FUTURE NETWORK TRENDS

CREATING INTELLIGENT DIGITAL INFRASTRUCTURE

BY: ERIK EKUDDEN, CTO

All around the world, the unprecedented events of 2020 have brought into focus the critical role that digital infrastructure plays in the functioning of virtually every aspect of contemporary society. More than ever before, communication technologies are providing innovative solutions to help address social, environmental and economic challenges by enhancing efficiency and enabling both intensified network usage and more well-informed decisions.

One of the most important features of digital infrastructure is the ability to bridge distances and make it easier to efficiently meet societal needs in terms of resource utilization, collaboration, competence transfer, status verification, privacy protection, security and safety. The communications industry supports other industries by enabling them to deliver digital products and services such as health care, education, finance, commerce, governance and agriculture. It also plays a vital role in tackling climate change by helping other industries reduce emissions and improve efficiency.

In last year's trends article, I introduced the concept of the network platform and explained how it serves as a catalyst in the development of an open marketplace that is always available to any consumer of the digital infrastructure. The network platform forms the core of the digital infrastructure, with the ability to ensure long-term competitiveness for enterprises and meet the full range of societal needs as well. It is a trustworthy solution that guarantees resilience, privacy, reliability and safety for all types of organizations – public, private and everything in between. It also has the scale, cost performance and quality required to support future innovations. As a result of these characteristics, it is the most sustainable solution to address all future communication needs.

Future technologies will enable a fully digitalized, automated and programmable world of connected humans, machines, things and places. All experiences and sensations will be transparent across the boundaries of physical and virtual realities. Traffic in future networks will be generated not only by human communication but also by connected, intelligent machines and bots that are embedded with artificial intelligence (AI). As time goes on, the percentage of traffic generated by humans will drop as that of traffic generated by machines and computer vision systems – including autonomous vehicles, drones and surveillance systems – rises.

The machines and other 'things' that make up the Internet of Things (IoT) require even more sophisticated communication than humans do. For example, connected, intelligent machines must be able to interact dynamically with the network. Sensor data will be used to support the development of pervasive cyber-physical systems consisting of physical objects connected to collaborative digital twins. Future network capabilities will also include support for the transfer of sensing modalities such as sensations and smell.

The network platform acts as a seamless universal connectivity fabric characterized by its almost limitless scalability and affordability. It is capable of exposing capabilities beyond communication services, such as embedded compute and storage as well as a distributed intelligence that supports users with insights and reasoning.

In this article, I will explain the ongoing evolution of the network platform in terms of the key needs that are driving its evolution (trends 1-3) and the emerging capabilities that will meet both those and other needs (trends 4-7).

Trends 1-3: The key drivers of network platform evolution

The three key drivers that are most significant to the evolution of the network platform are all related to bridging the gap between physical reality and the digital realm. Most notably, this involves delivering sensory experiences over networks and utilizing digital representations to make the physical world fully programmable.

TREND #1: A COLLABORATIVE, AUTOMATED PHYSICAL WORLD

As physical and digital realities become increasingly interconnected, advanced cyber-physical systems have begun to emerge. These systems consist of humans, physical objects (machines and other things), processes, networking and computation, and the interactions between them all. Their primary purpose is to provide individuals, organizations and enterprises with full transparency to monitor and control assets and places, thereby generating massive benefits in terms of efficiency. One early example of this is the way that cyber-physical systems can help planners optimize energy and materials usage.

Soon, there will be hundreds of billions of connected physical objects with embedded sensing, actuation and computing capabilities, which continuously generate informative data. The sensor data generated by physical objects can be used to create their digital twins. Collaborative digital twins will have the ability to manage the interactions between the physical objects they represent.

Digitalizing the physical environment in which the physical objects interact requires sensor data fusion – that is, using data from multiple sources to create an accurate digital representation of the physical environment. One example of sensor data fusion is achieving high-precision positioning by combining network-based positioning data with information from other sensors such as cameras and inertial measurement units.

Ultimately, the joint communication and sensing in future systems will make it possible to leverage all the interconnected digital twins and digital representations of the environment to create a complete digital representation of everything.

TREND #2: CONNECTED, INTELLIGENT MACHINES

Machines will become increasingly intelligent and autonomous as their cognitive abilities continue to expand. Their understanding of the world around them will continue to grow in tandem with their ability to interact with other machines as part of a cognitive system of systems.

An intelligent machine uses sensors to monitor the environment and adjust its actions to accomplish specific tasks in the face of uncertainty and variability. These machines include three major subsystems: sensors, actuators and control. Examples of intelligent machines include industrial robots, speech recognition/voice synthesis and self-guided vehicles. The complexity of control and logic skills makes expert systems central in the realm of intelligent machines.

