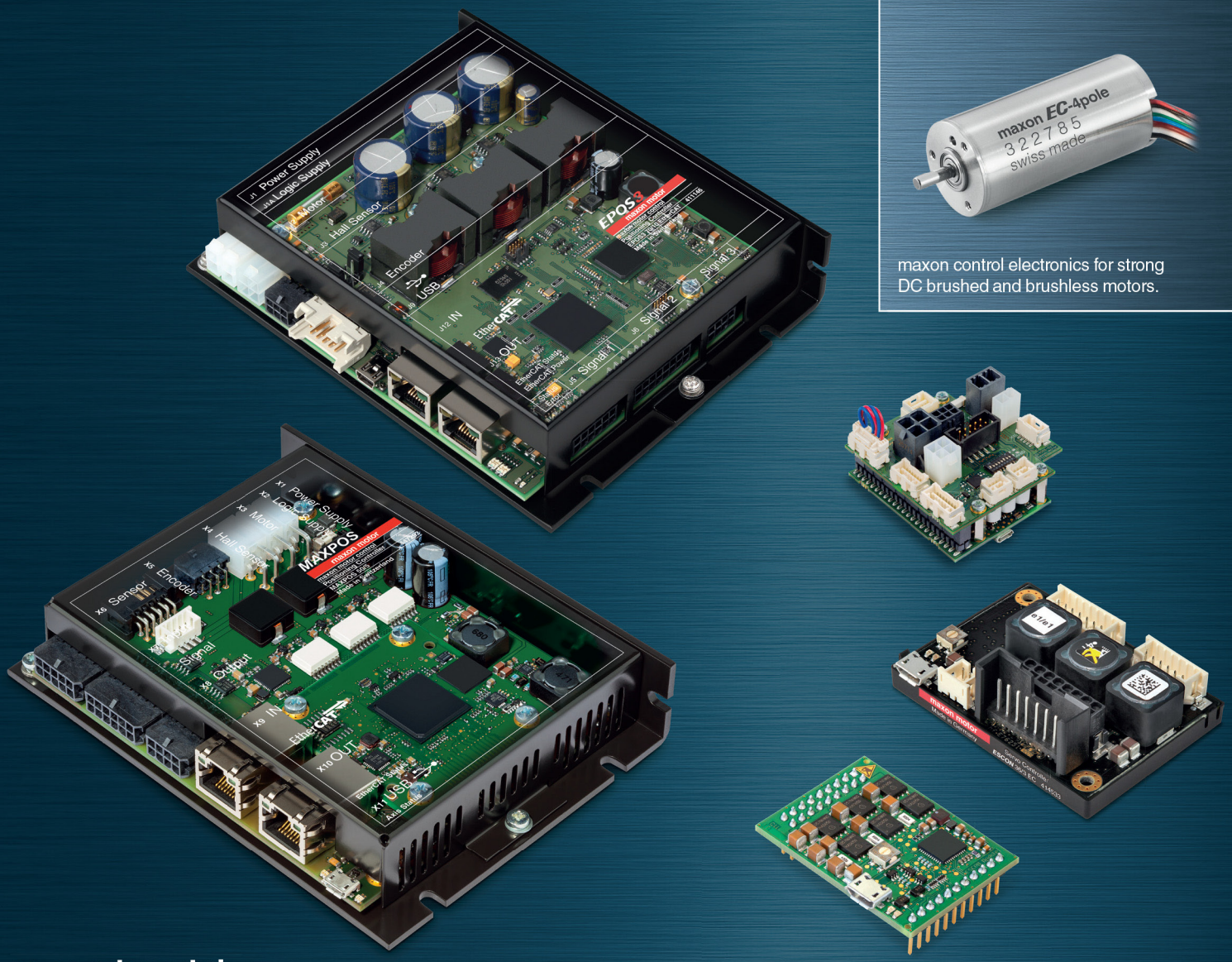
robotics business review

RESEARCH REPORT

Industrial Internet of Things:

Putting It All Together



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"McKinsey Global Institute suggested that the current hype surrounding the IoT [$6.2 trillion] may even understate its true potential, and projects a potential economic impact, including consumer surplus, as high as $11.1 trillion by 2025."

—The Internet of Things: Mapping the Value Beyond the Hype

Introduction

As robotics and autonomous technologies evolve they are inevitably becoming ever more entwined in day to day industrial operations across a whole range of sectors.

Industries as far apart as manufacturing, logistics and agriculture continue to benefit from radically improved picking, mobility, image recognition, learning and autonomy functions - and a variety of emerging applications are helping to transform entire supply chains from farms and production facilities to distribution centers, warehouses and retailers.

In tandem with this explosion in innovative robotics, the world of business is also becoming more and more exposed to revolutionary developments, like 3D printing, artificial intelligence and cloud computing, that are changing the way technology is designed, controlled and managed.

One of the most interesting examples of such a change is the ongoing creation of the Industrial Internet of Things (IIoT), which is finally gathering momentum as the rapid growth in Internet of Things (IoT) technologies and techniques helps to establish the long talked about convergence of the IT and industrial worlds.

At its most basic level, the IIoT uses standard networking technology and computer hardware to connect equipment, products and even entire production facilities - in the process making it far simpler to monitor and control the whole manufacturing process by enabling the component parts of production sites to communicate with one another almost instantaneously.

Although impressive enough in isolation, many industry observers now believe that such capabilities represent just the beginning of a long list of potential functions - and that, although still very much a work in progress, the reach of the IIoT could soon extend much further.

In fact, by bringing together a variety of novel IT and robotics technologies, and yoking together a Universe of Things, the IIoT has the potential to facilitate a growing number of industrial automation solutions, nurture a potentially game changing approach to the way that industrial operations are carried out - and usher in an age where every machine communicates with all others, each controlled from anywhere on virtually any device.

By harnessing trends such as digitization, miniaturization, and communication via Cloud technologies, some even predict it could ultimately revolutionize the way we manufacture, ship, warehouse and sell just about everything, and have dramatic impacts on overheads, revenues, profits, personnel and customer engagement.

Whatever the IIoT eventually looks like, it is difficult to deny that robot-driven automation will play a key role and, by contributing to ongoing advances in manufacturing and logistics productivity, speed, and simplicity, form a pivotal role in leading the charge.

The key challenge now is to enhance and deepen understanding of not only how the IIoT will affect the robotics sector - but of how the robotics sector can help to shape the industrial internet.

Assessing the size of the IIoT market

Taken as a whole, there is no doubt that the IoT market looks set to expand substantially over the next few years. A 2015 report by global management consulting firm McKinsey highlighted IoT as one of twelve key 'disruptive technologies' and concluded that, as soon as 2025, the sector could boast an overall economic impact in the region of $6.2 trillion - and could potentially

drive productivity and reduce operating costs across a number of industries, including health care, mining and manufacturing.

