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Creating and Deploying Industrial IoT Solutions in Enterprise Environments

This paper focuses on enabling and leveraging computational power at the edge

white paper

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Resume

The first paper in a short series on the Industrial IoT (IIoT) focused on the intrinsic need to decouple data generation from data usage, functionality that is enabled by replicating the decoupled ICT architecture of enterprise environments. This is needed in order to allow data to be shared between apps, enable interaction, interoperability and resource sharing. These are mandatory parameters: without them solutions cannot deliver the multi-faceted IoT vision.

One of the primary goals of that vision is the generation of business intelligence that makes business processes more efficient, that saves time and can be the basis for new business models and revenue streams. Its foundation is an architecture that enables interaction between sensors, actuators and devices in the field with business applications in the enterprise. This is realized by layering IoT/M2M building blocks on top of each other, without creating dependencies between them, in order to realize a complete, end-to-end “stack”.

This paper will cover the functionality of these building blocks and chapter four will show how they can be assembled in order to enable the creation of future-proof, customized solutions. In addition we will demonstrate how this IoT stack enables the efficient, fast development of applications and the relative ease with which they can be deployed and managed in networks comprising hundreds of thousands of distributed end points.

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Right now innovative applications and cloud computing technologies are combining to create significant new capabilities in which input - from machines, people, sensors, video streams, maps and newsfeeds - is digitized and placed onto networks. These inputs are integrated into systems that connect devices, people, processes in order to provide collective awareness, increase efficiency, and thereby enable better decision-making in the enterprise. As a result, IIoT solutions are more complex than those of traditional M2M since they involve IT (Information Technology), the enterprise domain, and OT (Operational Technology, the M2M domain, in a much more flexible and integrated way.

Eurotech facilitates and simplifies the creation, deployment & management of applications for this converged IT/OT environment. This process involves leveraging virtualization technology in different ways, including employing a Java-based software framework for IoT gateways and edge devices. Abstracting embedded hardware and operating system features enable effective and flexible programming of IIoT edge devices and gateways.

In the resume we indicated that Eurotech offer enables the creation of customized solutions. It is hard to overstate the importance of that simple statement because the way that data is generated, and the kind of data that is used, can be company specific. Many companies, especially SMEs, build their success on the special value they provide to their customers. It can be found in the processes, technologies, products and services that represent the company's core competence. Something that gives them a competitive edge: maybe it's a unique selling proposition. Quite often this special value manifests itself in software implemented at the edge. This value and its competitive advantage has to be retained and extended in an IIoT solution.

That would appear to be an obvious requirement, but because of the intrinsic complexity of IIoT solutions this is not an easy task. Many vendors offer technology that tries to solve the complexity at the edge using "parameterization', where data is normalized in rather static but graphically attractive structures in order to make it easier to handle. However, there is a downside to this approach: it makes it harder or even impossible to embed a company's unique selling propositions, e.g. leverage the benefits of digital transformation. Normalizing IIoT in this way makes companies more equal - less competitive.

Therefore in order to ensure the creation of solutions that deliver IIoT's promise, e.g. more efficiency operations and the enablement of brand-new business models, both the edge devices and the infrastructure need to be fully programmable.

The IT/OT infrastructure

The complexity of this converged environment indicates the need for an infrastructure that can pull everything together, i.e. act as an intermediary system between the distributed, software-defined M2M/IoT devices at one end and the business applications at the other. This is realized via the functional integration of an intelligent multi-service approach at the edge and an integration platform in the cloud or data center.

An application framework, which is embedded in the multi-service gateway, provides wide, deep and seamless integration with the devices and the gateway's operating system. The framework also provides functionality that

simplifies the design, deployment and remote management of the embedded applications.

Everyware Cloud, Eurotech IoT Integration Platform, unites the OT domain and the IT domain. It acts like an “operating system” for the IoT infrastructure. On the enterprise side it’s an application enablement platform. On the operational side it provides all the data, device and embedded application management required to effectively deploy and maintain distributed intelligent systems in the field.

Security

It is hard to overstate the importance of security. In earlier years IT security was enabled by a firewalled perimeter and virtual private networks, but the widespread use of mobile phones, connected applications and the increased level of sophistication of the attackers has led to breaches in those fortified perimeters.

Dissolving the barrier between the IT and OT domains in an IIoT solution that does not employ robust security mechanisms can be exploited in similar ways. A single security product solution cannot enable end-to-end security: there is no silver bullet; it is essential to look at the entire system holistically. Security must be a fundamental part of the overall architecture of an IIoT system, i.e. be designed in, not added afterwards.

That is the approach that Eurotech has taken and it is detailed in another white paper titled “Securing Enterprise IoT Environments”. This paper includes short references to the location of the company’s security mechanisms but please refer to the security paper for detailed information.

Chapter 1: Software development and deployment of IIoT Gateways and Edge Devices

This chapter covers the pivotal role of multi-service gateways in application development as well as Eurotech's offer, which is firmly based on standards, Java & OSGi. It also considers the concept of solution-specific devices as well as the benefits of employing virtualization technology at the edge

Eurotech employs a programmable, multi-service gateway that plays a pivotal, connectivity role in the IIoT architecture. South facing OT field protocols and interfaces provide connectivity between local devices & sensors and the gateway. North facing communication technologies like cellular networks, satellite, Ethernet, and Wi-Fi deliver data to the Cloud.

The programmable gateway enables data acquisition, integration, and rules activation, thereby providing dynamic intelligence at the edge. It functions as a bridge between IT and OT by streamlining the different data formats and data rates.

In order to simplify edge device development, deployment and management, the company Everyware Software Framework (ESF) is embedded in the gateway. This enables device software development to be realized in Java, which from an enterprise IT perspective is a high-level, easy-to-use language.

ESF is a commercial, enterprise-ready edition of Eclipse Kura, the popular open-source Java/OSGi middleware for IoT gateways. Eclipse Kura provides a development environment for Java programmers that simplifies the creation of embedded applications. It provides a set of common services for Java developers building applications, including I/O access, data services, network configuration and remote management.

ESF's architecture, shown in figure 1, is based on different software layers, which allows developers to start writing the application on top of a solid, hardware abstracted platform equipped with all the necessary development tools and specific libraries. The Java Virtual Machine enables device (hardware and software)

abstraction. It also allows developers and device administrators to take advantage of ESF native integration with the M2M / IoT Integration Platform.

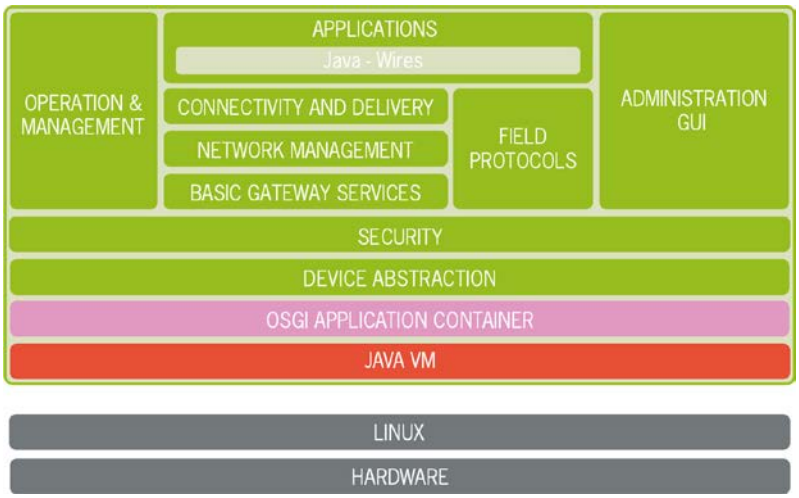


Figure 1. ESF enables wide, deep, seamless integration of applications with the operating system (Linux) and the hardware (devices), while providing full flexibility in terms of programming.

