Internet of Things
The Power of the IoT Platform

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Abstract: According to Forbes Magazine (August 18, 2014), the Internet of Things (IoT) takes over Big Data as the most hyped technology. As already well-known the IoT can be characterized by its elements and paradigms (Atzori et al, 2010). The tight integration of the physical and digital worlds enables companies using sensors, software, machine-to-machine learning and other technologies to gather and analyse data from physical objects or other large data streams and sharing this information across platforms in order to develop a common operating picture. (Gubi et al, 2013). If we look towards the promising value IoT is an umbrella for covering various value aspects related operational excellence and new business opportunities (Xiaocong & Jidong, 2010). Having stated that, we would like to focus on the envisions of an IoT value in which digital and physical entities are linked, by means of a single IT platform to enable a whole new class of products and services (Bröring et al, 2017). We believe that once issues such as the security issue are covered, a single and comprehensive IoT IT platform is THE unique element serving not only as an enabler for an IoT ecosystem (Bröring et al, 2017) but combines two previously separated worlds: it expands the value reach of the IoT for process excellence as well as for new business opportunities and new intelligent products.

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1 INTRODUCTION

The IoT is a network of uniquely identifiable "things" using the internet and emerging technologies (Miorandi, 2012), (McKinsey, 2013) communicating without human interaction using IP connectivity (Meadon, 2013), (Lopez Research, 2013). The IoT refers to the network of networks encompassing IP connected processes, and devices (Karimi, 2013) to enable new cyber-physical transformation of everyday objects into smart objects that can understand and react to their environment enabling novel computing applications (Kortuem et al, 2010) and forming pervasive computing environments. (Meiser 1991). As these IoT- enabled objects share information about their condition and surrounding environment with people, software systems and other machines (Lopez Research, 2015) new modes of collaboration and intelligence are fostered - a trend that we call "smart business." (Harbor-Research, 2013)

In this article we aim at providing a view on the IoT fundamentals following a focused view on the value of the IoT for the business combined with a use-case from the manufacturing area to underline our basic assumption that the single IT platform is the unique key and value of the IoT (Roussos & Kostakos, 2004), (Dobson et al. 2006), (Elmenreich et al., 2009) driving a transformation in operational excellence as well in product design practices that focus on a certain product intelligence, real-time contextually rich decisions, event-analysis and broad access to data.

The transfer of the ability to communicate onto "things" leads to an „intelligence charging" of previously stupid objects to an autonomous communication. Consequently, the objects drop off from the pure repetitive tasks towards an own level of "intelligence" enabling a continuous adaptation towards its environment. With the convergence of the physical & virtual worlds a continuous data flow and information enrichment is enabled and autonomous, pattern-based reactions become possible. This end-to-end principle in network operations (Saltzer, Reed, & Clark, 1994) then allows decentral decision-making and optimizing procedures. This technological enablement leads to a

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paradigm shift within operational excellence and business development due to the provisioning of one single content centric IT platform (Jacobson et al, 2009) facilitating a spontaneous, self-governed and adaptive communication with the ability of an autonomous analysis of patterns and to derive appropriate measure decentral.

2 INTERNET OF THINGS - FUNDAMENTALS

The IoT idea is not new but it only recently became relevant to the practical world, because of the progress made in hardware development in the last decade. (Fleisch, 2010)

In 1999 Kevin Ashton had the idea of the IoT at MITs AutoID lab (Ashton, 2009): „The Internet of Things enables us to track and count everything, and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best, without the limitations of human-entered data." His basic idea was to empower computers with their own means of gathering information using RFID and sensor technology (Michahelles et al., 2007), (Akyilidiz et al, 2004), (Roussos & Kostakos, 2009), Murphy & Butler, 2006) to observe, identify and understand the world—without the limitations of human-entered data."(Lopez Research, 2013a) For this article we would consider the following perspective on IoT:

- Global network interconnecting smart objects by means of extended Internet technologies. (Ma, 2011)
- Set of supporting technologies necessary to realize such a vision (including, Ad Hoc Networks. (Blazevic, Buttyan, Capkun, Giordano, Hubaux, & Le Boudec, 2001).
- Ensemble of applications and services leveraging such technologies to open new business and market opportunities. (Azori, Iera, & Morabito, 2010), (Strategy, I. T. U, 2005)

2.1 IoT Core Elements

The IoT infrastructure comprises existing and involving internet and network developments with a specific object-identification, sensors and connection capability as the basis of independent cooperative services and applications. They are characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability.

The core elements of the IoT are (e.g. SAP 2014, Cisco, 2012, LNS Research, 2015):

- **Things:** IoT offers a multitude of new opportunities to develop new products and services of higher relevance, context-aware, helping people and machines make more relevant and valuable decisions and be more efficient by linking computer networks, sensors, actuators, machines, and devices. (Da Xu, He, & Li, 2014)
- **Network Infrastructure:** IoT devices communicate with networks via the network layer which provides the physical infrastructure for transporting sensor/device data over wireless and wired telecommunications networks. (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014)
- **Communication Services:** The ubiquitous and inexpensive communication services form the backbones for transporting sensor/device data to collection and analytics systems. (Iera, Floerkemeier, Mitsugi, & Morabito, 2010).
- **Big Data Analytics:** The set of data generated by IoT devices will need to be collected, stored and analysed as a key source for patter analysis and decision making. (Chen, Mao, & Liu, 2014).

