Exploiting RFID in a Challenging Environment: A Commercial Case Study of Plant Rental and Intermittent-wireless Hand-held PDA-based Scanners

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Abstract. This experience report presents an overview of the Phalanx software system from Spartan Solutions. This is an RFID-based asset-tracking solution, exploiting robust hand-held PDA-based scanners with intermittent wireless connectivity to integrate operational activities with ERP/logistical information systems for the plant-rental sector. Unusual challenges in the operating environment and user community have been overcome using novel techniques and unique combinations of technology and methodology. The Phalanx system is an exemplar of an innovative RFID application overcoming significant data management problems. Wireless security issues have been addressed and the system includes internal web-services interfaces that are now being extended for exploitation in operational and corporate oversight applications. The middleware platform enables integration of previously separate applications, with extension of business processes to the operational domain. The experiences reported have been gained in development, deployment and use in several countries and offer an insight into the effectiveness of an RFID-enabled infrastructure for improved business performance in a new commercial sector.

1 Introduction

Spartan Solutions Ltd is a UK-based leading edge technology company and software consultancy offering RFID-based asset tracking systems with total integration into existing logistics and servicing management systems and business processes. Spartan is a major player in asset tracking for the rental market, with systems deployed in the UK, mainland Europe and North America.

This short paper presents a commercial case study demonstrating integration of an innovative RFID-enabled application with commercial logistics software, using intermittently connected hand-held wireless devices. The challenging field conditions faced by Spartan's rental customers have directly influenced the overall software architecture for their application systems, and the Phalanx middleware layer is designed specifically to address the business needs of Spartan's principal markets.

Dickman P., P. McSorley G., Liddell J., Glen J. and Green J. (2007).
Exploiting RFID in a Challenging Environment: A Commercial Case Study of Plant Rental and Intermittent-wireless Hand-held PDA-based Scanners.
In *Proceedings of the 1st International Workshop on RFID Technology - Concepts, Applications, Challenges*, pages 75-81
DOI: 10.5220/0002426500750081

2 Background: Asset Tracking in the Rental Market

Plant rental companies operate in a highly-competitive market, providing a broad spectrum of items for their customers, ranging from mobile generators that can be the size of a small car or a shipping container, to individual cables or boxes of tent pegs, leased for periods of days or weeks. Although the logistical processes in such companies are usually highly automated, with efficient call-centre based front offices, the nature of the items being rented means they tend to be stored in large depots, or even fields. Furthermore, since many of the items are large and metallic, and some are stored inside walk-in containers, there are challenges for any electromagnetic or line-of-sight communication system deployed to support item handling.

Traditionally, paper-based processes are used to manage the dispatch and return of rented items. Order sheets are printed from the order management system and carried into the storage yards, where they are updated as required to reflect on-the-ground knowledge and essential ad-hoc decisions about deployment made by experienced field staff. This transition to paper introduces a significant dislocation in several respects. Management lose visibility of activity and the disciplined automated processes can be disrupted, leading to non-compliant behaviour by operations staff. Worse still, updates from the paper sheets back into the automated logistics systems can take days, or indeed never be properly completed. Consequently, the tracking of rented assets becomes somewhat hit-and-miss, and invariably errors occur that require manual rectification.

Spartan offers a tailorable computerised solution based on RFID tags affixed to the rentable items, and hand-held wireless PDAs with integrated RFID scanners. Developing this system involved overcoming a number of significant problems, as described in the next two sections. The advances described here are essential enabling steps for the deployment of RFID technologies in other challenging environments. The Phalanx system, which is at the core of Spartan's software products, is now deployed at sites across the UK, Europe and North America, with worldwide deployment planned for late 2007, as a result of substantial contracts with major multi-national rental companies. In partnership with manufacturers of hand-held computers and the leading specialist software houses producing order management systems for the rental market, Spartan are revolutionising the business practises of an entire sector, exploiting RFID technology in conjunction with their specialist sector know-how and software.

