A Reference Architecture for Mobile Knowledge Management

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Abstract: Although mobile knowledge management (mKM) is being perceived as an emerging R&D field, its concepts and approaches are not well-established, as compared to the general field of Knowledge Management (KM). In this paper, we try to establish a definition for mKM. Taking into account building blocks of KM in enterprises and the abstract use cases of mKM systems, we introduce a reference architecture for mKM systems as a basis for verifying and comparing concepts and system architectures. Finally, we address the potential suitability of mKM as a prototype model for mobile, situation-aware information processing in the field of Ambient Intelligence Environments.

Key Words: knowledge management, mobile computing, context awareness, ambient intelligence

1 Introduction

Over many years, research on mobile information systems concentrated heavily on technical issues like device capabilities, media presentation, and communication networks, leaving human issues aside. As a result, mobile networks and devices are very powerful today, but their acceptance in business use is mostly limited to mobile telephoning and transmitting email over 3G networks like UMTS. Only occasionally do the devices serve as personal information organizers.

Technical achievements like digital cameras in Smartphones and Bluetooth are only rarely used to organize mobile work. Coherent and user-centric integration of these powerful technologies into work processes is still lacking. Addressing this deficit, more recent research has focused on situational assistance. Initial operative systems (Location Based Services) dealt mainly with the location aspect of the user's context. However, so far, the broader approach of general context awareness has yet to make its way to the market of mobile work support.

Knowledge management, by contrast, has quite a history of verified concepts as to how to support the user in his daily work and how to make knowledge-intensive work in particular more effective. The user plays the central role and in order to assist him, one of the most important issues in KM systems is the organization of information. But the well-established KM approaches are lacking an elaborated approach to focus in particular on mobile work, assisted with modern mobile IT.

We, therefore, chose the KM user-centered approach to the implementation of mobile information systems and found a promising approach in the interdisciplinary combination of KM and mobile computing to overcome the shortcomings of both areas. A recently emerging notion in this area is Mobile Knowledge Management, sometimes referred to as mKM.

This research field tries to combine the specific strengths of both areas by

1. extending knowledge management systems by the anytime, anywhere information access metaphor and making KM functionality available on ultra portable devices using mobile connectivity, and
2. extending mobile computing to a user-centered discipline that supports the user actively in mobile, knowledge-intensive working environments.

In our opinion, the merging of both disciplines in such a joint effort can accomplish two goals, that of making knowledge management ubiquitous (i.e., moving away from the desktop) and that of making mobile computing useful (i.e., focusing on the user and assisting him actively). So far, mobile knowledge management systems (such as [Fagrell et al., 2000]) have been introduced as technical

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implementations of systems that are mainly capable of retrieving task-based or location-based information on different mobile devices or device categories.

This paper tries to elaborate a holistic approach that identifies the basic functionalities for knowledge management systems in mobile environments and proposes a reference model for such systems. This model might help to compare different systems in their conceptual design and in the KM functionality provided to their users. The model is generic enough to be used in different application domains, but is specific enough to cover only use cases related to the knowledge management domain. In section 2, we start out with an analysis of mobile work in general, and what role information plays in mobile environments.

2 Mobile Knowledge Management

We strive for IT support facilitating knowledge registration, distribution, and usage in spatially distributed business processes (in short: mobile work). When work is both knowledge-intensive (e.g. associated with recording a great deal of new information to be shared with other people) and mobile (i.e., outside the office, often without any pre-planned infrastructure [Kristoffersen et al., 1998]), the acquisition and sharing of the organizational knowledge becomes challenging. These challenges pertain to limitations with which mobile workers are confronted. Some of these limitations can be classified as (cf. [Tazari et al., 2005] and [Kristoffersen et al., 1998])

- technical and infrastructure-conditional limitations of mobile devices and mobile connectivity,
- organizational limitations, such as distance to experts and corporate resources, and
- individual limitations concerning the cognitive load resulting from concurrent tasks, time pressure, ad-hoc situations, distracting or “manipulated” environments under the strong influence of the needs and desires of the customer.