Exhibit E1

Twelve potentially economically disruptive technologies

Mobile Internet	Increasingly inexpensive and capable mobile computing devices and Internet connectivity
Automation of knowledge work	Intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments
The Internet of Things	Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization
Cloud technology	Use of computer hardware and software resources delivered over a network or the Internet, often as a service
Advanced robotics	Increasingly capable robots with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans
Autonomous and near-autonomous vehicles	Vehicles that can navigate and operate with reduced or no human intervention
Next-generation genomics	Fast, low-cost gene sequencing, advanced big data analytics, and synthetic biology ("writing" DNA)
Energy storage	Devices or systems that store energy for later use, including batteries
3D printing	Additive manufacturing techniques to create objects by printing layers of material based on digital models
Advanced materials	Materials designed to have superior characteristics (e.g., strength, weight, conductivity) or functionality
Advanced oil and gas exploration and recovery	Exploration and recovery techniques that make extraction of unconventional oil and gas economical
Renewable energy	Generation of electricity from renewable sources with reduced harmful climate impact

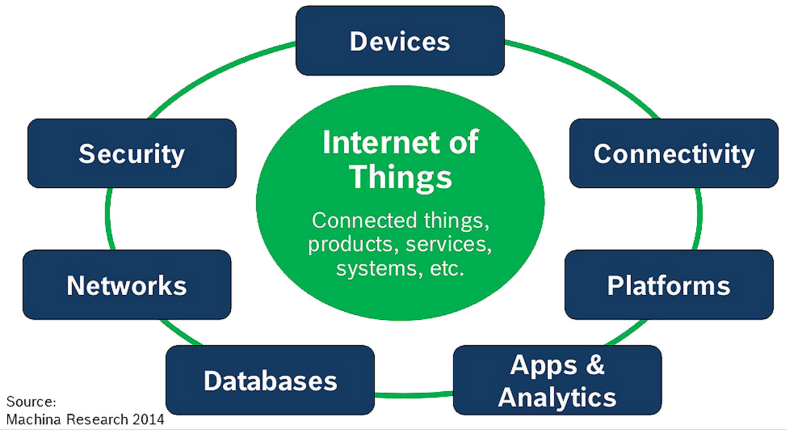
SOURCE: McKinsey Global Institute analysis

In the 2015 report, *Unlocking the potential of the Internet of Things*, the McKinsey Global Institute suggested that the current hype surrounding the IoT may even understate its true potential, and projects a potential economic impact, including consumer surplus, as high as $11.1 trillion per year in 2025.

Meanwhile, industrial behemoth GE, already a key player in the burgeoning IIoT space, believes that the insights into operations unlocked by the industrial internet could significantly improve industrial productivity. This potential is particularly salient given that the company estimates that an improvement in productivity of just 1% across its global manufacturing base equates to a cool $500 million in annual savings - with a similar improvement in productivity across all industries potentially translating into a $10 trillion to $15 trillion addition in worldwide GDP over the next 15 years.

Key enabling technologies

Most IIoT systems will rely on a wide range of enabling technologies, including cloud platforms, smart devices, big data analytics and advanced automation. One of the most vital elements of any robot or machine-based IIoT system is likely to be mobile sensor technology, which imbues robots with the capacity to physically react to analyzed data.



By enabling users to monitor robots and machines on the factory floor, or even across plants and the wider supply chain, smart mobile sensors can also help organizations to optimize the use of their physical assets - for instance by allowing companies to ramp up the performance, and extend the functional working lives, of robots.

Cloud technologies are also likely to continue to act as central co-ordinating components of many successful IIoT applications. By acting as repositories of data collected from IIoT enabled robotic devices, machinery and equipment, cloud platforms such as Microsoft Azure will become an increasingly useful organising and analytical tool for industrial workers charged with overseeing and controlling factory-based systems.

If, as is predicted, the wave of data collected from IIoT systems grows into a tsunami, adequate storage technologies will also become critical requirements. Speaking at this year's annual *Open Compute Project Summit* in California, Urz Holze, senior vice president for technical infrastructure at Google, argued that large improvements in storage are likely to become increasingly important.

Potential opportunities and benefits

By fusing together the worldwide scope of the internet with ever improving capacities to control and manipulate the material world of machines, robots and production facilities, the IIoT brings with it an unprecedented range of potential opportunities and benefits.

Of the many and varied potential opportunities offered by the IIoT, perhaps one of the most prominent is the potential for the creation and storage of a valuable array of machine, operational and environmental data. Many mobile sensors and IIoT enabled devices are now capable of facilitating the capture, retrieval and processing of increasingly large sets of data from a broad range of sources such as IT data centers and plant-focused operational technology (OT) systems.

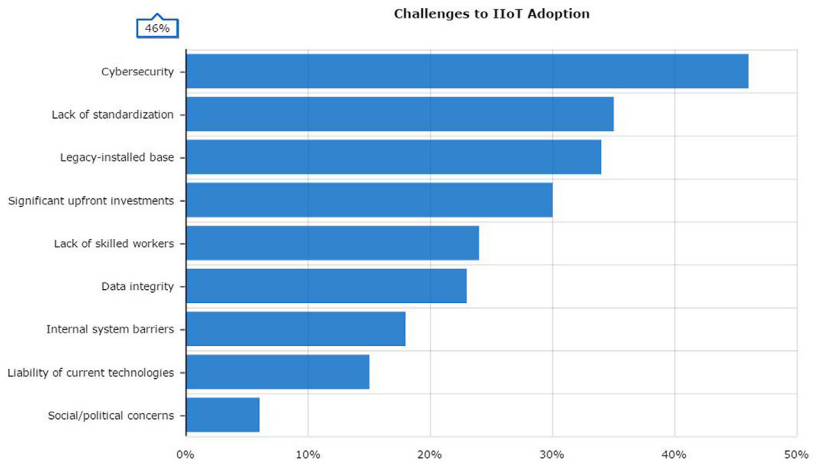
By using cutting edge analytical technology, this data can then be used to provide important insight into the nature of onsite operations - and feed into ongoing optimization efforts.

A 2015 report, *Industrial Internet of Things: Unleashing the Potential of Connected Products and Services*, by the World Economic Forum (WEF) and Accenture, also concludes that the chief disruption of the IIoT will come via 'new value creation made possible by massive volumes of data from connected products, and the increased ability to make automated decisions and take actions in real time.'

