HBRP PUBLICATION

Journal of Advanced Research in Industrial Engineering
Volume 3 Issue 3

Internet of Things Based Maintenance Management System for Industrial Equipments

Nilabha Sankar Mitra*
Associate Professor
Department of Mechanical Engineering, Haldia Institute of Technology, Haldia, West Bengal

***Corresponding Author**
E-Mail Id:- *nilabha1972@gmail.com*

ABSTRACT

Conservation and sound operating artificial outfit are critical for any manufacturing company. Standardization of the maintenance infrastructure and establishment of a systematic maintenance program is essential for the process. However condition monitoring must also be a part of smart manufacturing program that seeks to improve the operational efficiency of a production system. The internet of things refers the billions of physical devices around the world connected to the internet which collects and shares the data. This paper presents a hint of an internet of things based predictive maintenance management system for industrial equipments.

Keywords*:-Predictive maintenance, Condition Monitoring, Equipment Management System (EMS), Industry 4.0, Internet of Things (IoT), Industrial Internet of Things (IIoT)*

INTRODUCTION

Internet of Things (IoT) describes physical objects, which are embedded with sensors, processing ability, software and other technologies [1-4]. These objects connect and exchanges data with other devices and systems over the internet or their communication networks. An IoT system consists of sensors/devices which communicate with the cloud through some kind of connectivity. After the data enters the cloud, the software processes it and then decides to perform an action such as automatically adjusting the sensors/devices without the need for the user or sending an alert.

The objective behind the Internet of things is to have devices that self-report in real time in proving efficiency and bringing important information to the surface more quickly than a system depending on human intervention. The term Internet of Things is 16 years old but the actual idea of connected devices had been around longer, at least since the 70s. The internet was new trend in 1999 and as because somehow some sense was made, the term “Internet of Things” was accepted. Internet of things is defined as detectors and selectors embedded in physical objects linked through wired and wireless networks, often using the same Internet Protocol (IP) that connects the internet. The term Internet of Things was invented initially to promote Radio Frequency Identification (RFID, a wireless system comprised of tags and readers) technology. The popularity of the term IoT did not accelerate until 2010/2011 and reached mass market in early 2014. One of the nearest and significant technology is M2M.

It is a machine to machine direct communication between devices using any communication channel, including wired and wireless. Machine to machine communication can include artificial instrumentation, enabling a detector or cadence to communicate the information it records to operation software that can use it. The field of Internet of Things has evolved due to convergence of multiple techniques including ubiquitous computing, commodity sensors, increasingly powerful embedded systems and machine learning. Traditional fields of embedded systems, wireless sensor networks, control systems, home, building and factory automation etc. independently and collectively strengthens the Internet of Things in the consumer market.

The Internet of Things (IoT) is a system of interrelating computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UID) and the capability to transfer data over a network without taking mortal to mortal or mortal to computer commerce.

A “thing” in the Internet of Things can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has a built in sensor to alert the driver or any other natural or manmade object that can be assigned an internet protocol address and is able to transfer data over a network. An IoT ecosystem consists of web enabled smart devices that use embedded systems such as processors, sensors and communication hardware, to collect, send and act on the data they acquire from the environments. IoT bias partake the detector data they collect by connecting to an IoT gateway or other edge device, where data is either transferred to the pall to be anatomized or anatomized locally.

Occasionally these bias communicate with other affiliated bias and act on the information, they get from one another. The devices do most of the work without human interventions, although people can interact with the devices. The connectivity, networking and communication protocols used with these web enabled devices largely depend upon the specific IoT applications deployed. IoT can also make use of artificial intelligence and machine learning to aid in data collecting processes easier and more dynamic. The working of IoT system is shown in Figure 1.

