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Procedia Computer Science 00 (2018) 000–000

Procedia Computer Science

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The 15th International Conference on Mobile Systems and Pervasive Computing (MobiSPC 2018)

Towards a Beacon-based Situational Prioritization Framework for Process-Aware Information Systems

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Abstract

The ongoing digitalization of enterprise computing solutions and the creation of ubiquitous workspaces offer new advantages for many business domains. However, it is cost- and work-intensive to create these new kinds of workspaces by adopting interconnecting things and migrating applications into the cloud. On the other, enterprises increasingly strive for the potential of the new workspace opportunities to support their operational processes in the best way. For this purpose, we present an approach to enhance the integration of human resources into business processes by gathering environmental information and reacting to situational changes of workers. More specifically, we present a framework based on beacon technology to determine a situational priority for work items with the goal to properly support the worker in his or her decision-making process. We regard such framework as important aspect for many business domains in order to cope with the demands emerging in the light of work management that requires ubiquitous access to all enterprise resources in the best possible way.

Keywords: Process-aware Information Systems ; Mobile Computing ; Human Computer Interaction ; Worklists ; HC-PAIS

1. Introduction

The digitalization of enterprise systems and processes are not only the key drivers for developing new business models and the Internet of Things. The trend to support work by digitalization mechanisms enables and furthermore requires new approaches of human-computer interaction (HCI) within businesses. Although there exists an increasing interest in HCI research for end-user products due to the dramatic development of smart mobile devices [12], the emerging changes in enterprise computing are often neglected by researchers as well as business managers [20]. However, particularly the latter actors are getting more and more pressure to add value to legacy enterprise systems by integrating the existing smart and interconnected devices. To tackle these technological discrepancies and provide suitable solutions, it is necessary to take a closer look on how processes within businesses (e.g., manufacturing processes) are currently supported by Process-aware Information Systems (PAIS) [18, 3]. Due to the efforts in research

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over the last decade, PAIS do not only provide the automation of process steps, they are also capable of powerful features like process monitoring [7], process mining [1], built-in flexibility [16, 18], and work distribution (cf. [17]). One current research trend in PAIS constitutes Human-Centric Process-aware Information System (HC-PAIS) [6], which pursues the enhancement of integration of human resources in business processes by including the human factor [19] in the software design and realized functionalities. To utilize this potential in human resource support and supporting the trending of interconnecting IT solutions with physical devices [15], we developed an approach to enhance the interaction of humans in business processes. More specifically, we present a framework based on beacon technology to determine a situational priority for work items and to properly support the worker in his or her decision-making process. In particular, we propose a method to integrate environmental data into work item prioritization. The remainder of this paper is organized as follows. Section 2 discusses related work, while Section 3 imposes the addressed challenges. In Section 4, the proposed framework is introduced, whereas Section 5 concludes the paper with a summary and outlook.

2. Related Work

In the context of this paper, the handling and execution of process on mobile devices is crucial. Interestingly, only few approaches deal with this topic though the increasing mobility of computing devices revolutionized the interaction with computer systems. In this context, [5] introduces criteria of usability for mobile devices and applications. In [13], the requirements of executing processes with mobile devices are imposed and discussed. Furthermore, a fully fledged mobile client was developed that both considered the characteristics of mobile devices and integrated the latter successfully with existing PAIS. Following this, [14] defined a status model that is necessary to prevent and handle exceptions while processing work items. In [8], an approach is presented to retrieve and integrate environmental information for process execution with mobile devices. Moreover, the results of [4] demonstrate how important human factors in working environments are in general. [21], in turn, showed again that the consideration of the human factor in HCI is of utmost importance. Furthermore, [23] presented an approach to develop a HC-PAIS. Another work that is relevant in our context constitutes [11], it introduces an approach for indoor localization through the signal strength of Bluetooth LE beacons.