A comprehensive Java-based device management framework

Many companies offer device management in the form of small software agents. Typically these agents are written with a high level of portability in mind. They may give customers API access, which would enable some customization, e.g. the ability to set a few parameters on how much data to send or when to report.

A more significant limitation to this approach is that it typically does not integrate deeply enough with the IoT gateway´s capabilities and operating system, e.g. file system, I/O, networking, and security. As a result it lacks flexibility, e.g. it is not easy to add new technology options and features. At the gateway level, a more robust and open device application framework is needed to enable the requisite advanced device management features.

As illustrated, ESF's device application framework adds a layer between the operating system and the business application on the gateway. This collection of cohesive software components lets customers modify, reconfigure and maintain their application over time, so it evolves as market demands change. The resulting adaptability and flexibility to meet market requirements gives customers a huge competitive advantage.

A Java-based IoT device application framework results in shorter, more deterministic device software development. Using an IT-centric approach to implement the device logic in smart edge devices improves both device management (beyond the gateway) and the embedded application management.

Java is ideal for application code development in connected devices, enabling a robust software infrastructure for service delivery platforms. This enables easy code development through software simulation before porting onto the embedded devices, thereby reducing time to market.

With more than 9 Million programmers, Java is the most popular programming language[1]. It allows the requisite abstraction (virtualization) of hardware and software functions, something that is needed to ensure compatibility between systems utilizing different hardware architectures and operating systems. This approach also protects a company's software investment since it eliminates the negative impact that would otherwise result when changes to the underlying hardware and software are made.

These changes might involve finding replacement hardware / software when components (chip sets) go end-of-life and when more computational power or new

[1] https://blogs.oracle.com/oracleuniversity/why-is-java-the-most-popular-programming-language

hardware features are required, but it can also occur if there is a need to deploy an application in a different vertical market, e.g. impose specific requirements with regards to environmental aspects and certifications.

The Open Services Gateway initiative (OSGi)

OSGi is a modular platform that provides a vendor-independent, standards-based approach to modularizing Java software applications and infrastructure. Its proven services model enables application and infrastructure modules to communicate locally and distributed across a network, providing a coherent architecture for IoT services. The OSGi specifications are tested, proven and ready to provide highly scalable remote management and effective maintenance over the long term.

Applications or components come as bundles for deployment and can be remotely installed, started, discovered, stopped, updated and uninstalled. The ideal device application framework should be Java-based and leverage the OSGi. Programming devices is simple: developers can write an application bundle to go into the application management layer and do something completely different with the data or simply extend or use another bundle.

Building on proven architecture and software building blocks that would require many years to develop, the use of a device application framework results in shorter, more deterministic device software development.

Eurotech supports different implementations of OSGi (open source as well as commercial) when they are compliant with the standards published by the OSGi Alliance.

When employed in ESF or Eclipse Kura, in combination with the Everyware Cloud IoT Integration Platform, the framework enables the solution to securely:

- Install an application
- Start the application
- Stop the application and
- Update the application

A powerful combination

The ESF combination of Java and OSGi facilitates application development as well as the modularization of software components and applications, which assures interoperability of apps and services between different devices.

Through ESF, Eurotech provides a set of common services for Java developers building IoT applications, including I/O access, data services, network configuration and remote management. Eurotech assures a strong foundation for IoT applications by relying on leading industry partners to provide the technology basis for device, network, and service abstraction as well as efficient development.

Remote management saves time and money by enabling updates, configuration and troubleshooting without physically touching the device. For instance, remote management means that a network of thousands of devices can be updated all at one time or in pre-defined groups remotely. And in the industrial market, managing devices remotely saves money when technicians need not be sent to service devices in the field.

Java-based advanced device application frameworks, which abstract and isolate the developer from the complexity of the hardware and the networking sub-systems,

simplify the development and re-usability of integrated hardware and software solutions, while enabling advanced remote management functions.

Device cloud client

The Everyware Cloud Client is an integral element of ESF, but it is also offered in various configurations as a "thin cloud client", thereby ensuring that all data management and many of the security and device management functions of the integration platform can be utilized – also by systems that might have hardware constraints or which use operating systems other than Linux.
Everyware Cloud Client software can be embedded in smart sensors and smart edge node products in order to transfer data to the cloud for data management. These products might not have the requisite resources to run ESF. In a nutshell, the Device Cloud Client provides additional functionality: not the full ESF set, but whatever is possible within the limits of the product's resources. This includes the ability to talk MQTT (Message Queue Telemetry Transport) in a secure way with the integration platform and the enterprise world of applications.

The integration of the Everyware Cloud Client in ESF allows the full value proposition of Eurotech IoT/M2M building blocks to be leveraged, including additional strong security features, remote device management functions and embedded application management. It also ensures proper resource management in situations where multi-IoT-Cloud connectivity is required.

Development and deployment

Figure 2 illustrates how the advanced functionality provided by ESF enables a simple three-step development and deployment model. This model, although well-understood, being based on established best practice from an enterprise IT perspective, represents a revolutionary step for developing software for distributed devices.
Step one: create the application on a PC using Java, a process that emulates the way regular IT applications are developed. Step two: deploy the application on the multi-service gateway and side-load the app onto the device. Step three: provision and manage the applications that run on the field devices from the Cloud using device management services. These services are also used to facilitate deployment in the field (step two).

Figure 2. An experienced enterprise programmer will immediately recognize this application development and deployment process. However, it represents a paradigm shift in the OT / embedded space.

Leveraging an integrated development environment like the very popular Eclipse IDE (Integrated Development Environment) allows the programming of edge devices to be performed easily by enterprise software developers. All their software development know-how and experience can be applied, also for distributed (embedded) systems.

Field bus & technology support

Most IoT edge solutions are based on the integration of sensors, actuators, PLC´s, field buses and protocols. Quite often it is the specific combination of new and legacy OT technology that is the first challenge to overcome when creating a solution.
For example, PLCs will normally be connected through serial or LAN interfaces using field-bus communications protocols. While some of these technologies and protocols are open standards, there are literally hundreds that are proprietary and specific to vendors and vertical solutions. Examples in the industrial domain there are field protocols like Modbus or OPC-UA, in transportation CAN, or in energy M-Bus.

IoT device middleware like ESF or Kura is designed to achieve integration in a very efficient way. Re-usable software modules and bundles are available and variants are easy to create. They ensure robust interfacing and interaction with devices as well as the other OT technical building blocks needed for environments comprising different vertical solutions.

To further simplify the integration of popular OT technology Eurotech has made a significant contribution to the development of a technology called “Wires” as employed in the context of the Eclipse Kura open source project. Wires simplifies the creation of edge computing applications by leveraging reusable configurable components. They can be wired together, as illustrated in figure 3, in order to enable configurable cooperation between components.

In the dataflow programming model, application logic is expressed as a directed graph (flow), where each node can have inputs, outputs and independent processing units. The node processing units process inputs and produce outputs for downstream nodes. The processing unit of a node executes independently and does not affect the execution of other nodes. Thus, the nodes are reusable and portable.

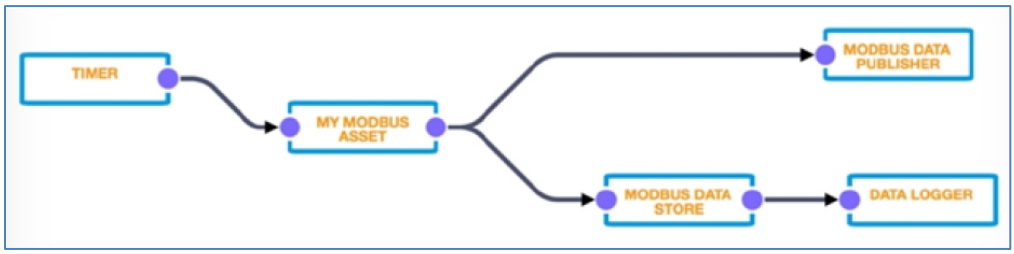


Figure 3. Wires components simplify the programming aspects of integrating sensors, actuators and other OT products.

