ORACLE
JAVA EMBEDDED

Java and the Internet of Things: Automating the Industrial Economy

ORACLE WHITE PAPER | FEBRUARY 2015

ORACLE

Java and the Internet of Things: Automating the Industrial Economy

Industrial automation involves the integration of physical machinery and processes with sensors, computers, and software. The result is an intelligent manufacturing infrastructure for increased safety and efficiency, and lowered costs. However, industrial automation comes with its own set of challenges. These include the need to connect multiple proprietary control systems, maintain end-to-end system uptime, reduce energy consumption and total costs, adhere to regulatory requirements, and increase safety and security at every phase.

At its core, industrial automation aims to bring together the advances of two transformative revolutions: the machines, facilities, fleets and networks that arose from the Industrial Revolution, and the powerful advances in computing, information and communication systems established via the Internet Revolution. The intersection of these two diverse and disparate sets of technologies often results in a mixture of individual solutions. Businesses need their distributed manufacturing and business processes and control systems to behave like a *single*, flexible computing platform combined securely with a modern development platform to build, deploy and update applications. Oracle Java Embedded delivers this.

The Need for Integration in the Internet of Things

The next major transformation in industrial automation is underway. Intelligent devices, ubiquitous Internet connectivity and growing IT infrastructure are combining to uncover and drive new business opportunities. As manufacturers increasingly automate their processes and machines, they become an important and growing segment of the Internet of Things (IoT). This term is used to define a system in which the Internet is connected to the real world via ubiquitous sensors and devices. The vision of IoT is to integrate diverse sets of data from physical sensors and the rest of IT to enable analytics that can anticipate events, issues and other needs. As a result, the system as a whole can have a view of what's taking place at any location and point in time. This leads to a set of connected systems that could greatly reduce waste, lower costs, and eliminate loss for just about any human-machine or machine-machine activity.

Deploying a smarter manufacturing infrastructure based on IoT methods allows businesses to build and maintain a wealth of knowledge across manufacturing, control and business processes. For example, immediate access to plant-wide information provides factory managers with enhanced environmental condition monitoring capabilities. At the same time, readily available asset information can optimize factory production performance and process control to help managers gain a competitive edge in market production. All the while, real-time data—used as part of a feedback loop—can be used to improve quality, drive out inefficiencies, and ensure human safety at all levels.

A timeline of innovations in industrial processes (Figure 1) shows an increase in productivity and quality with each milestone. We're now moving through Industry 4.0, the *automated industrial economy*, where IoT is helping to increase efficiencies through deep insight, reduce system failures with predicative analytics, drive new business through discovery, and cut costs by uncovering waste.

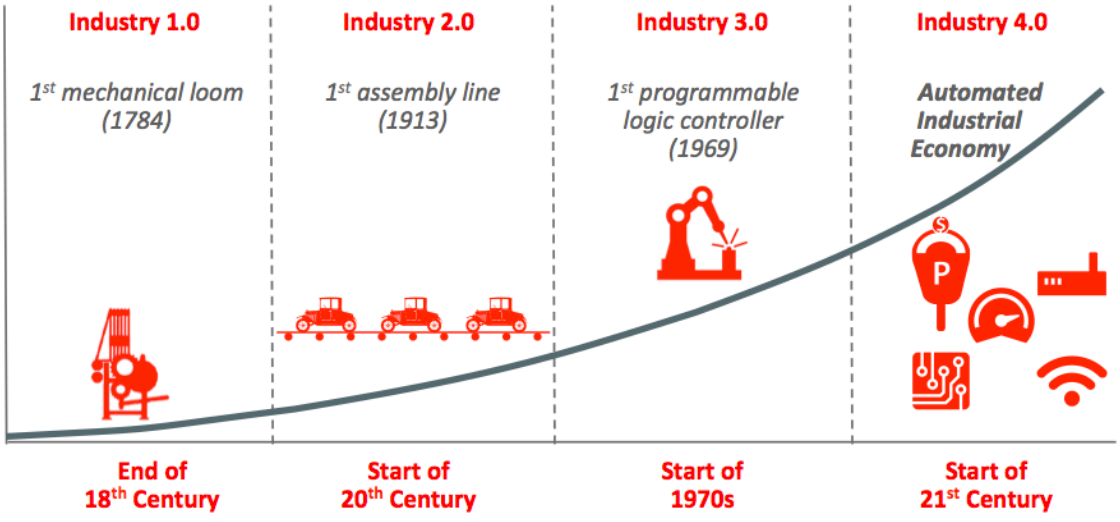

Figure 1. Industry 4.0 is the next leap in industrial automation driven by IoT.

At the intersection of today's industrial automation requirements and the rapidly emerging IoT technology wave, no other platform today is better positioned to enable an end-to-end automated industrial economy strategy than Oracle Java Embedded. Given its ability to run on a wide range of devices, from mobile and embedded systems with limited CPU and memory, to servers with immense power and capacity, Java is meant to power a world of compute resources with ubiquitous connectivity. Java-powered devices in this ecosystem will communicate with each other

and with people via sensors and controllers, gathering data and ultimately being able to understand and control events in real time.

The number of cellular machine-to-machine (M2M) connections in industrial automation applications is predicted to grow at a compound annual rate of 23.2 percent—from 2.5 million connections at the end of 2013 to 7.1 million connections by 2018 ("Industrial Automation and Wireless M2M," M2M Research Series 2013, *Berg Insight).*

Automating the Industrial Economy

The automation of industrial processes involves industrial control systems, which usually include supervisory control and data acquisition (SCADA) systems, or other distributed control systems (DCS). They communicate over secure channels to computers controlling remote equipment that can be distributed geographically.

*The Industrial Controls and Factory Automation market is projected to reach $301.9 billion by 2020 (*Markets and Markets, *May 2014).*

A typical SCADA system integrates a sensor tier to acquire data from physical machines and other components; a control tier with industrial controllers to interact with the machinery and sensors; and a supervisor tier with human-machine interface (HMI) systems to monitor and control the entire automated process.

According to research by Berg Insight, both the number of devices and the amount of data collected is increasing end-to-end in industrial automation systems (Figure 2). This is driving the need for additional control and management systems for these devices, as well as new analytics to find hidden value in the data collected.

