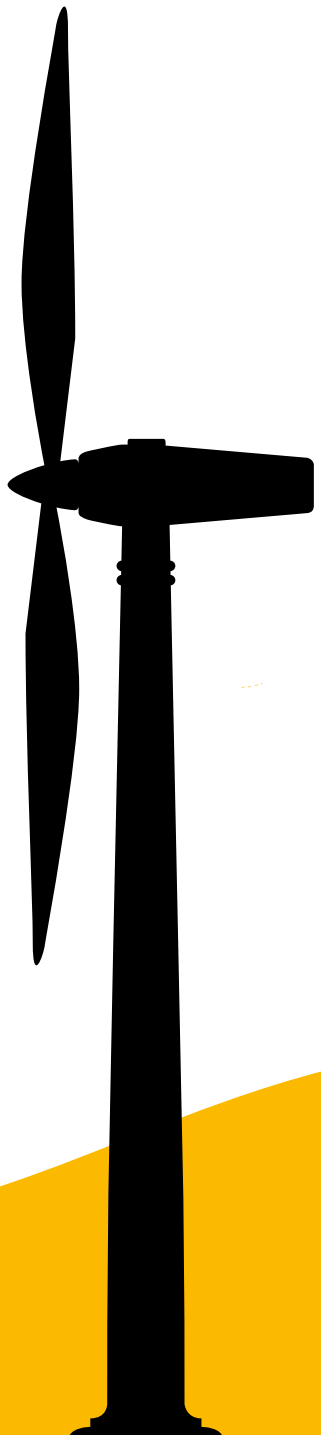
SAP Thought Leadership Paper
Internet of Things

SAP Brings You the Internet of Things for Business

Connect, Transform, and Reimagine Business in a Hyperconnected Future



The Best-Run Businesses Run SAP®

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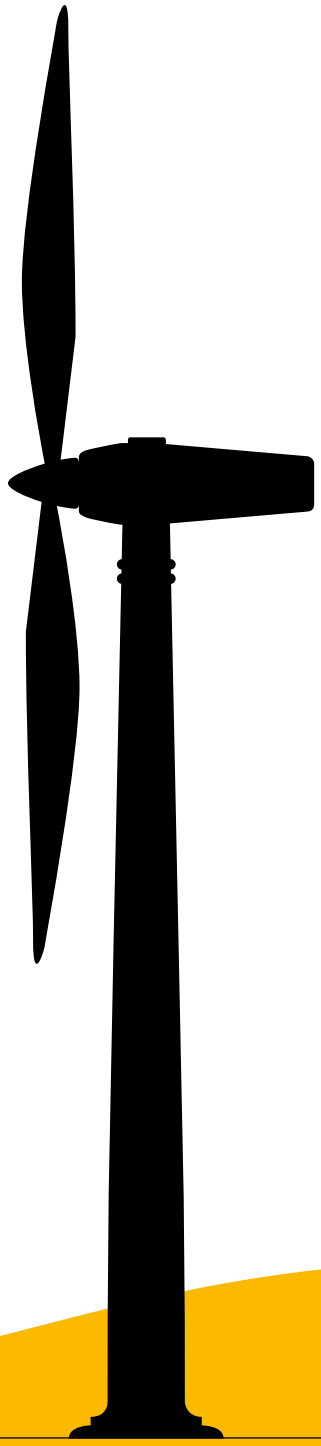
The Internet of Things (IoT) will forever change our personal and professional lives. Embedded intelligence in a growing network of connected devices will increasingly connect people and businesses to **everything else** – and become the very fabric of a networked economy. This paper shares insights into IoT trends, opportunities, and technologies and discusses how SAP® solutions for the IoT provide what's needed to generate intelligence from connected things, people, and devices to optimize processes and operations.



The Networked Economy

Metcalfe's law teaches us that the value of a communications network increases with every new node that joins the network. With only two phones on a telecommunications network, the value of having a phone is rather low. When billions of phones exist on the network, having a phone is a gateway to more conversations than anyone could have in their lifetime.

Over the past decade, we've seen Metcalfe's law demonstrate its power in the realm of the Internet. The growth of social networks is one example of this phenomenon at work. Facebook, once a tool for college students to connect with each other online, has become one of the cornerstones of the Internet, providing social context to many of our everyday online interactions. Facebook's existence as a university fad seems a distant memory.

Jump ahead 10-plus years, and we are beginning to see enterprises take advantage of this same principle. They are creating value by leveraging hundreds of millions of potential connections on the Internet. For example, online professional networks have streamlined the act of recruiting the best talent. Business networks have prospered, with millions of companies connecting their supplier, customer, and payment systems to seamlessly engage in online, collaborative commerce. And more recently, we're starting to see massive volumes of connected sensors and smart devices leveraged to transform business models and simplify complex tasks. This is the Internet of Things (IoT), and it will increasingly connect people and businesses to everything else to become, in essence, the very fabric that supports a new **networked economy**. When these changes are coupled with improvements in network infrastructure, Big Data analytics, and smart applications – all connected in the cloud – businesses will enter the era of true hyperconnectivity.