2.2 IoT Enablers

If we take a look at the value the IoT adds for both businesses and consumers (…) we can state that every business process in essentially every industry is affected. (Fleisch, 2010) A number of significant enablers have come together to enable the rise of the IoT promising many opportunities and benefits (Kranenburg & Bassi, 2012):

- **Technology:** The drop of costs for the necessary IoT technology components is fundamental. In almost all applications, low-cost data communication links (both short distance and long distance) are essential e.g. RFID tags and other hardware to make IoT tracking practical for low-value, high-volume items in package delivery and retailing, inexpensive, low-cost battery power to keep distributed sensors and active tags operating.
- **Intellectual Property, Security, Privacy and Confidentiality:** IoT enabled products and services not only have to create a compelling value proposition for data. The way how and where the data are used have

to be appropriately protected as privacy breaching attacks pose considerable challenges in the development and deployment of IoT applications. (Ukil, 2014)

- **Business Organization and Culture:** Due to the combination of physical and digital worlds the IoT challenges conventional notions of organizational responsibilities. In an IoT world, IT is embedded and directly affects the business metrics against which the operations are measured. This leads to the need of a closer alignment of business and IT. Additionally there is the need for an enhanced data-driven decision making within the business, as well as the ability to adapt their organizations to new processes and business models. (Dijkman. Sprenkels, Peeters, & Janssen, 2015)
- **Public Policy:** Certain IoT applications cannot proceed without regulatory approval. As technology is evolving rapidly, the policy frame needs to be updated and clear. In addition, regulators must establish rules about liability. Policy makers also often have a role to play in shaping market rules that affect IoT adoption.

2.3 IoT Benefits

As companies increase in operational optimization maturity, the IoT offers improved capabilities to serve customer needs and a subsequent increase in financial and operational performance.

The IoT impacts and revolutionizes the business and offers benefits as it helps to gain efficiencies, harness intelligence from a wide range of equipment, improve operations and increase customer satisfaction. While there are many ways that the IoT could impact the business, we would like to highlight the three major benefits categories: (Harbor Research, 2013)

- **Communication:** The IoT communicates information to people and systems, such as state and health of equipment (e.g. it's on or off, charged, full or empty). The key benefit is the ability to continuously and seamlessly communicate with an improved end-to-end interaction. (Suraki, Suraki, & Nejati, 2012)
- **Control / Automation:** In a connected world based on an open IoT environment, a business will have visibility into a device's condition enabling pattern analysis and self-adapting and self-learning capabilities. (Kishore,Preuveneers, & Berbers, 2014).
- **Cost Savings / Increase Revenue:** Companies will adopt the IoT to save money and increase revenue. (Färe, & Grosskopf, 2012), (Insights, O. E. C. D., & Revenue, I. The Internet of things) With new sensor information, the IoT minimizes equipment failure and allow the business to perform a planned maintenance. (Wilson, & Rosenbaum, 2005), or measure items (Swan, 2012). Additionally the connected supply chain enables the understanding of the customers demand at a very early stage by connecting its demand and behaviour providing products and services faster and thus generate the new revenue streams earlier.

2.4 IoT Challenges

Beyond the benefits, there are a number of (…) challenges ahead (Haller et al, 2008) to be considered in order to realize the IoT value. These challenges are:

- **Architectual**: IoT encompasses a wide range of technologies with an increasing number of smart interconnected devices involved. (Uckelmann, Harrison, & Michahelles, 2011) The communications among these devices are expected to happen anytime, anywhere for any related services in a wireless, autonomic, and ad hoc manner becoming more mobile, decentralized. The requirement towards an IoT architecture is therefore to support data integrations over different environments to provide the appropriate service (Shang, Zhang, & Chen, 2012). This has to be supported by modular and interoperable components managing volumes of data from various sources and determine relevant features, to interpret data, show their relationships, and support decision-making. A heterogeneous and open architecture have to be in place following standards without fixed, end-to-end solutions.
- **Hardware:** IoT is enabled by smart objects devices with enhanced inter-device communication leading to smart systems and the creation of new services. Therefore, hardware researches are focusing on designing wireless identifiable systems with low size, low cost sufficient functionality. (Lanzisera, 2014)
- **Privacy and Security:** Compared with traditional networks the security and privacy issues of IoT become more prominent

because of the combinations of things, services, and networks, security of IoT needs to cover more management objects and levels than traditional network security (Ning, 2013) and privacy. Especially for privacy there are a partial solution with Privacy Enhancing Technologies (PET) is presented by The Privacy Coach. (Broenink, van Kranenburg, et al., 2011)

- **Standards:** Standards play an important role in forming IoT as they are essential to allow all actors to equally access and use. As global standards are more relevant than local agreements the developments and coordination of standards and proposals will promote a further enhancement and development of the entire IoT infrastructure and applications, services, and devices. (Främling, & Maharjan, 2013)
- **Business:** For a professional usage within the business mature IoT applications to reduce the risk of failure is are fundamental prerequisite. In addition, since the IoT is an investment and challenging the traditional business models the IoT applications have be profitable for the business. (Dijkman, Sprenkels, Peeters, & Janssen 2015), (Li & Xu, 2013) This is what the IoT applications are perceived as a help for the business and to seamlessly transform the organization into a networked (business) model. (Nold & van Kranenburg, 2010), (van Kranenburg, 2011)

2.5 Security as a Key Issue on IoT

While foster on a large network of integrated and interoperable devices there are new challenges simply because the IoT offers a larger attack surface and bigger consequences.