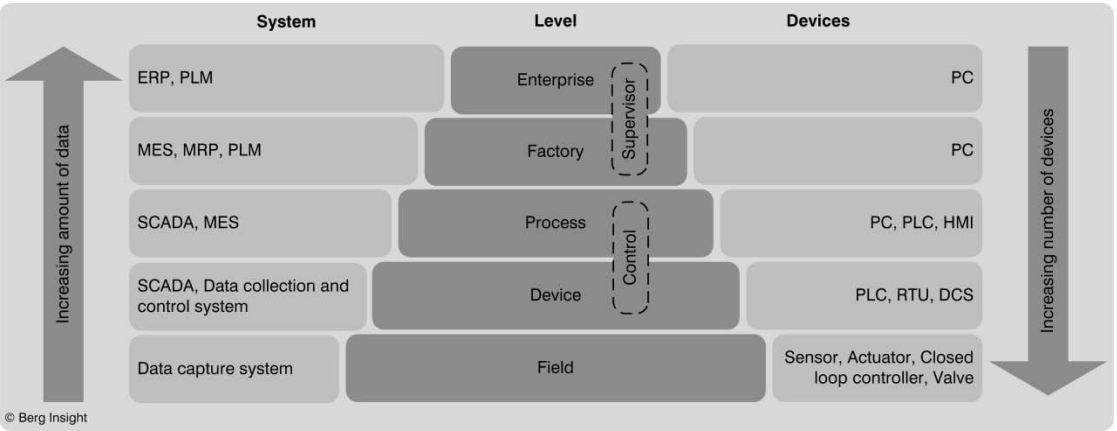

Figure 2. The number of IoT devices and the amount of data collected is increasing in industrial automation solutions ("Industrial Automation and Wireless M2M," *M2M Research Series 2013*, Berg Insight).

Ten years ago there was a marked difference in the cost of technologies used in industrial controllers. But with the commoditization of processors, memory, embedded software, and communications, the cost differential has become insignificant for new offerings from all vendors. Still, the traditional processes used within many manufacturing organizations to enable bespoke, customized applications don't scale efficiently. You need new strategies and technologies, such as Java, to minimize time and effort spent on non-differentiating tasks, and to restore innovation. To make a difference, a newer, deeper level of data acquisition and associated analytics is needed. The answer lies with the Internet of Things.

IoT in Industrial Automation

Fully leveraging low-cost, low-energy sensors and devices that make up the Internet of Things can help unlock savings in terms of power consumption and total system cost. IoT enables sensors and end devices to directly communicate with enterprise infrastructure to provide in-context data awareness around system functionality. According to the 2014 VDC Research paper, "Brewing Embedded Market Success with Java," IoT technology is helping manufacturers sell more products, and bundle additional services with each sale thanks to enhanced business analytics (Figure 3). The end-to-end control and insight delivered by IoT to all levels of industrial processes can greatly expand the industrial economy.

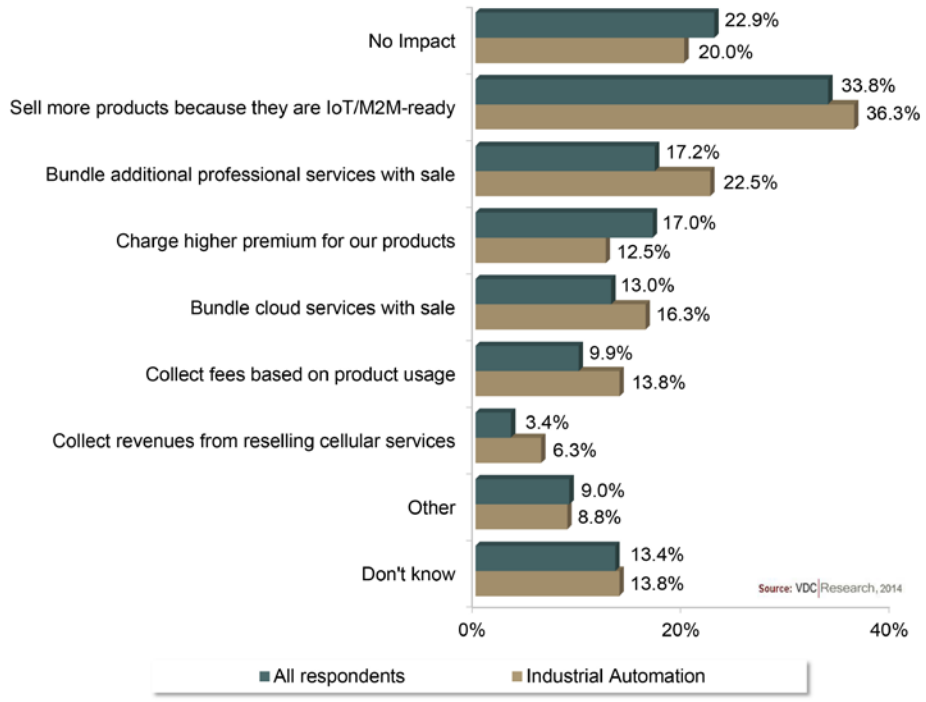

Figure 3. How is IoT impacting manufacturers' business model?

Research indicates that the use of IoT and M2M technology in industrial automation systems will increase by 25 percent over the next three years ("Brewing Embedded Market Success with Java," VDC Research, 2014).

Sensors and Devices Uncover Hidden Value

A robust IoT platform allows you to seamlessly integrate every automation system and component via standard communication protocols, linking controllers and actuators, machinery, enterprise systems, automated systems, and even video and audio feeds. The goal is to combine sensors and devices (and their data) with analytics to discover previously untapped operational efficiencies and achieve greater optimization.

IoT is driving a new generation of controllers and sensors with increased connectivity and embedded intelligence to further increase automation, optimization and uptime. Wireless IoT protocols deliver expanded connectivity with easier integration across manufacturing sites.

IoT: Seeing Through the Fog and Cloud

The distributed nature of industrial automation processes also works well with the cloud. Industry leaders are working quickly to build out specialized cloud infrastructure to connect automation systems and handle your big data needs. Leveraging ready-made cloud systems saves you system integration time and costs, allowing you to focus on innovative analytics, deep process optimizations, and greater end-to-end value.

By combining device data with analytics, you'll uncover hidden value in your automation data, such as the ability to predict the onset of equipment failure and initiate repairs before they occur, and gain greater system insight. Additionally, easier and cheaper integration of devices and systems equates to increased innovation and the creation of end-to-end process feedback loops. All of this enables continuous refinement in your processes and greater system intelligence, giving you a competitive edge.

Companies have struggled over the integration of their manufacturing and business systems. IoT and the cloud can turn your ERP, material requirements planning, manufacturing resource planning, and manufacturing execution system into one integrated suite encompassing business functions, supply chain management, asset management, production scheduling, and end-to-end optimization ("Internet of Things: Industrial automation industry exploring and implementing IoT," by Bill Lydon, ISA, 2014).

Beyond the potential benefits of industrial automation, there are challenges and concerns that need to be considered. Let's explore these now and how, once again, technology can come to the rescue.

