Nerve – Edge Intelligence for Industrial Automation

Today, the industrial automation market faces the challenge of an inflexible infrastructure that is not prepared for the rapidly changing demands of business. The Nerve platform from TTTech, including software infrastructure from Nebbiolo, addresses this issue by acting as the missing link between your business and your machines.

Introduction

Businesses are well accustomed to highly flexible enterprise IT systems that enable efficient and innovative modes of working. Now, attentions have turned to industrial automation systems, where businesses are demanding an operations infrastructure that delivers comparable levels of service to enterprise IT. This however, requires improvements in interoperability, information transparency and connectivity that pose huge challenges for operations technology. The solution must fully address and mitigate all of the potential risks to the highly secure and safety-critical production environments that exist in factories and power plants.

Industrial automation has typically operated in silos, with systems that are separated from one another both physically and logically. Convergence of these systems can significantly improve operational efficiencies, but that presupposes a level of interoperability between vendors and solutions which doesn't currently exist in industrial automation. A truly open platform is required, one that can host solutions from any vendor and provide an interface to multiple systems.
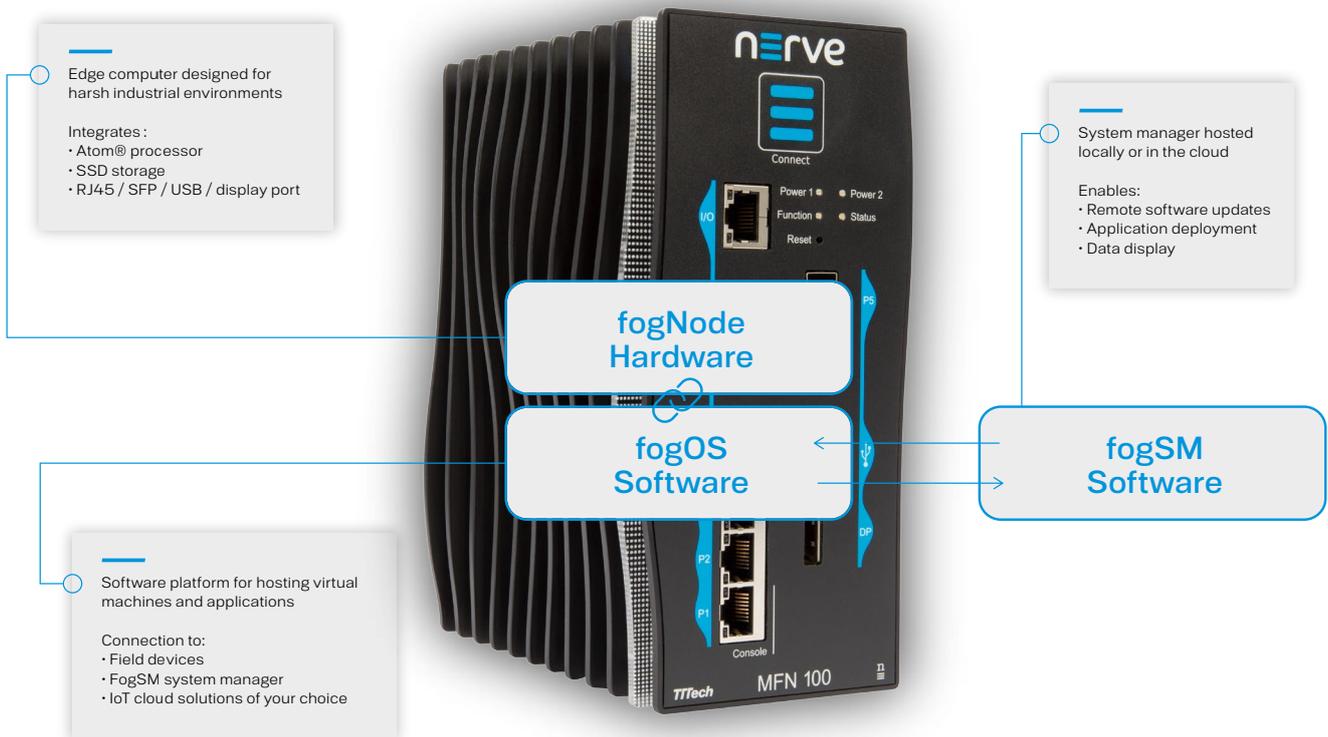
Closer integration of systems and remote access to information has clear implications for data security. Access to different sets of data has to be facilitated and managed so that proprietary production information does not fall into the wrong hands. Connections in and out of plants must also be secure in order to protect against hackers or malicious attackers. In some cases, provisions must be made for information to remain within the plant for exclusively local visualization and analysis of data.

