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Automated personnel-assets-consumables-drug tracking in ambulance services for more effective and efficient medical emergency interventions

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ABSTRACT

Patient delivery time is no longer considered as the only critical factor, in ambulatory services. Presently, five clinical performance indicators are used to decide patient satisfaction. Unfortunately, the emergency ambulance services in rapidly growing metropolitan areas do not meet current satisfaction expectations; because of human errors in the management of the objects onboard the ambulances. But, human involvement in the information management of emergency interventions can be reduced by electronic tracking of personnel, assets, consumables and drugs (PACD) carried in the ambulances. Electronic tracking needs the support of automation software, which should be integrated to the overall hospital information system. Our work presents a complete solution based on a centralized database supported by radio frequency identification (RFID) and bluetooth low energy (BLE) identification and tracking technologies. Each object in an ambulance is identified and tracked by the best suited technology. The automated identification and tracking reduces manual paper documentation and frees the personnel to better focus on medical activities. The presence and amounts of the PACD are automatically monitored, warning about their depletion, non-presence or maintenance dates. The computerized two way hospital–ambulance communication link provides information sharing and instantaneous feedback for better and faster diagnosis decisions. A fully implemented system is presented, with detailed hardware and software descriptions. The benefits and the clinical outcomes of the proposed system are discussed, which lead to improved personnel efficiency and more effective interventions.

1. Introduction

The convergence of large populations in cities has led to enormous metropolitan areas and high traffic densities. Both developments have hampered the provision of rapid ambulance services. Dissatisfaction of citizens is frequently reported in the news, about late or inadequate ambulance interventions. Accurate figures on unsuccessful ambulance runs are difficult to obtain however; because city authorities

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often attribute the cause of failure to dense traffic conditions or long travel distances.

The ambulance services are provided by dedicated vehicles, medical healthcare-personnel, assets (computers, medical devices and communication equipment), consumables and drugs (Personnel-Assets-Consumables-Drugs: PACD). The ambulances are based and supported logistically either by hospitals or specifically designated ambulance centers. The logistic support includes the supply of all of the PACD on the ambulance, previous personal-medical patient information and the intervention instructions for special cases. Therefore, the ambulance service should be looked upon as a professional, dedicated emergency service supported and managed by capable, large organizations. The city ambulance services directive [1] is a depiction; which lists the filling out of a daily ambulance maintenance form as one of the duties of the doctor on call, at the city ambulance service center [2]. The form contains a list of all assets which should be manually checked and signed, at multiple times a day. However, repeated manual form completion many times during a day is prone to human errors and does not guarantee practical compliance. For example, despite error-free and complete form evidence, some drugs and assets were missing from an ambulance [3]. The practice of manual forms and hence the same type of errors are common, in many countries. Missing assets do not necessarily mean the negligence of the personnel, because theft may be the reason. In July 2011 and August 2014 – in two separate incidents – assets worth up to 30,000 U.S. dollars were stolen from ambulances parked in front of the hospitals [4,5]. Missing PACD items that are not reflected in the maintenance forms violate the general "rule of PACD presence"; i.e. PACDs' guaranteed presence on the ambulance at the call site. However, if the disappearance of a PACD is detected immediately, a notification can be sent for its replacement. Additionally, if it were possible to observe the circumstances of the item's removal, similar events may be prevented from happening. Fortunately, today's capable RFID tracking technologies are ready to enable healthcare organizations to provide the needed monitoring and notification.

Radio frequency identification (RFID) is a technology which is widely used in healthcare [6,7]. Major RFID hospital application areas are asset tracking, safe drug administration and real time object location [8]. RFID is based on a simple principle, in which an electronic sticker (tag) is used to give a unique identification number (ID) to its beholder. The tag contains a microcontroller whose integrated memory holds the unique ID. An antenna is needed to communicate with the outer world, for the identification process to take place [9]. After obtaining the ID, the reader relays it to a server; which searches its database to match the ID to an already recorded item. As in every electronic device, a trade-off exists between the cost and the operating distance of a tag. Due to the trade-off, RFID tags are divided into two categories, as Active and Passive. The more expensive, active tags require a battery source to energize the microcontroller, to be able to support long lifetime and operating distances. The low-cost passive tag is energized electromagnetically by the reader, which in fact is an alternative to the paper barcode. The passive tags are sub-divided into categories, but the most popular are the ultra-high frequency (UHF) and the high frequency (HF) tags. The HF tags are also called near field communication (NFC) cards because of the low operating distance. The categories and features of RFID tags can be found in many books, but a summary is available in our preceding work [9].

Various frequencies and communication protocols are used in active tags for additional features, beyond providing an ID. BLE is a new version of the regular bluetooth communication that promotes the technology into a suitable category, for RFID [10]. A popular, commercial BLE-based item used for identification is the iBeacon (a trademark of Apple Inc.) [11]. Although designed for mobile phone applications, iBeacons are gradually becoming more common in healthcare, as well [12]. An iBeacon is a low energy consuming device that periodically broadcasts a unique identification number (ID). Any device with BLE capability that comes within the iBeacon's transmission range can identify the iBeacon and launch a pre-defined application. Thus, devices can detect proximity to specific locations and perform location aware activities.

The differing properties combined with the cost considerations make using one single identification technology for diverse applications impractical. For example, accommodating an iBeacon on a small syringe is not practical due to size mismatch. In addition, the price of an iBeacon is much higher than the syringe's. On the other hand, a UHF RFID sticker is cheaper than a syringe and suitable as a sticker on each item. UHF tags also provide bunch reading of all syringes present in an ambulance, within a second. Fig. 1 of presentation [13] summarizes the comparison of various communication technologies. The Wi-Fi and Wi-Max technologies are good for computer-to-computer communication, with high data transfer rates and long operating distances. But, Wi technologies are relatively 100 times more expensive than the passive RFID technologies. However, identification and tracking do not require high transfer rates. Transfer rates less than 1 MB/s are enough to acquire the ID of a tag, in less than a second. If there are many items to track another consideration; the cost becomes a big factor. Naturally, the usual choice of tracking cheap and small sized items is using cheap UHF tags. For tracking expensive and bulky items, higher cost technologies like BLE are more suitable. Another constraint is forcing the tracked person or item to come very close to its reader. In other words, intentionally reading each tag one by one is necessary. Hence, the popular NFC tags with an operating distance of a few centimeters (Fig. 1) can specifically compel personnel or expensive assets to be present physically, at the site of the reader. The NFC technology also provides higher security than the UHF tags, for acquiring the ID number through the insecure air medium [9]. Therefore, it can be concluded that the variety of the ambulance PACD requires a combination of RFID technologies, for efficient tracking.

In this paper, the next section presents the identification and analysis of the problem, as well as the related work. Our proposed solution is called Effective and Efficient Ambulance PACD Tracking System (EEAPTS); which is a software application for tracking PACDs, supported by RFID and BLE technologies. The details of the proposed solution are given in Sections 3 and 4. Section 4 also presents an integration example. Section 5 presents the discussion; Section 6 depicts the