The Value of Oracle in the Industrial Economy

Quicker business decisions based on real-time data gathering enable you to more effectively adapt to changes in markets and competition, and to deliver greater value to your end customers. In fact, with big data analytics, companies can often predict market changes and customer needs before they occur. To accomplish this, you need to have the right amount of analytics and intelligence at every point in your system, from servers to smart devices, and the gateway computers that interconnect.

Oracle technology is used throughout many automated systems deployed at leading manufacturing and facilities companies globally. Oracle products are helping companies gain deeper insight into their processes, with fast data and enhanced analytics to uncover greater value, quicker than before. For instance, technology and services from Oracle are repeatedly chosen to help in the following areas (Figure 4):

- ***Operations:*** *increase efficiency and effectiveness through process optimization.*
- ***Resource tracking:*** *the ability to track assets and resources across an entire enterprise. This includes physical devices and machines, as well as employees and other human resources.*
- ***Process feedback loops:*** *the implementation of analytics and business intelligence to gather real-time operations data, analyze the data to predict needs, failures, and future value, and optimize and measure processes based on this data.*
- ***Manufacturing flexibility:*** *the ability to reconfigure, enhance, and modify manufacturing lines, machines, and processes systematically and without human intervention through advanced logic and control.*

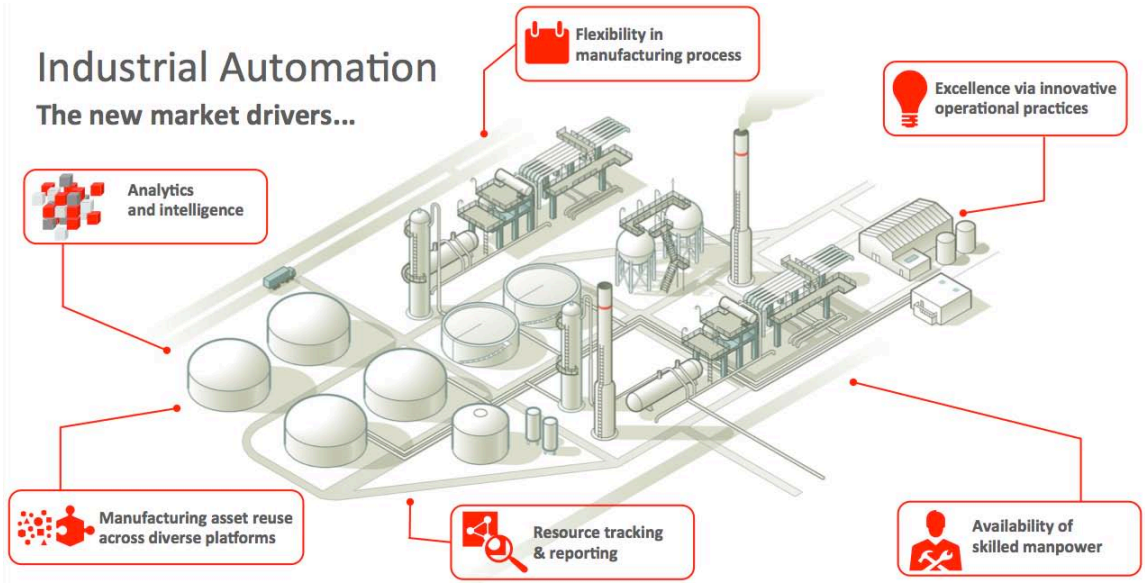

Figure 4. Oracle's Internet of Things platform delivers enhanced data analytics for greater automation value.

The Challenges of IoT in Industrial Automation

Increased automation and non-human intervention represents enormous potential for increased efficiency and value throughout the entire industrial domain. The Internet of Things adds to this by vastly increasing the potential to innovate. But with all of this come potential challenges and concerns.

- **Safety and security**: The first challenge is the safety of workers and security of systems involved in production, control, and monitoring processes. This is the central challenge of combining control systems with communication or social systems, yet maximum value demands an integrated experience.
- **Implementation portability and cost:** Manufactures are challenged with the additional potential cost of increased automation. Many of the systems involve disparate and diverse legacy applications, implemented over time, which need to be integrated with newer technology. Often proprietary, they require specialized tools and implementation skills, while others require varying hardware and OS support.
- **System availability and uptime**: When entire assembly lines, factory conveyor systems, plant operations, or city-municipal services are at stake, the uptime of each individual component is critical. From sensors and control systems to servers, every part of the automated system must work flawlessly and communicate reliably to ensure the highest level of productivity.
- **Energy consumption**: Given the breadth of IT deployment in a typical industrial automation solution, energy usage can fluctuate and otherwise become hard to predict or plan and budget for. The ability to continually reduce energy consumption can be a competitive advantage.
- **Standards and regulatory requirements**: Failing to meet standards and requirements of regulatory bodies may result in waste in terms of energy and other resources, non-interoperable production lines, worker safety hazards, or the risk of being shut down due to non-compliance.
- **Enterprise integration and coordination**: When your automated processes connect to your corporate network and decision-making systems, it truly adds value. Building autonomous control systems that leverage the value of IoT means increased integration with outside systems and enhanced connectivity.

Increased Value: Java and Industrial Automation

Oracle Java Embedded is built for the end-to-end demands of the automated industrial economy, and meant to work at all points of a SCADA or DCS. Java is a key technology for both the enterprise and embedded market, with billions of devices, gateways, desktops and servers dependent on it to run their core functions. Java and Oracle's enterprise IT solutions work together to offer you a *single* end-to-end IoT platform for all of your industrial automation applications, so you don't need to build custom infrastructure each time.

Java Embedded packs enterprise server power into small controllers and devices. Whether it's used in an industrial controller, a data acquisition and control server, or other critical production systems, Java technology offers a number of key features (Figure 5) that make it the ideal platform for industrial automation. It enables headless, lights-out operation, a robust and secure application environment, remote software provisioning and management, and reliable end-to-end connectivity, all built on the industry standard Java language and virtual machine already used in IT. Overall, Java Embedded addresses all of the challenges listed and more.

