The Industrial Maintenance Based on Internet of Things: New Opportunities and New Issues

Mohamed RAMADANY[1] and Driss AMEGOUZ[2]

[1,2]Laboratory computer-integrated manufacturing, Energy and Sustainability, High School of Technology, University Sidi Mohamed Ben Abdellah, Fez, Morocco

[1]mramadany@gmail.com, [2]amegouz@yahoo.fr

***Abstract*– In industry, the Internet of Things with connected objects is combined with growing waiting around the optimization and improvement of maintenance. It allows new possibilities and opportunities, including predictive maintenance. However, this integration of the internet of things in industrial environment generates new issues. This research work is devoted initially, to present the state of art applications of the Internet of Things for predictive maintenance. Second, we are going to review the opportunities for such a system for industrial maintenance. Finally, we will understand the issues related to the deployment of the Internet of Things for a maintenance application.**

***Keywords*– Internet of Things, Optimization, Opportunities, Predictive Maintenance and Issues**

I. INTRODUCTION

Continuing advances in microelectronics technology, including that of smart sensors and the development of ubiquitous computing, have contributed in recent years to the development of the Internet of Things. The principle of this emerging technology is to integrate and embedded sensors and intelligent systems in the objects so that they can communicate and exchange data constantly and in real time. Indeed, the data has become a veritable gold mine of the 21st century, prompting industrial companies in a race to recover data. This data can be recovered to form the pillars in search of improvements and optimizations on several fronts to ensure competitiveness. In fact, thanks to a set of tools and processes exploiting these data, manufacturers have a better knowledge of their environment, for better decision making and efficient responsiveness. It is in this context that the Internet of Things offers a wide range of applications in various sectors, such as energy, sustainable development, transport, logistics, distribution, home automation, healthcare and that industrial monitoring.

To focus on the development of the Internet of Things, we present some statistics: the ABI Research estimates that more than 10 billion, the number of currently connected wireless objects in the world. According to the latest figures released by the ITU (International Telecommunication Union), the number of objects will reach 50 billion by 2020, it is also the same projection made by Cisco [1]. In terms of revenue, “The new factory”, postulates that the market for the internet of things is estimated at $ 220 billion in 2010, products and services.

The firm A.T. Keanery for the Montaigne Institute estimates between € 74 billion in 2020 and € 138 billion, the potential for value creation of the Internet of Things in France. If today 75% the number of connected objects are computer equipment, in 2020, this figure does not exceed 25% due to the growth of M2M (Machine to Machine), which is of major interest to the industrial sector.

In industry, the Internet of Things, via the connected objects is combined with growing waiting around optimization and improved maintenance. Indeed, the use of data through appropriate algorithms, and analysis of current and historical operating data, and the data attached to the human and material resources for maintenance, will open the field to new opportunities for industrial maintenance and allows imagining new services and approaches in maintenance. However, this technology generates new issues related to the deployment of the Internet of Things. Our contribution aims through this article, is initially to present a state of art applications of the Internet of Things, in the second place; we are going to review the opportunities for such a system for industrial maintenance. Finally, we will understand the issues arising following the deployment of the Internet of Things for maintenance application.

II. SOME DEFINITIONS

In the literature associated with the Internet of Things, we can find many definitions. Some definitions consider the technical aspects of the Internet of Things; others focus on applications and features. We present without completeness some definitions.

The CERP (Cluster for European Research Projects on the Internet of Things), defines the Internet of Things as "a dynamic infrastructure of a global network. This global network has self-configuration capabilities and standards-based communication protocols, interoperable. Physical and virtual objects have identities, physical attributes, virtual personalities and intelligent interfaces.

According to the ITU (International Telecommunication Union), the Internet of Things is defined as an extension of the internet, by creating a ubiquitous network and self-hosted physical objects connected identifiable and addressable allowing developing applications in key vertical sectors and these sectors through integrated chips.

Another definition characterizes a more technical view, the Internet of Things. It is "a network of networks that allows via standardized and unified electronic identification systems and wireless mobile devices, identify directly and unambiguously, the digital entities and physical objects in the purpose is to collect, store, transfer and processing without dis-continuity between the physical and virtual worlds, the data relating to them " [2].