Reliability is another crucial factor to be considered as systems become interconnected and converged. Downtime can be dramatically reduced by making use of shared resources, but care should be taken that systems do not adversely affect one another. Platforms need to be able to provide all of the benefits of converged functionality whilst also protecting the real-time and safety integrity of critical applications.

Above all, industrial automation demands that decisions are made in real-time. An enterprise IT system or cloud is not designed to handle this type of high-speed processing, so decentralized (and potentially autonomous) analytics and decision making at the edge are required. Such an infrastructure can then provide a subset of data to the cloud for less latency critical analytics and decision making. Bridging the continuum between edge and cloud is key to the fog computing architecture implemented by TTTech's Nerve platform.

3 elements of the Nerve platform

The Nerve platform comprises three tightly integrated elements that build on solutions developed by TTTech alongside key technology partner and fog computing pioneer Nebbiolo Technologies. The three elements are fogNode™ edge computing devices, fogOS™ real-time operating system and middleware orchestration, and fogSM™ centralized system management software.

Edge computer designed for harsh industrial environments

Integrates :
· Atom® processor
· SSD storage
· RJ45 / SFP / USB / display port

System manager hosted locally or in the cloud

Enables:
· Remote software updates
· Application deployment
· Data display

fogNode Hardware

fogOS Software

fogSM Software

Software platform for hosting virtual machines and applications

Connection to:
· Field devices
· FogSM system manager
· IoT cloud solutions of your choice

fogNode hardware

TTTech offers Machine fogNode (MFNTM) devices in its Nerve platform. The MFN 100 is an edge computer, designed for harsh industrial environments (-40 °C to +70 °C). The device is based on an Intel Atom x5-E3940/50 CPU and offers 4GB/8GB RAM and up to 512GB SSD storage. MFN 100 supports fieldbus connectivity and also integrates a Time Sensitive Networking (TSN) switch for open, standard deterministic Ethernet communication. fogNodes are shipped with integrated fogOS and fogSM software from Nebbiolo Technologies.

fogOS software

fogOS is a software stack that provides a secure virtualized platform for virtual machines, containers and application hosting. It also offers open interfaces for communicating with field devices, the fogSM system manager and IoT cloud solutions of your choice. fog OS enables local functionality such as storage, visualization and data processing via a pre-installed time-series database and Grafana plug-in. A real-time hypervisor ensures that applications and operating systems running as virtual machines are isolated and secure. Applications can also be run as lightweight containers in Linux-based dockers.

fogSM software

fogSM is a centralized management system for updating device software and deploying applications to fogNodes. It can be hosted remotely in the cloud or locally on a server or fogNode. fogSM is intended to be used for a multitude of management tasks. Data from thousands of fogNodes worldwide can be visualized in Grafana, and there is a time-series database for aggregated stream and batch analytics. Access rights are defined and managed via a secure RBAC model making sure that data is only available to those who are authorized to use it. The application store and configuration store in fogSM can be used to upload and deploy new applications or configurations to multiple fogNodes simultaneously.