Business transformation in the IoT ecosystem depends on software optimized for edge computing, machine-data storage, real-time analysis, and connectivity.

The Internet of Things for Business

The number of Internet users worldwide has grown enormously over the last 15 years and is now estimated to be close to 3 billion. But even more striking is the vast array of intelligent devices that are now connecting to the vast information network around them. Estimates vary, but many analysts speculate that the number of connected devices could be more than 50 billion by 2020 – extending the reach of software-enabled insight by an order of magnitude.

Along with the growth in connected devices comes a wide array of opportunity. For the first time in modern history, insight can be offered to businesses and consumers wherever products exist. Devices ranging from connected toasters to connected turbines can analyze their own contextual information and advise customers about optimal ways they can be put to use. While we've long envisioned these types of "intelligent devices," they are now a reality thanks to recent gains in the realms of connectivity, sensor technology, and real-time data processing for a wide array of products. It's never been cheaper, easier, or faster to embed software in a product and deliver insight.

The act of adding intelligence to an ever-expanding network of connected devices is poised to create tangible value for enterprises around the globe. Whether there will be 30, 40, 50, or 60 billion connected devices by 2020, the implication is the same: the way everyone does business will change.

For supporting evidence, look no further than the impact on enterprises. Numerous analysts and other experts have weighed in on the potential impact of the Internet of Things, citing trillions of dollars in financial impact, with 50% of the world's industries being affected.

SAP is taking an active role in this evolving new market. As the creator of the software used by companies to run their core business operations, SAP expects to be at the center of the changes in business processes made possible as billions of connected devices come online. Whether companies use the Internet of Things to transform their logistics, customer engagement processes, or internal ticketing systems, the applications built to take advantage of the new machine data must be able to interact with SAP solutions.

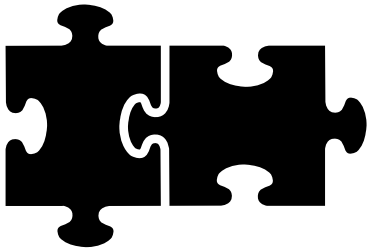
SAP's goal is to enable the **Internet of Things** for our customers to help run their businesses better. To accomplish this task, we are working to make it even simpler to **connect** the new generation of Internet-enabled devices in the cloud. We are delivering new products that support our customers as they **transform** their existing business processes by harnessing the machine data generated by their connected devices. And we're delivering the platform technology needed to **reimagine** customer experiences from the ground up. When your child's car seat can tell you if your child is at risk of catching a cold, the value of the car seat changes dramatically.

Helping our customers put the IoT to work for their businesses requires SAP to work with a host of new partners. Never before have so many different types of vendors been required to support new ways of doing business. While SAP technologies and applications will play a critical role in this environment, we have a deep appreciation for members of our community that will help us create this new value for our customers.

In the remainder of this document, we'll walk through the details of our point of view on this emerging area of the technology world. We'll share our thoughts on:

- What technologies will be required to deliver robust and compelling solutions
- What types of alliances need to be forged to deliver business value to enterprises
- What solutions can be expected in this new world of connected devices
- How SAP expects to invest in its ecosystem, developer community, and platform to maximize the value our customers and software partners can deliver to the market

We look forward to reader feedback. Our customers and developers that leverage SAP technologies and applications can best predict whether our proposed approach is compelling. We believe this is the path forward. We believe our approach to technology, ecosystem development, and value creation with our customers will help all of us capitalize on the Internet of Things together. But, at the same time, we also welcome everyone's feedback and are primed to listen.



Solutions based on new layers of connectedness can transform operational processes, unlocking enormous value through greater efficiency.

Engage with us and share your thoughts on the Internet of Things community, accessible at **scn.sap.com/community/internet-of-things**.

AN IoT REFERENCE POINT

As we move through our perspective on this increasingly significant technology market, we have identified the capabilities solution providers need to have in this evolving market, as shown in the following table.

Any solution deployed to take advantage of smart, connected devices starts with the device. At the edge of the network, there needs to be some digitally enabled piece of hardware collecting information, sending that information home for central processing, or processing it at the edge. That device then needs to be connected in some way – for example, through the cloud. Only by interpreting the hardware's unique signals and transmitting them over wired or wireless pathways back to a central environment can that data be made sense of and acted upon centrally.

Any core IoT system will also require data storage capabilities that enable not only a nearly infinite store of low-value data but also high-performance storage for the data that is critical to real-time business performance.

In addition, IoT solutions require access to that new machine data as well as an ever-expanding array of other business information sources to provide true business value and meet users' expectations.

In the following sections, we explain how SAP is delivering solutions that can execute against these broad requirements, where we intend to partner, and how we are already working with customers to deliver value.