Wires employs a Dataflow Programming Model in which every node in a dataflow graph represents either the field objects attached to an IoT service gateway or any computational resource that acts on data from the field object. A developer can make use of Wires to visually or programmatically connect block instances together to define a dataflow graph that will consume data, process it, and eventually publish it to the cloud.

The initial release of Wires supports a wide variety of devices, sensors and field bus protocols, including Modbus and OPC-UA.

System Management

The software building blocks that Eurotech provides for building end-to-end IoT solutions enable not only edge application development and life cycle management, but also the ability to monitor and manage a wide range of IoT devices. In addition a growing number of companies see the need to extend IT system and infrastructure management best practices and tools to the OT domain. Eurotech is working closely with its ecosystem partners to provide integrated and validated solutions. Partnerships include the work done with Red Hat on open source centric deployments as well as joint efforts with VMware to integrate with leading system management and virtualization technologies - on both the edge devices and the data center side of integrated IoT/OT infrastructures.

The hardware level

Devices and platforms from Eurotech minimize size, weight and power consumption and they leverage the company's experience in wireless communications. This includes support for satellite, cellular, Wi-Fi and other data transport methods, thereby providing uninterrupted communication between remote locations, fleets of trucks, trains, mobile command centers and any vehicle that is on the go.

	Product Family Prefix	Traget Vertical Market	Power	Certifications	Connectors	IP-Level	Enclosure
	Bolt	Rolling Stock	Insulated Protected 24-110VDC	EN50155 EN45545	M12 Circular	IP6X (IP54)	Aluminium Extrusion
	Dyna	Light rail Automotive	Protected 6-36VDC	E-mark SAE J1445	M12 Industrial	IP5X	Sheet metal
	Relia	Industrial	Protected 12-24VDC	FCC, CE	Industrial	IP4X	Sheet metal / Plastic

Figure 4. Examples for product families of Multi-service IoT Gateways and Edge Servers, designed to meet specific vertical market requirements.

At the hardware level Eurotech minimizes development risk and development costs by using both off-the-shelf, general-purpose and purpose-built IoT Gateways and CPU boards designed to meet specific vertical market requirements, e.g. industrial, healthcare, transportation and defence.

Solution-specific appliances

Eurotech has advanced the ready-for-use approach by developing devices (hardware and software integrated) that have been custom designed for specific vertical segments or applications. In IT a purpose built solution combining application specific software with hardware is often referred to as appliance.

It is worth noting that the concept of software defined multi-service gateways allows companies to build and customize IoT appliances to match their individual needs. ESF, the IoT middleware, abstracts the hardware specific aspects of an edge device / gateway as well as software aspects (including the all-important operating system, networking, security and even embedded custom application functions). The result is a single consolidated way to configure and manage these devices.

Application-specific devices or smart edge nodes that incorporate the requisite sensory capabilities can be programmed and optimized in order to function as required in a customer-specific application.
IoT appliances (smart edge nodes and sensors) have been developed, with considerable success for both vertical and customer-specific applications. Examples include: environmental monitoring systems, automatic license plate recognition systems and gateways that have been optimized for specific vertical applications such as heavy duty transportation, defense, smart energy or utilities.

Open systems and standards

Eurotech is totally committed to open standards. The company is a founding member of the IoT Working Group within the Eclipse Foundation, which is an open source community of tools, projects and working groups. The company has

contributed significantly to several projects like Eclipse Paho™, Eclipse Kura™ and Eclipse Kapua™.

Eclipse Paho provides open-source client implementations of the open and standardized messaging protocol MQTT aimed at new, existing and emerging applications for IoT. Eclipse Kura is a Java/OSGi-based middleware for IoT gateways. Eclipse Kura APIs enable access to the underlying hardware. The Eclipse Kapua project, combined with the existing Eclipse Kura project, offers developers and end users an open platform for end-to-end IoT deployments. It helps prevent proprietary lock-ins and enables community-driven development.

Eurotech comprehensive offer, which provides a strong foundation for IoT applications, is based on leveraging industry standards, decades of experience, and partnerships with leading industry companies. They include the deployment of Oracle Java SE, which can be employed in combination with high-performance databases and business intelligence software.

Another example of the flexibility and openness of ESF as an IoT edge device middleware is a solution developed in partnership with IBM involving the integration of Informix, a powerful time-series database technology. This will provide the foundation for leveraging a wide range of IBM business intelligence and data analytics solutions.

It is worth nothing that third-party devices running operating systems other than Linux, or using development environments other than Java/OSGi, can be connected to the Everyware Cloud. In addition third-party hardware can run ESF and Kura.

- Together, Eurotech and its technology and ecosystem partners ensure successful and deterministic development and deployment of M2M/IoT solutions for a broad range of vertical markets. The combination of an enabling IoT integration platform and a Java based application framework allows companies to focus on their core

competencies and provide higher value to their customers through services, improved efficiency, and reduced costs.

Conclusions

The key objective of this chapter was to outline Eurotech robust creation and deployment environment and indicate how the creation of applications is abstracted from the infrastructure.

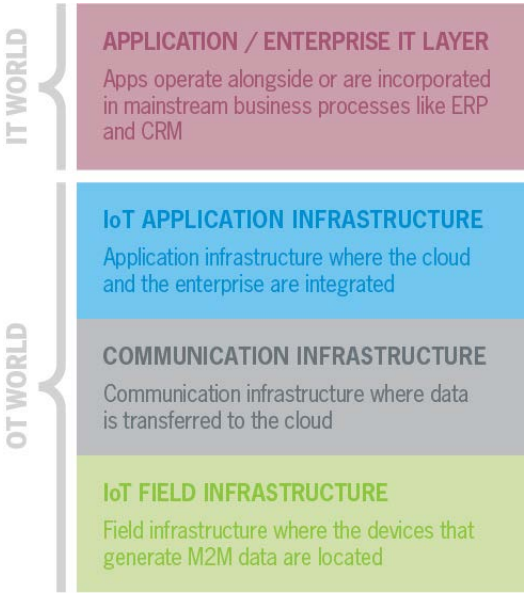
This environment employs IT and OT open standards and partnerships with leading vendors like VMware, IBM, Oracle and Red Hat enable additional functionality to be employed. Add the company pre-certified devices and solution-specific appliances to this software mix and the result is an offer that enables solutions to start delivering the benefits for which they were designed in the shortest possible time frames.

Chapter 2: Communication Technology and Infrastructure

This chapter maps the various communication technologies to the multi-layered architecture. It highlights low data rate LTE / 4G developments and outlines the functionality of managed service providers.

Eurotech end-to-end architecture comprises two worlds: IT and OT. Applications are created and deployed in the latter and they operate in the former, alongside or incorporated in mainstream business processes like ERPs and CRMs. Seamless integration between these disparate worlds, which is enabled by Everyware Cloud, is a mandatory requirement for IoT solutions.

In this chapter we take a deeper look into the OT world. As illustrated, it divides into three layers. The field infrastructure where the devices that generate M2M data are located. The communication infrastructure that transfers the data. And the IoT application infrastructure, which is the layer that enables integration between the cloud and the enterprise.



If we now focus on the communication infrastructure, then it is clear that south-facing protocols and interfaces are needed to communicate with the field infrastructure, as well as north-facing Internet connectivity technologies that communicate with the cloud.