Nerve and the automation pyramid

The Nerve platform operates across multiple layers of the classical automation pyramid and is capable of converging functions to the extent that old boundaries are merged or no longer apply. fogOS running on an MFN can operate across both the control level and the supervisory level. fogOS can be used as gateway that interfaces with existing Programmable Logic Control (PLC) devices and accesses data via OPC UA, or it can act as the PLC by hosting control applications and interfacing directly with field level devices (IOs). fogOS also provides localized supervisory functions such as storage, analytics and visualization. HMI software can also run on fogOS with monitors connecting to the MFN via display port.
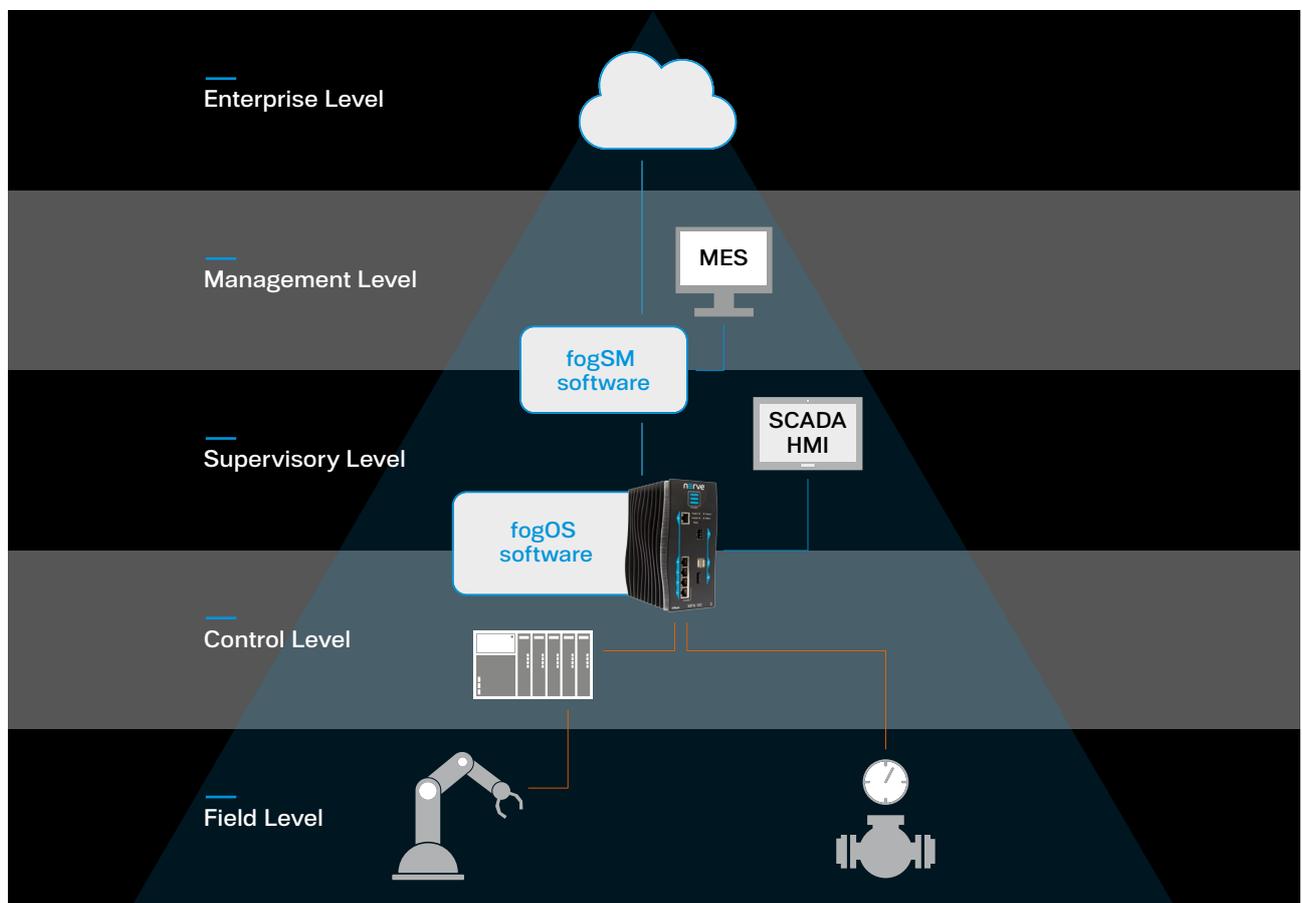

fogSM straddles the supervisory level and the management level in the classical automation pyramid. Hosted locally or in a cloud, fogSM can provide wider supervisory functions such as storage, analytics and visualization. It can also interface with existing Manufacturing Execution Systems (MES) as well as offering management functions for device software configuration, updates and application deployment.

What makes Nerve special – differentiation and advantages

Nerve offers key features that address the challenges that the industrial automation market is facing today. Nerve drives value for customers in the areas of resource virtualization, data connectivity, open interoperability and centralized management.