3. Problem Statement

One further step in digitalization constitutes the interconnection of physical and virtual things with Cyber-Physical Systems (CPS). However, the interconnection of things is just one side of the coin. On the other, the utilization of generated data to increase both the performance and the efficiency of business processes must be also considered properly. Despite the fact that PAIS have created powerful features since many years and several realized frameworks are available, the integration of environmental and sensor data is not considered in the basic architecture of PAIS. This problem developed historically as in the early stages of business process management the availability of sensor data and capability of mobile devices was limited. Furthermore, limitations were part of the system design as for example the worklist management do only provide the minimum of information about work items before they are selected by the user to minimize the transferred data between client and server. This approach may be acceptable when the size of the user's worklist or the freedom of choice is limited. However, from today's perspective, this approach is limiting a user to make the best decision from the business perspective as a supporting system should provide all the information that is necessary to support workers in their decision-making process. Interestingly, the integration of smart mobile devices comprises unused potential to increase the knowledge about process execution both on client and server side. Though current PAIS provide the functionalities to meet the requirements of supporting the operational process of businesses, many systems pose a lack of integration of mobile devices and environmental data.

Requirements and Conceptual Adaptations

We propose to extend the PAIS reference architecture instead of building new systems on top. By raising the questions *"How can the integration of human resources in processes be supported by mobile devices?"* and *"How*

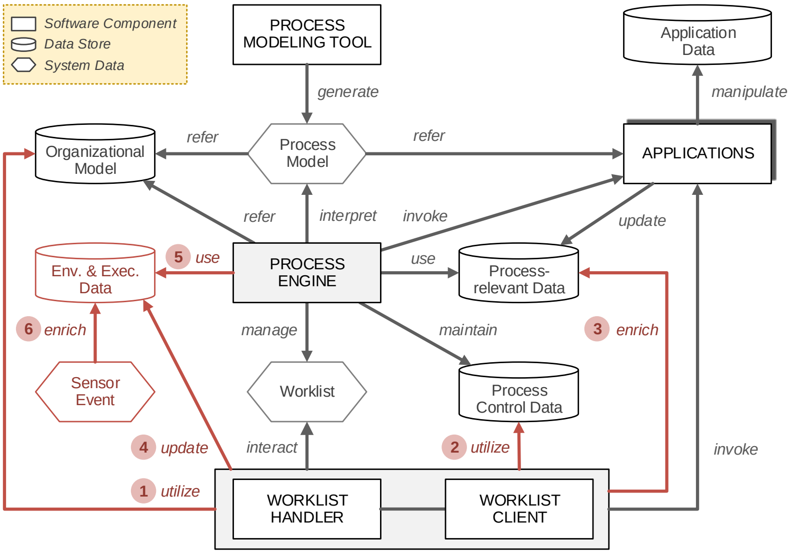

Fig. 1. Reference Architecture of PAIS with Framework-related Additions (adopted from [24])

can the obtained information support the decision making process of both humans and PAIS?", we face the following requirements:

Human Integration The human factor should be included to the system design of PAIS. To be more precise, modern PAIS should include mechanisms to satisfy human needs at work (cf. [4]).

Mobile Integration Mobile devices should be treated as first-class citizen in PAIS. In particular, PAIS have to meet the requirements of mobile process execution in terms of mobile device characteristics (cf. [13]) and process execution (cf. [14]). Furthermore, the mobile devices should increase the knowledge of the process execution by collecting sensor data to enrich the knowledge about the process execution environment.

Extended Data Exchange To support the decision-making process, existing data sources should be shared with the client and vice versa. For example, the utilization of the organizational model can significantly enhance a worklist handler (cf. [13]) to support social interaction within a business.

Human-Computer Interaction The interaction of humans and computing devices should be strengthened by implementing context-aware communication mechanisms.

Worklist Management The worklist management should not only provide worklists to its clients. It should be, in turn, extended to a fully fledged management platform as it plays the central role in work distribution and performance optimization. Moreover, the decision making should be configurable since there are different types of processes (cf. [2]).

To meet the imposed requirements, we propose to extend the reference architecture of PAIS as depicted in Fig. 1. To enable new mechanisms of social interaction in PAIS, clients should have direct access to the organizational model to utilize the containing information (cf. Fig. 1, ①). To provide sufficient information of the process state, the client must use existing process control data (cf. Fig. 1, ②) to combine the required information. The latter enables the worklist handler to resolve the current state into single decision-making parameters (e.g., blocking work items of other users) and therefore supports the user's choice for the next work item. Expanding social interaction (e.g., delegation of work items) enables users to share work items, but does not provide the possibility to enrich the process-relevant data (cf. Fig. 1, ③). For this reason, we propose to provide a feature to add work item dependent data (e.g., additional information for work item delegation) to the process that is shared with other assigned users. As

