, augmented with meta-data models and data governance

Support for unified and expressive data formats to allow AI workflow automation and plug-and-play

Coordination between multiple, distributed AI applications, ensuring compliance with intents, consistent end-to-end operational view and means to act on it

AI models life-cycle management, re-usability of generated knowledge and acceleration of models deployment

Support for deployment diversity

Data: data sources, their locations and characteristics (local, ephemeral…), data distribution, data storage

Compute: computation elements locations, types and capabilities

Operations: constraints and capabilities for various AI models training and inference options; connecting the AI applications to the orchestration and control end points

Considering also other factors for regulatory and sustainable approach (energy, data sharing/replication, compute/data co-location)

Trust and adoption

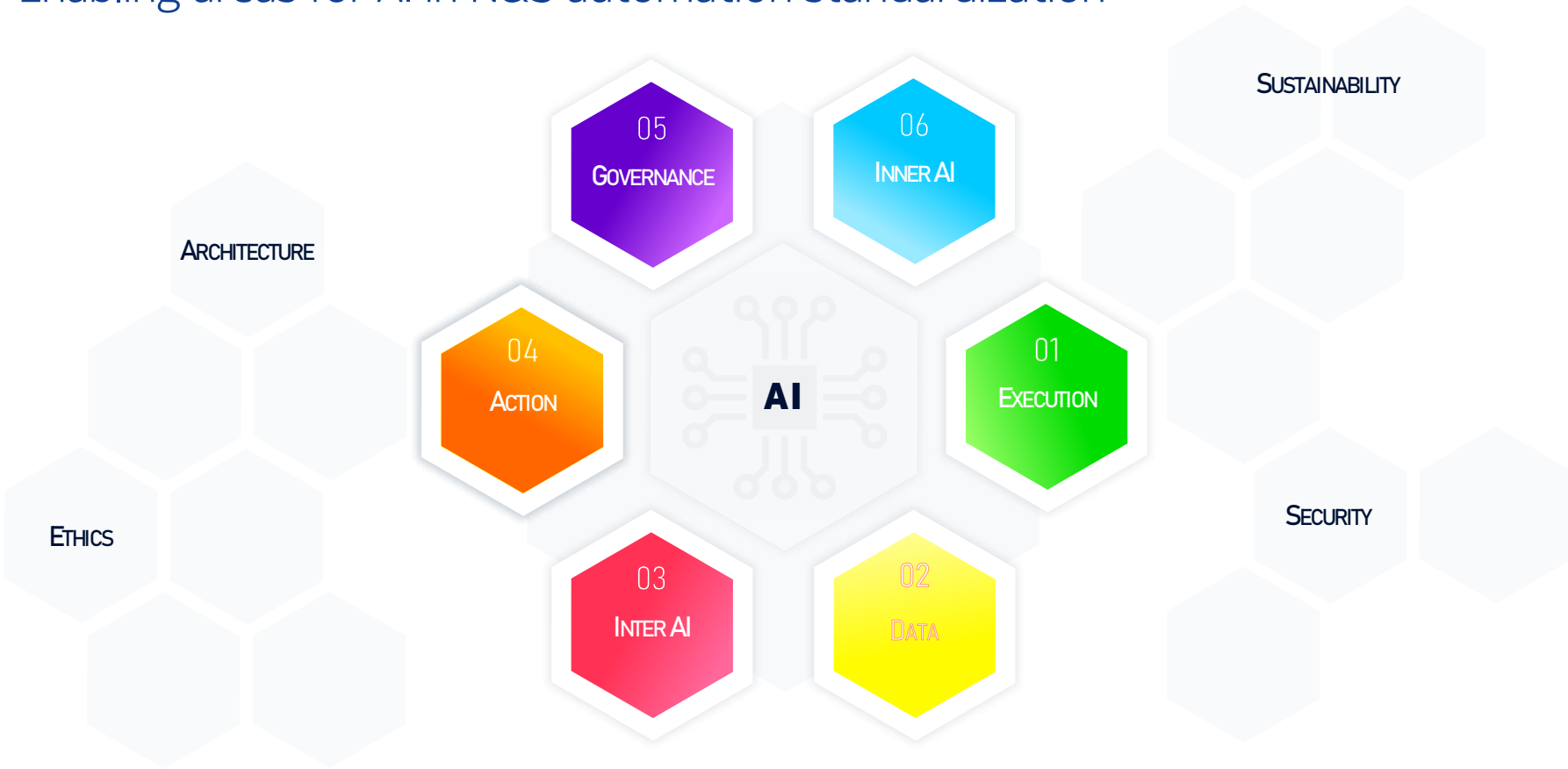
On-par privacy and security requirements; improvement and alignment to capabilities and constraints of AI-based solutions