Technology	Capability
Applications and analytics (inherently connected)	• Use-case-specific business applications • Device-data visualizations and analytics
Application platform	• Application-enablement services • Access to device-data libraries and core application integration
Data platform	• Intelligent data storage enabling efficient capture and use of device data
Connectivity	• Middleware and protocols to interpret data from connected devices • Connectivity for data transmission
Edge devices (edge software and hardware)	• Devices with sense and response capabilities • Embedded software to manage edge processing and data transmission

SAP Solutions for the IoT: Connect, Transform, and Reimagine Business

To help our customers join the IoT revolution without disrupting their existing business processes, SAP will continue to offer line-of-business and industry-specific solutions that build on our existing footprint in core transactional business solutions, assets, and capabilities. Presently, the prioritized IoT solutions support Industry 4.0 for manufacturing, predictive maintenance, and connected logistics. These core IoT applications will be integrated with SAP Business Suite applications that customers are running today – both on premise and in the cloud.

INDUSTRY 4.0 AND RESPONSIVE MANUFACTURING

The Internet of Things is being called the fourth industrial revolution, as it allows the physical and digital worlds to converge through all layers of production to completely transform the way manufacturing operations are run.

This is critical for a number of reasons. First, industrial production requirements are changing. As customers grow savvier, they are demanding products that more precisely meet their expectations. And second, companies face increasing pressure to manufacture at more competitive prices. To adapt to these changing conditions, the fields of systems engineering, production IT, and business systems must fuse together more closely than ever to achieve higher levels of efficiency.

To address these challenges, SAP has a comprehensive set of manufacturing solutions that form the foundation of our Industry 4.0 solutions. SAP is focusing on the automation of business processes in manufacturing – processes orchestrated by transactions on the shop floor as a basis for seamless integration of connected machines with SAP solutions. The SAP Manufacturing Execution and SAP Manufacturing Integration and Intelligence applications enable responsive manufacturing and a high degree of integration between the shop floor and the top floor.

The Industry 4.0 vision is not limited to automation of a single production facility. It incorporates integration across core functions, from production, materials sourcing, supply chain, and warehousing all the way to sale of the final product. This high level of integration and visibility across business processes will enable greater operational efficiency, responsive manufacturing, and improved product design.

More than 1,400 SAP customers are using manufacturing solutions from SAP to automate their manufacturing operations. Visionary companies like Harley-Davidson Inc. are at the forefront of Industry 4.0 innovation with its use of end-to-end digital engineering. In Harley-Davidson's new manufacturing facility, every machine is a connected device, and every variable is continuously measured and analyzed. Equipment provides performance data that the manufacturing system uses to anticipate maintenance issues before machines break, which minimizes workflow interruptions. Harley can tell to the nearest tenth of a second how long it takes to install every component on a motorcycle, and the system alerts floor managers about issues at the individual component level. Harley even measures the temperature, humidity, and the RPMs of the ventilation fans in the buildings. All this data is analyzed continuously to identify factors that will improve efficiency and throughput.

In this new, state-of-the-art facility, Harley-Davidson can build 1,700 bike variations on one production line and ship a customized bike approximately every 90 seconds. Harley-Davidson now manufactures 25% percent more motorcycles with 30% fewer people, and the locked schedule to build a motorcycle has been slashed from 21 days to 6 six hours.

PREDICTIVE MAINTENANCE AND SERVICE

Owners, operators, or manufacturers of machines and equipment often have to manage their assets at remote sites, limiting their visibility into performance and usage. If a problem occurs – for instance, on a construction crane or wind turbine – it is often costly to identify and even more costly to address in a timely way. And if maintenance crews fail to resolve an issue, it can result in system failure, equipment downtime, or hazardous conditions for workers.

The SAP Predictive Maintenance and Service solution, based on SAP HANA® Cloud Platform, allows equipment manufacturers and operators of machinery and assets to monitor machine health remotely, predict failures, and proactively maintain assets. Specifically, owners, operators, or manufacturers of machines and equipment can collect sensor and telemetry data from remote assets and merge it with business data, such as past maintenance records and contextual data (such as weather and traffic data). They can then analyze this data to find patterns and root causes for failures – insights that help them predict when an asset or equipment will fail and proactively apply preventive measures to prevent the failure from occurring.

SAP Predictive Maintenance and Service allows asset owners and operators to monitor asset performance, reduce unplanned downtime, and manage asset-related risks while aligning priorities between operations and maintenance. Equipment manufacturers can analyze warranty claims, proactively manage spare-part stocks, assign the right technicians, and optimize product design and manufacturing. Dealers and aftermarket service providers can offer add-on services for asset operators and optimize services delivery, maximize machine uptime, and raise service efficiency – all while reducing costs.

For SAP customers in manufacturing-based and asset-intensive industries, a predictive maintenance and service solution is a natural extension of processes already supported by SAP Business Suite software, such as enterprise asset management and customer service management. For example, SAP Predictive Maintenance and Service helps customers experience more reliable asset availability, greater customer retention, better customer service levels, and higher service-contract renewal rates.

Learn more about **SAP customers innovating with the Internet of Things**.

