Ubiquity and RFID:
Combining mobile landscapes with pervasive ecosystems

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Introduction

Weiser (1991, p1) proclaims that the "most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it". More than three billion mobile phones are weaving themselves into the lives of more than half of the earth's population, but while they are ubiquitously carried in handbags and pockets, they are still very much distinguishable as means of reaching others, of telling the time, as cameras etc. Whereas many technologies have become smaller, they have neither disappeared nor started to "serve human needs invisibly, unobtrusively" (Norman, 1991, p9). On the contrary, as new technologies converge and incorporate additional functionality, they demand a heightened level of cognitive awareness and attention from their users.

Distinguishing between mobile computing technology and pervasive computing technology, the former is characterised by rendering computing portable within a context, and the latter by increasing embeddedness of computing allowing for a merger and automatic sensing of this context (Lyytinen and Yoo, 2002b; McCullough, 2004). The mobile phone is not an embedded technology; it is aware of only one particular aspect of its context, the availability of cells it can connect to. Radio Frequency Identification

(RFID) technology, on the other hand, is a good example of a pervasive technology where miniscule tags embedded in the environment support automatic sensoring. The aim of this paper is to explore the organisational consequences of combining mobile- and pervasive computing into a ubiquitous ecosystem. Specifically, we consider mobile RFID, or the convergence of a mobile phone with an RFID transceiver (reader), in combination with passive transponders (tags) embedded in the work environment, and a system that introduces real-time interactivity between the physical work environment and the data collected from it.

In its rather long history since WW2, RFID was limited by bulkiness, short read-ranges and the inability to conduct secure transactions. Advanced tags allow for cryptography, and tag-reader events permit novel opportunities for secure object-to-object interaction. Presumably, as these technologies vanish into the background, they allow the user to re-surface at the centre of the activity (McCullough, 2004; Norman, 1999; Weiser, 1991).

Industry has responded to the newfound popularity of RFID in a number of different ways. IDTechEx and AutoID-Labs promote the advantages of RFID, particularly in comparison to barcode technology, and provide astonishing market data. Accordingly, a total value of the entire RFID market will exceed $5.29 billion for 2008, with 2.16 billion tags (Das and Harrop, 2008), each uniquely identifying its bearer, and enabling batch processing without the need for line-of-sight between tags and readers. With an enormous growth projected over the next ten years, the number of tags supplied in 2018 over 300 times that of 2008 (ibid.), RFID tags and readers should now start to appear everywhere. However, those who experiment with RFID often decide against a permanent adoption of the technology (Kilcourse, 2006). For example, as one of the proclaimed early adopters, the retail industry should, in theory, welcome auto-identification technologies with open arms. Nonetheless, despite opportunities to improve supply chain management, demand management, inventory and shelve space management, and target marketing and customer relationship management, only a small fraction has adopted the technology (ibid.). This has spurred the popular press to cast a shadow of doubt over the future of RFID (e.g., The Economist 2007), and has caught the attention of academics. The call for papers for this Special Issue of EJIS, as well as empirical investigations of RFID in

corporate settings (e.g., Brown and Bakhru, 2006) suggest that the slow uptake and decisions against RFID are driven by either uncertainties related to business cases, a questionable return on investment or a lack of technical know-how.

Drawing from two in-depth Action Research projects, this paper departs from this common wisdom. It proposes that business concerns (in terms of strategic value, financial return etc.), and technological hurdles may be secondary concerns to the unique organizational challenges that shape, and are shaped by, RFID projects. Commissioned by a leading mobile device manufacturer anonymised here as Nalle, the authors of this paper accompanied the development of a synchronous "mobile RFID" system aimed at improving total asset visibility and the access to real-time data on objects on the move.

The two projects discussed in this paper concentrate on prototype projects in blue-collar work settings that suffer from disruptive communication problems between mobile workers and their stationary colleagues. RFID technology was deployed in order to improve corporate communication and data transfer by tagging objects, and equipping mobile workers with synchronous readers that transmit automated data from the field in real time to the organization's back-office. Our study of the security firm Morrison Patrolling and the industrial waste management organisation Grizzly Waste Management clearly demonstrates organisational barriers to successful innovation with RFID technology beyond those traditionally documented. The fact that the same RFID technology was considered highly successful at Morrison Patrolling, but led to a range of problems at Grizzly Waste, raised a number of considerations unique to the ubiquity that the technology offers to an organisational setting.

Whereas Kietzmann (2008) explores how the stakeholders in this innovation process co-constructed the technology, this article takes an in-depth look at the organisational challenges of expanding support for mobile work with pervasive technology and establishing closer automated relationships between physical activities and data recorded about them. The resulting research first focuses on developing an analytical framework that conceptually separates work activities in the incumbent mobile landscapes versus the emergent pervasive RFID ecosystems. Second, Activity Theory is applied in the analysis

to reveal emerging contradictions that stemmed from the complex assembly of subjects and objects with their new tools. The ensuing discussion concentrates on assessing the conditions that demarcate the ubiquity that results from this combination of mobile work activities with pervasive RFID technology.

