# Smart Collaborative Processes Monitoring in Real-time Business Environment

## *Applications of Internet of Things and Cloud-data Repository*

Ahm Shamsuzzoha[1], Sven Abels[2], Simon Kuspert[2] and Petri Helo[1]
[1]*Department of Production, University of Vaasa, PO Box 700, Vaasa, Finland*
[2]*Ascora GmbH, Innovation & Product Development, Birkenallee 43, 27777 Ganderkesee, Germany*

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Abstract: In today's business world there is a growing concern with business collaboration among companies, especially small and medium enterprises (SMEs). The objective of forming and operating such collaborative networks is to achieve market benefit through sharing resources, expertise and knowledge among the networked partners. It is therefore necessary to track and trace each business process within such business networks in a real-time environment in order to enhance their success level and reduce possible risks or uncertainties. Keeping such an objective in mind, this research highlights the basic principles of business process monitoring through smart technologies such as the Internet of Things (IoT) and cloud-based data repository. Smart process monitoring through the combination of Internet of Things technology and cloud-based data repository system is rarely discussed in the field of collaborative business. Within the scope of this research, generic scenarios of both the IoT and cloud-based data storage are described with the objective of implementing them in a collaborative business process monitoring domain. An implementation example is highlighted in this paper, where IoT and cloud-based data storage are showcased in business process monitoring and management. The overall research outcomes and future research directions are also articulated in the conclusion section of this paper.

## 1 INTRODUCTION

An increasing level of market diversification and customers' complex needs are exerting extra pressure on global manufacturing companies, especially on small and medium enterprises (SMEs), where there is a shortage of costly resources, expert knowledge and innovative skills. To overcome such constraints, SMEs are looking for an effective collaboration environment where they can explore their business opportunities through enhanced capacities and capabilities. In such perspectives, business collaboration among companies (SMEs) is becoming of growing interest globally due to its inherent benefits (Romero and Molina, 2010).

In order to execute successful business collaboration, it is necessary to monitor and manage business processes within a real-time environment. This business process monitoring demands the interoperability of existing technologies as used by the individual partner companies. Within a business network this interoperability process monitoring contributes to process synchronization that ensures reliability and safety (Smith, 2003). Synchronized business processes within the VF environment support monitoring and managing effectively and efficiently. This real-time process monitoring would be beneficial to the process owners in planning ahead in case of process abnormality. This planning process contributes substantially to avoiding or minimizing the risk level.

Therefore, the objectives of this research are to ascertain the obstacles to business process monitoring, look for appropriate technologies and tools which are available in the market or the need to design and develop process monitoring from scratch, and, in addition, to ensure a secured database design that can store and retrieve the monitoring data across a collaborative business network. These objectives can be summarized into two specific research themes: (i) to find out how sensor-based


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technologies and tools such as the Internet of Things (IoT) can support collaborative business processes monitoring, and (ii) to check how a cloud-based data repository system can be implemented successfully to store and retrieve data as used to monitor and manage collaborative business processes.

## 2 RESEARCH MODEL

IoT is a topical issue nowadays in the technological world, which can be successfully implemented to achieve increased business control through its sensor-based technologies in either wired, wireless or hybrid systems. It is an integrated part of the future Internet technology that can be defined as the dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols that can be used as an intelligent interface to business process monitoring within a VF network.

In addition to the implementation of IoT there is growing concern within the business community with storing a maximum amount of VF process monitored data securely, which can then be retrieved according to need. This brings about the necessity to harness a data storage facility which can easily be accessed with minimum time and cost. Recently, researchers have been focusing on the issue of cloud-based data repository in the form of cloud manufacturing, cloud computing, cloud-based information systems and monitoring, etc., which can easily fulfil the needs of different kinds of manufacturing data storage and retrieval.

This research particularly emphasizes investigating the possibilities of how an implementation of IoT technology and cloud-based data repository can be realized effectively to monitor business processes thoroughly. Figure 1 displays the proposed research model to monitor business processes in a VF environment.