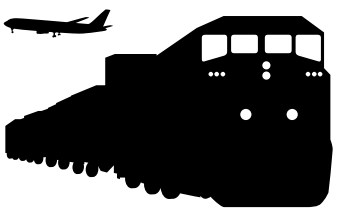
Kaeser Compressors Inc., one of the world's largest suppliers of compressed air systems, is delivering a high level of customer service by using a predictive maintenance solution powered by the SAP HANA platform. This solution enables real-time monitoring of parameters – such as power consumption, operational availability and safety, and compressed air quality – from a customer's air station against minimum and maximum allowed values. Service engineers can analyze this real-time data from a portal without having to visit the customer site. This accelerates the resolution of any problem, keeping customer operations reliable and efficient.

This predictive maintenance solution has enabled Kaeser to respond proactively to customers' maintenance needs and provide higher levels of service with increased equipment uptime, faster time to resolution, reduced operational risks, and accelerated innovation cycles. Most importantly, Kaeser has been able to align its products and services more closely with the needs of its customers.

CONNECTED LOGISTICS

Population analysts predict that more than half the world's population will live in cities by 2020. City infrastructures are already struggling to meet current population levels and resulting traffic. Existing infrastructures, such as roads, railways, waterways, and airspace, have limited capacity and must be optimized to meet the rapidly growing demand.

The IoT can help address this societal and economic challenge by bringing major transformation to traffic and transportation operations, resulting in greater efficiencies from existing physical infrastructures – and eventually, more scalable and sustainable cities. SAP Connected Logistics software is an innovation in SAP offerings for transportation and supply chain management that provides new levels of collaboration and transparency across business entities in a logistics hub. With this software, SAP solutions can support the ability to monitor the movement and location of physical assets and provide transparency across the ecosystem of business partners involved in these movements, which is a key enabler for location-based services and tracking applications used for fleet management and remote tracking.



To participate in the world of IoT and create business value, an enterprise must address IoT solutions within business operations and IT architecture.

Learn more about **SAP HANA at Kaeser Compressors**.

SAP Connected Logistics allows companies, institutions, and individuals dealing with ever-increasing time pressure and growth constraints to gain greater – and even real-time – visibility into their complete business network, regardless of whether they have a direct business relation to one another or not. Connected logistics will merge real-time location data from the various parties of a logistics hub in one place and allow them to communicate more efficiently and gain significant cost efficiencies. For example, by enabling better orchestration, SAP Connected Logistics can help shorten wait times for pickup and delivery and support better utilization of existing physical infrastructures, resulting in fewer delays within responsive supply chains seeking to meet real-time demand.

Consider the benefits being realized by the **Hamburg Port Authority** (HPA), the largest port in Germany, which handles approximately 10,000 ships and 9 million containers every year. Sascha Westermann, head of intermodal operational traffic management at HPA, anticipates that the port will be handling 25 million containers by 2025. The main challenge is lack of expansion space. "We can't increase the port's surface area, so we need to look at ways to become more efficient in the space that we have," explains Westermann.

Along with HPA, SAP is working with partner **T-Systems International GmbH** to build a logistics business network solution leveraging T-Systems' TelematicOne platform. This platform unifies telematics data to one interface and reports geo-fence alarms to the connected logistics application from SAP. This application also enables truck drivers to receive up-to-date information about incidents and the current parking situation using mobile tablets.

Using this joint solution, HPA now has real-time visibility across more than 400 entities in its logistics business network. The port has visibility into current street conditions and communicates that information to trucks. This is added to up-to-date parking space information from parking space providers. If the ship is delayed and the container gate is not open, the driver is informed to wait at a parking area. As the ship arrives, the container gate notifies the driver, who is then given the optimal route to pick up the shipment. This high level of connectivity throughout the network results in lower wait times, faster turnarounds, more efficient route planning, and lower fuel costs.

Learn more about **Hamburg Port Authority's solution**.

Technical Foundation for the Internet of Things

The Internet of Things goes beyond operational monitoring and control. Rich operational context from connected devices, representing the collective wisdom of several systems, can be used to optimize existing business processes and enable new innovations and business models. For example, cars can recommend next stops based on driver preferences. A network of vending machines can propose real-time offers based on customer's purchase history. Insurance companies can offer tailored insurance plans based on actual driver performance. Manufacturers can make a custom product – called "manufacturing to a lot of 1" – at scale. And companies can track, trace, and monitor their extended supply chain operations. The opportunities are enormous, but the questions most often asked include:

- What technologies are required to take advantage of these types of solutions today?
- How do we piece together a system of connected things that can help us transform our business model?
- What are the types of solutions that could help us drive down cost, increase revenue, or gain valuable customer insight?

The functional components of the core IoT applications available from SAP, as described above, can be used separately as foundational services for building other applications. For example, functionality from SAP Predictive Maintenance and Service can be used across remote machine monitoring, geo-location-based tracking and tracing, and consumables management.

But more broadly, SAP technology enables partners and developers to build new horizontal and vertical applications based on SAP HANA Cloud Platform. A software development kit (SDK) enables these new applications to reuse core SAP software or components as services. Partners can also use the SAP HANA Cloud Platform for developing Java-based applications.