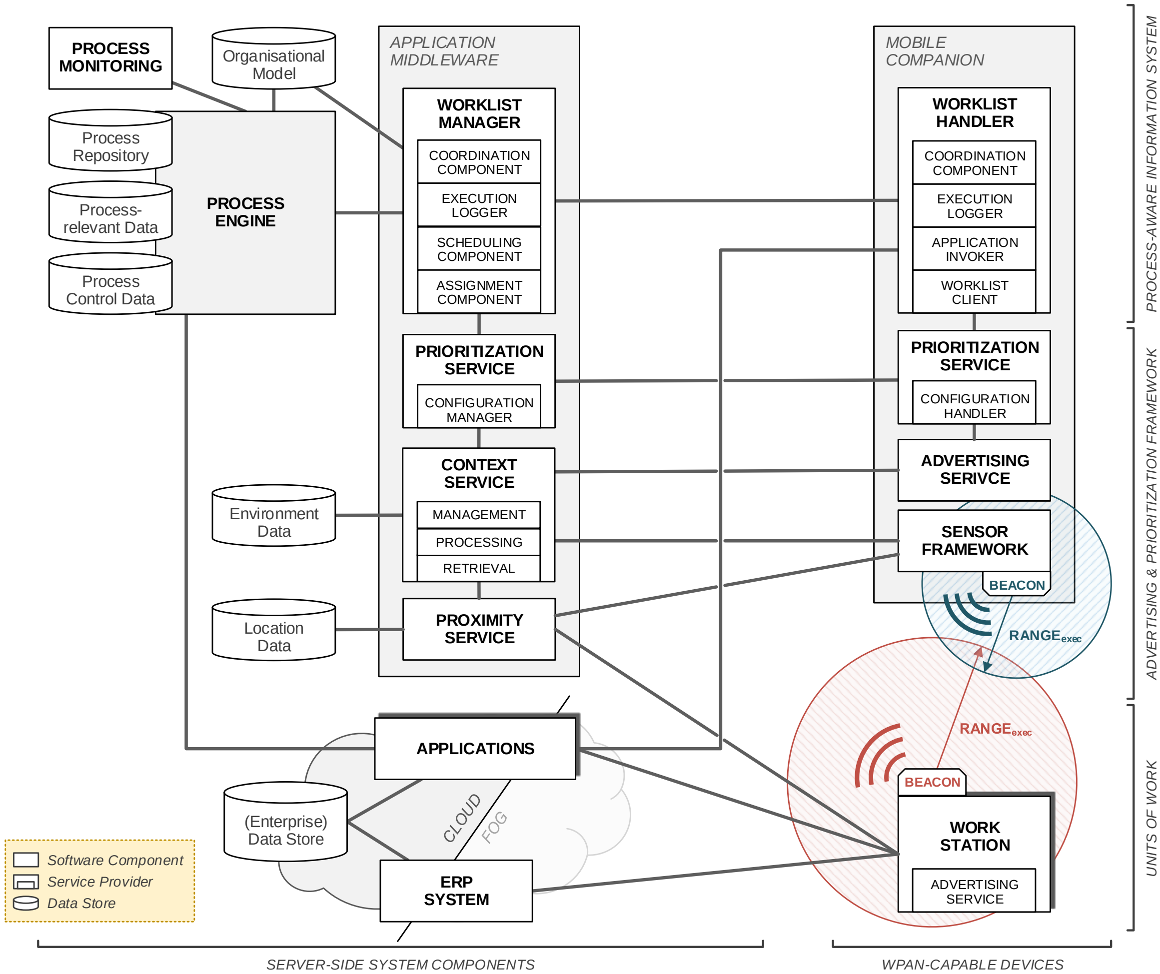

Fig. 2. Overview of the Framework Components

many requirements need environmental data to retrieve the current context, a data store that is capable of gathering sensor information of users and other process participants (cf. Fig 1, ④) must be implemented. As a consequence, the reference architecture of PAIS should be aware of a new type of system data: the sensor-related event data (cf. Fig. 1, ⑥). The gathered information should also be available to the process engine that it can use the environmental data to increase the knowledge of process execution.

