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무선 네트워크와 RFID 기술을 이용한 원격 Infusion Pump 모니터링 시스템 설계

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Design of Remote Infusion Pump Monitoring System Using Wireless Network and RFID Technology

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요 약 병원에서 Infusion Pump를 사용하여 환자에게 자동적으로 지속적이고 정밀하게 약물을 투여하는 것이 가능해졌다. 그러나 Infusion Pump를 부착한 환자가 이동하는 도중 응급 상황이 발생할 경우, 이에 대한 대처가 신속 정확하게 이루어지지 않고 있는 실정이다. 이러한 문제로 인하여 Infusion Pump를 통해 정맥 내로 투여되는 약물 양에 약간의 오차라도 생기면 환자에게 치명적일 수 있다. 따라서 본 연구에서는 무선 네트워크와 RFID 기술을 이용한 원격 Infusion Pump 모니터링 시스템을 제안하였다. 제안한 시스템은 Infusion Pump에 이상이 발생한 경우 Infusion Pump에 대한 상태 정보(고장 종류)와 환자의 위치 정보를 간호사 station에 자동으로 알려줌으로써 Infusion Pump를 사용하는 환자들에게 신속하고 정확한 의료 서비스를 제공할 수 있을 뿐만 아니라 Infusion Pump로 인한 의료사고를 사전에 예방할 수 있다.

주제어 : Infusion Pump, 원격 모니터링 시스템, RFID, 무선 네트워크, 위치 추적

Abstract Development of infusion pumps enabled injecting medical substances continuously and automatically to patients in hospitals. However, in cases when patients encountered emergent situations when moving to other areas, no clear measures were taken. The problem is that even the lightest error in injecting medical substances could be critical to the patient. That is why we proposes a remote infusion monitoring system using wireless network and RFID technology in this paper. When a problem occurs in the infusion pump, the medical personnel are informed of their patients' emergent situation and location information via wireless network so not only can they swiftly and accurately provide medical services but also can prevent safety accidents due to infusion pumps.

Key Words : Infusion Pump, Remote Monitoring System, RFID, Wireless Network, Location Tracking

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1. Introduction

Infusion pumps are medical devices usually used in cases of intensive patients, aphasia patients, infants, or any other patients who need an accurate injection of medical substances over a long period of time. For safety measures, infusion pumps are designed to stop or set an alarm when any error is detected[1]. But the critical flaw of this feature is that it only informs the patient who's wearing the device, and not the medical personnel who are far away. This is dangerous, because in order for the patient to be cared, the nurse must find the patient which may cause confusion and waste of time[2]. In worse cases when the patient is too far away from the nurse, there may even be a possibility for nurses to not hear the alarm, leaving the patient neglected. True, it is said that deaths caused by infusion pumps only consisted 710 of patient deaths from 2005 to 2010[3], which was quite rare. Still, errors from infusion pumps occur more frequently than other immobile medical devices[4]. Also, often times nurses mal-operate infusion pumps and cause medical accidents[5]. Above all else, the FDA(Food and Drug Administration) have launched a project to help address safety problems associated with infusion pumps[6], therefore making this problem any less trivial.

The advance of IT technology enabled ubiquitous healthcare, providing remote monitoring services to patients without having to meet them in person. In ubiquitous healthcare, medical personnel gathers patients' physical vital signs, chemical vital signs and environmental parameters through wired and wireless network remote monitoring so that they can provide medical services without time or space constraints[7]. Also, in ubiquitous healthcare, the medical personnel are informed of their patients' emergent situation and location via wireless network so they can swiftly and accurately provide medical services[8]. However, in most hospitals, sensing emergent situations from afar and immediately sending accurate information to medical personnel is not systematically built. Therefore, a remote infusion pump monitoring system as an efficient hospital automation system[9] is needed to serve swift and accurate medical care to patients.

In reality, quite a number of hospitalized patients die due to other causes than the disease he or she is suffering from. The reasons were diverse, such as diagnosing different medicine, over-dosage of medicine, diagnosing different blood type, medical device malfunction, surgery malpractice, falling down from beds due to weak safety measures and so on. Also, a research showed that 43.5% of dead patients could've lived through the accident if appropriate measures were taken[10]. Also, there is concern of malfunction of infusion pumps when patients move around. Therefore, this paper proposes a remote infusion monitoring system using wireless network and RFID technology to prevent safety accidents due to infusion pumps, and to provide safe and credible drug injection.