The integrated environment and platform addresses process control issues but offers significant additional benefits. In particular, the reality of operations behaviour can be captured for exploitation in the enterprise systems with minimal latency. Forms of information never normally seen in an ERP system, such as GPS and timing data, are also made available and reports can be generated based on these new modalities. Furthermore, other technologies can be enabled by extension of the computer-based approach into the operations domain. Modular design allows the system to be tailored to the needs of the company, for example allowing a small amount of added telemetry, or a simple warehouse management application to be integrated, in situations that do not merit the cost of a full-function inventory management solution. This flexibility is the key to maximising business value using an asset management system and is only possible because unified business processes are extended throughout the operational sphere by the Phalanx software system.

3 Hardware Challenges: RFID in a Difficult Environment

Several physical environment challenges had to be overcome in order to properly exploit the potential of RFID as a support mechanism for plant rental. The items to be tagged include large metal entities that are subject to “robust” handling, both when being loaded onto lorries for delivery and subsequently when in use. This introduces significant difficulties. Firstly, the RFID tags used on large metal items require backing plates, to ensure a clear scanned signal can be achieved. Secondly, they must be reliably attached to ensure they are not subsequently lost, and this must be achieved without physical impact on the plant, so neither welding nor drilling is acceptable. Further, the tags must be entirely weatherproof and designed to withstand physical shocks. Fortunately, tags meeting these requirements, and appropriate attachment techniques, are commercially available. Normal RFID tags are unusable when directly attached to sheet metal, so Spartan has deployed some 25,000 tags designed specifically for such use, with a special backing. Of these, only 5 failed in-house acceptance tests due to manufacturing faults, and none have been reported as failing in the field.

The electromagnetic challenges extend beyond the difficulty of tagging metals. The yards and fields in which some of the tagged items are stored are large in extent and uniform wireless coverage is further impeded due to the presence of metallic containers and other sources of interference. To avoid the costly requirement for large-scale wireless networking, the approach taken was to attach RFID scanners to PDAs and to develop the software system to permit intermittent interactions between the central systems and those PDAs.

4 Workforce Challenges: Process Integration and Usability

The combination of advances in RFID hardware and the Phalanx software system, integrated with ERP systems, offer the potential for considerable improvement in processing of rental orders and in turnaround of the rented items. However, achieving those benefits required both extension of the computer-mediated business processes into the realm of plant handling and order fulfilment and buy-in from the staff responsible for handling the tagged equipment.

Typically, carefully designed ERP processes break down or are violated by operations staff due to problems accessing information or because of a difficulty with the instructions given to them. The key to success in this field is the realisation that operations staff must be able to change and adjust orders, leaving them with the final decision as to which items will be dispatched. Failing to exploit this expertise always leads to problems, and successful companies are very reliant on operational experience and insights. In manual order completion the field staff will also often correct errors and dispatch slightly different equipment from that listed, using their expertise to interpret the order and adjust the request as necessary. The office staff normally never hear of these changes, or, if they do, the information is rarely linked meaningfully to the original order. Automating the systems, eliminating the paper-based step, allows prompt, accurate and complete updates, showing precisely which items were dispatched.

Rapid feedback also allows order-taking staff in call centres, who are not aware of local conditions in the operations sites, to better understand the issues involved in

order dispatch, and to learn from changes made by operations staff. This interaction improves the service offered to customers and also empowers the operational staff, who are able to address difficulties in a more effective and thorough fashion, knowing that their decisions are being acted upon and valued. In addition, the more accurate oversight of equipment which this approach offers allows far better control over maintenance and servicing.

The extent to which orders are modified varies enormously between companies, and between locations for a single company. Early field testing of the Phalanx system for a major customer showed that in excess of 50% of orders were subject to at least one modification or correction by operations staff. Even after significant improvements in upstream (front-office and sales) processes, modification rates in the range 30%-40% continue to be reported. The most frequent cause is that an essential component has been omitted from an order, however operations staff might also decide, for example, to upgrade to a newer item to avoid sending a piece of equipment that appears excessively worn (albeit usable) to a high-profile location.

Thus the advantage of extending automation into the operations area is that the embedded business processes can allow for final-stage flexibility, with immediate feedback and continual oversight as orders are changed and satisfied. However, these benefits are only realisable if the existing, carefully designed ERP and logistical processes are honoured. Requiring substantial process change during the introduction of the asset-tracking system would eliminate most of the advantages and it was therefore essential that the Phalanx system be adaptable and consistent with existing business processes. Integration of Phalanx into a company's information infrastructure requires flexibility in terms of process modelling and an ability to integrate into a range of database and order management systems.

