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Towards Smart Environments Using Smart Objects

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Abstract. Barcodes, RFID, WLAN, Bluetooth and many more technologies are used in hospitals. They are the technological bases for different applications such as patient monitoring, asset management and facility management. However, most of these applications exist side by side with hardly any integration and even interoperability is not guaranteed. Introducing the concept of smart objects inspired by the Internet of Things can improve the situation by separating the capabilities and functions of an object from the implementing technology such as RFID or WLAN. By aligning technological and business developments smart objects have the power to transform a hospital from an agglomeration of technologies into a smart environment.

Keywords. Smart Objects, Logistics, Internet of Things

1. Introduction

For many years, barcodes have been used e.g. on wristbands, packages and documents to identify patients, drugs, lab samples and charts. Today, radio-based technologies such as RFID and sensor networks are already in use and under development in the healthcare domain [1, 2]. Wireless LAN is built into many mobile computers and Bluetooth is often used for point of care devices [3].

This is why hospitals are confronted today with a plethora of approaches for implementing business scenarios such as asset management with RFID and WLAN, cooling chain monitoring using sensor networks and RFID, and patient tracking using virtually any existing technology. The problem is that most approaches are not necessarily compatible or seamlessly integrated into legacy systems. Thus, the full power of innovative identification and locating systems is not utilized. A conglomerate of technologies/products/concepts exists but hardly any attempts to integrate those into a (virtual) single platform have been made.

Introducing the concept of smart objects inspired by the Internet of Things will improve the situation. Smart objects are using smart tags attached to an object or person to identify or locate it, or to enable further functions of sensing and acting. Smart object networks should be interoperable by design allowing the user to purchase

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or replace a smart tag according to functional requirements not what else is installed. Of course, this will require technological as well as organisational advances.

For the remainder of this contribution, first smart objects and related technical implementations are described. Then, we depict the vision of turning hospitals into smart environments based upon smart object technologies before concluding with future research challenges.

2. Smart Objects

By combining a tag with sensors and actors thus enabling it to participate in its surrounding we call it a smart tag. And by pairing smart tags with real life objects such as mobile medical devices, blood bags and patients, the objects become "smart", i.e. a smart object. Smart objects typically meet following requirements [4]:

- An identity, which must be unique in its context or system
- Sensors to gather the actual status of the object and actuators to interact with the environment
- The ability to determine the current position
- Memory to store master data, to record past events and gathered data
- The ability to communicate with other objects
- The intelligence to act autonomously to reach a given goal

As can be seen, these properties can be met by using Automatic Identification and Data Communication (AIDC) technologies. These main technologies for building smart tags are already existent and in use in hospitals:

- Barcodes are the oldest and most widely used AIDC technology. Barcode labels are very cheap, can hold up to a few kilobytes of information and be attached to virtually any product such as blood bags and lab probes [5].
- Radio-frequency Identification (RFID) [6] is often considered as a radio-based successor of barcodes. In contrast to other radio-based technologies, RFID tags are extremely robust and solutions exist for deep-frozen bio probes, blood bags in a centrifuge or extreme heat while e.g. sterilizing surgical instruments. Recent developments in RFID labelling include printable tags [7].
- Wireless Sensor Networks [8] consist of active tags that not only communicate data upon request like RFID, but exchange data in a network via multiple hops. Computing power on the tags allows for local processing of sensor data and sometimes tags even work collaboratively to solve complex problems, including measurement, detection, classification, and tracking in the physical world.
- Wireless LAN (WLAN) is well known from mobile computing and often infrastructures already exist in hospitals and can be reused. WLAN tags may be used similar to sensor network tags but require more energy thus limiting long term use [9].
- Ultrasound tags can be used as a replacement for radio-based tagging of patients and devices on room level [10]. A major advantage is the absence of electromagnetic interference.
- Infrared waves allow for short-range communication similar to ultrasound [10].

An integration platform (also: middleware) serves as façade and bridges the gap between the technology and the legacy systems. It is an abstraction layer, which controls the interaction between these technologies and existing enterprise infrastructures, supports intra-corporate and cross-company integration, and aims at reducing integration costs significantly. Beside the simple data exchange, typical integration functions comprise the filtering, aggregation and (pre-) processing of sensor data. This is why they often include a business rule engine and solutions for complex event processing [11, 12]. Both can be used to detect relevant events or alarms [13].

The combination of AIDC technologies and integration platforms aims at identifying objects, knowing where they are and collect data without further manual efforts [6]. This allows synchronizing the real world with its virtual counterpart and therefore enables better process and decision support.

