Addressing the real-world challenges of IoT solution development

BY PTC AND BOSCH SOFTWARE INNOVATIONS

The Internet of Things (IoT) is changing the way many companies do business. Traditional manufacturers are integrating their physical products with internet-based backend services, and internet companies are extending their offerings by integrating data from sensors and physical assets. New companies are entering the market with IoT offerings that combine physical products with internet-based services. Sensor-generated data and machine learning solutions enable new, data-driven business models.

All these players can benefit from fast and easy development of IoT solutions. To facilitate this, PTC has teamed up with Bosch Software Innovations to deliver a joint offering that focuses on the following three points:

- **Rapid application development for IoT**: Quickly and efficiently building user interfaces and applications for IoT use cases that require cost efficiency and fast time to market.

- **Managing heterogeneity and diversity**: Handling large numbers of heterogeneous, constantly evolving assets and devices in the IoT.

- **Building customizable IoT solutions**: Supporting IoT solution vendors in creating solutions that can be easily customized for different use cases.

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Together, the Bosch IoT Suite and the ThingWorx IoT application enablement platform can integrate smart, connected products with enterprise’s processes, including manufacturing, sales, marketing, and after-sales services, in a variety of industries.

Real-world use cases

Throughout this whitepaper, we will rely on two real-world examples in order to provide more practical insights into the challenges of developing IoT solutions.

Our first use case is the Track & Trace solution, which facilitates the management of large fleets of heterogeneous industrial power tools used for drilling, tightening, welding, measurement, etc. This solution is the result of an official testbed of the Industrial Internet Consortium (IIC) and is under development with Bosch, Tech Mahindra, and Cisco. Leveraging wireless tool connectivity and indoor localization, it improves operational equipment efficiency (OEE) and production quality. Figure 2 provides an overview.

Figure 2: Track & Trace use case

The second example is a Remote Condition Monitoring solution that addresses possible defects on conveyor belts in the mining industry. To meet capacity utilization targets, conveyor belts must operate continuously. Several sensors are mounted on the electric motors and gearbox shafts to measure vibration. This information is collected to predict possible defects, better manage maintenance, and reduce overall downtimes. Machine learning capabilities are being used to analyze these vibration patterns and define deviations (such as a failure in the electric motor) so an alarm can be triggered before the deviation actually occurs.

About PTC

PTC is a global provider of technology platforms and solutions that transform how companies create, operate, and service the “things” in the Internet of Things. The company’s next-generation ThingWorx technology platform gives developers the tools they need to capture, analyze, and capitalize on the vast amounts of data being generated by smart, connected products and systems.

About Bosch Software Innovations

Bosch Software Innovations, the Bosch Group’s software and systems house, designs, develops, and operates innovative software and system solutions that help customers around the world both in the Internet of Things and in the traditional enterprise environment. The Bosch IoT Suite is Bosch Software Innovations’ comprehensive toolbox in the Cloud. The software package, which is provided as Platform as a Service, allows the interaction of devices, users, companies and partners on a centralized platform.
Challenges of IoT solution development

These two use cases, as well as many other IoT projects that PTC and Bosch Software Innovations have completed in various market segments, reveal the 3 challenges that most IoT applications typically encounter.

(1) Rapid application development for the IoT

The evolutionary nature of most IoT projects requires applications that can be developed and modified in a rapid and flexible manner. This is especially true for projects in the early, exploratory phases, as requirements might change during later, more mature phases. We have defined two types of projects:

- Projects with **custom application development**: Some IoT applications have very high requirements with respect to data volume, performance, and algorithmic complexity. Typically, these applications have to support a high number of end users. Take for example a smart home solution with millions of households using the system. These applications have sophisticated UIs that are usually hand-coded and highly optimized – at a high cost.

- Projects that require **rapid application development** (the “application long tail”): At the opposite end of the spectrum are a very high number of more specialized applications with lower complexity. These are usually employed by a smaller number of specialist users, e.g. a plant’s management team. Developing highly customized and optimized UIs for these applications is often cost prohibitive because of the high number of applications required and the small number of specialist users. These applications are sometimes also referred to as the “application long tail,” since they represent the long tail of the curve that maps complexity and the number of applications for this use case.

(2) Managing heterogeneity and diversity

Many product vendors want to leverage device connectivity and cloud-based applications to offer new services such as predictive maintenance and usage-based billing. However, they face a problem when it comes to managing the heterogeneity of their product portfolio in the IoT. Reasons for the high level of heterogeneity include the ever-increasing number of product categories, a large number of product versions, and the constant evolution of individual products. Figure 4 provides an overview of the device heterogeneity that needs to be solved in the Track & Trace use case.

The same problem applies to the vibration sensors in the conveyor belt use case. These sensors come in a wide variety of types (e.g. inductive, piezoelectric, or magnetic), each of which has a different set of features as well as varying levels of accuracy and performance.
(3) Building customizable IoT solutions

Although IoT solutions and applications have their roots in individual IoT projects, these solutions will become increasingly pre-packaged or standardized over time. IoT solution vendors have started developing standard IoT solutions and selling them to multiple customers and markets, just as we have seen with ERP (enterprise resource planning), CRM (customer relationship management), PLM (product lifecycle management), and other packaged applications. Consequently, it is very important that end customers have an easy way to customize the solution to fit their specific needs.