Employee perceptions must also be considered and their concerns addressed. Operational activities in the plant rental sector have not previously tended to be associated with technology, and it was foreseen that some staff might be hesitant about adopting, or wary of the introduction of, "automation". To eliminate such worries, the user community was involved throughout system development and deployment. An explicit design goal for the handheld systems was that they should be usable with minimal training and without the need for a detailed instruction manual. This "pick up and use" approach required that the handhelds were clearly compatible with existing practise, and that the interfaces were highly intuitive and aligned closely with the operational culture of the adopting companies.

5 Software Challenges: System Integration and Intermittent Connectivity

Addressing the issue of intermittent connectivity by employing hand-held computers merely transfers the challenge of integration from the networking infrastructure to the middleware software. Perfect consistency cannot be achieved between the corporate information systems and intermittently-connected handhelds, given that changes will be introduced in both settings. It was, therefore, essential that the software solution be designed to permit, detect and support the resolution of, inconsistencies.

For example, operational staff engaged in order fulfilment may have to substitute items or modify an order if faced with an inconsistency, or if the requested item is unavailable (e.g. if it is damaged during handling). Simultaneously, an update to the order could be received from the customer, or a request could be generated for the item being used to substitute for the faulty plant. In either case, at the time the order fulfilment information is passed back to the corporate logistics software, the discrepancies must be detected and flagged for immediate resolution. In a traditional paper-based system this issue might only be noticed hours or days later, long after the substituted equipment has been shipped. In an integrated system such as Phalanx the problem is detected within seconds or minutes and can be resolved before loading is completed.

Furthermore, updates can be automatically communicated to the operations staff, allowing them to be promptly informed of changes and avoiding them wasting time on activities that have become unnecessary or counter-productive. On a large site, the passing of updates to whoever is handling an order is vastly improved by automation. In traditional paper-based systems considerable time can be wasted determining who is handling a particular order and finding them, whereas the automated system directly passes information to whichever handheld is being used to progress the order.

The movement of large items of plant means that, in principle, the handheld devices could be damaged or destroyed. Although Health & Safety training means that accidents are extremely rare, and the PDAs used are designed for rough-handling, the Phalanx system has been designed to cope in the event that a handheld fails or is destroyed (e.g. dropped or crushed). The central middleware elements are aware of the tasks passed to each handheld, and the only updates that would be lost are those occurring after the last period of wireless connectivity — a significant improvement over the superseded paper-based approaches.

User acceptance and conformity with existing business processes are both crucial to the success of such a software system. To this end, Spartan employ user-centred development processes for the handheld applications and business process-oriented approaches to the integration with existing ERP solutions and other corporate information systems. Working with company operations staff has ensured widespread user acceptance, and the exploitation of agile techniques has allowed rapid iterations and updates to address issues and suggestions in a manner that has further reinforced the sense of ownership for operations staff.

An early version of the Phalanx software architecture [1] is shown in Figure 1. This example uses a Movex™ ERP system [2], with an underlying Oracle™ database [3], as the main enterprise software platform, but other ERP systems, e.g. from SAP, are also supported. The Business (BAL) and Data (DAL) Abstraction Layers give access to the core database used by Phalanx to manage activity on the handheld devices. The writeback service passes updates into the central system to capture changes introduced by the operations staff. The extraction service provides an indirection layer, simplifying the integration of Phalanx with customers' existing systems.

This version, using Windows Mobile™ and Microsoft™ .NET Framework 2.0 [4], has been described, from a customer perspective, in a Microsoft Case Study [5]. Most significantly, its deployment reduced rental turnaround times from days to minutes.

