Automation and AI/ML in fixed networks

White paper

NOKIA

Contents

The need for automation in fixed networks

Over recent decades, broadband access has grown dramatically in importance. It has become a human right[1] and started to change practically every aspect of our daily life. Broadband now provides the underlying infrastructure for our growing digital economy. The years of rapid growth in subscribers, data volumes and speeds are not expected to stop any time soon.

Broadband infrastructure currently finds itself in a disruptive and innovative time, where past paradigms no longer hold true. Communication services used to have a lifespan of 10+ years and their definition remained largely unchanged over that period. Now, cloud solutions, smart homes, machine-to-machine, 5G and Industry 4.0 are changing those metrics. These new services must support more symmetrical traffic, fluctuating demand, lower latency, always-on behavior, and respond to changes in seconds, rather than several minutes or hours.

With a continual increase in communication services and broadband innovations, the traditional skills needed to build and run a network no longer suffice. However, automation has come along at the right time to help operators simplify operations, reduce human error and boost productivity. Automation assists with the increased number of options, technologies, parameters and dimensions to optimize. As network elements get redefined through programmable software and cloud evolutions, new use cases drive the need for a more IT-like approach with better efficiency, agility and DevOps capabilities. Furthermore, the pressure on cost per Gigabit requires improvements in hardware performance, thus driving the invention of algorithms consuming less CPU power. These are areas where artificial intelligence (AI) and machine learning (ML) can complement, or even surpass, existing algorithmic power, and augment human capabilities in planning cycles, adapting to change and responding to threats.

Taking incremental steps in automation

The telecom industry has passed through a very long history of technology innovations and process improvements. As a result, communication networks were perfected and even lost their initial appearance when they became automated in the millionth repetition. It started in the early 20th century when automated telephone exchanges came into existence and a telephone operator no longer had to manually connect calls with cord pairs on switchboards. Since then, automation has never ceased, and the industry has changed dramatically.

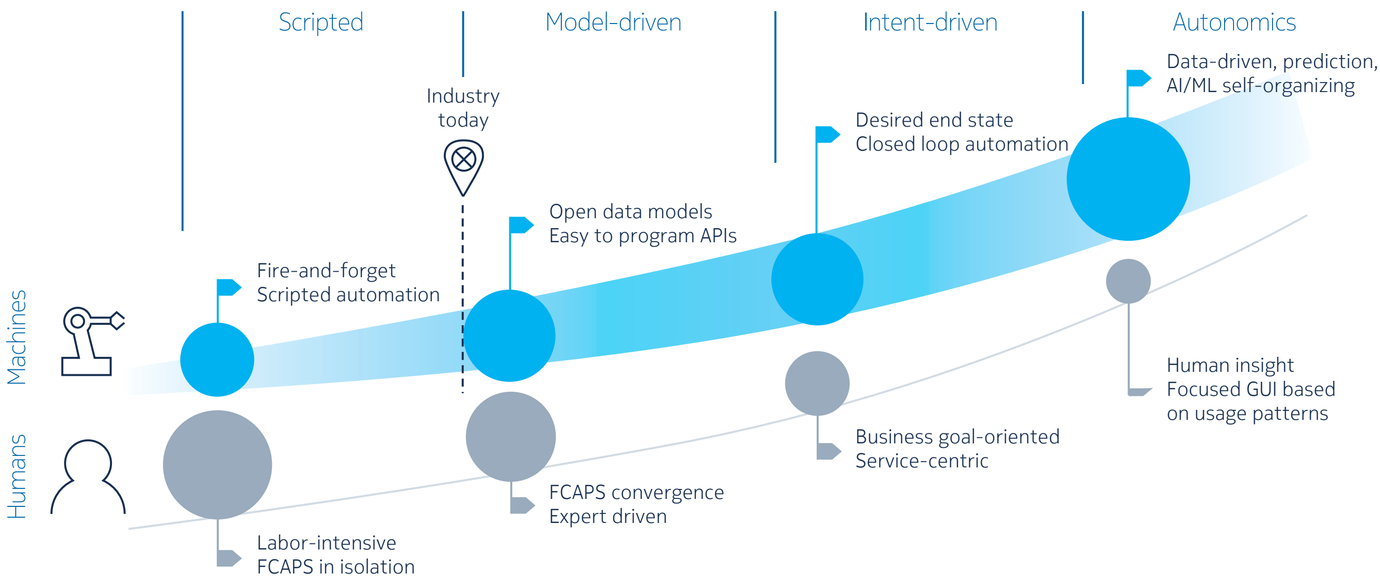
While the industry has become more effective than ever, the knowledge and skills of human experts in the exploitation of networks have never gone away. Humans take care of an overwhelming number of tasks to deliver the best possible broadband experience. The operational landscape is complex, laborious and demands fast reactions to keep everything running smoothly. As shown in Figure 1, we see the modern broadband industry as being less than halfway in a four-phase journey of applying more automated and intelligent control over the network, where transparency and openness becomes indispensable for successful network autonomics.

The first phase is characterized by scripted, proprietary, network-centric systems with point-and-click management systems, which are extremely inflexible and where every action needs endless human intervention for each technology/vendor stack. New features or services do not reach operators fast enough. To advance to the second phase, the industry has coalesced around the adoption of open APIs.

1 World Summit on the Information Society, December 2003

Nokia contributes widely to open initiatives and standardization bodies to create common data models for the industry to work with. Open APIs make networks easily extensible with different technologies and vendors. Standardization and interoperability are fundamental to save resources for both operators and vendors, as they are freed from endless integration and testing cycles and can focus instead on innovation and customer value.