III. STATE OF ART

The Internet of Things offers a broader range in applications ranging from logistics to create smart spaces as shown in the following Fig. 1.

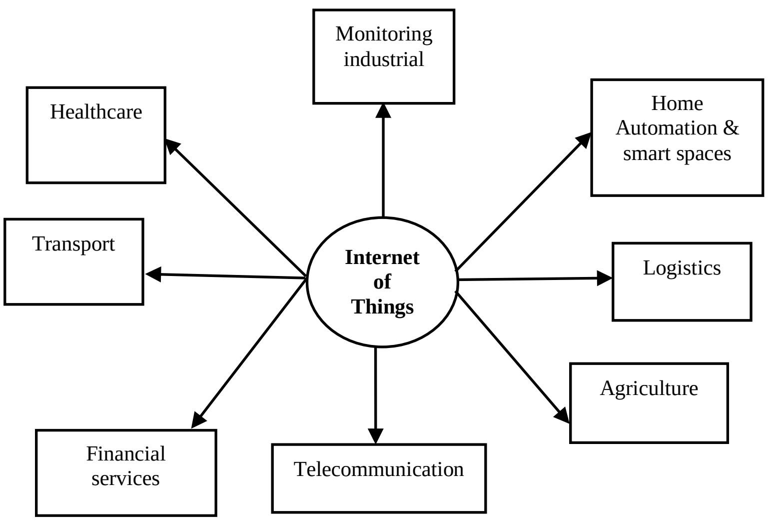

Fig. 1. Applications of the Internet of Things

The trend for industrial monitoring is the use of the Internet of Things for predictive maintenance, indeed the machines can be equipped with many intelligent sensors that measure quantities related to the significant operating parameters such as pressure, temperature, audible noise, vibration and other parameters. These data will be transmitted and treated, to lead to models within the framework of a predictive solution. The aim is to detect early signs of failure before it occurs. This reflects a radical change in predictive maintenance.

The next state of art encompasses the latest technological breakthroughs in the application of the Internet of Things for a predictive maintenance application.

Bombardier offers the integration of a system able to transmitting data on the aircraft's state of health to the ground, during the flight. After landing, the information can be downloaded via Wi-Fi system [3]. The aim of this integrated system is to contribute to predictive analysis and more targeted maintenance recommendations. In addition, the col-lection and processing of these data will allow the digitization of technical manuals. The access to information by maintenance teams, engineering teams and the board teams is guaranteed with digital tablets.

General Electric created the analytical platform Predictivity dedicated to big data, to initiate a project to build a global network of interconnected machines. This platform applied to the aviation sector, can collect and analyze data measured by aircraft engines, and offers services to airlines. As a guide, the group signed a contract in 2012 with the Airsea Company. The aim was to achieve savings between 20 and 50 million dollars over five years, thanks to predictive maintenance and a fuel consumption program [3].

The British engine manufacturer Rolls Royce manufacturing propulsion engines for airplanes and ships across the sky and oceans, equipped these engines by hundreds of smart sensors, which record every detail of their operation and re-port any change or deterioration in real time to the control center. [4] Through analytical techniques coupled with a form of artificial intelligence, it could lead to an automated analysis, and optimize predictive maintenance. This will change the operational parameter settings and identify the maintenance actions to be taken in advance. Therefore, those airlines can plan interventions without penalizing passengers. On the other hand, this type of maintenance allows easy management of supply for optimum stock of spare parts with delivery optimized to cover all the world's airports. Indeed, when a fault occurs on an airport far, the company must house and feed the passengers, send another plane and mobilize on-site maintenance team with the necessary spare parts, causing additional costs and expensive for the company.

In aviation industry, the fuel system is one of the most sensitive equipment in the aircraft. At Air France KLM, we anticipate the surprises failures on the fuel system of its Airbus A380. These failures are now detected 10 to 20 days be-fore they occur [5]. Thanks, to embed sensors that cover, the actions on its fleet of 10 Airbus A380, the analysis of these big data via a behavior analysis algorithm of the plane and low signal detection can predict failure. The resulting decision is then immediately transferred to the maintenance teams. Since its establishment in July 2015, a failure was detected on the circulation pump that supplies the fuel to the engines. Air France KLM plans to extend to other sensitive organs A 380.