Following section I, in section II we will take a look at some technologies related to ubiquitous healthcare and how patients are cared through infusion pumps. In section III, the proposed remote infusion pump monitoring system will be presented in detail. In section IV, the result of applying the proposed system will be evaluated. Lastly in section V, conclusion, limitations and future research will be discussed.

2. Related Technologies

2.1 Infusion Pump Usage Example (Maternity Hospitals)

True, most of the patients who are hospitalized in maternity hospitals are mothers who have gone through normal delivery or cesarean delivery. However, in some cases they are hospitalized in early stages(before delivery) for safe delivery and for solving premature obstetric labor. In cases of premature obstetric labor, the mother's uterine cervix is thinned to

almost 20% of the normal thickness, is extended to more than 1cm, and is contracted more than 4 times per 20 minutes or more than 8 times per 60 minutes. Premature obstetric labor may lead to premature birth, which consists 65.21% of total infant death in South Korea[11]. Not only that, even if a premature born infant makes it alive, they are highly likely to suffer from dyspnea, lung disease, cerebral hemorrhage, cerebral palsy and necrotizing enterocolitis. This is why this is such a critical patient problem in maternity hospitals.

Therefore, in order to suppress the contraction of the patients'womb, a medical substance called Ritodrine Hydrochloride(Yutopar) is injected into the patient. Yutopar is a beta adrenergic agonist, and is used in mixture with dextrose when injected to a patient using infusion pumps. The initial amount is 0.05mg/minute and it increases by 0.05mg/minute every 10 minutes, but the recommended limit is up till 0.15~0.3mg/minute[12].

2.2 Infusion Pump

Infusion pumps are used to inject medical drugs to patients through their blood vessels. In the past, South Korea has mostly relied on import for supply of infusion pumps. But due to the effort of professionalized venture companies, high-tech infusion pumps are being produced domestically nowadays. Medical substances can be injected precisely, periodically and safely. For example, a recent model called 'MP-1000' from Daiwha Corp., LTD, has a error range of 5% or less, making it possible to handle even the minimum medical substances[13].

It might differ depending on models but a common infusion pump would stop and set an alarm in the following conditions: COMPLETION when the drug is fully injected to the patient, AIR when there is air in line, OCCLUSION when the injection line is clogged, FLOW ERR when there is an error in the infusion set and the injection interval is irregular, EMPTY when there is nothing filled in the infusion tube, DOOR when the infusion pumps' doors are open, and PURGE when the medical substance is suddenly injected too quickly.

2.3 Bluetooth

Bluetooth is a WPAN(Wireless Personal Area Network) technology often compared to Wibree, ZigBee, NFC(Near Field Communication), UWB (Ultra-Wide Band) which supports a wireless communication range of approximately 10m. Bluetooth is an industry standard for WPAN technology which started from Ericson Laboratory. Bluetooth was developed to substitute wired network to wireless communication network within the range of PAN[14].

Bluetooth has two advantages compared to other networks. First, having higher security and secondly having a low error probability. Bluetooth has high network security because iftwo or more devices want to communicate with each other using Bluetooth, they have to go through a process called 'pairing', which has a strong exclusiveness towards other devices. Secondly, Bluetooth uses a spread spectrum communication method, therefore has no limit in network numbers or device numbers. To put terms in an easy way, due to this method, in Bluetooth network even though the data sending rates may be slow, as long as there is at least one other communication channels available, network will never fail.

2.4 RFID Technology

2.4.1RFID system

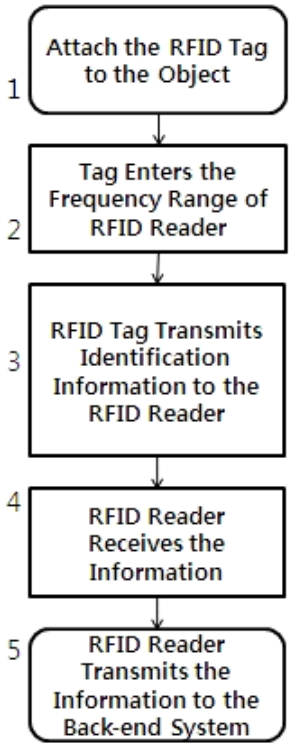
RFID system is mainly used for acknowledging the ID and the location of the object that has a RFID tag attached to it through the RFID reader. Since acknowledging the location of the patient plays a crucial role in serving medical service[15], therefore RFID technology has a great implication in healthcare fields. RFID uses KHz~MHz frequency to compute and

gather data from far distances.