Figure 1. Taking the next steps on the journey towards autonomic networks



At this model-driven stage, the programming is still imperative (if x, do y) and network centric. However, the industry is now heading into the third phase, where networks are operated in a more intuitive way. This will see us applying intent-based automation where the operator defines service-centric policies and the network will be able to self-adjust, automatically find misconfigurations, and fix them via audit facilities and coordinated control loops. This allows the automation of repetitive and dynamic processes that are a drain on a service provider's resources.

The final phase is a more self-aware, self-governing, data-driven network that applies AI/ML to automate operations, predict and prevent issues, and provide detailed analysis for anomaly detection, action recommendation and capacity planning. Operators get better insight into the customer experience, while the need for detailed inspection by human experts is reduced. Nokia sees machine learning as an incremental evolution of product and solution capabilities.

Automated networks: the final frontier

In this section we dive deeper into network automation and how Nokia can help assure a smooth network roll-out and sustainable network lifecycle. With increasing service level expectations and network complexity, network automation is a vital step in the digital transformation of an operator's business. To succeed, a multidisciplinary approach is required to rigorously evaluate and continuously improve how networks are built and run. Figure 2 shows an automation framework taxonomy that describes the end-to-end journey from conception to deployment. Each of the five categories holds unique opportunities and use cases for automation and optimization.

Innovate and develop

Automation in the R&D stages is part of Nokia's corporate culture. R&D optimization delivers quality and transparency for agile technology creation and improved product innovation. This brings direct benefits for operators as it leads to better products with fewer failures and faster time-to-market. It is important to have modern requirement-gathering and documentation, an intuitive software development environment and workflow automation from feature inception until feature delivery. A fast and reliable solution regression capability protects product quality as it can uncover issues early via robot test frameworks and daily build verification tests. DevOps capabilities stimulate continuous feedback and frequent commits via a state-of-the-art CI/CD pipeline, leveraging the flexibility of our SDAN-based product line and modular service-based architecture. Quality metrics such as code churn and code coverage are the basis for identifying the code that need to be auto-regressed and tested on a day-to-day basis.

Marketing and sales

In this category, one can distinguish two broad groups of tools. The first group is operationally focused. Marketing, sales and customer relationship management tools are used to quickly act with personalized communication and deal with order processing, nurturing leads, the sales funnel and consumer behavior. Operations can identify areas in the network having spare capacity and automatically notify marketing and sales teams who can plan campaigns to sell more services.

The second group of tools is strategically focused. This set of tools helps with modeling new customer services and identify the market opportunities for new technologies like 5G, fiber-to-the-home and software-defined networking. These tools combine technology, market and business model knowledge and help operators make strategic decisions with automated ROI and TCO models. Using Nokia Bell Labs patented algorithms, we can model accurately a tailored strategy for new service launches and broadband network evolutions.

Figure 2. Automation framework taxonomy

Innovate and develop
- Build, CI/CD pipeline
- Software development and code review
- Requirement management
- Fault management
- Quality prediction
- Test case production
- Test management

Marketing and sales
- Market readiness
- Strategy modeling
- Business case modeling
- Identify opportunities
- Subscriber lifecycle and consumer behavior
- Data monitization

Plan and verify
- Network and service design
- Network dimensioning and resource planning
- Capacity planning
- Policy and assurance metrics creation
- Digital software delivery
- Network optimization
- Unit testing
- System verification
- Solution validation

Activate and perform
- Installation and activation
- Pre-validation
- Config management
- Service provisioning
- Layer 1 & 2 algorithms
- Move-add-change
- Migration/upgrade
- Scale-in/out
- Service assurance

Maintain and support
- Health monitoring
- Anomaly detection, fault diagnosis, trouble ticket management
- Back-up and restore
- Disaster recovery
- Traffic prediction
- Predictive care
- Customer experience
- Network and security auditing

Plan and verify

Investment in the planning, design, integration and validation steps can avoid unnecessary risks, costs and delays in the rollout and operational phases. Network planning, dimensioning, assurance metrics, capacity management and resource planning use sophisticated design algorithms, often combined with intuitive, easy-to-use graphical user interfaces. For example, intelligent tools automate design of the physical fiber infrastructure. They optimize the physical fiber layout, considering homes passed and subscriber take rates, rights-of-way, digging options, material and labor costs. Another example is design tools to automate the selection of best migration path for PSTN migrations. Gathering data from voice switches into the migration design tools results in optimal sequencing for migrating PSTN switches.

This phase also marks the iterative integration and verification activities, confirming the network is performing and operation is sufficiently robust to commence deployment.

Activate and perform

Nokia is the innovation leader in making fixed services available to subscribers and has proven this for every established and emerging fixed access technology. We help carriers accelerate the time to market of broadband services with easy device turn-up, consistent configuration management and automated service provisioning.

An example is guiding the end user and field technician to install a wireless CPE in the best location at home. Once installed, other automatic processes guarantee the subscriber SLA is fulfilled based on dynamic cell assignment, coverage/capacity algorithms and post-installation diagnostics. Similarly, we have solutions to speed up and simplify the FTTH activation. Today's multi-step activation is transformed into an automated process where FTTH subscribers don't need to schedule an appointment or wait for on-site assistance from a technician.

In the home, Nokia WiFi Beacons, gateways and ONTs use smart automation and mesh technology to optimize the Wi-Fi network performance. Real-time algorithms for roaming, intelligent channel selection and network self-healing maximize the end-user experience locally. By using a cloud controller, operators can also optimize metrics across many premises (such as the transmission power) to achieve a higher average throughput for an entire area.