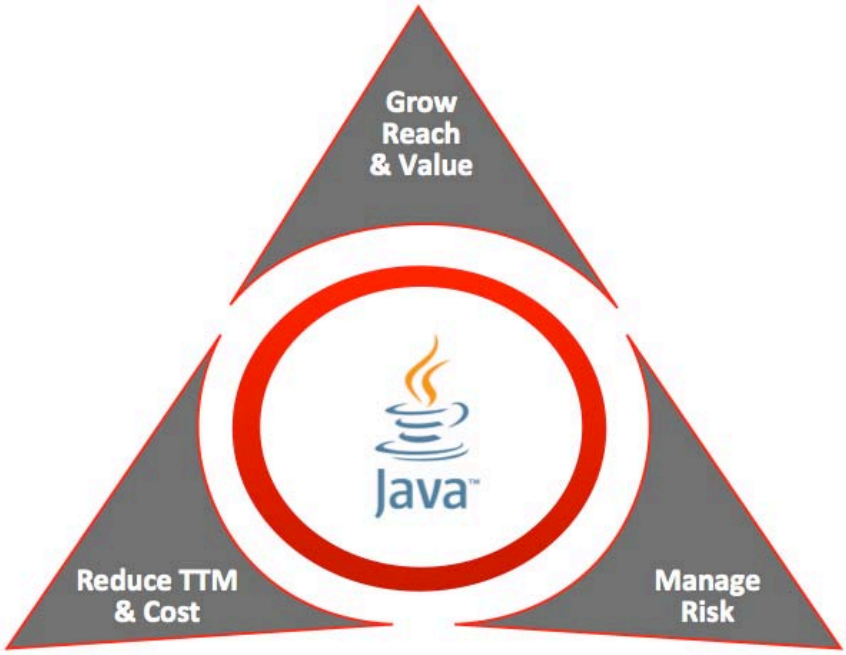

Figure 5. Oracle Java Embedded reduces costs and risks, and delivers value for end-to-end automated processes.

Safety and Security

The Java Virtual Machine (JVM) is a proven secure technology, providing a secure environment to run multiple applications, where each is isolated from the other, the operating system and other software components (Figure 6). The JVM also abstracts the complexities of varying server and embedded hardware platforms, providing a consistent, reliable, and secure environment for your applications. Oracle focuses on security, with frequent patches and updates across varying server and embedded hardware platforms, so you can focus on your solution.

The security features of Java and its libraries include secure messaging, user authentication and authorization, device identity, data encryption, public key infrastructure (PKI), code signing, and more.

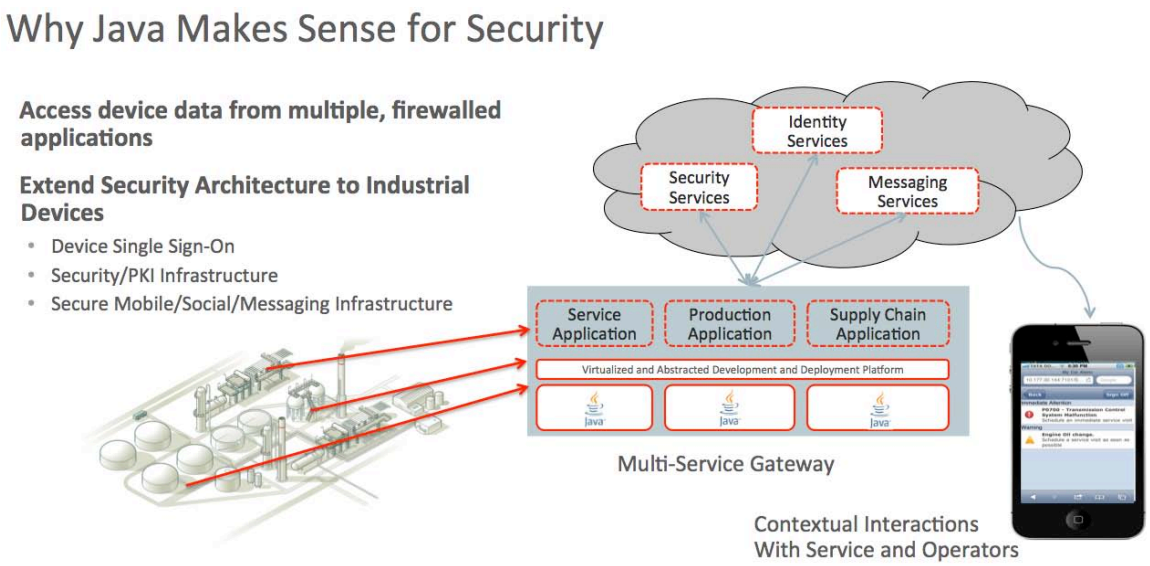

Figure 6. Oracle Java Embedded enables security and identity management throughout industrial automation solutions.

Additionally, the “write once, run anywhere” mantra of Java development applies to security as well. Developing componentized Java applications according to supported security standards means you’re less likely to need to build in new security measures as your hardware platform changes.

Total Connectivity Solution

Demand for data from the factory floor—or equivalent manufacturing and control processes—is increasing, along with the need to control a greater number of sensors, devices and machines along the way. The importance of reliable connectivity has grown along with it, and so have the risks if this data is lost. Java offers multiple robust communication services needed to reduce this risk, including those based on standards used in the industrial automation space. With rich third-party support, this includes Modbus, industrial Ethernet, 6LoWPAN, ZigBee, Z-Wave, controller area networks, Profibus and many others.

Java’s connectivity frameworks along with the wireless communication and web service APIs allow Java Embedded applications to work seamlessly, reliably and securely with cloud-based enterprise services. This capability is crucial when deploying remote devices and infrastructure as part of an IoT value chain. Often, the connection type chosen is based on multiple factors, including cost and device accessibility. Because Java supports a broad range of connectivity options, you can choose the type best for your solution.

The end result is that Java will provide you with the processing and communication needed to combine your business functions, supply chain management, asset management, production scheduling, and optimization with predictive maintenance and big data analytics, end-to-end. What’s more, Java is engineered to work equally across your embedded devices and gateways, and your back-end servers, abstracting the communication and hardware differences for ease of development.

Java-enabled Cellular Connectivity

When cellular modems are embedded in manufacturing or factory equipment, the equipment vendor can perform configuration and fine-tuning remotely, saving time and costs. Cellular connectivity enables the service partner to perform remote and predictive future maintenance to minimize downtime. Continuous monitoring enables errors to be detected and addressed as soon as possible, and in many cases predicted, to help avoid further damage. Java Embedded applications can run directly on cellular controller chips from multiple vendors, easily enabling this and other custom functionality. The number of cellular-capable devices and equipment installed in automation solutions has increased steadily since 2012, and is forecast to continue growing for the next four years (Table 1).

