IoT based smart manufacturing system - Case studies*

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ABSTRACT

Keywords:
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Manufacturing now a days growing and becoming more complex, automated and computerized. Smart manufacturing is an emerging form of production manufacturing asset of today and in the future with involvement of smart sensors, actuators, communication technology, smart consumer devices like smart phones and tablets and data-intensive modeling. This paper will highlight a review of IoT application in smart manufacturing. Case studies on advanced techniques used in manufacturing industries for different operation such as Monitoring and controlling of smart equipment, IoT based Smart factory connectivity for industries, Hazardous Gas Detection, Electromyogram (EMG) monitoring system, and Tool wears characterization, Defect predictive in a manufacturing system, Machinery Health monitoring are presented.

1. Introduction

The "Internet of Things (IoT)" is strongly applied in many different applications, various frameworks, and domains in our daily lives from small device domestic applications to large industrial systems. The IoT is the use of sensors, actuators, and data communication technology built into physical things from roadways to pacemakers that enables those objects to be tracked, controlled, or coordinated across the data network or interconnect with the aim of creating value [1-3].

As per Fig.1, IoT applications are considered connected to different devices through communications gateways. It is normal that IoT innovation will make ready for momentous applications in a decent variety of territories. For example, medicinal services, security, observation, transportation, and industry. Also, it will have the capacity to communicate with subsystems. For example, propelled machine-to-machine (M to M) correspondence, basic leadership, autonomic systems administration, and distributed computing with cutting-edge identification and activation advances.

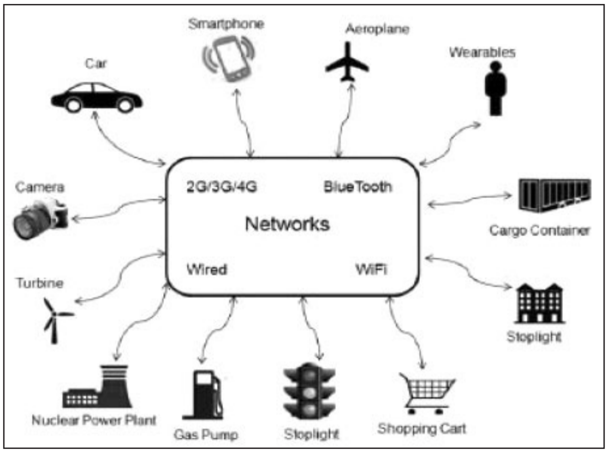

Fig. 1. Internet of things (IoT) [4].

IoT comprises both static and dynamic objects of the physical things and the virtual world, which can be recognized and coordinated into correspondence systems. The basic highlights of IoT include: (i) Interconnectivity, (ii) Things-related administrations (security assurance and semantic consistency), (iii) Heterogeneity, (iv) Support of dynamic changes in the state and the number of

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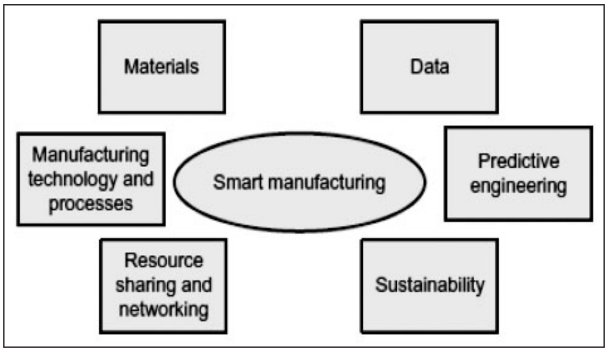

Fig. 2. Six pillars of smart manufacturing [6].

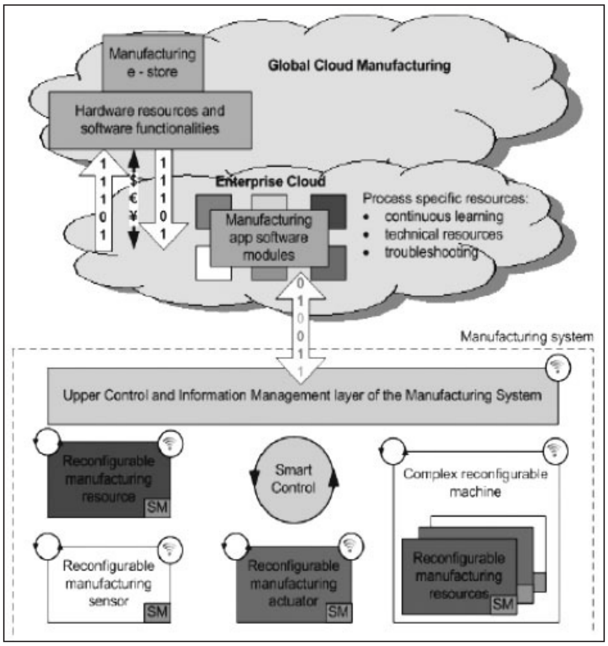

Fig. 3. A simplified view of the proposed IoT architecture for manufacturing [7].