Keeping these limitations in mind, we consider mKM at the definition level in this section and discuss the IT-related concepts in section 3.

2.1 The Survey

Research into the state-of-the-art of mobile KM has shown that the term mobile KM is used more and more often, although it is not yet very specific and well-defined. In many cases, it is understood as the mobile access to established knowledge and document management systems with user interfaces designed and adapted to small display sizes. This is in contrast to the rather general concept of Knowledge Management, which addresses different areas of human, organizational and technical issues.

Nonetheless, there are already some more detailed statements that address the mobility aspect more specifically. Lehner et al, for instance, see the mobility of knowledge in conjunction with (the chance for) mobile access to knowledge and information, the mobility of knowledge through the mobility of its source (e.g. mobile expert), the mobility of knowledge through the mobility of its formation place, and the change of the place in which knowledge-intensive processes take place [Lehner and Berger, 2002]. This definition, however, concentrates on “mobile knowledge” and disregards the management aspect.

Von Guretzky identifies in [von Guretzky, 2002] the relations between the enterprise and its customers, employees, and business partners (such as suppliers) as an important issue in mKM from a stakeholder perspective. In the first category, he suggests satisfying the knowledge needs of the customers in ad-hoc situations by putting the accordingly prepared information on the portals of the so-called knowledge brokers – basically, some sort of support for mobile access. For the internal relation between the enterprise and its employees, von Guretzky sees the value of mKM in the increased mobility and flexibility of the involved people and the economy of time and cost when performing tasks. Because the relevant knowledge can be flexibly linked with the operative business processes, mobile employees can make their decisions on-the-spot when visiting the customer and record information directly at its point of creation. Finally, he believes that mKM can make for a fast and cost-effective cross-enterprise connection of knowledge sources and drains [von Guretzky, 2002].

Assuming that the focus of KM is "the steering of the organizational learning process according to some normative, strategic, and operative knowledge goals" [Probst et al., 1999], we believe that supplying subscribed customers with high-quality, up-to-date, and well-structured info about the provided products and services surely lends itself to the strategic goal of enlarging the market share (cp. [von Guretzky, 2002]), but it is not a knowledge goal of the enterprise. The technical goals of providing mobile access to enterprise resources, however, have a common ground regarding the enterprise relations, both with its mobile customers and with its mobile employees.

On the other hand, a cross-enterprise connection of knowledge sources and drains leading to a certain level of resource sharing (e.g. sharing info resources and software services) is certainly a knowledge goal when supporting mobile workers. But in the case of assisting mobile business partners, such as mobile suppliers, an enterprise certainly follows some strategic goal, but no knowledge goal.[1] The techniques to support cross-enterprise connections in mobile work will contribute to the former case, though.

2.2 Our View

Obviously, there is a direct connection between mKM and technical progress in the field of Mobile Computing, in areas such as mobile networks and mobile and personal devices. Hence, we do not define mKM as an enhancement to the management discipline "knowledge management". That is, for us, the question is about the focus of mKM as a distinguished part of knowledge management in organizations.

Our understanding of mobile KM has as its focus the seamless integration of mobile work into the corporate knowledge management control loop, especially where knowledge is associated while performing tasks, tasks necessitate out-of-office work, and tasks necessitate communication. Thereby, the most important organizational knowledge goals specific to mobile work can often be classified as (cf. [Tazari et al., 2005])

- facilitating the registration and sharing of insights without pushing the technique into the foreground and distracting mobile workers from the actual work,
- exploiting available and accessible resources for optimized task handling, whether they are remote (at home, in the office, or on the Web) or local (accompanying or at the customer's site), and as
- privacy-aware situational support for mobile workers, especially when confronted with ad-hoc situations.

