8-2010

Integration for innovation: Studying the role of middleware in RFID applications

Taline Jadaan
Viktoria Institute, Gothenburg, Sweden, taline@viktoria.se

Dick Stenmark
Viktoria Institute, Gothenburg University, Gothenburg, Sweden, dicks@ituniv.se

Integration for innovation: Studying the role of middleware in RFID applications

Taline Jadaan
Viktoria Institute,
Gothenburg, Sweden
taline@viktoria.se

Dick Stenmark
Viktoria Institute, Gothenburg, Sweden
Gothenburg University, Gothenburg, Sweden
dicks@ituniv.se

ABSTRACT

This paper is based on an interpretative multiple case study of two organization where we examine how different middleware architecture approaches affect the utilization of sensor technology, in particular Radio Frequency Identification (RFID). Our study reveals five interesting findings. First, sensor technology is able to digitize and automate previously manual routines but the received value of this process alone is often limited. Second, the possibility of downstream exploitation, and thus innovation, is inhibited when sensor data is too rigidly packaged. Third, organizations should have a clear strategy or vision regarding the desired business benefits when filtering and aggregating sensor data. Fourth, to enable innovative business solutions organizations should combine sensor data with business application data. Fifth, and finally, when utilizing sensor data organizations should prioritize exploitation over exploration since it enables organizations to obtain business innovation.

Keywords

Sensor technology, middleware, RFID, business value, integration, innovation, digitalization.

INTRODUCTION

Much of the work that previously was carried out manually and supported by analog tools is today replaced by the automated processes based on sensor technologies. A sensor is an artifact capable of sensing the state of some underlying system(s) and transmitting information regarding this state to some higher-level unit in an automatic fashion (Rooney *et al.*, 2006). This automation is the result of the advances in information technologies (IT) and enables today's organizations to digitize much of their work (Yoo et al., 2009). As the cost of wireless sensors is decreasing, the use of sensors and thus also the number of sensor networks are likely to grow rapidly. While early sensor networks typically acted in isolation, we are now seeing that they become interconnected through general purpose networks and shared infrastructure components.

The growing use of sensor technology is partly propelled by the need for organizations to expand their boundaries in order to be innovative and to survive in a competitive business landscape (Hult *et al.,* 2004; Barsh, 2008; Lindgren *et al*., 2008). This development provides complex scenarios that introduce a whole set of challenges to organizations, including support for heterogeneity and scalability (Horré *et al.*, 2007; Aberer *et al.*, 2007). Sensor technology has until recently largely been used within the retail industry and in supply chain management applications, but is now becoming used more broadly. This growing deployment has generated an increasing interest among information systems (IS) researchers (Spiekermann & Ziekow, 2005), e.g., in studies of multi-contextuality (Lindgren *et al.*, 2008), remote diagnostics systems (Jonsson *et al.*, 2009), and business innovation (Stenmark & Jadaan, 2010) to name but a few recent contributions.

Sensor data is a source of new possibilities for innovations (Lindgren *et a*l., 2008; Stenmark & Jadaan, 2010), but sensors also typically generate more data than organizations can effectively handle and therefore organizations utilize various sorts of middleware components to help them reduce and process the data (Floerkemeier & Lampe, 2005). However, despite the fact that this is a non-trivial process, the role of the middleware has not been studied much by IS scholars and the literature within related fields describes this filtering and aggregation in a rather trivializing and unreflective way. In this paper we aim to make a contribution to the business innovation field by studying two organizations' use of different middleware approaches when implementing sensor technology.

SENSOR TECHNOLOGY AND BUSINESS INNOVATION

One essential element of organizational renewal is the ability to bring in external information and link that to the existing organizational knowledge. IS scholars have recently suggested that sensor technology contributes to such boundary spanning by its ability to automatically detect and collect information about its environment (Lindgren *et al*., 2008; Stenmark &

Jadaan, 2010). Used in business applications, sensor technology has thus the potential to enhance existing operations by automating and digitizing manual and analogue routines, but also - and more interestingly - to offer entirely new business opportunities (Rooney et al., 2006). March (1991) has shown that when choosing between exploitation (i.e., building on previous experiences and known, safe solutions) and exploration (i.e., plunging into new, albeit uncertain, possibilities), the former is to prefer in the short run but the latter is essential for long-term success. Exploration often requires organizations to reach outside the boundaries traditionally defining their domains, both organizationally and technologically. This boundary spanning is argued to have strong impact on a firm's innovative capacity (March, 1991; Quaadgras, 2005).