Units (1000s)	2012	2013	2014	2015	2016	2017	2018
Devices:							
» ***Factory automation***	270	280	310	360	450	610	820
» ***Process automation***	450	480	550	640	760	990	1,280
TOTAL	720	760	860	1,000	1,210	1,600	2,100
Connections:							
» ***Factory automation***	760	930	1,140	1,380	1,700	2,170	2,770
» ***Process automation***	1,240	1,570	1,960	2,420	2,900	3,530	4,330
TOTAL	2,000	2,500	3,100	3,800	4,600	5,700	7,100

Table 1. Industrial automation cellular-enabled devices by vertical, 2012-2018 ("Industrial Automation and Wireless M2M," M2M Research Series 2013, *Berg Insight).*

Ultimate Flexibility

To maximize the benefits of IoT, you require full flexibility in terms of where processing is performed. For example, it's generally most efficient to process data close to where it's captured. Oracle offers the ability to analyze events at the right location, in the cloud or on-site with embedded devices, depending on the relative value and time sensitivity of the data. The flexibility of Java Embedded is ideal for intelligent controllers and autonomous systems, as it enables *more* processing and decision making to take place at any remote station.

Part of the Java innovation and value proposition for industrial automation is its ability to quickly and securely provision new sensors, controllers, and other components within the automated process. If your current platform doesn't allow you to safely provision and manage your distributed IT, then you risk losing future revenue if you cannot react quickly enough to changes in markets and competition.

With Java, you can add new applications and update already deployed applications even after your solution is in use. This allows your globally deployed system to evolve to future needs over time via automated software updates. Adding to this, Java Embedded supports remote device management, including the ability to update the JVM, its libraries, and applications remotely, reliably, and securely.

Reliability and Availability

Oracle Java SE Embedded is a widely used and vital platform that offers industry-best reliability, performance, throughput, security, and cross-platform support. Relied upon to run critical applications, Java supports many types of systems ranging from key business functions to robust and secure embedded devices. These include intelligent network equipment that can never fail, military defense systems, key financial systems, and more.

Hardware Abstraction

The Java Embedded Virtual Machine offers an abstraction to underlying details and changes to embedded hardware, including the wide range of industrial controllers, sensors, and gateway computers used in industrial automation. This provides greater flexibility when deploying multiple forms of embedded hardware over time or across countries, even when the original reference system is no longer available. Existing Java applications can be deployed on new embedded systems with minimal or no changes.

For developers, Java allows you to decouple your application from the multitude of variations of hardware and operating systems in the embedded world. You just use Java and its single set of tools to focus on business value and time to market, regardless of hardware platform.

Optimized for Embedded Systems

Oracle Java Embedded enables intelligent devices (such as industrial controllers) to be developed rapidly and at lower cost, easily resolving many development and application issues. This includes easy integration with enterprise and other environments.

Oracle is focusing on helping the market reap the benefits of the transformation to smarter devices both on the production floor, and within the enterprise (i.e. enterprise applications). By running on the latest energy-efficient embedded hardware platforms, Java helps you build applications that consume less power, and automate and control edge devices to further save energy costs.

Maximized Innovation

According to both TIOBE and the IEEE (Figure 7), Java is continuously ranked as the most widely used development language in the world with more than nine million developers, and is used to develop a wide range of applications from enterprise to embedded.

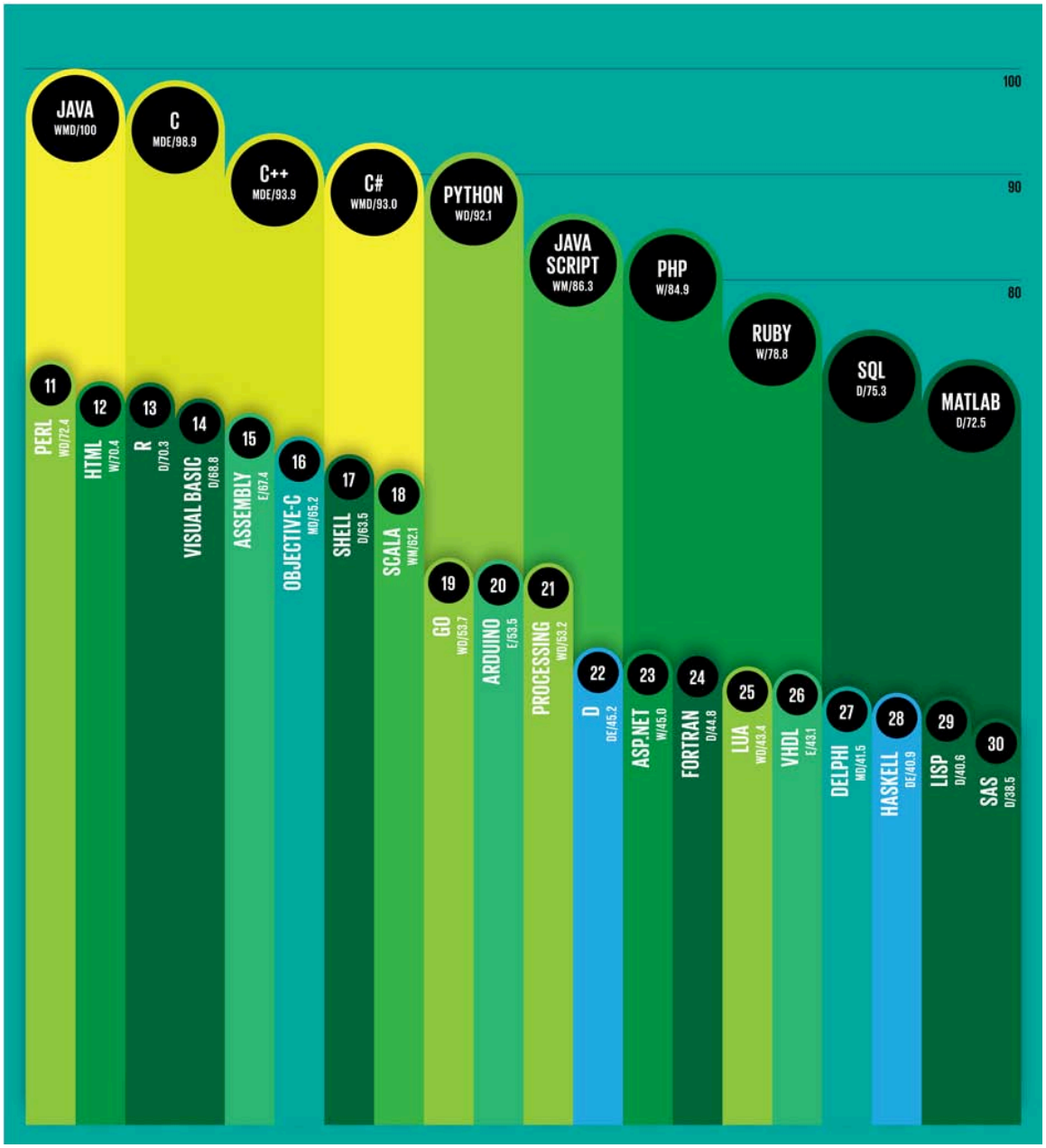

Figure 7. IEEE Spectrum's 2014 top-ranked programming languages.