Support for different levels of supervision and visibility for human operators

Support incremental evolution to AI/ML, integration of learnings from experience and deployments to the standardization process

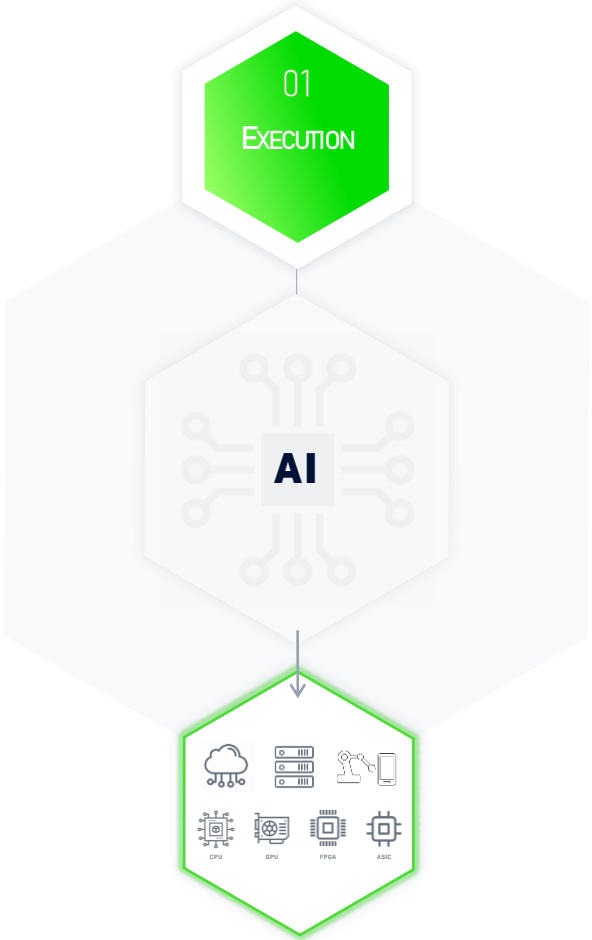
Openness vs. trust dilemma: new disaggregated solutions add management complexity and call for more transparency and accountability

Enabling areas for AI in N&S automation standardization



Considerations

- The infrastructure capabilities should support the AI application execution requirements and constraints (e.g. flexibility/efficiency) in any environment (e.g. on-cloud, on-premise, on-device)
- The environment may compose a computing continuum, need to take into account the diversity of execution environment
- Different deployment options of the AI components driven for example by real-time requirements need to be supported, and planned consistently across domains