Lyytinen & Yoo (2002b) characterises ubiquitous technologies as implementing both mobile and pervasive characteristics. This paper contributes to the emerging theoretical discussion of how socio-technical arrangements can be characterised in terms of mobility, pervasiveness and ubiquity (Lyytinen and Yoo, 2002b; McCullough, 2004). It is argued that without a proper understanding of the formative conditions of the auto-identification context and resulting organizational information flows, firms will be ill-prepared for RFID projects, regardless of how well they master technological and financial issues. More theoretically, this article argues that the unique properties discussed here for mobility, pervasiveness and ubiquity improve our conceptual understanding of mobile work in the face of increasingly embedded and mobile technologies. We move from the interpretive flexibility of a landscape of people-centric mobile activities to a systemic rigidity imposed by a highly embedded, context-aware and tool-centric pervasive ecosystem. When combined, the resulting ubiquitous arrangements of mobile work and pervasive technology considerably change the conditions of both the technological but also the social constituents of mobile activities. This paper does not contribute business- or technology "success factors", but rather explores possible "failure factors" of mobile RFID projects. Moreover, by focusing specifically on the integration of data from a variety of actors in the field, this paper presents insights into ubiquitous RFID systems that extend existing discussions of fixed-location or asynchronous RFID projects.

The following section outlines current approaches to understanding mobile work, the development of mobile RFID and the concept of ubiquity. Next, we introduce two empirical RFID projects that formed the basis of this study. We then present our analysis of mobility versus pervasiveness as conceptual foundations necessary for the subsequent discussion of ubiquitous computing environments. We conclude by outlining the formative conditions of ubiquity that shape the possibility for success or failure among organizations about to adopt RFID into their mobile work environments.

Understanding Ubiquity, Work and Mobile RFID

Mobile information and communication technology has a tremendous potential for impacting businesses processes (Sørensen, et al., 2008). This has often been characterised in terms of the ability to support work anytime and anywhere (Kleinrock, 1996). However, since work is still very much situated in specific physical contexts and governed by timing of external events (Lindstrom, et al., 1997), it is indeed questionable if this temporal and spatial flexibility is the most relevant one to consider (Wiberg and Ljungberg, 2000).

However, Weiser's (1991) projection that mobile devices would become invisible and interwoven into the fabric of the mobile landscape to the point where the two would become indistinguishable is becoming more interesting now. Mobile devices vanish on a conceptual level, when their functionality becomes consciously inseparable from the work activities they support, and on a physical level by blending into the environment to a point where the device itself becomes impossible to tell apart from its surrounding. For mobile systems to disappear, they need to connect tightly to their work activities and environments; they need to become "aware" of the context (McCullough, 2004) and become part of it. This, however, cannot yet be achieved by off-the-shelve products; common mobile devices today are not at all affected by the respective context of their operating environment and offer no built-in knowledge base or knowledge capability of their surroundings (Lyytinen and Yoo, 2002a).

The arrival of *mobile Radio-Frequency Identification* (mobile RFID) as the first true auto-identification technology for mobile activities fundamentally alters such levels of conceptual and physical embeddedness. New RFID applications emerge every day; however, so far only the tags are mobile by virtue of being attached to a movable object (e.g., to items on a truck or in the form of a transit pass like the Oyster Card in London). Today's readers, on the other hand, are mostly hardwired to an existing infrastructure for

power and connectivity (e.g., the gates of a warehouse, or the reader in a bus). Others are portable but asynchronous and can store data but not transmit it simultaneously.

The recent convergence of a portable RFID reader with the affordances of a mobile phone allows for automated data capture and synchronous transmission to the back-office. This "killer combination, not killer-application" (Roberge, 2004, p1) presents truly unique opportunities for the mobility of work (Angell and Kietzmann, 2006). Small, synchronous and mobile RFID transceivers have become powerful and affordable enough to read data from miniscule, undetectable tags that are built into the tools of mobile workers, into their identification cards, and into mobile and non-mobile objects of their work (e.g., within security vehicles and buildings). Moreover, coupling a mobile phone with an RFID reader also allows the user to attach a message to each tag event, thereby enriching the data transfer with meaningful comments. As a result, data can instantly flow in both directions between tags and therefore workers in the field, and their remote communication partners.

We wish to situate the discussion of mobile RFID technology within the context of ubiquity, the concept famously coined by Weiser (1991). Lyytinen & Yoo (2002b) continue Weiser's characterisation of ubiquitous technology argues that ubiquity can be understood as the combined effect of mobile- and pervasive computing. Mobile computing implies information and communication technology that can be carried along and pervasive computing is the result of rendering computers invisible by embedding them in their environment. Embedding RFID tags in the organisational context of work and reading these tags with a mobile RFID reader enables real-time interactivity between the context of work and the information recorded about this context. This represents a prototypical example of the arrangement of mobile- and pervasive computing, and this paper aims at understand how this combination can contribute to our emerging understanding of ubiquity.

We examine the use of mobile RFID in terms of the shift from incumbent work activities to those mediated by the new tools. We here rely on Engeström's Activity Triangle (1987), and his use of Activity Systems as a conceptual lens by which to investigate the

contradictions emerging between mobile workers, their superiors and the implicit and explicit rules that govern their work. As mediating artefacts, the incumbent and new technologies are examined beyond their physical, objective affordances (Gibson, 1977), but within their subjective contexts (Dourish, 2001). This holistic approach to studying activities, rather than artefacts only, has been widely recognized among IS scholars (Bødker, 1991; Nardi, 1995; Wiberg, 2001). This study supports a project-focus on "mobile RFID in action" that focuses on the mutual interdependencies of its social and technical constituents.