That is, mKM systems must not only provide mobile access to existing KM systems, but also contribute to at least some of the above management goals. Taking a glance at the well-established building blocks" (see Figure 1) of Knowledge Management [Probst et al., 1999], the dedicated areas of mKM (as indicated with an exclamation mark in Figure 1, as well) can easily be outlined as to:

- knowledge preservation: e.g. on-site, mobile registration of new knowledge,
- knowledge sharing / distribution: e.g. ad-hoc distribution to co-workers and mobile collaboration, and
- knowledge use: e.g. mobile accessibility of knowledge and situational assistance.

Typical use cases within these building blocks are:

- Knowledge Development:
  to capture information, to author / register knowledge, to rank / evaluate knowledge, to prepare knowledge for later mobile use
- Knowledge Sharing / Distribution:
  to share knowledge, to perform mobile collaboration, to communicate

[1] Von Guretzky rightly classifies mobile customer relationship management (m-CRM) and mobile enterprise resource planning (m-ERP) in the category of relations between the enterprise and its mobile employees, which supports our assumption about the substance of management goals in relation to customers and suppliers.

- Knowledge Use:
  to retrieve & present knowledge, to get situational assistance, to post-process (report) the captured knowledge

Bold elements relate to those use cases, whose support with mobile IT in mKM we consider mandatory. Others might be optional in different usage domains or cover important non-mobile phases in knowledge work, e.g. work preparation and post-processing.

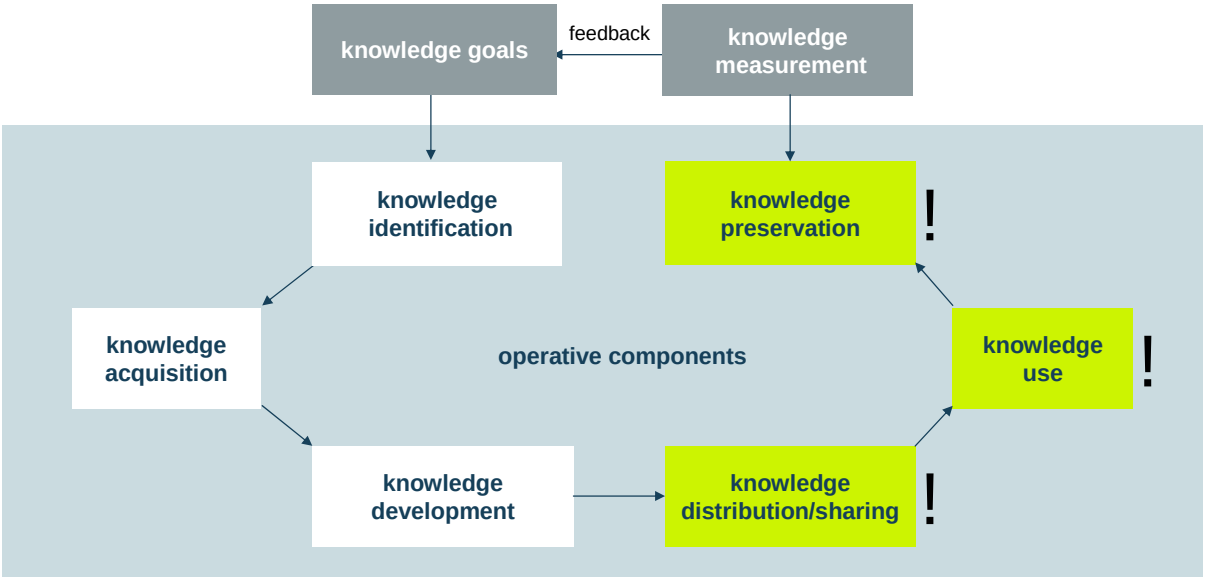

Figure 1: building blocks of Knowledge Management [Probst et al., 1999]

2.3 Prerequisites: Context Awareness and Media Management

Considering the above-mentioned knowledge goals and use cases in mobile knowledge work, a prerequisite for fulfilling them is context awareness (see also [Tazari et al., 2005]). By *context*, we mean the user context in terms of all the temporal, personal, organizational, environmental, and even global conditions surrounding the user. This is the situational view to the context as it is investigated in Mobile Computing, Ubiquitous/Pervasive Computing as well as Ambient Intelligence. We believe that the user context is a excellent supplement to the idea of usage context, which is normally related to the resources that are known to be in use, such as open files and running programs, and the informational context resulting from the relationships among information items.

