Sophisticated E-Manufacturing Through Wireless Sensor Networks

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Abstract - Today's world expects things to happen in smarter and quicker way. Manufacturing the products in a simple and cheaper way is a biggest challenge. At one end, the cost of materials and equipments are increasing; correspondingly, one has to meet the time bounded market demands. E-manufacturing is a trend in current industries wherever the quantity by quality ratio is greater than one. Due to the techno-commercial constraints that exist within the industry, convolution comes into picture. Wireless sensors are not only sensing devices, but also can be transformed into a network, through which such constraints can be prevailed over. This paper deals with the entities pertaining to e-manufacturing and how this can be advanced using wireless sensor networks. Many a times, gap in communication leads to huge losses to the industries thereby loosing the market brand and value. This approach of advancing the process can fill such gaps to considerable extent which facilitates in sustainability and safety issues through which, reduced product error, zero downtime can be achieved thereby rapid changes in manufacturing can be achieved which in turn can broaden the business opportunities of the entity.

Index Terms: E-Manufacturing, Wireless sensor network, Wireless communication, factory automation

I. INTRODUCTION

Society has become very dependent on automation which covers numerous areas such as trade, environmental protection engineering, traffic engineering, agriculture, building engineering and medical engineering in addition to the industrial production with which it is popularly associated. Automation engineering requires knowledge in both hardware and software and their corresponding applications. When this enhancement was introduced, the industry has found that mechanization is necessary to sustain in this competitive world. The knowledge of electrical, electronics, software and control engineering are necessary along with the basic mechanical engineering knowledge in order to automate the process in manufacturing firm. That means interface between disciplines is a key role. The driving force includes hydraulics, pneumatics, electrical, electronics, programming, sensors and actuators, etc. Automation plays an increasingly important role in the Industrial economy which uses the control systems and multidisciplinary technologies in the production of goods and services.

All over the world across industries, constant drive towards the objectives of processing products and services at cheaper costs and in lesser cycle-times is universal. Different names have been endorsed to this advanced process of manufacturing, as this technology raise to higher levels of sophistications. E-Manufacturing is deduced in the sense of constant drive with an incarnation of integrated applications of various technologies. Wireless sensor network is a new addition to this set of manufacturing technology, which acts as a communicating agent between various equipments, there by incorporating the whole shop floor into a single entity.

II. AN ERA OF CHANGING THE MANUFACTURING STRATEGIES

In Industries, Development and manufacturing have increasingly become a single integrated process. In such a process of integration, creativity and economics takes a combined role. The time taken for travelling from the original idea to sequential production has been significantly reduced. Due to this, even sophisticated products can be economically manufactured as per the market demand. E-manufacturing is comprises of integrated loop with use of Internet and e-business technologies. The Internet has considerable impact on end products; as such technologies can provide services and add product functions. It covers various characteristics of manufacturing such as, Product design and development, Manufacturing, Marketing and Sales, Customer service, Procurement, Vendor relations, Strategy development, Logistics, etc