According to the reports' authors, the business opportunities presented by this upsurge in data capture will fall into one of four main areas - greatly *improved operational efficiency*, including reduced downtime and better asset utilization via predictive maintenance and remote management; the *emergence of an outcome economy* driven by software-enhanced services, novel hardware developments and 'increased visibility' into the patterns of behavior of products, processes, customers and partners; *new connected ecosystems* that will coalesce around innovative software platforms that confuse existing industry boundaries; and *collaboration between humans and machines*, which the report team predict will result in 'unprecedented levels of productivity and more engaging work experiences.'

Navigating the risks and challenges

Although the potential benefits of the IIoT are now becoming increasingly clear, companies and governments still face a number of key challenges to ensure they are fully realized.



Perhaps foremost amongst these hurdles is the need to ensure that robust data security and privacy systems are put in place - particularly in the light of ongoing concerns about industrial espionage, cyber-security and consumer protection.

Partly in recognition of these concerns, the U.S. Department of Commerce has recently launched a consultation exercise to gauge public views on the 'benefits, challenges and potential roles for the government in fostering the advancement of the Internet of Things' - and it is to be hoped that more such initiatives will be rolled out across the globe in the years to come.

According to the World Economic Forum (2015), further barriers to the uptake of IIoT include the 'lack of interoperability' among existing systems - which the Forum believes will 'significantly increase complexity and cost in industrial internet deployments' - as well as 'uncertain return on investments on new technologies, immature or untested technologies, lack of data governance rules across geographic boundaries and a shortage of digital talent.'

Another one of the key challenges facing industrial users seeking to navigate their way through the nascent IIoT landscape is the need to gain a deeper understanding of the wide array of available software systems and platforms - as well as how they relate to their own unique industrial setting.

In a recent interview with Forbes magazine, Brian Carpizo, who heads up the manufacturing and supply chain team at Uptake, a Chicago-based outfit that collaborates with large industrial customers keen on leveraging the opportunities afforded by IoT, laid down the early steps that manufacturers embracing IIoT are likely to take, as well as possible problems they are likely to face early on - such as the need to contend with the confusing number of software languages used.

I. Defining the Industrial Internet of Things (IIoT)

Getting to grips with terminology

From the IIoT and IoT to Industry 4.0 and smart factories, it's increasingly easy to get confused by the terminology used to describe the industrial internet.

However, it is important to realize that, although many of these terms refer to quite similar technologies and systems, the exact definitions differ in sometimes quite subtle ways. In basic terms, the *Internet of Things* (IoT) refers to the 'network of physical devices, vehicles, buildings and other items - embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data.'

Crucially, the IoT is not related to any particular use in isolation, but rather to the connection of such devices across all potential applications, whether domestic, industrial or otherwise. In contrast, the *Industrial Internet of Things* (IIoT) refers to the use of the IoT in specifically industrial applications, like factories, manufacturing facilities and warehouses. The term *Industry* 4.0 was originally coined in Germany, and relates to the ongoing 'trend of automation and data exchange in manufacturing technologies.' In practice, Industry 4.0 is broadly similar to, and inter-changeable with the IIoT.

Finally, *smart factory* refers to a key parallel trend to IIoT, and can be defined as a manufacturing system where each machine, robot, installation and logistical

element interacts independently, without the need for human input - and communicates at least partially via the IIoT.

From industrial revolution to industrial internet

Since the dawn of the industrial age, dramatic changes in technology - and in the way such technology is used - have periodically prompted rapid progress in performance and productivity.

The first such change was the birth of the steam age, which ushered in a brave new era of industrial expansion and enabled hitherto undreamt of output levels - characterized by a rapid upsurge in the use of steam transport, the roll-out of machinery in steam-powered factories and the wide-scale production of machine tools.

The next change, often called the 'second industrial revolution,' was initially brought about by the discovery of new methods of steel production, and eventually grew to include the chemical, petroleum and automotive industries. It was also characterized by the adoption of mass production and assembly line type operations of the type initially made popular by ground breaking companies like Ford.

A third substantial change was brought about by rapid advances in technologies such as the transistor and micro-processor, that together heralded the dawn of the electronic age - an era further enhanced by the establishment and rapid growth of the internet.

During this stage many manufacturing, assembly and distribution facilities - at least in developed industrial economies - experienced a rapid upsurge in the automation of activities, coupled with the mass roll-out of computer-enabled equipment such Computer Numeric Controlled (CNC) machines.

In the view of many observers, the technological changes and opportunities made possible by the expansion of the IoT will now position the IIoT at the heart of a fourth wave of new innovation - and help to create a further step change improvement in industrial productivity. In doing so, the IIoT will form a vital and central part of the ongoing creation and fusion of cyber-physical systems.

Some key component parts, platforms and enabling technologies of typical IIoT systems

- Cloud computing technology
- Software platforms
- Smart devices
- Mobile sensors and actuators
- Artificial intelligence (AI)
- Big Data analytics
- Advanced robotic and automation technology
- Machine vision and image recognition technology
- Wireless networking technology
- RFID (Radio Frequency Identification) and GPS technology
- Optics technology
- Transmitters
- Memory
- Storage technology
- Processors
- Networking components

Case study: Rolls-Royce takes the IIoT to the skies

One company that plans to be in the vanguard of IIoT application is global aerospace engineering company Rolls Royce, which earlier this year teamed up with Microsoft to integrate the latter's' Azure IoT Suite and Cortana Intelligence Suite into its service solutions - with the aim of expanding its digital know how to support the existing and emerging generation of Rolls-Royce intelligent engines.

By introducing IIoT capability into its sector leading TotalCare® services, the company expects that a combination of IoT, advanced data analytics and cloud technologies will help to 'fundamentally change' all of its engine-related operations and services - in the process resulting in 'significantly' reduced costs, improvements in on-time performance and the provision of better value to its customers, as well as 'the industry as a whole.'

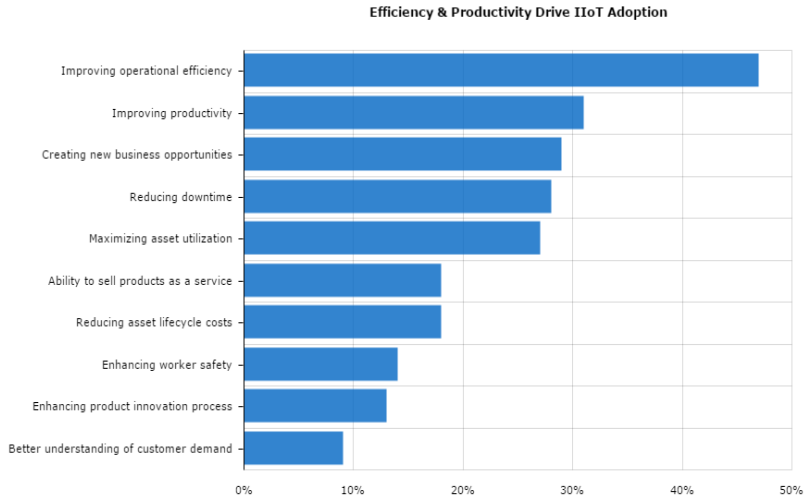
In practical terms, the system will be put to the task of aggregating far larger quantities of airline operational data collected from a number of disparate geographical sources around the globe - before analyzing it to uncover unique 'data insights.'