RFID based information system is consisted of tag, reader, network, platform(middleware), and application service which is interlocked with wired or wireless communication. The RFID tag and the RFID reader are the most important features of RFID technology. RFID tag stores user data and the RFID reader reads the data from the tag and sends the information to the back-end system[16].The tag also contains an antenna for communication and a micro chip which stores the data. According to its energy type, it is divided into an active tag and a passive tag[17]. The RFID reader is connected to the PC, PDA(Personal Digital Assistant) or any other digital devices through networks such as WLAN or Bluetooth. A service which uses RFID technology is a system or a solution that analyzes and applies data to achieve location information[18]

2.4.2 Location Tracking Using RFID Technology

RFID uses 'RFID tagging system' which is one of the ways to track location of an object such as 'triangulation'[19] and 'active bat system'[20]. RFID tagging system only recognizes the location of the readers that are set up in a certain space. For instance, when the object approaches to the reader(of course, the tag is attached to the object), the RFID tagging system recognizes that reader as the location of the object. The overall flow of how RFID system works is shown in [Fig. 1]. First the tag is attached to an object. And when the tag enters the frequency range of the reader, it senses the frequency sent from the reader and transmits a carrier wave containing identification information in reply. The RFID reader receives that identification information and then transmits the information into the back-end system. And the location of the object is the location of the RFID reader, so ultimately, the location information is sent to the main computer or PDA GUI for easier recognition[21].

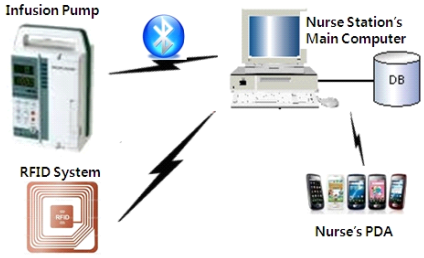


[Fig. 1] The Flow Chart of RFID System

3. Architecture of Remote Infusion Monitoring System

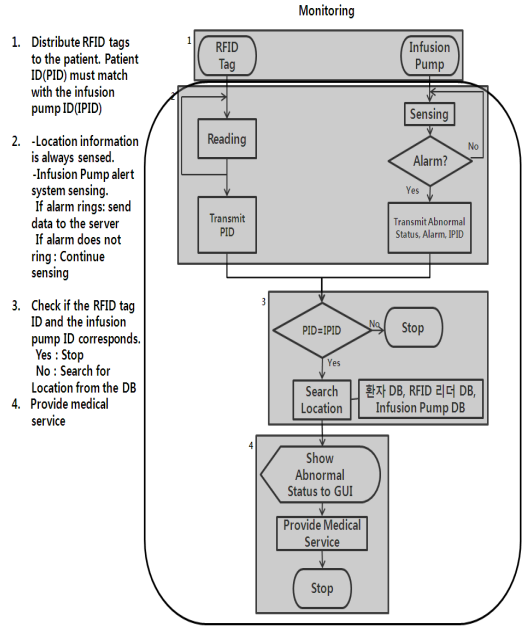
3.1 System Architecture

In this section is presented the remote infusion pump monitoring model using Bluetooth, infusion pump, RFID and PDA. The infusion pump model used in this paper is MP-1000 from Daihwa Corp., LTD. As shown in [Fig. 2], Infusion pump converts the alarm signal into radio frequency and transmits the data to the nurse station's main computer and PDA via Bluetooth, whereas RFID transmits the location information to the nurse station's main computer and nurse's PDA. The data is gathered altogether and is shown in an easily recognizable GUI.