The network platform will provide an automated environment in which interconnected, intelligent machines can communicate, including support for AI-to-AI communication and autonomous systems such as communication among self-driving vehicles and intelligent machines in factories.

Intelligent machines have their own way of perceiving information (data), which is different from how humans perceive it. For example, communication among intelligent machines requires new types of video compression mechanisms, as today's video codecs are optimized for human perception.

Another aspect to consider is how intelligent machines will interact and communicate with each other. To improve the reliability and efficiency of machine-to-machine communication, machines will need to understand the meaning of the communication in terms of capabilities, intentions and needs. This will require semantics-driven communication.

Cognition is one of the most important capabilities of an intelligent machine. Cognitive machines are capable of self-learning from their interactions and experiences with their environment. They generate hypotheses and reasoned arguments, make recommendations and take actions. They can adapt and make sense of complexity and handle unpredictability. The future network will empower cognitive machines by providing them with new network features and services such as sensing, high-precision positioning and distributed computing capabilities.

TREND #3: THE INTERNET OF SENSES

The ability to deliver multisensory experiences over future networks will make it easier than ever before to transfer skills over the internet. It will ultimately lead to the emergence of the internet of senses, which combines visual, audio, haptic and other technologies to allow human beings to have remote sensory experiences.

The internet of senses will enable seamless interaction with remote things and machines, making it possible to fully realize use cases such as remote health checks, remote operation of machinery, holographic communication and virtual reality (VR) vacations. Among other benefits, the internet of senses is expected to have a significant impact in terms of sustainability, by dramatically reducing the need for travel.

In the years ahead, major leaps forward are expected in sensor and actuator technologies, such as the actuation of smell and high-quality touch sensation. During remote operations, the advances in haptic devices will allow virtual objects to be perceived just as the real objects themselves. Holographic communication will be possible without wearing extended reality glasses, due to 3D light field display technologies.

Body augmentation capabilities will enable humans to be smarter, stronger and more capable. Other examples are contact lenses that can display augmented reality (AR) content, universal translator earbuds that allow for language-independent communication and exoskeletons that increase physical strength. Eventually, brain- computer interfaces will enable communication at the speed of thought where, instead of speaking to machines, humans will merely think in order to direct them.

The network platform supports the internet of senses with novel network enablers such as distributed compute, high-precision positioning, integrated sensing and application programming interfaces. These are needed to support bandwidth and latency reservation, network latency reporting and network slice prioritization.

USE CASE

DIGITAL TWIN IN THE PORT OF LIVORNO

Ericsson has deployed a digital twin in the Italian port of Livorno (Leghorn). As a result, terminal port operations will increasingly become a mixture of physical machinery, robotics systems, automated vehicles, human-operated digital platforms and AI-based software systems. All those components, served by a 5G solution, transform the port environment into a 'playground' in which to experience the future of an automated physical world.

The port's digital twin makes use of a plethora of real-time data captured by connected objects at the physical port, including sensors, cameras and vehicles. An AI operation management system operates on the digital model to determine the sequence of logistics tasks and activities. Feedback from these processes provides live updates to the human supervisors using VR and to the docks/quay operators through AR.

Results indicate that there are about 60 direct and indirect benefits of the solution, including improved competitiveness, increased safety for personnel, sustainable growth of the port city, improved management of logistics and a positive environmental impact.

Trends 4-7: Critical enablers of the future network platform

The network platform is designed to deliver the kind of extreme performance required by application areas such as the internet of senses and communication among intelligent machines. It will also serve new types of devices with close-to-zero-cost and close-to-zero-energy implementations, which can be embedded into everything. Looking ahead, increasingly advanced technologies in four areas (trends 4-7) will expand the capabilities of the digital infrastructure through the network platform.

TREND #4: OMNIPRESENT AND NON-LIMITING CONNECTIVITY

The concept of ubiquitous radio access is evolving toward the vision of a future network that will deliver non-limiting performance to satisfy the needs of humans, things and machines by enhancing multidimensional coverage, stellar capacity and augmenting capabilities.

Access coverage everywhere

Further densification of networks is needed to provide high-speed coverage everywhere. Connected airborne devices, such as drones, require access on altitudes up to several kilometers, making it necessary to have a 3D point of view including the elevation aspect to provide coverage. There is also a need to ensure high-performing indoor connectivity by increasing the number of indoor small cells and fully integrating them.

Flexible network topologies and deployments

Network topologies and deployments will need to become increasingly flexible to provide coverage everywhere and deliver extreme performance. One possibility is a multi-hop-based radio network, where a multitude of nodes collaborate to forward a message to the receiver. This solution is particularly interesting for smaller cells of limited reach. Satellites, high-altitude platforms and airborne cells can be integrated into the network as a complement to extend coverage. Further components in a flexible topology can include connected device relay and the possibility for ad-hoc deployments of networks. Ultimately, distributed massive MIMO (multiple-input, multiple-output) solutions may lead to fully distributed connectivity, where many radio network nodes simultaneously serve a user, without fixed-cell borders.