Nokia optimizes the network roll-out using proven end-to-end delivery automation and blue printed tasks and processes. The workflow automation tools enforce the process and drive efficient cooperation between the different stakeholders in the roll out process and provide close to real-time reporting. This results in reduced roll-out costs of up to 30% and reduction in roll-out errors by a factor of three.

At Nokia, we have a long history of broadband network transformations. Our migration factory approach automates and streamlines the migration process. This ensures high quality, fast execution and service continuity during the entire migration. Migration use cases vary from PSTN and ATM migrations to IP, GPON to XGS-PON migration, and the migration to SDN.

With Nokia Software-defined Access Networks, we introduce zero-touch operations, which brings the node ready-for-service without the installer needing to apply any configuration commands. This results in increased flexibility, fewer errors, and reduced labor costs. SDAN also introduces intent-based networking (IBN) which simplifies network integration and automation. With IBN, operators define the outcome they want to achieve in terms of a service definition, and the network will automatically self-configure to support it across any technology environment. It also makes networks more robust with self-adjusting capabilities that continuously monitor the state of the network against intents and execute changes as necessary across the network.

Maintain and support

Continuous network monitoring is essential in detecting and reporting failures as soon as possible. Unfortunately, manual investigation is impeded by the huge number of measurements that take place. Automation scales the operational activities and ensures that services offered over networks meet a pre-defined quality level.

Automation finds its way in event detection and incident resolution systems to make networks easier to maintain, to do advanced monitoring, health checks, network optimization and to deliver fast recovery after failures. Self-service portals, remote diagnostic tools, knowledge bases and semi-automated restoration workflows can help to correlate faults, do root cause analysis, recommend solutions and guide the repair process. This helps to proactively manage the network, predict problems before they become service effecting, reduce time-consuming on-site visits, and frees support teams from repetitive manual work. The result is a network delivering a consistent quality-of-service and high availability at reduced operational cost.

An example is the Nokia Home Analytics solution which detects home issues and monitors subscribers' experience using telemetry from TR-069 managed home devices. The solution provides interactive recommendations for problems that affect customer experience, either reactively (with the help desk) or proactively (with self-care or automatically triggered actions).

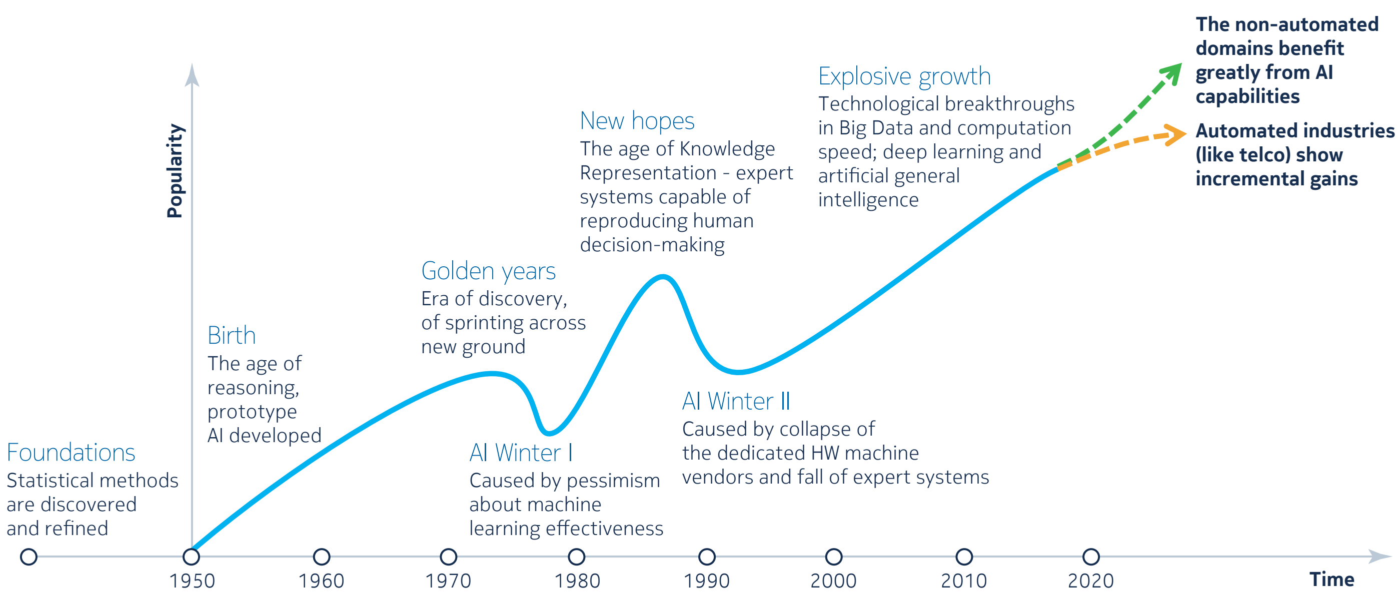
Another automation example is Nokia Predictive Care powered by Nokia's Analytics and Automation platform that combines big data collection and storage, intelligent analytics and automation. Nokia is revolutionizing the support model to move away from traditional reactive support to predict faults proactively in the network and then solve them as fast as possible.

Artificial Intelligence principles

The use of AI as the heart of the application reduces the need for man-made algorithms, since AI systems recognize patterns in data and gain knowledge from it without being explicitly programmed. For suitable use cases, AI can automatically create a model that identifies the best response to a wide variety of inputs, avoiding the need for writing traditional software.

