Business Potential and Impact of Industry 4.0 in Manufacturing Organizations

Gajanan Gambhire,
Assistant Professor, Industrial and Production Engineering Department, Vishwakarma Institute of Technology
Pune
gajanan.gambhire@vit.edu

Tejas Gujar
B.Tech Student, Industrial Engg., Vishwakarma Institute of Technology
Pune
gujar.tejas2010@gmail.com

Saurabh Pathak
M.Tech Student, Industrial Engg., Vishwakarma Institute of Technology,
Pune
saurabhpathak05@gmail.com

***Abstract*—Communication and automation was limited to the interaction between machine and the user with user being the operator of the machine. Industry 4.0 driven by IoT has brought the tectonic shift on how the communication happens which is not just limited to Human-Machine interaction but also Machine-Machine data exchange. This has led to new form of automation with physical systems/resources connected to internet and indeed with each other. These interconnected devices generate large amount of data which when deciphered properly can provide us with range of different applications in every possible sector. Manufacturing industries in India being at the forefront of this implementation currently, IoT provides best of communication and automation techniques to increase productivity and profits.**

Keywords—IoT; OEE, Lean; Automation; Mistake Proofing; Manufacturing* sector, Quality *Analysis*; *Energy sector; Blockchain

I. INTRODUCTION

Communication and automation has undergone a tectonic shift throughout the history and especially in recent past. Traditional ways of communication were manual, one way communication between a machine and an operator which were not just time consuming but also less accurate. Then was the digital revolution with the use of electronics and IT to further automate production and its processes. This industrial automation made waves in manufacturing sector by increasing productivity and reducing high human costs. In recent years the focus has now broadened with decision makers seeking solutions to make their processes more flexible, safer and more accurate. With the introduction of the Internet of Things (IoT) in industrial applications, manufacturing sector is undergoing a tremendous change. This is made possible in part by recent technological advances in computing communication and automation that allows interconnection on a wider and more fine-grained scale.

Gathering data from mechanized equipment is not a new concept. Historically, on site technicians would review systems data on machine's display screen and depending on the situation, they would make manual adjustments to fix or improve the process. This was slow, expensive and inefficient. And so the need for flexible, transparent and more efficient solutions surfaced (as in this case for data exchange). This is where IoT fits in providing us with logical next step in industrial communication and automation.

The IoT is a network of connected sensors, actuators, and everyday objects that are used in various domains. [1]

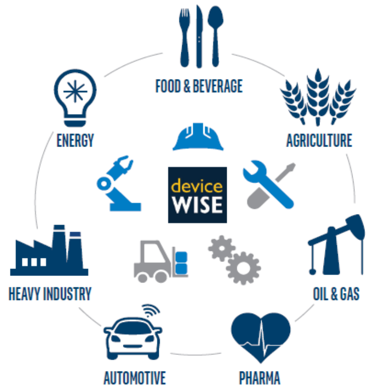


Fig 1: Different domains of Internet of Things (Intel Solutions)

Fig 2: Internet of Things Timeline

Like the IoT, the Industrial IoT (IIoT) is the connection of devices over the Internet, but with a focus on the transfer, command and control of mission critical information and responses. The IIoT is used in fields – where reliability and accuracy are not optional. Industrial IoT enables machines to work better, fail less often and produce higher quality output. [2] Industry 4.0 was introduced in 2011 as a German government initiative dedicated to ensured competitiveness for the manufacturing industry. While both IoT and IIoT operate at a business level, Industry 4.0 remains a primarily government and academic-based movement.

978-1-5386-5257-2/18/$31.00 ©2018 IEEE

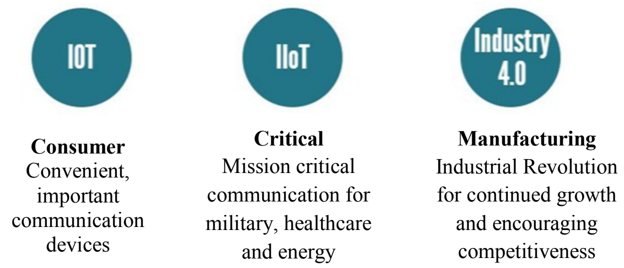
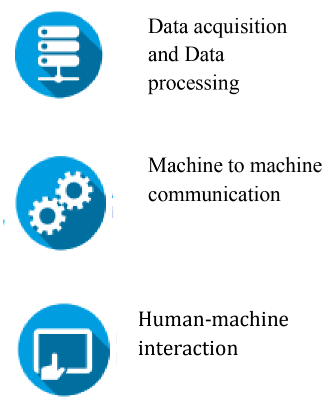


Fig 3: Internet of Things, Industrial IoT, Industry 4.