gadgets, (v) Tremendous scale [4-5].

2. Smart Manufacturing

One of the generally used terms describing the production of future is smart manufacturing. Industry 4.0 is the main reason for the evolution of smart manufacturing and this was introduced in Germany for the first time to increase the production rate [6].

2.1. Six pillars of smart manufacturing

Smart manufacturing was motivated by the concept of highly developed in the realm of computing. Fig. 2 shows six pillars of smart manufacturing and also they are neither exhaustive nor stationary [6].

The pillars of smart manufacturing are

Pillar 1: Manufacturing technology and process

Pillar 2: Materials

Pillar 3: Data

Pillar 4: Predictive engineering

Pillar 5: Sustainability

Pillar 6: Recourse sharing and networking

3. Case Studies

3.1. Monitoring and controlling of smart equipment using IoT in manufacturing industry

Fig. 3 shows the simplified view of the proposed IoT architecture for manufacturing application. As per Fig. 3, the manufacturing system is built out of smart reconfigurable manufacturing facilities that are connected to wired and wireless communication between them and to the manufacturing control system and information management layer. The actuators and sensors are the reconfigurable manufacturing resources. These reconfigurable resources are addressable by using communication network and they have the ability to control, monitor, process, store, receive and send data.

The manufacturing cloud is designed and that will be connected to the manufacturing system or manufacturing resources in the plant. It is anticipated to provide access to computer application and data sharing. It represents the global network that could buy and sell the products, software, and hardware manufacturing resource, raw material and technical data [7].

The main three expected outputs from the architecture are:

1. The development of the reconfigurable resources can rearrange their building block in order to suitable process needs by choosing the correct software application.
2. The graphical operator-process interface will provide enjoyable user experience to the manufacturing process by means of smartphones, PCs, and tablets.
3. It will provide an enterprise with access to a manufacturing e-store. [7]

3.2. Smart factory connectivity for the industrial IoT

The innovations driven in industries by Industrial Internet of Things (IIoT) will significantly improve efficiencies and productivity. The result will be reduced waste, lower operating cost, and increase in overall productivity. The connected factories require a rush of smart and interconnected devices, factory processes, out coming in an explosion of data generated, aggregated and analyzed. It must be processed in real time so as not to produce s bottleneck, even still have the bandwidth to provide context and intelligent analytics. In this case study, the researchers describe the smart factory connectivity challenges for IIoT devices and the solution available today to manage these real-time data processing problems [8].

3.2.1. Substantial challenge

The challenges facing while implementing IIoT are,

- Ensuring the reliability and quality of the products and process.
- Improving the efficiency of the manufacturing processes and adopting predictive maintenance.
- Establishing products faster with more intelligent management.
- Connecting interconnected multi-located manufacturing facilities.

To overcome the above challenges, there is a wide scale adoption of modern techniques. The information technology (IT) and operational technology (OT) need to work in the combination to achieve better manufacturing efficiencies.

The existing fieldbus protocols such as RS-232 are extremely insufficient due to its low bandwidth, susceptibility to noise and cycle time limitations. Actually, the time delay between data transfer from a sensor to the main computer is typically less than a second. The modern suitable Ethernet protocols that attains this requirement are Ethernet/IP™, Modbus® TCP, CC-Link® TCP, EtherCAT®, PROFINET®, and Sercos™

III. This case study will cover two of the most popular protocols, EtherCAT and Ethernet/IP, and their suitability.

Ethernet/IP: This protocol is a part of industrial Ethernet and that make use of TCP/IP and UDP/IP stacks for communication. It employs CIP (Common Industrial Protocol) in its application, session and presentation layers.