4. Proposed Approach

The objective of our approach is to support the integration of human resources with business processes utilizing mobile technology. In particular, we follow the idea of a *Mobile Companion* that guides workers through their daily business and provides sensor data to enrich process knowledge at server-side and to communicate with nearby systems at client-side. To realize such an approach, the framework should (i) provide a fully fledged worklist handler and client, (ii) consider the human factor in terms of process execution, (iii) include environmental data in the process execution and decision-making, (iv) consider the necessity of segregating software component to make them cloud-aware, and (v) extend existing PAIS components.

By partly adopting research results of [13] and [14], a fully fledged worklist handler can be realized on client-side. One major challenge in all mobile systems constitutes the exception handling when the connection of the mobile device to the back-end system is lost. To maintain the work and decision-making ability in an disconnected situation, we propose to mirror all the necessary system components (i.e., components that are involved in decision-making processes and work distribution) of the PAIS as secondary components. To keep the overall consistency, all actions must be logged and synchronized with the server-side system. Considering the human factor and integration of environmental data in process execution and work distribution, we developed the idea of *Situational Prioritization*. Large worklists with sparse information about work items seduces workers to come to inefficient decisions in choosing upcoming work items. By using the situational prioritization, the recalculated value can be compared with the predefined value to assist the workers. To promote HCI in the work environments, we propose a beacon-based proximity service to enable nearby interactions. By using fixed beacons for work stations or CPS and roaming mobile devices, an accurate proximity determination (cf. [11] and [9]) as well as cost-effective implementation is possible. This setting is the basis for another location-based service to integrate humans in business processes that we propose: the *Beacon-based Advertising*. By using the situational prioritization, the advertising service is capable of alerting the user with adequate instruments that an high-priority work item is active in his or her surrounding area. These instruments may have different levels that range from low-level alerts like ambient promotion to high-level alerts like notifications on multiple channels (i.e., notification on mobile device with active sound and vibration).

Table 1. Identified Attributes for the Situational Prioritization

Category	Attribute	Source	D	C	M	RT	BT	DT
Activity Context	Urgency	Work Item	✓	×	×	✓	✓	✓
	Familiarity	Execution Log	×	✓	×	✓	✓	×
	Cost-Benefit Ratio*	Work Item	×	✓	×	✓	✓	✓
	Ability*	Organisational Model	✓	×	×	✓	✓	✓
	Previous Decisions	Execution Log	×	✓	×	✓	×	×
Process Context	Blocking Work Item	Process Instance	×	✓	×	✓	×	×
	Delegated Work Item	Process Instance	✓	×	×	✓	×	×
	Substitution	Process Instance	✓	×	×	✓	×	×
	Escalation	Process Instance	✓	×	×	✓	×	×
	Participant Selection	Process Instance	✓	×	×	✓	✓	×
	Participant Autonomy	Process Instance	✓	×	×	✓	×	×
Mobile Context	Proximity to Execution Location	Proximity Service	×	✓	×	✓	×	×
	Connectivity	Worklist Handler	×	×	✓	✓	×	×
	Type of Connectivity	Worklist Handler	×	×	✓	✓	×	×
	Battery Status	Worklist Handler	×	×	✓	✓	×	×
	Users Nearby	Sensor Framework	×	×	✓	✓	×	×
Intrinsic Motivation	Skill Variety*	Process Model	✓	×	×	✓	×	✓
	Task Identity*	Process Instance	✓	✓	×	✓	✓	×
	Task Significance*	Process Model	✓	×	×	✓	×	✓
	Autonomy	Process Model	✓	×	×	✓	×	✓
Extrinsic Motivation	Reward for Item Execution*	Process Model	✓	×	×	✓	✓	✓

Type → $D = Defined, C = Calculated, M = Measured$ / Phase → $RT = RunTime, BT = BuildTime, DT = DesignTime$
*PAIS must be capable of and the requirement must be specified by a modeler.