How far this technology can take us remains to be seen (Figure 3). Augmentation of human intelligence with AI has the potential to help civilization flourish like never before and start the fourth industrial revolution. On the other hand, we might be in a hype bubble that may disappoint. A service provider's network is already very lean today, it has already gone through extended automation phases. While researchers are passing the trough of disillusionment[2], recent AI/ML developments in telecom show promising results. We expect this will lead to a productivity increase for more and more tasks, especially because AI relies on learning from data and, these days, there is more and more data available to train AI algorithms. The volume and sources of data have increased dramatically with the proliferation of the Internet, online cloud-based applications, and through the introduction of the Internet of Things (IoT).

Figure 3. Artificial Intelligence has finally reached its plateau of productivity. It has finally found practical applications that are relevant to the industry and is unlikely to fade away again[3].



2 From "The Hype Cycle" concept, source: https://en.wikipedia.org/wiki/Hype_cycle
3 "Machine Learning in Telecommunication Networks is Happening Now", A Nokia Book edited by Krzysztof Waściński, 2019

AI is an umbrella term for a branch of computer science technologies, and can be defined as:

> "Any human-made device or system that perceives its environment and makes decisions and/or takes actions that maximize its chance of success at some goal."

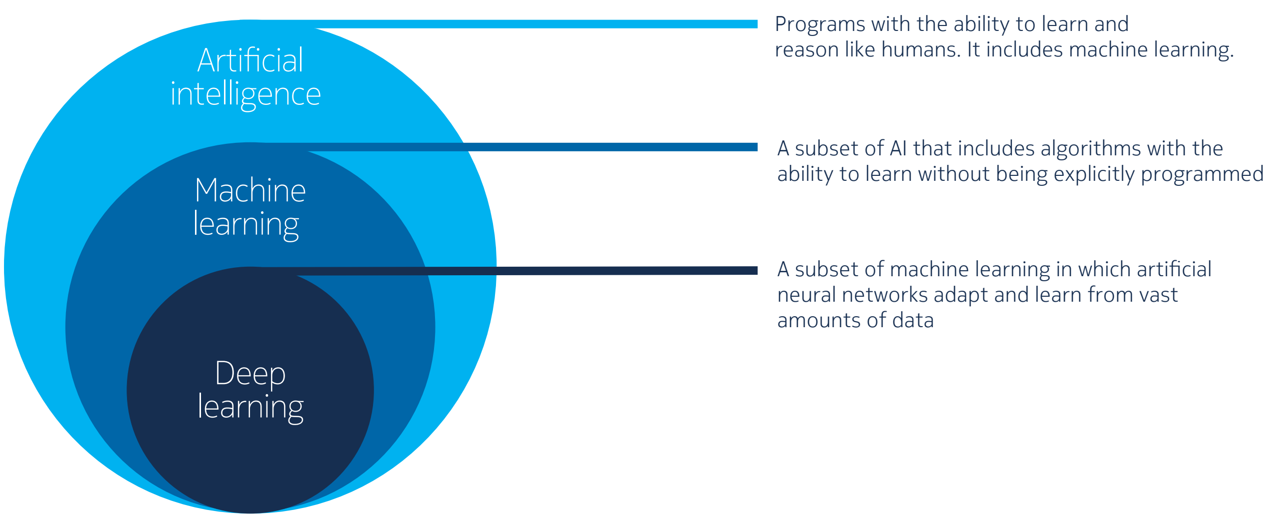
An AI system could in principle be completely constructed by programming clever rules. This was the mainstream trend some decades ago and sometimes referred to as "good old-fashioned AI". The main problem of this rule-based system is that each time there is a new problem, the programmer needs to rewrite the rules.

Machine learning forms a sub-category within artificial intelligence and gives computational systems the ability to learn how to perform a task without being explicitly programmed. ML can recognize patterns from the data and learn various useful features of the data. Much of the recent progress in artificial intelligence results from successful implementation of ML.

Deep learning is a special class of machine learning, based on deep neural networks, that can model complex relationships between input features and target outputs. The idea of convolutional neural networks was invented in the late 1980s by Yann LeCun at Bell Labs, which is now part of Nokia. Today, neural networks have become increasingly efficient and can solve tasks that were not possible before.

Researchers have now succeeded in teaching a humanoid robot to do human-like tasks, such as walking, running and even doing backflips. Although running ML-based techniques is more complex, with special requirements for support, data collection, computing power and management, this is balanced by the enhanced capabilities they offer. The use of AI/ML can make systems more intelligent and automated, enabling predictive and near-real-time actions.

Figure 4. Scientific classification of Artificial Intelligence and Machine Learning



AI is still a nascent area in telecommunications. Although many players have begun to experiment with AI, recent research[4] shows that nearly half of all service providers have not gone live with a single AI initiative, and those who have initiatives in place tend to be focused on using AI to improve existing business processes.

4 Nokia White Paper: What will it take to create an AI-driven telecoms industry?

A key use case for machine learning is the recognition of patterns, detection of irregularities and taking action to resolve the problem detected.

Anomaly detection

The basic concept of real-time anomaly detection is to compare live collected data with a reference, or expected range, that is known to correspond to a normal, healthy condition. The different levels of anomaly detection algorithm differ in the way the expected range is determined. In the simplest form, the expected range is simply manually defined by a person with the required domain expertise. Those KPI values are set once and are updated very unfrequently as it relies on manual operation.

To scale this method, it is possible to use automatic fingerprinting, to set the expected range automatically, for example, right after a new service has been deployed. This mechanism, although very robust and powerful, is limited by the "normal" variation of some KPIs. Typically, parameters that are influenced by temperature or network traffic will exhibit a daily cyclical or seasonal pattern, and complicate the detection of a real anomaly.