Standards needs

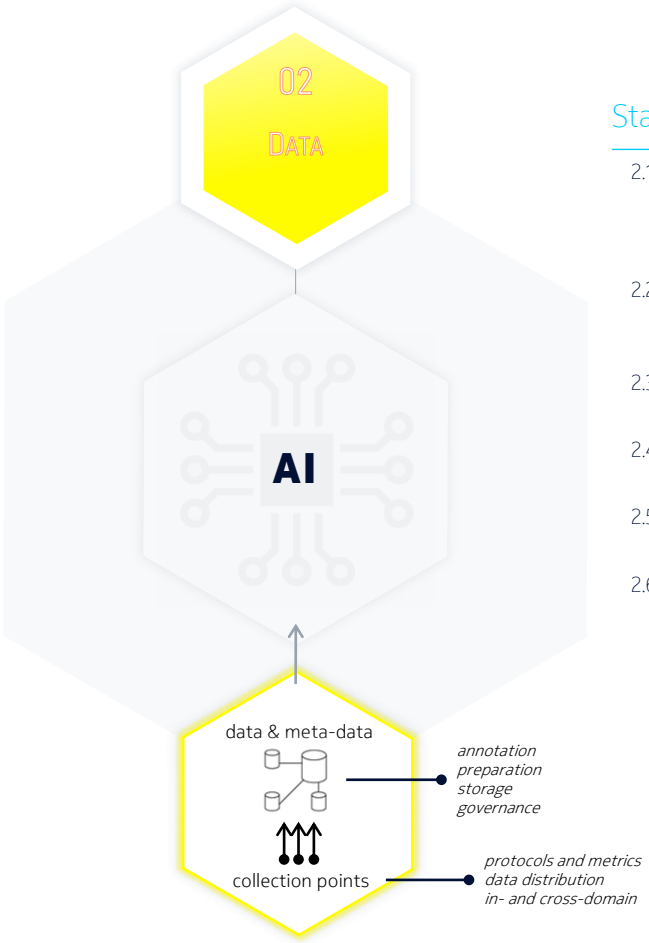
1.1 Ability to express requirements and constraints for deployment options of AI applications (affinity/placement/embedding) including distribution of components

1.2 Ability to dynamically adapt the provisioning and operations of AI components to take into account live network conditions, applications and solution requirements

1.3 Normalize the expression of AI application needs and capabilities, for both the training and inference phases

Considerations

- Ensure access to the right (training and inference) data, at the right place, and at the right time
- Automation challenge when faced with lack of proper data (synthetic vs. operational data, limited access to data…)
- Data workflow encompasses annotation (and its automation), preparation, storage, collection points provisioning and available metrics
- Data needs for richer description and expressiveness
- Data tsunami balanced with intelligent data collection, addressing liberal to conservative approaches for data collection
- Data patterns are dynamic and change over time: limited validity of the learned model, limited generalization of the inferred knowledge (techniques tailored to a too specific use case or even dataset)
- Data governance with proper support and exposure for security and privacy, public vs. private data, anonymization, data encryption, etc.



Standards needs

2.1 Ability for the AI application to express what data is required, under which form(s), pre-processing, storage requirements (persistency, availability, latency), discoverability and understanding of meta-data

2.2 Ability to convey semantics at different levels, as well as purpose to enable AI workflow automation and machine-to-machine operations