The following sections explain our perspective on the necessary technology and capabilities of an IoT platform.

DELIVERING IoT SOLUTIONS: AN OVERVIEW

The starting point of any IoT solution is the physical entity of interest: silicon. We're starting to see advances in technology in the areas of miniature sensors, communications, and compute infrastructures that make it easy for manufacturers to embed an ever-increasing set of smart sensors in increasingly sophisticated devices. We are also seeing the ubiquity of mobile networks that allow assets to connect while moving across large geographical spaces. And with the advent of energy-efficient devices, broadband communication channels, and protocols specially designed for information transport from and to endpoints, we're seeing a flood of data coming from the edge of networks (a concept we will explore later in more detail) to the processing centers.

Data transfer from the edge of the network to processing centers must take into account the variability inherent in device communication, which can range from high-frequency pulses to batch uploads. These methods for data transfer work whether there are consistent and stable communication channels or channels with intermittent disruptions. These variations are well-known and have led to highly customized and use-case-specific implementations. But Internet-based communication over public networks offers new solution models that, along with a promise of standardization, could lead to packaged solutions going forward.

Despite these challenges of device integration, if data is collected from an ever-expanding network of endpoints, it must be brought into a central space for processing. So it's critical that IoT solutions have the ability to store large volumes of historical and diverse data and respond in real-time to incoming data streams.

Information that is already summarized and made relevant to operational and enterprise decision making can be saved in a real-time data store for immediate access.

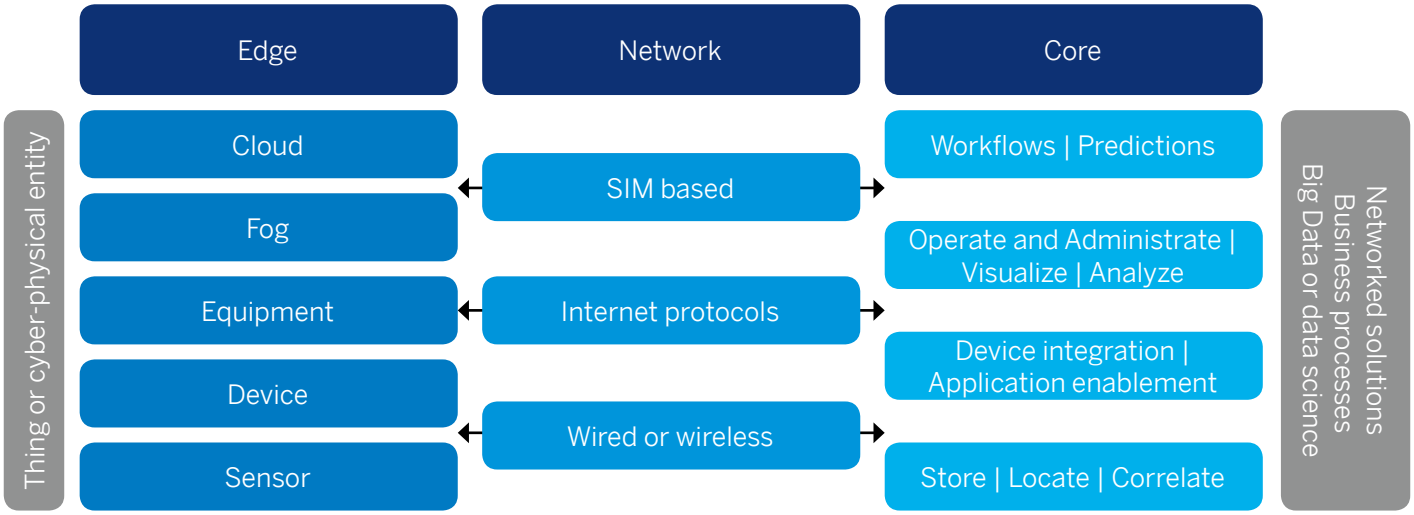
When business-relevant data is stored and accessible, advanced analytics (including predictive analytics) and machine learning techniques can be applied to it. These tools allow processing of new information that was previously unknown or ignored to detect patterns and risks. In fact, applying predictive techniques on top of the monitoring and automation support is what makes the Internet of Things game changing.

Three Domains of Interest

To simplify the IoT solution space, let's explore the three important parts of an IoT solution, as shown in the figure.

The three main parts of an IoT solution are the edge, the network, and the core.

Figure: The Three Components of an Internet of Things Solution



The Edge

Cyber-physical integration occurs at the edge of a network. There is a natural hierarchy of aggregation, starting from sensors and components all the way up to device clouds. In this hierarchy of information aggregation, organization, and contextualization, enterprises must make choices depending on what information can be delegated to the compute infrastructures at the edge and what information must be propagated to the central processing space.