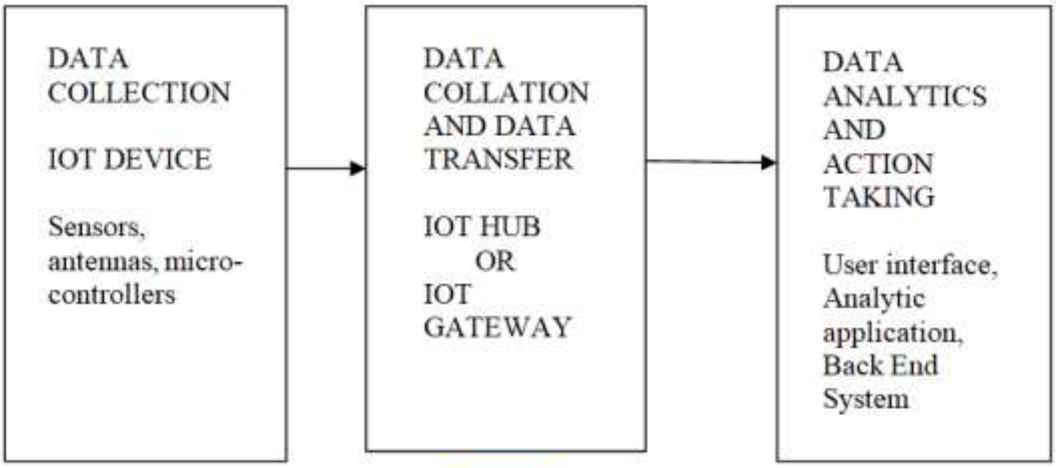

Fig.1:- Concept of working of] Internet of Things (IOT)

WORKING OF INTERNET OF THINGS

Industrial IoT (IIoT) refers to the application of technology in industrial settings, especially with respect to instrumentation and control of sensors and devices that engage cloud technologies. Recently the industries have used machine to machine communications to achieve wireless automation and control. But with the emergence of cloud and allied technologies (such as analytics and machine learning) industries can achieve a new automation layer and with it can create new revenue and business models. IIoT is sometimes called the fourth wave of industrial revolution. The most common uses of IIoT are smart manufacturing, connected assets and preventive and predictive maintenance, smart power grids, smart cities, connected logistics, smart digital supply chains.

INDUSTRY 4.0 AND ITS RELATION WITH IIoT

Over the last years, the global industrial landscape has drastically changed owing to various technological advancements, developments and innovations. The fourth industrial revolution (Industry 4.0) is characterized by the diverse innovative application and services, its various interconnected devices as well as its novel manufacturing operations. Industry 4.0 can be regarded as a highly integrated, digitized, automated, autonomous and efficient manufacturing environment. Industry 4.0 is driven by the following technological clusters data, computational power and connectivity, analytics and intelligence, human-machine interaction and digital to physical conversion.

Assiduity 4.0 combines the powers of traditional diligence with cutting edge technologies enabling smart products to be integrated into integrated digital and physical processes. These processes interact and cross geographical and organizational borders. Industry 4.0 focuses on end to end digitalization of all physical assets and their integration with digital ecosystems while enabling them to seamlessly generate, analyze and communicate data.

The leading driving factors of Industry 4.0 are digitalization of horizontal and vertical value chains, digitalization of product and service offerings and digital business models and customer access. Industry 4.0 aims at enhancing and upgrading the current manufacturing facilities, management and maintenance systems and technologies to an intelligent level by utilizing key technologies such as Internet of Things (IoT) , Internet of Services (IoS), Cyber Physical System (CPS), autonomous, flexible and co-operative robotics, simulations that leverage real time data and mirror real world into a virtual model , big data analytics, augmented reality (AR), additive manufacturing, information and communication technology (ICT) and advanced networking technology (e.g cloud computing).

Industry 4.0 seeks to address the dynamic global market and the competitive nature of today’s industries in line with continuously changing customer’s and market needs. Integration of horizontal and vertical systems will allow that enterprises, departments, functions and capabilities evolve in an interconnected network that enables an automated value chain.

Out of various subsystems of Industry 4.0, IIoT is a specific category of IoT which focuses on its applications in intelligent manufacturing and modern industries. IIoT, which is used in the context of Industry 4.0, is considered as a complex integration of diverse devices and systems. More specifically, with a view of producing a system which functions more efficiently than the sum of its parts.