Focusing on RFID technology, Niederman et al. (2007) maintain that RFID has the potential to become transformational, i.e., rather than simply replace existing solutions and automate manual routines RFID can enable business innovations in an previously unseen scale. However, such transformation requires the technology to become integrated in the day-to-day operations and supported by corresponding changes in organization, business and technology (Niederman *et al.*, 2007). It is thus argued that technology alone is not enough to create new business opportunities but it is the successful combination of technological change and process renewal that facilitates business innovation (Stenmark & Jadaan, 2010).

It is generally recognized that sensor networks generate large amounts of data, e.g. Rooney *et al.* (2006) report that the retail industry may handle millions of orders on a daily basis, and integration of fine-grained sensor data into high-order business applications is by no means a straightforward or trivial process. The approach typically advocated is to reduce the amount of data by applying some sort of networking architecture that includes a middleware (or edgeware or gateway) component (Floerkemeier & Lampe, 2005; Rooney *et al.*, 2006; Vijayaraman *et al.*, 2006; Horré *et a*l., 2007; Aberer *et al.*, 2007). Using RFID as an illustrative example of sensor technology, Floerkemeier and Lampe (2005) sketch out a three-layered architecture (see Figure 1.). First there is the sensing device layer, in their case the RFID tag and the associated reader. Second, there is the middleware layer, which in their case acquires the RFID data, filters it, aggregates it, and distributes it further. Third, there is the application layer, where in their case the RFID data is combined with application logic and turned into information that the business can benefit from (Floerkemeier & Lampe, 2005).

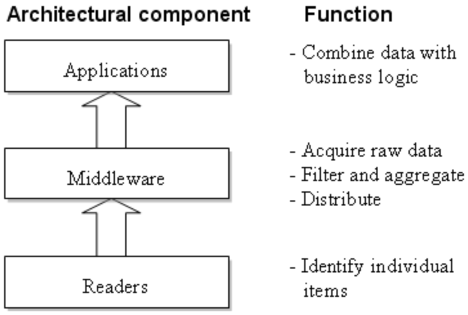

Figure 1. Overview of architectural components of an RFID system (Floerkemeier & Lampe, 2005)

However, as Niederman *et al.* (2007) point out, adding layers between the data source and the final business application introduces new challenges. As each intermediary layer processes data by filtering and aggregating it, details and granularity are lost. The obvious challenge is to be able to predict at filtering time what data will prove to be useful to downstream applications, since the deletion of detailed information at an early stage is irreversible (Niederman *et al.*, 2007). This delicate balancing act has thus far received surprisingly little attention from the research community, whereas more technical aspects such as making the middleware architecture more fault tolerant (Rooney et al., 2006) or more effective (Floerkemeier & Lampe, 2005; Horré *et al.*, 2007) have been in focus. Studying how two organizations use different middleware approaches when implementing sensor technology, we are able to further our understanding of how technological, organizational, and business-oriented changes in relation to sensor technology contribute to innovation.

RESEARCH METHOD

Research context

During 2008 we studied how two organizations, hereafter referred to as SteelCo and PaperCo, used different middleware approaches when implementing sensor technology. Both organizations were highly dependent on the railway for their daily operations and needed to know the content of and the order of railways cars to be able to plan and enhance their unloading and storing processes. By improving tracking of the cars the organizations were able to improve predictability in goods delivery, which would result in business value for both organizations and their customers.