While analyzing and exploiting the user's context in the office environment is very difficult, mobile knowledge management seems to be a promising research area. One of the major characteristics within mobile environments is the change of the user's location and thus, the change of the location-related context, because mobile work is inherently correlated to its location[2]. If, for instance, the user is a member of the sales force and meets a customer, s/he will most likely want to deal with information concerning the customer. A construction manager who meets a contractor at a specific place on-site most likely wants to delegate or communicate issues relating to that specific place and to the specific role of that contractor. A very interesting conclusion of these considerations is the inverse case, when mobile workers try to document their insights, the user context can be utilized as automatic metadata to annotate the registered information and bring it into context.

Thus, when capturing information, the mobile context (creation context) might be captured, as well, and can be used to structure / augment the captured media: context metadata is added; relations between different (new and pre-existing) media elements, tasks and events are established. In the

[2] As stated in [Kristoffersen et al., 1998], "Mobile work comes into play only when work cannot be conducted locally, in other words, the complete context for the task cannot be established before one is 'on location'."

case of retrieval the usage context is exploited to filter the context-augmented information for usage relevance.

Media management is of specific interest in mobile KM, as particularly in mobile situations, a diversity of media is captured, due to the simple physical constraints. As opposed to office work, it is much easier to capture an image, record a voice note or draft a sketch than write down a descriptive text. This holds true even if no IT is involved. Thus, well-established mobile business processes, such as, for example, site inspections, suffer today (without specific IT support) from heterogeneous, location-related sets of media, captured in different non-digital and digital formats (paper sketches, voice notes on tape, digital images in cameras), which can hardly be consistently re-integrated into one descriptive digital "information object" afterwards (see example in Figure 2).

Figure 2: example process site inspection

The most important goal of context-aware information processing in the above-mentioned sense is, therefore, to support consistent media capturing and to enable situational media retrieval. For knowledge acquisition, this does mean facilitation of the simultaneous capturing of media and their interrelations in context, or their relations to other knowledge objects, respectively. In the case of knowledge retrieval, the current user and usage context is to be evaluated for extracting the relevant interrelated information parts / media elements.

3 mKM Concepts and Reference Model

3.1 The Key Concept

As pointed out in section 2.3, the key concept of mobile KM is context-aware information processing. This means that the system has certain knowledge about the user's current situation while assisting the user in the tasks he is performing with his portable computing device. This concept has also been presented in existing approaches to non-mobile KM (see e.g. [Ludger van Elst, 2001], [Abecker et al., 2000]). Thus, some of the most important features of Knowledge Management systems are to support knowledge workers in the creation, capturing, organization, linking and searching of knowledge ([Maier, 2004]).

In a slight variation of the widespread understanding of knowledge being information in a specific context, our operative understanding of knowledge for mKM is: *information generated or needed within the specific context of an action (here: working action) a person is performing or is going to perform* (Figure 3, left side).

With this task-oriented view on knowledge, the core building blocks of mKM can be arranged in a cube-like form as given in Figure 3 (right side). It is referencing the three notions of context, information and action in adjunct planes. The model is structured in different abstraction layers from top to bottom, as well as in planes showing system use cases from front to back and planes that illustrate different cases of context application from top to bottom.

Although having three planes, the cube is not meant to be a 3-dimensional *space* – the edges represent the dependencies between knowledge action, information handling and situational technologies; thus, "Concept Cube" is put in quotes.

The planes of the "Concept Cube":

1. System use cases (top): What operational support does an mKM system enable?

This plane references the “action” dimension. It describes the specific support a user of an mKM system gets within his mobile knowledge work. The building blocks of this layer are based on the key concepts elements: Context-Aware (CA) knowledge capturing and CA knowledge retrieval. These elements incorporate aspects that focus on mobile computing technology like device-specific presentation and sharing across different platforms.