IIoT provides solutions and functions through the use of appropriate services, networking technologies, applications, sensors, software, middleware and storage systems, which develop insight and improve the potential of monitoring and controlling enterprises, processes and assets and provides vital solutions for more effective planning, scheduling and controlling of manufacturing operations and systems.

MECHANICAL FAILURE OF EQUIPMENTS AND RELEVANCE OF IIoT

As technology continues to evolve, industrial machines and equipment that were installed ten to twenty years ago have become outdated. Larger plants are more likely to employ advanced manufacturing technology than the smaller ones [5]. Still there are industries that use the outdated machines due to sunk costs and uncertain market conditions, lack of justification for upgrading or they cannot afford to shut down the plant for upgrades [6].

In case of industrial low voltage motors, which are used in wide range of industrial applications viz. oil, paper, food, pharmaceuticals, water and packaging, are designed to operate under specific conditions. Industrial low voltage motors use a specific amount of energy, have a certain operating temperature uses certain insulation system, vibrate at certain frequencies and are capable of handling load according to the peak torque. Any change in these factors may indicate a pending failure and there is a need for upgradation and maintenance.

Mechanical failures are ranked as the most frequently occurred cause of breakdown and stoppages in the world wide petrochemical plants [7-8]. From the previous studies [9-14] on several areas of application have shown that monitoring and analyzing the key performance indicators and physical parameters associated with operating machines, results in increased safety and usage of limited life parts, reduction in unscheduled maintenance and manual inspection and reduction in faults. Further the cost of operating problematic components can be reduced when they can be detected prior to a failure and when on time maintenance is performed with minimum disruption to productivity. The impact of condition monitoring in mechanical maintenance on the economics of manufacturing industries is observed in several countries over the world [15]. It was found that the condition based maintenance caused 50-80% reduction in maintenance costs, 30% reduction in spares inventories and 20-80% increase in overall profitability of plants.

Vital utilities that are accompanied by the Internet of Things applications in both domestic [16,17] and industrial settings are monitoring and hence prompt decision making for efficient management [18]. Predictive maintenance using IoT technology capable of 10-40% savings in cost per year [19]. Considering more sophisticated and expensive machines that are being used now-a-days makes it easier for companies that use outdated technology to justify condition monitoring expenditure.

Low cost real time condition monitoring system for managing industrial equipments using Internet of Things can be designed and developed. The Equipment Management System (EMS) can be developed consisting of monitoring system to record vibration and temperature of equipment and transmit data through a wireless network to a data logging centre. The IoT device can identify abnormal operating conditions from sensor input values that exceeds predefined set points.

When the equipment approaches an abnormal condition, the system changes state and informs the user through an alert to perform an RFID enforced inspection. The alarm system remains actuated until an inspector visits the outfit. The EMS can be accessed remotely to allow the user to examine the current condition and behavior of the equipment.

IIoT PROTOTYPE CONCEPT

An IIoT prototype can be developed consisting hardware architecture and software.

HARDWARE ARCHITECTURE

The configuration of the hardware consists of an XBee shield mounted on the top of the micro-controller. A non-contact infrared temperature sensor and a thermistor are connected to the XBee shield as input sensor devices to provide the information about the temperature conditions.

An accelerometer gyroscope sensor can be used as input for monitoring the motor vibration frequency level. Two XBee radio frequency communication modules were used to send and receive signals for all the notifications as well as to allow the wireless connectivity between the EMS and a computer logging station. The XBee modules were tested, paired and configured through an open access multi-platform application that allows developers to set up and configure the modules. The one XBee module was configured as an output device to communicate and transmit real time data of the input sensors to another XBee receiver module. The XBee receiver was set up as an input connected to a stationary computer workstation that was used as a central point for data logging and analysis. The Equipment Management System is shown in Figure 2.