Resource virtualization
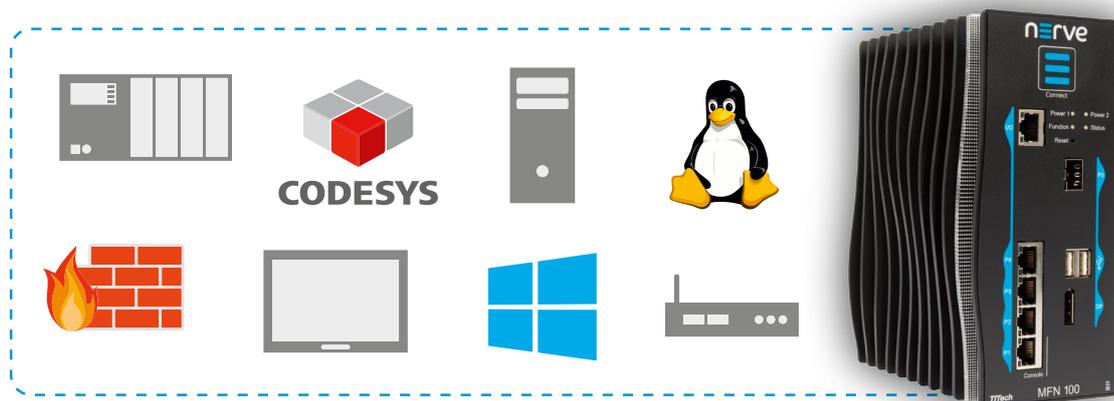
Nerve optimizes virtualization technology for the industrial world. Sharing computation resources between different operating systems and applications enables you to converge various functionality (e.g. industrial PC, gateway, PLC and firewall) in one device. By enabling resources to be virtualized, Nerve makes hardware work harder for you.

fogOS operates with a KVM real-time hypervisor which can securely run multiple virtual machines on the same device. In the MFN 100 this is backed up by an Intel Atom supporting VT-d (PCIe passthrough). This allows virtual machines to have direct access to network interfaces, and to run applications with practically the same performance as in non-virtualized environments.

Reduce hardware spending by 50% or more

Virtual machines can be used for entire operating systems such as Windows and Linux, or for applications such as a firewall, or HMI and PLC software. With Nerve, users can migrate their legacy software environment as a virtual machine, making it easy to support existing applications whilst also enabling new software to be developed. Isolating individual applications in virtual machines can improve stability, security and scalability of software by protecting applications from potential malfunctions or hackers affecting other applications. Decoupling software functionality from hardware in this way dramatically reduces the risk of hardware obsolescence and the risks of being locked-in to one hardware platform.

Nerve also offers the option to run Linux applications in lightweight Docker containers. Dockers can further help to reduce CPU and memory resource demands, and they deliver faster and easier application updates compared to virtual machines.

Data connectivity
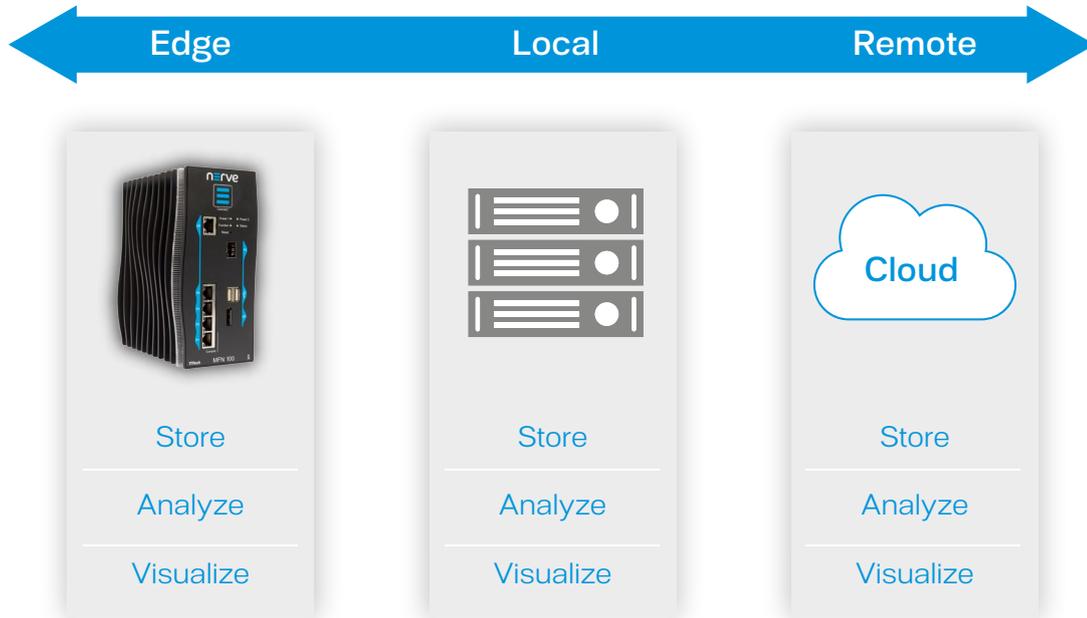
Nerve enables data to be used in three ways: at the edge, on your local server or remotely in a cloud. This gives machine builders and plant operators the flexibility to choose where and when data is stored, visualized and processed. Nerve provides the information you need, wherever it's needed.