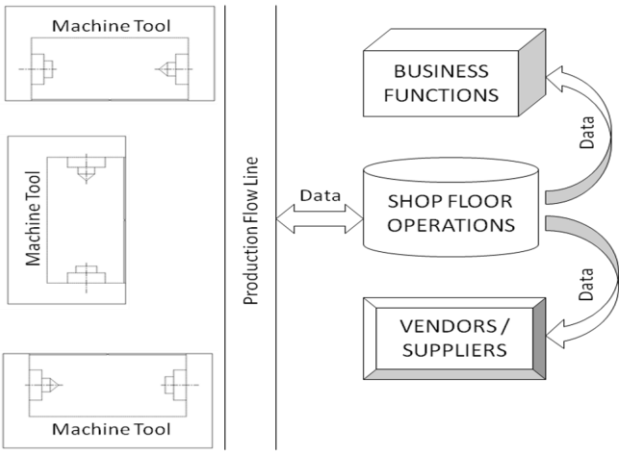

Fig 1: Automated factory without E-Manufacturing

Meeting the customer demands is a goal of every business entity by providing quality products and services. We see that there is a rapid change in technology, especially in the manufacturing sector, due to which the customers are demanding added value, low risk, and better assimilation of products. *Fig 1* shows the factory automation without e-manufacturing technology, wherein the communication gap exist. It is necessary to fill this gap, through which the control system can be made more advanced by directing, monitoring and controlling the factory operations effectively with minimum error hence forth meeting the time bounded market demands. Hence it is necessary to modify the manufacturing strategies, through which enhanced performance and customer satisfaction can be achieved. E-Manufacturing is becoming trendy with the enhanced use of the internet and can be most clearly illustrated as the application of the Internet to manufacturing which can also referred to as a framework for collaborative Virtual Manufacturing.

In manufacturing firms, especially Original Equipment Manufacturers, the design and production processes are outsourced for producing elements through supply chain. The Combined attributes of Quality era suggests a very special business model for manufacturing – enterprise integration or E-Manufacturing. Here, industries will be able to exchange all the necessary information between inter-departments, suppliers and customers quickly and easily. The Internet is used at the production line as well level in E-manufacturing and Computer Numerical Control devices are connected via internet or intranet to production planning, Enterprise Resource Planning, etc. With this, the E-Manufacturing aims to expand the framework into a common platform to enable planning and control for quicker, easier, secure and cost-effective collaborations. As this kind of system enables the team members to work under single roof, there is a scope of increased productivity and error free outputs. Hence, this new production enterprise is rich in information.

III. INTERNAL COMMUNICATION THROUGH WIRELESS SENSORS

Applications such as physical security, healthcare, and industrial process control are deployed with wired sensors and are gaining acceptance in new market segments such as building automation, asset management, and home security. However, the cost of wiring point-to-point is the limitation for new usages.

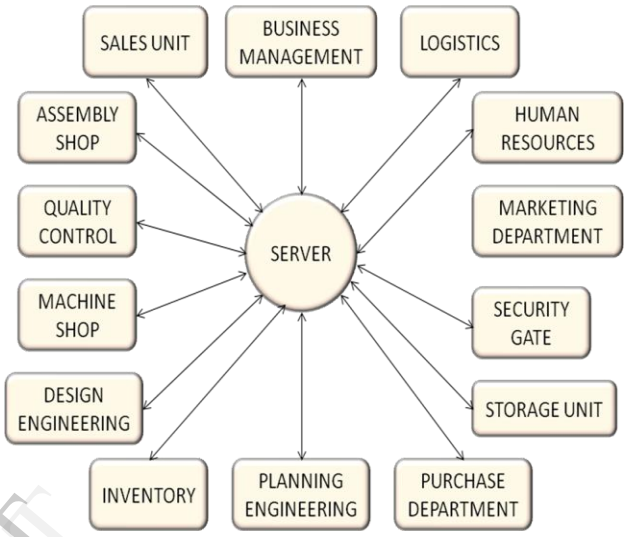

Fig 2: Various Factory Operations communicating with Server

Industrial Communications through wireless sensor networks is a smart approach and are recognized as the most appropriate approach to solve such issues and enable a wider development of machine-to machine applications. It is a form of mesh networking, with self-healing and self-forming properties. Here most of the devices operate for years using AAA batteries. WSN solution is cheaper and faster to install. Since wireless is unreliable by nature, networking is challenging and it is necessary to understand the sources of unreliability in order to account for them in communication systems. There is a close link between wireless sensor meshing and the signals which forms interference. Multipath fading and external interference such as Wi-Fi are major sources of unreliability in wireless networks. Such interference temporarily prevents communication between two radio waves and it is required to retransmit the signal, which in turn consumes more power. When wireless signals leaps off the objects in the neighborhood of transmitter, various echoes interfere at the receiver's antenna in a hostile way, this results in multipath loss.