In the rail sector, the French National Society of Rail-Ways, via Colas Rail, Bouygues Group subsidiary dedicated to railway works, proposes to place a washer connected at tightening of the splint, metal part that can mechanically join two rails butt. Each day the washer transmits data on its clamping level to a central server, which analyzes this information. Thus, an alert can be generated in real time in case of failure of the clamping element. On the other hand, the evolution of the tightening trend helps to plan maintenance operations just in time to make reliable track. This technological pierced is a major theme of innovation in 2016. In the same context, the Internet of Things has enabled SNCF technicians, who performed before regular tours aboard their vans to check the status of switch heaters, to know the state of these facilities without even move.

ThyssenKrupp Elevators The group, which has a fleet of 1.1 million elevators, to monitor each year, aims to push the boundaries of maintenance by offering lifts with a radically improved durability [7]. By connecting sensors and systems to the cloud lifts, the group could collect in-formation that feed the monitoring system. Therefore, when the elevator reports a problem, it sends an error code with three or four most likely causes for this code. This gives a vision to technician, for what needs maintenance elevator and when. So, the elevators anticipating themselves the repairs they need.

In the naval field, [8] considers the remote diagnosis of marine lubrication oil, using smart sensors, developing software to continuously monitor the lubrication system of a ship. This, in order to have a clear understanding of the status of engine wear, which is the main element in the propulsion system of a ship.

IV. OPPORTUNITTIES OF INTERNET OF THINGS FOR MAINTENANCE

When an equipment or industrial system is able to providing a continuous information on its behavior and that of its users, a huge field is open to the imagination of possible opportunities for maintenance applications. With this hybridization between real and virtual environments, additional value is created in both environments. Indeed, the object increases its value by the available information associated with it. Conversely, information on the subject believes using data reported by the object and its context of use.

Internet of Things can give a new dimension to maintenance, it is a new concept, which may be called "Maintenance Based on the Internet of Things" .Through the generation of big data, and new correlations will generate new hypotheses in failure analysis. Maintenance based on the Internet of Things, allows the responsible of maintenance department to take relevant decisions on scheduling and management of maintenance resources for better efficiency.

Indeed, the resources of maintenance whether human or material resources, will also be part of the connected objects, which provide a global vision for the responsible service of maintenance.

A. Optimal management of material resources

Material resources includes all the tools necessary to the execution of the maintenance tasks, as well as, spare parts, operating manuals, and maintenance tasks required for maintenance, supplies, and IT resources [9]. Internet of things connects these resources through identification chips. This will facilitate the location of these resources in the factory and their availability to provide the resources needed for maintenance.

Take the example of spare parts, thanks to the internet of things; it will be readily to know if they are available. We can also determine the amount of these parts. In addition, they will be easily located in the store of spare parts, which contains thousands of items. Therefore, the maintenance manager have all the information attached to it, in real-time. For example, if there is a stock shortage of these spare parts, or are they reserved for other interventions already planned?

On the other hand, the analysis of the related information to these spare parts makes it possible to manage their supply in a manner optimal, in order to fight the sources of wasting as regards spare parts, by minimizing very expensive stocks of the spare parts. For manuals, they serve not only users of the equipment, but also to service technicians, who must understand in detail how this equipment is used in practice. The service manual is essential to the inspection, preventive maintenance, repair and calibration of equipment [9]. A digitalization is necessary, to be part of the system of the Internet of Things, this digitization provides access to textbooks through tablets or smartphones, more will be continuously fed with information to new situations encountered failures on machines. Another advantage is the ability to translate from web tools, if these manuals are expressed in foreign languages, not mastered by maintenance workers.

For the computer's resources, the presence of a basic utility of data, of a management system of the maintenance computer-assisted or software of the diagnosis of the failures facilitates in a considerable way the tasks of maintenance. Thanks to the Internet of the objects, these resources offers a traceability and a rational conservation of the documents, as well as the follow-up of the indicators of performances of the tasks carried out.