Now, imagine a hypothetical "solution" that employed Wi-Fi for local-area communications with the devices and cellular for wide area communications with the cloud. A vendor might propose something along these lines because it is based on an agenda: the company's product portfolio. However, a real solution would allow companies to not only select the technology that met their individual requirement, but also to mix and match technologies and add or drop them in future.

There is no prize for guessing what Eurotech provides. We do not have an agenda: the company is communication technology agnostic. Depending on the target application, specific edge devices are available as standard products into which mainstream communications technologies are easily integrated. Other communication technologies can be implemented as configurable options. Alternatively, customized standard gateways can be provided. They are cost effective, enable a short time-to-market, and involve minimal development effort due to the modular design of the gateways' hardware and software architecture.

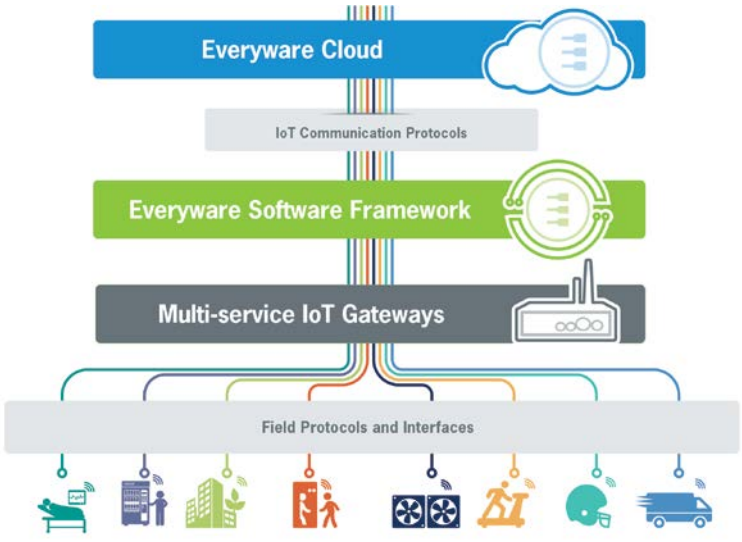


Figure 5. South-facing protocols communicate with the IoT field infrastructure and the north-facing protocols communicate with the IIoT applications infrastructure and the Everyware Cloud. This clearly indicates that the multi-service gateway plays a pivotal, connectivity role in the IoT architecture.

The IoT field infrastructure protocols and interfaces provide connectivity between local devices and sensors and the multi-service gateway. Typical examples of south-facing field technologies include ZigBee, Bluetooth / BLE, Ethernet, Wi-Fi, and RFID. In addition field bus technologies like Modbus and CAN are supported over serial, USB and other interfaces. As and when new protocols like LoRa go mainstream they will be enabled in order to ensure that solutions continue to deliver the optimum performance.

At the next level, the Communications Infrastructure, Internet connectivity (at OSI Model Layers 1 & 2) is enabled by various communication technologies like Cellular Networks, Satellite, Ethernet and Wi-Fi.

IoT Protocols

The IoT Application Infrastructure (OSI Layer 5), which is layered above TCP (or sometimes UDP) in the TCP/IP protocol stack, employs communication protocols that address the specific needs of devices that are unattended, geographically dispersed, and often mobile. Eurotech supports different protocols, but we advocate the use of MQTT (Message Queue Telemetry Transport).

MQTT is a lightweight protocol optimized for M2M device communications, but it's also a heavyweight technology. IM-type messages can be used and files exchanged. It has the following attributes: message oriented, publish & subscribe, and hierarchical namespace. In addition MQTT has three QoS levels. It is standardized by OASIS and client software is for example available through Eclipse Paho.

Eurotech and IBM co-authored the MQTT protocol, submitted it to the OASIS consortium as a standard for IoT communications and donated open-source code

through the Eclipse Foundation IoT working group. In 2016 MQTT has also become an ISO/IEC Standard.

Cellular networks

As indicated earlier, Eurotech supports virtually all mainstream communications technologies, wireline as well as wireless. Vendor-neutral advice can be provided on the optimum technology for a customer-specific requirements and it includes cellular communications, which is provided by Mobile Network Operators (MNOs).
In most cases customers will have employed the services of one or more MNOs for voice and data communications and extending the service for M2M / IoT traffic would *appear* to be an obvious option. Appear was italicized to indicate that the service requirements are significantly different, e.g. high data rates are not always required. There are other parameters that should be considered, but if we stay with data rates then at first sight it is not obvious why, for example, LTE / 4G will deliver cost-effective performance.

LTE is correctly perceived as a high-speed / low-latency service, which it is. However, the technology employed is significantly different to that of earlier generation networks: 2G, 2.5G and 3G and it results in a ground-breaking combination of efficiency and flexibility, but more significant is the fact that it enables data to be transmitted at widely different rates.
Right now the maximum rate is 450 Mbps; the lowest is the 1 Mbps service known as LTE-M; the M stands for Machine Type Communication. In addition a narrow-band LTE service, known as NB-IoT has been developed and deployments have started. This service will provide low power, cost-effective, wide area network performance having data rates measured in a couple of hundreds of kbps, which is more than adequate

for most IoT applications where the transfer of large amounts of data is not necessary.

Global and local SIMs

Global SIMs provide worldwide, cellular network connectivity with a single SIM. For example, Vodafone global SIMs enable roaming connectivity in many countries, as do those of Arkessa, Telefonica, and Telenor Connexion. This removes the need to change SIMs in IoT/M2M terminals (or gateways) when changing the country in which they are going to be used. This is very convenient if devices, machines or other equipment move on a regular basis. There is no need to select local MNOs and make and manage different services. In general, global SIMs will save operational cost. However, since offers are based on roaming technology, the associated cost is typically higher than that of a local service.

Local SIMs enable access to a local MNO's footprint, which is often limited to a single country or region. Nevertheless it might be the better solution for a particular application: either because of legal and pricing reasons, more flexibility, or the specific geographic coverage of that provider. If operating in a single, or a small number of countries, then local SIMs might be the better choice.

If the SIM card is used with non-mobile equipment or assets and stays in one country, then local SIM offerings are typically the better choice. On the other hand, if SIMs are used with (mobile) equipment that is globally dispersed and a more consolidated communication management view is required, then global SIMs might be the better choice.

The selection of the optimum cellular technology and the communications provider will normally be determined by the specific use case. For example, low data rate for a

typical IoT application or high rate / low latency for video surveillance. Moreover there is a wide range of complementary wide area and metropolitan area communication technologies that can be employed, e.g. LoRa.

MVNOs and managed service providers

A mobile virtual network operator (MVNO) is a wireless communications services provider that does not own the network over which it provides services to its customers. The basic concept was simple: MVNOs buy airtime wholesale and sell it retail at competitive prices, but in today's IoT market more than baseline cellular connectivity is needed.

The embedded Universal Integrated Circuit Card (eUICC) is an innovative technology that is poised to transform cellular connectivity. With conventional SIM cards, if a user wants to change the network operator, they need to swap the physical SIM inside their device. The development of eUICC enabled SIMs means that enterprises can remotely provision SIM profiles over the air.

Today MVNO services have been largely replaced by those of MSPs (Managed Service Providers). They can include the delivery of network, application, plus system and e-management services using a multi-carrier global wireless data network and 24/7 support. A "pure play" MSP focuses on management services as its core offer. The offers of many MSPs will include local area network technologies such as LoRa as well as alternative wide area connectivity like SigFox. They may also include advanced services such connectivity management, data routing, billing, and event decision-making.

The wide range of connectivity technologies and service options that are available align with the fact that businesses, both large and small, need to focus on their core competence and its importance is set to grow as enterprises start implementing comprehensive digital transformations. For example, IoT can be seen as a process that brings the physical world into the digital domain. Therefore one can question the wisdom of making cellular technology decisions internally and of managing the network versus outsourcing those aspects to a managed services provider.