The Network

Internet connectivity is ubiquitous and enabled by several channels of communication. As we consider the network required to enable the IoT, new and emerging themes from mobile networks and personal area networks need to be evaluated in terms of economics and scalability for specific scenarios:

- **Mobile networks** are integral because every smartphone is increasingly seen as an endpoint of the IoT as well as a consumption endpoint that informs mobile users about their interactions on the network. We are also starting to see increasing use of ruggedized, SIM-enabled devices that can be used in more challenging environments. As a result of this mobile proliferation, mobile network operators are starting to offer services for the provisioning and management of connected devices.
- **Personal area networks** encompass a variety of technologies geared toward wearables and short-range interactions. When it comes to consumer IoT, or interactions between people and smart things, personal area networks are attractive solutions because they offer low-energy consumption and meet the need for wireless digital connectivity.

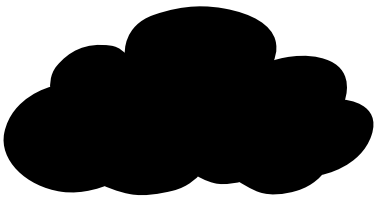
The evolution of packaged IoT solutions will be slow until we see simple, scalable, semantically rich, and developer-friendly standards emerge in the space of IoT connectivity. We are starting to see standards bodies and consortiums address this issue and work toward a uniform and scalable mechanism for network connectivity.

The Core

Most traditional enterprises have kept the operational technology (OT) world separate from the information technology (IT) world. This independence translates not only into different systems but also into different procedures and decision models.

The IoT is breaking down these silos, offering end-to-end visibility into all the data that can be used to operate efficiently and, as a result, deliver better value to customers.

IoT solutions can be experienced in the cloud, enabling enterprises to enjoy an optimized technology infrastructure for all business operations.



Bringing the Parts Together

To participate fully in the digitized world of IoT – and innovate in ways that create business value – each enterprise must determine how to address these three elements of IoT solutions within their business operations and information architecture. Given the pace of technological evolution, it is a challenge for any institution to do this internally from the ground up. Therefore, organizations should consider:

- Using an IoT-ready technology infrastructure to develop, deliver, and monetize IoT applications
- Establishing a rich partner and developer ecosystem to complement and extend the solutions that can be developed on the IoT foundation

These two paths coexist well and deliver value together. In the next section, we explore the key characteristics of an IoT-ready technology infrastructure for business application development. Based on the terminology in this section, we focus on the **core** of the IoT solution with some suitable extensions for the **edge**. This keeps the conversation focused on business transformation that will help organizations realize the promise of IoT.

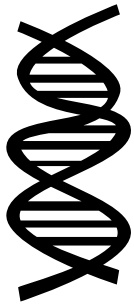
Building an IoT solution involves three main steps, or phases:

1. **Data integration:** This is the first and primary step. It brings a variety of data into a coherent, complete set – from the edge to the core – to offer the deepest and broadest insights possible.
2. **Data management:** This step, which brings together IT and OT infrastructures, requires special attention. Data management must address the challenge of managing large volumes of data, as well as layering on contextual information such as asset taxonomy and time and location data.
3. **Business innovation:** Once foundational data integration and data management are put in place, many types of business innovation are possible. Enterprises can create meaningful insights and reimagine their business models and customer experiences.

As an organization progresses through these steps, they can realize business value. Let's explore these three phases in more detail.

Data Integration

Data integration is the glue that connects the physical and the digital worlds. IoT-ready infrastructures must provide many ways to facilitate integration, as explored in the following sections.



The IoT allows physical and digital worlds to converge through all layers of production to completely transform how manufacturing operations are run.

Device Connectors

Every smart thing or product has its own unique dialect of digital integration. To report across a variety of devices, data needs to be normalized in a way that is useful for further processing. Until standards in communication protocols are established, we will continue to see several variants of data formats and protocols.

By creating adapters and converters that localize the variations, IoT device connectors serve three purposes:

- **Enable protocol translation:** This allows the unique device dialect of each connector to be transformed without loss of information into a protocol that is consistent with the service levels of a given scenario and understood by the relevant processing engines.
- **Provide a pluggable framework for edge compute:** A framework allows companies to push compute activities as close to a device as possible – for example, to enable real-time responses, data summarization, correlations across streams, or even autonomous operations across a community of devices. In such scenarios, this framework allows companies to plug in other relevant services.
- **Manage intermittent connectivity:** While connectivity is typically ubiquitous, in practice there are instances when the quality of connectivity is not optimal – for instance, when several geographically distributed things must communicate to enable product functionality. If poor connectivity hurts functionality, it can be disastrous. Companies must design for smart persistence and efficient data transfers once connectivity is restored.

Data Center and Third-Party Integration

Many vendors have started to offer device clouds, which are aggregations of data collected from various endpoints. These device clouds allow companies to augment their own data for even deeper insights and to enable new business models. They follow several of the standard integration models and best practices and include value-added services relevant to tracking, tracing, monitoring, and controlling devices.