Each machine tool consists of several wireless as well as wired sensors depending on the requirement. Each group of sensors at a machine tool is termed as cluster of sensors, out of which one is a cluster head as shown in *Fig 3*.

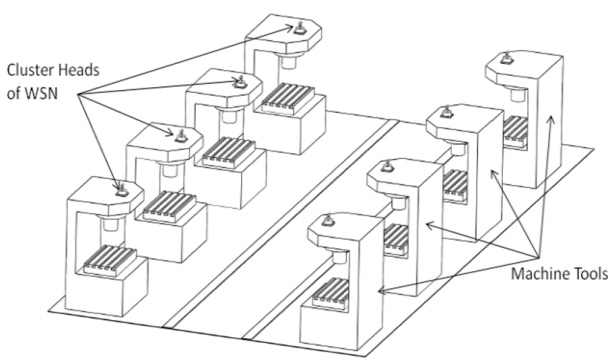

Fig 3: Production Line with Wireless Sensor Network

Each sensor is called node, and the communication between these nodes within the cluster is sent to the cluster head. Likewise, similar arrangement is made at each machine tool and other equipments. Hence the number of cluster heads in a production shop is nearly equal to the number of tools and equipments and they communicate with each other through the respective cluster heads and report the data to the base station. The proprietary Wireless Interface for Sensors and Actuators specification is based on IEEE 802.15.1. It targets factory automation wireless sensor networks with cycle time of 2ms and packet error as low as 1/9. The end devices communicate wirelessly via standard Bluetooth transceivers, while the base station is equipped with a specific transceiver, which is capable of receiving four channels in parallel. Additionally, the base stations swap the data with network manager by means of wired field bus.

IV. CONTROL LOOP

Various researches results has indicated that the induced benefits of implementing the technology of wireless communication collectively with the sensors and actuators, due to a variety of challenges at the end-user level, a cautious approach was adopted by the technology leaders. Several process control applications will have inflexible requirements and failure of a control loop may cause impulsive plant shutdown or even accidents in the processing plants. As the requirements for closed loop control are inflexible, the journey from wireless process monitoring and open loop control to closed loop control for the technology transit is longer.

Continuous data request and asymmetric or spontaneous data traffic are some of the important parameters in data communication in these process control applications. In order to carry smooth operation, main concern is the quality of service, which requires the correct data at the right time. Challenges are coming from poor quality radio frequency (RF) links due to multipath fading, or interference, high noise, long path lengths or obstacles and low signal due to lack of power for the reliability of the data. Machines such as vibrator, motors and actuators can produce a significant amount of electromagnetic noise in the factory, which causes due to lack or excess of power. Corruption or elimination of the data signal occurs due to the interference in equivalent frequency band from supplementary sources. Uncertainties on the loss of data packets and communication delay arise based on the changing radio conditions.

V. SMART WIRELESS TECHNOLOGY

In networking technology Standards play a vital role, with end users supporting the development of standards-based solutions. In the industrial environment, there will be huge number of communicating nodes and it is not an easy task to assign a protocol to each node without defines set of standard instructions. Standardization provides solution in delivering a smart and flexible way of assignments. These standards includes both for wireless sensors and actuators as well as for Intranet and Internet protocols. Wireless HART/IEC62591 is the standard in industrial process, beyond the market, Internet Protocol (IP) is the communications standard. All equipments and devices use IP to communicate with each another when connected to the Internet. Each one of them acquires an IP address which is clearly identified on the Internet. The exchanging data packets contain an IP header and a series of bytes will encode the addresses of the device that has created the packet, and the destination device. Many other protocols are needed to form a protocol stack like TCP, HTTP, etc., but generally the Internet Protocol is the denominator.

The basis for any network based systems is network topology. When choosing the communication topology for a WSN, aspects such as connectivity, adaptability, mobility, and scalability need to be considered in addition to the responsiveness and reliability.