2.3 Support for flexible use of real and synthetic / simulated datasets, according to AI application data requirements

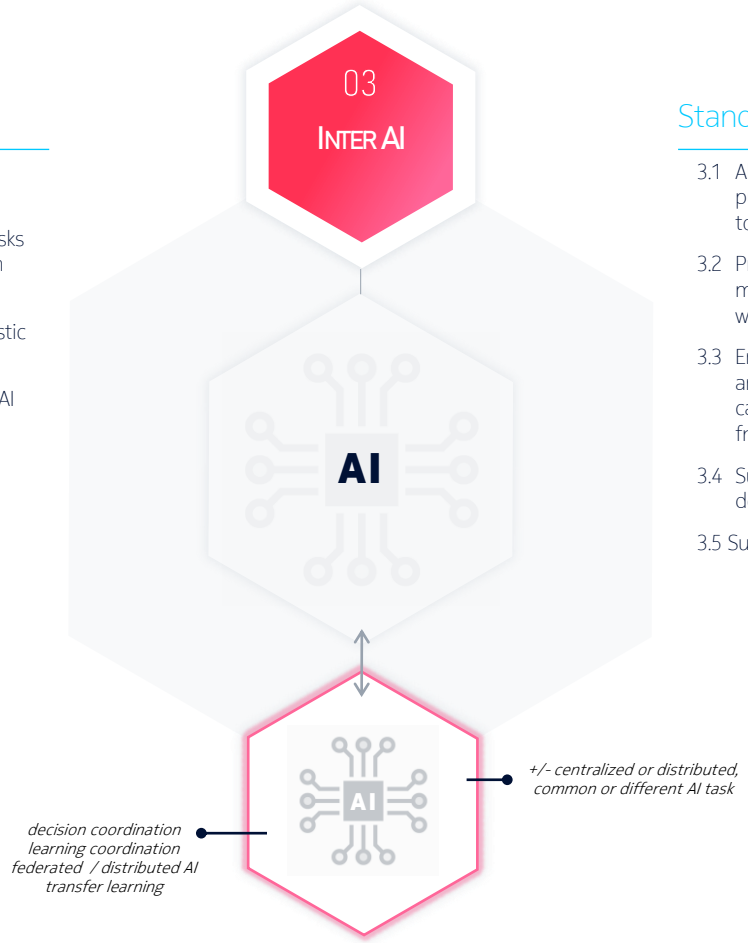
2.4 Augment data collection frameworks with automatically identified qualitative criteria and prediction capabilities

2.5 Support transfer of knowledge between domains, provide descriptions of domain characteristics

2.6 Utilize standards and best practices for data governance; extend as needed to support specificities of AI techniques together with security and privacy considerations

Considerations

- Spectrum of learning approaches ranges from fully-centralized to fully-distributed
- AI applications can collaborate in learning different tasks or contribute collectively to solve a common problem
- Coordination between multiple, distributed AI applications is essential to ensure consistent and holistic operational view and means to act on it
- Applicability of transfer learning is dependent on the AI model semantics
- Trust relationship between AI applications, proper authentication validation and access control to AI applications operations



Standards needs

3.1 Ability to convey semantics at different levels, as well as purpose to enable AI workflow automation and machine-to-machine (AI-to-AI) operations

3.2 Provide common logical interface and information/data models to enable inter-AI coordination and interaction, as well as sharing of the learning task description

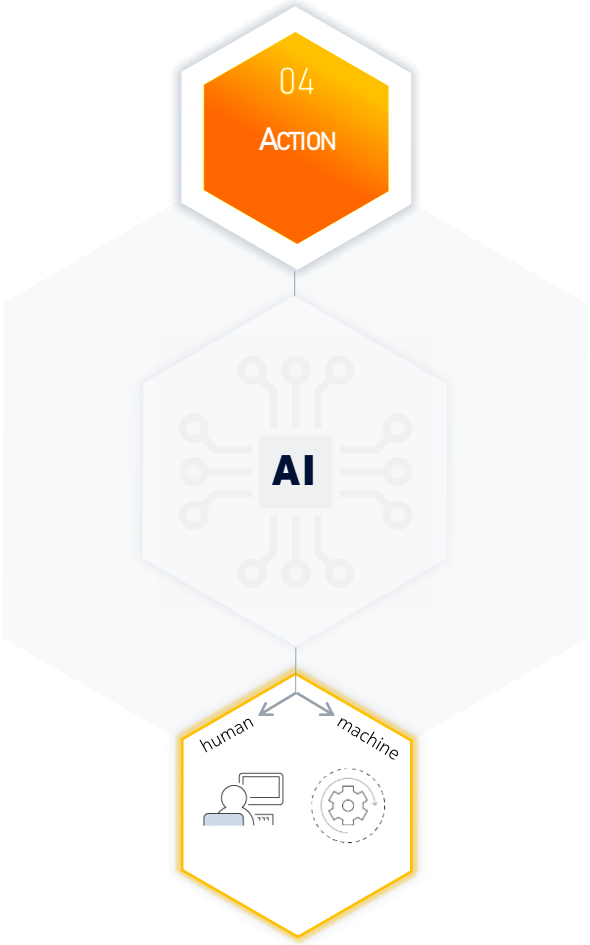
3.3 Ensure healthy balance in preserving business value and IP, and supporting an open innovation model (e.g. level of capability and details exposure to allow AI model swapping from one vendor to another)