Support across the board

Most of today's wireless technologies will continue, delivering the functionality for which they were designed. Moreover we can expect more new technologies to be created and marketed. In some cases they will provide an alternative approach that might have additional functionality or be more cost effective, or in other cases they might be the optimum way of providing connectivity in a specific, vertical application. Time will tell, but Eurotech Multi-service IoT Gateways are based on a modular, future-proof design. Changing the I/O module enables new technologies to be employed. And new gateways for specific vertical applications / markets such as manufacturing, smart city, healthcare and smart homes will be developed in order to deliver the optimum performance and feature set also from a communication options perspective to these sectors.

Conclusions

At times it seems that there is a plethora of wireless technologies. This is particularly true in the case of local area networks, and the list is growing: it's a healthy development. Choices are made by our customers, following the needs of their

applications. They are not dictated by the limitations of a company's M2M / IoT infrastructure or components. Eurotech is communication technology agnostic. Moreover the company multi-service intelligent gateways not only accommodate the mainstream technologies, but as indicated earlier they are also designed to be future-proof.

Chapter 3: Enabling and managing a unified infrastructure

This chapter covers the functionality needed to enable the creation and deployment of a seamless, unified IT / OT infrastructure. It considers IoT from an IT-centric perspective, its role in a bigger picture, that of digital transformation, and the importance of ecosystems.

As indicated earlier, in IoT solutions the consumers and producers of data have to be decoupled. Data generation and the consumption of data in the respective business applications have to be realized in ways that avoid OT application silos.

Decoupling is realized using middleware and communication protocols / technologies that are typically located in the cloud or data center. It enables solutions to be deployed in a virtual architecture, in which virtual circuit links appear to function as physical links between data sources and data destinations.

However, the two domains, IT and OT, need to function within a unified infrastructure. They need to be unified in order to enable the creation and deployment of holistic end-to-end IoT solutions. It's needed to allow data to be shared between apps, enable interaction and interoperability. This functionality is taken for granted in IT environments.

Eurotech Everyware Cloud unites the OT domain and the IT domain, i.e. it embraces both IoT perspectives. It's an integration platform that acts like an "operating system" for the IoT infrastructure. On the enterprise side it's an application enablement platform. On the operational side it provides the data, device and embedded application management required to deploy and maintain distributed intelligent systems in the field.

Enterprise Computing

IoT is normally depicted as an end-to-end solution going from devices in the field through to enterprise environments. That is the OT-centric view. But an IT-centric view goes in the opposite direction - enterprise to field - and that underlines a development that is reshaping business and technical requirements. The ability to intelligently monitor and control those devices is revolutionizing enterprise computing. It's ushering in a new era of networked computing that can include hundreds of thousands or even millions of intelligent end points.

In a nutshell, IoT is becoming an integral component of a much bigger picture that will deliver two significant benefits. One, facilitate digital transformation, which is set to impact on almost all aspects of our society. And two, it will be disruptive. This is a benefit because it will lead to the development of brand-new business models, models that open up new ways of thinking and of doing things. For example changing a business model based on selling a product into an outcome or service model. However, the integration process itself should not be disruptive. Enterprises have made significant investments in IT systems and technologies, therefore adding IoT capabilities has to be done efficiently and in a way that leverages those investments. We need new ways in order to make IoT a core component of digital transformation, which is reshaping virtually every aspect of business and our experience as customers. Enabling IoT by integrating the world of OT and the world of IT in seamless and non-intrusive ways is a key requirement.

Lots of things are needed to enable that transition and they are happening. Enterprise computing operates in an efficient, powerful, IT-centric environment. In order to enable seamless integration we need to re-architect the underlying OT infrastructure. That entails leveraging computational power at the edge in scenarios where it makes sense. Chip sets pack a lot of processing power and they are also

getting smaller and cheaper, which means that it's cost effective to embed multi-core chips sets in intelligent gateways where they handle complex tasks like real-time analytics at the local level. This capability is provided by third party software embedded in our gateways and it is enabled and managed through Eurotech IoT middleware and IoT Integration Platform. This approach means that there is no lock-in to a particular data analytics vendor.

The ability to analyze data at the edge, i.e. in real time, generates real-time, insightful business intelligence that allows decisions to be made "in the moment". This is a relatively recent development, one that leverages the value of data collected at the edge of the network. Eurotech enables a combination of real-time data analytics in the gateways and long-term data analytics in the cloud, which is used to discover hidden patterns, unknown correlations, market trends, customer preferences and other useful business information.

It's hard to overstate the importance of open source and industry standards. Also the fact that this is an ecosystem play: there is no "one size fits all"; no company has all the requisite knowhow and experience. In addition re-architecting the infrastructure should enable fast delivery of data from the field and it should be flexible, businesses need to be prepared for changes that simply cannot be anticipated. Moreover the architecture should enable access to data from devices across applications, build relationships between data sources, and take action in one area based on data from another. And last but by no means least, be agile, enable the creation of customized, changing and evolving solutions.

It's a tall order but Eurotech has the requisite knowhow and experience. The company has been creating and deploying end-to-end OT solutions that integrate with enterprise back-office systems for more than two decades, starting with ultra-robust solutions developed for the oil and gas industry as well as transportation. And from

the very early days the company has been fully committed to open source. For example, Eurotech co-authored with IBM the MQTT protocol and offered implementations as open-source code through the Eclipse Foundation. Companies offering advanced medical treatment and diagnostic machines employ this robust IoT protocol to communicate globally with medical devices in hospitals and clinics. It is also used in smart buildings, Industry 4.0 solutions, smart energy solutions and is widely employed in rail transportation.

Our ecosystem

Red Hat has become a very important ecosystem partner: this is particularly important in the open source domain. The relationship started when Eurotech became a Red Hat ISV Advanced Partner and soon led to the decision to team up to deliver joint solutions and architecture blueprints to customers across multiple industries. There was a joint recognition of the need to push intelligence to the edge of the network and to deliver solutions that provide complex, real-time event processing, business rules, data transformation, and interoperability.

The companies' competencies and products complement each other, with Eurotech being strong on the OT side and Red Hat on the IT side. The respective technologies allow the creation of an end-to-end, open source, *enterprise-ready* IoT stack.

Both companies contribute to and make extensive use of open source technologies like Eclipse Kura™, the popular open source Java/OSGi middleware and Eclipse Kapua™, the open source IoT integration platform. Open source and Java are important pillars in both companies' strategies. Eurotech also employs Red Hat® JBoss® Fuse and Red Hat® JBoss® A-MQ technologies.

Red Hat JBoss Middleware provides cloud-native services, from developer tools to data management in order to develop applications faster, smarter, and more flexibly. Red Hat JBoss A-MQ is a flexible, high-performance messaging platform that delivers information reliably, enabling real-time integration and robust connectivity.

Together with Red Hat and other ecosystem partner's enterprise grade open source software elements, ranging from mobile platforms to process automation solutions to BI & analytics, CIOs and software architects get the basic building blocks to effectively address many of the needs and challenges associated with the digital transformation of today's enterprises.

IIoT clearly is an ecosystem play - close partnerships with very different players are required to deliver a complete set of elements addressing the customer's needs & requirements. Strong partnerships with companies focusing on as different aspects as system / infrastructure management, virtualization technology, data management, business applications, BI & analytics, wide & metropolitan area communication, security & authentication and many others are required.

Another example of the flexibility and openness of ESF as an IoT edge device middleware is a solution developed in partnership with IBM involving the integration of Informix®, a powerful time-series database technology. This will provide the foundation for leveraging a wide range of IBM's business intelligence and data analytics solutions.

Another good example of a powerful partnership is documented in the joint efforts with VMware that integrate leading system management and virtualization technologies - on both the edge device and the data center side of IoT/OT infrastructures.