Today, IoT is able to extend intelligent computing and communication capabilities to everyday objects, such as traditional tools, sensors, cameras, cars, and appliances which are normally not considered as computing devices. Allowing these things to communicate and work with each other collaboratively to achieve common goals with minimal human intervention. These interconnected devices link our physical world to the digital world to make the life easier and smarter. The IoT is growing rapidly, it is expected that by 2025, the IoT will connect every object of our daily life to the digital world as stated by the US National Intelligence Council. [1]

II. INDUSTRY 4.0: CLUSTERS

To bring industry 4.0 into a structure based model required for implementation and easy understanding it can be divided into following clusters:



A. *Data acquisition and data processing*

Data acquisition and data processing are enablers for interaction between hardware based sensors and actuators to interact with the physical world. An additional middleware required here is cloud computing. This process can be initiated with objects being equipped with sensors, processing modules making that object into a smart object. Internet of things and services provides a bridge between connecting these smart objects with global internet. [3]

All the data acquired from these sensors will be stored in big data platforms as database for analytical applications mentioned below.

B. *M2M communication*

One of the main aspects of Industry 4.0 is machine to machine communication. The concept behind M2M communication is to have intelligent machines and equipments with minimal human interaction. Based on the information available the production process can be changed autonomously according to the auto-production plan. The key structure required for M2M is vertical and horizontal integration as given below. [3]

C. *HMI*

The third cluster is human-machine interaction. The approach of human-machine interaction is based on the information sharing and collaboration between production machines and employees by interfaces like virtual reality and augmented reality. HMI solutions and applications are still under ongoing research and development for industrial practices.

III. ORGANIZATION STRUCTURE AND IOT INTEGRATION

During implementation of IoT it is very critical to understand how the industry is structured and how should it be integrated with different sectors. It is basically divided into three kinds of integration. These are horizontal integration through value networks to facilitate inter-corporation collaboration, vertical integration of hierarchical subsystems inside a manufacturing system and end to end connectivity across value chain to support connectivity

A. *Horizontal Integration*: It is becoming increasingly necessary for every industry to have smooth and efficient co-operation and co-ordination with different corporations within an industry, which is called as inter-corporation. By inter-corporation horizontal integration, related corporations can form an efficient ecosystem, finance, information and material can flow among these corporations. The approach of horizontal integration specifies the global communication between machines or systems on the same level. [4] This is also leading to emerging of new business models.

B. *Vertical Integration*: It is essential to vertically integrate actuators and sensors, across different levels right up to the enterprise resource planning (ERP) level to enable a flexible and reconfigurable manufacturing system. Data from ERP system contain information about the production process parameters of every single product. The vertical integration connects machines and data on different levels. This mean it makes it possible for gapless data connection of machine process. A gapless vertical integration enables an individual one piece flow without manual changeovers. [4]By this integration, the smart machines form self-organized system that can be dynamically reconfigured to adapt to different product types, this massive information is collected and processed to make production process transparent.

C. *End to End Integration*: In a product centric value chain process, a chain of activities is involved such as customer requirement, product design and development, production planning, production engineering, production services, maintenance and recycle. By such a integration, a continuous and consistent value chain with a customized product are possible.