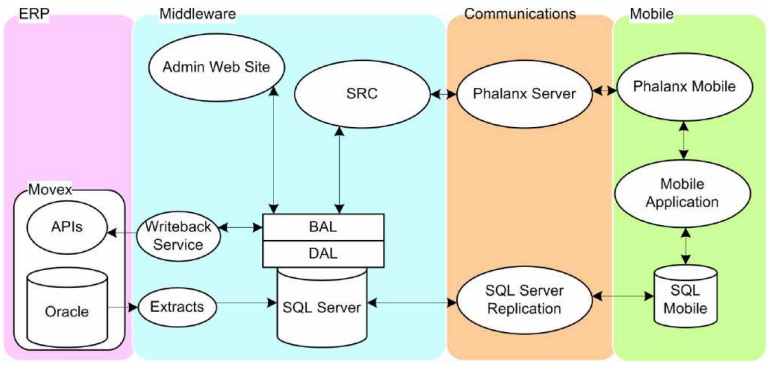

Fig. 1. Outline Software Architecture.

6 Ongoing Work

Ongoing work within Spartan is further exploiting the extension of business processes into the operational domain. The Phalanx suite is being enhanced to exploit the real-time information potential of the system, with new interfaces for depot managers and senior management. Having unified ERP and operational activities, senior management can also be connected to the resource. Traditional approaches can provide business information for senior management, extracting it from the ERP systems, however this tends to be time-consuming, clumsy and costly. By means of a lightweight, reconfigurable web-based view onto the internal Phalanx information repositories, senior management are being given a clear and continuously-updated insight into the activity in their depots and the effectiveness of their company processes.

7 Lessons Learnt

The Phalanx system is a real-world commercially-deployed middleware solution that exploits RFID-data in a seamless integration with existing enterprise information systems, extending business processes into the operational domain. Phalanx solves critical closed-loop supply chain problems, and is one of a new generation of sector-specific integrated software solutions that are leveraging the potential of RFID technologies in conjunction with a more flexible unifying approach to business process design.

Exploitation of RFID advances in the plant rental sector required an integration with existing ERP and related infrastructures. Traditionally, ERP solutions focus on large reliable server-based systems with many carefully-designed and strictly enforced process steps. Operational activities tend, in contrast, to be very lean with a minimal number of small process steps and flexibility in approach to rapidly resolve unforeseen and unforeseeable problems. Fusing these two very different perspectives has required a unique hybrid approach at many levels. Distinct software development methodologies (user versus process focused) have been deployed for the handheld software and central components; inconsistency of information is allowed, detected and managed; and highly reliable centralised systems interact flexibly with highly portable equipment for operations staff, exploiting network connectivity whenever it is available.

The software technologies deployed within the Phalanx system include: wireless security mechanisms (based on 802.11x and an authentication server), web services, purpose-built lightweight communication mechanisms, COTS database systems and business process modelling software.

User-engagement throughout development and deployment has been critical to the successful adoption of RFID in this field. In particular, uptake is detectably more rapid and thorough in sites involved in early stage development and configuration of the systems, with slightly more resistance on sites at which the customer simply deploys clones of the system. Such deep user involvement is likely to be essential to the successful development of future RFID applications in process-rich environments, as these technologies penetrate other sectors.

Furthermore, to aid the transition to Phalanx, the Spartan handheld solution has been designed to also work without any RFID or barcode tagging. In the absence of tags, operators would simply type in the serial number of the equipment being picked, returned or serviced. However, manual data entry slows the logistics process down and is subject to human error. To ease the burden of retro-fitting a tag to the asset, a very simple tagging process is supported on the handheld which takes no more than a couple of minutes per piece of equipment. This means tagging can be quickly performed in bulk (for example during an equipment audit) or scheduled into routine maintenance.

As senior managers in two multinationals have independently stated: adopting the Phalanx system is a “no brainer”, given the substantial business benefits that accrue immediately. Nonetheless, these advantages are only achievable because of careful integration with existing practises and processes, unifying the operational and planning activities despite the apparent contradictions and inconsistencies they present.

The key benefits of RFID-based item tracking are well understood. The experiences reported here demonstrate the difficulties that must be resolved before that value can be realised in demanding and process-rich domains, and identify approaches and techniques that have been successfully deployed to overcome a number of key problems.

Acknowledgements

A Knowledge Transfer Partnership (KTP 0856), part-funded by the UK DTI, supports the collaboration between the Department of Computing Science at the University of Glasgow and Spartan Solutions Ltd.

References

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4. Windows Mobile and Microsoft are registered trademarks of Microsoft Corporation.
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