Enabling Pervasive Healthcare by Means of Event-Driven Service-Oriented Architectures

The Case of Bed Management in Mid-Sized to Large-Sized Hospitals

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Abstract—**Healthcare providing organizations have achieved considerable achievements in efficiency and effectiveness due to the use of Information Systems (IS) in the past. However, focus was generally targeted towards "managerial IS", often resulting in additional efforts for doctors and nurses. This paper proposes event-driven service oriented architecture as a means for improving the convenience of care delivery, i.e. the satisfaction of care providers and patients, while at the same time improving performance of back-end processes. Based on the case of pervasive bed-management this paper exemplifies how IS can be integrated with smart devices to create value in such a specialized and inherently event-driven context as can be found in hospitals.**

Keywords: Event-driven SOA, Value of IT, Health Information Systems

I. Beyond Mangerial Information Systems, Creating Value for Health Professionals

Influenced by the demographic aging, the increased competitiveness and increasingly restrained budgets, the healthcare industry is facing a number of challenges. While we consider information technology (IT) and information systems (IS) key to support healthcare providing organizations to cope with the challenges of the future, in the past IS providers seem to have sometimes ignored that the main focus in healthcare is to treat and cure patients as good as possible. Healthcare organizations' goals are mainly achieved through accurate medical diagnoses, adequate treatments and sufficient patient care. Hence, maintaining an exact medical documentation or efficient administration may sometimes be considered only a secondary activity necessary to enable their core "business".

Electronic health records[1] (EHR), as an example, inarguably contribute to quality and security of healthcare services by reduction of medical errors through better availability of patient information and sharing of such information. However, many "managerial IS" [1] implemented in the past may have improved the overall performance of healthcare organizations but often resulted in additional efforts for health professionals (doctors, nurses). Therefore we see the need of next generation IS solutions and services to focus on improving the convenience of care delivery, i.e. the satisfaction of care providers and patients, while at the same time improving efficiency and effectiveness of back-end processes such as documentation or accounting. By supporting the treatment through pervasive IT and IS, such solutions will more directly enhance the quality of service delivery and hence improve the acceptance of IS by hospital staff, while maintaining or reducing the overall cost of delivering current care levels.

After defining our understanding of pervasiveness in healthcare, the remainder of this article will focus on event-driven service oriented architecture (SOA). We consider event-driven SOA as a means to enable more direct value of IT/IS, assuming that cost reduction should not be considered the primary value driver of IT for the healthcare industry. This potential value is exemplified based on the process of pervasive bed management, which integrates smart-devices with an event-driven workflow coordination and process automation.

II. Pervasive Health Care by Means of Event-Driven SOA

In line with the definition of pervasive healthcare that underlies this conference and focusing in this article on healthcare providing organizations, in particular mid-sized to large-sized European hospitals, we consider three core characteristics of pervasiveness. 1) We relate pervasiveness to the *coverage* of services and processes within hospitals that are supported by IS-based solutions seeking to support healthcare services independent of location and time or other restraints. While coverage may be considered a necessity to enabling integrated, high-quality healthcare services, sufficient value of IS in particular for health professionals can only be achieved if 2) access to information and operation of IS are designed such that they *seamlessly integrate* with their core tasks (diagnosis, treatment, care) and are provided through devices that *match the respective working environment*. In addition to coverage and seamless integration 3) we consider *process automation* a fundamental feature of pervasiveness.

In order to enable such a level of pervasiveness, we consider an event-driven SOA as the IS design paradigm that best matches the requirements of complex systems such as can be found in hospitals. Healthcare services within a hospital context are provided by means of a high division of labor

[1] By the term electronic health record, we refer to an "aggregation of patient-centric health data that originates in the patient record systems of multiple independent healthcare organizations for the purpose of facilitating care across multiple organizations" [2].

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between highly specialized professional groups [3]. Accordingly a typical treatment process involves a number of sub-processes (e.g. initial patient encounter, diagnosis, treatment, discharge, aftercare) where services are provided by these different professional groups and respective organizational units within the hospital. Treatment processes hence need to be designed and coordinated across a number of involved professional groups and their respective interfaces. A particular need for coordination exists between medical doctors and nurses who jointly provide the hospital's services for healing and relief of acute illnesses, for preventive healthcare and for the permanent care of the chronically sick.

Integration and synchronization of individual tasks are essential for efficient and safe treatment of patients. The collaboration as well as individual activities of health professionals are thereby inherently event-driven. The occurrence of a triggering event, such as the arrival of a laboratory result or the sudden change in vital parameters of a patient, initiates respective activities or processes at the triggered entity.

Event-driven IS matches this mode of operation of healthcare providing organizations. It enhances the prevalent concept of static pre-defined business processes that are designed using predictions based on past averages with the concept of an "event bus" using external rules that define the flow of events among IS components. If combined with SOA, pervasiveness can be facilitated by enabling interaction between self-contained components of disparate applications. These components can then be integrated in a "mix and match" fashion based on clear descriptions of their interfaces.