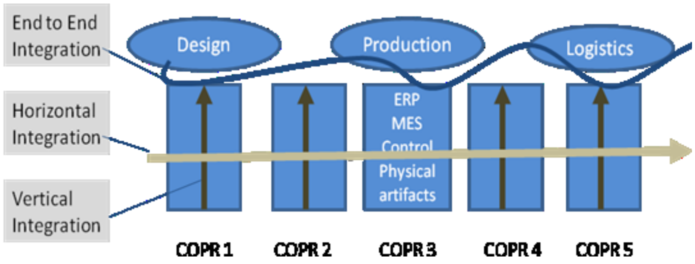


Fig 4: Illustration of three kinds of integration and their relationship

IV. FLOW OF IMPLEMENTATION

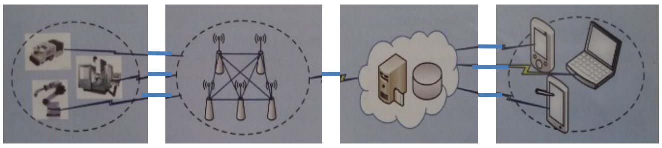


Fig 5: A framework for data acquisition process

First step is to connect all of the system with sensors and actuators to capture the data, this is called as data acquisition and then using big data and analytics the data acquired is processed. Then as we start analyzing and evaluating the data and with this information we can carry out the applications mentioned below. There are various platforms today which provide one stop cloud based IIoT solutions like Datonis®, Infinite Uptime, and ERIXISTM. These platforms let you securely connect and process IoT data at scale. It provides the ability to analyze and visualize this data in real-time, integrate IoT data into your business applications and rapidly make operational decisions that impact your business.

Then next step is controlling the machines or system from any de-centralized place i.e. it should be possible to add/edit/delete a program and/or make any necessary changes on the machine or system according to our needs not from on ground (i.e. shop floor) but sitting at any place. And further this is to be expanded to where once we change a parameter on any one of the systems all other systems will modify themselves accordingly and be ready for the new process without any human intervention. This can be termed as machine to machine communication.

We here can add a new sphere of human-machine interaction. This mainly consists of 2 parts virtual reality and augmented reality. It is still going under wide exploration of new possibilities and techniques as to how to implement and incorporate them into our existing systems. Presently, it can be used in ways like predictive maintenance being carried out using augmented reality and virtual reality. If we a take a tablet or a cell phone near our system, variety of different information could be obtained directly ranging from its performance efficiency, next maintenance required based on alert notifications received, the program it is currently caring out and possibility of changing any of the specifications as and when required from any place possible.

V. BUSINESS POTENTIAL

In country like India where manufacturing sector contributes almost 17.1% of its total GDP, we can boost this greatly by merging some its applications with our enormous IT sector. This is where Industry 4.0 plays a very major role in accordance with current initiatives of government like Make in India and Start-up India; IT Sector IoT based companies can provide wide number of different application based on end to end solutions in various sectors to areas like HR, Quality, Energy and Manufacturing Industries. The detail impact of each of these is explained in below section.

VI. APPLICATIONS

Today, we gather large amount of data at multiple points which is analyzed and communicated to remote technicians (or machines) and acted on in instant. So the possibilities are enormous and its applicability is wide ranged.

A. *Industry OEE (Overall Equipment Effectiveness)*

A concept introduced in 1982 by JIPM (Japanese Institute of Plant Maintenance), is a KPI in conjunction with lean manufacturing efforts to provide an indicator of success. One of the major goals of TPM is OEE and is calculated using six equipment losses identified within TPM. Its calculation requires equipment availability (breakdown and changeovers), productivity (minor stoppages and reduced speeds), and quality (defects and setup scrap) data to arrive at a number that communicates with us how our equipment or production line is operating industries track the efficiency of their equipment by measuring Overall Equipment Effectiveness (OEE) which is a combination of machine availability, performance and quality. Production lines are composed of various machines that perform specialized tasks. These machines are usually not connected i.e. while critical parameters that govern the operation of a machine and the information that a machine produces about its own performance was always generated but never collected and analyzed.

Table 1: TRADITIONAL METHOD FOR OEE CALCULATION

Month:- Dec 2017 Losses report		630T1		630T2	
	UNIT	Cumm.	%	Cumm.	%
Std cycle time	Sec.	7.80		7.82	
Total day production	Nos.	201918		226488	
Rejection	Nos.	475		836	
OK Production	Nos.	201443		225652	
Total Equipment failure loss	Hrs.	6.50	**1.2**	7.50	**1.3**
Total Set up / Adjustment loss	Hrs.	44.75	**8.0**	44.50	**7.7**
Total Tool change loss	Hrs.	15.75	**2.8**	23.75	**4.1**
Total Start up loss	Hrs.	0.50	**0.1**	0.50	**0.1**
Total Minor stoppages		6.75	**1.2**	0.75	**0.1**
Total Shutdown loss	Hrs.	12.00	**2.1**	19.25	**3.2**
Total Management loss	Hrs.	1.00	**0.2**	1.00	**0.2**
Total logistics loss	Hrs.	0.00	**0.0**	0.75	**0.1**
Total Measure & adjustment loss	Hrs.	18.50	**3.3**	20.75	**3.6**
Total Die / Jig / Tool loss	**Hrs.**	**48.25**	**8.59305**	**31.5**	**5.45691**
DOWN TIME	**Hrs.**	**143.046**	**25.4756**	**132.849**	**23.014**
Total available time	Hrs.	573.50		596.50	
Net available time	Hrs.	561.50		577.25	
UPTIME	Hrs.	418.45		444.40	
% UTILIZATION	%	74.52		76.99	
ACTUAL CYCLE TIME	Sec.	7.63		7.27	
% PRODUCTION EFFICIENCY	%	102.28		107.49	
RATE OF QUALITY	%	99.76		99.63	
O E E	%	**76.04**		**82.44**	