3.4 Support transfer and re-use of knowledge, models descriptions and characteristics

3.5 Support building mutual trust between AI applications

Considerations

- Case-tailored AI application and limited integration with the overall management activities pose challenges for end-to-end, AI empowered workflows and closed-loop automation deployments
- Currently, outputs of AI applications are not standardized
  - Output format and syntax depend on the AI model and implementation environment (e.g. different software libraries used)
  - Output semantics are AI applications specific
- AI application outputs can be descriptive, predictive and prescriptive; each with respective requirements for the decision-to-action automation (incl. human in the loop)
- AI applications outputs can target either human operators or machines
  - Outputs towards humans must be interpretable to allow decision enhancement and making output actionable.
- AI (ML) applications outputs are decoupled from domain knowledge, thus requiring intermediate step to contextualize, interpret and enrich AI outputs with other sources of information (e.g. human expertise, business intelligence…)



Standards needs

4.1 Develop common description of AI application output, supporting:

a. Documentation: AI output can be automatically discovered or advertised, and linked appropriately in the management workflows ; AI output can also be used by human for design purposes

b. Identification: AI output can be automatically recognized and separated from any other output

Note: the description should be standardized, model- and semantic-based (e.g. ontologies) to enable per category AI model re-use ; AI output should contain proper meta-data describing e.g. accuracy

4.2 Enable support for different levels of action implementation such as informative (e.g. advice, suggestion, or recommendation), explicative (e.g. insight, hindsight, diagnosis) or imperative (e.g. prescription, command, authorization, or order)

4.3 Enable automatic, context-driven mapping between AI applications outputs and network/service/resource orchestration and control (closed-loop via actionable output)

4.4 Provide support in the transition phase involving human in the loop (e.g. for consent, verification, etc.)

Considerations

Usability

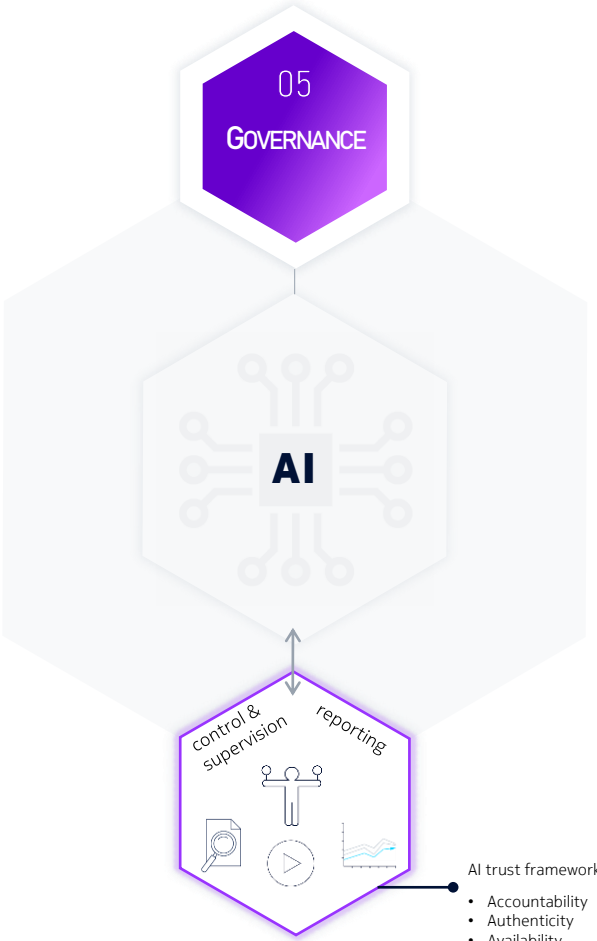
- AI should be easy to use, should reduce workload, and empower human operator with greater capabilities
- High-level, declarative goals (intents) hide complexity and simplify the setting of AI applications objectives, covering the comprehensive scope of governance aspects (security, privacy…) Current intent models, languages and functionality are not sufficiently developed and standardized. (e.g. for intent expression, translation, validation, assurance)
- Networking and AI expertise are different; new skills and tools are required for human operators to build, deploy, and tune AI applications during their entire lifecycle and automation process
- Different forms of human inputs must be supported (e.g. to define context for actions, to support unsupervised learning)