## 3 LITERATURE REVIEW

SMEs can achieve manufacturing agility and higher competiveness through forming collaborative business networks, where valuable resources, knowledge and expertise can be shared for mutual benefits (Rabelo, 2008). From the SME point of view, business collaboration is an alternative to traditional supply chain management, where companies can enhance their value adding activities and have better control within the business domain (Walters and Rainbird, 2007).

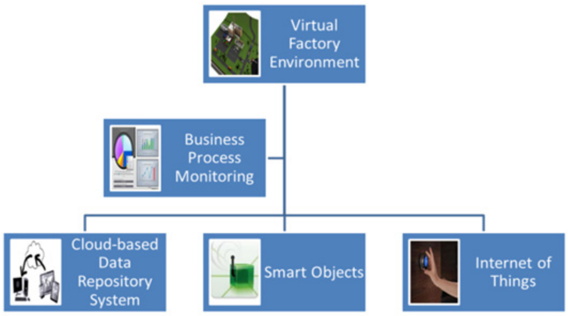


Figure 1: The research model.

Business process monitoring can be viewed from the contribution it makes in adding value to the potential customer and the alignment and realization of the strategic business objectives. Process improvement as achieved through process monitoring will start by obtaining better understanding of the customers and their demand on the business. There is a lack of automated support in process monitoring, which is mostly an isolated set of activities separated from the actual process execution. It is critical for business network partners to monitor and manage accompanied processes. Various sensor-based technologies are applied to monitor individual products or processes (Angeles, 2005; Krastela et al., 2011; Miorandi et al., 2012), but only limited research has been performed to monitor processes within business networks. Most of the research work in network process monitoring has been done mainly to identify focused abnormalities in the partner's premises (such as machine breakdown, labour unrest, production delay, etc.) and not necessarily to obtain information on the processes as a whole (Hallikas et al., 2004).

With increased awareness of business process monitoring it needs to be approached holistically and with the support of technology (Jeston and Nelis, 2008). Recently developed technologies such as the Internet of Things and smart objects can successfully contribute to process monitoring through their inherent sensor-based approach (Bandyopadhyay and Sen, 2011). Wireless sensor networks have been a very promising development in business process monitoring during the last few years, but there is a distinct lack of real applications in collaborative networks. This process monitoring is enhanced through smart technologies such as RFID tags, GPRS trackers, smart objects, IoT, etc (Kortuem et al., 2010).This monitored data needs to be stored and retrieved within a secured and encrypted database such as a cloud-based data repository system. To enable process monitoring and management over the cloud is a concept that companies are embracing, and this service is growing in popularity among different manufacturing companies that have yet to transition IT operations over to the cloud (Lombardi and Di Pierto, 2010). The process monitoring related to network business operations is defined and stored within the cloud storage. All the relevant information associated with a process such as process template, process model, process editor, process design, etc., is stored and retrieved from the cloud storage as necessary. This functionality from the cloud storage provides extra benefits in terms of managing the processes from the user side to the data management side (Shamsuzzoha et al., 2013).

## 4 INTERNET OF THINGS: CONCEPTS AND IMPLEMENTATION PERSPECTIVES

The application of IoT is mainly the result of a global network interconnecting smart objects by means of internet technologies (Kortuem et al., 2010; Uckelmann et al., 2011). It envisions a future in which digital and physical entities can be interfaced through appropriate information and communication technologies. In industry, where there is a demand for smart environments it helps to improve automation in industrial plants through the automatic identification of objects with a massive deployment of sensor-enabling technologies and tools such as RFID tags, sensors/actuators, machine-to-machine communications devices, etc., (Atzori et al., 2010).Implementing RFID tags as a source of smart objects enables the tracking objects and the EPC (electronic product code) serves as a link to data which can provide information about each individual object through the Internet.