SteelCo was formed in 1978 and has approximately 9,200 employees in 45 countries. The organization produce high strength steel and operates production facilities both in Sweden and the US. SteelCo started using RFID to tag the railway cars carrying their products from their plant to their storage facility. PaperCo has some 52,000 employees and operates in 60 countries. The organization produces personal care products such as tissue, packaging, solid-wood, and publication papers. Together with an external information broker, PaperCo started to use RFID in a pilot project to tag the railway cars transporting their goods. To be able to collect RFID data the organizations contacted the Swedish Railroad Administration (SRA) who has an overall responsibility for the rail transport systems in Sweden, and who is the only one allowed to set up reader stations along the tracks.

Data collection and analysis

In this interpretative multiple case study (Walsham, 1995) qualitative data was collected through semi-structured, in-depth interviews with five individuals from each of the two organizations. In addition on-site observations were carried out at six occasions and internal documentation was collected. The respondents represented both operational and managerial levels in the organizations; two general managers, two operation staff members, four logistic planners and two technicians. The interviews lasted an average of 49 minutes and were all recorded at the respondents' sites and later transcribed.

Data collection and data analysis have partly been carried out in parallel, as advocated by Miles and Huberman (1994). The analytic phases consist of three parallel flows of activities: *data reduction*, *data display*, and *conclusion drawing*. Data reduction refers to the process of selecting, simplifying and abstracting the raw data, such as transcribed interviews, field notes, and internal documentation. For this paper, we have analyzed the material using Floerkemeier and Lampe's (2005) overview of functional components of an RFID system (see Figure1). Data display is an organized spatial way of presenting the data systematically. Using post-it notes with the respondents' statements we arranged along three themes; technology, organization, and business. This visual displaying helped us noticing both differences and similarities between and within the organizations. During conclusion drawing these aspects were further analyzed by comparing and contrasting our provisional results with the literature until we reached a plausible understanding that covered all our findings.

EMPIRICAL DATA

PaperCo and SteelCo showed many similarities when it came to their reasons for wanting to implement RFID. The objective for both organizations was to track and trace railway cars transporting goods between their facilities. The SRA was in charge of installing RFID reader stations at strategic locations along the tracks i.e., near the organizations' facilities. For these projects three reader stations were set up for each organization but the readers were placed where it was convenient for the SRA (e.g., near existing power supply and communication lines) rather than where they would have been most useful for the organizations.

Before introducing RFID the logistic planners at the two organizations received phone calls and faxes from the train operators informing them about the number and order of cars loaded and ready for transport. These were manually assembled lists and the organizations had manually to verify that the specification and the actual order of the cars matched. In addition the planners received information about what content was loaded on to each car through the organizations' internal information systems. The content information was also handled manually which sometimes caused discrepancies between the description in the system and the actually state.

> ”*We have sort of an information gap… we know what the factory has on-loaded but we don't know what we will receive, what is on the train*.” General Manager, PaperCo logistics

Another problem was that the offloading and storage processes were based on the order and content of the cars but cars were often rearranged within the train set many times between departure and arrival. In addition, the train operator could decide that only seven of the planned ten cars could be included. This meant that the information the logistic planner had was often incorrect or incomplete and by the time the correct information was received it was too late to rearrange or replace the cars or cargo. Further, not knowing the exact location of the cars forced the organizations to give only rough estimates to their customers regarding the arrival time of the cargo.

> ”*We depend upon the train operator to report when shunting the cars… We don't receive information until it's in their systems. […] Sometimes they report it an hour late or something ...*” General Manager, SteelCo logistics

By equipping their railway cars with RFID tags and having SRA set up reader stations along the tracks, the organizations not only envisaged the elimination of errors but also hoped to be able to improve the predictability in goods delivery. The anticipated improvement came along two lines; first the replacement of faxes and phone calls with automated processes; second, the tracking of the content, order and location of the railway cars. In all the organizations aimed to improve their workflow and generate business benefits.

Despite the fact that both of these organizations had similar needs and motives for adopting RFID solutions different strategies were utilized during the implementation. We shall now describe these approaches one at a time.

PaperCo

PaperCo's RFID project was a small-scale joint effort between PaperCo, the SRA, and an external information broker (hereafter referred to as BrokerCo). PaperCo installed RFID tags on approximately 150 of their railway cars. The tags themselves contained only information regarding the identity of the cars but they generated a timestamp, the relative position within the train set, and the geographical location when passing a reader station. The project initially had technical problems with the reader stations but these were eventually resolved. Being a small-scale pilot study, the RFID project was a low priority project and PaperCo did not assign any internal IT resources. Instead, they left the development of the middleware to BrokerCo to filter and aggregate the RFID data before presenting it to PaperCo.