Platform deployment flexibility is key

The ability to provide deployment options beyond a public cloud offering is key in many customer scenarios. On-premise and private cloud deployments are possible in modules or as a complete IoT integration package, resembling the full feature set of Eurotech Everyware Cloud Public Cloud SaaS offering.

The IoT Integration Platform is architected and implemented in a modular fashion and is leveraging virtualization & container technology (Docker, VMware VMs, v-open & Openshift) to simplify the deployment and management on the data center side.

Managing devices

Devices operation and management is a mission-critical function, but it is also a key IT requirement. In end-to-end solutions the OT domain is a de facto seamless extension to the enterprise infrastructure, which means that devices become part of a management umbrella that includes PCs, notebooks, notepads and smartphones.

The device management component of Everyware Cloud includes: management of device configurations and other software components; logging and monitoring of vital data from the distributed systems; life-cycle management of applications / business logic on the devices; and transparent and secure remote access to the devices.

Figure 6. This functional overview of Everywhere Cloud indicates that device management is an integral component.

Everyware Cloud lets users develop integration flows that connect applications residing in a private or public cloud and then deploy them without installing or managing any additional hardware or middleware. It simplifies device and data management by connecting distributed devices over secure and reliable cloud services.

Everyware Cloud can be implemented as a private cloud: as such it enables companies to select and purchase the specific elements they wish to implement within their IT infrastructure or in an IoT solution. This is enabled using Docker modules. Docker is an ecosystem of software and cloud providers that allows users to package an application with all of its dependencies into a standardized container for software development and deployment.

Standard interfaces, layered on top of TCP/IP connections, standard interfaces (API's, tools & protocols) are provided to seamlessly integrate with enterprise and cloud applications, big data, analytics and management solutions. Data can be provided in real-time aggregated data-streams or as historical data.

Enterprise Service Bus concept

Everywhere Cloud also acts conceptually as an Enterprise Service Bus (ESB) for Machines. In enterprise environments an ESB allows ICT systems to be added and dropped without making changes to the infrastructure. It's a proven concept. The ESB for Machines is used to connect distributed IoT systems to business applications.

Devices and applications publish data onto the "Machine ESB" depending on local conditions and business logic. Applications receive the relevant data in real time, based on prior selections of topics of interest. This approach also provides the ability

to quickly add more topics as new services and technologies emerge. At the same time all the data is stored in a robust database. This basic functionality is exposed via APIs and there are alternative ways of enabling flexible access to both real-time aggregated data and historic data.

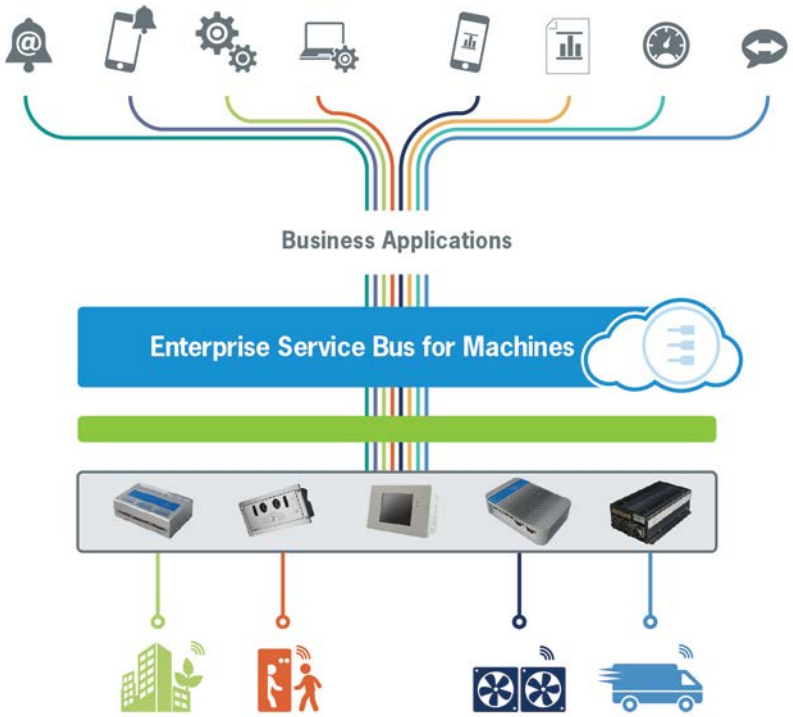


Figure 7. An ESB for Machines allows any relevant enterprise application to interact with any M2M data source. It provides a de facto seamless enterprise extension to an IoT domain.

Eurotech built ESB for Machines on an established product designed for implementing communication between mutually interacting software applications in a service-oriented architecture. This architecture is based on software components that provide application functionality as services to other applications. Being in software means that the architecture is intrinsically flexible.

Legacy M2M Systems

Eurotech intelligent gateways can be used to retrofit legacy M2M solutions, thereby bringing them into a unified environment. This is facilitated by the device/protocol-specific adaptors, which are created using modular software building blocks on the device side. On the enterprise IT side there are generic adapters for device data management as well as device management and different standard ways of retrieving device data.

Integration platforms as a service

According to Gartner iPaaS (integration Platform as a Service) is a suite of cloud services enabling development, execution and governance of integration flows within individual or across multiple organizations.

An iPaaS offer provides users with a combination of cloud services – collectively called integration platform services, to develop, execute, and manage integration flows. Integration flows running on iPaaS can connect, in a many-to-many fashion, to any combination of on- and off-premises apps, services, processes, and data.

Eurotech IoT Integration Platform, Everyware Cloud, is very similar, but it does not involve “bridging” or “integrating” enterprise applications. Instead it provides similar functionality between distributed devices in the field and enterprise applications. This is an important distinction. The bridge is made on the OT side, which is where it is needed in an IoT solution: iPaaS does it on the IT side.

In addition, Everyware Cloud features include a comprehensive set of cloud services having the functional elements needed to perform message transformation, message

routing, protocol conversions, data normalization, service virtualization, tracking, accounting, administration plus life-cycle management of the distributed devices.
This allows the software platform to deliver additional functionality to the enterprise environment. From the IT perspective the IoT infrastructure looks like another enterprise application; therefore it allows interaction with the infrastructure in IT centric ways. The distributed device "network" is at one end of an integration flow; the enterprise application is at the other end.

Everyware Cloud. The key benefits

Everyware Cloud provides the general benefits of cloud computing plus the ability to collect, control, transport and analyze data coming from the field, regardless of its size, e.g. an office building, campus, city, county or the wider world. It also provides the necessary remote device and embedded application management functions required to deploy and maintain IoT solutions with the best TCO (Total Cost of Ownership).
The key benefits include:

- **Simplicity:** Users create or enhance business processes using the Cloud's multifaceted event processing rules engine. It eliminates the regular complex and tedious manual process. Users can create rules quickly, adjust them instantly and add new rules easily.

- **Speed:** Data from the field is only as useful as the enterprise's ability to access it. The faster users can access the data, the more valuable it is in driving business actions. Everyware Cloud provides real-time aggregated data streams to the applications residing in the IT world. Everyware Cloud also offers long live data periods for the retrieval of historical data.

- **Flexibility:** Businesses need to be prepared for changes that simply cannot be anticipated. The Cloud's broker model lets users access data from devices across applications, build relationships between data sources, and take action in one area based on data from another.

- **Efficiency:** Eurotech Integration Platform embodies the IoT vision via its ability to combine key attributes - simplicity, speed and flexibility - and to facilitate integration with the business IT environment. In a nutshell, it's an efficient enabler, which is epitomized by the deployment of MQTT as communications protocol. This is a lightweight protocol optimized for IoT device communications; it's also a heavyweight technology. MQTT was co-authored by Eurotech and IBM and it has become an ISO/IEC Standard.