EtherCAT: Ethernet of Control Automation Technology (EtherCAT) is a highly flexible protocol. The operating principle of this protocol is On-the-fly processing. The typical frame sizes for industrial applications are valve control, switching and operational synchronization are short. Table 1. shows that the 5x faster real-time response of EtherCAT is possible compared with other protocols.

Many companies offered EtherCAT solution for its high flexibility in operation. Renesas, one of the industries which offered EtherCAT applications that meet the connectivity challenges. Fig. 4 shows the developed kits that enable easy evolution of the respective device for targeted applications [8].

Table 1
Ether CAT boasts a 5x faster real-time response time as compared to other Protocols [8].

Protocol	Response Time (for 100 axles)	Jitter	Data Rate
Ethernet/IP CIPSync ODVA	1 ms	<1 ms	100 Mbit/s
Ethernet Powerlink EPSG	<1 ms	<1 ms	100 Mbit/s
PROFINET-IRT PNO	<1 ms	<1 ms	100 Mbit/s
SERCOS-III IGS	<0.5 ms	<0.1 ms	100 Mbit/s
EtherCAT ETG	0.1 ms	<0.1 ms	100 Mbit/s

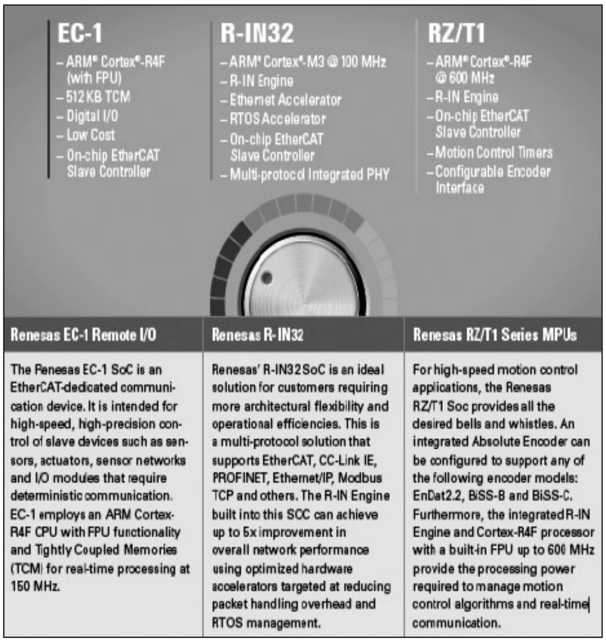

Fig. 4. Kits for three device applications.

3.3 Hazardous gas detection using AVR microcontroller

The safety is a major criterion in the current era and appropriate safety system has to be present in industrial areas. The main objective of the case studies is to design an AVR microcontroller based combustible and hazardous gas (LPG, LNG, propane, butane, etc…) detecting and alerting by using IoT application.

The MQ-6 gas sensor was used to detect the hazardous gases which are combustible in the environment with a power supply of 5V supplied by the DC battery. Both the factions were communicated over the internet and sending messages to user mobile number are done by wireless GSM module. Initially, the work is exulted in a programming language developed. The software to the AVR microcontroller is embedded C and the PROTEUS is used to simulate the project on software. Block Diagram of the User Interactive Gas Leakage and Fire Alarm System is shown in the Fig.5[9].

The simulated project is implanted practically where the hazardous gas like LPG and combustible gas were sensed by MQ-6 gas sensor and is monitored by the AVR microcontroller and displayed in LCD. In critical condition, when LPG exceeds from normal level of 1000ppm and in the same way the propane exceeds 10000ppm, then the alarm is generated and an SMS is sent to the authorized user there by alerting system which helps in faster diffusion of the critical situation in the industries.

The advantage of this auto-detection and alerting system over the conventional method is that, it offers a quick response and accurate detection of an emergency situation and it helps faster diffusion of the critical situation [9].

3.4. IoT based tool wear characterization

This case study proposes IoT architecture enabled manufacturing system and demonstrates it on bench top milling machine by mounting cutting tools with low-cost sensors along with other sensor. The MEMS sensors are used to work with an IoT enabled system. Sherline 8020 series mini CNC milling machine used houses a 90V, 60W spindle motor that rotates at 70-2800rpm. The feed drives are controlled by three 3.3 V NEMA23 DC stepper motor with 9.7 kg-cm of torque with step-angle of 1.8 degrees. The

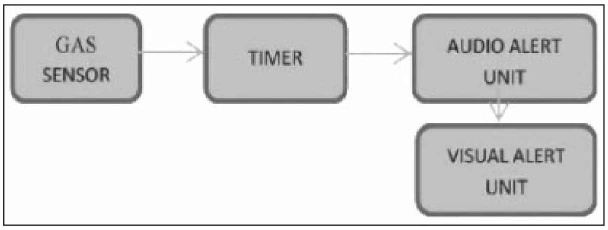

Fig. 5. Diagram of the user interactive gas leakage and fire alarm system [9].