There exist three types of network topology for industrial WSN applications: mesh, star and star mesh. In star network, each node has a designated forwarding path. If there is a failure between two nodes, the information is lost, so that site surveys and link-level configuration are performed during system installation. Compared to star network, star mesh network has increased adaptability, mobility, and scalability by providing multiple routing nodes but they do not offer full end-to-end redundancy. In mesh network, each end nodes are also routing nodes, so that all nodes are fully connected to provide full redundancy. Signals are transmitted from source to sink through multiple paths; if failure happens in one path, the information can still be obtained through other paths. The self organizing and self healing features make the mesh network highly adaptive to node failures/relocation and easily scalable for network expanding. Only for mesh network can a new node be added anywhere without sophisticated site surveys as long as it is within transmission range of at least two other nodes. It requires less manual configurations for each node and provides greater expandability when more nodes are to be added in the future. This makes it a more suitable choice for deployments that are subjected to changes. The drawback is that extra delay and processing time is introduced due to multiple hops and paths.

Following are the major challenges that come into picture during the installation of wireless sensor network into a system or production line:

- Precluding isolated nodes
- Capability of the system to adapt to changing RF environments
- Loss of key components such as routing nodes and gateways
- Ability of the system to support mobile devices
- Affect on system parameters and on the latency of existing services when a new node is added in the network

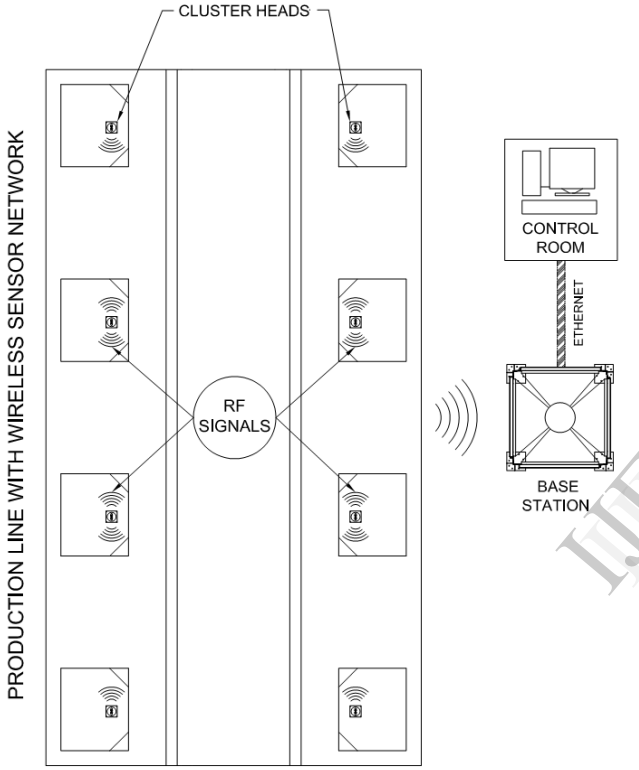

Fig 4: Smart Communication

The communication is said to be smart because the data transfer is made through Bluetooth, radio waves and intranet protocols in the factory at various levels and departments depending on the feasibility without allowing the signal interpolation within the cluster network. *Fig 4* illustrates such communication considered in a production line using wireless sensor network within the production shop and intranet protocols outside the shop floor. When each signal is bifurcated like this, the problem of signal interference is eliminated and the wireless signals need not to be triggered again. This ensures the signal transfer at the rated speed without any interruption.