During internal project meetings PaperCo, BrokerCo, and the SRA discussed technical details regarding tags and reader stations, information needs, and project goals. However, not having an explicit idea regarding the business opportunities RFID data could enable, it was difficult for PaperCo to provide BrokerCo with a formal functionality specification. Instead much of the design decisions were left to BrokerCo. Based on how they understood PaperCo´s operation needs, BrokerCo created a standalone web application that offered a set of business functions that unfortunately were not sufficiently anchored in PaperCo's business objectives. Representatives of PaperCo felt that this was much due to insufficient planning at the start of the project.

> "*BrokerCo in their isolation makes a solution and they think "This will solve the problem" […] And when we start to use it we notice certain problems and you have to make changes and it may not be so easy to change it because certain principles may have to be modified […] This should have been discussed more in the beginning…*" General Manager, PaperCo logistics

Even if PaperCo had problems specifying explicitly what they wanted they would probably have been able to give feedback on the proposed solution had they been given an opportunity. In retrospect, PaperCo thinks it was the lack of communication between PaperCo and BrokerCo that resulted in a set of function of little actual business value.

> "*One should perhaps have been more careful and precise and said "Okay, in part one we should focus on this" and discussed "Who would benefit from this?" […] The solution should have been synchronized with us because we know what's important […] It is the order within the train set and to know that precisely this car has passed a reader…*" General Manager, PaperCo logistics

Since BrokerCo provided a set of functions presented in a standalone web application, this could not be integrated with PaperCo´s operational information systems. The logistic planner had therefore to switch between systems to get the information needed, which was inconvenient. Instead it was easier to continue to use the fax messages, since these were readily available when the planner arrived in the morning. Eventually PaperCo concluded that an external information broker was not the best solution. They needed to integrate RFID data into their own business systems, and they also needed to ensure that these actions resulted in business benefits for the organization. Thus they excluded BrokerCo from the process and had the SRA send the RFID data directly to them without any intermediaries. This action led to a situation where PapeCo became more proactive in the way of organizing their work.

SteelCo

Having studied other organizations' use of RFID SteelCo concluded that if the technology worked for others it should work for them, too. Hence, they saw no need for a pilot test. They decided to tag the cars in their internal goods flow so that they could identify individual cars, determine their position within the train set and know where they were geographically.

SteelCo did not engage any external information broker but mobilized resources internally to develop the middleware themselves. They also formed a vision about what business benefits could be obtained from the RFID data. The organization wanted to know at every moment where the cars were located and to be able to manage the resources needed to move the goods around. With RFID technology in place, SteelCo knew what material was on its way when the train passed a reader station and therefore optimal unloading and storing processes could be calculated. The organization could now act more efficiently.

> "*We have managed to reduce a work shift group and will eventually eliminate it all together. We used to have staff around the clock to enter the storage codes manually. We don't need that anymore*." General Manager, SteelCo logistics

Designing their own middleware solution, SteelCo had direct access to the fine grained RFID data, and could develop their own functions instead of receive predefined functions from an information broker as was the case in PaperCo. The functions developed by SteelCo did not rely solely on RFID data but were the result of an integration process where RFID data was combined with data from their own business systems. For example, car identity (RFID data) was combined with shipping information (business system data) specifying what material was loaded onto which car. This combined information was then used innovatively to create a graphical image that the forklift drivers could use when to unloading the goods.

Different units within the organization made different use of the received RFID data and many business units had their own integration and their own applications tailor-made to fit their specific needs. This approach resulted in more direct and tangible benefits at the local level. The downside with this approach was the redundancy resulting from similar functions being created at several places across the organization. However, SteelCo did not see this fragmentation as a problem.