- **Versatility:** Everyware Cloud levels the playing field. It gives small and medium size businesses new capabilities that used to be available only to companies that could invest huge amounts of time and resources. With a good idea and the Eurotech Everyware Cloud, businesses of any size can take on their largest competitors.

- **Agility:** Eurotech offer enables the creation of customized solutions. It is hard to overstate the importance of that simple statement because the way that data is generated, and the kind of data that is used, can be company specific. Software-defined Multi-service Gateways allow companies to build and customize IoT appliances to match their individual needs.

TCO. Total Cost of Ownership

When evaluating TCOs it's the total cost of the service that is important, not that of individual aspects like the requisite hardware. In order to get services up and running the software and hardware of edge systems has to be selected or developed and integrated. Devices have to be certified, which can be a costly procedure that takes valuable time and resources. Then there is the cost of transmitting the data i.e. the financial arrangements that have to be made with a (mobile) service provider. And finally there is the cost of maintaining and managing the IoT infrastructure.

Eurotech has eliminated the cost of obtaining certification from mobile network operators as well as long times-to-market. Rugged cellular modems in the company ReliaCELL family are small, self-contained, *carrier certified* products that can be attached through USB interfaces to existing IoT gateways and edge devices. And many of the Multi-service IoT Gateways in the ReliaGATE product family are offered with integrated cellular modems that are pre-certified.

Maintaining and managing the infrastructure is enabled by the IoT Integration Platform. The feature set includes tracking, accounting, administration plus life cycle management of the distributed devices.

Another key parameter is time-to-market. Delays caused by whatever reason will not only result in failure to realize the benefits of the solution, but they may also result in the opportunity being lost to the competition.

Open systems and standards

Eurotech is totally committed to open standards. The company is a founding member of the IoT Working Group within the Eclipse Foundation, which is an open source community of tools, projects and working groups. The company has contributed significantly to several projects like Paho, Kura and Kapua.

Kapua is the Eclipse Open Source project name for the IoT Platform element that supplements and enables from a data and device management perspective the projects and developments around IoT devices, gateways, smart sensors and communication protocols. It represents the data center / cloud building block that provides a complete, open source stack that integrates seamlessly with the world of IT.

Virtualization and hyperconvergence

Virtualization is used to create a software-based (virtual) representation of a hardware resource. It is a key IT technology that can be applied to applications, servers, storage, and networks and it is making its way into the OT domain. The technology allows IoT devices to become virtual machines (VMs) that run on industry-standard x86 servers.

There are different ways to leverage virtualization technology and its benefits. In this document we are focusing on the concept of a VM as a tightly isolated software container with an operating system and application inside. Each self-contained VM is completely independent. Putting multiple VMs on a single computer enables several operating systems and applications to run on a single physical server, thereby providing economies of scale and greater efficiency. In turn it enables local

computing resources to be consolidated, a key feature that enhances operational efficiency at the edge.

Hyperconvergence is a relatively new term. It refers to a system that employs a software-centric architecture and the application of virtualization technology in order to enable the tight integration of compute, storage, and networking resources. This development replaces disparate, heterogeneous data center equipment with integrated and optimized hardware that includes servers, storage and networking devices.

A thin layer of software called hypervisor decouples the virtual machines from the host and dynamically allocates computing resources to each virtual machine as needed. Note that cloud computing is not the same thing as virtualization; rather, it's something you can do using virtualization.

In IoT hyperconvergence's primary role is the ability to enhance operational efficiency at the network edge. As indicated earlier, employing intelligent gateways located at the edge allow data analysis to be performed in a local facility, thereby generating real-time, insightful business intelligence that allows decisions to be made "in the moment".

In the context of the trend towards edge computing, Eurotech and VMware have jointly developed technology that employs VMware virtualization knowhow and experience, taking it from its regular role in the data center / cloud and extending the benefits out to the edge of the OT network. This indicates that hyperconvergence facilitates the shifting balance between cloud and edge computing.

In addition it raises the hyperconvergence bar. The consolidation of functional elements in data centers at the hypervisor level, together with federated

management, reduces inefficiencies and minimizes the total cost of ownership of the underlying IT infrastructure. In order to provide similar benefits at the edge, Eurotech will market edge server and IoT gateway products that are pre-installed with VMware virtualization technology.

The planned products address application scenarios where currently multiple computer systems are deployed, each of which enables a specific OT solution. These systems will typically involve different hardware and software implementations, which will inevitably result in logistic and support problems, thereby reducing operational performance and increasing maintenance costs.

Employing virtualization technology at the edge addresses these issues by reducing the effort and cost for managing and maintaining the various systems. Typical multiple computer systems range from demanding transportation solutions such as rolling stock, construction & mining machines, marine vessels, smart energy / smart grid and retail.

Conclusions

Eurotech end-to-end solutions are created and deployed in a seamless infrastructure, i.e. one that embraces IoT from both the IT and OT perspectives. This means that the OT domain becomes a de facto seamless extension to an enterprise's environments.

Everyware Cloud is a pivotal component. It's an application enablement platform for the enterprise IT domain and for the OT domain it provides operation technology for data, security, device and embedded application management.

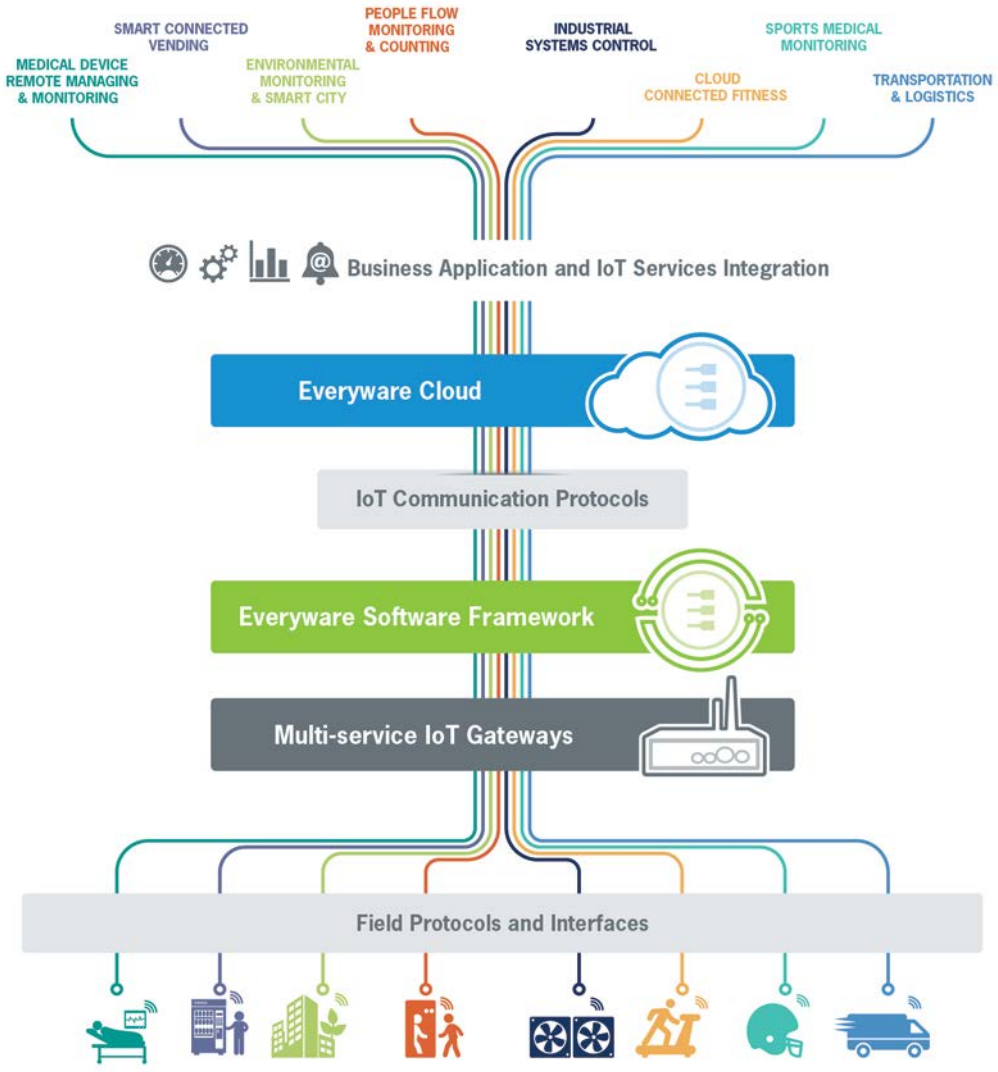
In addition Eurotech ecosystem includes powerful IT partners such as Red Hat, VMware, Oracle and IBM. The companies' competencies and products complement each other and the respective technologies have enabled the creation of an end-to-end, open source, *enterprise-ready* IoT stack.