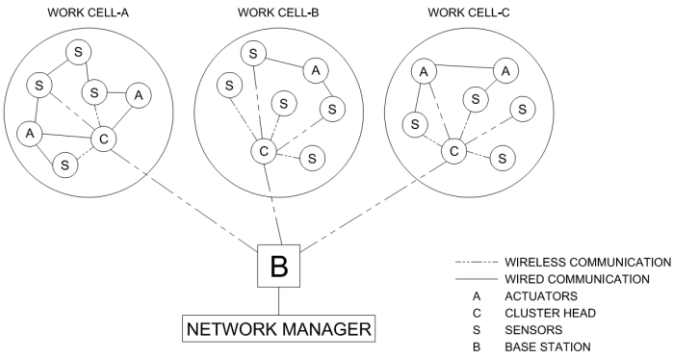

Fig 5: Communication Network in a typical factory

The communication network in a typical factory is illustrated in *Fig 5*. Here both wired and wireless data transfers are considered where the wired data transfer refers to hard wiring bus and wireless data transfer refers wireless sensors as well as intranet communication. In practical industrial environment, it is impossible to eliminate the wired sensors completely, hence both wired and wireless sensors and actuators are considered.

VI. BENEFITS WITH WSN IN E-MANUFACTURING

Wireless Sensor Networks enable incremental value for number of additional usages. It enables Environmental control for power savings in heating, cooling, and lighting. WSN facilitates Device monitoring to prevent accidents and failures, or limit their consequences and triggers alarm and alerts for open loop control. The enterprise largely benefit from the introduction of additional wireless sensor systems. Following are some of the benefits.

i) Power consumption

Power consumption or the life of battery is a governing factor that affects the design of most WSNs. In this application, power consumption constraints can be ignored because in industrial plant all the WSN sensor nodes are installed either in a MCC or on the motor frame with access to mains power. In both cases, the power can be supplied from very inexpensive ac/dc converters. Additionally, this also eliminates the implementation of complicated communication protocols and routing algorithms of WSNs, which are primarily intended to reduce power consumption.

ii) Maintenance made easy

Wired network is time consuming and complicated task for an electrical control engineer, who has to deal with various wiring maintenance problems after the installation; such as corrosion, water in the channel, burned cabling, freezing, physical wear caused by frequent movement of instrumentation, and unexpected power outage. Wireless device is almost care-free, only a battery change is necessary after years of operation. In addition to this, it is also possible to relocate current wireless devices or deploy

additional wireless devices on the control system after it has been installed with minimal changes to the existing configuration.

iii) Cost cutting

Installation with cables for an automation project can incur as high as 80% of total system cost and can exceed INR 62,000 ($1,000) per linear foot in regulated environments. Wireless approach can eliminate the wiring, conduit and installation costs in larger extent.

iv) Better concert

In wired control systems, the devices share a single bus, where as in Industrial WSN, multiple wireless communications can act simultaneously if there is no mutual radio interference. More sensors/data points can be used to beat the performance of traditional wired control system. Industrial WSNs can transmit the data at greater speed.

v) Quality of Service

Quality of Service can be defined as the well defined and controllable behavior of a system with respect to its parameters. The communal effect of service performance establishes the level of satisfaction of a user of the service. The requirements of industrial automation networks are different from usual computer networks. Here the traffic is mainly composed of short packets containing sensor measurements or the commands from actuator or end effectors that need to be conveyed timely. Hence the service quality is better than the conventional one.

VII. CONCLUSION

Design links with manufacturing - DFM is now accepted as a desirable goal and many workers have reported progress in an improved data model based on the Standard for Exchange of Product Model data (STEP). The smart way of communication is not limited to shop floor environment but also to all available departments. Communication between design and production through this sophisticated approach can eliminate the production errors. Similarly inter-data transfer at each levels of manufacturing can boost the firm with much higher confidence to become a market leader in producing products and providing services with the ideal ratio of quality by quantity.

We have seen the pace at which wireless telephone communication has taken its place over the wired telephone connections, which has revolutionized the world to unbelievable extent. This sophisticated e-manufacturing can bring such a change in the field of manufacturing in near future.

VIII. FUTURE SCOPE

Adding value to a product can increase its demand in market. Such an addition should not increase the product cost to unaffordable extent. Similarly the addition of features and strategies to current manufacturing environment should always try to deliver the product and service with minimum time and with least possible economy. This factor needs to be considered in future projects. A case study needs to be considered upon which this proposal is imposed at design level and the same has to be analyzed to check the feasibility and stipulation in the current industries.

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