In addition the Equipment Management System (EMS) should be equipped with an RFID reader, an RGB LED and a passive buzzer to further increase the situation awareness of the operator on the shop floor. The LED and the sound alarm are to be used as outputs for extra precaution to indicate the current state of the equipment and provide visual and audio feedback when critical and abnormal situations are detected. An authorized individual can manually turn off the alarm by swiping the RFID card onto the RFID reader. The architecture diagram illustrates the internal view of the system architecture in order to understand the interactions of different components.

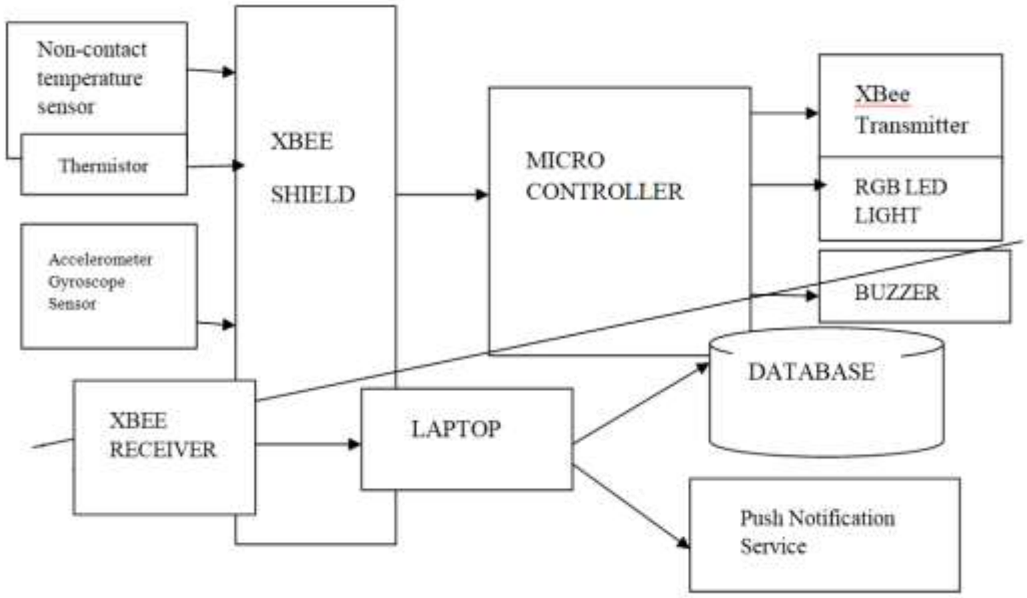

Fig.2:- *Equipment Management System Architecture*

EQUIPMENT MANAGEMENT SYSTEM ARCHITECTURE

SOFTWARE

Several algorithms were developed and integrated for capturing the most dominant vibration frequencies, for notifying the operator via an email about the motor's condition and for enforcing equipment inspection through an RFID batch to dismiss the alarm. The memory and sampling rate limitations of the micro-controller should be considered for developing the algorithm in order to capture the most dominant frequency and a signal generator should be used to adjust the frequency, waveforms, offset and amplitude of standard vibration signals. For example Fast Fourier Transformation (FFT) can be used for algorithm for the micro-controller [20].

Prior to the completion of EMS activation the user must define the maximum allowable temperature and the vibration range depending on the specification of the equipment and desired safety factors. The temperature boundaries are to be specified in 3 different states --- stable, warning and alarm.

Once the user has manually input the temperature and vibration thresholds, the vibration and temperature sensors scan for input data, send them to a computer (data logging centre) and using a python script program are stored in a csv train for farther analysis. Contingent upon the vibration frequency and temperature values, the color of the RGB LED changes. Green LED can indicate the stable state, yellow LED indicate the warning state and red LED color indicates an alarm state.

CONCLUSION

This paper presented a design and development ideas of a real time condition monitoring and maintenance management system for industrial equipment with IoT. The device monitors the temperature and vibration frequency level of industrial equipments wirelessly transmits the data to a logging station and sends a push notification in case of an alarm. The presented condition monitoring system can be further developed by integrating data mining and machine learning approaches to capture early indicators of potential faults.