As the automated industrial economy demands new innovations and advancement, finding available talent will increasingly become a challenge (Figure 8). Being able to leverage Java's large pool of talent and tools will both better enable this innovation, and reduce costs as you standardize your development end-to-end.

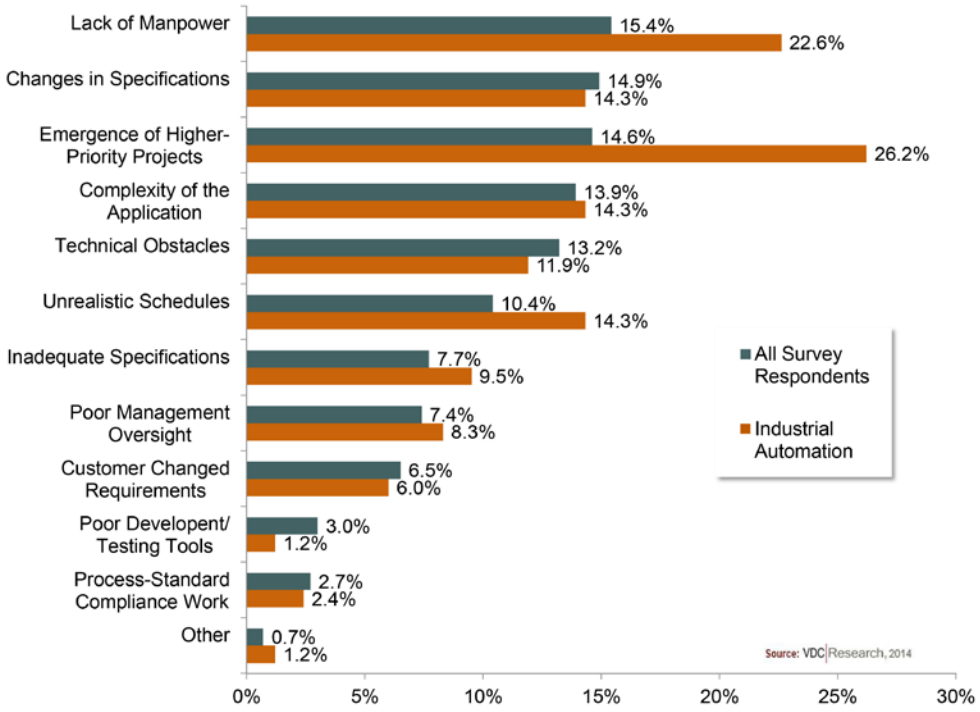

Figure 8. The top reasons for delays in industrial automation projects ("Enabling Innovation in Industrial IoT Systems," VDC Research, 2014).

Java provides the opportunity to have teams focused on controller software, communications gateways, human-machine interfaces, and back-end data collection and analysis using the same tools and environment. No other development platform can provide this unique set of values.

Java Reference Architecture for Industrial Automation

Oracle has defined a reference architecture to illustrate how Java Embedded can solve many needs in the automated industrial economy. This architecture serves as a guideline for the multiple use cases to which Java can be applied, and is meant to be adjusted to the specific use cases in the industry. For instance, Figure 9 illustrates how Java can be used to integrate new IoT functionality into a process with an existing system, showing a solution that leverages TCP-IP or industrial automation-specific protocols such as OPC Unified Architecture (OPC-UA), an industrial communication protocol for interoperability developed by the OPC Foundation.

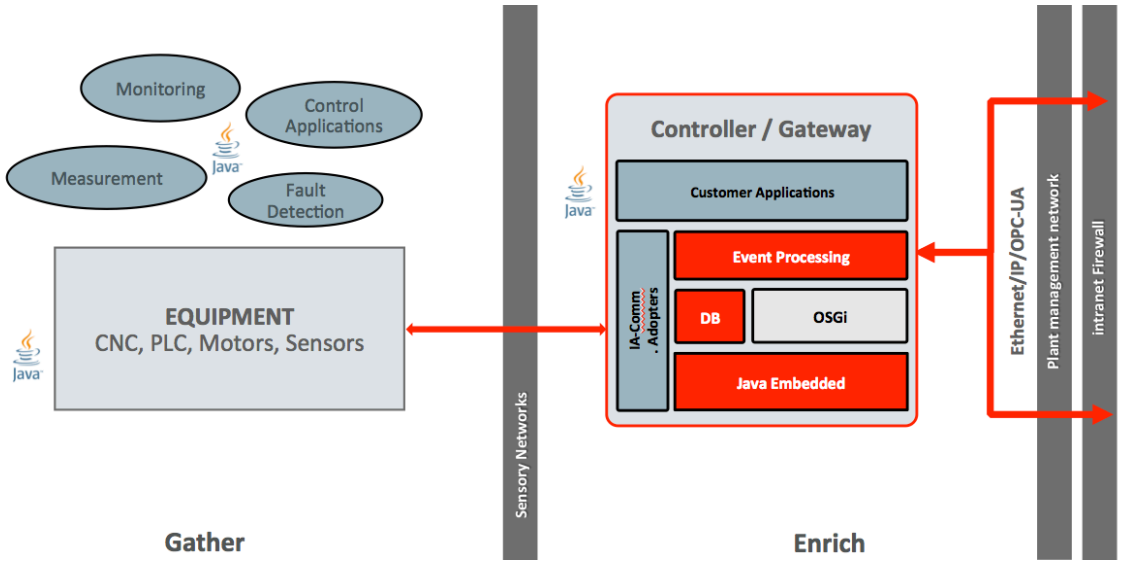

Figure 9. The Oracle reference architecture for industrial automation controller-to-enterprise integration.

The gateway in this architecture is an industrial controller or higher-end system that can convert from OPC-UA to a backend system, in a controller-to-enterprise scenario. Java-based gateways run real-time analytics that connect multitudes of devices and sensors via the varying protocols used in industrial automation. This saves costs and adds efficiency when integrating edge devices of all types, while helping to reduce network requirements and overall latency.

As shown in Figure 10, the gateway software may execute on the same physical controller as the OPC-UA server or in another slot of the industrial controller.