2. Context awareness (right):

This plane models how context management is used to derive different action-specific contexts as creation context or current context to finally form the situational assistance (situation management). Whereas situation management is needed in the use case layer to enable situational assistance, the action-specific contexts are used to inter-relate and semantically pre-structure information objects (front). The context models combine aspects from KM (e.g. task, workflow, process) and mobile computing (e.g. device, location, connectivity).

3. “Data layers” (front): How is information modeled as “information in context” to be usable within the system use cases?

The combination of information and semantic description is crucial in every KM system and not specific to, but indispensable in mobile KM. The squares that are modelled and instantiated in the semantic layer refer to documents on the local machine, web pages on the Internet, and databases of customer information, to name only a few possible sources. Using ontologies, these items can be interrelated in a computer-understandable way, which is essential for a knowledge management system. The circles represent situational elements, such as tasks, locations, or people, that are very crucial to mobile knowledge management. The relations between situational elements and documents specify in which situation information has been recorded, or at which location certain information is of importance for the user.

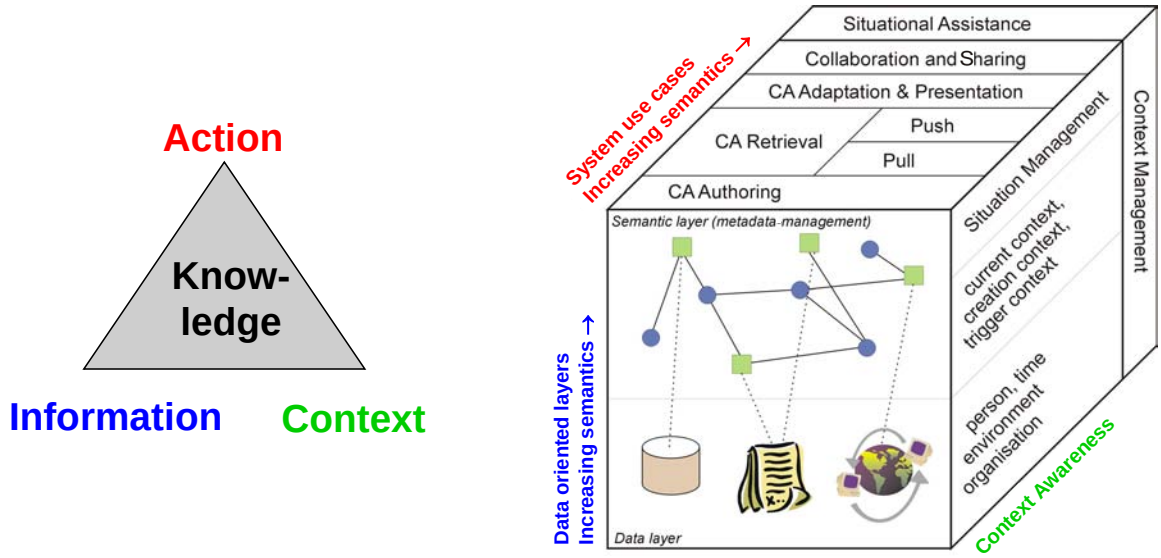

Figure 3: mKM knowledge concept (left) and “Concept Cube” of mKM building blocks (right)

3.2 The Reference Architecture

Unfolding and detailing the “Concept Cube” with respect to the mKM use cases within section 2.2 leads finally to the mKM Reference Architecture as shown in Figure 3.

The shaded components in bold letters indicate the indispensable system elements (in reference to the mandatory use cases): context / situation management with facilitation of different context types for context-aware authoring and retrieval / presentation, and last, but not least, knowledge sharing. We believe that for an active assistance in mobile work settings, systems must implement each of these functional blocks and need a context and domain model, which must be adjusted from case to case.