Data storage is handled by a time-series database hosted on fogOS at the device level, or on fogSM hosted locally on a server or remotely in a cloud. Data transport between device and system manager is configurable, providing an easy to use, consistent view of data locally and centrally. fogOS supports multiple standard interfaces (AMQP, MQTT, REST/JSON, OPC UA), meaning that you can also connect Nerve to the IoT cloud solution of your choice. Data can be integrated quickly and easily into existing IoT cloud solutions such as Microsoft Azure, SAP, IBM Cloud, AWS and more.

Securely access data where you need it most

Visualization of data is also offered within the Nerve platform. Grafana is integrated in both the local UI and the system manager for querying, visualizing and understanding data from individual devices or aggregated from devices globally. Local visualization reduces the processing load in the system manager or IoT cloud solution and ensures that staff on site are seeing the same easy-to-interpret graphical representation of data as those working remotely.

Processing of data can also be executed locally in order to reduce the volume of data being sent to the cloud. Basic and advanced analytics functions are built in to the Nerve platform - delivering benefits both in terms of improving data security and in reducing bandwidth load and associated costs. Nerve provides a high degree of control over data processing, with a graphical editor that enables you to manipulate data without any need for coding.

Open interoperability
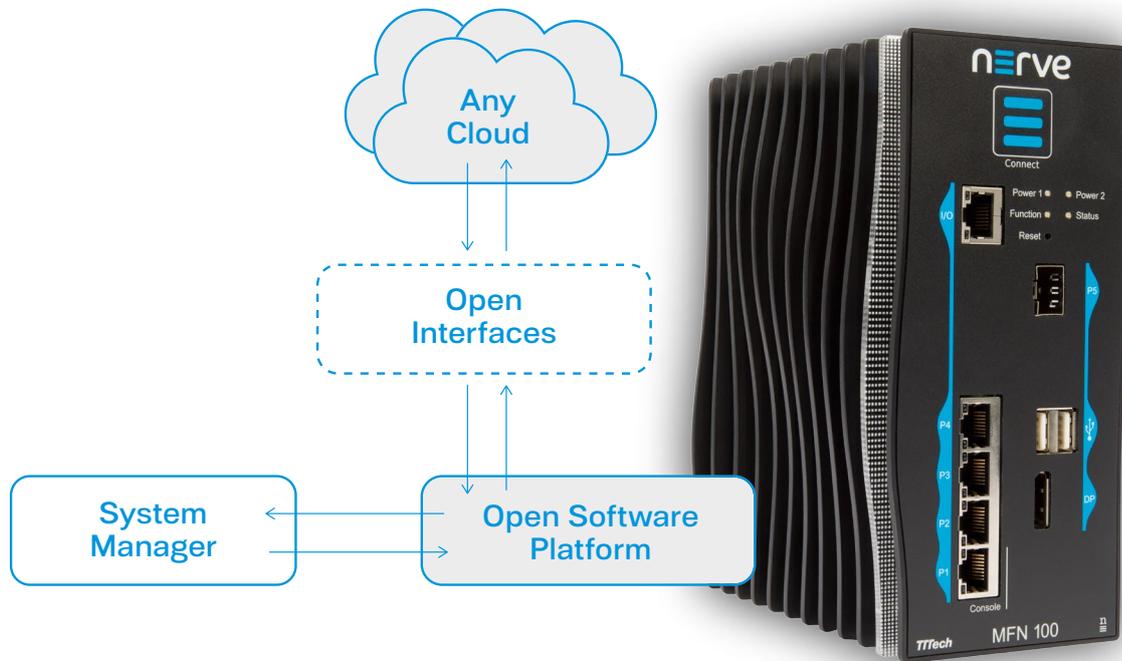
Nerve is designed with openness, interoperability and flexibility in mind. The platform helps you become vendor independent, giving you the freedom to choose the solutions, from any provider, which best suit your business needs.