Very often industries used and some still using manual methods to calculate OEE of a machine which resulted in the following issues such as

1) The process was manual, time-consuming and costly.
2) The process was carried out infrequently thus real data was not available.
3) Data was inaccurate, outdated and prone to human errors
4) There was an inability to react to efficiency trends in real-time due to lack of real-time machine data
5) The lack of historical trends which meant that future throughput trends could not be predicted.

IOT helps the manufacturer to identify & remedy such areas which are negatively impacting the overall OEE.

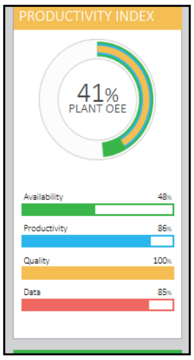


Fig 6: Productivity Index (Overall equipment effectiveness)

Fig 7: Dashboard on computer

IOT helped in following ways for Improvement of OEE

Improvement in Machine Utilization – By viewing details on how their machines are operating, down to the last seconds, customers can now plan their production and their maintenance schedules optimally.

Visibility for Machine Downtime –tracking of machine downtime to the last seconds. By providing idle-time reasoning, which can lead to focus on the top reasons for reduced production on a daily basis and immediately correct them.

True OEE Calculation – OEE is now being calculated automatically with no manual intervention. This forms a benchmark for any process improvement initiatives on the assembly line. Line owners can directly view the impact of an initiative and take a decision.

Similarly it is possible to get losses reports, cycle time report and live line utilization report.

IoT provides following benefits:

1) Plug-and-play OEE solution
2) Automated pattern recognition to identify setup, downtime and production states
3) Automated productivity estimation without human intervention
4) No data manipulation, let the machine speak directly
5) Going paperless

B. *IoT impact on Lean Management*

Lean manufacturing first implemented by Toyota Motor Corporation is a set of methods and tools with a management philosophy to increase productivity and decrease manufacturing cost by eliminating wastes (MUDA). [5] Today, in India majority of industrial companies follow Lean manufacturing principles. So an overview of how these lean principles might be impacted when it meets with IoT which is coming up so rapidly is explored. To support this concept of an IoT with lean an impact matrix is created where elements of Lean are considered with Industry 4.0 technologies and gives an estimation first impact.

Table 2: IMPACT MATRIX BETWEEN LEAN AND INDUSTRY 4.0

	Data acquisition and processing			
	Sensors and Actuators	**Cloud Computing**	**Big Data**	**Analytics**
5s	1	1	1	1
Kaizen	1	1	2	3
Just in Time	2	2	2	3
Takt time	1	1	1	3
Waste Reduction	1	1	2	3

The valuation is based as '1' being estimated low impact and '3' being highest estimated impact.

For example, Analytics have maximum impact on Kaizens as various algorithms can be used to find the best possible solutions whereas sensors and actuators having no significant on Kaizen as it will help only in collecting the data. Similarly for Just in Time data collection is very important aspect hence the use on sensors which is faster and accurate way and will impact more.

This is estimate of the positive impact it can have some of the common lean principles as it is still in implementation stage. M2M communication and HMI will also have an impact to a large extent on these principles which is to be gauged as we move along with implementation. This impact matrix will support the developmental decisions during initial phase.