Using such an IS infrastructure, enables hospitals to replace existing paper forms and documentation systems with applications and devices that reduce the effort for non-medical tasks and to directly support their core activities by adding smart devices (RFID, sensor/actuator networks) and/or mobile devices for the end users that interface with the event-driven SOA landscape. In the following we will present potential business value generated by such an infrastructure based on the use-case of integrated bed-management.

III. Pervasive Bed Management – Integrating an Event-Driven SOA with Smart Devices

Together with its staff and required supplies, inpatient beds account for a large share of a hospital's assets. Hence, the management of hospital beds is a core activity which involves both medical and administrative personnel at different stages of a patient's treatment process. During the planning phase of bed assignments it is important to ensure that patients are admitted to wards appropriate to their clinical needs. In addition, while aiming for a highest possible utilization, capacities need to be assigned such that planned admissions don't need to be cancelled due to capacity shortages and sufficient emergency admissions can be handled.

While most of the planning phase can be supported through IS in a deterministic (non-event-driven) manner, in particular emergency admissions trigger events which are currently in most cases handled without IS support despite the complexity of issues to be considered (infections, appropriateness of the ward, personal preferences/insurance coverage, etc.).

During medical treatment, tasks of bed management mainly relate to transfer of patients, e.g. between wards due to changed medical conditions, and to short-term movements of patients, e.g. for specific therapy, surgery or diagnostics (x-ray, etc.). According to [4], approximately seven per cent of inpatients admitted to German hospitals in 2006 were transferred to a different ward. If staff and rooms (and potentially patients) were equipped with RFID and respective readers, the effort for nursing staff related to the currently mostly paper-based (in most cases at least initiated through paper work) or standard computer-based transfer processes could be reduced considerably.

As shown in figure 1, the events triggered by the smart devices can be integrated with respective components of the hospital application landscape. Data entry required by the medical staff could then be provided through mobile devices using standard personal digital assistants, or tablets such as the medical clinical assistant (MCA), a reference design of tablets for health professionals designed by Intel together with Motion Computing, whose C5 has been the first product based on the MCA platform. Thereby the effort for non-value-adding tasks related to such a transfer could be considerably reduced. For example, the data to be provided by a nurse could be minimized to distinguishing between short-term moves and transfers to another ward and the identification of the destination department. In addition, subsequent required activities/processes could be initiated (e.g. documentation in administrative applications, enabling access to the patient's electronic health records at the destination ward).

As an example, the triggering event of a change in vital parameters from a patient who has been assigned to a general surgery ward for post-operation treatment of a hip arthroplasty may result in direct intervention by nursing and medical staff of the general surgery ward. An angina pectoris diagnosis requires the patient to be moved to an internal medicine ward for further surveillance and treatment. The diagram in figure 1 shows a possible implementation of such a patient transfer process involving a central bed management organization unit. Based on the angina pectoris diagnosis, the central bed management plans an optimal bed allocation e.g. by analyzing current ward utilization. A subsequent transfer order is triggered and results in an alerting of the nurse, e.g. through a mobile device (PDA) or a pager, to move the patient to the new destination ward. The task to move the patient is confirmed and as a result a transfer order is created in the respective patient management system. As soon as the physical movement of the patient to the room in the destination ward is detected, e.g. through RFID-tagged beds and/or RFID equipped patient identifiers (wristband, etc.), this event triggers the next step of the transfer process. The nurse is requested to complete the transfer order through providing additional information such as the location within the room. The information required in this step is however less extensive compared to a standard non-integrated post-process documentation. This is because part of the information can be derived from context/environmental parameters tracked e.g. through RFID. Subsequent steps associated to the patient's movement can then automatically be initiated.

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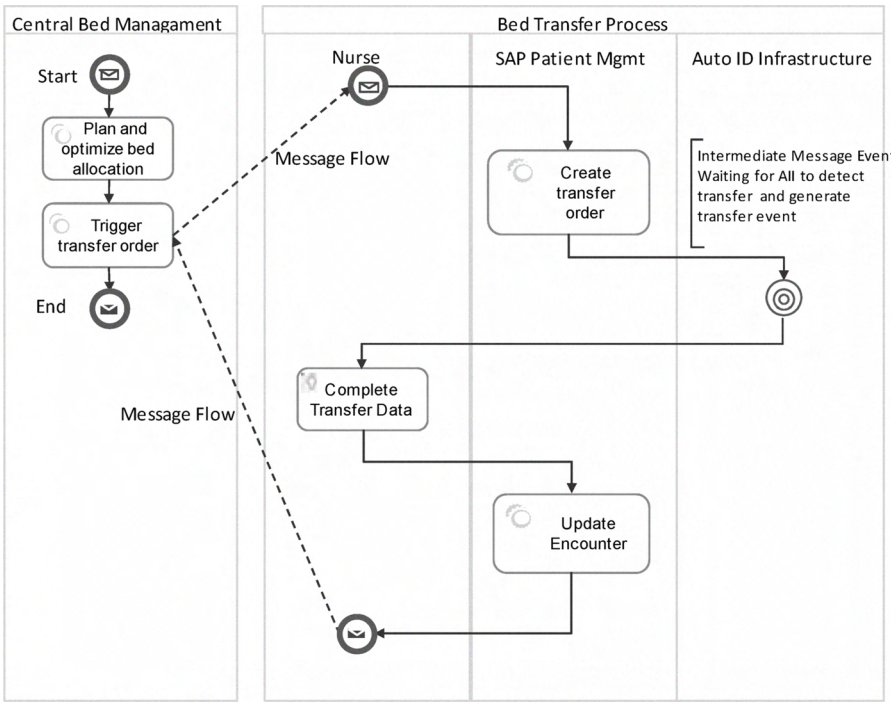