- Larger Attack Surface: systems in the past largely ran deep in secured data centers, operated by dedicated teams. Now, once they become IoT devices they may have a questionable security – are potentially physically accessible – and are connected over public networks to a cloud environment.
- Bigger Consequences: In the past system were largely administrative. Now the IoT solutions will take actions in the real world, reacting to events from the real world i.e. scheduling maintenance, issuing purchase orders, creating transactions, etc. Potentially actions back to actuators and relays: close doors, shut down production lines, start a heating system, manage street lighting, etc.

The basic attack form is to provide input into a system leading to an unexpected state desired by the attacker. In the normal state systems (computer programs, applications, end-to-end solutions) allow for input, which is processed and leads to a predictable output. A malicious input can be appended to otherwise legitimate requests to affect an unexpected outcome (buffer overflows, SQL injection, etc.) Malicious input can be submitted where the system cannot distinguish between legitimate and malicious input: impersonation attacks or "spoofing".

To enable the business to generate the value that is inherent in the IoT, it is a must to ensure an adequate security. This IoT security needs to be "things-driven":

- Machine focused interaction & patterns with deceiving machines
- Standard and limited selection of communication with consistent communication intervals, numerous protocols (Zigbee, BT, Sigfox, etc.) and valid fields and fixed or semi fixed geo-locations (current use cases)
- Identity management and provisioning of 'Things'
- Data driven offering – Security is Key: Any IoT solution is predicated on the 'data economy'. If the data is compromised and cannot be 'trusted' then the entire IoT value proposition is at risk.

Having stated these key principles of a machine-driven IoT security concept, we would like to outline the key elements of a IoT security concept:

- **Physical security**: the physical security of IoT devices must be ensured. IoT devices should not be easily removed, lost or stolen. Only the required external ports and connectors should be used on IoT devices. IoT devices must not be easily disassembled. In cases where IoT devices are not able to be physically secured, it MUST be ensured that the device does not contain any data of value or the data is sufficiently secured on the IoT device itself.
- **Secure configuration:** IoT devices must be in a secure default state. This includes secure booting and the secure default state. Operating system or firmware updates for the IoT device must be kept up-to-date. Additionally, only signed and trusted updates need to be used for the device. IoT devices should use a trusted time server and

ensure the use of proper time. IoT devices must use whitelisting approach for firewalling and only required network traffic should be allowed. Other security requirements such as passwords, logging, authentication and access control must follow related security policies and directives.

- **Security of data at rest:** Data which is classified as non-public data and stored on the device must be encrypted on the IoT device using approved encryption methods. If data is not stored on the IoT device, encryption may not be required.

In addition to the pure security, compliance is a further degree of security, that needs to be achieved and secured:

- **Compliance to Cloud Infrastructure Security Directive**: this includes securing network communications from the IoT device to the cloud by using secure protocols such as TLS. Transport encryption as well as identity verification must be ensured.
- **Compliance to secure product development standards**: Web services and data processing services must not be susceptible to XSS, SQL injection or CSRF. Services should not be vulnerable to overflows, DoS attacks and fuzzing attacks. Authentication must be done in a secure way, using certificates, SAMLv2 or oAuth if possible. Compliance to a password policy must be ensured.
- **Compliance of data storage and data processing with laws and regulations:** storage and processing of IoT device data must ensure compliance with data protection laws and regulations. All governmental or industry certificates for IoT devices and related data (Laws, regulations, standards, Tüv, GS, etc.) must be followed.

3 VALUE

Having outlined the core elements we can define three fundamental steps on the way towards IoT-driven value and benefit realization:

- **Things to Insight:** using the technology to provide insights with real-time data allowing to act in the moment with data driven decisions and further more to transform data into meaningful insights and strategy. (Liu & Zhou, 2012)
- **Insight to Action** evolving the business processes (Del Giudice, 2016) and the business model (Li & Xu, 2013) towards the IoT with simple, streamlined and informing processes to make the business more efficient and effective in the business network.
- **Action to Outcomes:** with the technological basis new business opportunities, sources of value and ecosystem advantage can be achieved. (Waltari & Kangasharju, 2016)

Following we would like to give a practical example for the value and benefits generated in regards to operational excellence within a manufacturing environment.

3.1 Example: IoT Operational Excellence Driven by IoT

As stated in various articles, the IoT promises significant value for the manufacturing are and production processes. (Tao, Zuo, Da Xu & Zhang, 2014), (Zhang, Zhao, Sun, Wang, & Si 2012), Houyou, Huth, Kloukinas, Trsek, & Rotondi, 2012), (Bi, Da Xu, & Wang, 2014)

Since the manufacturing ecosystem becomes more complex (Leminen, Westerlund, Rajahonka, & Siuruainen, 2012). it was important for Villeroy & Boch (V&B) to modernize their production processes with the ability to access, analyze, and manage vast volumes of data exceeding while keeping the capability of traditional data processing (Borkar, Carey & Li, 2012). This increases the production efficiency leading to an improved productivity and better production quality (Manyika et al, 2011) addressing the ultimate target to improve the overall operational efficiency. In that context IoT presents an extraordinary opportunity (Vailaya, 2012), as it promises – and as we later see kept the promise – new and valuable production process insights shifting from a production that relies on representative heuristics towards a fact-driven production with manufacturing intelligence.

Villeroy & Boch (V&B) is an innovative company with a time-honored tradition and one of the most important brands in the ceramics industry. Since its origins over 265 years ago, the company has developed into an international lifestyle brand. Currently, V&B is represented in 125 countries around the world and 14 production facilities worldwide with a focus on business activities in the company divisions ‘Bathroom and Wellness’ and ‘Tableware’.