Moreover, the access to the system of the Internet of Things has a major importance, due to a large number of documents and technical recommendations, which are available online. Then it is possible to look further into knowledge and an exploitation of the experience feedback through similar failures or preventive actions on equipment identical to those, which will undergo the tasks of maintenance.

B. Optimal allocation of human resources

In the majority of the cases, it is difficult to automate the tasks of maintenance, since each task has its particular aspect; this is why the staff of maintenance has a major importance for the person in charge of the service of maintenance. The internet of Things allows maintenance personnel to have sufficient knowledge and information about the machine in question, and the appropriate tools to perform tasks.

In addition, the agents of maintenance can be equipped with bracelets or waistcoat to inform about their localization, and even biometric measurements (body temperature, blood pressure, beats of heart etc.), which will make it possible to go up in real time the health status of the operators. The objective is to make it possible to the person in charge of maintenance to follow in real time the advance of the human interventions and the optimization of the allocation of re-sources, by holding the tasks stressing for those, which pre-sent data adequate relating to the health status. For example, to carry out a task with risk or requiring a concentration, the responsible maintenance, will make the choice of an operator who does not present the signs of stress or disease. Therefore, the data should not announce a chronic disease or the catch of drugs for side effects, which can influence the concentration and the attention of the operator.

Furthermore, the location of maintenance workers in the various sectors of the factory will have information about the availability of these agents and avoid their unnecessary moves, as well as the exact time of repair or intervention. What constitutes credible data for possible improvement in quality studies or for exploit of feedback?

C. Equipment availability

Thanks to the Internet of Things, each incident on the equipment is analyzed to provide a model type that feed later the model to generate alerts. Thus, new signs of failure could enrich processing algorithms, which is of major interest for predictive maintenance. Therefore, the availability of industrial equipment is increased. In other words, companies based on the analysis and data processing could reduce the number of maintenance interventions, avoiding futile interventions that are wasteful and a hindrance to the availability of this equipment.

On the other hand, the replacement or the renewal of equipment is optimized to the extent that it is performed when the equipment actually needs. This orientation will take the place of classical logic, replacement of statistical forecasting

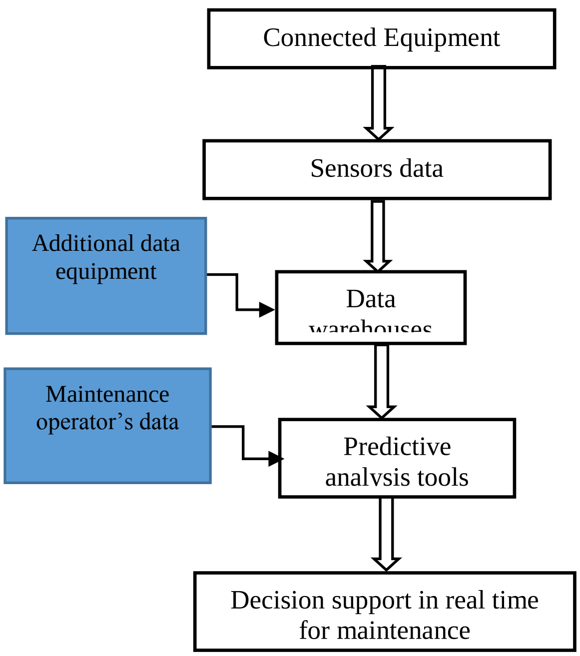

Fig. 2. Opportunity of the Internet of Things for availability

D. More fast intervention

Opportunities also arise in the curative maintenance. Indeed, thanks to the precision alerts provided following the analysis of data from the Internet of Things, the technician can quickly go to the part responsible for the failure, without following the technical manual for complex equipment as did previously. The identification time and locating the origin of the failure is greatly reduced. This early identification allows you to choose immediately the correct replacement part and the appropriate tools to perform intervention of maintenance.

E. Benchmarking for maintenance

Internet of Things through consulting data even corporate activity or data equipment suppliers could be a source for benchmarking in maintenance. In fact, the maintenance department could have data on the nature and type of failures that affect the same type of equipment, power consumption and spare parts of these same facilities, as well as the length of statements made by the maintenance crews from other similar industries. This helps improve a company's performance through the development of an action plan, drawn up by the findings of this analysis.

