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THE DEVELOPMENT OF MATERIAL FLOW ARCHITECTURE USING RFID TECHNOLOGY IN REAL INDUSTRIAL ENVIRONMENT

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Abstract

The development of Radio Frequency Identification (RFID) technology is widely used to monitor pallets, cases or individual items in industrial manufacturing fields. However, this method was implemented only at the warehouse where it captured raw materials that need to undergo with manufacturing process until it becomes products but it was not monitor during the process in production line. Our proposed is to build the RFID system that can capture real-time data and monitoring during the entire production work flow where the transmission, tracing, storage and retrieval of overall process can be done. This technology is associate with unique electronic identity that are embedded to raw materials throughout the manufacturing cycle where it was registered to the RFID reader at every workstation so that the information for the start and end at each job can be transmitted to the main server at real-time for storage, categorizing, tracing, processing and analyzing. By these technology systems, we can promptly update of production-line information with real-time visibility of the whole work in progress production management among offices and sites in a construction supply chain environment.

Keywords: Radio Frequency Identification (RFID), real-time data, unique electronic identity, production management

Abstrak

Pembangunan Pengenalan Frekuensi Radio (RFID) digunakan secara meluas untuk memantau palet-palet, bekas-bekas atau barang individu dalam bidang pembuatan perindustrian. Walau bagaimanapun, kaedah ini telah dilaksanakan hanya di gudang di mana ia memantau bahan mentah yang perlu menjalani proses pembuatan sehingga menjadi produk tetapi ia tidak dipantau semasa proses aliran pengeluaran. Cadangan kami adalah untuk membina sistem RFID yang boleh memantau data pada masa sebenar dan pemantauan semasa keseluruhan aliran kerja pengeluaran di mana penghantaran, pengesanan, penyimpanan dan mendapatkan semula keseluruhan proses boleh dilakukan. Teknologi ini menggunakan identiti elektronik unik yang dilekatkan kepada bahan-bahan mentah sepanjang kitaran pembuatan di mana ia telah didaftarkan kepada pembaca RFID di setiap stesen kerja supaya maklumat untuk permulaan dan pengakhiran pada setiap kerja boleh dihantar kepada pelayan utama pada masa sebenar untuk penyimpanan, mengkategorikan, mengesan, pemprosesan dan menganalisis. Dengan sistem teknologi ini, kita boleh mengemas kini maklumat aliran pengeluaran dengan segera pada masa sebenar keseluruhan kerja dengan meningkatkan pengurusan pengeluaran di kalangan pekerja dalam persekitaran pembangunan rantaian bekalan.

Kata kunci: Radio Frequency Identification (RFID), real-time data, unique electronic identity, production management

1.0 INTRODUCTION

With the pace and demands of today's technology, especially in the industrial field there is a significant relationship between manufacturers, subsidiaries, suppliers and others in delivering and receiving information which is important to meet with each other [1]. Therefore, the use of RFID technology is said to be one of solution for use in applications especially that major in supply chain management and logistic

for movement and storage of raw materials, stock in process starting from the internal manufacturing process until the movement of finished goods to the consumers. Usually these same goes in retail stock management in where goods and services are delivered to their end users. It is important to have data integration between partners especially in retail supply chain process [2].

Figure 1 shows an example of basic RFID-enabled supply chain system. The process started where each boxes are tagged with pallet tag at the supplier warehouse and the RFID reader 1 scanned it automatically. Next the pallets are loaded into a truck at the warehouse loading zone and were scanned by RFID reader 2. The truck then departs at the warehouse where pallets were unloaded from the truck which all boxes are unpacked from the pallet and once again the reader 3 scanned it. Finally the whole process was recorded and can be monitor from the RFID database manager where all of the information was kept automatically.

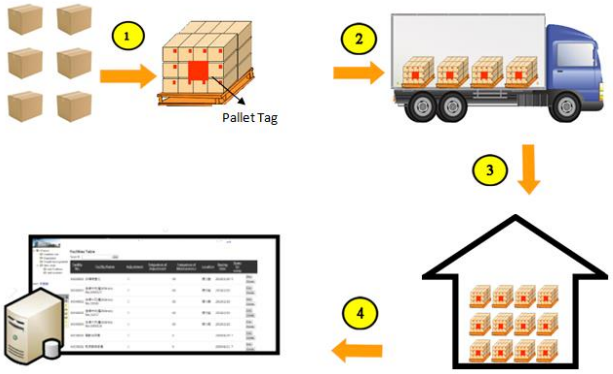

Figure 1 The various stages taken when transporting various RFID-enabled items in a supply chain

RFID has been developed in the security system for detection any anti-counterfeiting of product, electronic security keys and toll collection as theft prevention. There are also implementations of RFID technology in healthcare industry where a pilot project to track admission of patients in hospital was launched by Siemens Business Services used RFID bracelets [3]. Others common application that applied using RFID systems are tracking and identification, payment and stored-value systems, access control, auto-counterfeiting and many more as we can see the potential of RFID tagging technology for improving efficiency the management of facilities.