AI/ML is the perfect answer to this problem. By relying on well-known techniques such as rolling mean and standard deviation and auto-regressive (ARIMA) algorithms, it is possible to dissociate a seasonal repetitive pattern and a fundamental trend from the background noise, allowing a more accurate prediction of the expected range and making the anomaly detection faster and more accurate. Going even further, any deep learning technique that has proven to be efficient on time series prediction (all kinds of convolution or recurrent neural networks) can be used.

Typical use cases for real-time anomaly detection include degradation of optical signal power, peak in network traffic, abnormal/unfair user data consumption, board temperature, CPU and RAM usage.

Closed-loop Automation and AI/ML

Detecting anomalies is not enough. If anomalies result in a degradation of service, the root cause must be identified, and proper remedy action must be taken. In many cases, the root cause is directly derived from the type of issue detected, irrespective of the fault domain (physical layer outside plant, Ethernet layer, equipment hardware or software). Usually, when the root cause is identified, the remedy action can be directly determined and automatically applied.

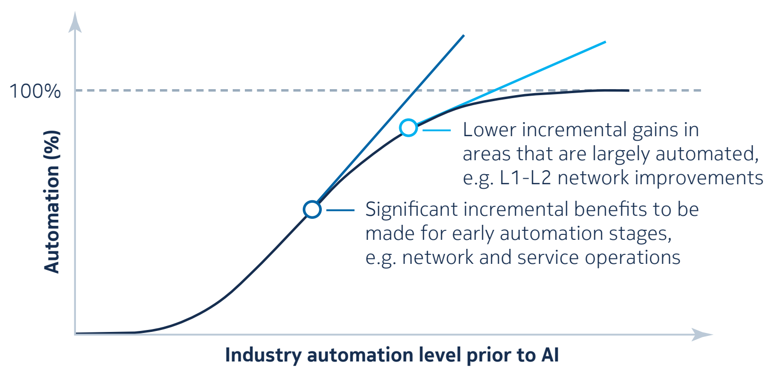
Here also, different levels of algorithmic complexity exist. In the simpler cases, when the repair action can be directly derived from the detected anomaly or root cause, simple rule engine can be used (a.k.a. "if-this-then-that" type of automation). Multiple rules can be combined to address slightly more complex problems, assuming the rules are "humanly manageable" as they must be manually configured and maintain by qualified people.

However, for complex problems, it is not always obvious to derive an optimal set of rules manually. Here again, AI/ML comes to the rescue. Reinforcement learning is typically a technique that can automatically identify the best configuration changes to apply to a system (to the network) in order to maximize a certain objective, such as network stability, performance and fair sharing.

AI/ML applications for fixed networks

Nokia expects ML to be used at all levels of the fixed network to make faster, better and more predictable decisions. Focused problem solving and a deep understanding of the domain are combined with modelling and simulations of the system behavior. We expect the benefits of AI/ML throughout Layer-1 and Layer-2 optimizations to be incremental rather than disruptive, due to the highly optimized nature of these layers. The optimization target is typically 10% to 20% in this field. For activities which involve human resources, like operations and development, we expect higher gains in the range of 30% to 40%. Areas where a lot of automation practices have already been implemented today receive less focus for AI/ML research as the learning technique may not outperform existing algorithms or would simply lead to minimal improvements.

Figure 5. The incremental benefits of AI/ML in the telecommunication industry



Nokia's end-to-end portfolio includes AI-as-a-service, platform components, hardware products, network management and dedicated software components with AI/ML capabilities. The following section describes examples where AI/ML can uncover valuable insights.

Innovate and develop

Software quality prediction

Quality control in software development is a challenge. Nokia uses data-driven engineering to identify defects and highlight code that requires attention. ML-based analytics can predict quality based on parameters from code lines, test lines, commit, review, story metrics, etc.

Software development

- One way to eliminate bugs or design defects is to use pair programming or code reviews, but they are dependent on developers analyzing the source code and providing suggestions. Using ML code can be screened, and reviews automated to spot the parts of code which need further human attention.
- Recommender systems provide developers with an automated smart search for not-yet-experienced code items that may be relevant to the user's current task. Code is then easily integrated, and this helps in making faster and better decisions.

Test suite automation

ML technology can automate the selection of regression test cases based on code changes and predict the potential solution for failed test cases. Upfront filtering, source code mapping and smart test case selection contribute to shortening the overall regression testing time.

Telemetry design for serviceability

One of the most critical aspects about measuring systems performance is the sampling resolution. Increasing the resolution of the data collection adds inherently overhead costs. It is key to ensure that data telemetry is designed appropriately to meet predictive care and closed-loop automation needs without impacting network element performance.

Automated log analysis

ML-based log analysis focuses on removing noisy data, clustering log events and detecting anomalies. There is no easy way to detect similar events in logging data. ML learns to automate the log parsing and analysis. It uses experience from captured events, recognized symptoms and classifiers learnt on lab testing to identify the most likely root cause, indicate the affected software modules and route the problem automatically to the proper team.

Marketing and sales

Consumer behavior prediction

Operators typically define multiple commercial offers linked to different target bitrates. It is difficult to predict customers' reaction to a change in pricing plan, introduction of a new offer or deprecation of an existing one. AI can help in segmenting the market, in customer churn prediction and in telling which new services to add to attract and retain new customers.

Personalized service recommendation

ML analytics allow marketers and sales teams to nurture leads and target clients with improved accuracy. Consumers might not be aware of the availability of higher service offerings or don't know what to expect. Using AI/ML, it is possible to identify upsell opportunities and recommend the most appropriate service for every individual based on their traffic pattern.