Furthermore, this benchmarking will be a source of innovation in maintenance methodologies, insofar as the Internet of Things will enable an update of the classic maintenance methods.

F. Optimizing the safety of the maintenance tasks

The Internet of Things, connected via clothing worn by workers, could contribute to improving business actions, by measuring values and the exposure time to the factors of painfulness of the operations maintenance. These strain factors could contribute to dangerous events that lead to serious accidents. In addition, the Internet of Things will enable the reduction of musculoskeletal disorders and occupational hazards affecting such handling operators, employees subject to chemical agents and radiation, delegating certain tasks with connected devices.

Regarding the machines internal circulation and handling that must coexist in a factory, thanks to the Internet of Things, all the machines will be connected, to coordinate their movements and they will find their moves in space with each other. This will, for example, to check beforehand, as neighboring machines are in a position consistent with the movement of a machine to avoid accidents. Moreover, the fact of equipping workers with headsets connected, allowing heavy handling equipment such as cranes and large machines used in mines for extraction of ore easily locate workers in case of difficulty visibility by drivers and avoid the risk to be crushed.

G. Contribution to conceptual maintenance

Best maintenance is that which one does not do, it has resulted in the design of fully reliable entities during their lifetime. Internet of Things can contribute to the design of such entities. In fact, thanks to this technological feat, equipment manufacturers will be able to access data on their machines and industrial equipment, to reflect the excesses observed in use, correct and prevent them from happening again when the design of the same range of facilities or new lines of equipment.

H. Optimization of maintenance trade gestures

On the level of conditions for executing tasks of maintenance, the implementation of connected supports (tablets laptop, bracelets, smartphones…), for the operators of maintenance will allow the optimization of the gestures trade.

In fact, the relative data with the task of maintenance will be transferred uninterrupted and in real time, which will make it possible to bring up to date the operational range of the maintenance intervention, and to contribute to the ergonomic revision of the various tasks of maintenance.

V. NEW ISSUES

The implementation and deployment of the internet of things technologies for operation maintenance evoke certain issues. These can be classified according to the issues of technical, financial, ethical, legal, and other related resistance to change, human maintenance resources, heterogeneous data, and standardization.

A. Technical issue

The deployment of the Internet of Things requires the implementation of several systems namely, the object identification system, the intelligent sensor network system, the data storage system and predictive analytics system. Furthermore, we must consider the tools that will interface the entire chain of the Internet of things: objects, platforms and software. Also worth mentioning is the maintenance of these systems, and data transmission in a critical environment in which these connected objects must be able to communicate their positions and operating parameters via a reliable and permanent connection. On the other hand, management of the acquisition of big data, with storage and treatment is a problem on the Big Data for maintenance service. This technical problem could further accentuate the cumbersome of decision process.

B. Financial issue

The integration of the Internet of the objects in the company for an application of maintenance requires an investment. This initial investment is generated by the acquisition of the systems and the networks, which will manage the system of Internet of the objects, like for energy necessary for operation.

C. Legal issue

It concerns the legal aspects, the new models and legal frameworks for the use of the Internet of Things. These legal frameworks also address the trade secret and sensitive data of the maintenance department and in general the company. The question that will concern the exploitation of other companies' data. The legal framework will also affect the digital security of connected objects, as they may be subject to sabotage or attacks by computer virus. So virtual attacks can have physical repercussions. Furthermore, the implementation of clothing connected to maintenance operators also requires a legal framework to prevent trade union conflicts.

D. Ethical issue

It is generated by monitoring the health of operators and their behavior during maintenance interventions via the connected clothing. It constantly monitoring might be considered invasion of privacy of the operators, and will have an invasive for these operators. Also noteworthy in this context that operator can demonstrate a denial to the fact that the head of the maintenance department will access their data on their health status. This may contribute to a reluctance on their part or even the lack of desire to the Internet system objects. Thus, reflection is needed to prevent overflow.

E. Issue related to the reluctance and resistance to change

The integration of a new technology often generates resistance, which is due to the uncertainty of the performance and the mastery of new technologies, which could contribute to a lack of desire and distrust on the part of the technicians or operators. Indeed, the fact of putting the shelves that allow interfacing the data available to them can be considered as a burden and more work. Therefore, it will encourage them to make an additional effort, which will force them to stay permanent monitoring of the production system.