4.1. Framework Components

Our framework (cf. Fig. 2) can be divided into two dimensions. The horizontal axis describes the operational site, whereas the vertical axis classifies the system components into three different areas of activity. The components on the top belong to the PAIS system components. The structure is very similar to the reference model (cf. Fig. 1) as it should represent the broad spectrum of PAIS implementations. The important requirement of decoupling the worklist manager (cf. Sec. 3) was meet by grouping high-load services into an application middleware. The worklist manager consists of several services that control the coordination as well as scheduling and assignment of work items as well as implements the server-side *Execution Logger* that is capable of synchronizing offline-executed work items. Furthermore, at the client-side, we propose a fully fledged worklist handler that mirrors important process-related functionalities. To enhance HCI in terms of business processes, the components of our approach are pictured in the vertical center of Fig. 2. The prioritization service that calculates the situational prioritization is located in this group of components as well as the advertising service. As both services are unable to operate without environmental data, the sensor framework on the client-side and the corresponding counterpart to store the gathered context is also located in this component group. Thereby, the sensor framework is responsible for both retrieving sensor information and sending beacons to estimate proximity. To protect privacy interests and ensure reliable positioning with high accuracy and precision in short as well as middle ranges (cf. [9]), we propose the use of Wireless Personal Area Network (WPAN) techniques (e.g., Bluetooth LE or UWB) to restrict the signal range of the beacon frame. The system components at the bottom of Fig. 2 can be classified as units of work as they are the value adding components. As counterpart to the sensor framework of the mobile companion, we propose to equip work stations with beacons. These beacons define the range of execution that surrounds the machines and are also responsible for tracking the user. They may also be connected to applications that are running on physical machines (i.e., when working with CPS), in the cloud or fog.

4.2. Situational Prioritization

Another major challenge of PAIS constitutes the static prioritization techniques. To be more precise, most of the systems provide the possibility to define the priority at design time that can only be changed when escalation events occur. This strategy is often insufficient as priority may change while running a process. For example, a worker is passing a machine that has an urgent maintenance work item with status *middle priority*. While the proximity isn't changing the priority from the item perspective, it may change the priority from the process perspective as it is more efficient to process the work item when the worker is closely located to the machine. To meet another requirement, the human factor should be also considered when calculating the priority. Considering the results of [4], we propose to integrate motivational aspects to the prioritization as they are also influencing the efficiency of the worker. As depicted in Table 1, task identity (i.e., workers should process as many task from one process instance as possible) should be considered in the prioritization as it increases the intrinsic motivation. To calculate a situational priority, we identified influencing attributes that should be included to provide the user a meaningful value (cf. Tab. 1).

Table 2. Identified Cases of Mobile Companion Detection

Case	Device 1	$\text{Connectivity}_{Device1}$	Direction of Detection	Device 2	$\text{Connectivity}_{Device2}$
1	Mobile Companion	connected	→	Work Station	disconnected
2	Mobile Companion	connected	←	Work Station	disconnected
3	Mobile Companion	disconnected	→	Work Station	disconnected
4	Mobile Companion	disconnected	←	Work Station	connected
5	Mobile Companion	connected	→	Work Station	connected
6	Mobile Companion	connected	↔	Work Station	connected

4.3. Beacon-based Advertising

As the raise of attention constitutes one of the most valuable resources for workers, we propose to use a situational prioritization to perform advertisements for high-priority work items. By combining the proximity information from the mobile companions as well as beacon-equipped work stations with the situational prioritization, a location-based advertising can be implemented as top-level service. As shown in Fig. 2, the beacon of the sensor framework can only be detected in a specific range. We denote this range as the *Execution Range*. According to [4], workers motivation and satisfaction is partly depending on the autonomy of choosing the next work item. Hence, we propose to use advertising