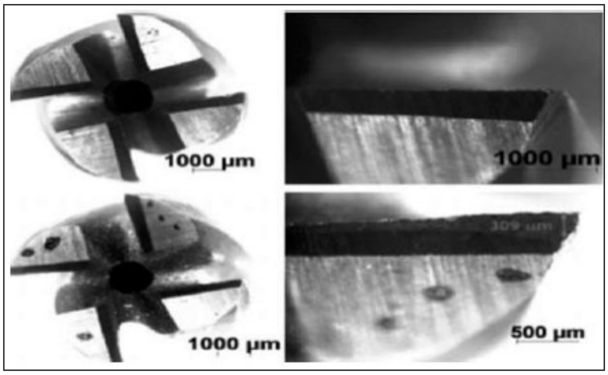

Fig. 6. Tool before (top) and after (bottom) machining [10].

computer consists of an OS with Linux kernel and it runs EMC2 to control the CNC machine. The stepper drives are controlled by stepper motor controller which is interfaced through IEEE 1284 port from the computer.

An MPU6050 (MEMS accelerometer) and a Dyatran 3145AG (Industry-grade accelerometer) were used to get the vibration data during cutting. An ACS712 (motor current sensor) sensor is used to measure the spindle motor current during the machining process. The MLX90614-KSFBAI-000-TU I2C infrared thermometer is used to measure the temperature at the tool-work interface. The researcher used the PYTHON program that controls the CNC milling machine using EMC2/ LinuxCNC controller and Raspberry PI 2 (RPi) has been use as an interface to acquire data from the sensors.

The experiment was carried out by marching MS (mild steel) workpiece of dimension 114mmx48mmx13mm and the tool used was HSS (high-speed steel) of diameter 7mm and four cutting edges. Spindle speed was manually varied to target 1500 rpm, 2000 rpm, and 2500 rpm. Each milling tool was operated at one of the above spindle speed with a feed rate of 40 mm/min and depth of cut of 0.05 mm for a length of 40mm. The images of tool edges were captured by STEMI 2000 CS stereo microscope after each pass. This image was then processed in Image software to get the value of tool wear. Fig.6 shows the typical image and tool wear [10].

3.5. Defect predictive in manufacturing system using IoT

Nowadays the industries becoming smart plants by applying information and communication technology (ICT). The smart manufacturing technology is gaining importance that can provide excellent and intelligent services such as automatic recognition of product quality and automatic management of material inventory information online in real time. The aim of the case study is to defect detection and tracing of the causes of past failure in the manufacturing process in real time and to implement the system that predicts future failure due to changes occur during cutting.

In order to implement smart defect prediction system and to collect data in real time, researcher used system components such as A) Wireless sensor node IEEE 802.15.4 Phy chipset that supports the 2.4 MHz ISM band. B) Gateway- which transmits a packet of sensor node using a wireless sensor network to a server. The gate used a Linux-based embedded system and Master Node for wireless sensor network. C) Actuator- it provides visual or auditory feedback to the customers. D) Server and E) PC based measurement system.

The system implemented in the plant consists of three processes, PET bottles manufacturing in step 1, Filled bottled water in step 2, and packing the products in the step 3 is as shown in Fig.7.

In order to apply the IoT based defect predictive manufacturing, it is necessary to understand the current production facilities in the industry. The production line selected and installed depends on the target total production amount and system cost at the time of introduction. In order to collect the process information from different manufacturer equipment, the researchers construct the system using wireless sensors and gateways. Compatible with equipments of different sources presented in the plant.

In order to predict the defects using stored information, the researcher designed and implemented Manufacturing factory data analysis, web application with the following structure that is shown in Fig.8 and applied this with bottled water factory. The quality prediction management

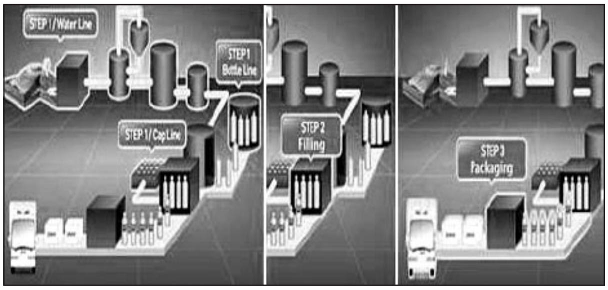

Fig. 7. The process in three stages [11].

