



Convergence of IoT and product lifecycle management in medical health care

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ABSTRACT

Emerging trends in Internet of Medical Things (IoMT) or Medical Internet of Things (MIoT), and miniaturized devices with have entirely changed the landscape of the every corner. Main challenges that heterogeneous sensor-enabled devices are facing during the connectivity and convergence with other domains are, first, the information/knowledge sharing and collaboration between several communicating parties such as, from manufacturing engineer to medical expert, then from hospitals/healthcare centers to patients during disease diagnosis and treatment. Second, battery lifecycle and energy management of wearable/portable devices. This paper solves first problem by integrating IoMT with Product Lifecycle Management (PLM), to regulate the information transfer from one entity to another and between devices in an efficient and accurate way. While, second issue is resolved by proposing two, battery recovery-based algorithm (BRA), and joint energy harvesting and duty-cycle optimization-based (JEHDO) algorithm for managing the battery lifecycle and energy of the resource-constrained tiny wearable devices, respectively. Besides, a novel joint IoMT and PLM based framework is proposed for medical healthcare applications. Experimental results reveal that BRA and JEHDO are battery-efficient and energy-efficient respectively.

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1. Introduction

For the promising medical world, the transformation of conventional methods into digital form is the first and foremost priority to encourage the electronics medical (e-medical) market, wearable/portable/handheld devices which are the need of hour for information sharing/transformation, management between several entities. So, keeping in view the demand and importance of the emerging trend Internet of Things (IoT) is adopted jointly with product lifecycle management (PLM); a decisive and intelligent business approach for effectively managing the lifecycle of IoT-based devices during patient's treatment in the medical hospitals/centers/theaters. In other words almost every aspect of human lives for instance, factories to farms, cities to towns and healthcare to well-being etc. will be covered uniformly up to 2020, so PLM technology is no exception [1,2]. In addition this research merely considers the use of IoT in healthcare application which is known as, Internet of Medical Things (IoMT) or Medical IoT (MIoT) or

Healthcare IoT. IoMT consists of interconnected devices, e.g., wireless body sensor networks (WBSNs), Wi-Fi, IEEE 802.15.4 (ZigBee), RFIDs, Tags, Sensors, PDAs, Smartphones, etc., that could sense, process and transmit information in healthcare, and wearables, etc. [3]. The IoT, also referred to as the Internet of Everything (IoE), or the Industrial IoT, which has the great potential to reshape the entire business world. The connection of devices in IoT provides transformational opportunities for managing battery lifecycle and energy of the products (i.e., wearable/portable/handheld devices). Henceforth, it is important to understand the operational mechanism of the battery in these small devices due to their power hungry nature before integrating with other emerging technologies such as, PLM for effective and economical service provisioning, value chain supply to the medical companies and enterprises.

Recently, due to rapidly changing healthcare scenario and very tough competition from stakeholders provokes lower growth and profit margins, and it is challenging to manage unlimited wearable devices and their connectivity. However, the hospitals and medical theaters are looking at more holistic approaches for bringing state-of-the-art technologies into healthcare industries to accelerate examination and caregiving facilities at cost-effective rates. This is very cumbersome because of large loop-holes between available technological skill sets and desired healthcare demands. Besides, it

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is observed that large number of medical healthcare companies are not properly managing the cross-functional collaboration which is desperately needed to revise and support traditional healthcare market conditions [4,5].

One substantial and hybrid approach to cope-up with aforementioned healthcare challenges is the joint IoT and PLM based set-up for managing health related information across the medical devices, hospitals and physicians, etc. Also our proposed solution provide medical hospitals, centers and organizations with the ability to collaborate and share information very quickly and efficiently. By considering this feeling as the need of hour, some key solutions for managing health market's performance in terms of battery lifecycle and energy resources for small IoT devices.

Gartner [1] examine through research report that the growth to be 6.4 billion IoT device by 2016, and 20.8 billion by 2020. The data presented showed that the trend is expected to grow further in the near future. In most of the existing devices infrastructure, it is difficult to accommodate changes to the devices after deployment, including connectivity modifications, feature enhancement, technology upgrades, etc. So, IoT device lifecycle management is the key element for industries to have complete insight and control of their devices infrastructure. Today, device lifecycle management enables many industries to transition to 'smart' ecosystems, like smart energy (e.g., Internet of Energy or smart grid), smart buildings, smart retail, smart transportation, smart cities, smart factories, and smart agriculture [6–9]. As more and more devices get connected, the challenges with energy and battery lifecycle management of the sensor nodes becomes critical. In addition IoT's remote device lifecycle management plays a key role in enabling a 360° with bright and big picture of the medical healthcare industry. According to a device pilot study, about 88% of companies find the device management as a major concern and are incorporating methods to manage their devices seamlessly. In such a scenario, a platform is needed to manage all on-field devices with ease. The interesting question is that what experiences people want and how can they be satisfied? Customers' experiences can be replicated to the extent that the estimation of their thinking and feelings would be made while encountering products". The technology also connects engineers, medical experts and end-users (i.e., patients and doctors) in a collaborative interactive environment using data-rich 3D simulations of medical devices and processes. The IoT and Artificial Intelligence (AI) further offer huge opportunities for PLM. The more data you collect from each part of the device process, the greater the potential.