An additional plan can include the development of a digital twin of the system to simulate anomalies and collect simulation data that can be used as an input to predictive maintenance machine learning algorithm.

REFERENCES

1. Alam, T. (2018). A reliable communication framework and its use in internet of things (IoT). *CSEIT1835111| Received*, *10*, 450-456.
2. Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE communications surveys & tutorials*, *17*(4), 2347-2376.
3. Atzori, L., Iera, A., & Morabito, G. (2017). Understanding the Internet of Things: definition, potentials, and societal role of a fast evolving paradigm. *Ad Hoc Networks*, *56*, 122-140.
4. da Costa, K. A., Papa, J. P., Lisboa, C. O., Munoz, R., & de Albuquerque, V. H. C. (2019). Internet of Things: A survey on machine learning-based intrusion detection approaches. *Computer Networks*, *151*, 147-157.
5. Dunne, T. (1994). Plant age and technology use in US manufacturing industries. *The RAND Journal of Economics*, 488-499.
6. Lambson, V. E. (1991). Industry evolution with sunk costs and

uncertain market conditions. *International Journal of Industrial Organization*, *9*(2), 171-196.

7. Garrison, W. G. (1986). One Hundred Largest Losses—A Thirty-Year Review of Property Damage Losses in the Hydrocarbon. *Chemical Industries, 9th ed., M & M Protection Consultants, Chicago, Ill., USA*.
8. Carson, P. A., & Mumford, C. J. (1979). An analysis of incidents involving major hazards in the chemical industry. *Journal of Hazardous materials*, *3*(2), 149-165.
9. McInerny, S. A., & Dai, Y. (2003). Basic vibration signal processing for bearing fault detection. *IEEE Transactions on education*, *46*(1), 149-156.
10. Nandi, S., Toliyat, H. A., & Li, X. (2005). Condition monitoring and fault diagnosis of electrical motors—A review. *IEEE transactions on energy conversion*, *20*(4), 719-729.
11. Bergasa, L. M., Nuevo, J., Sotelo, M. A., Barea, R., & Lopez, M. E. (2006). Real-time system for monitoring driver vigilance. *IEEE Transactions on Intelligent Transportation Systems*, *7*(1), 63-77.
12. Yang, W., Tavner, P. J., Crabtree, C. J., & Wilkinson, M. (2009). Cost-effective condition monitoring for wind turbines. *IEEE Transactions on industrial electronics*, *57*(1), 263-271.
13. Hodge, V. J., O'Keefe, S., Weeks, M., & Moulds, A. (2014). Wireless sensor networks for condition monitoring in the railway industry: A survey. *IEEE Transactions on intelligent transportation systems*, *16*(3), 1088-1106.
14. Goyal, D., Chaudhary, A., Dang, R. K., Pabla, B. S., & Dhami, S. S. (2018). Condition monitoring of rotating machines: a review. *World Scientific News*, *113*, 98-108.
15. Rao, B. (Ed.). (1996). *Handbook of condition monitoring*. Elsevier.
16. 16) Kelly, S. D. T., Suryadevara, N. K., & Mukhopadhyay, S. C. (2013). Towards the implementation of IoT for environmental condition monitoring in homes. *IEEE sensors journal*, *13*(10), 3846-3853.
17. Angelopoulou, A., Mykoniatis, K., Carlson, K., & Kim, S. J. (2014, June). UCF Smart Mailbox: Reinforcing Communications in the Neighborhoods. In *International Conference on Human-Computer Interaction* (pp. 393-398). Springer, Cham.
18. Asghari, P., Rahmani, A. M., & Javadi, H. H. S. (2019). Internet of Things applications: A systematic review. *Computer Networks*, *148*, 241-261.
19. Manyika, J., Chui, M., Bisson, P., Woetzel, J., Dobbs, R., Bughin, J., & Aharon, D. (2015). Unlocking the Potential of the Internet of Things. *McKinsey Global Institute*, *1*.
20. Fast Fourier Transformation for Arduino [Online] Available
21. https:// github.com/kosme/arduinoFFT [Accessed 2019].