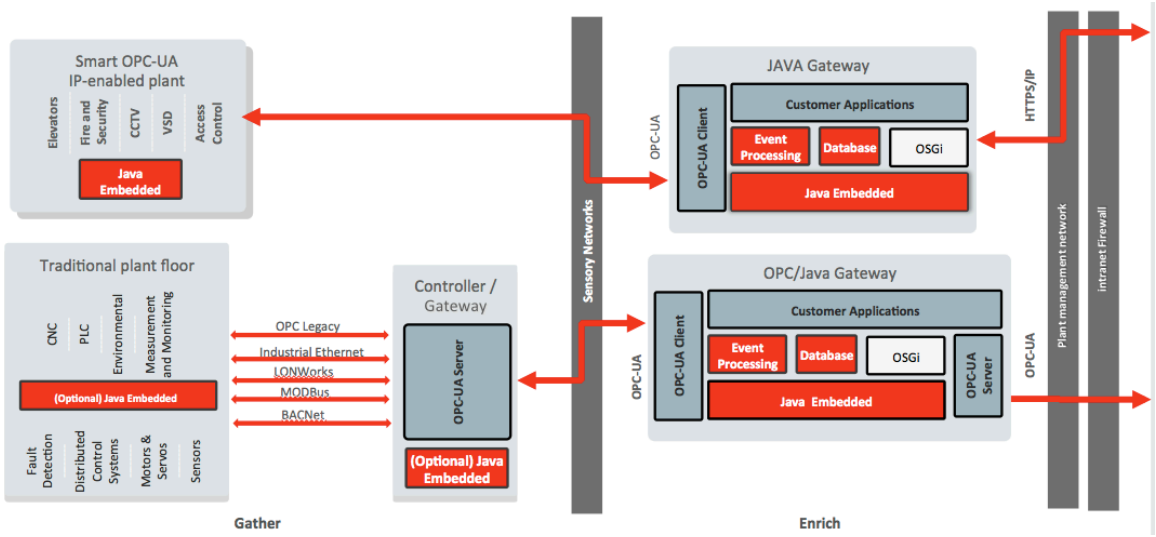

Figure 10. Oracle's reference architecture using Java for industrial automation with OPC integration.

Oracle's architecture covers and supports multiple applications within a single industrial controller, or distributed across multiple embedded computers and devices with high-speed reliable communications. Example use cases include:

- Data gathering, aggregation, and reporting on various performance parameters, such as belt speed, temperature, pressure, power consumption, and so on
- Localized analytics to process this data at the point of capture for enhanced reporting, enrichment, and alerts
- Cost-based communication routing, to ensure reliable communication starting from the least-expensive connectivity options to others as needed; this includes the use of embedded cellular for seamless communication failover if wired or other connections are severed
- Real-time alerting in case of fault detection
- Digital dashboards for distributed HMIs

To ensure safety and security of the systems implemented and managed, Java Embedded provides the following comprehensive set of industry standard implementations:

- Certificate-based security, Java cryptography extension with crypto acceleration, and near field communication (NFC) support
- Java secure sockets extension (JSSE) for secure communication
- Java authentication and authorization (JAAS) for user, device, and data identity
- Public key cryptography standard (PKCS-11) for data encryption
- Security and trust services (SATSA) for additional encrypted security features and communication capability

The figure below illustrates the event flow for typical industrial automation use cases such as remote device authentication, sensor data acquisition and processing, the management of devices including knowing their current status, and the reconfiguration of services and rules to adjust processes based on feedback.

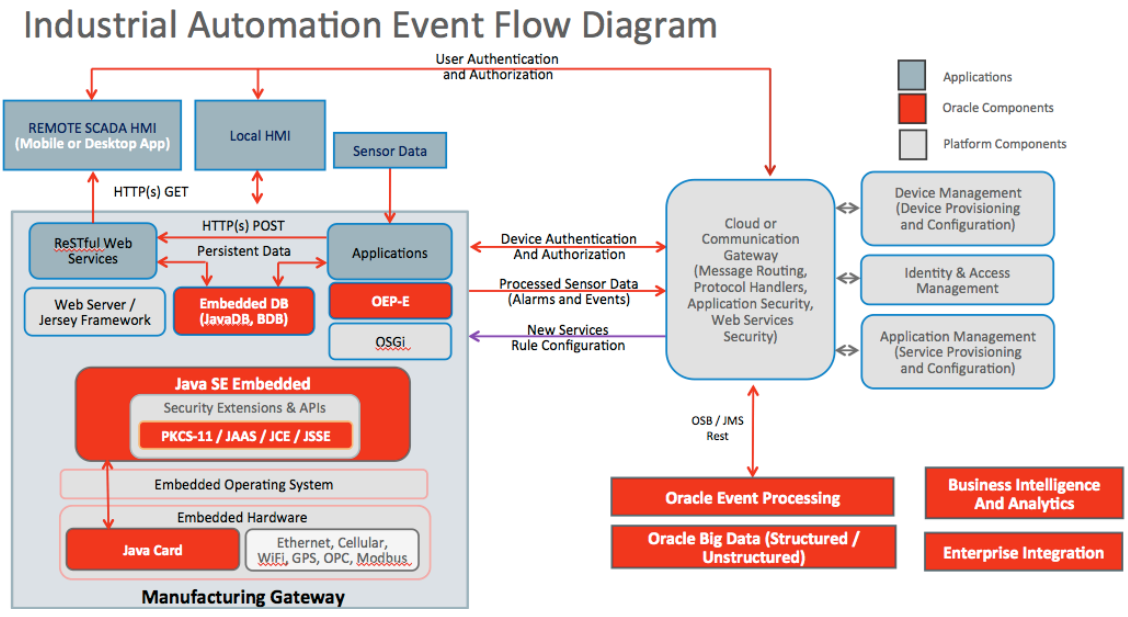

Figure 11. Sample industrial automation event flow diagram in a Java Embedded-based system.

Additionally, the Oracle reference architecture for Java in industrial automation supports integration through RESTful services, embedded SOA-based web services, secure local storage of data, and integration with enterprise systems per the figure below.