F. Issue of new skills

To manage the systems of the Internet of Things, the maintenance department will be in the obligation to integrate new skills and new jobs. These will involve the deployment of object identification systems, interfaces that are attached and managing big data. In addition, the implementation of connected objects and tools adapted to the maintenance work will introduce ergonomists trades for maintenance.

G. Issue of standardization

For a service of maintenance, the heterogeneity, which represents the objects connected as well as the data, which are attached to it, as well as the entities with which they interact, requires a standard architecture, which must be evolutionary and flexible. In addition, communication protocols adopted within the framework of the Internet of the objects different from a company with another from where need for thinking of a standardization of these protocols.

This standardization imposed by heterogeneity, will allow an interworking of the objects, indeed the absence or the lack of interworking presents an obstacle to collaboration between the various actors of maintenance. Thus, this standardization will remove the dependence on a particular programming language or a well-defined protocol of data transmission.

H. Issue of heterogeneity data

The big data resulting from the Internet of Things can be numeric values or multimedia (photos and video installations), sometimes coupled with symbolic data (interventions report, historical interventions). This presents a major challenge to treatment systems that have heterogeneous entries very large and very diverse nature. Hence the need for a tool to return results to the precise specifications for decision support of responsible maintenance service. In this context a hash function, coupled with a form of artificial intelligence is required.

VI. CONCLUSION

In this research work, we tried to apprehend the notion of the Internet of Things within a framework of plant maintenance, through a state of synthetic and very recent art state of its application for predictive maintenance. Then we presented the system appropriateness's such for maintenance in general in order to initiate this concept of maintenance based on the Internet of Things. Thus, the connected factory becomes a reality. However, we have shown that this integration of the Inter-net of Things for maintenance application generates a panoply of issues.

Like prospects for this research work, opportunities and the approaches presented will make it possible to imagine new functions for maintenance. Therefore, the function of maintenance should consider new models relating to the execution and the management of maintenance, while improving its internal processes, its competences and its knowledge. A reflection on solutions with the evoked issues is also para-mount. Moreover, this new concept maintenance based on the Internet of Things can extend to encircle, maintainability, safety, reliability and quality. In addition, we plan to conduct an investigation near the Moroccan industrial companies, in order to initiate them with this new concept, and to identify the real issues that present an obstacle to the deployment of the technology of the Internet of Things in Moroccan industrial environment.

REFERENCES

[1] Cisco, "Value of the internet of everything for cities, States and Countries", 2013.

[2] P.Benghouzi, S.Bureau and F. Massit. "The Internet of Things: challenges for Europe". New edition. Paris: Publishing house of the human sciences, 2009.

[3] O. James, "The big data opens the era of aviation service», http://www.usine-digitale.fr/article/les-big-data-ouvrent-l-ere-de-l-aeronautique-de-service.N334101, 09 Jun. 2015.

[4] http://www.ilovemybi.com, "Big data at Rolls-Royce: the success of predictive maintenance", 2015.

[5] R. Loukil, "Air France KLM anticipate failures of its A380 aircraft to big data » http://www.usine-digitale.fr/article/air-france-klm-anticipe-les-pannes-de-ses-avions-a380-au-big-data.N365483, 30 Nov. 2015.

[6] http://www.alliancy.fr, "When the industry explores the big data", Alliancy, le mag, http://www.alliancy.fr/dossier/dossier-les-entreprises-face-au-cloud/quand-lindustrie-explore-le-big-data, 16 Jun 2015.

[7] M. Bairati, "Find levers of competitiveness through intelligent systems", http://ideas.microsoft.fr/thyssenkrupp-ascenseurs-internet-objet-connectes-competitivite/#Rq6WMmDRI4XbMvk5.97, Dec. 2014.

[8] D. Baglee, "Remote diagnostics of marine lubrication oil using intelligent sensor systems", Magazine of Marine Maintenance Technology International, Oct. 2014.

[9] M. Ramadany, and D. Amegouz, "Proposal of a general model for sharing maintenance resources", International Congress of Industrial Engineering and Management Systems, personal communication, May 2015.