The Rolls Royce team will then build upon this process using a combination of embedded engineering know how, predictive techniques and smart data analysis systems to further refine the insight in the hope of helping airlines across the globe to manage routes more efficiently, slash fuel consumption and 'ensure the right teams and equipment are in place to service engines more quickly and maintain the highest levels of availability.'

Perhaps more impressively, the company is also aiming to use the new IIoT system to dramatically improve overall airline efficiency - to the extent that it feels confident enough to promote a vision of 'every journey, for every passenger, taking off and landing on time, every time.'

II. Growing the Market

A growing number of companies and research organizations across the world are now adopting the view that the IIoT could not just improve overall industrial productivity and output - but could potentially transform the way in which industrial processes are carried out at a fundamental level.



Although medium and long-term estimates of the likely size of the IIoT market vary from place to place, analysts are now in a position to provide a stronger sense of its likely direction and growth trajectory.

They are also increasingly able to shine a light on some of the key pre-requisites - ranging from technological skills development and financial investment to central government support and coordination - that will be needed to ensure that the nascent sector continues its onward march.

Gauging the future market potential

Although much of the early progress, and indeed hype, relating to IoT systems has stemmed from applications in the consumer sphere, many seasoned observers believe that, in the long-run, the industrial internet may 'ultimately dwarf the consumer side in potential business and socioeconomic impacts.' (WEF, 2015).

In doing so, it is possible, perhaps even likely, that the IIoT will prove to be a fundamentally transformative development in a wide range of industries, from manufacturing, mining and healthcare to agriculture, transportation and oil and gas - which together account for almost two-thirds of the global economy.

According to the McKinsey Global Institute (MGI, 2015), IoT applications in factories have the potential to create value between $1.2 trillion and $3.7 trillion each year in 2025.

As reported in the Institute's 2015 report, the lions' share of this value creating potential will come from *operations optimization* - by improving the variety of processes that help to make factories more efficient. Relevant advances in this area range from sensors designed to replace humans in managing the recalibration of machine performance to the adjustment of workflows using data captured from production machinery.

In practice, MGI reports that such activities - enabled by new IIoT-enabled applications designed to remotely track, monitor and adjust machinery, using sensor data gathered from a variety of plant locations, and even throughout supply chains - could potentially create value in the region of '$633 billion to $1.8 trillion per year in the factory setting in 2025.'

Beyond the impressive headline figures, the staggering market potential of the IIoT is also now beginning to be recognized in more concrete terms at the national level.

For example, the 2016 McKinsey report, *Danish Manufacturing* - Winning in the Next Decade, estimates that, between now and 2025, the industrial internet could help to create some 35 billion DKK ($5.38 billion) in revenue, as well as 23 billion DKK ($3.53 billion) in exports and 10,000 new jobs across the country.

It also seems that the growth driving potential of robotics and IIoT applications has been recognized in Asia, with two recent research reports by the global market analyst IDC Manufacturing Insights predicting that robotics and IoT applications are set to emerge as key elements of the ASEAN manufacturing sector - helping to foster more cost effective production and assist companies struggling with soaring labor costs.

The two reports, *Robotics in ASEAN Manufacturing* and *IoT in ASEAN Manufacturing*, also reveal that the 'upcoming wave' of IIoT implementation is expected to broad-based and cross-operational, helping to bring about 'significant changes in manufacturing.'

In financial terms, IDC also estimates that manufacturing companies in the ASEAN region will increase their IoT technology investments to over $15 billion by 2019 -and that the Asia Pacific robotics market will continue its

upward trajectory, ultimately 'reaching $93 billion by 2019 and accounting for 69% of the global market.'

Amid the hype surrounding the potential growth of the IIoT it is perhaps wise to also consider the more cautionary voices in the business community.

For example, a November 2015 survey of almost 500 IT and business professionals carried out amongst Gartner Research Circle members revealed that 38% have 'no plans to implement IoT.' The survey also found that only 29% of respondent companies are currently using IoT technologies, with some 9% of the professionals questioned reporting 'no relevance at all in IoT technologies.'

However, in spite of this generally negative overall assessment, the Gartner team admits that so-called 'heavy industries' like utilities, oil and gas, and manufacturing are 'leading IoT adoption' - and predicts that more than 50 per cent of companies in asset-intensive industries will have implemented IoT by the end of 2016.

Some recent investments and acquisitions

Although the IIoT market is still in very much in its infancy, many companies both big and small are showing a keen interest in getting involved.

In 2014, IIoT activities attracted an impressive $1.5 billion in venture capital - a figure that continues to grow year on year. Regionally speaking, a recent Boston Consulting report, that presented the results of a survey of 300 German and U.S executives, finds that German companies are currently stealing a march on their U.S. counterparts - with 40 percent of Germans asked 'willing to take the risk' of installing IoT technology in their factories over the next few years, with only 24 percent of Americans 'willing to do the same.'

A large slice of the investment in the industrial internet sphere comes from major corporate venture funds of the likes of GE Ventures, Intel Capital, Qualcomm Ventures and Cisco Investments.

Another prominent recent example has come from German industrial giant Siemens, which via its Siemens Venture Capital arm, has launched a $100 million Industry of the Future Fund designed to back early-stage start-ups in industrial automation and other digital technologies 'that can transform future manufacturing.'

Meanwhile, the WEF (2015) reports that several dedicated and hybrid funds are also appearing in the IIoT market, including McRock Capital, which it describes as 'one of the first such funds devoted to start-ups in advanced manufacturing, grid automation, smart cities and digital oil fields.' GE has also unveiled a collaboration with Frost Data Capital - a 'big data incubator' company - to form Frost I3, set to fund and incubate thirty IIoT technology start-ups over the next few years.

In terms of robotics industry specific investments, the machine vision sector has also witnessed a lot of movement in recent months. In May 2016, UK-based micro-chip designer ARM Holdings swallowed up machine vision company Apical Ltd in a $350 million deal that is widely expected to help ARM to venture into new areas such as robotics, IoT and artificial intelligence.

Elsewhere, Chinese technology company Kuang-Chi has continued its emergence onto the world scene with a $20 million investment in eyeSight Technologies Ltd - and announced plans to turn its machine vision and gesture-recognition know how to robotics, IoT, and automotive applications. In other moves, Ubon Partners has pumped $6 million of equity finance into networked wireless sensor developer Disruptive Technologies.