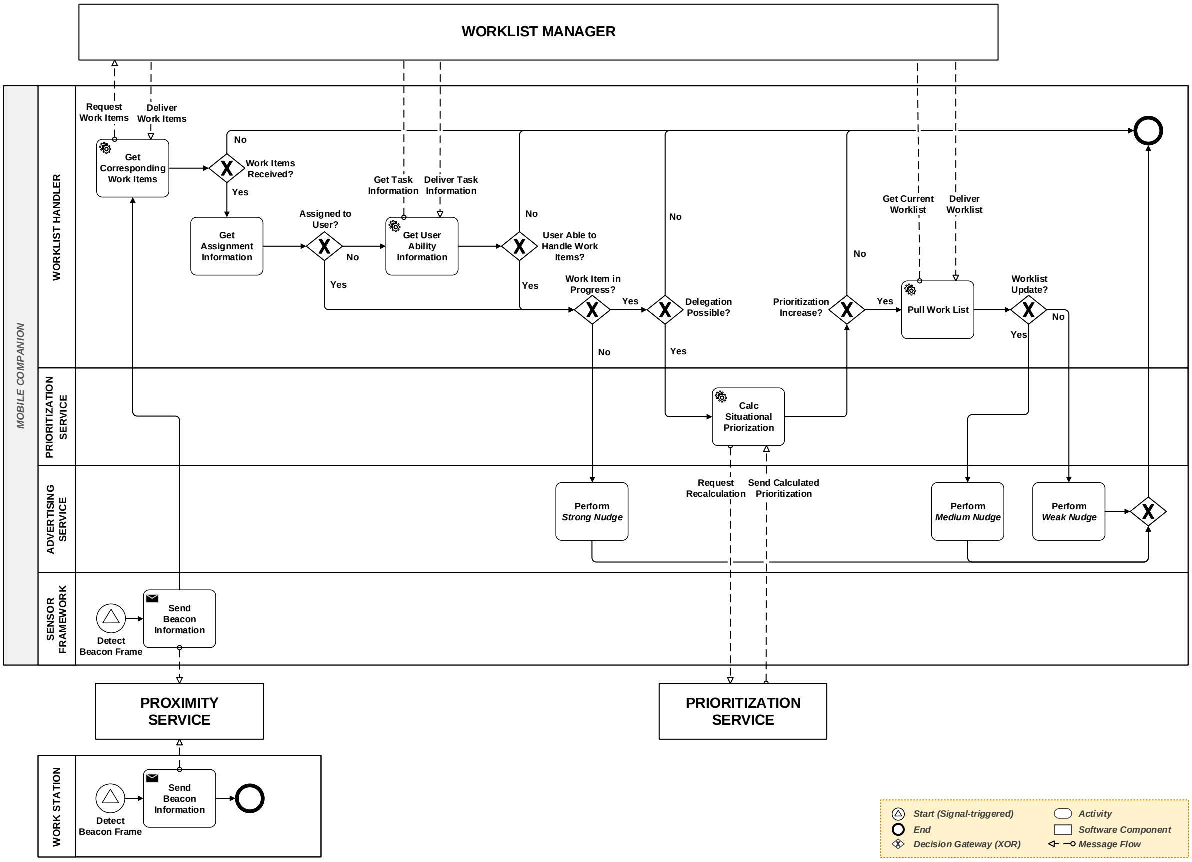

Fig. 3. Beacon Detection Procedure (Case 5) with WPAN-capable Work Station and Mobile Companion (modeled in BPMN [10]).

techniques to influence the users choice in a subconscious way. In particular, changing priority depending on the situation enables the process engine to dynamically react on environmental changes that would decrease efficiency and, hence, strengthens influence on the order of work item processing.

Moreover, as direct instructions would decrease motivation and satisfaction, we propose to integrate *Libertarian Paternalism* [22] into PAIS. Libertarian paternalism is a technique that subconsciously influence people to make the best choice by using psychological effects (e.g., placing things more prominent) without influence the decision-making process directly. In our framework, we therefore distinguish three types of so-called *Nudges*: strong, medium, and weak. Thereby, nudges cause different reactions, depending on the type. For example, a *Weak Nudge* may only place a visible information on the work station whereas a *Strong Nudge* is implemented as system notification by the operating system of the mobile device. Note that both the mobile companions and work stations should provide methods for advertisements. As work stations may not be programmable computers, but physical machines that are equipped with static beacons, we have identified six cases (cf. Table 2) that influence the advertising procedure. To illustrate the interplay of the participating system components, we conceived the beacon detection procedure that is instantiated when a worker enters the execution range in terms of a BPMN process model (cf. Fig. 3).

5. Summary and Outlook

We introduced a novel approach that uses environmental information to enhance the integration of human resources into business processes. To reach this goal, we first identified several extension points in the reference architecture of

PAIS. We then imposed requirements to overcome these shortcomings and presented our adaptions to the reference architecture of PAIS. We further presented our approach with a beacon-based framework that supports workers in their decision-making process for the next work item. Furthermore, we identified several attributes that influence the so-called situational prioritization. Finally, we presented an advertising mechanism to subconsciously influence the worker in his decision-making process. Currently, we are realizing a prototype based on the presented framework. Altogether, this paper presents a novel approach to integrate humans into business processes by promoting the mobile device as first-class citizen for worklist management and task execution.

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