This automatic identification of objects can be used extensively to improve data handling capabilities for an individual product or batch identification. Its implementation perspective may fill the information gap between logistics and supply chain networks through tracking and tracing objects as they move along the supply chain. This tracking includes both real-time position tracking of object-flow monitoring to improve the workflow in supply chains and the tracking of motion through choke points, such as access to designated areas. It ensures the foundation for product identification and authentication, anti-counterfeiting and other supply chain integrity. This product identification and authentication supports the reduction of incidents harmful to products (such as wrong place/time/condition), comprehensive and current product maintenance to meet the requirements of security procedures, and avoiding theft or losses of important products.

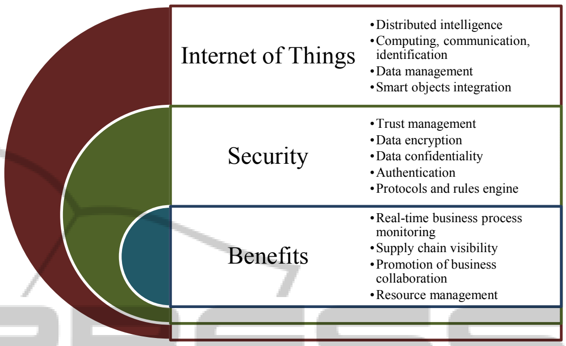


Figure 2: A holistic scenario of the Internet of Things within the business domain.

A holistic scenario of the Internet of Things can be presented as in Figure 2, where the concerns related to its implementation are highlighted. From Figure 2, it is noticed that the IoT is needed to define itself with its inherent security issue and benefits to the business community. In the definition it is highlighted that IoT enables distributed intelligence, identification, data management and integration of smart objects. In terms of its security concern, IoT needs to comply with trust management, data encryption and confidentiality, authentication, protocols and rule engine. The benefits of IoT are mainly focused on real-time business process monitoring, supply chain visibility, promotion of business collaboration and resource management.

## 5 CLOUD-BASED DATA REPOSITORY: CONCEPTS AND IMPLEMENTATION PERSPECTIVES

A cloud-based data repository system is nowadays an attractive element within a business domain. This data repository system has a relation between cloud computing and the Internet of Things by collecting and storing data in the cloud. The tracking information as received from the smart objects allows for the combination of real-world object data and IT-based process information. In this case, a cloud-based data warehouse is created containing current and former manufacturing process information and it also provides cloud-based data management and archiving solutions. This data management system provides necessary support in collaborative business through data analysis and reporting in order to detect process failures, to perform risk assessment and to identify space for improvement. It also allows for business traceability and continuity and provides competitive advantage for manufacturing companies.

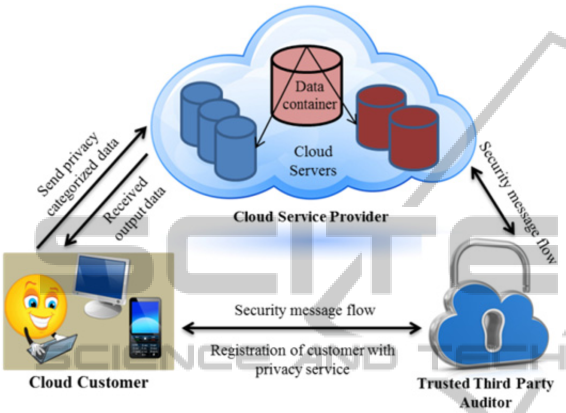


Figure 3: An architecture of cloud-based data storage service.

A high-level architecture description of cloud-based data storage service is illustrated in Figure 3. This architecture consists of three different entities: cloud user, cloud service provider and trusted third party auditor (TTPA). The cloud customer employs the cloud storage and computing resource facilities to remotely store and process data, whereas the cloud service provider, which has significant storage space and computation resources, manages and operates a cloud infrastructure of storage and computing services. The TTPA is considered as a seller of a cloud privacy service in collaboration with the cloud service provider (Wang et al., 2010; Lin and Squicciarini, 2010). From Figure 3, it is assumed that a cloud customer has a large amount of data files which he/she wants to store on a cloud server, which is managed by a cloud service provider. For this purpose, the user needs to register with TTPA before receiving output data securely. The Internet is the basic communication system for information exchange between the cloud customer and the computing cloud.