Skills development and government support

As the IIoT gathers momentum, the industrial workplace is likely to face a period of prolonged transformation, characterized by unprecedented opportunities for networking and connectivity - as well as enhanced levels of productivity. In order to ensure that these new opportunities are fully realized, this radically altered landscape will call on people to acquire new skills and adapt to new modes of working.

In particular, the deepening synergy between humans, intelligent assistants, and robots equipped with mobile sensors will permanently change the nature of existing jobs and dramatically change the mix of skills required to thrive in new workplace environments.

Although the jury is still out on the ultimate impact of the robot-dominated workplace on overall employment levels, it is becoming increasingly evident that low-skilled job roles will continue to be replaced with machines. That said, the same technological changes that threaten employment at the lower end of the skills spectrum are also likely to create spaces for novel and highly-skilled positions focused on managing and optimizing emerging IIoT systems.

According to the WEF (2015), firms also look set to employ IIoT technologies and smart machines to deliver skills training and 'augment' worker capabilities - helping to improve job safety, whilst simultaneously making them more 'productive, flexible and engaging.'

As the IIoT gathers pace, governments around the world are also likely to play a key role - and the unique position of governments in providing investment and establishing a nurturing fiscal and regulatory environment, as well as in pulling together expertise and providing information will continue to be very important.

Several national governments around the world have already launched strategies focused on fostering steady growth in the IIoT and Industry 4.0. One interesting example is China, which last year published the Made in China 2025 strategy, designed to harness the internet, big data analytics and advanced computing technology to transform the country's manufacturing base - with a key focus on innovation in technologies like intelligent sensing components, robotics, cloud platforms and control systems.

Elsewhere, the U.S. government launched a national consultation exercise to assess the potential role of government in fostering the advancement of the IoT earlier this year. In Europe, the German government has also led the way, highlighting Industry 4.0 initiatives as a key part of the innovative High-Tech Strategy Action Plan launched in 2012.

Generally speaking though - and as argued in a 2015 World Economic Forum (WEF) report - governments and policy makers around the world still need to raise their game in a number of key areas if the IIoT is ever to reach its full potential.

For instance, data protection and liability policies aimed at streamlining data flow across national boundaries may need to be re-examined and updated - and current regulations governing the activities of companies in industries like utilities and healthcare may also need to be reconsidered to 'encourage investment and the adoption of new digital processes.' In emerging markets too, governments are also likely to need to significantly raise investment in domestic digital infrastructure.

III. Key IIoT Technologies and Platforms

In order to establish a complete IIoT system, companies and other organizations will need to rely on a whole range of hardware and software related components, platforms and packages.

Although the exact make up of each individual system will of course vary depending on specific factors like location, sector specific requirements and cost considerations, it is likely that most set-ups will be comprised of some combination of robot or machine mounted smart sensors, cloud technologies and software platforms.

A few key hardware technologies

When it comes to the hardware that will be used to drive the future IIoT, industrial companies will be called upon to build their systems from a wide range of individual and connected technologies.

One of the most important component parts of any system will be the mobile smart sensors and actuators that will be mounted on machinery, robots and equipment. In particular, smart sensor node systems like the Wzzard Intelligent Sensing Platform, recently developed by Advantech B+B Smartworx, are likely to constitute a central element in connected IIoT set-ups - particularly through their capacity to enable self-powered, independent and scalable IoT systems.

Sensors like these will form the engine room, where vital data on robot and machine performance and activity is first collected before being transmitted to other parts of an IIoT system for analysis and interpretation.

In a move calculated to help pave the way towards a more harmonized approach to IIoT hardware deployment, Advantech B+B Smartworx has also recently joined forces with two other leading IoT outfits, Connect2 Systems and DevicePilot, to unveil the first ever end-to-end IoT ecosystem created from a mixture re-usable infrastructure and open industry standards for use in large scale industrial and commercial applications.

Other hardware technologies that will help to underpin the IIoT include radio frequency identification (RFID) and GPS tag-based systems - of the kind developed by companies like Valarm - as well as machine vision and image recognition, laser and optics technologies and wireless networking technology.

Emerging software platforms

As the IIoT gathers pace, it is a safe bet to assume that many businesses will adjust the main focus of their attention away from the creation of material products and towards more outcome-oriented services - paving the way for a new competitive arena centered on a firm's capacity to provide customers with concrete results and benefits.

In the industrial sphere, such services could range from assurances relating to machine uptime and robot productivity to guaranteed picking and sorting speeds in warehouses and distribution centers.

In their 2015 report, the WEF and Accenture argue that the provision of such services will call for enhanced levels of cooperation across a new 'ecosystem' of organizations - brought together with the common aim of combining their products and services to fulfil customer expectations.

In paving the way for such an ecosystem, the authors also predict the emergence of software platforms that will facilitate improved data capture, as

well as its 'aggregation and exchange across the ecosystem' - simultaneously helping to 'create, distribute and monetize new products and services at unprecedented speed and scale.'

In recognition of the vital importance of this area, a number of large companies have already made some early plays in the IIoT sector - notable Microsoft, with its Azure offering and GE, with its Predix software platform, billed as the 'world's first industrial operating system.'

Under a cloud

Although sometimes overlooked, it is perhaps easy to forget the potentially central role of cloud technologies and platforms in helping to bring together IIoT systems and shape them into a coherent and unified whole.

In moving towards this objective, a number of companies have embarked on very interesting initiatives to explore how cloud applications can be used in innovative IIoT applications.

One notable example is the software giant Microsoft, which has launched a joint initiative with industrial robot manufacturer KUKA Robotics to demonstrate how industrial robots could collaborate more intimately with people by utilizing a combination of IoT, 3D sensing technologies and cloud networking - all linked together via its Azure cloud platform.

At a high-profile demonstration at last year's Hanover Messe, a major German industrial fair, the project team showed how a KUKA industrial robot arm can stream movement data to the Azure platform for use and analysis by human staff charged with overseeing production.

According to Microsoft, the novel combination of Microsoft Azure IoT services with Kinect hardware and the OPC-UA communication standard has helped to form 'one of the world's first showcases blending IT with robotic technologies into a smart manufacturing solution with new capabilities.'