[Fig. 2] The Overall Architecture of Proposed Patient Monitoring Model

The specific monitoring flow chart of our proposed patient monitoring model is shown in [Fig. 3]. If a hospitalized patient is in need for infusion pump assistance, an infusion pump which has an RFID tag attached is distributed to the patient. So the monitoring begins. If there is nothing wrong with the infusion pump, then no alarm signal is transmitted, but the patient's location information is constantly sent to the main computer or PDA for real time surveillance. If something goes wrong with the infusion pump, the alarm is set at the nurses'main computer or PDA, along with the type of trouble the patient's in. This kind of feature has two critical advantages compared to the infusion pump that is used nowadays. First, currently used pumps do not support features that set the alarm in the nurses' main computer or PDA…only the alarm in the infusion pump itself. Secondly, the proposed model sends the information including the type of trouble(OCCLUSSION, FLOW ERR, AIR etc…see section III.2) the infusion pump has caused, which current infusion models cannot. Due to these features in the proposed model, the medical staff can not only check where the patient is but also check what kind of trouble he or she is in, thereby enabling swift and accurate actions to be taken. Also, multitasking is possible, because for instance, if another problem was caused when checking on the problem that was already caused, nurses may check their PDA and subsequently continue tasks without having to go back and check again in the nurse station.



[Fig. 3] Specific Flow of Location Recognition and Infusion Pump Monitoring

3.2 Alert Data Flow Process

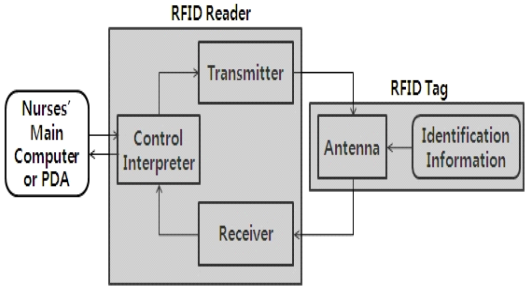
After setting a certain amount injection fluid of the infusion pump, in order to secure the safety of the patient, a remote monitoring system such as the one proposed in this paper is needed. The proposed model in this paper supports features that transmit 'alert data' to the main computer or PDA in infusion pump emergency situations. The alert data types are COMPLETION, AIR, OCCLUSION, FLOW ERR, EMPTY, DOOR and PURGE(see the specific features in II.2). The alert data is sent from the infusion pump to the main computer or PDA through Bluetooth, and is shown in an easily recognizable GUI. For example, on the top of the display screen the patient's name and ID is shown so that nurses could check them in the nurse station no matter how far the patient is away.

3.3 Location Data Flow Process

On account of the RFID system, nurses in the nurse station can watch over patients'location data real time.

This location data, if used along with the alarm data in emergent situations, can enable nurses to act swiftly and accurately to patients who are in need of assistance.

The main computer or PDA constantly communicates with the RFID reader, ordering it to sense the location of the RFID tag. The control interpreter built in the RFID reader receives this message and hands over this message to the transmitter. Then, the transmitter sends frequency signals within the reader's transmission range. If the RFID tag comes within this transmission range, its antenna reacts to it and transmits the identification information through carrier wave as a reply. The RFID reader's receiver receives this information, and sends it back to the control interpreter. Finally, the identification information is interpreted, sent to the nurses' main computer or PDA, and displayed in the screen in a simple GUI. Identification information, RFID reader's location, and patient information should be kept in a database server. [Fig. 4] shows the location data flow process between the main computer, PDA, RFID reader and the RFID tag.



[Fig. 4] Location Data Flow Process

3.4 Patient's Location Tracking Scenario

In order to keep track of patient's location, the RFID readers were set up in the hospital as shown in [Fig. 5]. Important thing to keep in mind is that the entire hospital must be within the frequency range of at least one RFID reader. One missing spot could create a dead zone, therefore there must be a sufficient number of RFID readers to cover all areas in the hospital.

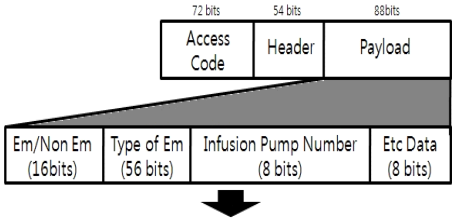
[Fig. 5] RFID Readers Set Up in a Hospital

Suppose a patient was moving from location A(the patient's ward) to location F, as shown in [Fig. 5]. The patient will have to cross location B, C, D, E in order to get to location F, so each of the readers will send the location data along with the patient's ID. The sequence A, B, C, D, E, F will be the patient's movement route, and the location where the reader is currently reading the tag will naturally be the patient's current location(which in this case, is F). If the patient suddenly collapsed in location F, the patient's location information as well as the problem type will be sent to the nurses' station, therefore enabling swift and accurate medical actions.