Let’s take a closer look at the Track & Trace solution, which is designed to be used by customers in different industries, such as automotive and aircraft manufacturing. In addition to benefitting from the basic functionalities, most customers want to extend the core Track & Trace solution; for instance, they want to integrate it with their own processes and systems. Experience has shown that Track & Trace customers have individual requirements in areas such as:

- Different power tools: In addition to the tools supported out of the box, customers usually have other tools that need to be integrated. This requires adding new interfaces and customizing them as well as existing interfaces.

- Specific manufacturing processes: In general, each customer has different requirements for process integration; for example, how to handle a problem that occurs during a tightening step.

From the end customer’s perspective (e.g. an automotive company), the question is how such customization is best achieved:

- If they buy a COTS (commercial off-the-shelf) solution, they will most likely get a cost-efficient Track & Trace solution and high implementation speed – provided they stick with the standard functionality. However, as soon as they start customizing, the solution will most likely become very costly and complicated.

- On the other hand, if the customer decides to develop the Track & Trace solution from scratch, the initial cost and time required will be very high, even if the final result is a solution that meets 100% of the requirements.

The ideal compromise between these two alternatives is to use an IoT solution that is based on a flexible platform, like the two use cases presented in this whitepaper.

![Figure 5: Trade-off for different types of IoT solutions](image)
Joint offering – Bosch IoT Suite & ThingWorx

To meet the requirements outlined above, Bosch Software Innovations and PTC offer a combined IoT technology stack that has already been proven in multiple projects. The integrated architecture of the Bosch IoT Suite and the ThingWorx IoT application enablement platform allows IoT developers to connect and control heterogeneous devices and systems, develop IoT applications cost effectively and rapidly for complex IT landscapes, and quickly and easily adjust IoT solutions to the specific needs of individual companies and sectors. Figure 6 below gives an overview of the key architectural components that have been used to implement the two real-world examples used throughout this whitepaper.

The distributed devices are analyzed and information models derived according to the Eclipse Vorto standard, which provides an abstract definition of the devices to be integrated. The OSGi-based gateway software, ProSyst mBS, leverages these interface definitions to enable communication to and from the devices and integrate them with the central backend via the Bosch IoT Remote Manager. The Production Rules Configurator provides a rules engine and can be used to help automate complex decisions. The ThingWorx application enablement platform is used to build dynamic API and UI-centric applications, which in turn leverage the ThingWorx core solution model. The Vorto-based code generator can generate a ThingWorx model, creating an elegant synergy between an open and industry-standard modeling framework and a fully realized API that is ready for application construction.

Figure 6: Bosch IoT Suite and ThingWorx's joint architecture
(1) ThingWorx Mashup Builder – Speeding up with the help of UI widgets

Developers frequently need to rapidly create prototypes for IoT applications. To address that need, ThingWorx provides a powerful browser-based rapid application development environment. At the heart of this environment is the ThingWorx Foundation. It enables innovators to rapidly create and deploy game-changing applications, solutions, and experiences for today's smart, connected world.

The steps required within the ThingWorx mashup builder can be summarized as follows:

- Define the layout of the application
- Position the UI widgets in the layout
- Add the data sources based on the data model
- Link data sources to the UI widgets
- Preview the web app and optimize the styles, etc.

The ThingWorx platform was designed with expandability in mind. New UI widgets and other extensions and connectors are available from the ThingWorx Marketplace. As ThingWorx widgets are based on internet standards, users can even expand or create them themselves.

ThingWorx does not distinguish between reports, dashboards, and application screens. They can all be developed the same way, using the drag-and-drop codeless mashup builder to quickly build content. Mashups can be designed with responsive layouts to automatically adjust to the client’s device and browser. The ThingWorx runtime environment understands client platform capabilities, allowing users to be directed to different content and mashups as specific form factors are required. Dashboards can be utilized to allow end users the ability to create their own customized view of the data that is important to them.

Since the primarily UI design is independent of the information or data model, the core mashup can be reused for different data models and bound to different data sources. Also, mashups can contain other mashups, which allows the reuse of UI modules in multiple web applications.
(2) Bosch IoT Suite – Connecting and managing devices easily

The Bosch IoT Suite provides the foundation for service enablement, both in terms of connecting things to the internet – reliably, securely, cost effectively, and at scale – and in terms of delivering the backing application logic for value-added services. The Suite consists of a set of software services that provide all the necessary key middleware capabilities for building a sophisticated IoT application from top to bottom. Customers can use any combination of these IoT services as needed to rapidly implement the desired solution.

The following key components of the Bosch IoT Suite have been used in the context of these use cases:

ProSyst mBS – Getting heterogeneous devices working together

ProSyst's mBS is an IoT middleware stack for gateways that facilitates the interaction between connected devices in the mobility, smart home, and connected industry segments. It is based on open standards with OSGi at its core. OSGi is a globally accepted standard and the key to our gateway technology and remote technical management, used to manage distributed devices and by multi-device vendors with complex software requirements.