Mobile RFID Projects

This research explores two projects aimed at involving mobile RFID prototypes within traditional mobile work settings. The research employed Action Research as a well-established methodology in Information Systems (Baskerville and Myers, 2004; Baskerville and Pries-Heje, 1999) to investigate the effects of the unique affordances of the auto-identification technology on various aspects of work at Morrison Patrolling, a security services company, and Grizzly Waste Management, a firm that provides and empties large scale industrial waste containers.

Morrison Patrolling

This particular trial focused on the adoption of mobile RFID at the " manned security services" department of Morrison Patrolling in Manchester (name and place are changed). In a regular shift, a security guard usually arrived at the main office, where he collected a worksheet that contained the various stops for his shift, a vehicle and a mobile phone. Throughout his twelve-hour shift, he covered hundreds of kilometres without returning to the office. He patrolled the assigned premises, checked windows, doors and gates, and ensured that they were secure. In the event that they were not, he called his superior to inform him that he would be late for his remaining stops. In the event of an emergency at a different site, a dispatcher called the guard on his mobile phone to direct him away from his scheduled visits and towards the more urgent matter.

The problems that motivated Morrison Patrolling to participate in a mobile RFID project were plentiful. Most importantly, it was very difficult for anyone, including superiors or dispatchers, to know where the guards were throughout their shifts. For Morrison Patrolling's customers it was also very frustrating not to know if their premises were secure, if the guard ever came to check and if so, at what time and in which intervals. In response, customers called the guards' superiors, who in fact spent most of their time on the phone responding to questions from customers and inquiring about the whereabouts of the individual guards and the status of their work. Likewise, the guards spent an enormous amount of time on the phone, reporting on their progress and location. Lastly, in case of a break-in, detailed documentation from the guard was required immediately, by the customer, by Morrison, by the Police and the property insurers. However, it took two weeks to synchronize the security guards' paper logs with the location and time recorded for every event on their asynchronous readers. The inefficiencies caused by the time delays and the constant telephone calls between customers, managers and mobile workers motivated Morrison to adopt a mobile RFID solution. In the planning stage, use-cases were derived, midlets for the mobile readers developed and approximately 900 passive RFID tags distributed along the guards' chosen checkpoints.

During the execution of the project, each guard logged into the system at the beginning of his shift by reading the tag attached to his identification card and his vehicle. For the remainder of his shift, he read tags that were attached to windows, gates and doors, and chose among the available options on the menu of the phone (e.g., *All ok*). Managers were also able to enter messages into the RFID system from their offices, which were relayed to the guards via tag events (e.g., upon reading the tag of Gate A, the system sent a message reminding the guard to read a newly added, nearby tag attached to Gate B). Through this system, all of the problems that were previously voiced were addressed. Managers and dispatchers had a clear understanding where the guards were, and more importantly, they knew instantly that a premise had been checked. Through an extranet, Morrison's customers were further able to see the tag-data, the time of the tag event and the comments selected by the guards. No more data-processing was needed, insurances and the authorities no longer needed to wait for the results from the head-office. This not only freed up time for everyone, but it also placed the information in the hands of those

who urgently required it and allowed the guards and managers to focus on the central activity of their work (e.g., securing buildings rather than writing reports).

Grizzly Waste Management

The second project was hosted at Grizzly Waste Management (name also changed), particularly at the "waste in transit" operations, which involved the planning and control of the flow of waste from industrial customer sites to landfill sites. Participants of this RFID trial were drivers of bulk carrier vehicles (trucks/ lorries) who serviced waste requirements for a number of regular customers who always kept one of Grizzly Waste's massive containers on their site and relied on scheduled waste collection (e.g., large scale bakeries), or they were ad-hoc customers who called upon Grizzly Waste for waste removal for a specific project (e.g., construction projects). By and large, the responsibilities of the truck drivers involved the maintenance of their vehicles, the collection of full containers from customers' sites and the delivery of empty containers to customers. Full containers were emptied, or *tipped*, at so-called transfer stations or taken directly to landfill sites, depending on the distance and time available. At the beginning of a shift, a driver collected the worksheet for the day along with a truck and then set off for the remainder of the day. In case of changes to the routing and servicing requirements, a dispatcher called the truck driver on his mobile phone. At the end of his shift, the driver returned the vehicle along with a paper log of all the stops of the day.

A number of difficulties similar to the Security Guard case marked this manual system. It was not always clear where the trucks were, if they carried empty or full containers or when they would be arriving at the customers' sites. In some cases, this halted projects that urgently required an empty container, in others it lead to massive rework requirements when garbage was temporarily dumped at transfer stations and then needed to be transferred to other trucks and eventually the landfill later. Another difficulty was the flexibility that was demanded by Grizzly's customers, who at times called to cancel a pick-up with short notice because their container was not yet full. Possibly the most astonishing problem was that these containers seemed to go missing. Some lay dormant at transfer stations or customer sites, but others were impossible to locate at all.