Plan and verify

Radio resource management

Radio resource management controls a lot of complex parameters such as transmit power, user allocation, data rates, modulation schemes, error coding, etc. The objective is to utilize the limited radio-frequency spectrum as efficiently as possible. ML techniques such as smart schedulers and interference coordination can be used to get the throughput higher and latency lower.

Optical channel equalization

The performance of fiber-optic communication systems is highly influenced by channel interference and dispersion, especially when running at Gigabit speeds. AI-based digital signal processing can be used to accelerate fiber channel equalization by preloading equalizer coefficients and increase receiver sensibility with AI-based channel inversion and non-linearity cancellation. This can reduce costs by supporting higher power classes with the same optics.

Capacity planning

Historical data alone does not help to reliably predict traffic congestion in advance. ML can improve the capacity planning by pro-actively monitoring the resource and network usage and issue a notification before running out of capacity or identify capacity issues during network planning. By relying on machine learning techniques, it is possible to learn from telemetry data the actual traffic patterns induced by subscriber behavior, and to predict the SLA conformance (for example in terms of speed test success probability).

NOKIA

Plug and Play node configuration

ML can learn configuration best-practices from existing deployments and propose the correct settings during an initial connection. Configuring a DSLAM or OLT requires expert engineering skills and uses pre-defined rules. This makes the installation difficult. Operators prefer that DSL or PON connections work out-of-the-box to accelerate the time-to-market of their services.

Activate and perform

Physical layer optimization

- Finding the ideal parameter configuration for digital beamforming in massive MIMO systems is not an obvious task. The configuration for each set-up depends on several factors such as the physical environment and distributions of users. In these scenarios, ML can improve user throughput significantly with reasonable implementation complexity.
- The fixed access PHY layer offers a lot flexibility in term of time slot (cDTA), spectrum and power allocation. The optimal configuration depends on the traffic volume and user pattern (HSI, video, home working). Tuning parameters manually requires in-depth expertise as the optimal settings can be different for every node.
- Indoor positioning using Wi-Fi sensing and neural networks can provide highly accurate information for position, presence, motion detection, device tracking, home security, building automation and health care systems.

Smart SLA management

ML can help verify whether services meet SLA and predict near-future capacity trends. Verifying SLA compliance (throughput, error rate, latency) is a must. Operators want to verify that SLAs are met and ensure future compliance as more users, services or virtual network operators become active on the same network. Operators typically rely on data capping techniques, but these do not ensure fair bandwidth sharing and optimal network utilization. Using AI/ML-driven closed-loop automation, it is possible to improve this control mechanism.

Maintain and support

Predictive care

AI/ML helps to proactively monitor network trends and identify problematic conditions. The real cause of problems is identified fast and with high accuracy. Outage duration can be reduced by 34% and issue resolution accelerated by 40%. By adding RPA (Robot Process Automation) and smart ticket analysis, the care process can automate operator tasks that are highly repetitive and use structured data. Digital assistants and NLP (Natural Language Processing) technologies are also being used on a large scale, for example, in conversational agents and chatbot-type services to find answers to problems.

Outside plant analysis

- Copper channel fault diagnosis determines where shorts and opens are occurring, detect bridged-taps or load coils, and identify disturbances in channel frequency response. When DSL service is interrupted, operators need to know where the fault is located (at the central office or customer premises) and the type of fault (bad contact, broken CPE, etc.). Deep learning improves the capabilities, accuracy and completeness of today’s line diagnostic tools such as Hlog and SELT.

- Uncontrolled crosstalk and noise disturbances can seriously impact vectoring performance and DSL stability. It is possible to detect known signatures as well as abnormal but unknown patterns. AI can be applied to correlate the error-behavior over the lines and exclude ill-behaving lines or notch bands to improve performance.
- Fiber bends and optical connector problems can give transmission errors which are difficult to isolate. Using OTDR and RSSI parameters, AI can identify and locate problems, making the repair process much faster and the field force more effective.

Predictive hardware maintenance

Applying ML on-line diagnostics, crosstalk, error and retransmission counters can detect ports that exhibit non-linear unstable behavior (e.g. caused by lightning). AI detects that a board is close to a reset by monitoring CPU/RAM usage and takes action to avoid service interruption. AI can also detect that optical transceiver performance (sensitivity, transmitted power) is slowly drifting due to ageing and recommend replacement before transmission errors arise.

Incident advisor systems

Traditional network operations use rule-based systems to identify and resolve problems. However, ML broadens the set of network behavior that can be captured and provides insights into correlation and causation without pre-written rules. Event noise reduction algorithms achieve efficient clustering to identify incidents and, with supervised classification, a knowledge base can be built for suggesting resolutions and vetted workflows.

Quality-of-Experience optimization

PHY-layer SLA are usually defined in terms of throughput, error rate and latency, but customers perceive the quality of service at the application layer, e.g. web responsiveness or video stream quality (pixelization, buffering problems). There is usually no trivial way to relate SLA at the PHY-layer to the perceived quality of service. AI can be used to predict application quality from PHY-layer parameters for an optimal subscriber experience.

AI cyber security

The growing volume and sophistication of cyber threats is overwhelming. AI has proven potential to improve threat detection and enable critical, time-saving automation in security operations. It can help security teams respond better to ambiguity, evolve to a probabilistic model of security operations and identify malware infections in the communication network.