3.5 Alert Data Packet Structure for Bluetooth Communication

As shown in [Fig. 6], Bluetooth data packets are basically consisted of access code, header, and payload. The access code and the header is a fixed standard of Bluetooth transmission, and only the payload vary depending on the type of data the user wants to send. Payload bits can vary from 0 to up to 2,745 bits. In this paper, we set the payload capacity to 88 bits in order to include the information we need based on the proposed model. 2 bytes(16 bits) to include emergency and non emergency data, 7 bytes(56 bits) to include types of emergencies, 1 byte(8 bits) to include identification number, and the last 1 byte(8 bits) for

spare space. It is through this proposed data packet can the emergency type be sent to the main computer or the PDA, and be shown in graphic user interface.

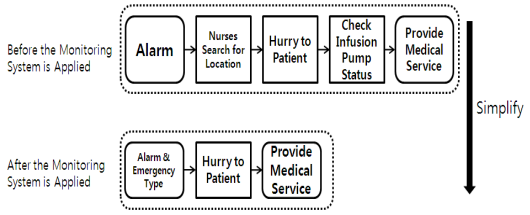


Em/Non Em	Emergency
	Non Emergency
Type of Em	Completion
	Air
	Occlusion
	Flow Err
	Empty
	Door
	Purge
Infusion Pump Number	1 or 2 or 3...
Etc data	...

[Fig. 6] Structure of the Proposed Alert Data Packet For Bluetooth Communication

4. Evaluation

Before the proposed system is applied, when the alarm goes off from the infusion pump nurses have to first search where the alarm is coming from, hurry towards the patient, check the patient's emergency status, and repair the infusion pump. Especially, it is estimated that a lot of time will be taken for the nurses to find where the patients are. Duties overlap, movements are wasted, time is wasted and most of all, the workload of nurses increase. But if the proposed system is applied, the whole process is simplified, and the workload is decreased. The alarm and the emergency type is sent directly to the nurses' main computer and PDA, making it possible for nurses to prepare for the emergency in advance and spot the patient in danger at the same time. Swift and accurate medical service can be provided. The simplified process is shown in [Fig. 7].



[Fig. 7] Process Simplification When Monitoring System is Applied

Also, since the alarm and the emergency type is sent to the nurses' PDA, even if another problem occurred during an emergency situation, nurses can check both situations simultaneously, thereby making multitasking possible. The advantages are specifically compared in <Table 1>.

〈Table 1〉 Before and After Comparison Table

	Before Monitoring System is Applied	After Monitoring System is Applied	Specifications
Time Needed to Provide Medical Service	Long	Short	Patient Search Time Reduced
Movement	Long	Short	Patient Search Time Reduced
Nurses' Workload	Large	Small	Patient Search Time Reduced, Infusion Pump Repair Time Reduced
Multitasking	Not Able	Able	Caring Neighboring Patients Possible Due to PDA

There are additional profits when RFID technology is used. For instance, if RFID tags are attached to frequently used hospital equipments, equipment loss and equipment theft can be prevented, overall, making equipment management easier[22]. Also, if RFID tags

are attached to newborn infants, their hospital information such as birth date, health status, medication status can be simply managed and infant identification confusion can be prevented.

5. Conclusion

This paper presented an infusion pump monitoring system using RFID system and wireless communication network. Using infusion pumps on patients mean that precise amount and injection rate should be precisely calculated, and that if even the slightest problem occurs, it could be fatal to the patient. Therefore, the proposed monitoring system helps solve this problem through providing alarm along with emergency type to medical staff, enabling swift and accurate medical actions to be taken. Current models of infusion pumps do not support features to send emergency types to nurse station so the patient is in danger of being neglected, although the chances are low. However, these chances increase when guardians are not with the patients, or when the patient is mobile. The proposed system allows location information and emergency type to be sent through RFID and Bluetooth to nurses' station so that medical staff may react instantly and accurately. In other words, Emergency types such as OCCLUSION, AIR, FLOW ERR is sent along with the patient location so that nurses may provide personalized medical service. Also, since this overall information is sent to the nurses' PDA, it will reduce movement process and time, so as a result, reducing their workload.

Future research about surveying the satisfaction of nurses' workload and quality of medical service is recommended, since the proposed monitoring system is expected to reduce the workload of nurses and prevent safety accidents from infusion pumps.

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