Multiprotocol Connectivity

Due to the convergence of several development streams, today's connectivity environment is based on several protocols, and each is optimized for a different scenario. While the improvements in compute and connectivity offer flexible use of protocols, the plethora of connectors and connectivity cannot be wished away at the edge – at least not yet. So it's necessary to have a portfolio of connectors or connection protocols that can help onboard existing devices to an IoT solution. This is made possible with multiprotocol connectivity.

Operational System Integration

Process- and asset-intensive industries have standardized on a technology infrastructure that includes supervisory control and data acquisition (SCADA) systems, historians, manufacturing execution systems (MES), and so on. Any transformative IoT solution must integrate with existing operational infrastructures and provide mapping into enterprise systems to achieve complete integration between the two behemoth infrastructures within an enterprise.

Data Management

Once data integration is established, data management is the next priority. It's critical for IoT because edge devices can transmit data intermittently, as high-frequency pulses or periodic, large data dumps. The IoT infrastructure must have not only massive storage capabilities, but also compute and processing mechanisms that can scale as data volumes increase and vary in size. These capabilities should be able to scale in environments that are hazardous and where connections could be interrupted. Let's explore some key data management capabilities needed to manage data within IoT solutions.

Embedded Persistence

The need for smart persistence at the edge can be addressed by using embedded data stores. Ideally, these data stores should be a combination of a small footprint to address deployment on smaller devices, zero-administration overhead on remote deployments to address the issue of potentially inaccessible deployment, and reliable data synchronization support to allow for bidirectional communication. Embedded data stores can keep track of device configuration and persist data during intermittent connection failure. They can also be used to store executable modules that can participate in the lifecycle management of the software on the device or compute operations at the edge.

Stream Processing and Summarization

Even as devices send out heartbeat signals, there are significant opportunities for pushing compute functions closer to where the data is generated. Dedicated stream-processing mechanisms can support smart summarization of information, correlation across various streams, and pattern and anomaly detection, as well as scalability across several endpoints.

Tiered Data Storage

The amount of data generated from endpoints can vary anywhere from low kilobytes to high terabytes. Unless an IoT infrastructure has a smart data-storage solution, data sizes and growth in volume can rapidly overwhelm the infrastructure. What's needed is tiered data storage that supports different usage scenarios with different service levels. For example, an IoT solution may offer a variety of storage options to analysts, executives, and data scientists, such as a mix of in-memory, disk-optimized, and distributed and highly available data stores.

Series-Data Management

The time dimension of data from a connected "thing" is critical. Without that information, it is difficult to generate insights from data series. Typically, time series–enabled data stores are best suited for this purpose. These data stores maintain large amounts of highly compressed data and make the data accessible for use by advanced analytical tools with little overhead.

SAP's open approach to working with IoT partners makes it easier for our customers to find their path toward the ideal IoT solution.

Device-Data Management

The goal of managing device data is to integrate edge data with business processes and workflows. To do this, contextual data must be associated with device data using some type of system. For example, in a tag-based system, the standard taxonomies and naming conventions used in operational environments are also used to organize data so that it can be integrated into business processes and workflows. And in direct connection systems, name-value pairs arranged in a hierarchical format are used to integrate edge data with business processes and workflows.

Business Innovation

Having laid out IoT-relevant data management capabilities, let's focus on how to unlock the value of device data and use it to drive business innovation.

Visibility

All device data – which should be hierarchically structured into logical groups like devices, assets, or plant floor – can offer unprecedented insight into all operations across an enterprise. Classical operational infrastructures have achieved significant maturity when it comes to managing a complex, real-time, and highly reliable operational environment. But they are not necessarily able to onboard new, data-generating devices into their infrastructures, devices that are increasingly part of IoT solutions. Organizations need a way to incorporate new data streams into consumption streams – and with minimal cost.

IoT magnifies this requirement since the points of interest can now start to include smart devices that onboard themselves into the system and add to data streams. Thus, IoT infrastructures must provide visibility into the entire ecosystem of devices – both modern and classical – even as the number of endpoints grows exponentially.

Workflow

Device data can be extremely valuable for companies seeking new operational efficiencies. But the chasm between OT and IT often limits the efficiencies they can realize. To bridge this chasm, organizations need to bring edge device data into their core business processes – and enable bi-directional communication so that information and actions triggered by business processes can be propagated back to the edge. This requires standardizing on how edge and business data is integrated.

Analytics

Once the data is available for consumption and is amenable to new types of visual representation, static reports are no longer interesting. Consumers of this data want the flexibility to view, chart, drill into, and explore the data. Given the amount of information inherent in such a system, offering high performance during analytics and exploration is important for an engaging user experience.

Advanced Analytics: Predictive and Recommendations

The next step in extracting value from device data involves mining historical data for specific patterns. These patterns can then be used to derive insights about existing and future operations.

From an IT perspective, this requires having an infrastructure that's capable of supporting very large data sets and applying machine learning algorithms to them. The resulting models can be incorporated into operational flows so that as device data is received, the models can generate projections, forecasts, and recommendations – all examples of intelligence from the edge.