Nerve enables you to create, deploy and run your own applications. There is absolutely no lock-in to any single application source or vendor. Linux-based fogOS provides a standard application environment, meaning that there is no need for developers to work on the software infrastructure around apps. Python SDKs with REST APIs are available to aid integration, letting you focus resources on the key competences that really drive value. Standard Docker applications can also be easily sourced and deployed via the application store in fogSM.

Avoid being locked-in to a single solution or vendor

Open interfaces are also offered for IoT cloud solutions. fogOS can support connectors to multiple clouds simultaneously, via a multitude of protocols (AMQP, MQTT, REST/JSON, OPC UA). This offers the flexibility to choose an IoT cloud solution from any provider and to quickly and securely integrate machine data into that system. Connection to a cloud-based fogSM is pre-configured in Nerve, however it can also be run on-premises as a virtual machine in cases where it is not possible to connect to a cloud due to reasons of data security or internet connectivity.

Nerve supports a range of options for connectivity at the field level and the control level. A built in TSN switch makes it possible to exchange data deterministically between devices from different vendors. OPC UA enables the open exchange of data between devices and up to the cloud. PROFINET slave support enables the connection of field devices via legacy Ethernet based protocols (other protocols can be implemented on request) making integration possible in brown field use-cases.

Centralized management
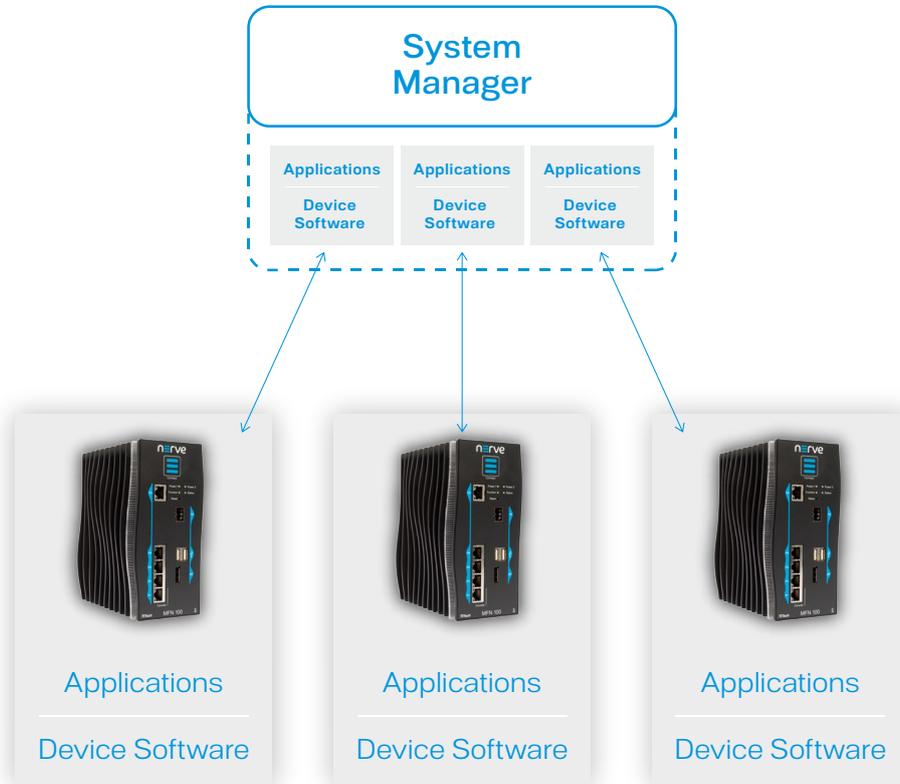
Through the fogSM system manager, Nerve puts installed devices at your fingertips, enabling you to apply software updates to machines without needing to be on site. Central management of device software and applications delivers new operational flexibility and reduces support and maintenance efforts.

fogSM provides a secure deployment mechanism with signed software verification at the device and transfer over encrypted TLS (SSL) connections. Updating software from fogSM significantly reduces maintenance time and effort and helps to ensure consistency of software in devices. This can be used to respond to security threats or critical bugs, where patches can be applied quickly and accurately. The fogSM application store can also be used for deploying new applications to add functionality to multiple devices simultaneously or to selected fogNodes only.

Provide flexible support and cut maintenance costs

The system manager provides an overview of all connected devices. The status of device software can be tracked centrally and be shown in a hierarchical view or by geolocation. VNC and RDP support also make it possible to securely view screens of virtual machines, giving an enhanced ability to asses and resolve software failures remotely.