> "*They have integrated RFID data into their system and this other unit has built their own. But having different systems is no problem as long as the interfaces are defined. […] We have agreed upon the communication interfaces so it´s no problem. We don´t need to have the same system everywhere*." Operation staff member, SteelCo

DISCUSSION

In our study of sensor technology we focus on the use of RFID tags on railway cars. Although this means that the number of objects handled is relatively small compared to the retail industry, the challenges are similar when it comes to the configuration of the middleware architecture. We have studied two organizations' use of different middleware approaches and identified three overarching aspects that we will discuss in this section.

Integration for innovation

Theory suggests that sensor technology has the ability to transformate organizations by facilitating radical business innovations when the technology is tightly integrated with the ordinary business systems. This is exactly what happened at SteelCo when they developed an application for the forklift drivers, by combining RFID data and shipping information, to know what goods were in what cars. Improving the unloading and storage processes the organization was able to reduce costs and make substantial efficiency gains. Theory claims that such integration of data affects technology, organization, and business and enables innovation. Our empirical data illustrates how this unfolds at SteelCo. As for technology, the development of SteelCo's graphical application was made possible only by having access to RFID data. Further, based on the RFID data, existing routines, applications and work tasks were changed or new ones were introduced, e.g., the forklift drivers received their orders direct to their vehicles instead of having to phone someone and ask, and the warehouse operators did not have to enter the product codes into the system manually. For the business, finally, RFID gave the organization full control of where the goods were and when it was arriving. All this was enabled by the access to data in its native and hence "dynamic" format.

In contrast the logistic planner at PaperCo had to switch between two applications to obtain both the RFID data and the business data, which made her work less efficient and eventually lead to her abandoning the RFID data application. What the middleware did was simply to digitize the information that earlier was received by faxes and phone calls. In this case the RFID data did neither affect technology nor organization or business. Having two separate applications to attend, the logistic planner's work was not simplified but made more cumbersome, which led to her reverting to manual routines. As this illustrates is not sufficient only to digitize existing manual routines. What is important is to integrate the results with ordinary business information systems and such integration becomes difficult when the data has been aggregated or hidden behind an application layer.

Focus on Business value

We showed earlier how previous research suggested that sensor data needs to be aggregated by the middleware component in order to be consumable to the organization. Although this process is described as a challenge there is still little advice as how to go about. The challenge as described earlier is to remove details without eliminating the possibility to be innovative, and the key to this process is to understand what generates business value. As is evident from our case descriptions, SteelCo had a visions and a business strategy regarding the use of sensor data and business value did thus govern the development of new applications. Bringing the middleware layer closer to the application layer, in this case by engaging the in-house IT department, who knew the business, SteelCo was able to filter and aggregate the RFID data at a more precisely, which led to tangible business benefits.

This was clearly not the case at PaperCo where the middleware layer was developed by BrokerCo, an external information broker, who had limited knowledge of PaperCo's business needs. Not having an overall business strategy for sensor data, it was difficult for PaperCo to identify business opportunities even for themselves. Expressing to BrokerCo what sort of middleware functionality they should develop therefore became problematic. In addition, the project did not focus enough on what parts within PaperCo would benefit from the sensor data. Consequently not only the development but also the functional design of the middleware layer was pretty much left to BrokerCo, who built the application based on their own understanding of what PaperCo required. The lack of synchronization between the BrokerCo and PaperCo resulted in a solution that did not generate any business value for PaperCo, since the fixed format of the web application did not allow for exploitation.

In our case study, one company turned to an external information broker whereas the other one used in-house resources. We argue that it was not the fact that BrokerCo was an external part that *per se* caused the problems. It was rather the fact that the BrokerCo developers were not sufficiently familiar with the business objectives of the host organization. This can also happen with internal resources, if the in-house IT department is too detached from the core business.

Designing for exploration or exploitation

Looking at how SteelCo developed their business applications it is apparent that they did so by combining RFID data with existing business data at the application layer, i.e., close to the actual business. Knowing what strategic goals sensor data was supposed to contribute to and having full access to the middleware layer made it possible to pre-process data with high precision instead of having to make rough estimates about what data might be useful for each specific application. Focusing on business value SteelCo developed unit-specific applications based on the local requirements that each unit expressed by combining the high precision sensor data with data from the local business applications. Innovative solutions are thus not the result of the integration *per se*, but by *the possibility to combine previously separated data sources* that the integration enables.