Trust

- Networks are critical systems; AI results must be reliable, measurable, interpretable and accountable
- The AI applications outputs should be presented to the human operator in different forms adapted to the situation, to the level of trust and expertise, and to the needs of the human operator
- AI shall be able to provide information about its past, current and future activities: what has/is/will happen and the related reasons
- Human operator shall be able to verify and consent AI application decision

Integration and operation

- AI applications should integrate and operate seamlessly within management functions, including appropriate and flexible composition and orchestration of AI applications functionality (e.g. data collection, knowledge extraction, inference, transfer…)



AI trust framework [1] ensuring:

- Accountability
- Authenticity
- Availability
- Integrity
- Privacy
- Quality
- Reliability
- Resilience
- Safety
- Security
- Transparency
- Usability

[1] according to ISO/IEC TR 24028:2020

Standards needs

5.1 Specify a comprehensive and coherent set of intent-based capabilities to enable simple usage and support for full spectrum of governance functionalities

5.2 Support for feature-rich, Human-AI interface with dynamic Levels of Autonomy (LoA) and Levels of Supervision (LoS) enabling advanced control, supervision and reporting

5.3 Enable support for dynamic and adaptive Human-AI interactions providing guidance for human inputs, decision verification, appropriate information representation – to support the shift of human role with introduction of AI-empowered management

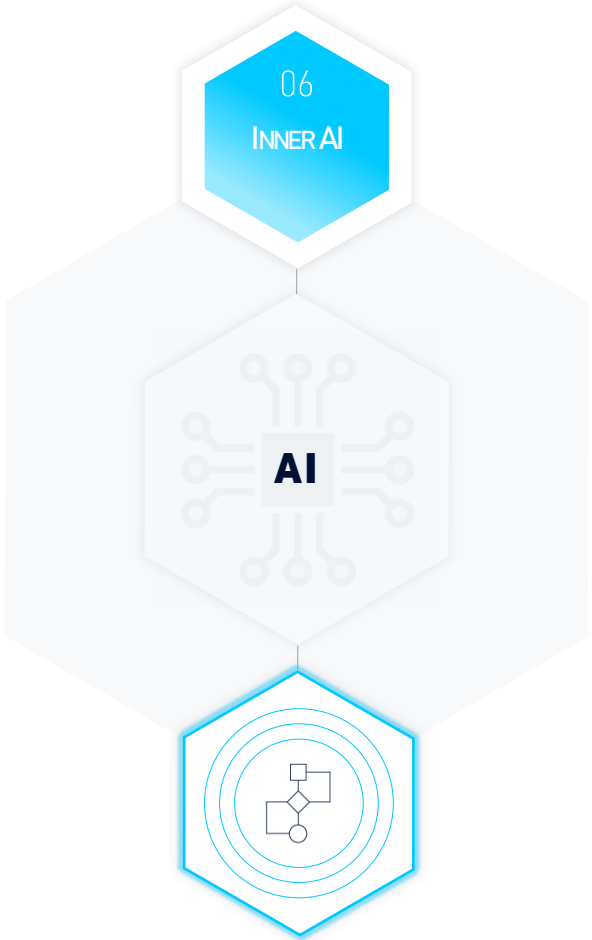
5.4 Support graceful fallback mechanism and procedures in case of AI "failure" e.g. by reverting to a more static and manual operation