The underlying motivation for this RFID trial was Grizzly Waste's desire to successfully trace where the company's containers were, whether they were full or empty, on their way to or from a customer's site or transfer station. RFID tags were attached to a total of 135 containers serviced by truck drivers.

At Grizzly Waste, drivers also read a tag on their ID card with the RFID reader, which activated their session on the phone and initiated the data transfer to the depot (main office). Dispatchers and managers then knew which drivers were working. Every time they collected, tipped or delivered a container, drivers read the container's tag and chose the respective option from the phone application. Depending on the option selected (e.g., "tipped"), the device queried the truck driver for the name of the transfer station or the conveyance number of the customer site at which the container was collected or left. Managers could also leave instructions for drivers. Once a tag was read, the display on the phone informed the driver of the next stop. Through the immediate transfer of this information Grizzly Waste's main office was able to collate all the time-stamped data and derive the whereabouts of each container and driver and whether they were on their way from or to a customer or tipping station. Based on this data, the dispatcher knew which drivers were available to respond to additional service-requests and what their approximate distance to this customer's site was. It also allowed to trace where the unique containers were and who used them last; before this systems the containers were not even numbered.

Analysis of Mobility vs. RFID Pervasiveness

From a business perspective, the new technology was very compelling in both projects. Middle managers and mobile workers had been motivated to help design of the menus on the mobile RFID device, configure use cases and distribute tags to automate those elements of work that were most time consuming and least enjoyable. Mobile RFID was able to raise, or informate, the level of other work practices by providing additional value

to the users, creating new demands for intellective skills and generating deeper levels of data.

The two projects, however, unveiled a number of issues that had been unforeseen. In some cases, these were of a technical nature. For instance, tags that were attached to steel containers suffered from electromagnetic interference (EMI), which disturbed the connection between tag and reader. The RFID tag was quickly redesigned by Nalle. Other issues were of a use-case nature. For instance, if a mobile worker forgot to close his session on the device at the end of his shift, the system assumed that the same worker continued the next day, although someone else had signed in. These issues were also resolved as soon as they were discovered. However, there were a number of contradictions that were neither technology-based nor business-specific, but unique to RFID. These issues separated the experience of Morrison Patrolling and Grizzly Waste, and eventually set apart a successful project with security guards from the unsuccessful project with garbage truck drivers. While the former adopted the technology into its everyday operations, the latter was unable to overcome the organizational RFID-driven challenges and abandoned the technology after the project.

Unexpected examples at Grizzly Waste included drivers who simply turned off their mobile RFID readers, who would not read all of the tags, or who selected inappropriate answers from the menu on the phone (e.g., entering that they had loaded a container without having unloaded the previous one). When asked about these seemingly strange uses of the new system, drivers responded that they had no signal reception, that tags were missing or that their mobile RFID readers had run out of battery. Closer examination revealed that all the tags were in place, and their batteries were fully charged. These phenomena were particularly interesting and needed to be evaluated further. What motivated the mobile workers to behave in such unexpected manner?

For the two cases and the technology illustrated here, the primary question that emerged was what elements of mobility and technology shaped the organisational experience, so that a similar introduction was successful in one case and considered a negative disruption in another. This lead to the recognition of fundamental differences between

"mobile landscapes" with the incumbent technology and the tightly connected, "pervasive ecosystems" mediated through the new mobile RFID device.

Mobile Landscapes

For garbage truck drivers and security guards alike, location remained an important component of their work. They had to collect containers from specific sites and check particular locations; however, it emerged that they followed a highly flexible approach to managing their own mobility and dependency on location. Garbage truck drivers collaborated with members of their community (even from competing companies), each informing the others of the stops on his daily worksheet. Once a collective understanding of all the jobs was established, truck drivers would swap their stops, mostly based on proximity, thereby minimizing the time each driver had to spend travelling. According to the drivers, this was the only way to service all of the clients in the time required. Moreover, this highly creative way of managing location and mobility required that containers were left at pre-arranged locations in the field, which helped explain why large containers seemingly went missing.

In either project, the mobile workers' communication partners were rarely co-located. Consequently, any communication that occurred relied on the subjects involved and on how they presented their work and location to others. For instance, workers often pretended to be "almost there", in other words close to their destination, when in fact they were still far away. The interaction of communication partners rested with negotiated shared activities, human-based reports and updates of mobile work. In discussions of mobile technology, the focus was thus placed directly on the human subject, and his subjective externalisation of work. More generally, this means that in interactions with mobile workers, the overall focus is to locate the individual users at the centre of their activities (Elichirigoity, 2004); the actual capture and transmission of data through mobile devices remains marginalised. From this perspective, ***mobile landscapes revolve around people-centric interactions*** (see Figure 1**)** (see also Kalakota and Robinson, 2002; Sørensen, 2005).