Although RFID is said to have many advantages yet to implement it in a system this technology poses challenges and problems where it requires expertise to be developed because there occur problems such as no special software to connect with basic peripheral hardware and operating system which is different from one another as well as lack of extensive knowledge about the program or the suitable language used to develop the overall RFID system [4]. Apart from that most of existing RFID system technology only manages monitoring the location and quantity of each product in the warehouse by attach a tag to the pallets since it known as the best system for inventory due to its rapidity and accuracy [5]. We realize that the monitoring process finished after the products arrived at the warehouse and these technology was not implemented in production line. This paper will review the issues highlighted with some solution to overcome the problem.

2.0 RFID TECHNOLOGY OVERVIEW

Basically, RFID system may contain two main components which is RFID tag and reader also middleware with database storage that able to manage all of the information that have been collected [6]. A tag is an intelligent chip that has unique identification number (ID) which can store useful electronically information such as serial number, stock number, batch number and production date or other specific information of some products. These tags are classified to three types: passive, active and semi-passive [7]. Each of these tag types has their own specification that can be used based on their functionality to operating a system. A passive tag are commonly used in many systems because it was cheap and has no internal battery with a long life where it can send data by electromagnetic field but yet it can store large capacity of information other than barcode labels technique [8]. An active tag are different because it require large battery with some electronic components for able to get higher signal strength and long range of communication line while a semi-passive tag uses "backscattering" also known as reflection where it sends the signal back to the reader [9]. Usually tags will be attached at pallets, bottles, cartons or at any suitable moveable objects that needed to track [10]. Each of the RFID tags have different frequency that can be used based on application needed with regulations or restrictions where these frequencies will determines the protocol used to communicate between the RFID sources and the reader. These frequencies range is from 100 KHz to over 5 GHz and we focus on passive RFID system that working at 860-960 MHz with 3m read range distance [11].

The RFID reader function is to collect all the information through wireless transmission by read and/or write data to the tags where it can monitor the current flow of existing objects. It must have logical components includes a reader API, communication, event management and antenna subsystem. Application Programming Interface (API) is application software that needed for RFID system to collect information from tags and send to

computer [12]. The reader will be affix at suitable places whether inside the factory, at portable mobile or at any equipment and devices.

A middleware is software that can react between computing nodes and will function as mediation for an application program and a network where it sends control commands [13]. They are different types of RFID middleware architecture that has been developed usually based on commercial used such as Microsoft BizTalk RFID, Oracle Fusion and Sun RFID Middleware while Accda have been developed for purpose of research [14]. RFID standards is needed to be implemented as it important to communicate with different types of tags, readers, software and accessories where companies can ensure their products can have a conjunction between computer system or software without need to contact with vendor or user. Besides, RFID standards may help in increasing the competition particularly in the industrial field that will lead to growth and expand this technology.

The last component which is database storage was used to collect all of the readings taken by RFID reader where it holds that information such as tracking logs, sales data or expiration dates. Having all information stored in a central database allows for higher level processes such as data cleaning, data mining and analytical evaluation. The Object Naming Service (ONS) is used to locate databases that will be associated with some tag identification value [15].

3.0 PROPOSED AND SOLUTION

A production line or manufacturing cell that has been installed to manufacture products in a factory usually includes a number of different types of machines that work in sequence to produce a finished part of products. RFID system can give efforts in genealogy tracking by collecting information such as product ID, timestamp, physical attributes, machine, order numbers and lot number at each step of processing. The system will give benefits to company as we can improve data accuracy when product processing, operator efficiency, gain more control over the warehouse and also to avoid products lost during the transportation from one process to another process workplace until the finished production line. Usually in a series of steps in the chip manufacturing processes designed the operator from each workspace will need to scan products or key in ID number or access codes from run card that given together with the production lot before started and finished the process. Sometimes they need to key in the quantity of each raw materials piece per production lot manually and they can possible made mistake by counting it.