The components in italic letters refer to process steps, that are not mobile, preparation of knowledge for mobile use, post-processing as knowledge evaluation and reporting), but very important in mobile work processes, and helpful, but not necessarily indispensable mobile assistance functionality (mobile collaboration on work-related information, situational assistance with situation-related information push to the user). These components are not meant to be exhaustive and are added exemplarily. They take into account the lessons learned in implementing a specific mKM solution within the area of mobile Facility Management (FM). Mobile FM business processes are on a conceptual level very similar to broad classes of other mobile work domains (e.g. maintenance, sales field forces etc.) and therefore represent a blueprint to some extent. Nevertheless, other domains might require more or other extensions like, for example, context-aware mobile authoring of "best practice solutions".

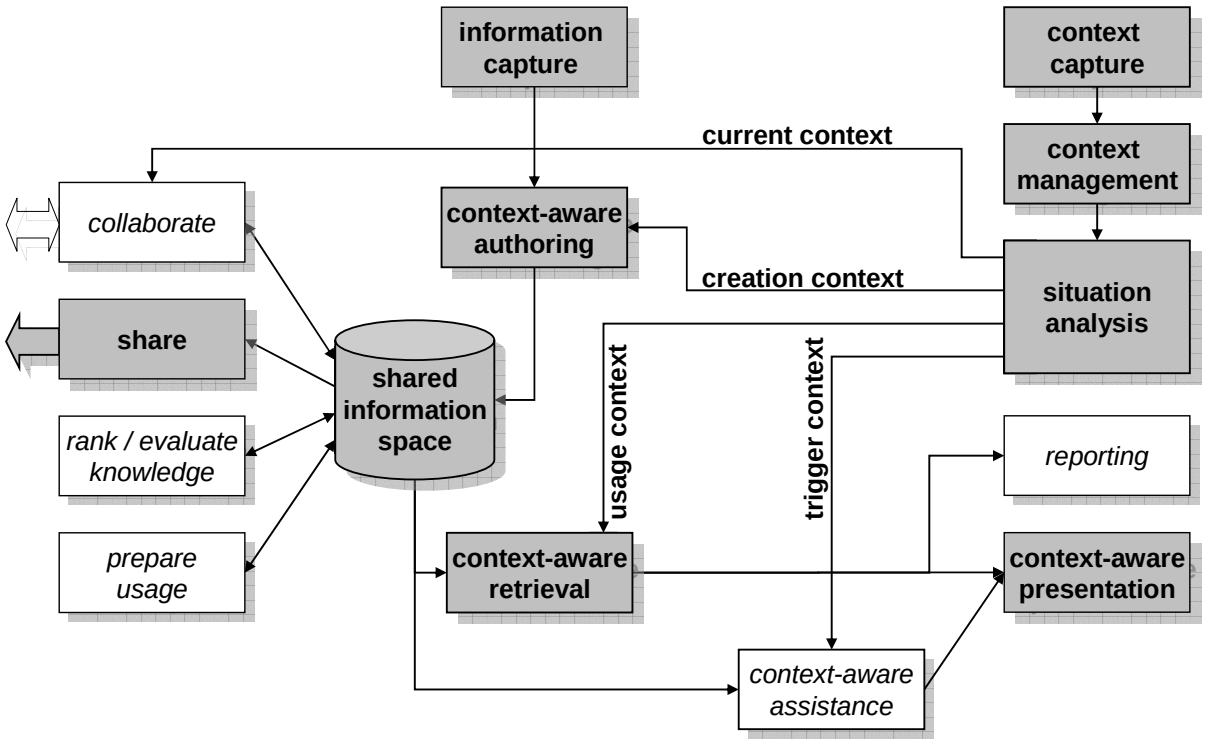

Figure 3: Reference Architecture for mobile Knowledge Management

3.3 Examples of Usage

The reference architecture presented allows the core functionality of mKM systems to be matched to conceptual or implemented architectures of mobile applications. It enables to identify if and how the application might be in itself a part of a KM loop, what might be missing for integration and finally if additional application-specific knowledge aspects are to be addressed. Three short examples of such system comparisons shall be provided with the help of the reference architecture.