C. Condition based Monitoring & Mistake Proofing

Industry 4.0 solutions can provide optimum support for condition based monitoring in industry. Condition based monitoring involves continuous monitoring of machine data to detect wear, making it easier to schedule repairs and thus reduce downtime. There is also potential to lower maintenance costs as only worn-out parts need replacing. For example spindles in a milling machine are prone to breakage during the process. And repairing these can be very expensive. This is where sensors like (vibration sensors) can be used to identify the working conditions of spindle like spindle speed and tension and its relevant alert settings can be preset. The sensors generate data which is then compared to the information from the machine and the specific workpiece being processed. By analyzing this data in real time, it is possible to constantly keep in check and predict in advance the actual occurrence of the failures as there are multiple signs and trends that the component shows 'symptoms' of imminent failure or high degradation in performance. [6] Early identification of underperformance and prediction of failure can help O&M teams resolve these issues quickly, increase generation and spindle life. This will also lead to develop better inventor management, optimize spares and reduce replacement costs.

Maintenance professionals can benefit in a lot of ways from these new technologies: their work schedules become targeted and more effective, machine downtimes and repair times decrease, and the production flow can be continuously improved. [7]

Mistake Proofing using Alarm system

After analysis and visualizing, these measured values alerts can be used to notify the employees via a sms or Email as soon as there are first a sign of breach in the set tolerance limits. These alerts are first indicators of failures and studying the frequency of alerts and correlation between alerts can give first level indication of issues in a system. If alert notifications become frequent it is an indication of thorough diagnosis of the system to pinpoint the possible reason for this failure. [6]

This can further be extrapolated into an shop floor alarm system, where PlCs are programmed to generate an alarm when any sensor value captured is outside of the tolerance that have been preset for that sensor or when the frequency of number of alerts goes beyond a certain limit. This addresses the very two important aspects

1) proactive maintenance
2) safety point of view in some extreme conditions

D. Incentive scheme in HR Management

Providing incentives to employees to encourage them to work harder or more efficiently can be a difficult issue, especially for small businesses Incentive packages should reward employees without affecting the company's ability to attract and retain top talent, and without causing additional tax burdens on employees or the company.

Current ways of incentive scheme

1) Employees receive a set percentage of the company earnings.
2) Frequent small rewards to show your manufacturing employees that their work is valued on a day-to-day basis. Institute a program that rewards employees for meeting weekly goals, such as producing a certain number of units, or for demonstrating key company values. Rewards can be small, such as a thank you note and a gift certificate to a local store.
3) Target incentives programs to all employees, not only management or employees who are your best performers. One way to do this is by setting personal goals for each employee and basing rewards on whether the employee meets or exceeds these individual goals and etc.

All these are done manually and after some target achievements and etc.

A new concept is introduced for incentives where we are monitoring all the data of productivity, OEE and also condition-based monitoring system (CBM). Based on this link between OEE and CBM a formula is derived. This formula is used to evaluate the performance of the worker on point basis. It not only takes into account the number of jobs the worker processes but also considers the machine maintenance during that specific activity period, points are added when the the production is achieved considering the maintained machine condition, and highest point achieving team will get the incentive based on the grading system. This gives a very holistic approach to evaluate the worker and give targeted incentives.

E. Quality Analysis using Statistical Process Control

A time series data follows something called a normal distribution in statistics and is represented by the famed bell-shaped curve. In such a case, there is a process control technique called the control chart which allows you to calculate the upper and lower control limits of the temperature based on the variation in the process. Considering an Example of Temprature control for a factory or any cold chain truck, if the temperature control system is good, meaning the variation is less, the upper and the lower control limits will actually be within the specified limits of 15^0 and 20^0 centigrade thus narrowing the band from 5^0C to say 4^0C.

Based on these control limits we may now set your analytics program to alert you based on certain rules so that you may ensure the regulation of the temperature back to the specified range if an anomaly occurs. A rule can say that as soon as the recorded temperature breaches the upper or the lower control limit an alert is generated. Or it may say that, generate alert only if three consecutive readings breach a limit

A rule may also be set that if more than, say, five consecutive readings are above or below the mean line (17.5^0C) an alert is sent, even though the values are within the control limits. The interpretation is that since the mean has shifted there is a likelihood of the temperature breaching the upper or lower limit depending on which side the mean has shifted.

Similarly, there can also be a trend rule, where, if several readings display a trend that the temperature is moving upwards or downwards an alert be generated, even though the values maybe within the control limits. Here also the interpretation is that since the temperature is moving upwards or downwards it is likely that it will breach the limits. For such, IOT can be used to maintain and controlling the temp.