As outlined above, a lot of research has been performed in the area of three core technologies: (i) Virtual Factories and their application of manufacturers and especially SMEs, (ii) The Internet of Things and its impact on monitoring and informing manufacturers about their goods, and (iii) Cloud Storage for managing information in a scalable and distributed manner. The following section demonstrates a use case for combining these approaches into a holistic information system.

# 6 IMPLEMENTATION OF IOT AND CLOUD-DATA STORAGE IN COLLABORATIVE BUSINESS ENVIRONMENT: A CASE EXAMPLE

The combination of both always-on connections and cheap hardware provide a vital base for the Internet of Things. In the FP7 EU ADVENTURE project[1], the consortium created a virtual factory environment for collaborative business. ADVENTURE allows different manufacturers to collaborate with the help of an ICT platform (ADVENTURE, 2011). The ultimate aim of this platform is to realize a “plug & play factory” approach in order to support the collaboration of partners in all phases. This plug-and-play virtual factory helps companies to move beyond existing operational limitations with technologies and methodologies that can establish and execute cross-organizational manufacturing processes.

ADVENTURE plug-and-play factory offers real-time process monitoring and makes process status information available to the process owner. The valuable information or data source is made available through the IoT. The data sources required for manufacturing processes, intermediate goods and manufactured goods are often enriched with identification, sensor and communication technologies. Through well-defined interfaces, up-to-date and real-time status information can be transmitted from ‘smart objects’ such as RFID tags, which are the formats of IoT. Accessing data from smart object sensors may be performed in three different ways in the ADVENTURE platform: (a) Firstly, dashboard users interface, (b) Secondly through a REST (Reliability Estimation System Testbed) interface and (c) Finally, an Android app.

*(a) VF process Monitoring through ADVENTURE Dashboard*

The dashboard system enables collaborating partners to view their processes and to drill down into

[1] http://fp7-adventure.eu

accessing IoT data from their processes. Figure 4 show an extract from the ADVENTURE dashboard. The dashboard uses IoT approaches to allow each partner to be informed about the overall manufacturing process and the current state of the collaboration.

The ADVENTURE dashboard contains several widgets or portlets based on the VF process needs. Figure 5 displays a snap shot of 'My Smart Object' widget. This widget mainly provides the visibility and status information of each of the smart objects within the VF processes. Along with the status information it also visualizes the location of the VF partner's smart objects and presents their status through displaying different colours (e.g. red for urgent, yellow for alert, green for normal). This widget may also be used to monitor temperature, $CO_2$ values and other relevant information received from the smart sensors.

For example, collaborating partners may be informed as to whether the temperature of a transport exceeds a specific limit and receive an alert whenever a specific threshold is passed.

*(b) VF process Monitoring through REST Interface*
Within the scope of this research, a REST interface has been provided by the cloud storage component, allowing external developers to access the data in a programmatic way. In this REST engine, VF operations are defined in the messages and offer a unique address for every process instance. It also offers the loose coupling of components, and each object supports the defined (standard) operations.

*(c) VF process Monitoring through an Android App*
An Android app designed and developed in this research allows virtual factory partners to access their sensor data as received from smart objects using a mobile tablet device. This mobile app allows manufacturers the possibility to check sensor data even when in the production hall. Figure 6 displays the screen design of the ADVENTURE Android app.