5.5 Develop required "Trust as a Service" framework for full AI application features management, including performance, testing, validation, benchmarking, accountability, etc. based on self-measurement and self-evaluation

5.6 Develop N&S automation related AI applications lifecycle management, with corresponding management services and automation enablers for AI-centric build-deploy-run-terminate workflows; in-line with full Dev-(Net-Sec)-Ops cycle

Considerations

- New types of algorithms or network-specific adaptation of algorithms may have new/different requirements and supporting needs from standards (driven by the evolution of AI technology)
- E.g. Machine Reasoning introduces novel requirements for 1) semantic data and knowledge representation, 2) algorithms integration with N&S automation frameworks, and 3) interactions with other forms of AI
- New use case categories (e.g. in the enterprise domain) may require adaptation of existing AI solutions (for CSP deployments) or development of new AI solutions
- AI-related aspects need to be modelled as part of a generic, multi-vendor closed loop-based N&S automation framework



Standards needs

6.1 Provide flexible and extensible integration and operation capabilities to cope with requirements of new AI approaches

Note: as Inner AI is primarily focused on the algorithmic aspects, it is not in scope of standardization activities

Additional important considerations

Architecture

Case-tailored solutions have been successfully introduced but remain fragmented due to the lack of a well-defined architecture that unites them all together.
Aligning to common architectural principles can help to incorporate the diverse AI-driven functions, leverage the advances in the development and support AI-Ops.

Machine reasoning

Augment ML systems to become more adaptive, intuitive, and flexible to address the full scope of automation tasks, by integrating machine reasoning approaches based on symbolic representation of knowledge and general-purpose inference methods.
Machine reasoning introduces novel requirements for 1) semantic data and knowledge representation, 2) algorithms integration with N&S automation frameworks, and 3) interactions with other forms of AI.

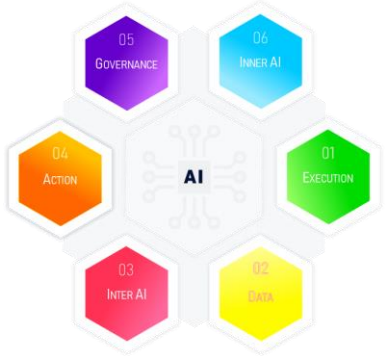
Security

AI security considers three main aspects: 1) protecting AI-empowered systems, 2) using AI for cyber-defense and 3) preparing for AI-empowered attacks.
As such, AI security in network and service management is a transversal consideration.

Ethics and regulation

Ethics and regulation refer to e.g. 1) privacy aspects related to the data handled by AI applications, 2) non-discriminatory and fair use of the AI-based decisions, 3) compliance with policies and legal frameworks, etc.

Research topics overview



AI Applications LCM

Robust, Explainable AI

Trustworthy AI, Human-AI interface

Intent-based Management

Security in/for AI

Network Abstraction

Distributed Training Management

Transfer Learning

AI Workflow

AI-adapted Interfaces

Multi-domain Data / Model Fusion

(Real-time) Data Distribution and Sharing

Cognitive Closed Loop Automation

New AI models

AI & Digital Twin

Inference Management

Self-Supervised AI

Enhanced Data Collection and Analytics

AI Platforms

AI Sandboxing

Model modularity, Domain Similarity

AI Output to Action Mapping

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Summary

1. Go Deep

Maximize automation by integrating the full range of AI capabilities

Research and specify key enabling, interoperable capabilities altogether at a level that allows composition and full lifecycle of AI-empowered N&S automation solutions

2. Go Wide

Support broadest application and deployment diversity across Telco + Verticals scenarios

Ensure portability and reusability in various environments thanks to modular, extensible, open, service-based and model-driven APIs

3. Go Safe

Foster wide adoption and sustainable use of AI technologies for N&S automation

Support transition of human role in control and supervision with means to interpret, evaluate and validate the behaviors of AI-based solutions

Develop governance and security frameworks to safeguard AI-driven operations and enable shift towards mission autonomy

Thank you !

Questions ?

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