PaperCo, through their external information broker, did also develop an application but unlike the SteelCo case this application was not unit-specific and was developed at the middleware layer, i.e., further away from the business. This gap caused two sorts of problems; the poor anchoring in the business needs and the difficulty to integrate. First, BrokerCo developed a general web application not based on local requirements but on BrokerCo's more high level understanding of PaperCo's business agenda. Second, when developing the application on the middleware layer BrokerCo had only access to the sensor data but was unable to combine this data with PaperCo's business data. Thus the resulting web application was impossible to integrate with the operational applications at PaperCo and, as we saw under the result section, it remained unused. This approach did neither allow for integration nor for combination of data and consequently did not result in innovation.

We are primarily not interested in *why* PaperCo and SteelCo did the things they did in their projects but on *the consequences* their actions resulted in. The two organizations in our study used sensor technology to digitize previously manual routines in hope of gaining business benefits by improving exciting operations and generating business innovations. Sensor data was in both cases collected at the reader layer and passed on to the middleware layer as indicated by (1) in Figure 2. However, only SteelCo was able to integrate the middleware data (see (2) in Figure 2) in a way that affected technology, organization, and business, while PaperCo's failed to integrate their middleware data (3), resulting in the planers relapsing to their manual routines. Finally, SteelCo combined data from both sensor and business applications (4) and thereby was able to generate business value in several innovative ways (5), whereas PaperCo's solution prevented such combination, and instead keep data in separate applications (6).

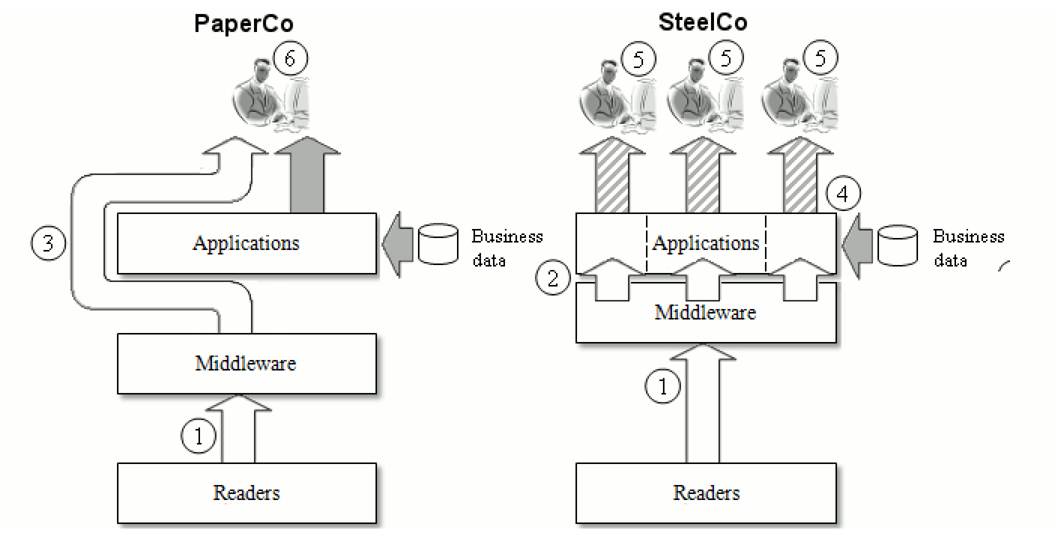

Figure 2. Different architectural approaches to middleware component at our two cases

CONCLUSION

In this paper we make a contribution to the business innovation field by examining how different middleware architectures affect the utilization of sensor technology in two organizations. Our conclusions can be summarized as follows:

- At the reader layer, it appears to be a straight forward process to let sensor technology digitize previously manual routines but the value of this process alone is limited
- At the middleware layer, sensor data must not be aggregated into too rigidly packaged formats since this will inhibit the possibilities for downstream exploration and thus prevent innovation
- The filtering and aggregation of sensor data at the middleware layer should be governed by a clear strategy or vision regarding the business value the data is supposed to generate
- At the application layer, sensor data should be combined with business application data to enable innovative business solutions