Access for zero-energy devices

The rapidly growing demand for vast numbers of connected sensors and actuators has made it necessary to invent zero-energy devices. These will be deployed once and will continuously report and act without the need for maintenance or external charging. The stepping stones along the way include narrowband IoT enhancements and massive machine type communication for 5G New Radio for local area networks (LANs) as well as for wide-area usage.

Extreme radio performance

The network will utilize higher frequency bands to deliver extreme performance. For example, communications over the terahertz frequency band (above 100GHz) have some attractive properties, including terabit-per-second link capacities and miniature transceivers.

The design of terahertz electronics includes very small antenna and radio frequency (RF) elements as well as high-performance oscillators.

Full duplex is another component that can, in some specific scenarios, substantially increase the link capacity compared with half duplex. Full duplex is made possible by self-interference suppression circuits.

Visible light wireless communication, piggybacking on the wide adoption of LED (light-emitting diode) lighting, is another potential step in the frequency domain to complement RF communications.

Network as a sensor

Higher frequencies will further enhance the spatial and temporal resolution of the radio signal. Reflections of such radio signals can be used to sense the surroundings. Furthermore, high frequencies have distinct atmospheric and material interactions, where different frequencies are more or less susceptible to things like absorption in water, for example. This has been shown to be sufficient to forecast weather and air quality.

Distance information to reflecting surfaces can be identified by integrating positioning and sensing capabilities. Such information can be used to detect obstacles and speed as well as to generate real-time local maps.

TREND #5: PERVASIVE NETWORK COMPUTE FABRIC

As distributed compute and storage continues to evolve, the lines between the device, the edge of the network and the cloud will become increasingly blurred. Everything can be viewed as a single, unified, integrated execution environment for distributed applications, including both network functions and third-party applications. In the network compute fabric, connectivity, compute and storage will be integrated, interacting to provide maximum performance, reliability, low jitter and millisecond latencies for the applications they serve.

Rather than processing data centrally, in many cases it is more efficient in terms of bandwidth and/or latency constraints to bring the processing closer to where the data is produced, insights are consumed and actions are taken. In some cases, local operation may be required by regulations or preferred for privacy, security or resilience reasons.

Aside from the applications, the network also provides a continuous execution environment for access and core functions. It runs on a distributed cloud infrastructure with integrated acceleration for data-intensive virtual network functions and applications.

The future network platform goes beyond the use of microservices to implement network functions as serverless architectures. The server management and capacity planning decisions are fully autonomous from the developer and the network operator. The network takes care

of the deployment, scaling and all resources required to ensure that the function deployed is always available at any scale.

Upcoming novel computing architectures include memory-centric computing, optical computing, nanocomputing, neuromorphic computing and even quantum computing. In the future, these architectures will enable continued exponential growth in compute capacity for most applications running on the network compute fabric – an important development as the end of Moore's law approaches.

TREND #6: TRUSTWORTHY INFRASTRUCTURE

Governments and enterprises are adopting advanced technologies for secure assurance of mission- and business-critical processes such as factory automation, remote control of assets and more. The highly trustworthy network platform fulfills the requirements of even the most mission- and business-critical use cases. It offers a fusion of connectivity and compute characterized by different dimensions of resilience, privacy, security, reliability and safety. It will also provide adaptable and verifiable dimensions of trustworthiness in a scalable and cost-efficient manner.

Rather than being designed per node or for a particular part of the network, the always-on characteristics of the network platform such as reliability, availability and resilience rise up to cover the complete network. Always-on mechanisms are built into user plane, control plane and device mobility solutions. All parts of the network will be addressed including transport nodes and transport networks, network infrastructure and site solutions.

To protect communication and data, secure identities are utilized at every layer between humans, devices and applications in different industry segments. These identities are securely anchored to devices and network nodes by root-of-trust mechanisms.

Network platform solutions utilize confidential computing to protect identities and their data and establish trust among network customers and their assets, thereby also offering assurance to users and regulators. This requires automated trust assessment of all network elements, things, machines and applications, as well as compute and storage resources by using remote attestation and AI.

Responsible AI will bring trustworthy automated protection and risk management. AI-based automation provides the ability to act on a high number of events affecting the network infrastructure or the network usage.

TREND #7: COGNITIVE NETWORK

In the vision of zero-touch network management and operations, networks are deployed and operated with minimum human intervention, using trustworthy AI technologies. All operational processes and tasks, including, for example, delivery, deployment, configuration, assurance and optimization, will be executed with 100 percent automation.