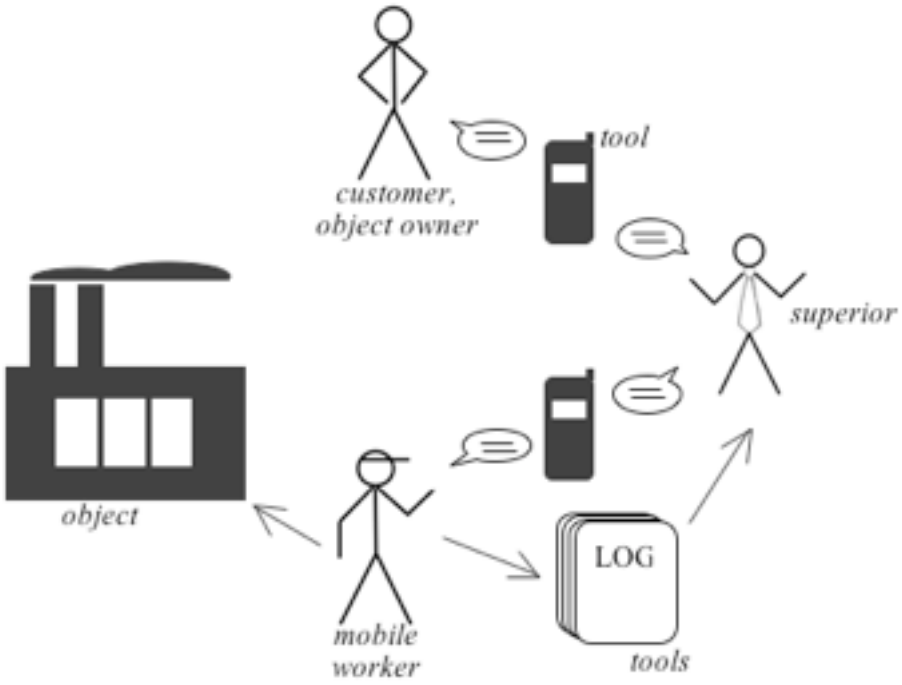

Figure 1: Mobile Landscapes

Pervasive RFID Ecosystems

On the surface, the implementation of a mobile RFID system was nothing more than adding small and very unassuming technological devices to these previously people-centric activities. These tiny tags, tied into already existing infrastructures were to help the IT system blend into the environment, help the technology disappear and allow the human to focus entirely on his primary activities and tasks (after all, the truck drivers were employed to empty and deliver containers, not to keep manual logs).

In this context, the terminology of "pervasiveness" is often applied to discuss "numerous, casually accessible, often invisible computing devices, frequently mobile or embedded in the environment and connected to an increasingly ubiquitous network structure" (National Institute of Standards and Technology, 2001). At first sight, tags and readers were simple tools aimed at improving the interaction between mobile workers, their work activities and other remote parties. Nonetheless, it was not the physical settings and

differences of old and new tools that mattered but rather the information flow they facilitated (Meyrowitz, 1994; Taylor, 2005).

The new social environment, shaped by RFID tags, readers and events, automatically identified the bearer of a tag or reader, whether human or object. The resulting flow of information occurred, unmistakably, according to previously established interaction protocols, triggered in turn by the increasingly involuntary interaction of reader and tag. In fact, with more RFID tags, sensors and readers distributed throughout the mobile work world, an architecture of devices emerged which became increasingly aware of its environment and facilitated and transmitted detailed information about technology-based interactions.

Security workers, for instance, were at times "called" by IT devices. Connected directly to a temperature sensor, for instance, an automatic dialler called the mobile phone of a guard to request his presence at a room full of IT servers that were dissipating too much heat. The guard then needed to verify via mobile RFID that the room was secure, and that no temperature leak was to blame for the excessive heat. As RFID tags were added, more and more of the human activity was driven by the data-demands of the increasingly smart IT infrastructure. As a result, the focus of the interaction shifted from the worker to the technological participant. In this sense, the new environment for mobile work is marked by increased attention to the tool at the core of mobile activities, at the expense of the human subject. In this comparison of mobile and pervasive work environments, ***pervasive ecosystems revolve around tool-centric interactions*** (Figure 2).