Machine vision and image recognition

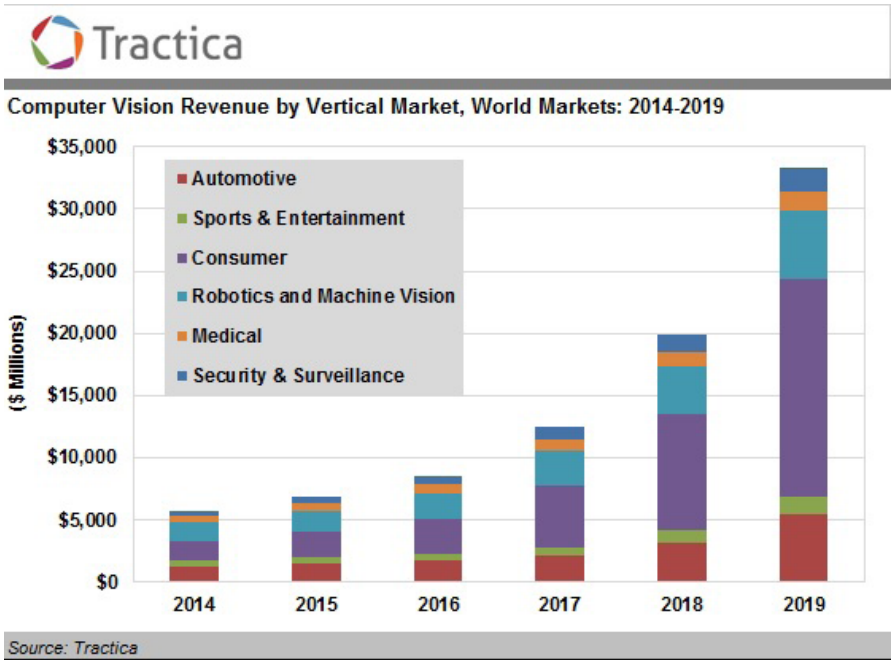
However the IIoT develops, robotics and automation technologies are sure to play a key role in its ongoing evolution. This is particularly true given the fact that robots now occupy a central position in the manufacturing infrastructure of most industrial nations.

As revealed in the 2015 World Robot Statistics report from the International Federation of Robotics (IFR), it is predicted that in the region of 1.3 million industrial robots will be in use globally by 2018 - and, across all industries, the current worldwide market value of robotic systems is put at $32 billion. The IFR report also confirms that there are now an average of 66 robotic units per 10,000 workers in the global manufacturing sector.

One robotics technology that is garnering a great deal of interest within the IIoT community is machine vision, which employs cutting edge image acquisition devices, including high-resolution cameras and sensors.

The general expectation is that, by helping to reduce reliance on subjective human-based measurement techniques, emerging industrial imaging technologies can speed up the adoption of more accurate industrial layouts and systems.

At the most basic level, machine vision technology can be used to perform a variety of very useful tasks in the factory setting. For example, robots featuring integrated camera systems can be more rapidly and flexibly installed - eliminating the need to use cumbersome set-up methods.



Machine vision processes can also be employed to enable the exact positioning of workpieces and reduce the incidence of expensive machine shut-downs by detecting, and eliminating, potential collisions with human workers at an early stage.

However, it is when combined with IIoT systems that machine vision technologies reveal their true potential. One promising application is the use of cutting edge image processing systems to more accurately read coded product information like bar or QR codes, even when they are blurry or otherwise defective. In such a way, the technology can be used to optimize logistics systems automatically control an items route through the various steps in the production process.

In his recent keynote address at the AIA Vision Show in Boston, Steve Varga, Principal Scientist for Imaging and Instrumentation Research and Development at Procter & Gamble also argued that, as robotics matures, machine vision will employ a combination of 3D imaging, motion analysis, and big data to create 'true perception and understanding' in manufacturing processes.

Elsewhere, Carnegie Mellon University (CMU) is working on software to enable robots to sort through clutter using machine vision techniques - and UK-based Cambridge Consultants is collecting colour and 3D data for picking and placing fruit using the Microsoft Kinect sensor and algorithms.

IV. Bringing it All Together

Organizations seeking to dive into the brave new world of the IIoT will need to source and install a wide array of hardware and software.

In establishing their individual systems, they are also likely to face a sometimes confusing choice between potentially useful technologies and components. Crucially though, the degree to which such disparate components are successfully integrated into a coherent single system is likely to govern the success or failure of individual projects.

In this light, initiatives and technologies aimed at facilitating the smooth integration and standardization of IIoT systems will continue to play an important role.

Nurturing interoperability and integration

As the IIoT grows, the task of knitting together the mish-mash of hardware and software packages and platforms is likely to emerge as an increasingly pressing challenge, not just for reasons of inter-operability and compatibility, but also to ensure that the potential revenue opportunities are maximized.

In fact, according to the McKinsey Global Institute (2015), the search for inter-operability between IoT systems is a 'critically important' part of the quest to capture maximum value, especially in view of its calculation that, on average, interoperability is a necessary prerequisite for around 40 percent of potential value across all IoT applications and almost 60 percent in some settings.

In its 2015 report, the World Economic Forum (WEF) also singles out the lack of interoperability among existing systems as 'another crucial barrier' - and one which will 'significantly increase complexity and cost in industrial internet deployments.'

Almost much of the existing operational technology systems tend to work 'largely in silos,' the report's authors also highlight the fact that, in the future, a 'fully functional digital ecosystem will require seamless data sharing between machines and other physical systems from different manufacturers.'

In such a way, the ongoing march towards what the WEF describes as 'seamless interoperability' will be 'further complicated by the long life span of typical industrial equipment, which would require costly retrofitting or replacement to work with the latest technologies.'

In an effort to help in overcoming such hurdles, organizations like the Industrial Internet Consortium (IIC) are already proving to be a very valuable resource. For example, the IIC has established a number of 'test beds' and working groups to tackle the issue of interoperability - which are already making steady progress.

Raising the standard

Another vital component in the tool box - and one that is sure to become increasingly necessary in ensuring that the IIoT runs in a seamless and harmonious way - is the move towards internationally recognized standards, which will play in central role in helping to lay the technical IIoT foundations that might eventually become applicable across multiple business domains.

One of the most important ongoing initiatives in this area is the oneM2M project - which was launched in 2012 as the global standards initiative for Machine-to- Machine (M2M) and the Internet of Things (IoT).

Amongst other things, the scheme aims to develop technical specifications for a common M2M Service Layer that can be 'embedded within various hardware and software to connect the wider range of devices worldwide with M2M applications servers.'

The scheme, supported by more than 200 companies drawn from the IT, telecommunications and manufacturing sectors, reached a key milestone earlier this year, when the coordinating team published updated editions of its Release 1 global specifications.

The M2M secretariat is confident that, by building on already well-proven protocols that enable applications across industry segments to communicate with each other, the updated standard will allow service providers 'to combine different IoT devices, technologies and applications, a critical feature in their efforts to provide services across a range of industries.'