The network itself will continuously learn from its environment observations, interactions with humans and previous experiences. The cognitive processes understand the current network situation, plan for wanted outcome, decide on what to do and act accordingly. The outcome serves as an input to learn from its actions. The cognitive network will be able to optimize its existing knowledge, build on experience and reason in order to solve new problems.

The network will utilize intent-based and distributed intelligence for multiple functions, including optimization of the radio interface, automation of network management and orchestration such as the optimization of parameters, handling of alarms and self-healing. AI algorithms will be deployed and trained at different network domains, for example, in management, the core network and the radio network. Physical layer algorithms, such as link adaptation, handover, power control and dynamic scheduling of resources can be optimized with AI agents.

Network management will become less complex through intelligent closed-loop automation with support for humans to interact with the network and monitor its behaviors. The network operator expresses the intent of a desired network state or goal, and the network internally resolves the detailed steps necessary to achieve that intent. Network knowledge, data and actions are shaped in such a way that the operator interacting with the network can understand them.

The cognitive network will be based on control design, using both machine reasoning and machine learning techniques that are distributed and capable of acting in real time. The network is a highly distributed system where multiple AI agents, present across the network, need to interwork to optimize overall network performance. Local decisions need to be coordinated with more central intent-based decisions. The central AI agent needs to make decisions in real time based on both local and global information. Multiple distributed AI agents share distributed insights throughout the network through federated learning.

Cognitive networks will be inherently trustworthy – that is, reliable, safe, secure, fair, transparent, sustainable and resilient – by design.

CONCLUSION

The network platform is the spinal cord of intelligent digital infrastructure

The digital infrastructure offers endless possibilities to individuals, enterprises and governments across the globe, with its unique ability to bridge vast distances and enable powerful new solutions to a wide range of social, environmental and economic challenges. Health care, education, finance, commerce, governance and agriculture are just a few of the sectors that stand to benefit from the massive efficiency gains that digital infrastructure can provide.

Designed to carry vital messages, commands, reasoning, insights, intelligence and all the sensory information needed to support the continuous evolution of industry and society, the network platform is designed to be the spinal cord of digital infrastructure. It is also the ideal platform for all types of innovation, with the ability to support interactions that empower an intelligent, sustainable and connected world.

The major advantage of the network platform is that it will be accessible anywhere, always-on and with guaranteed performance. Nomadic distributed processing and storage will be embedded into it to support advanced applications. It will be inherently reliable and resilient, fulfilling all the requirements for secure communication. Cognitive operations and maintenance of the network and its services will deliver the most cost-efficient and sustainable solution to meet any and all communication needs.

With this in mind, it is clear that the most important future network trends to watch in 2020 are those that relate most closely to the growth and expansion of intelligent digital infrastructure on the network platform. The first three of the seven trends this year are the key drivers of network platform evolution – the creation of a collaborative automated physical world, connected, intelligent machines and the internet of senses. All three highlight the growing need to bridge the gap between physical and digital realities. Trends 4-7 are increasingly advanced technologies in four areas – non-limiting connectivity, pervasive network compute fabric, trustworthy infrastructure and cognitive networks. Breakthroughs in these four areas will be essential to fully enable trends 1-3 and continuously expand the capabilities of the digital infrastructure through the network platform in the years and decades ahead.

◆ As Group CTO, Erik Ekudden is responsible for setting the direction of technology leadership for the Ericsson Group. His experience of working with technology leadership globally influences the strategic decisions and investments in, for example, mobility, distributed cloud, artificial intelligence and the Internet of Things. This builds on his decades-long career in technology strategies and industry activities. Ekudden joined Ericsson in 1993 and has held various management positions in the company, including Head of Technology Strategy, Chief Technology Officer Americas in Santa Clara (USA), and Head of Standardization and Industry. He is also a member of the Royal Swedish Academy of Engineering Sciences and the publisher of Ericsson Technology Review.

ERIK EKUDDEN
SENIOR VICE PRESIDENT, CHIEF TECHNOLOGY OFFICER
AND HEAD OF GROUP FUNCTION TECHNOLOGY

Further reading

- **Ericsson blog, What do cyber-physical systems have in store for us?, available at:** *https://www.ericsson.com/en/blog/2019/12/cyber-physical-systems-technology-trend*
- **Ericsson report, 10 Hot Consumer Trends 2030, available at:** *https://www.ericsson.com/en/reports-and-papers/consumerlab/reports/10-hot-consumer-trends-2030*
- **Ericsson blog, Driving business value in an open world, available at:** *https://www.ericsson.com/en/blog/2020/7/cto-driving-business-value-in-an-open-world*
- **Ericsson Technology Review, CTO Technology Trends 2019, available at:** *https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/technology-trends-2019*