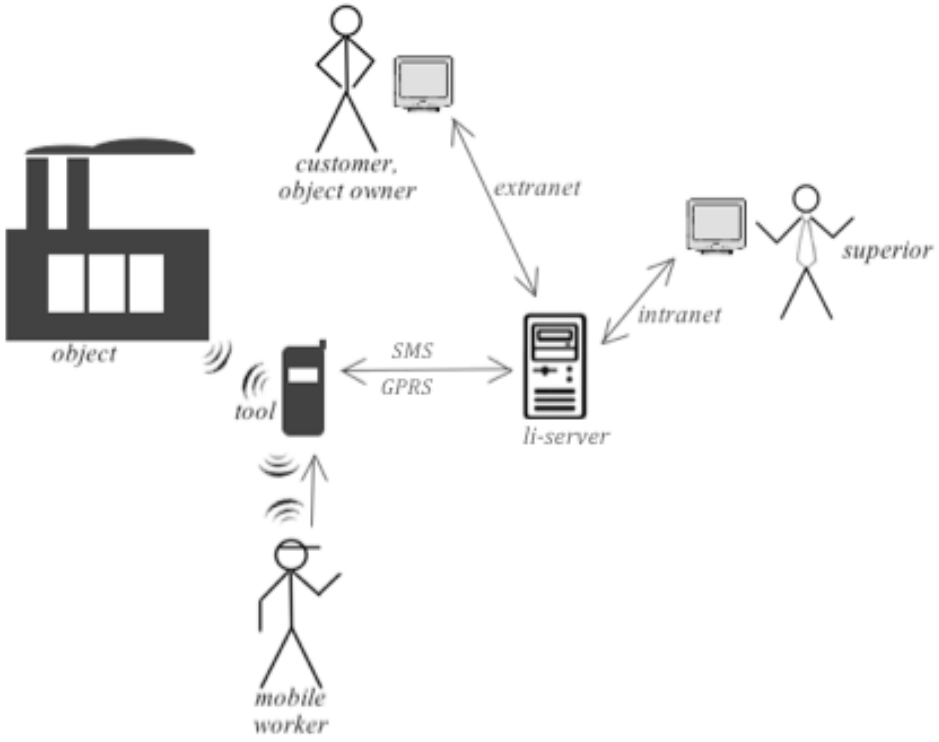

Figure 2: Pervasive RFID Ecosystem

In such pervasive ecosystems, sophisticated, tool-centric information flows change the relationships between artefacts, employees and employers, perhaps the very nature of mobile work. Specifically, by asking four basic questions (where, who, what and when?), the RFID technology provides a LIST of four essential, interrelated elements of mobile work, namely Location, Identity, Status and Time (Figure 3).

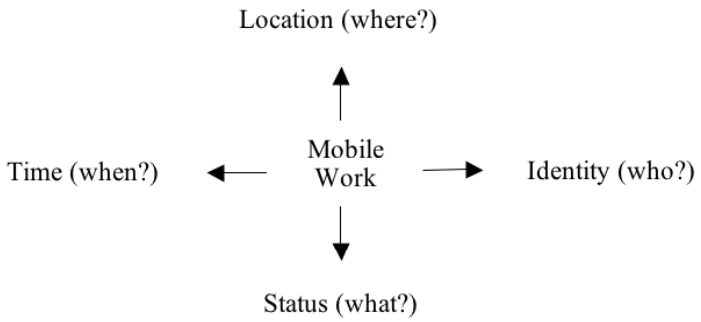

Figure 3: LIST of pervasive (RFID) elements

The first element of pervasive RFID ecosystems relates to the notion of *location*. While a lot of mobile work is carried out at particular locations (Wiberg and Grönlund, 2000), mobile actions and operations are not directly connected to any specific locale. In these cases, mobile workers perform their actions and operations with tools on objects anywhere within their terrain, leaving the organisation with no clear understanding of the whereabouts of their employees and equipment. Although exact identification of the location of objects or tools is not always possible with mobile RFID (e.g., based on read range limitations), pervasive technologies connect the location of the mobile activity to the more narrowly definable location of the objects of his work. Geofencing, or the triangulation of pertinent temporal and spatial information derived from tag events, further helps identify the location of subject, objects and tools.

Identity connects the agents participating in a particular mobile activity. In pervasive environments, the identity of the tool (i.e., the reader's unique identification number), the identity of its bearer (i.e., a mobile worker initiates his work shift by reading the tag of his ID card with the tool) and the identity of the object of the mobile activity can automatically be captured and connected. The use of auto-identification technology such as RFID overcomes the unreliability of manual, people-centric identification (Mitchell, 2003). In other words, in a pervasive environment, the device asks who was involved, and by reading the respective tags spins a web that encompasses the unique identity of the mobile worker, the tool used and the object worked on.

In previous mobile activities, the *object's status* is asynchronously reported and loosely connected to the actual object and reality of mobile work. In the pervasive activity, this status is increasingly reported without the input of the mobile worker. Local sensors, for instance, can automatically attach a temperature reading to a tag event or report other functional data of the equipment. In an effort to strengthen the associations within activities and to elicit data meaningful for other activities, most of the input is automated or offered through predetermined, standardised and menu-driven options ("All ok" for the security guard). The increasing use of sensors that automatically report on their status

combined with unique RFID events will provide higher cohesion between objects, tools and subjects as participants of the overall pervasive activity.

Lastly, the *temporal* aspect of mobile actions and operations is no longer dependent on the time subjectively logged by the mobile worker. Rather, it is strongly connected to time measured by the pervasive environment. For instance RFID tag events are based on the time stamp on the reader/phone and the time stamp on the updated database in the back-office.

Discussion – The Emergence of Ubiquity

Two concepts were discussed in the previous section. Mobile work is described as a people-centric activity; using mobile technologies refers to the ability to carry tools and use them by and large irrespective of location. Although mobile devices have become smaller, they continue to demand the attention of their users. Pervasiveness, on the other hand, refers to tightly connected, tool-centric assemblages of highly embedded computing devices that interact imperceptibly with other technological components of their ecosystems. So far, these two have happened in separation from each other, either in the case of mobile, synchronous devices (e.g., mobile phones) that are unaware of their environment, or in the case of highly embedded but immobile pervasive tools (e.g., stationary RFID readers).

Mobile RFID now presents the merger of these separate dimensions of embeddedness and mobility. By integrating mobility with the pervasive computing functionality (Lyytinen and Yoo, 2002a), the resulting ubiquity suggests that the mobile RFID system is able to gain a detailed view of its contextual environment (Figure 4). By automatically providing answers to four simple questions, it can therefore dynamically adjust its computing services accordingly and allow others to reconstruct fieldwork from remote sites.