The company IoT offer is holistic and it employs a comprehensive portfolio of state-of-the-art computing and communications technologies. Equally important is experience and knowledge gained by creating and deploying end-to-end ultra-robust solutions that integrate with enterprise back-office systems for more than two decades.

From the very early days the company has been fully committed to open and industry standards, leading to solutions based on ecosystems, that ensure seamless integration with other solutions, and that help to minimize risk and protect investments in software and hardware.

Chapter 4: The Big Picture

As well as providing a holistic representation of Eurotech's end-to-end solution, this chapter also summarizes the key functionality of four key components: (1) the Multi-Service Gateway; (2) the Everyware Software Framework; (3) the Everyware Cloud; and (4) the Enterprise Service Bus for Machines.



This Big Picture schematic reflects Eurotech's experience and expertise in both the OT and IT domains. The OT experience goes back to the early days of cellular data in the 1990's when analysts coined the term M2M. IT expertise is reflected in the 100% use of open systems and standards. The company's comprehensive offer enables seamless integration of the OT world with the business applications running in enterprise environments.

Reminders

The Multi-service IoT Gateway

Eurotech employs intelligent multi-service gateways that play a pivotal, connectivity role in the IIoT architecture. They handle south-facing, local area network technologies that deliver data to the gateway as well as wide area network technologies that transmit data to the cloud. In addition the company Everyware Software Framework (ESF) is embedded in the gateway.

The architecture is based on different software layers, which allows developers to start writing the application on top of a solid, hardware abstracted platform equipped with all the necessary development tools and specific libraries. The Java Virtual Machine enables device abstraction. In addition developers and device administrators can take advantage also of the ESF's native integration with the IoT Integration Platform.

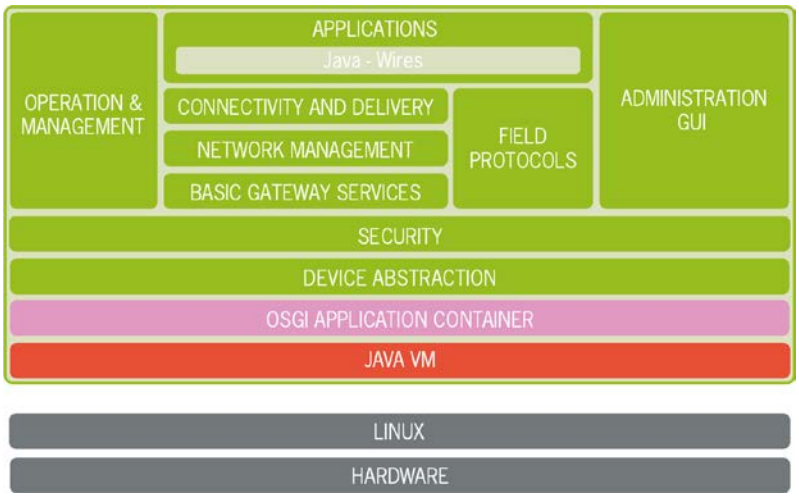


Figure 8. ESF enables wide, deep, seamless integration of applications with the operating system (Linux) and the hardware (devices), while providing full flexibility in terms of programming.

The term “gateway” does not do justice to this powerful feature set, which includes:

- Data aggregation using any mainstream connectivity technology: whatever works best for customers and their solutions. It includes support for legacy and new field protocols and technologies;
- A powerful IoT software framework to radically simplify software development and device management; enabling business intelligence and analytics at the edge;
- A communication protocol that addresses the special needs of unattended, geographically dispersed, often mobile devices;
- A multi IoT cloud client solution that allows the full value proposition of the company network edge building blocks to be leveraged and deployed with a wide range of leading IoT platforms
- These features indicate that the company gateway performs a powerful pivotal role in the M2M / IoT infrastructure.

Efficient IoT Protocols & Communication Technology Support

IoT applications typically rely on the Internet Protocol to communicate with assets in the field. This requires functionality, layered above TCP (or sometimes UDP) in the TCP/IP protocol stack, that addresses the specific needs of devices that are unattended, geographically dispersed, and often mobile. Eurotech supports different protocols, but we advocate the use of MQTT (Message Queue Telemetry Transport), a very popular lightweight protocol optimized for IoT device communications. It is standardized by OASIS and has become ISO/IEC Standard.

Everyware Cloud

Everywhere Cloud unites the OT domain and the IT domain. It is an IoT Integration Platform that acts like an "operating system for the IoT infrastructure and it works as an Application Enablement Platform for the Enterprise IT domain. On the operational technology side it provides all the data, device and embedded application management required to deploy and maintain distributed intelligent systems in the field.

Enterprise Service Bus concept

In enterprise environments concepts like ESB (also SOA) allow ICT systems to be added and dropped without making changes to the infrastructure. It's a proven concept. Everyware Cloud employs technologies that decouple (separate) data generation from data usage - just like the ESB for Machines that is used to connect distributed IoT systems to business applications.

Enterprise IT integration

Integration involves interaction between sensors, actuators and devices in the field with business applications in the enterprise.

Eurotech IoT Integration Platform, known as Everyware Cloud, is the pivotal enabling component. It's an application enablement platform for the IT enterprise domain and a data and device application management platform for the OT domain. You can think of it as a bridge between these domains. From the IT perspective the IoT infrastructure looks like another enterprise application, which allows interaction with the infrastructure in IT centric ways.

Connectivity to the IT domain is facilitated by standard interfaces (API's, tools & protocols) layered on top of TCP/IP connections. This enables seamless integration with enterprise and cloud applications, big data, analytics and management solutions. Everything is based on open systems and standards: there is no proprietary technology.

Security

Security must be a fundamental part of the overall architecture of an IIoT system, i.e. be designed in, not added afterwards. That is the approach that Eurotech takes and it's detailed in another white paper titled "*Securing Enterprise IoT Environments*".

Conclusions

In the resume we indicated that one of the primary goals of the IIoT vision is the generation of business intelligence that makes business processes more efficient, that saves time and can be the basis for new business models and revenue streams. Eurotech is delivering that vision.

Its foundation is an architecture that enables interaction between sensors, actuators and devices in the field with business applications in the enterprise. And it's realized by layering IoT building blocks on top of each other, without creating dependencies between them, in order to realize a complete, end-to-end "IoT stack".

The "Big Picture" schematic illustrates the breadth and depth of this architecture and it underlines the pivotal roles of Multi-service IoT Gateways and Everyware Cloud. The combination of a versatile end-to-end software stack and a seamless end-to-end infrastructure forms the foundation and backbone for a successful digital transformation of asset rich organizations and enterprises. In turn this enables the creation and deployment of solutions that leverage the benefits the 4th industrial revolution and deliver the IoT vision.