The team also reports that Release 1 has already been put to good use in 'service provider deployments in South Korea, Asia and Europe for smart city and transport system deployments.'

The global collaborative effort is now working hard towards the impending release of the second stage of oneM2M specifications, which are now slated for completion by Autumn 2016.

Although the full contents of 'Release 2' are not yet known, the global alliance has revealed that the updated standard will include enhanced security, features for home domain and industrial domain deployment and semantic interoperability - as well as interworking with popular IoT device ecosystems such as AllSeen Alliance, OCF and OMA LightWeightM2M - features it is confident will 'present the unique value proposition that application developers have been looking for – one common core interworking platform technology for the Internet of Things.'

Open-source platforms

In the quest for the compatibility and interoperability of systems in individual plants, as well as across the broader supply chain and beyond, open-source IIoT platforms - that allow other vendors to plug-in their own applications - are rapidly emerging as an important piece of the jigsaw.

As vendors find their feet, several innovative schemes are already up and running, including a welcome move by Microsoft to introduce new open-source cross-platform OPC UA support for IIoT applications.

Another one of the most interesting initiatives in recent years has been the Kaa Project, an open-source IIoT platform that is capable of acting as a control hub for connected production facilities.

Billed as 'hardware and transport-agnostic,' the project team claims that the system can be easily integrated with a broad variety of sensors, controllers, machines, and device gateways - in the process enabling 'many-to-many interoperability between them.'

By virtue of this focus on interoperability and unified data sharing, the expectation is that Kaa will allow disparate parts of a production line to become 'more responsive and capable to instantly react to different events or change their configuration settings accordingly.'

The project team also predicts that failure prediction and troubleshooting will also become 'reliable and straightforward.'

In terms of specific capabilities, Kaa also enables production line remote monitoring, unified factory-wide interconnectivity, predictive maintenance and failure mitigation and safety control, as well as gateway apps and edge analytics, centralized configuration data updates, workforce tracking and cloud-based data storage and analytics.

Elsewhere, Project mangOH™ is another very promising initiative, which claims to open up an entire new category of open source hardware platforms for the Internet-of-Things (IoT). By helping users to create some 90 per cent of their prototypes 'out-of-the-box,' the mangOH project team hope that software developers 'can build reliable IoT solutions easily and hardware designers can customize it to create new hardware IoT devices easily.'

Will one winner take all?

Although the IIoT sector is currently at a very early stage of development, some industry observers are already predicting that the market for cloud based industry solutions could eventually turn into a monopoly, or at the very least have room for only two or three big players.

One commentator that strongly holds this view is Bill Ruh, chief digital officer at General Electric, who in a recent interview with the New York Times stated: "It's winner-takes-all, a cloud-based platform to connect machines and build applications into it and have global scale…you're only going to have a few of those."

V. Key and Notable Companies

Some early leaders

Given the large degree of embedded expertise, finance and infrastructure available to them, it is perhaps unsurprising that much of the early growth in the IIoT sector has come from incumbent players.

In areas such as software and platform development, some of the most notable early winners have been global companies like General Electric (GE) - which has already made great strides in the area, predominantly with its innovate Predix platform that it hopes will one day underpin the industrial internet - and Microsoft, which has won over many early IIoT adopters with its Azure cloud-based system.

Elsewhere, globe-spanning outfits like Bosch, Siemens, Intel, Schneider Electric, Honeywell Process Solutions, 3M and Qualcomm have also experienced some early success.

Rockwell Automation: adding value in the oil and gas supply chain

One company that has already successfully embarked on an IIoT initiative is US automation technology giant Rockwell Automation. By supplying IoT-enabled automation equipment, the company is providing its customers in the oil industry with services to predict failures throughout the supply chain - as well

as enabling them to undertake real-time equipment performance tracking and carryout preventative design changes.

The system is held together with a Microsoft Azure package that also helps Rockwell's customers to analyse the resulting data and use it to underpin moves towards increased productivity and cost reduction.

Bright young things - notable start-ups in the IIoT sector

In much the same way that the internet prompted the emergence of a large number of innovative companies like Google, Facebook and Amazon, it is perhaps only a matter of time before the deep changes in the industrial landscape brought about by the IIoT leads to the rise of a brand new wave of disruptive start-up companies.

In seeking to exploit the opportunities afforded by the shake-up associated with the ongoing recalibration of the rules of competition, several innovative players have already begun to stake a claim for early dominance - with companies such as CargoSense, Samsara, Meshify and GreenRoad continuing to burst onto the scene across a variety of IoT related sectors.

Some Key IIoT Start-Up Companies and their main areas of expertise

Aptomar	Oil spill sensors
Bastille	IIoT cyber-security
BluePillar	Smart-meter technology
CargoSense	Container-mounted sensor technology
DorsaVi	IIoT sensors
Greenroad	Telematics data analysis
Groundsensing	Oil well location sensors
Meshify	Cloud platform provider
Metromile	IIoT hardware-based fleet insurance
Momentum Machines	IIoT enabled manufacturing robots
Rethink Robotics	IIoT enabled manufacturing robots
RoboCV	IIoT enabled warehouse robots
Samsara	IIoT sensors
Skycatch	UAV-based construction site mapping
SigFox	IIoT wireless networking
Telogis	Logistics fleet-tracking
TempoIQ	Cloud platform provider
Tendril	Smart-meter technology
Trilliant	Smart-meter technology

Source: Adapted from CB Insights, 2016.

Making sense of cargo: the CargoSense Black Box solution

One start-up company that has already made strong progress in the IIoT sector is CargoSense, which has created a container mounted sensor and software-as-a-service based system that enables customers to oversee a wide range of parameters - ranging from temperature and lane performance to packaging performance and environmental impact.

The solution has already garnered a great deal of praise in the IIoT community, culminating in a 2015 IoT Evolution Asset Tracking Award, which recognises 'excellence in innovation utilizing IoT technologies to automate asset tracking functions to increase efficiencies, reduce theft, or optimize utilization of the asset.'

VI. Key Sectors

As well as shaking up 'standard' manufacturing and assembly facilities, the IIoT also looks set to transform activities in an ever increasing range of sectors, from transportation and logistics, through agriculture, packaging and warehousing, to aviation, healthcare and energy - and there are now a growing number of examples of successful applications.

UK grocery outfit using IIoT based logistics to shake up e-commerce offering

In the UK, on-line grocery retailer Ocado expects the combination of cutting edge robotics and IoT applications to facilitate dramatic improvements in e-commerce and the anticipation of customer demand.

Earlier this year, the company teamed up with global product development and technology consultancy firm Cambridge Consultants to launch an innovative wireless communications system capable of wirelessly controlling up to 1,000 warehouse robots from a single base station. The system works in tandem with the proprietary Ocado Smart Platform, a state of the art approach to order fulfilment, featuring a novel design for warehouse automation, that is being actively marketed to retailers worldwide.