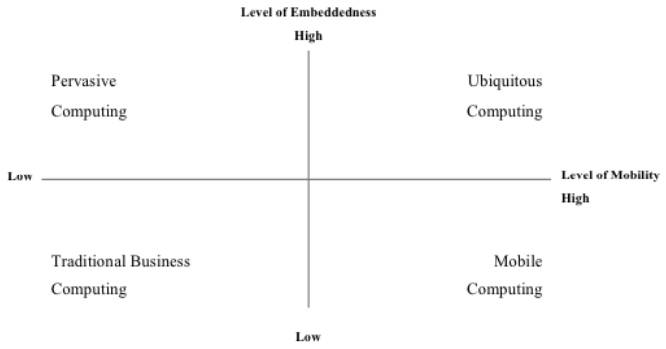

Figure 4: Dimensions of Ubiquitous Computing (Lyytinen, 2002)

By itself, this combination does not provide a contradiction, but it offers insights into the conditions that change in the evolution from mobile landscapes and pervasive RFID ecosystems. In other words, the challenge for organizations considering the adoption of mobile RFID into their mobile work activities is not the automatic transmission of LIST data from the field, but rather the conditions of transparency, persistency and control that set apart mobile landscapes and ubiquitous work arrangements with pervasive ecosystems.

Transparency

The extent to which an individual's work is *transparent* to others is a highly sensitive and political element of mobile work. Transparency in this case suggests a relationship of a mobile and a remote worker, and the visibility of the details of the former work practices to the latter.

In a *mobile landscape*, through their externalisations and representations, mobile workers made their work practices visible to others. The mobile worker enjoyed a latitude of choice regarding the interaction and content transparency shared with remote parties, enabled by the independent, mobile nature of the work activity (Al-Taitoon, 2005; Pinelle and Gutwin, 2003). For remote parties, the only synchronous access to mobile activities, actions and operations occurred via ad-hoc mobile phone calls or actual site visits. Asynchronous mediums such as paper-based logs and reports, did not necessarily lead to

a high degree of transparency of mobile work, as even in the best case scenario, remote parties were able to reconstruct only a very limited reality of mobile work.

Under ubiquity, on the other hand, details of various context-related variables are automatically captured and made visible, not only to the mobile worker, but also to his superiors and colleagues. As the mobile worker and his tools travelled together through the terrain of tagged objects of their labour, LIST details of his respective actions and operations were automatically collected and forwarded. Of course, this was the motive behind the introduction of the technology in the first place. However, a contradiction existed between the clear separation of public and private elements of work under mobility and the all-pervading transparency of the ubiquitous RFID environments (see also Junglas, et al., 2008). The daily hands-on work of a mobile worker was conducted predominantly in isolation from his colleagues and superiors. Only contexts and circumstances that required others' input or knowledge lead to externalisations, communication and cooperation between mobile workers and possibly their superiors. Once these communicative tasks were completed, cooperative mobile work became individual work again and was no longer visible to others. To this extent, mobile work is demarcated by both individual and cooperative work, the balance of which develops over the course of its cultural-historical trajectory. Ubiquitous activities, on the other hand, are highly mobile and transparent. The high cohesion and synchronicity of pervasive information unveiled very specific information based on an individual's behaviour beyond what is considered public or cooperative. Ubiquity no longer makes the distinction between individual and cooperative work and exposes previously hidden mobile information about Location, Identity, Status and Time to colleagues and superiors. The private, isolated conventions of mobile work disappear, giving way to potential transparency contradictions.

Ephemeral and Persistent Aspects of Mobile Work

Of course, another contradiction points to the permanence of this transparency. In mobile activities, workers carry out a number of short-lived tasks that are part of everyday mobile work. Many of these tasks are never disclosed, discussed or logged; they include

shortcuts or routine actions that do not receive any further attention since they are part of commonly accepted work practices. Ubiquitous systems now create a traceable path of increasingly transparent actions, previously considered passing mobile conventions. More importantly, a ubiquitous arrangement of pervasive and mobile technologies retains this contextual information and turns previously ephemeral tasks into persistent practices (Schmidt, 1994). Formerly temporary and invisible tasks now leave immediately available and permanently stored trails as external representations. Directly connected to the individual mobile worker, such information crosses space and time and becomes visible to others, at any moment in time. In essence, mobile RFID permits the collection and retention of information about the mobile worker's tasks, extending profiling, traditionally aimed at customers of an organisation (Perrin, 2006; Weinberg, 2006), to individual mobile workers. More than retaining work-related information, including conclusions about the particular tasks in the field, these permanent traces allow others to draw extended inferences about personally identifiable, previously undisclosed activities (e.g., the location and time of breaks) at any point in time (Sørensen, et al., 2000).

Control

In mobile activities the control of work involves instigating ad-hoc, synchronous voice communication by superiors to receive the status of mobile activities and to dispatch orders accordingly. In terms of control, this impromptu interaction between mobile activity and activity of the supervisor is flawed. It is neither based on an objective account of work practices, nor can it be validated that the mobile worker receiving orders actually follows them as instructed. The mobile worker remains largely sovereign and in charge of his participation in remote control mechanisms (Wiredu and Sørensen, 2005).