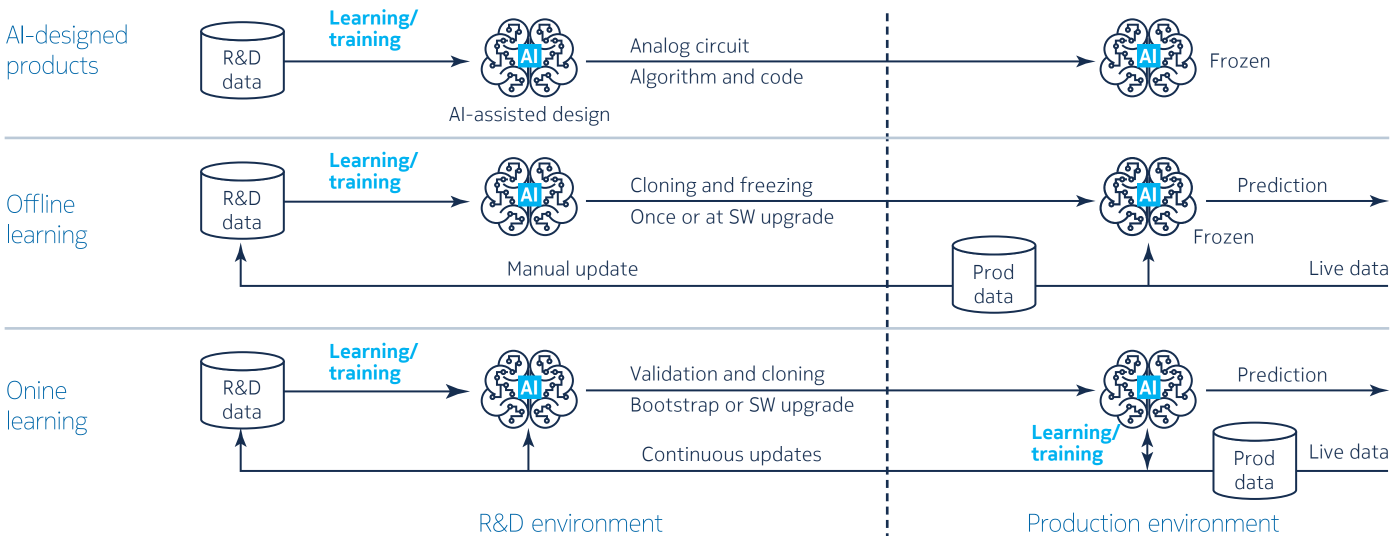
Data-centric AI strategies

As AI gets answers out of data, any application of AI can only be as good as the quality of the data collected. This means data becomes the most valuable component of the whole AI system. In response, Nokia Bell Labs has created a Future X network architecture with data collection in mind. The capture, transmission, storage and processing of massive data sets is embedded in hardware requirements and key algorithms of Nokia network solutions.

- **High-precision**. Complex data in the right format: config, logs, alarms, counters.
- **Centralized**. Avoid fragmented and incomplete view over inherently distributed data.
- **Consistency**. Fast telemetry for streaming and collecting real-time and historical data.
- **Standardized**. Non-proprietary data sets enable direct comparison for ML algorithms.
- **Future-proof**. High-quality data available in the cloud when you need it.
- **Security and privacy**: comply to Advanced Information Management (AIM) and General Data Protection Regulation (GDPR) needs
- **Platform openness**: operator can bring its own models/algorithms to process network data

It is good to realize how much data is commonly needed to implement an ML system. In many cases, we are talking about millions of data points. At this point, it is also good to note that there are numerous cases, in which massive data is not needed to ensure a sufficient service level, or the system can be continuously improved by collecting more data during service use.

Figure 6. AI designed products, offline learning and online learning



For fixed networks we see three levels of AI/ML applications.

AI-designed products/components

For decades, R&D engineers have relied on numerical simulators to design analogue circuits. These design tools optimize the circuit component, but as the number of components or parameters increases, finding the optimal value for every component is getting more complex. AI/ML techniques such as genetic algorithms or reinforcement learning can provide better results and can be used today to design better filters or antennas.

Similarly, the same concept can be applied to optimize the configuration parameters of algorithms embedded in network equipment software.

NOKIA

Offline learning

Offline learning algorithms are trained outside of the production environment. A first training phase is achieved during the development of the product using an initial data set. Later on, the performance can be improved by retraining the model with new batches of data. Offline learning is often easier to control as the output can be stepwise optimized. Typically, offline learning is used with supervised learning that relies on labeled data. However, accurately labeled data is not easy to come by: it requires manual work or data science experts to generate them, and models may need to be rebuilt to keep predictions accurate over time.

Example:

- Predictive maintenance algorithms that make predictions on failures in network equipment and/or passive elements (cables, connectors).

Online learning

Online learning is a common technique used in areas where it is impossible or undesirable to train over a single dataset. Online learning algorithms update their parameters sequentially when data becomes available, directly from the production environment. Online learning is used in situations where it is necessary to dynamically adapt to patterns in data that might change over time, or where training data might not be available all at once. However, testability and vulnerability to catastrophic deviation are a challenge, so monitoring and validation of the learning process is required to ensure predictions continue to be accurate.

Examples:

- Vocal assistant learning the voice characteristics of every individual user.
- Nodes learning the traffic habits of connected customers and improving its configuration.