To stay successful in their competitive markets the decision has been taken by V&B to implement a comprehensive IoT-based solution for producing faster and smarter (Heesen, 2016) with the use of available technologies to strengthen their competiveness. (Brown, Chui, & Manyika, 2011)

One key target was the improvement of the product quality and yield (the amount of output per unit of input) (Misra, 1975). Given the number and complexity of production activities that influence the yield in the ceramics, V&B needs a sophisticated approach to diagnose and correct process flaws. For this, a data-driven platform to process and analyze a complex dataset (Ward & Barker 2013), was crucial for the entire project.

The idea for achieving that target of yield reduction was to sense all unmatched processing data in real-time, combine them with production patterns and match them with predictive analytics to understand the relevant parameters and its correlations that are critical to the production process. (Kannengiesser, & Weichhart, 2015) This allows the steering of the processes on a detailed level helping to unlock the value of previously unused data and analyze the data in a way that hidden insights become transparent. The value was to gain the ability of a deep dive into process data, identifying unknown patterns and relationships among all process steps, provide transparency on factors and effects on yield and thus allowing work-in-process decisions. With this intelligent, forward-looking, anticipatory, and actionable information in place better (decentral) decisions become possible while opening the door for an optimization potential beyond the limits given by the former infrastructure. With the provisioning of an IoT-ready infrastructure a barely tapped pool of information and knowledge now leads to fact-driven actions within the production for enhanced quality and reduced cost.

The precise goal of the yield database project was to identify quality issues within the manufacturing process reducing product quality issues. The target was to ensure a production process that covers “Right at first Time”, meaning a final yield (= production without mistakes and any post processing). This requires not only a process monitoring but as well a monitoring of the used ingredients and of the environmental related variables to ensure the high quality of the final product addressing an unexplained variability within this production processes creating within product quality negatively affecting the production efficiency and cost.

To take advantage of IoT to significantly increase the yield, V&B segments the entire production process into clusters of closely related production activities. For each cluster, real-time machine data per each process step, the materials used, and other environmental data are collected and gathered in a central IT platform. (Cai, Da Xu, Xu, Xie, Qin, & Jiang, 2014). Next step was to apply various forms of statistical analysis to the raw data to determine interdependencies among the different process parameters (upstream and downstream) and their impact on yield. In addition to the already existing capturing of production data, sensor-generated data were seamlessly added to the analysis process. With this abundance of real-time shop-floor data in addition to the historical data and the capability to conduct sophisticated statistical assessments, another level of transparency will be achieved. The ability to capture new data from sources like machines and production units, directly generated from the origin through sensors, the new approach provides reliable ground-level information on what’s really happening at each moment of the production. In real time (Zhang, Zhang, Wang, Sun, Si, & Yang, 2015) and with the benefit of advanced predictive models this approach provides the capability for a quicker response to the signs of defects within the production while having insights about quality issues during the production process, allowing an appropriate production adaptation just in time, if necessary.

An IoT driven production has many advantages as a data - and fact-driven approach enables a deep dive into historical and real time process data, identifying patterns and relationships among process steps and the related data, and then either optimizing the entire production process, the factors that prove to have the greatest effect on e.g. yield or deciding on the entire production processing at a very early stage. For this the link to dedicated real-time production data is a novelty and surplus, since the historical data are already captured. Linking previously isolated data sets of historical data and real-time data, ultimately gains the capability to conduct sophisticated assessments revealing important insights in real life.

Hearing and seeing what happens within the production at the very moment it occurs, is just the first step. Being able to add value to these decisive moments with advanced analytics is where it gets interesting. Therefore, these data need to be transformed into information and knowledge meaning that the noise and the irrelevant information, need to be filtered and the relevant information need to put into a context, so that business can react upon it. These context data can be many things, e.g. production machine breakdown, walking around on the shop floor, getting feedback from quality inspections regarding the used raw materials, weather conditions. Merging the real time machine data and the environmental manufacturing data (Qu, Lei, Wang, Nie, Chen, & Huang, 2016) provide the context required to understand the production environment entirely and to know what is the best action to be taken in these production circumstances. Being able to contextualize the insights into real-time actions is the point where analytics really pay off. While turning insights into actions the information turns from a "nice-to-have" into a "need-to-have". To comprehensively address the complexity of the project three main dimensions, have to be considered:

- **Technological Dimension** with a suitable IT infrastructure and robust, actionable data to achieve the benefits proposed by IoT (Gerhardt, Griffin & Klemann, 2012) the IT infrastructure and data have to be in place. This infrastructure allows to continuously pull data and information from different sources within the production and link them together. In parallel, a rigorous process to ensure the data's quality was implemented. In that sense, it is most important to consider that all measures rely on normative data, stable measurements, and processes. Further, a robust data set that encompasses all necessary inputs was set up as it is the very foundation of any analytics. To ensure robust data that facilitate analytics are available, these data have to carefully extracted, validated, and visualized to ensure that they examine complete information rather than relying on aggregate data sets that capture averages or on a sampling of inputs, since such methods can lead to false positives or missed patterns.
- **Organizational Dimension** for a company-wide support addressing the new insights to manageable actions. The use IoT deserves an organizational adjustment, making sure that the generated knowledge leads to the appropriate consequences within the production process. To avoid that the investment taken gets lost on the level of tactical responsibility, a top management sponsorship needs to be secured making sure that the results gathered are adequately used within the manufacturing. To not only generate the knowledge but to make the knowledge "understandable" for the target audience, the new role of a data scientist emerged with the key responsibility to do the mining of the information and to generate the business-oriented knowledge base. This data scientist needs to be located in the respective business department to establish the link between methodology and business expertise as the analysis shall focus on solving important business issues and changing employee behavior. Still a non-answered question is, if the methodological competence center shall be established either within the corporate IT or be positioned as a new corporate analytics unit.
- **Knowledge Dimension** addressing the need of well-trained staff. Having a professional production organization in place that has worked within a certain methodology for quite some time, the appliance of IoT does not only reveal opportunities but leads to a change in the knowledge required of the team to overcome the traditional and well-established production handling. In addition to the introduction of the new role of the data scientist, existing roles in the production need to change as well. Even though it remains true that an experienced production professional will more quickly sense what will work than a junior, we need to accept that in a production environment as complex as today's, there is so much information to process before one can make an effective decision, that just being imaginative and following a 'gut feeling' no longer suffices. The new way of manufacturing requires an understanding of the power of data and analytical capabilities to truly grasp what to accomplish with this data set. (Miragliotta & Shrouf, 2012) This does mean that manufacturers need to ask what business problems they are trying to solve and which critical decisions is taken automatically or has to be initiated.

These dimensions allow not only the description of the complexity but serves as a guideline to understand the impact of the project as well as the changes and challenge.

The IoT era has only just emerged at V&B but the initial project phase has already showed a great pay-off whilst V&B is at the beginning of being able to make the prediction with a higher confidence at a level of insight and detail that was not possible before. By identifying the key influencing factors and their correlation impact for production failure, the analysis significantly helped to prevent yield loss early in the production process. The unified IT platform to prepare, visualize, and share the data and insights were one of the cornerstones of success.

The critical first step to capitalize on IoT was to consider how much data are at the companies' disposal. As `real-time' projects can only react as fast as the slowest system in the architecture, it is a challenge struggling with the legacy architecture filled with informational silos where data are only refreshed once every few hours, which makes it impossible to "listen" at decisive moments when they actually happen.

A further challenge is the data collection itself. Previously, V&B has collected vast troves of process data but used them only for tracking purposes, not as a basis for improving operational excellence. Therefore, it was necessary to invest in the systems and skills to allow the optimization of existing process information. Additionally, the need to rigorously assess production data even though they are less than complete as of today need to be overcome by applying traditional master data cleansing and harmonization approaches and to reconcile data inconsistencies and information gaps. Nevertheless, the IoT-based production is a critical tool for realizing improvements in yield, particularly in any manufacturing environment in which process complexity, process variability, and capacity restraints are present.

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4 CONCLUSIONS

IoT is enabled by smart devices, technologies and processes that are seamlessly connected. By taking advantage of the large volumes of data that are produced by sensors the IoT platform is a key enabler for scenarios seen in Industry 4.0 and Product-as-a-Service business transformations impacting operational efficiencies and new business models. The IoT platform delivers a functionality for building unique and differentiated IoT Applications.

The value of the IoT is the provisioning of common and integrative digital platform covering intelligent services and interoperable interfaces in order to support flexible and networked business environments to allow smart embedded devices working together seamlessly. The centralized production steering paradigm will be overcome towards a control systems will give way to decentralized intelligence. The IoT vision is not limited to operational excellence but incorporates as well the integration across core functions. With this high level of integration and visibility across business processes, connected with new technologies will enable not only greater operational efficiency, but as well responsive manufacturing, and improved product design and thus link previously disparate business areas with a common IT source. The IoT and its underlying technologies will not only optimize the processes of companies, it will also open new opportunities and transform the way companies interact with customers, suppliers, employees and governments. As seen in the example, Big Data and analytic capabilities are big differentiators and in this sense Big Data and IoT are symbiotic partners.

Based on a yield database project at V&B this example provides a practical insight on the path forward from a subjective rating of production parameters towards an objective and fact-based steering-competency. The challenges listed in the theoretical part have been approved, e.g. with the required the investment in systems is essential to generate the required process information, e.g. new sensor data, indexing data from multiple sources, so that they can be analyzed more easily and the organizational challenges as the required skill set needs to be in place. The staff has to be trained on spotting patterns and drawing actionable insights from information. The employees need to be able to understand the analysis revealed by a number of previously unseen sensitivities.

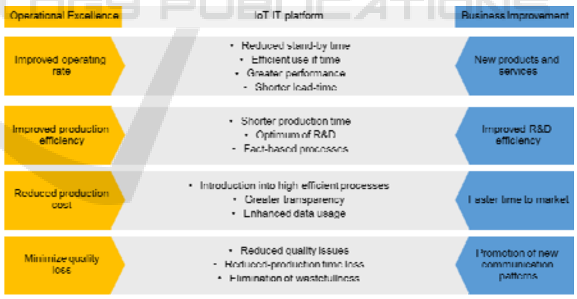

Figure 1: Benefits of a comprehensive IoT platform.