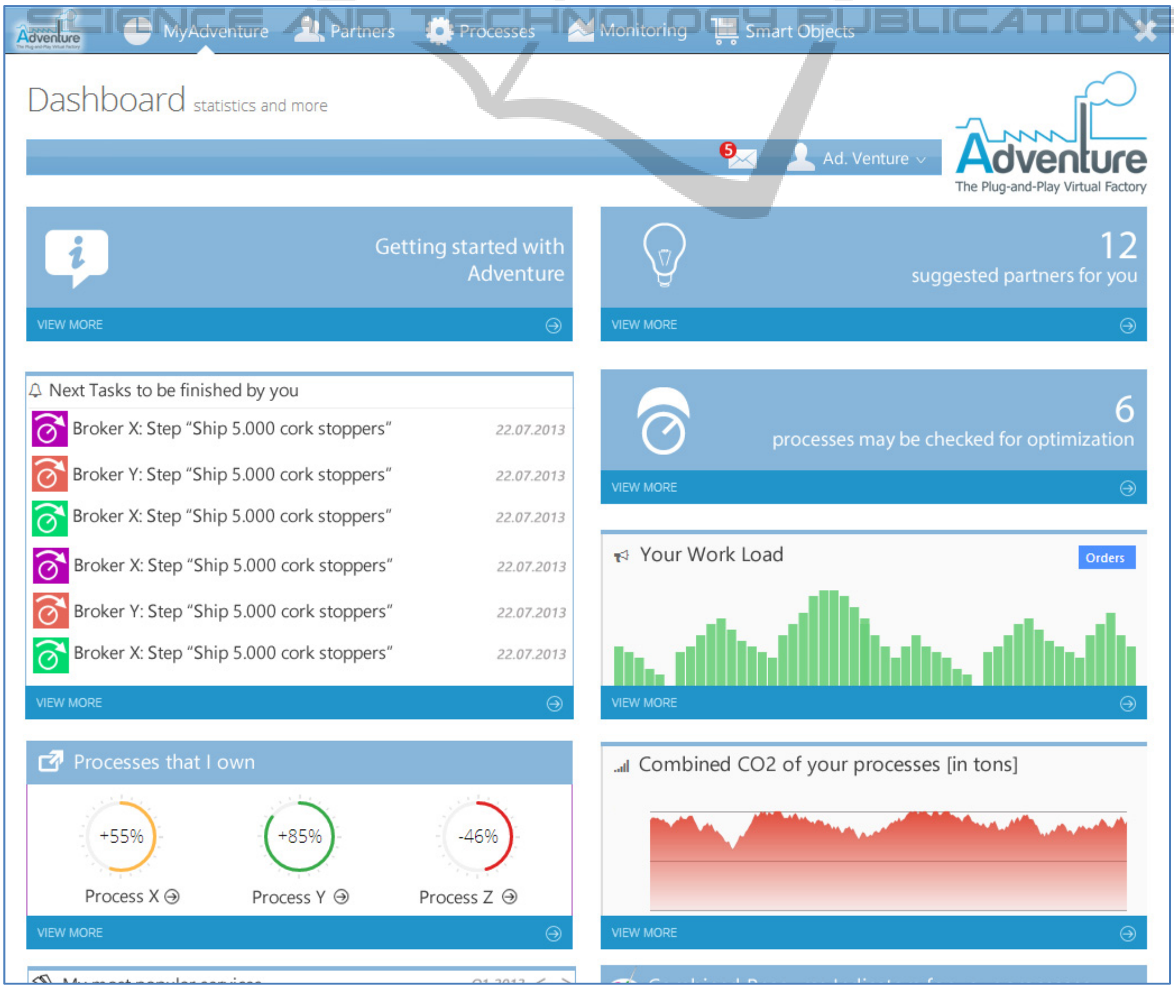

Figure 4: The ADVENTURE Dashboard.