IoT technology is already changing the rule of the game from developing medical devices and getting acknowledgment, and improving future trends in medical devices with the significant role of PLM technology in managing their connectivity. As with the increased complexity and connectivity of these portable devices over time, it is very necessary to adopt the PLM for managing the battery lifecycle and energy of them from hospital to the medical industries [10]. The use of PLM is very vital and foremost need for the small and large enterprises due to data sharing capability between different phases of the lifecycle. PLM is a permissive scheme connects and manages, all the mission-critical information that affects the working principle of the medical devices. Most significantly, PLM endeavors a process of rationalizing collaboration and communication between medical experts, consultants, engineers and business leaders and other pivotal disciplines. Because of light weight, portability, flexible nature of wearable sensor devices in IoT, the number of connected devices is set to overtake the world's human population. The ecosystem system of the widely connected medical devices popularly called as the IoMT. But energy-constrained and limited battery lifetime natured wearable sensor devices could not fulfill the requirements of medical world for long time. Therefore, development of battery lifecycle and energy management techniques is utmost important. Moreover, with

the recognizing and demanding role IoT technology, PLM has also become the center of attention and at the heart of the digital medical enterprises and industries, and has expanded both upstream into innovation management and downstream into product commercialization, with modern cloud-based solutions managing the entire lifecycle and energy. Internet itself is not the Paradigm shift of the IoT, but the changing nature of 'things'. Smart, connected devices are generating new value in bringing technical dream to reality and opening up new landscapes of medical market examined by Janet Marsh [11]. Smart connected devices improve the collaboration and flexibility across the entire value chain from the manufacturing engineers to medical industries, and the medical experts to the end users. Greg Cline [3] present that the things are already generating more data than people or applications, and next medical industrial revolution is already at our door-steps by urging the importance of integrated PLM in developing smart, connected medical products that utilize the IoT. Specifically, we will look at the way best-in-class firms by using PLM strategically, to maximize the benefit of the successfully developed and deployed wearable devices in medical market.

Main contribution of this research is threefold. First, integration of IoMT with Product Lifecycle Management (PLM), for regulating the information/data transfer/sharing, and collaboration from medical experts to patients and between devices is made. Second, two algorithms namely, battery recovery-based algorithm (BRA), and joint energy harvesting and duty-cycle optimization-based (JEHDO) are proposed for managing the battery lifecycle and energy of the resource-constrained portable devices, respectively. Third, a novel joint IoMT and PLM framework is proposed for healthcare applications.

The remaining of the paper is organized as follows. Section 2 reviewed related work on the PLM and IoMT. Joint IoMT and PLM Framework for healthcare applications is proposed in Section 3. Proposed solutions are presented in Section 4. Experimental results are depicted in Section 5. Section 6, presents the conclusion of the paper with future research directions.

2. Literature review

There is a tight and close knot between Internet of Things (IoT) and PLM in medical market due to rapid proliferation in Information Communication Technologies (ICTs) and sensors which brings a dynamic change in the industry and academia. As research on PLM and IoT has been conducted since long time and many researchers presented their work in different domains generally, business, entrepreneurship, civil engineering, economics, industry just name few. But role and use of joint IoT and PLM in digital medical markets and enterprises is not investigated any more up to now. Besides, after wide and rigorous review very limited works on the PLM and its integration with IoMT for healthcare applications are explored. Gartner [1] predicted that the number of smart devices will be three times greater by 2020, by analyzing the rapidly increasing pace. The assurance is that every day medical healthcare products get smarter through the low-cost and innovative sensors especially, radio frequency transceivers. But these features-based devices drain greater power, and a majority of tiny nodes are powered by batteries, which is a critical and interesting challenge. Michael Alba [2], present the report about the role and IoT as a game changer for the PLM and brings the technological revolution. Greg Cline [3], discuss the integration of PLM with the IoT in the current emerging wave of revolution in the industry and academia. Janet Marsh [11], examine the importance of the IoT in PLM for manufacturing process of the product. MyAgile PLM [10], reported that IoT is totally a new drive and paradigm shift for PLM in this present era. Nick Easen [4], discuss the digital transformation wave for reshaping the PLM. Aura Feeney [5], develop battery friendly

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