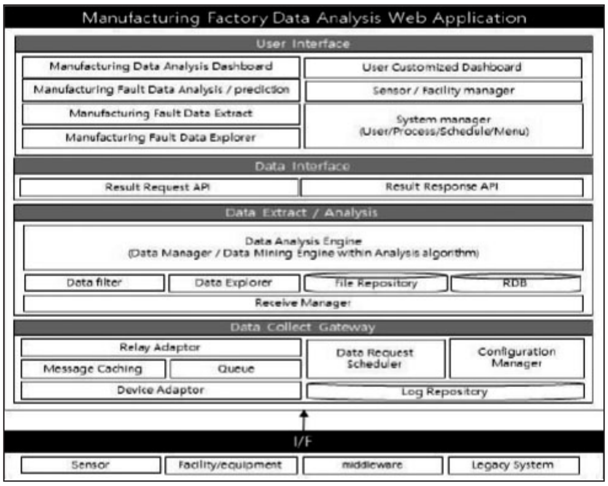

Fig. 8. Quality analysis forecast management platform structure.

system collected manufacturing process data and is transmitted from the gateway in real-time within the platform. The analytical forecasting algorithm is performed to extract process parameters that can affect the process; it is used as a rule base to predict poor quality prediction, optimizing operating conditions facilities and defect tracking. Fig.8 shows the system is implemented in order to enhance the quality control by providing the service function to optimize the operating condition of the facility.

3.6. Machinery health monitoring (MHM) in additive manufacturing

The main important fundamental manufacturing task is maintaining and monitoring machinery health monitoring.

This can be done with the help of many low-cost smart sensors and communication networks. As IoT and data science advances rapidly, detection of the faults in real time and even predicting the failure of equipment can be done in advance. This technology will reduce maintenance cost and improve productivity.

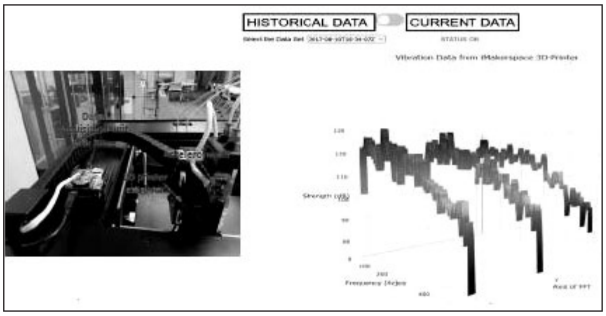

Fig. 9. Vibration data acquisition and visualization in the cloud (MS Azure) [12].

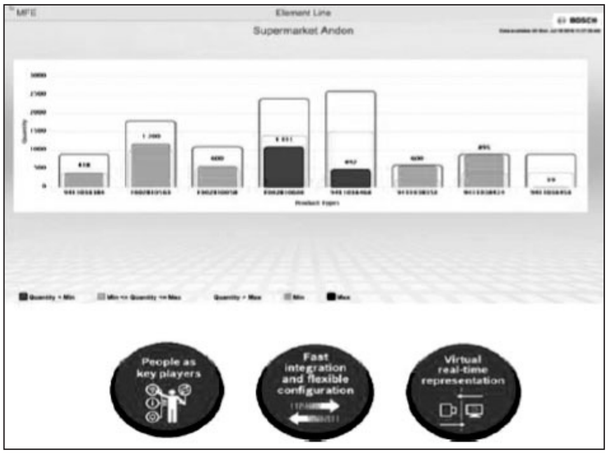

Fig. 10. Supermarket shows the maximum and minimum quantity of parts in real-time [13].