As organizations undergo digital transformations and integrate this intelligence into their operational environment, the fundamental principles of data-driven collaboration in the Web for e-commerce are firmly established. For instance, centralized governance and policy-driven data access enables businesses to participate in a financially interconnected and secure world. And this will ultimately drive the emergence of new kinds of business networks that enable high-value customer services – services that are enabled by device-data integration and the digital collaboration of diverse enterprises. In practical terms, this means, for example, that a customer registered with one business entity in the network can benefit from digital integration and e-commerce collaboration across all of the enterprises in that network.

Integration with Back-End Systems

Enterprises have realized significant efficiencies in operations due to use of SAP Business Suite software that runs their critical business operations. To drive value from the Internet of Things, it is important to integrate data from connected devices with core business data in back-end systems that run on premise and in the cloud. This additional context provides a stronger basis for data-driven decision making and for truly transforming core business processes.

THE SAP HANA PLATFORM: READY FOR IoT TRANSFORMATION

Each of the capabilities discussed above typically requires dedicated software and hardware to offer the varied service levels that an IoT solution demands. Every capability and function highlighted above can be realized efficiently within the SAP HANA platform and the SAP portfolio of solutions. SAP solutions for the Internet of Things, running on the SAP HANA platform, have the ability to integrate with core on-premise SAP and non-SAP back-end systems. SAP's open approach to working with IoT partners makes it easier for our customers to find their path toward the ideal IoT solution.

Because of SAP's cloud-first approach, IoT solutions can be experienced in a cloud platform as well, enabling enterprises to fully enjoy an optimized technology infrastructure for the entire scope of business operations.

The IoT Ecosystem

Central to the value of any IoT solution is the network of value providers associated with it. To illustrate this concept, consider an example such as fleet tracking. For over 20 years, companies have tracked commercial trucks using traditional systems and processes to find ways to save fuel and reduce downtime and maintenance. With an IoT fleet-tracking solution, companies can use sensors and analytics to expand what can be tracked and improved, such as driver behavior, route optimization, engine diagnostics, tire pressure, and so on. But to deliver such a solution requires numerous vendors in areas such as connected logistics and software applications, sensor and hardware manufacturers, and connectivity vendors. For this solution to work, all vendors must agree upon an integration approach so they can deliver value to the solution.

As enterprises explore new business models based on IoT solutions, they must perform due diligence on what vendors offer and how their offerings integrate with those provided by other vendors. In addition, they must break the cycle of custom development, which is rampant in the current machine-to-machine (M2M) world, and to move to packaged, scalable, standard solutions. These solutions require vendor communities to come together and deliver the experience consumers really want.

To facilitate integration among vendors, SAP solutions for the IoT conform to several enterprise standards. SAP plans to offer our ecosystem of developers and partners the building blocks to:

- Deliver IoT applications
- Provide new connections to the SAP HANA platform
- Leverage our libraries of statistical tools

SAP also intends to work with other software vendors to integrate their specialized capabilities in IoT technology with our offerings. SAP is open to embracing community-driven software, such as the Hadoop and Spark ecosystems.

With our commitment to delivering a diverse ecosystem of partners, we believe we can help our customers derive the utmost value from their SAP software landscapes. Our partners will be able to quickly build the vertical applications that will put the data customers create in SAP Business Suite applications to work in ways we've never imagined. Only with an eye toward delivering the entire ecosystem can SAP truly help our customers and development community harness the power of the Internet of Things.

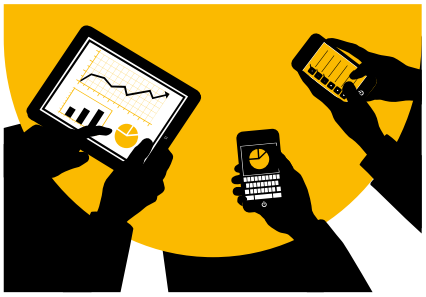
Adding intelligence to an ever-expanding network of connected devices is poised to create tangible value for enterprises around the globe.

Conclusion

The Internet of Things will be increasingly significant in the business world over the coming years. Enterprises will discover that solutions based on these new layers of connectedness can transform their operational processes, unlocking enormous value through greater efficiency. These enterprises will also find themselves with opportunities to transform their customers' experiences. When intelligence can be gathered from and applied to the edge of your network, anything is possible.

In our perspective, the underpinning of the business transformation to come is software architecture optimized for the unique needs of edge computing, machine-data storage, real-time analysis, and connectivity in the IoT ecosystem. At SAP, we're investing our resources to build this foundation. We're reaching out to and partnering with the other members of the technology ecosystem that can help our customers achieve their grandest ambitions when it comes to leveraging the Internet of Things to create true business value.

With the right platform, we can deliver differentiated applications for our customers and empower our developer ecosystem to do the same. There is no shortage of opportunity to tie the new data available to us from connected devices back to core business data to drive transformation. Our developer ecosystem will play a vital role in configuring our horizontal solutions for specific industry verticals and using SAP platform technology to deliver their own unique applications. By integrating SAP solutions with the Internet of Things, we can all win.



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