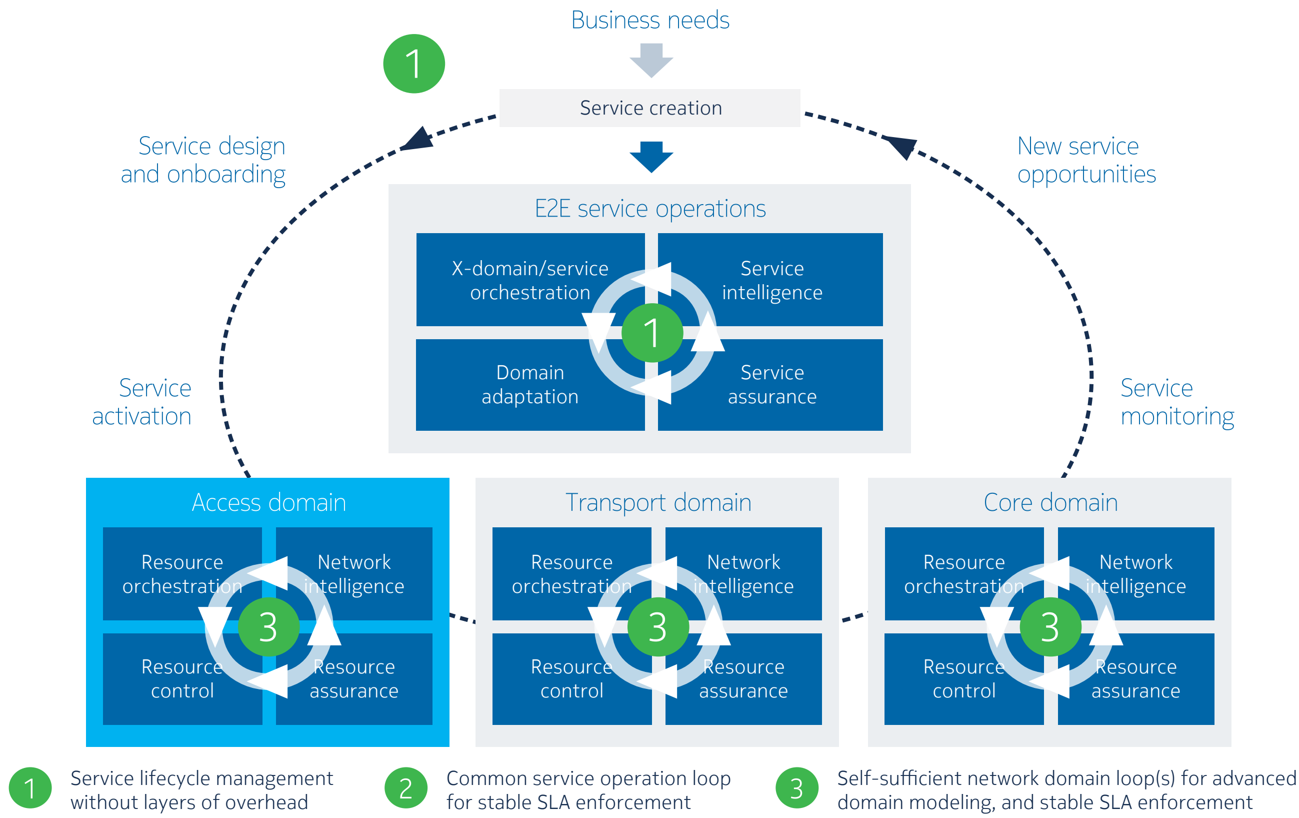
The role of humans and domain expertise

Artificial intelligence raises common concerns about displacing human workers. While it’s true that humans can’t compete with computers for some tasks, so far, automation hasn’t stopped job growth. That’s because automation can create jobs as well as destroy them. What usually happens with automation is that it complements working styles and humans get redirected to tasks that are more productive. In fact, early adopters of AI typically indicate having the challenge to reskill their workforce for augmented duties and in not having enough trained staff.

Future management and orchestration systems will use the strengths of both humans and computers. Automated solutions offer consistency and the ability to react quickly to problems. For example, it is imperative to deal with problems affecting network performance promptly. On the other hand, the continuous evaluation of telemetry information allows for more proactive management. Where network engineers are effectively assisted by AI-driven tools, it often leads to higher job satisfaction and upskill opportunities. The strengths of human users lie in their ability to take strategic decisions – even when it may not seem logical, for example, improving service quality in one area, and employing a more efficient energy saving approach in another.

NOKIA

Figure 7. Coordinated control loops for service lifecycle management span multiple levels



Nokia has the domain competence and data science experience to provide a unified AI approach. Nokia's end-to-end approach provides a set of centralized control loops. The approach can be summarized as one big decision system, which coordinates domain-specific optimization using interconnected control loops across service and network layers. In each loop, it is important that human operators have options to remain in control, and can decide to select, postpone, ignore or auto-execute the recommendations generated by data-driven analysis.

Conclusions

Without a doubt the field of advanced automation at the intersection of computer science, data science and domain knowledge will have a profound impact on communication networks now and in the future. While much progress has been made, AI is just beginning to come to the fore. We can expect AI to make important decisions for operators at an accelerating rate as science and technologies keep evolving. The line between automation and AI will continue to blur. By ethical and moral use of AI technology, Nokia has the ambition to become the leader in applying advanced automation to telecommunication solutions. We are uniquely positioned to pursue this goal, having access to massive amounts of network data and domain expertise with a fully integrated portfolio of products and services.

About Nokia

We create technology that helps the world act together.

As a trusted partner for critical networks, we are committed to innovation and technology leadership across mobile, fixed and cloud networks. We create value with intellectual property and long-term research, led by the award-winning Nokia Bell Labs.

Adhering to the highest standards of integrity and security, we help build the capabilities needed for a more productive, sustainable and inclusive world.

Nokia OYJ
Karakaari 7
02610 Espoo
Finland
Tel. +358 (0) 10 44 88 000

Document code: 1431652263982036858 (October) 207332