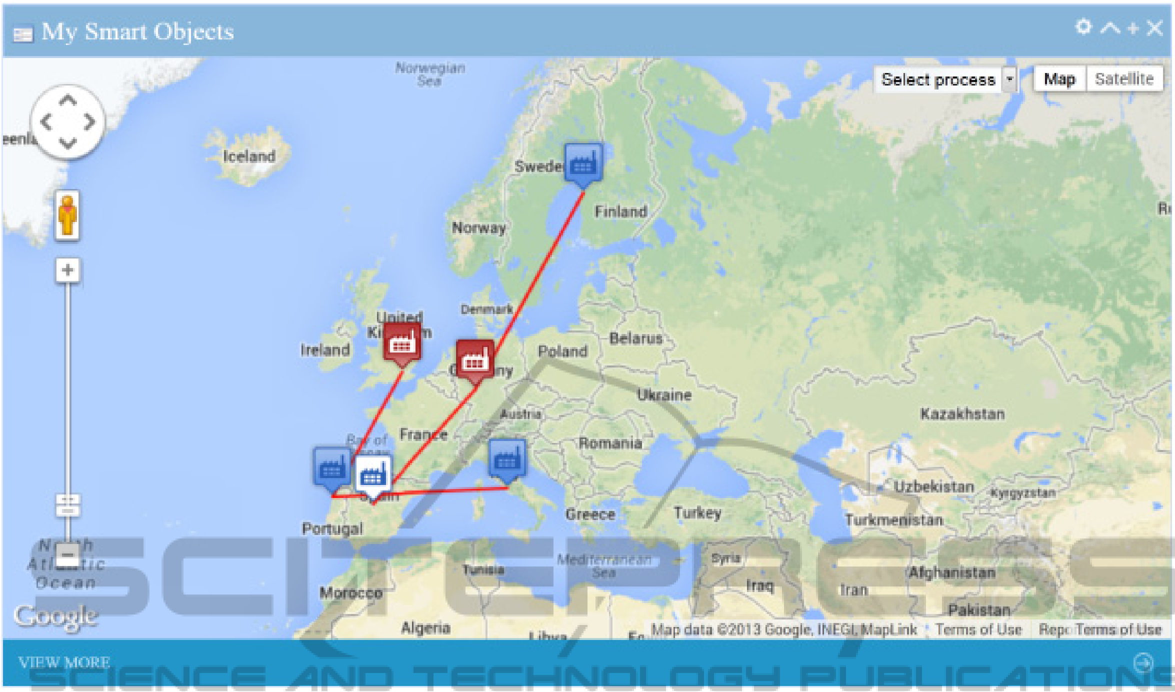


Figure 5: Snap shot of 'My Smart Object' widget.



## 7 DISCUSSIONS AND CONCLUSIONS

There is a growing need to create and execute business collaboration whatever the formats are (Camarinha-Matos and Afsarmanesh, 2007; Shamsuzzoha et al., 2013). The concept of virtual factory, which is a kind of plug-and-play factory, helps companies to move beyond their operational limits. Using this concept, companies will be able to manage cross-organizational manufacturing processes as though they are being carried out within a single company (Schulte et al., 2012). Currently, manufacturers lack the appropriate real-time information that would let them assess process status. The main problem exists in such cases where there is missing interoperability between business partners' IT systems as well as potential loss of information due to prevailing data silos. Ultimately, new methods and technologies are needed to connect diverse technologies and aggregate the data from them. In consequence, this research has implemented state-of-the-art technology and tools to execute collaborative business process monitoring in a cross-organizational environment and it closes all information gaps and integrates data seamlessly.

This research begins with high-level collaborative business process monitoring with special focus on the Internet of Things technology, along with cloud-based data repository. Growing interest in the IoT in the form of smart objects can be successfully applied to business process monitoring. These smart objects are mainly sensor-enabled technology that is used to identify proposed conditions and locations at the same time. These process conditions and location characteristics support real-time business process monitoring successfully. This technology is demonstrated through a mobile app, which works as a smart object and is used in collaborative business process monitoring. This mobile app was tested and validated successfully to be implemented as an IoT technology, applicable in smart process monitoring and management within a collaborative business environment.