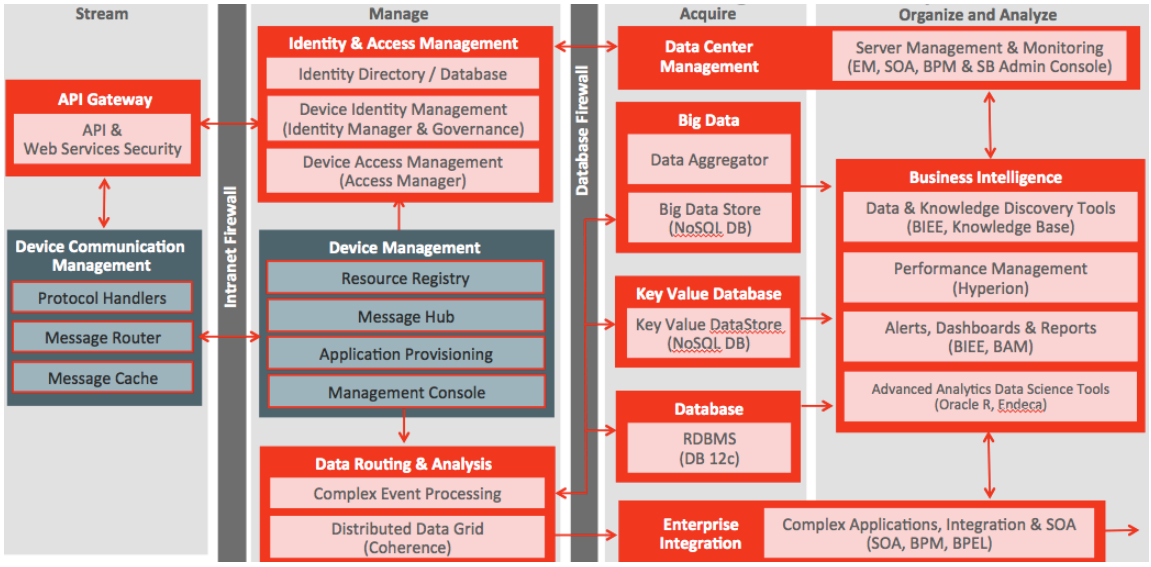

Figure 12. Oracle Big Data components and industrial automation enterprise integration.

With this architecture, Oracle Java Embedded delivers the following industrial automation business benefits:

- **Data management:** Ability to filter, analyze, and correlate sensor data and take action on the large amount of data generated
  - Real-time situational awareness, faster decisions, and immediate actions locally at the machine level and the enterprise back end
  - Agnostic of event sources, destination or underlying communication layer
  - Tooling and event flow monitoring
- **Remote device management:** Simplified and optimized network driven by remote device and application life cycle management
  - Application distribution and lifecycle management
  - Real-time device monitoring
  - Service management and diagnostics
- **Embedded system diversity:** Flexible architecture allowing for supporting applications to run on a variety of devices from multiple vendors, with minimized application maintenance costs
  - Consistent, Java-based application development environment
  - Support for the range of devices from small embedded to enterprise-level servers
  - Application distribution and lifecycle management
- **Security:** Critical data and applications secured on an open and integrated platform connecting devices to the enterprise network
  - Device enrollment and management
  - Access control, certification and compliance
  - Fine-grained entitlements and policy management

Java Beyond the Industrial Controller

The use of the cloud and big data analytics with advanced reporting is growing exponentially in industrial automation. For industrial controllers, Java Embedded is your foundation for configuration, programmability, and control. Beyond these critical systems, Java can handle big data collection, analytics, and visualization (Figure 13).

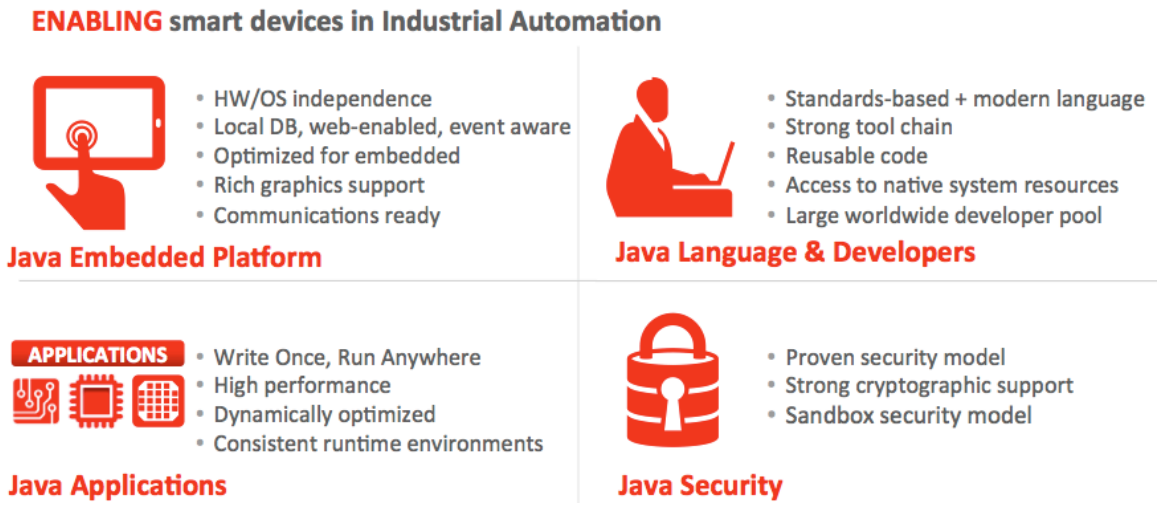

Figure 13. Java in industrial automation goes beyond controllers and powering the Internet of Things.

With Java Embedded and Oracle's Internet of Things platform you can quickly deploy applications that:

- Monitor local scenarios to improve global production
- Make smarter decisions by including local context
- Enable secure point-to-point communication in decision-making processes
- Connect cloud services using well-known enterprise productivity tools
- Enable new service providers related to machines and operators
- Implement predictive maintenance to reduce or eliminate downtime and improve spare parts inventory management
- Enable video analytics, where motion and still images from continuous manufacturing lines are monitored by machine
- Provision machinery, devices and computers at scale using cloud-based remote connectivity and configuration
- Use big data and analytics to enhance energy management, just-in-time manufacturing, demand-driven manufacturing, and predictive manufacturing

Getting Started with Oracle

The phrases “machine-to-machine” and the “Internet of Things” are not buzzwords anymore; they’re proven key industry differentiators. Oracle Java Embedded is the disruptive technology that gives manufacturers and facility operators the ability to innovate and meet the challenges of process automation, including flexibility, security, modularity and updateability. Java Embedded is engineered and optimized to meet the unique challenges of intelligent devices that unlock the business value of increased automation.

An open, standards-based platform with an unequalled developer ecosystem, Oracle Java Embedded makes it faster and more affordable to get innovative, reliable, and secure industrial automation solutions to market and provide the long-term support for success. Industrial communications is the heart of industrial automation, and Oracle’s Java-powered fast data and edge analytics are becoming just as critical. Now is the time to monetize analytics in the automated industrial economy with Java.

To learn more, visit oracle.com/goto/javaembedded and oracle.com/iot or read the brochure, Oracle’s Internet of Things Platform: Solutions for a Connected World.

Oracle Corporation, World Headquarters
500 Oracle Parkway
Redwood Shores, CA 94065, USA

Worldwide Inquiries
Phone: +1.650.506.7000
Fax: +1.650.506.7200

CONNECT WITH US

blogs.oracle.com/oracle
facebook.com/oracle
twitter.com/oracle
oracle.com

Hardware and Software, Engineered to Work Together