(1) mobile tourist guide: A specific mobile tourist guide application, for example, may provide contextual information to some degree: photos and descriptive textual information are geo-referenced in order to retrieve relevant information for the user at his current location. Perhaps a user model also allows preferences and information categories the user is interested in to be specified. But: actions are limited to retrieval and presentation. According to the reference model, neither knowledge capture nor sharing is supported. In fact, this is a situation-aware information system rather than being part of some tourist mKM system.

(2) site inspection support: A mobile workforce application supporting engineers in doing site-inspections for maintenance objectives has to follow the specific workflow of these business processes. In general, these processes need a preparation phase for planning the objects to be maintained / inspected / repaired, the site-inspection itself and a post-processing for reporting and subcontracting / delegating unsolved tasks. Supporting mobile IT systems need facilitation of

information retrieval in a specific working context (e.g. up-to-date information about the object inspected) for information capturing (to document the problem or / and its solution) and sharing, as well (e.g. for sub-task delegation). In summary, all core mKM core functionalities are needed and, in addition, workflow-specific extensions as knowledge preparation, reporting and delegation support may be needed. Thus, such solutions already fulfill all constraints of being an mKM solution.

(3) trade fair information system: Trade fair information systems often have mobile front ends, enabling context-related (location-based, user preferences) access to exhibitor information. Some even integrate simple "workflow" components, in which the customer can plan his tour of enterprises to be visited. It is quite common for enterprises to coordinate a fair visit with several members to cover a specific topic area. These groups could gain valuable assistance by using an mKM solution. Comparing the trade fair information system as described above to our mKM architecture, group-specific mobile information capture and upload would need to be added to the already existing central data storage for facilitation of mKM. Some kind of report / export component would also be a useful extension. The integration of such an mKM component into some legacy enterprise KM loop would even make this component mandatory to interface both processes.

4 mKM and Ambient Intelligence

Ambient Intelligence (AmI) was first sketched by the European Commission's Information Technologies Advisory Group (ISTAG). Taking the ISTAG vision statement [ISTAG, 2003], an Ambient Intelligent (AmI) Environment will imply a seamless environment of computing, advanced networking technology and specific interfaces, where humans shall be the center. Thus, the environment should be aware of specific characteristics of human presence and personalities, adapt to user needs, be capable of multimodal interaction, i.e., shall respond to spoken or gestured indications and perform any kind of supporting services in relation to the current context and situation of humans present. The objective of Ambient Intelligence is to assist people in interacting with their current environment within the scope of compound activities, using ubiquitous information infrastructures. This definition of AmI can be considered in many respects an extension of the concept of situation-aware mobile assistance through the addition of ubiquitous information devices.

With this strong focus on humans, i.e., most of all, the integral approach of intelligent recognition of a person's situation and desires, such an environment would match the mKM approach perfectly (i.e., for instance, the automated context capture). In the future, Ambient Intelligent Environments might evolve into an optimal "host" for sophisticated mobile knowledge support.

The European Commission has also pointed out dedicated clusters of research in line with the AmI vision. One of these is *"Metacontent services developments to improve information handling, knowledge management and community memory, involving techniques, such as smart tagging systems, semantic web technologies, and search technologies."* [ISTAG, 2001]. A future field of research for the work presented in this paper, therefore, will be to foster mKM approaches within the ongoing refinement of the AmI vision for the mutual benefit of both mKM and AmI.

5 Conclusion

With the growing number of systems that enhance knowledge-intensive work in mobile environments, it is becoming increasingly difficult to find their specific focus, their approach, and the differences among them. In this paper, we presented a definition of mKM along with a related mKM concept and reference architecture. Utilization of these resources can help to distinguish between mobile approaches and to conceptualize the differences. Furthermore, the reference architecture can facilitate the integration of existing or planned mobile IT support into enterprise KM loops within a variety of domains.

Finally, this reference might also be of substantial help in leveraging the fast-evolving vision of Ambient Intelligence for real world application in knowledge intensive settings.

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