Figure 2 showed the overall basic process through delivery chain of products from the warehouse until the finished line of the production process. First each of the raw materials has been packed and moved in tagged pallets that have been attached with the tag that contains a unique electronic product code (EPC) so it can be identified, counted and tracked through the RFID reader.

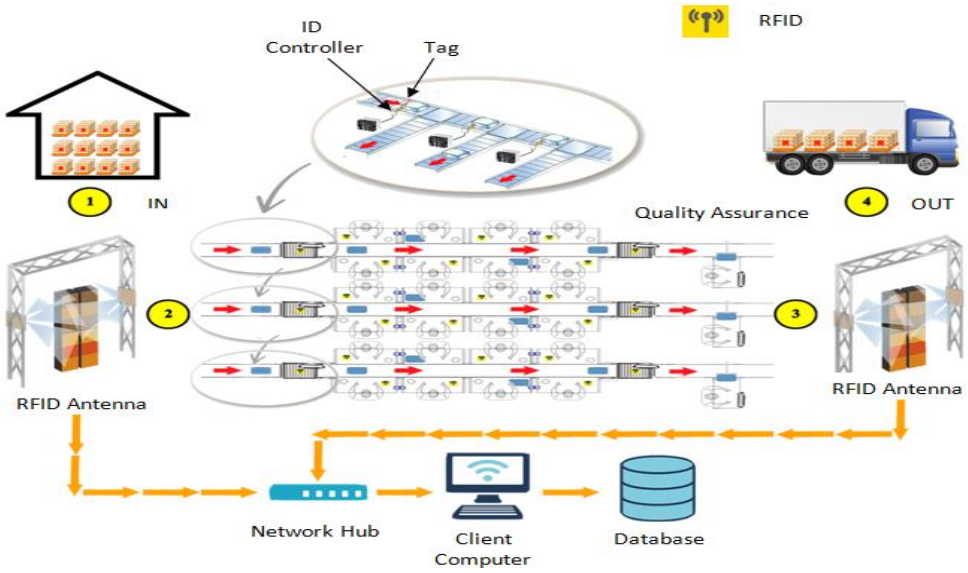

Figure 2 The structural framework of the proposed system

The EPC will be stored in memory chips and written to the tag through RFID writer. For example, tagged pallets with the tag ID 01-3240000A-000123-000004D9E contain 96 bits string of data divided to four parts. Once the tagged pallets of the raw materials leave the warehouse, RFID readers mounted over the loading dock door will hit the tagged pallets with radio waves that eventually power the tags and enable them to broadcast their unique EPC one by one. The reader is connected to the computer systems through software that was designed to retrieve auto tag ID which can send a query over the internet to an Object Name Service (ONS) database to obtain a server address so that more extensive information about the raw materials is stored.

The whole process starts when the operator in charge takes several production lots at the warehouse and brought to the assembly area for assembly process. There will be a few production lines at assembly area and as the operator takes production lots out, RFID reader will emits electromagnetic waves through antenna. The signal will be transmitted to the host computer where each tagged pallets of production lot contains a unique ID from the passive tags. Our proposed system can automatically monitor the quantity of production lot that is still remaining as tagged pallets enter the production line in real time. The incoming production lot with tagged palettes will be matched against the correct inventory quantities and any discrepancies occurred will be easier to identify. The operator labor that needed at each production line will reduce as the quantity check in and check out process manually or by key in task will be totally off. Additionally, they would not have to deal with searching for mistaken offload of production lot that is not at the right location because they can automatically relocate it from the monitoring system. The system detects unique EPC for each packed raw materials with two phases which is initial phase and detection phase. The platform can monitor tag movement within two operation station in which each tag is programmed with different identities. Specific tag identities enable the platform to distinguish the detected tag in a specified production line. The platform will automatically recollect data and each tag can be programmed, which enables the system to be utilized efficiently in real industrial applications. Data sent from the hardware is translated in the form of critical production information, such as lead time and moving time of different product in different production lot. We will integrate passive tags with sensors to operate without the batteries by get the power from the RF signal of the RFID reader [16]. Communication with passive tags work only when the energy of the EM field generated by a reader and when it was activated, the passive RFID tags elaborate the reader signal and reflect it modulated back to the interrogator or basically known as "backscatter". Next the operation is finished when reader receives signal and decodes the response.