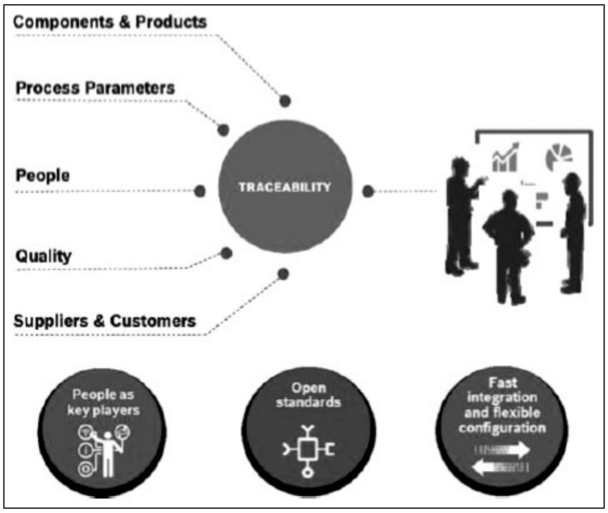

Fig. 11. Connectivity link of production system [13].

The experimental set was to collect the data from sensors wirelessly, store and visualize the data at Microsoft Azure clouds, and incorporate Artificial Intelligence to detect, trace and predict the failures. Fig.9 shows the vibration data acquisition front end mounted on a 3D printer and the data interpreted in the time frequency domain at MS Azure cloud, where data is kept on the Azure Web App for remote access. Moreover, Node-RED is used to send email alerts triggered by some pre-defined condition such as excessive vibration and failure of 3-D printing [12].

3.7. Intelligent supermarket: real time inventory management (SCM) - Industry 4.0 @ Bosch

Bosch Company was facing a business problems in inventory department where it was difficult to track materials with respect to its types in real-time, and lack of production planning system to show exactly what is to be produced in real time. Bosch has implemented and adopted IoT and other sensor technology to solve the inventory management issues by building an Integrated RFID system to visualize Real Time Inventory Data along with on a Supermarket Andon to display real time availability of critical components. And Andon shows maximum and minimum quantity of parts to be stocked and indicates in red when the stock goes above or below, the set limits and these leads to a comprehensive RFID enabled eKanban system. By implementing this production system was able to monitor Auto production schedule / Plan for Operator, as per availability in Super Market [13].

3.8. Traceability of manufactured lot – Industry 4.0 @ Bosch

Major issue in Supply Chain Management (SCM) is Traceability. Bosch Company has faced a business problem like No reliable method to track the products or raw materials in the production line, In case of a rework, no accountable method was available to trace root cause of problem and hence inaccurate inventory reporting caused increased stock. To overcome on this issue in SCM, Bosch has implemented an IoT which is integrated with RFID system to trace the flow of information of raw materials and products in the production line. Traceability provides valuable information of history of a manufactured lot which includes: steps performed, relevant process variables and quality controls. From ERP integration and Data Analytics, the Information about each and every component of the product assembly is attached to the final product and job order along with date, time, employee id, supplier details, etc. By Interlocking feature, it can be designed to eliminate chances of skips or deviations in the standard process sequence.

Other benefits include Proactive management of production defects with real time corrective action, Identify root cause of customer complaints and reduce time required to address them, customized information such as material, finish, etc. at each stage of production and better inventory visibility and optimized stock. [13]

4. Conclusion

This paper highlights some of the case studies about how smart manufacturing will work by applying IoT. The seven case studies presented are from different areas where the IoT can implement and improve the rate of production. Conclusions that can be extracted from each case study are: Case study 1: The connectivity solution between a manufacturing resource and monitoring device meets the needs by using the Wi-Fi module. Case study 2: The real-time, high-speed networking communication is the most critical to ensure efficient, safe and secure functioning of the automated processes and can be achieved by EtherCAT. Case study 3: It concludes that the importance of gas sensing is set to grow with increasing safety and environmental protection for household and industries. Case study 4: In manufacturing industry tool wear is the common criteria while doing operation on machines this problem was identified and replaced by using IoT application. Case study 5: In the case of unexpected situation such as power failure, equipment failure and network failure occurring in the factory, IoT system can be used to predicted the causes of failure and track effectively. Case study 6: The wireless system was used to collect the sensor data from the machine to detect and predict the failure. Case study 7: The integrated RFID System with super market Andon is used to collect the real time data to solve the inventory problems in the organization. Case Study 8: By implementing the integrated RFID system with ERP software tool in the supply chain management, issues of traceability of material flow has been successfully addressed.

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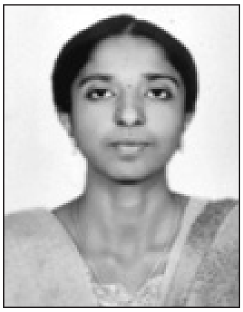

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