F. Forcasting in Energy Sector

In energy sector, we can leverage the data we get further by processing and using it to forecast, develop strategy for allocation of maintenance budget, valuation & other financial strategies relating to the asset. For example helping the grid operators manage the grid properly. Operator can feed in wind speed for past few hours as captured by met masts into the system which will process it by comparing it with existing records and with the help of the power curve it can forecast power generation for next couple of hours. This is will greatly help operators to manage load demands and to have te mximum possible power from clean energy on the grid. [6]

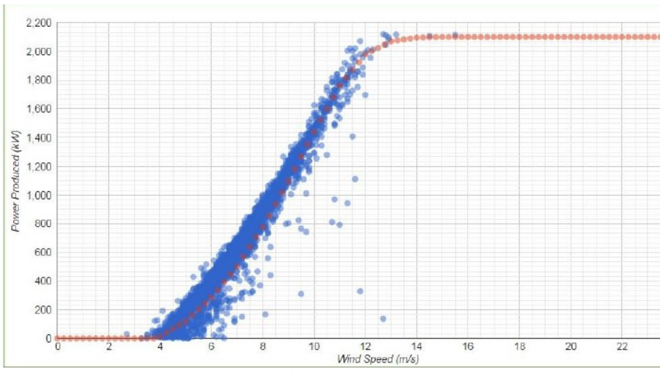


Fig 8: Wind turbine power curve

VII. SUMMARY AND CONCLUSION

Industry 4.0, driven by IoT (Internet of Things) is gaining huge traction in manufacturing industry. It has changed the way how communication happens and this has greatly altered the level of automation in industries. The physical world in manufacturing plants and digital world are rapidly getting interconnected like never before with machines communicating with each other and with their users in an unprecedented way. Data generated from these interconnected is huge and applicability is wide ranged and the focal areas being that of productivity and efficiency.

It is closer to being implemented than otherwise believed. Most of the necessary technological advances needed for it have already been made, and some manufacturers and agencies have already begun implementing a small-scale version of it. The main reasons why it has still not being implemented in its true form is because the industries are still gauging the impact it will have on the legal, ethical, security and social fields.

VIII. FUTURE SCOPE

The biggest problem with so much data is its security. Workers could potentially abuse it; hackers could potentially access it, and there will complete absence of privacy. For these reasons, the Internet of Things is very well pushed back longer than it truly needs to be. Conventional security and privacy approaches tend to be inapplicable for IoT, mainly due to its decentralized nature and the resource-constraints of the majority of its devices. Blockchain can be used here to provide security and privacy in IoT networks. The Blockchain here will be different in a way that it will not be a Bitocin Blockchain whose management is decentralized but rather a local Blockchain which is centrally managed by owner. The owner will be responsible for adding new devices by creating new transactions and can also remove devices by deleting existing ledgers. [8]

REFERENCES

[1] Q. I. Sarhan, Internet of things: a survey of challenges and issues, Duhok, Kurdistan Region, Kurdistan Region: Int. J. Internet of Things and Cyber-Assurance, 2016.

[2] V. Nathan, "Smart Manuractruing Report," Altizon Systems, Pune, 2017.

[3] C. H. Tobais Wagner, "Industry 4.0 impacts on lean production systems," in *The 50th CIRP Conference on Manufracturing systems*, 2017.

[4] D. L. J. W. A. Z. Shiyong Wang, Implementing stmart factory of Industrie 4.0: An Outlook, Guangzhou: Industrial Product Review, 2017.

[5] C. E. J. W. Adam Sanders, "Industry 4.0 Implies Lean Manufacturing: Research Activities in Idustry 4.0 Function as enabler for Lean Manufracturing," *Journal of Industrial Engineering and Management,* p. 23, 2016.

[6] Algo Engines, "DATA ANALYTICS FOR WIND FARM PERFORMANCE IMPROVEMENT," [Online]. Available: http://algoengines.com/wind/. [Accessed February 2018].

[7] M. KÖHLER, "Bosch," 15 February 2018. [Online]. Available: https://blog.bosch-si.com/industry40/industry-4-0-condition-monitoring-use-cases-in-detail/. [Accessed March 2018].

[8] S. S. K. R. J. Ali Dorri, "Blockchain in internet of things: Challenges and Solutions," *arXiv:1608.05187/ Cornell University Library,* p. 13, 2016.