While the IoT can in many ways lead to operational excellence, they conversely make the business far more complex. The level of complexity is immense, because it not only concerns isolated smart devices, but IT environments have to be considered, including various other smart devices, machines and IT systems, which are interacting across organizational boundaries. We propose the following key characteristics that outline the value of a comprehensive IoT IT platform:

Connectivity, interoperability, and comprehensiveness are key enablers. When used effectively, IoT can not only significantly improve operations and margins but also reduce cost, helping companies to make better decisions by using accurate, reliable, and scientific information to analyze risk, optimize processes, and predict failure. Furthermore the IoT platform is a basic technology driving the implementation of IoT-centric business applications built around event-driven architecture and IoT data, instead of business applications built around traditional master data leading to the development of intuitive, and radically user-oriented products turning the technological growth into business value.

REFERENCES

Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). Wireless sensor networks: a survey. Computer networks, 38(4), 393-422.

Ashton, K. (2009): That 'Internet of Things' Thing, in: RFID Journal.

Atzori, L., Iera, A., Morabito, G. (2010). The Internet of Things: a survey. In Computer Networks, 54, pp 2787–2805.

Bi, Z., Da Xu, L., & Wang, C. (2014). Internet of things for enterprise systems of modern manufacturing. IEEE Transactions on Industrial Informatics, 10(2), 1537-1546.

Blackstock, M., & Lea, R. (2014, October). IoT interoperability: A hub-based approach. In Internet of Things (IOT), 2014 International Conference on the (pp. 79-84). IEEE.

Blazevic, L., Buttyan, L., Capkun, S., Giordano, S., Hubaux, J. P., & Le Boudec, J. Y. (2001). Self organization in mobile ad hoc networks: the approach of Terminodes. IEEE Communications Magazine, 39(6), 166-174.

Borkar V., Carey, M.J. & Li, C. (2012): Inside Big Data Management, Ogres, Onions, or Parfaits?, EDBT/ICDT 2012 Joint Conference Berlin German.

Broenink, G., Hoepman, J. H., Hof, C. V. T., Van Kranenburg, R., Smits, D., & Wisman, T. (2010). The privacy coach: Supporting customer privacy in the internet of things. arXiv preprint arXiv:1001.4459.

Bröring, A., Schmid, S., Schindhelm, C. K., Khelil, A., Kaebisch, S., Kramer, D., ... & Galway, N. U. I. Enabling IoT Ecosystems through Platform Interoperability. IEEE Software, forthcoming, 2017.

Brown, B., Chui, M. & Manyika, J. (2011): Are you Ready for the era of 'Big Data'?, McKinsey Quarterly, McKinsey Global Institute, October 2011.

Cai, H., Da Xu, L., Xu, B., Xie, C., Qin, S., & Jiang, L. (2014). IoT-based configurable information service platform for product lifecycle management. IEEE Transactions on Industrial Informatics, 10(2), 1558-1567.

Carlini, S. (2016). The Drivers and Benefits of Edge Computing. Schneider Electric–Data Center Science Center, 8.

Chen, Y., et al. (2014). Time-reversal wireless paradigm for green internet of things: An overview. IEEE Internet of Things Journal, 1(1), 81-98.

Chen, M., Mao, S., & Liu, Y. (2014). Big data: a survey. Mobile Networks and Applications, 19(2), 171-209.

Cisco (2012): The Internet of Everything How More Relevant and Valuable Connections Will Change the World, Retrieved February 1, 2016 from http://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoE.pdf.

CMI (2015): Things on the Internet to 'The Internet of Things' - Market Overview, Competitive Market Intelligence, January 2015.

Cohen, R. B. (2016). Case Studies on How the Internet of Things (Iot) Helps Firms Optimize Their Digital Performance and How Iot Will Have a Large Economic Impact in the Future (Presentation Slides). Available at SSRN 2775301.

Da Xu, L., He, W., & Li, S. (2014). Internet of things in industries: A survey. IEEE Transactions on Industrial Informatics, 10(4), 2233-2243.

Del Giudice, M. (2016). Discovering the Internet of Things (IoT) within the business process management: a literature review on technological revitalization. Business Process Management Journal, 22(2), 263-270.

Dijkman, R. M., Sprenkels, B., Peeters, T., & Janssen, A. (2015). Business models for the Internet of Things. International Journal of Information Management, 35(6), 672-678.

Dobson, S., Denazis, S., Fernández, A., Gaïti, D., Gelenbe, E., Massacci, F., ... & Zambonelli, F. (2006). A survey of autonomic communications. ACM Transactions on Autonomous and Adaptive Systems (TAAS), 1(2), 223-259.

Elmenreich, W., D'Souza, R., Bettstetter, C., & de Meer, H. (2009, December). A survey of models and design methods for self-organizing networked systems. In International Workshop on Self-Organizing Systems (pp. 37-49). Springer Berlin Heidelberg.

Färe, R., & Grosskopf, S. (2012). Cost and revenue constrained production. Springer Science & Business Media.

Fleisch, E. (2010): What is the internet of things? An economic perspective, in: Economics, Management, and Financial Markets, 2010.

Främling, K., & Maharjan, M. (2013). Standardized communication between intelligent products for the IoT. IFAC Proceedings Volumes, 46(7), 157-162.

Gerhardt, B., Griffin, K. & Klemann, R. (2012): Unlocking Value in the Fragmented World of Big Data Analytics, Cisco Internet Business Solutions Group, June 2012. http://www.cisco.com/web/about/ac79/docs/sp/Information-Infomediaries.pdf.

Gubi, J., et al (2013): Internet of Things (IoT): A vision, architectural elements, and future directions, in: Elsevier, Future Generation Computer Systems, Volume 29, Issue 7, September 2013, pp 1645–1660.