3.1 Hardware

Our proposed monitoring system involves the hardware and software development. One of the selected hardware is XBee Module. XBee is a brand produced by Digi International as a radio frequency communication module. XBee module was used as a transceiver in this proposed idea where the transceiver is a device that can do operation of transmitting and receiving for radio frequency communication in a single housing [17]. Next we used SkyeModule M10 UHF Module with frequency 860-960 MHz as RFID reader platform because it is a technology that can support a variety of UHF RFID tags and can read distances as far as up to 5 meters [18]. Figure 3 illustrates the arrangement for the measurement and pilot testing in real industrial environment.

First we do the IP address setup for each reader so the computer can find the reader that have been initialize and to make sure each of the reader function well also the quantity of origin tagged pallets and tag ID was declared. The RFID reader use radio frequency (RF) transmission of bit streams to communicate in order to identify, classify, and/or track tag ID. The reader will receives RF energy from each tag and the operation of interrogation, decoding and processing of the received tag ID information was connected with storage system to manage the overall database for relevant information.

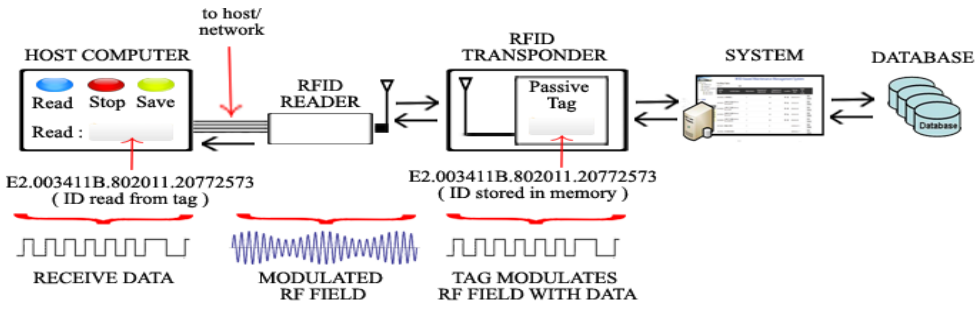

Figure 3 A graphical represented arrangement of pilot testing

3.2 Software

The software involved in building the system was Java, X-CTU, MySQL and XAMPP. We used Java to develop the programming language in order to obtain real time data from RFID reader. X-CTU was used by XBee module configuration to configure and testing for update parameters, upgrades firmware and execute communication testing comfortably [19]. The database system was built by MySQL to record the RFID data that was sent from RFID readers. XAMPP function as netbeans web server and developers tools. Figure 4 show the sample snapshot interface window that we get from the system:

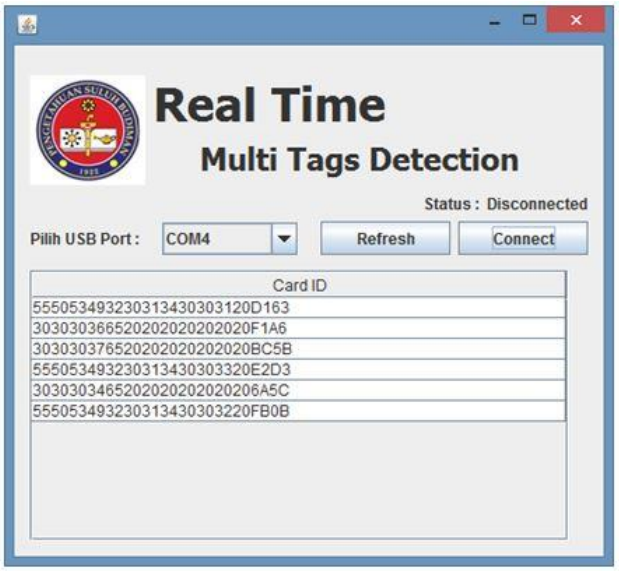

Figure 4 Snapshot from interface windows

Figure 4 show how tags were detected in real time during experimental test. There are few of tag ID has been captured by RFID reader when the tagged pallets with unique serial number were in visible range.