Optimized for use in commercial embedded and resource-constrained platforms and products, mBS supports all major IoT protocols, thus facilitating the integration of devices and sensors. What's more, the device abstraction layer and automation rules engine ease the development of complex distributed IoT applications. Business logic can be deployed locally to allow for data filtering, local business rule execution, and other logic required for automation close to the assets and devices. Finally, mBS allows collection of all required data from assets and devices in a central backend.
Bosch IoT Suite services - tailor-made for Internet of Things scenarios

The Bosch IoT Suite provides strong support for remote management of heterogeneous devices and assets. As just one of the cloud services offered in the Suite, the Bosch IoT Remote Manager allows developers to wrap the often very low-level and technical asset and device interfaces in a common language. The Suite additionally provides capabilities for software lifecycle management operations, firmware over-the-air updates, remote configuration and provisioning, as well as diagnostics. It also serves as the foundation for the implementation of rich IoT applications with sophisticated user interfaces, for which the ThingWorx rapid application enablement platform can be used.

Production Rules Configurator - Detect deviations early on to ensure a timely response

The Production Rules Configurator offers a graphical approach to rules modeling that enables users to monitor how well specified parameters in the manufacturing environment are adhered to. The software detects any deviations that occur and immediately notifies the responsible persons allowing them to take the necessary steps to keep the manufacturing process running smoothly.

Eclipse Vorto - Managing interoperability in the IoT

The “glue” that holds the Bosch IoT Suite and ThingWorx together is called Eclipse Vorto. Vorto is an open-source project backed by the Eclipse Foundation and defines a technology-independent language to describe the interfaces of devices and assets in the IoT. It facilitates the creation and management of information models describing the attributes and the capabilities of real-world devices.

By using the Vorto standard, product managers and developers are able to define the interfaces of devices and assets regardless of who manufactured the technology. This includes all the attributes (e.g. battery status) and services (e.g. getTighteningPerformance) that the asset or device provides. An example of a Vorto-based definition of a tightening tool looks like this (excerpt):

![Figure 9: Example of a Vorto information model](image-url)
A repository is provided to manage multiple versions of Vorto information models and support interface versions and dependencies management. Code generators for information models ensure a quick integration of devices into different platforms. The example shown in Figure 10 manages six VIDs for three products (e.g. version 1.0 - 1.1 for the Nexo).

A Vorto information model generates the following:

- ThingWorx solution model, comprising the abstract and dynamic “Thing API”
- ProSyst mBS skeleton, which can be easily mapped to a custom device driver

UIs can be created using the ThingWorx mashup builder based on the generated ThingWorx model.

(3) Flexible combination – Allowing solution customization

ThingWorx’s RAD features and the flexibility of the Bosch IoT Suite’s device management allow customers to develop highly customizable applications such as the Track & Trace solution.

Changes in the data model need to be performed only once in the Vorto information model – they are then available in both the Bosch IoT Suite and the ThingWorx Foundation. With help from the ThingWorx mashup builder, those changes can be easily incorporated into existing web applications.

Furthermore, by leveraging the capabilities of the ThingWorx mashup builder, existing web applications such as the Track & Trace solution can be rapidly customized in the following areas:

- Usage of different UI widgets
- Layout of the mashup (e.g. dashboard-like, tabbed view)
- Styles throughout the whole UI (e.g. colors, font sizes, font styles)
- Logos and other visual elements
- Data filtering and other data operators and expressions

Figure 10: Vorto repository

Figure 11: Customization using the ThingWorx mashup builder
Expanding the underlying information model allows for further customization. Connections to enterprise systems such as CRM, ERP, PLM, and others as well as to general or specific web services (such as social media or weather forecasts) can be established, added to the data model, and incorporated into the UIs. ThingWorx treats those elements in the same way it treats connected devices: as things to retrieve information from and to interact with.

In general, ThingWorx “things” (regardless of the type of thing) are characterized by the following elements:

- **Properties**: what kind of data describes a thing or can be provided by the thing
- **Services**: interaction with other elements and other things
- **Events**: triggered by defined conditions
- **Subscriptions**: actions that should happen on the case of an event

These characteristics can be defined either directly in ThingWorx in a codeless model or by using existing definitions that are made available in the ThingWorx Marketplace (e.g. enterprise systems connectivity).

Consequently, it is possible to embed an existing application such as the Track & Trace solution into an existing IT and process landscape and customize the UI.

### Summary and outlook

Integrating and managing large groups of assets and connected devices is not easy. Because of product variants and versions, the number of interface versions to be managed over time can easily reach into the thousands, even for a medium-size product portfolio. This problem is a challenging one to solve, and the Vorto community – with its powerful interface definition language, interface repository, and code generators for different IoT target environments – is a welcome solution. Being able to integrate Vorto with the ThingWorx rapid application development environment helps to address the “IoT application long tail” – the need to rapidly build custom applications for many different use cases. And finally, leveraging Vorto, ThingWorx, and the Bosch IoT Suite can be an interesting approach for IoT solution providers, because solutions built on this combination of powerful tools can be easily customized by end customers.