User access rights can be defined and managed via fogSM. Role-based access has clear data benefits and can also increase productivity for users by only showing relevant information to them. Access control protects against accidental or intentional disruption of systems by unauthorized users. With multi-tenancy support, one system manager can be used to serve multiple customers, enabling even more cost-effective use of fogSM.

TTTech and Nebbiolo – a groundbreaking partnership

TTTech and Nebbiolo Technologies are working together to achieve real-time capable, scalable and secure fog computing solutions. TTTech (along with robotics giant KUKA) invested in Nebbiolo in 2015 after seeing the value that the Silicon Valley startup could bring to the world of industrial automation. Nebbiolo is pioneering fog computing technology with its real-time capable architecture and flexible software infrastructure. Nerve takes advantage of Nebbiolo's centralized management platform that offers customers new levels of access to installed devices and the ability to update software and deploy applications remotely.

Nebbiolo Technologies also recognized the value and expertise that TTTech brings to the partnership. TTTech has a wealth of experience in real-time & safe control technology, which is being integrated into the Nerve platform. Deterministic communication is also a key factor in distributed fog computing architectures. TTTech is leading the way in the integration of two technologies - OPC UA and TSN (Time Sensitive Networking) – that provide all of the open, standard building blocks required to unify communication for industrial automation and enable the broad convergence of information technology (IT) and operations technology (OT).

Concepts of fog computing in industrial automation

Fog computing is at the heart of the Nerve platform, enabling a highly virtualized architecture that provides compute, storage and networking between devices at the edge and traditional cloud computing in data centers. Fog computing is not intended as a replacement for cloud computing or edge computing, rather it is an extension of functionalities that can lie anywhere along the spectrum between cloud and edge.

In industrial automation, fog computing is enabling intelligence to be distributed and pushed out to machines. This can manifest itself as edge analytics and machine learning, or in control functions that are shared between a federation of machines. To this end, fog computing provides an infrastructure similar to that found in mobile phones today. Core software can be centrally hosted in the cloud and deployed as lightweight applications whenever and wherever they are required. This increases flexibility on the factory floor and shifts value towards specialist application software rather than homogenous industrial systems from single vendors.

Fog computing architectures have some inherent characteristics that set them apart from traditional cloud or edge only solutions.

- Edge location and low latency. Being at the edge of industrial networks requires fast and deterministic communication. Providing this between devices (as well as to I/Os) enables critical real-time applications to be included in the wider IoT infrastructure.

- Geographical distribution. Fog computing can address applications that demand widely distributed deployments that cloud computing alone cannot cover. This can include multiple sites or factories where internet connectivity cannot always be guaranteed.

- Interoperability and federation. Seamless support of services requires the cooperation of different providers. Hence, fog components must be able to interoperate, and services must be federated across domains.

- Real-time interactions. Important fog computing applications involve real-time interactions rather than batch processing. For this reason, processing and control functionality is supported at the edge.

- Heterogeneity. fogNodes come in different form factors and will be deployed in a wide variety of environments. Fog computing upends the old order of large standalone systems from single vendors.

- Security. An integrated system with multiple layers of security from cloud to edge provides defense in depth. Fog computing can include security mechanisms such as granular network, virtual machine and container-based segmentation, hardware root of trust and encryption of data at rest and in motion.

- IT-OT convergence. Fog computing brings innovations from the IT world into the OT domain. Inheriting elements from both the IT and the OT domains, the fog computing architecture naturally brings to the OT domain the most impactful innovations developed for the IT domain at the various levels of the software stack, from networking to security to the data level and to the application level.

Case studies

Machine builder

A renowned producer of precision metal working machinery in Germany was searching for an innovative IoT solution to address the thousands of products they install in factories around the world. The company wants to access data from these machines which can be analyzed and stored both locally and in the cloud.

Each machine generates more than 50,000 data points per second and every piece produced generates around 250 MB of data. The machine control system (PLC) is not able to provide data in high enough frequency for meaningful analytics to be performed and the sheer volume of data means that even if it were extracted, it would not be feasible to send it all to the cloud. Data is typically stored and then analyzed offline, significantly affecting speed and agility during development cycles.