4.0 EXPERIMENTAL SET-UP

We validate the effectiveness of our proposed ideas through the experimental test where our goal is to monitor and capture real-time data for the whole process in production line. We focused on important data such as the amount of data to be queried for quantity incoming production lot and after the finished process, serial label ID and current location for each production lot. The equipped EPC was labeled at the tagged pallets so it can easily to be identified counted and tracked automatically [20]. We used EPC Gen 2 Class 1 developed by EPCglobal where it has a minimum memory of 256 bits of which 96 bits [21]. Each of EPC sequence has its own functionality which is the header bits determines structure of global numbering system such as trade identification number, serial shipping container code and the global location number. The domain manager provide identity manufacturer of production items where tag are attached to while object class defines the product itself. The serial ID number is unique for the individual product for each manufacturer can have approximately up to 2^{36} [22]. We have developed the user interface in order to obtain real-time data from RFID readers. We connected XBee module using a USB cable to personal computer (PC) so that we can configure it and perform communication testing as shown in Figure 5.

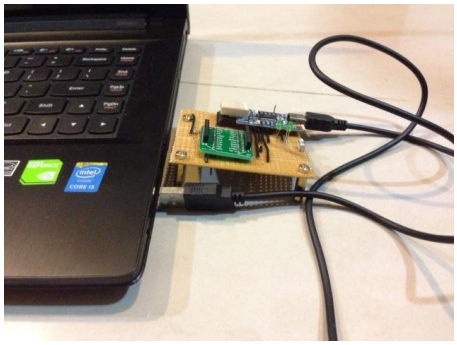

Figure 5 XBee module connected to PC

We set the Personal Area Network (PAN) ID and baud rate to default value of 3332 and 9600 bits/second respectively where X-CTU software helps by manage to retrieve data from hardware system. There are a few antennas mounted together with RFID reader. These RFID reader runs an anti-collision protocol to read multiple tags by prevent interference between two or more installed antennas [23].

5.0 RESULTS AND DISCUSSION

Table 1 showed the demonstration result that we get in order to monitor incoming production lot at each station. The list of antenna was set to initial value so the program will know how to access all tag ID data by each antenna. To read the data the system first should determine the initial quantity of production lot by its own EPC code that has been attached at tagged pallets. After operator take the desired production lot to be assemble at production line the reader once again scan the remaining quantity production lot through tagged pallets that have left. If successful the several of tag ID information can be read, displayed and written in database. The real time data can be displayed on the screen after the system update the reading operational. Operator can get information such as tag ID, reader number, production lot quantity, and last read time as shown

in Table 1 for example of the data in MySQL database storage:

Table 1 The data retrieved from the MySQL database

No	Tag ID	Reader Number	Quantity	Timestamp
1	01-3240000A-000123-000004D9E	01	500/500	2014-01-30 12:33:26
2	01-3240000A-000123-000004D9E	02	500/500	2014-01-30 14:45:20
			:	
			:	
7	01-3240000A-000123-000004D9E	07	500/500	2014-01-30 23:33:25

MySQL is an open-source database system that has Application Programmable Interface (API) function together which is widely used in several industries [24]. Data shows the specific antenna for specific reader that read the tag ID. The reader number and antenna number has indicated the position and movement of current production lot. We used two antenna located at each gate in front of production line in order to communicate with the tags to transmit an electromagnetic field so passive tags will be activated when it is within the range. The important of these antennas which is one will ensure the emission of energy to the tag while the other is to receive energy back from the tags. Each of production lot quantity was recorded when operator took it from tagged pallets and go through the RFID reader. The transaction of time and current quantity of production lot at first production line was updated and recorded before final assembled raw materials taken out from the last production line. The presented information is important as the operator can easily view the status with other relevant data of the inventory quickly in detailed. We understand that exchanged information between communication nodes in RFID system may be lost during transition operation. Our system are provided with data processing service (DPSS) which will function to filtering out multiple tag ID that has been captured between two or multiple reader and antenna so the system database only kept the needed tag ID and displayed it.

We come out with simulated analysis where tagged pallets with tag ID 01-3240000A-000123-000004D9E moving through at three different production line that we get based on experimental test that we has done. We described percentage accuracy total loss of tagged pallets for each production lot quantity to complete their assembled process before go into another production line as shown in Figure 6 below:

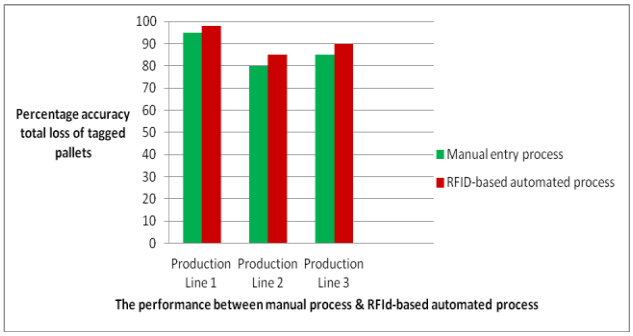

Figure 6 Analysis simulated tagged pallets moving through three production line

Based on the analysis, we compared percentage accuracy total loss of tagged pallets between manual process and RFID-based automated process when production lot entered the production line. The result shows that RFID-based automated processes are simultaneously increased accuracy of the data entry process that usually done in manually by operator up to 98% over to 80%.