Another concern in business process monitoring is the need to store and retrieve process monitoring data and information securely. One such business objective, a cloud-based data repository system, is also presented within the scope on this research. The basic framework for cloud-based data storage along with its implementation aspects is also discussed in this paper. A generic model of cloud data storage is formulated that supports the storage and retrieval of data in collaboration business processes successfully. This model also contributes to

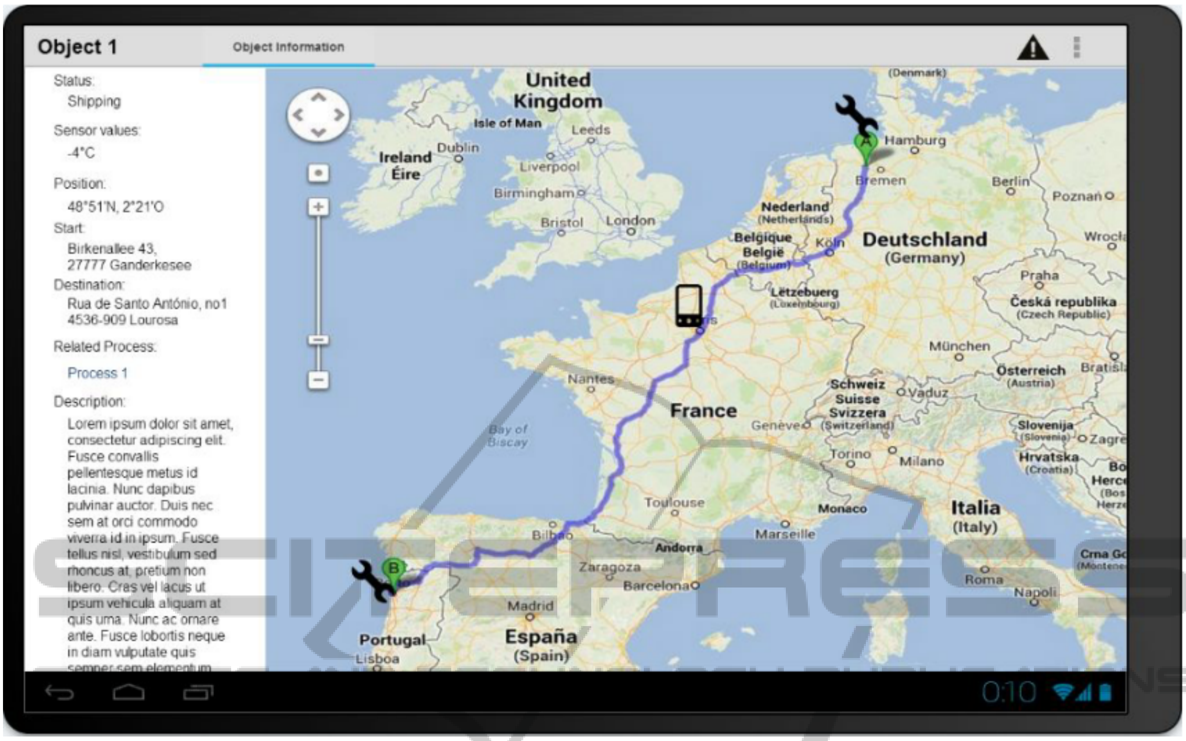


Figure 6: Android app view showing information about a process status.

providing benefits like availability (being able to access data from anywhere), relatively low cost (paying as a function of need) and on demand data sharing among collaborative partners. In cloud-storage systems, the data owner may represent either an individual partner or all collaborative partners, who rely on the cloud server for remote data storage and maintenance and thus are relieved of the burden of building and maintaining a local storage infrastructure.

This research presented a case example where the virtual factory's business process monitoring is highlighted. This monitoring process is accomplished by the application of IoT technology in the form of smart objects and sensors and is visualized through the ADVENTURE dashboard, REST interface and Android app. All the process monitored data is stored within cloud-based data storage, which was designed and developed within the scope of this research. Different types of data such as structured, semi-structured, binary and semantic are stored in separate buckets of cloud-storage in order to avoid data becoming mixed up and maintaining data security and individuality.

This is on-going research, where the future research activities are planned towards the development of an open source Web-enabled communication infrastructure that is accessed and used by potential companies (mainly SMEs) to monitor and manage their business processes within a collaborative business environment. The research results in the form of business process monitoring are validated in one case company and will be validated in another case company in the near future.. In future work, the business process monitoring data will be analysed and used as the performance measures of KPIs (key performance indicators) and the governance model o virtual factory partners.

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