Haller, S., et al (2008): The Internet of Things in an Enterprise Context, in: Future Internet – FIS 2008, Volume 5468 of the series Lecture Notes in Computer Science pp 14-28.

Harbor Research (2013): IoT Market Opps, Paper 2013.

Heesen, B. (2016): Effective Strategy Execution, Management for Professionals, Springer Verlag Berlin Heidelberg, 2016.

Houyou, A. M., Huth, H. P., Kloukinas, C., Trsek, H., & Rotondi, D. (2012, September). Agile manufacturing: General challenges and an IoT@ Work perspective. In Proceedings of 2012 IEEE 17th International Conference on Emerging Technologies & Factory Automation (ETFA 2012) (pp. 1-7). IEEE.

IDC (2014): IDC FutureScape: Worldwide Internet of Things 2015 Predictions, IDC Analyze the Future, December 3, 2014.

Iera, A., Floerkemeier, C., Mitsugi, J., & Morabito, G. (2010). The internet of things [guest editorial]. IEEE Wireless Communications, 17(6), 8-9.

Insights, O. E. C. D., & Revenue, I. The Internet of things.

Jacobson, V., Smetters, D. K., Thornton, J. D., Plass, M. F., Briggs, N. H., & Braynard, R. L. (2009, December). Networking named content. In Proceedings of the 5th international conference on Emerging networking experiments and technologies (pp. 1-12). ACM.

Kannengiesser, U., & Weichhart, G. (2015). Designing and executing interoperable IoT manufacturing systems. Enterprise Interoperability: Interoperability for Agility, Resilience and Plasticity of Collaborations (I-ESA 14 Proceedings), 229.

Karimi, K. (2013): The Building Blocks Needed To Make Internet of Things (IoT) Happen, White Paper, Freescale Semiconductor Inc., 9/25/2013.

Kishore Ramakrishnan, A., Preuveneers, D., & Berbers, Y. (2014). Enabling self-learning in dynamic and open IoT environments. Procedia Computer Science, 32, 207-214.

Khan, R., Khan, S. U., Zaheer, R., & Khan, S. (2012, December). Future internet: the internet of things architecture, possible applications and key challenges. In Frontiers of Information Technology (FIT), 2012 10th International Conference on (pp. 257-260). IEEE.

Kortuem, G., et al (2010): Smart objects as building blocks for the Internet of things, in: Internet Computing, IEEE (Volume: 14, Issue: 1), pp 44-51.

Lanzisera, S., Weber, A. R., Liao, A., Pajak, D., & Meier, A. K. (2014). Communicating power supplies: Bringing the internet to the ubiquitous energy gateways of electronic devices. IEEE Internet of Things Journal, 1(2), 153-160.

Leminen, S., Westerlund, M., Rajahonka, M., & Siuruainen, R. (2012). Towards iot ecosystems and business models. In Internet of Things, Smart Spaces, and Next Generation Networking (pp. 15-26). Springer Berlin Heidelberg.

Li, F., Vögler, M., Claeßens, M., & Dustdar, S. (2013, June). Efficient and Scalable IoT Service Delivery on Cloud. In IEEE CLOUD (pp. 740-747).

Li, H., & Xu, Z. Z. (2013). Research on business model of Internet of Things based on MOP. In International Asia Conference on Industrial Engineering and Management Innovation (IEMI2012) Proceedings (pp. 1131-1138). Springer Berlin Heidelberg.

Liu, Y., & Zhou, G. (2012, January). Key technologies and applications of internet of things. In Intelligent Computation Technology and Automation (ICICTA), 2012 Fifth International Conference on (pp. 197-200). IEEE.

LNS Research (2015): Revolutionize your Manufacturing System Manufacturing Architecture with IIoT & Big Data, 2015.

Lopez Research (2013a): An Introduction to the Internet of Things, White Paper published by Cisco, Aug 25, 2013.

Lopez Research (2013b): 4 Things Your Business Should Know About Internet of Things, December 10, 2013, Retrieved February 15, 2016, from: http://www.lopezresearch.com/2013/12/10/4-things-your-business-should-know-about-internet-of-things/

Ma, H. D. (2011). Internet of things: Objectives and scientific challenges. Journal of Computer science and Technology, 26(6), 919-924.

MacManus (2010): Chinese Premier Talks Up Internet of Things, Richard MacManus, ReadWrite, January 19, 2010.

Manyika, J. et al (2011): "Big data: The next frontier for innovation, competition, and productivity", McKinsey Global Institute, http://www.mckinsey.com/~/media/McKinsey/dotcom/Insights%20and%20pubs/MGI/Research/Technology%20and%20Innovation/Big%20Data/MGI_big_data_full_report.ashx.

McKinsey (2013): The Internet of Things and the Future of Manufacturing, McKinsey & Company, Interview June 2013, Retrieved February 15, 2016, from: http://www.mckinsey.com/insights/business_technology/the_internet_of_things_and_the_future_of_manufacturing.

McKinsey (2015): The Internet of Things: Mapping the value beyond the hype, McKinsey Global Institute, June 2015.

Michahelles, F., Thiesse, F., Schmidt, A., & Williams, J. R. (2007). Pervasive RFID and near field communication technology. IEEE Pervasive Computing, 6(3), 94-96.

Miorandi, D., et al (2012): Internet of things: Vision, applications and research challenges, Survey paper in: Ad Hoc Networks, Elsevier, Volume 10, Issue 7, September 2012, pp 1497–1516.