5.1 Similar Work

The adoption of RFID technology for many applications especially in supply chain management may integrate between suppliers, distributors, manufacturers and customers to achieve service satisfaction with each other [25]. Our proposed ideas is closely related to the method [26], where they integrate RFID system with Automated Storage and Retrieval System (ASRS) to store all kinds of products in the store room. The products were attached with tags embedded with unique ID number. The readers will transmit information to base station and finally send the data to asset master. This work is similar with [27] where they implement intelligent storage and retrieval systems based on RFID in their automated warehouse to improve storage and retrieve targets at shelves namely SK6 produced by Yaskawa. It helps to identify target recognition, automatic localization and automated storage retrieval system of attached tags. The system used combination of vision technology and RFID for image processing, teaching and remote mode to recognize and locate the target. Both systems was designed to recognize the accurate location of products using passive tag however there were no implementation of the same method in production line.

Table 2 shows the difference previous work in the same application. Although similar RFID technology was used, the novelty of our proposed system is different.

Table 2 Existing system using RFID technology

Existing System	Short Descriptions	Tag and Reader Used
Hybrid RFID Sensor Network [28].	Providing solution to monitor complete information for logistics centre resource management.	Passive and Active tag. Skyetek DKM9 UHF.
Passive UHF RFID Tag for Industry Application [29].	Configure securiy and managemen system for assets tracking, monitoring and control system.	UH113MZ3 Passive tag. UHF RFID reader R600.
The development of a RFID based leanness monitoring system [30].	Develop a system to determine the lead time of value stream map for production system.	85mm RFID Disk Tags. Texas Instruments 251B Low Frequency RFID reader.

Our proposed ideas is associate with unique electronic identity that are embedded to raw materials throughout the manufacturing cycle where it was registered to the RFID reader at every workstation so that the information for the start and end at each job can be transmitted to the main server at real-time for storage, categorizing, tracing, processing and analyzing. Our system helps in providing information systems and inventory levels in line encompasses inaccuracy factors such as transaction errors, misplaced items, damage and supply errors. The built network can help increasing the operational processes such as start and end processing job at production line. The communication gathered from real time information helps to justify the availability of raw materials required for production. Obtained information data captured by the RFID reader helps deliver actual information on the operational status of production line. This includes the quantity and type stored raw materials, location, operator in charge ID, types of operation and so on.

The network operated at 2.4GHz where data collected was stored and transferred to the host computer for communication wirelessly. The database systems that serve for data storage and retrieval helps reduce the use of time and human errors.

6.0 CONCLUSION

The development of RFID system has meets in widely environment as it's in widespread of sensor technology which is use to monitor or measure at physical location for their pressure, temperature, speed, vibration and many more. Basically, passive RFID reader will be used in tracking and monitoring system and act as a sensor platform to generate respond from available RFID tags. RFID reader also known as interrogator where it was types of sensor device that functions as a sensor node to perform readings of identification for object and sends it to the host application through wireless system. Active RFID also recently used in manufacturing application because it can covers wider area within 15-25 meters. It was equipped with battery and works by transmits ID information to active RFID reader through sensor network or coordinator. The RFID system that we propose can be used in industrial to design a production flow which perfectly helps in balances labor, material and equipment to minimize cost and maximizing profit. It also helps in to simplify the complexity of manual operations, reduce human errors and enhance efficiency during production flow. Passive tags that we used are likely the most widespread RFID tags in the market because it cheap and suitable for wide range of applications. The development of middleware approach can be seen as a high level than (API) that will response in fetching useful information. We believed that EPC Class-1 Generation-2 UHF reader technology in a real world was a good choice to improve data management system. Apart from this, management and line managers can access to the real-time data at anywhere and anytime other than monitor the progress of each task, understand employee's individual working efficiency and supervise production line performance. Through this paper, we have evaluated the performance of RFID technology especially in data management as we understand that it was major challenges in industrial sector. The simulation result shows that our proposed ideas was able to accurately count the total loss of tagged pallets for each production lot quantity to complete their assembled process before go into another production line.

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