In RFID ecosystems, the transparency of activities increases dramatically and consequently amplifies the amount of knowledge about mobile work at the disposal of superiors. On the organisation's side, new automatic data-flows have an undeniable impact on the granularity of control exercised by and expected from superiors. Interestingly, the increased transparency allowed more control, even when this was not desired and superiors saw their own discretion challenged, too. The amount of

automatically-captured field data that was now in the hands of the organisation demanded control of work activities that were previously entrusted to the mobile worker, and placed those in managerial positions at times in new and undesirable positions. In previous mobile settings, they could decide which data to query from the field and how to react to it. In the ubiquitous system, the information was automatically presented to managers and demanded corrective action if the mobile worker veered off course. Accordingly, the difference between using a tool for its functional affordances or as a means of increasing transparency and thus control are blurring with mobile RFID, where one largely implies the other.

Conclusion

Mobile landscapes develop over time, based on commonly accepted configurations of mobile work practices. In terms of mediation, transparency and control mobile environments leave a degree of interpretive freedom and flexibility to the mobile worker and his superiors; they are highly centred on individuals at the heart of the activity.

Pervasive RFID ecosystems; however, are much less flexible and present an architecture of a more rigid and enforceable structure. The embeddedness of technology into mobile work environments creates a ubiquitous flow of LIST information (i.e., location, identity, status and time) from the context of work outward to peers and superiors of mobile workers. As a result, under ubiquity, a mobile worker no longer travels through his work world autonomously, without traceable interaction (Rosander, 2000), as with pervasive RFID technology "mobility becomes less of a description of an autonomous user freely moving in the world and more of a contingent subject-position made possible by object-object communication" (Elichirigoity, 2004, p10).

This implies that the interaction of mobile workers and their superiors are dramatically altered, as superiors gain access to context-specific information based on the individual mobile worker's behaviour. Through dynamically reconfiguring computing environments and redirecting a mobile worker's actions, mobile RFID systems and superiors

accompany a mobile worker along the navigation of his workspace. Rather than overseeing activities from a distance, superiors are quasi co-present and have immediate access to pervasive information of mobile work. As mobile activities become more transparent and controllable, the identity of the mobile worker shifts to one that is no longer autonomous. Accordingly, the embeddedness of devices presents a potentially invasive work environment, which largely affects the worker's ability to exercise discretion in his work activities. As technologies disappear, the embedded system overrides the worker's judgment by prescribing at least a partial order and an invariant sequence to his mobile work activities and tasks.

In some cases, the conditions that demarcate mobile landscapes with incumbent technologies disagree with those introduced through the new pervasive RFID ecosystems, in others they support them. According to Activity Theory, it is the potential contradictions that shape the success of the new RFID system. If small enough, as was the case at Morrison Patrolling, the contradictions lead the organization through expansive learning cycles, and the new technology becomes part of the existing activity. If too large, as was the case at Grizzly Waste Management, contradictions will not be overcome, change the activity altogether or lead to the abandonment of the new technology.

The question that this discussion set out to answer was why a new technology such as mobile RFID supports some mobile work contexts while it truly upsets others. The conceptual distinction made here between mobility and pervasiveness as people and tool-centric activities, respectively, adds clarity to this question. As an investigative lens, it points out that embedding devices can have far-reaching implications, both good and bad. This further challenges the widely accepted credo that once technologies disappear and fade into the background, they can seamlessly support human activities.

The conceptualization of a LIST (location, identity, status and time) of RFID-driven data to and from the field contributes to our understanding of auto-identification technologies at work. When combining embedded, pervasive technologies within mobile work activities, as evaluated in the context of two empirical mobile RFID projects, a number of

conditions of mobile work are affected (Table 1). In activity theory parlance, this can lead to a host of contradictions between mobile landscapes and pervasive RFID ecosystems that in turn shape the success of the new technology in its organizational context.

Potential Contradiction	Conditions of Activities in a	
	Mobile Landscape	**Pervasive RFID Ecosystem**
Obtrusion	Obtrusive, requires context changes	Unobtrusive, silent, context-specific
Transparency	Selective, based on worker's representation	Automatic, universal data from all workers
Permanence	Ephemeral	Persistent
Discretion & Control	Worker and superior remain autonomous	RFID imposes and enforces rigid rules

Table 1: Conditions and potential contradictions

As we embed increasingly many RFID devices into our everyday environments we increasingly model the social in the technical (Sørensen and Gibson, 2006). As projected, many more tags will be attached to mobile objects, and as the technology discussed here displays, readers have been developed that are both mobile and synchronous. In this sense, the trajectory discussed, from mobility and pervasiveness to imminent ubiquity, is both timely and very important. While industry promotes a pervasive utopia in which the technology moves to the background, proposing that the human will re-emerge at the centre of activities, this study raises a word of caution and suggests that the opposite can come true. As more RFID tags are embedded and more mobile readers replace traditional mobile phones, the interpretive flexibility of mobile work will make way for rigidity of ubiquitous systems, and while technological interaction may become imperceptible, its impact on organisational arrangements may be felt more than ever. It is true that the degree to which ubiquitous computing environments wield control over the mobile work environments varies considerably from one mobile setting to the next. But as we continue to invite more and more embedded devices into our mobile work environments, understanding the uniqueness and potentially contradictory conditions of mobility, pervasiveness and ubiquity, becomes essential for our understanding of projects in which technologies can truly vanish and support mobile work, and in which mobile RFID projects will truly upset organisations.

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