Miragliotta, G., & Shrouf, F. (2012, September). Using Internet of Things to improve eco-efficiency in manufacturing: a review on available knowledge and a framework for IoT adoption. In IFIP International Conference on Advances in Production Management Systems (pp. 96-102). Springer Berlin Heidelberg.

Misra, R. B. (1975). Optimum production lot size model for a system with deteriorating inventory. The International Journal of Production Research, 13(5), 495-505.

Murphy, M., & Butler, J. Proactive computing: RFID & sensor networks, Final Report on the Conference organised by DG Information Society and Media, Networks and Communication Technologies Directorate, March 2006.

Ning, H., Liu, H., & Yang, L. T. (2013). Cyberentity security in the Internet of Things. Computer, (4), 46-53.

Nold, C., & van Kranenburg, R. (2010). Situated technologies pamphlets 8: The internet of people for a post-oil world. The Architectural League of New York, New York.

Qu, T., Lei, S. P., Wang, Z. Z., Nie, D. X., Chen, X., & Huang, G. Q. (2016). IoT-based real-time production logistics synchronization system under smart cloud manufacturing. The International Journal of Advanced Manufacturing Technology, 84(1-4), 147-164.

Roussos, G., & Kostakos, V. (2009). RFID in pervasive computing: state-of-the-art and outlook. Pervasive and Mobile Computing, 5(1), 110-131.

SAP SE (2014): SAP Solutions for the Internet of Things – Built for Your Business.

Saltzer, J. H., Reed, D. P., & Clark, D. D. (1984). End-to-end arguments in system design. ACM Transactions on Computer Systems (TOCS), 2(4), 277-288.

Shang, X., Zhang, R., & Chen, Y. (2012). Internet of things (IoT) service architecture and its application in e-commerce. Journal of Electronic Commerce in Organizations (JECO), 10(3), 44-55.

Suraki, M. Y., Suraki, M. Y., & Nejati, O. (2012, October). Benefit of internet of things to improve business interaction with depression prevention and treatment. In e-Health Networking, Applications and Services (Healthcom), 2012 IEEE 14th International Conference on (pp. 403-406). IEEE.

Strategy, I. T. U., & Unit, P. (2005). ITU Internet Reports 2005: The internet of things. Geneva: International Telecommunication Union (ITU).

Swan, M. (2012): Sensor Mania! The Internet of Things, Wearable Computing, Objective Metrics, and the Quantified Self 2.0, in: Journal of Sensor and Actuator Networks — Open Access Journal, Volume 1, Journal 1.

Tao, F., Zuo, Y., Da Xu, L., & Zhang, L. (2014). IoT-based intelligent perception and access of manufacturing resource toward cloud manufacturing. IEEE Transactions on Industrial Informatics, 10(2), 1547-1557.

Uckelmann, D., Harrison, M., & Michahelles, F. (2011). An architectural approach towards the future internet of things. In Architecting the internet of things (pp. 1-24). Springer Berlin Heidelberg.

Ukil, A., Bandyopadhyay, S., & Pal, A. (2014, April). Iot-privacy: To be private or not to be private. In Computer Communications Workshops (INFOCOM WKSHPS), 2014 IEEE Conference on (pp. 123-124). IEEE.

Van Kranenburg, R., Anzelmo, E., Bassi, A., Caprio, D., Dodson, S., & Ratto, M. (2011). The internet of things. A critique of ambient technology and the all-seeing network of RFID, Network Notebooks, 2.

Van Kranenburg, R., & Bassi, A. (2012). IoT challenges. Communications in Mobile Computing, 1(1), 1.

Vailaya, A. (2012): What's All the Buzz Around "Big Data?", IEEE Women in Engineering Magazine, December 2012, pp 24-31.

Verizon (2015): State of the Market THE INTERNET OF THINGS, Discover how IoT is transforming business results, 2015.

Ward, J. S. & Barker, A. (2013): Undefined By Data: A Survey of Big Data Definitions, In Proceedings of IEEE CloudCom 2013, pp 647-654, IEEE Computer Society, December 2013.

Waltari, O., & Kangasharju, J. (2016, January). Content-centric networking in the internet of things. In 2016 13th IEEE Annual Consumer Communications & Networking Conference (CCNC) (pp. 73-78). IEEE.

Weiser, M. (1991). The computer for the 21st century. Scientific american, 265(3), 94-104.

Weiser, M. (1993). Some computer science issues in ubiquitous computing. Communications of the ACM, 36(7), 75-84.

Wilson, Ch. & Rosenbaum, St. (2005): Categories of Return on Investment and Their Practical / Implications, in: Cost-Justifying Usability: An Update for the Internet Age, Second Edition, by Randolph G. Bias, Deborah J. Mayhew, pp 215 – 256.

Xiaocong, Q., & Jidong, Z. (2010, November). Study on the structure of "Internet of Things (IOT)" business operation support platform. In Communication Technology (ICCT), 2010 12th IEEE International Conference on (pp. 1068-1071). IEEE.

Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of things for smart cities. IEEE Internet of Things Journal, 1(1), 22-32.

Zhang, Y. F., Zhao, X. B., Sun, S. D., Wang, J. Q., & Si, S. B. (2012). Implementing method and key technologies for IoT-based manufacturing execution system. Computer Integrated Manufacturing Systems, 18(12), 2634-2642.

Zhang, Y., Zhang, G., Wang, J., Sun, S., Si, S., & Yang, T. (2015). Real-time information capturing and integration framework of the internet of manufacturing things. International Journal of Computer Integrated Manufacturing, 28(8), 811-822.