Figure 1 Event-driven transfer and short term movement of patient

Setting this process example into the context of the three features of pervasiveness – coverage, seamless integration and process automation – a number of improvements in convenience of care and performance of back-end processes can be realized based on an event-driven SOA environment. With regards to coverage, compared to classic bed management processes which often require a high volume of personal interaction, the integration of sensor technology for asset and patient management enables real-time access to resource availability and hence more efficient bed allocation. In addition an integrated system landscape can react to the events triggered by a transfer process for example by enabling access to medical data based on the patient's current location/ward assignment, also improving privacy. Automation is enabled on the one hand through workflow support, e.g. through triggering events that require human intervention, hence reducing process idle times. On the other hand particularly back-end process can be fully automated, e.g. by using event-driven documentation of activities. Integrating real-world events with IS and allowing the hospital staff to manipulate and access information through situation specific devices and user interfaces, efforts can be reduced through better integration of the IS/IT with their tasks.

IV. CONCLUSION

This paper presented the concept of event-driven SOA as an architectural paradigm and discussed its potential impact on the pervasiveness of IS in healthcare. While the case of bed management is only one sample process, it clearly identifies potential value of IS implementing an event-driven SOA. Similarly to the movement/transfer of patient, a patient discharge triggers a number of events, which – if appropriately handled by an event-driven SOA – can considerably contribute to the performance of hospitals and external institutions involved in subsequent care (practitioners, rehabilitation, home care, etc.). The triggering processes such as cleaning and preparation of the used beds influences the availability of beds and respective ability to plan new admissions. Also, regulations in most European countries limit the period for accounting of services provided to a patient based on the discharge date. Therefore, if accounting systems and respective users are notified of discharge events, costly non-billings due to insufficient accountings can be avoided.

A number of scientific studies [2, 5, 6] support the value that lies in such IS infrastructures, in particular if they are designed with a focus on end-users. Taking into account that hospital environments have long established and refined work practices, introduction of new technology into such an environment needs to consider existing processes and aims to carefully interface with them [5], which is clearly supported by event-driven SOA. Research results of the project wearIT@work [7] – a research project funded under the 6th Framework Program of the European Union – has come to similar conclusions as those presented in this paper. Focusing primarily on the user interaction with IT/IS, the impact on medical staff has been evaluated in the context of the daily ward round scenario. The ward round is one of the central elements of clinical healthcare where most of the important decisions about the patient's future treatment are made.

Most common activities during the ward round include accessing patient data, organizing a laboratory analysis or an examination. An in-depth analysis of the current ward round activities enabled the identification of a number of challenges in its current mode of operation [8]:

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- Preparation of all paper documents needed during the ward round is necessary
- Post-processing (documentation) of information created during the ward round is necessary
- Documentation is performed in several steps, sometimes involving several people
- The nurses are only authorized to enter some, but not all kinds of information
- No reliable method of patient identification available
- In some departments the available time for the ward round is extremely short

The project evaluated the impact of staff support in the context of navigation in electronic patient documents at the point of care based on a new wearable IT/IS solution that provides a gesture and pen-based user interface. It was able to identify a number of benefits. In particular with respect to collaboration, the direct availability of electronic information was considered to have a positive impact e.g. when patients need to be transferred to a different organization or organization unit within the hospital for subsequent treatment. The solution was also found to foster better collaboration between staff members of a ward and to have a positive impact on patient interaction e.g. through the ability to share information with the patient [9].

Addressing efficiency and effectiveness of hospital-internal processes as well as networkability (i.e. the ability to connect and interact with other organizations) of healthcare providing organizations, event-driven SOA requires a flexible and highly capable business processes management infrastructure as well as a smart devices middleware to integrate sensors and actuators. Setting up such an infrastructure may require considerable investments and efforts to integrate historically grown, heterogeneous application landscapes. However, its direct impact on the convenience of care provision as well as the performance of back-end processes is considered to outweigh associated costs and efforts.

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