Nerve provides an open platform that solves the immediate challenges of the machine builder and offers scope for innovation in the future. The MFN 100 connects directly to the machine sensors, bypassing the PLC and providing rich data via OPC UA. This data can then be stored directly on the 512GB SSD of the MFN 100 and analyzed locally using applications hosted on fogOS. A subset of production data is then securely transferred to a private cloud where Thingworx is used to perform big data analytics.

The machine builder benefits greatly from the flexibility of Nerve. The open software infrastructure enables sourcing of 3rd party applications (such as Node-RED) from the Docker store, which are then easily deployed from fogSM and hosted on fogOS. This centrally managed process reduces software development and maintenance efforts for the machine builder. The multiple communication ports on MFN 100 have been configured to connect to the machine's internal network, to a fieldbus, to the WAN and to production IT and service networks. This gateway functionality enables remote access to machine data for the first time. In future, more analytics functions will be hosted by fogOS at the edge, meaning that development cycles and deployment times for improved application software will be further shortened, thus increasing machine efficiency and value.

Plant builder

One the world's largest hydroelectric companies, with over 30,000 turbines installed worldwide, was looking to upgrade to an effective IoT solution for hydroelectric power plants. The company wants to access more data from their turbines and offer new services to customers, whilst also simplifying the infrastructure and reducing associated costs.

The turbine control system (PLC) is only able to provide a small set of data, and access to more sensor data would require a duplicate PLC to be added to the system. In order to send turbine data to a private cloud, the plant owner runs a Windows-based application which requires a dedicated IPC at the edge to host it. A Cisco ASA firewall requires a further piece of hardware that creates yet more system complexity and adds cost.

Nerve offers a virtualized platform onto which the IPC and firewall functionality can be converged. The turbine data application runs as a Windows virtual machine hosted on the MFN 100 and the Cisco ASA firewall is hosted directly in fogOS, providing a VPN tunnel to the plant owner's private cloud. The MFN 100 additionally provides fieldbus connectivity, allowing a much wider set of data to be accessed directly from the turbine sensors without the need to add a second PLC to the system.

The plant owner benefits from the capacity for resource virtualization in Nerve. The convergence of functions onto one platform enables the removal of two hardware pieces from the system which cuts capital expenditure by more than half and also reduces operational costs such as maintenance and training. Via the fogSM system manager, the plant owner is able to take advantage of new opportunities for updating applications at the edge that were previously inaccessible. Crucially, Nerve also offers offline functionality such as data storage and visualization for those power plants that are extremely remote and have limited internet access.

Summary

The industrial automation market is facing a huge challenge. Customers and internal stakeholders are demanding advances in productivity, flexibility and efficiency, but in order to fulfil data security, reliability and real-time operation requirements, systems largely remain manually managed, unsecured and siloed. Fog computing offers an innovative solution to this challenge as it protects critical elements of OT infrastructure, whilst also bringing IT usability features to the edge.

The Nerve platform combines edge computing hardware with middleware orchestration and centralized system management software. The implementation of these elements in a fog computing architecture provides efficient resource virtualization, secure data connectivity, open interoperability and modern centralized management. These features are helping industrial automation companies such as machine builders, system integrators and plant owners to reduce costs and create new value with more flexible manufacturing, smarter maintenance, higher productivity levels and shorter time to market.

To get started with Nerve please contact your local representative via **industrialiotsales@tttech.com**.

You can find out more about the Nerve platform at **www.tttech.com** and more resources on fog computing at **www.nebbiolo.tech**.

References

Fog Computing Overview Video: **https://vimeo.com/228299847**

OpenFog Consortium Website: **https://www.openfogconsortium.org/**

Fog Computing and Its Role in the Internet of Things, Flavio Bonomi, Rodolfo Milito, Jiang Zhu, Sateesh Addepalli
https://www.nebbiolo.tech/wp-content/uploads/fog-computing-and-its-role-in-the-internet-of-things-white-paper.pdf

Fog computing as enabler for the Industrial Internet of Things, Wilfried Steiner, Stefan Poledna
https://www.springerprofessional.de/en/fog-computing-as-enabler-for-the-industrial-internet-of-things/11002362

Fog for 5G and IoT, Mung Chiang (Editor), Bharath Balasubramanian (Editor), Flavio Bonomi (Editor)
https://www.wiley.com/en-us/Fog+for+5G+and+IoT-p-9781119187134

Fog Networking: An Overview on Research Opportunities, Mung Chiang
http://www.princeton.edu/~chiangm/FogResearchOverview.pdf