3. Building Smart Environments

But making objects smart is only a first step. Knowing the identity of an object ("what is") should be complemented by "where is", "when is", and "in what condition" [14]. While existing wireless AIDC technologies meet many smart object requirements, the concept of smart objects goes beyond the application of a single technology, as there will be no one-size-fits-all solution based on RFID or WLAN. Sensor networks are much more expensive than RFID as they require local intelligence for processing complex protocols, but meshing nodes can generate energy efficient communication networks for pro-active services where RFID fails. And the omission of a fixed infrastructure such as gates and reader with RFID is another advantage in dynamic environments. WLAN on the other hand is more energy consuming, but has much larger bandwidth for communication and is built in many new mobile devices. Besides technological differences, hospitals already have invested in products and infrastructures of disparate technologies.

This is why many different types of smart objects will exist, depending on the objects to which a smart label is attached, the functional requirements and the extent to which the smart object has to participate with its surrounding [15]. Therefore, also the developments come from various application areas each focusing on different aspects of sensors, communication, interaction and use cases such as Ambient Assisted Living, Near Field Communication, and even Building Automation [16-18].

Overcoming these mostly segregated developments is the main vision of the Internet of Things [19], that is based on the idea that every object (person, machine, system) participates and communicates in a universal network. Concepts beyond the classical Internet are required to integrate networking with service development and advanced concepts of network and service capabilities, trust and security and well as new architectures for distributed, adaptive and "intelligent" systems [20]. This is where the concept of simply connected objects ends and the Internet of Things begins [19]. In the end, aligning the technology with organizational and work processes enables smart environments.

We believe the Internet of Things has advantages also in the healthcare setting, enabling the building of smart environments supporting many medical and logistics scenarios. There should be a common vision on what hospitals of the future could look like to help coordinating the individual development efforts (Figure 1).

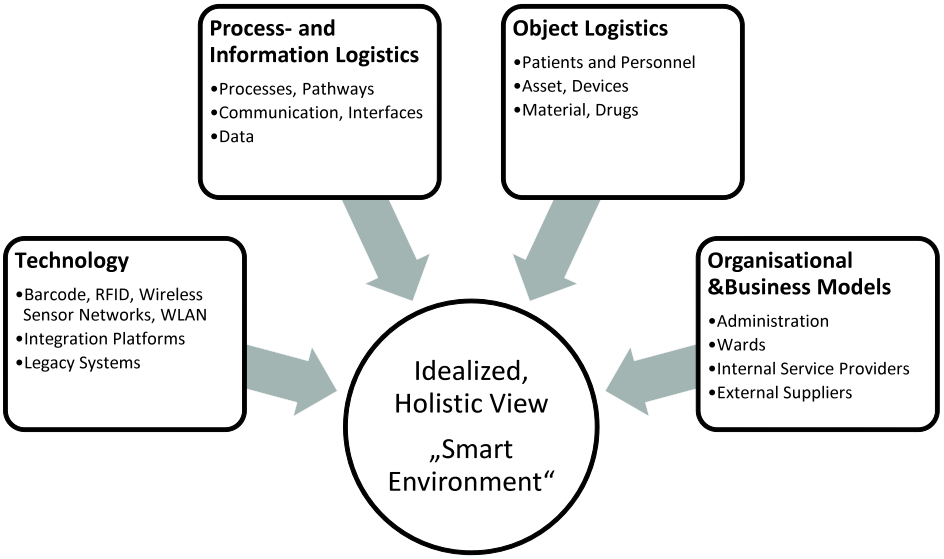

Figure 1. Aligning disparate developments by a holistic view on a hospital as smart environment

Many different technologies, each with its own capabilities and restrictions are available. There is also an enormous speed in innovation and evolution, making technology affordable, smaller, faster, more energy efficient. Yet, there is still a lack in integration on a technical as well as a business level.

4. Conclusion

Introducing the technologies into the healthcare sector by tagging people, material, and buildings for identification, tracking and monitoring will increase transparency and will allow better process- and information logistics. This is where the concept of smart object will help to overcome technological barriers by separating the implementation of the infrastructure from the development of smart object based business services. Smart object networks should be interoperable by design allowing the user to purchase or replace a smart tag according to functional requirements not what else is installed.

Advancing the smart object concept requires on one side work on the technological solution, making the hardware smaller, cheaper and more energy efficient; making the protocols more reliable and secure; designing services that last. On the other side, integration and interoperability is still neglected. To unleash the full potential, smart object networks require interchange of data and services across technologies and locations.

But in the end, new developments will only stay, if a real benefit is perceived. Business models along the whole value chain have to be found so that cost can be minimized or split among stakeholders, and benefits exist. However, this will require organisational changes beyond short-sighted replacement of one technology with another [14].

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[20] National Intelligence Council, editor. Appendix F- Background: The Internet of Things. Disruptive Civil Technologies Six Technologies with Potential Impacts on US Interests out to 2025; 2008.