When data is neatly packaged for a specific application it becomes easy to for the organization to *exploit* it and reach short term business benefits. The disadvantage is that it becomes almost impossible to use data for other purpose, which obstructs innovation. When data is not packaged but allowed to retain its original dynamic and disordered format it becomes more difficult for organization to use it immediately but it opens up for *exploration*, which is essential for long-term business benefits. Regarding the balance between exploitation and exploration, our findings reveal that digitization, integration and combination of data, which is what leads to business innovation, require that exploitation is prioritized.

ACKNOWLEDGEMENT

This work was funded by the Swedish Railroad Administration FUD # F08-6506/AL50

REFERENCES

1. Aberer, K., Hauswirth, M. and Salehi, A. (2007) Infrastructure for data processing in large-scale interconnected sensor networks, in Proceedings of Mobile Data Management 2007, May 7-11, 2007, Mannheim, Germany, 198-205.
2. Barsh, J. (2008) Innovative Management: A Conversation with Gary Hamel and Lowell Bryan, McKinsey Quarterly, 31(1), 25-35.
3. Floerkemeier, C. and Lampe, M. (2005) RFID middleware design – addressing application requirements and RFID constraints, in Proceedings of SOC 2005, Grenoble, France, 219-224.

4. Horré, W., Michiels, S., Matthys, N., Joosen, W. and Verbaeten, P. (2007) On the Integration of Sensor Networks and General Purpose IT Infrastructure, in Proceedings of MidSens '07, Newport Beach, USA, 7-12.
5. Hult, G.T., Hurley, R.F. and Knight, G.A. (2004) Innovativeness: Its antecedents and impact on business performance, Industrial marketing management, 33(5), 429-438.
6. Jonsson, K., Holmström, J. and Lyytinen, K. (2009) Turn to the material: Remote diagnostics systems and new forms of boundary-spanning, Information and Organization, 9(4), 233-252.
7. Lindgren, R., Andersson, M. and Henfridsson, O. (2008) Multi-contextuality in boundary-spanning, Information Systems Journal, 18(6), 641–661.
8. March, J. G. (1991) Exploration and Exploitation in Organizational Learning, Organization Science, 2(1), 71-87.
9. Miles, M.B. and Huberman, A.M. (1994) Qualitative Data Analysis: An Expanded Sourcebook, 2nd edition, Thousand Oaks, CA: Sage Publications.
10. Niederman, F., Mathieu, R.G., Morley, R. and Kwon, I.-W. (2007) Examining RFID application in supply chain management, Communications of the ACM, 50(7), 93-101.
11. Quaadgras, A. (2005) Who joins the platform? The case of the RFID business ecosystem, in Proceedings of HICSS-38, Hawaii, USA, 2005.
12. Rooney, S., Bauer, D. and Scotton, P. (2006) Techniques for Integrating Sensors into the Enterprise Network, IEEE eTransactions on Network and Service Management, 2(1), 43-52.
13. Spiekermann, S. and Ziekow, H. (2005) RFID: A 7-Point Plan to Ensure Privacy, in Proceedings of ECIS 2005, Regensburg, Germany, 26-28 May, 2005, 688-699.
14. Stenmark, D. and Jadaan, T. (2010) Enabling process innovation through boundary spanning: A multiple case study of sensor technology application, in Proceedings of ECIS 2010, Pretoria, South Africa, June 7-9, 2010.
15. Vijayaraman, B.S., and Osyk, B.A. (2006) An Empirical Study of RFID Implementation in the Warehousing Industry, International Journal of Logistics Management, 17(1), 6-20.
16. Walsham, G. (1995) Interpretive Case Studies in Is Research: Nature and Method, European Journal of Information Systems, 4(2), 74-81.
17. Yoo, Y., Boland, R.J., Lyytinen, K. and Majchrzak, A. (2009) Call for Papers - Special Issue: Organizing for Innovation in the Digitized World, Organization Science, 20(1), 278-279.