In the future, the company hopes that IoT advances will allow it to establish a 'grocery delivery pipe to the home.'

"We have this concept of the 'broadband of grocery' - our vision is very much that by using better and better data about what our customers want, and smarter and smarter machine learning, we can predict when groceries would run out," says Paul Clarke, director of technology at Ocado.

From dusty shelves to self-aware bins

For many years, companies have relied on a combination of manual labour and fork lift trucks to manage the throughput of goods in their plants and warehouses.

However, according to Christian Schwede, head of department at Fraunhofer IML, Europe's largest industry research organization, that could soon be set to change as a result of IIoT innovations.

In particular, Schwede points to the increasing use of IIoT-enabled Automated Guided Vehicles (AGVs), which he believes will soon help companies to increase productivity and visibility.

Schwede also highlights a number of novel examples - including racking systems that are capable of ordering supplies autonomously, as well as bins that are aware of their own contents and control processes, containers that could independently organize loads and routes and trucks 'transporting goods without a driver.'

A precision approach to agriculture

Rapid advances in data processing and machine vision, coupled with steady progress in the use of drones for aerial surveying and robots capable of weeding vegetable crops, mean that the agricultural sector is now also well positioned to make full use of the opportunities offered by IIoT applications.

The adoption of 'precision agriculture' systems, where farmers harness data to maximize yields whilst simultaneously reducing water, fertilizer, and pesticide use has mushroomed in recent years, and many observers predict that 'swarms' of unmanned aerial vehicles (UAVs) could soon be used to gather valuable data as part of the IIoT, enabling farmers to manage resources more efficiently.

One such innovative application, currently being developed by MIT Media Lab researcher Caleb Harper, is a 'plant data center' for indoor urban agriculture - which could enable more precise control and crop management by identifying the location and characteristics of individual broccoli plants.

Food packaging

Some companies in the food packaging sector are also breaking new ground in the adoption of IoT applications - primarily by introducing 'intelligent' packaging that is capable of harnessing the capacities inherent in IoT and Big Data to create novel two way interactions with packaging mounted sensors - including RFID (radio-frequency identification), NFC (near-field communication), Bluetooth, and smart labels.

Many organizations in the sector are now waking up to the notion that they can use such technologies to establish simple IIoT systems - helping them to track and trace packages and use the transit data collected to make informed decisions relating to future strategies.

Some observers have already pointed out the wide range of potential benefits of such systems, including advances in food safety achieved by combining 'sensor information, supply chain and custody, and Big Data analytics to track food from source to store.'

One key example of such benefits is the fresh fish sector, which must constantly face up to sizeable challenges relating to quality control. To help in overcoming these challenges, companies are now able to employ Big Data and IoT sensory evaluation methods to objectively gauge the relative freshness of newly landed fish using non-invasive devices like those created by Seafood Analytics.

Novel devices like these make use of electrical currents to quickly assess whether an individual fish has been previously frozen - as well as to accurately measure the time on ice and time since harvest and assess the remaining shelf life.

Moreover, by adopting smart packaging methods, companies in the sector are now able to embed sensors capable of tracking environmental conditions throughout the entire length of the supply chain.

Once they eventually reach the fishmongers, shops and retailers, cutting edge sensors and advanced energy solutions - such as those devised by companies like Vitabeam - can then help to extend the shelf life of fish for human consumption, while simultaneously eradicating harmful bacteria that can speed up decomposition.

In such a way, every single point along the supply chain, from the fishing boat to the retailer, is monitored and verified - in the process facilitating increased economies of scale, as well as dramatically lowering the risk of product recalls and fostering improved accountability across the sector.

VII. Key Emerging Trends

Trend #1: Big Data

The growing capacity for industrial users to use IIoT enabled devices to remotely monitor and manage facilities and equipment also opens up a new realm of possibilities for data driven decision making.

As well as helping users to save time and costs and improve the overall performance of industrial process and systems, the data collected from connected devices could help to create a 'digital feedback loop' that could soon enable companies to apply some of the cutting-edge data science techniques developed in other sectors to the world of manufacturing and supply chain operations.

In turn, this is likely to improve the analytical and predictive capacity of industrial equipment - a development that could lead to novel control systems, as well as lower costs and better opportunities for revenue generation, particularly amongst software providers.

Ultimately, it is possible that such advances could prompt a fundamental shift in the way that value and profit is generated by industrial equipment - away from hardware and towards software.

In this light, it is perhaps understandable that a growing number of software companies are now seeking to muscle in on this nascent market - and vie to be the main provider of the central platforms that will eventually underpin the IIoT.

Trend #2: Artificial Intelligence (AI) and machine learning

As the IIoT sector grows, it is important to realize that its scale-up will not occur in isolation from other equally ground breaking developments.

In terms of the range of applications and potential impact on all areas of human activity, such developments don't come much bigger that artificial intelligence (AI). According to a recent Research and Markets report, more than half of all enterprise IT organizations are currently experimenting with AI in various forms - ranging from machine learning, deep learning and computer vision to image recognition, voice recognition and artificial neural networks.

The report also finds that North America is set to lead the way in the application of AI in Big Data and IoT between over the next five years - and that the AI-powered predictive analytics market will grow to around $18.5 billion over the same period.

Autonomous robots and intelligent agents are also well placed to be the top application areas, with AI expected to 'find its way into edge data devices for security and real-time data analytics.'

Trend #3: Security

In an effort to fully exploit the potential of the IIoT, many companies are likely to be driven to capture as much data as possible about how the products made in their factories are used by consumers.

Amongst other things, such data could come in useful in identifying new revenue generating opportunities or ironing out design flaws. Such increases in the flow of information between the producers and consumers of goods could well raise legitimate concerns about privacy - and customers will probably seek cast iron assurances that they can trust manufacturers to uphold the highest standards of data security.

In some cases, the upsurge in the sharing of data brought about by IIoT connectivity could also increase the vulnerability of companies to industrial espionage, cyber-attacks and information leaks. In rising to the challenge of ensuring continued data security, organizations will therefore need to devise far more sophisticated cyber-security strategies.

This is because the ever evolving fusion of the material and virtual realms introduced by the industrial internet will mean that a focus on a limited number of key locations - as is the case in many current systems - will no longer be sufficiently robust.

Instead, as pointed out by WEF and Accenture in their 2015 report, companies will need to establish new security frameworks 'that span the entire cyber physical stack, from device-level authentication and application security, to system-wide assurance, resiliency and incidence response models.'

Trend #4: Toward nationwide networks?

Another compelling trend in the world of IIoT is the move towards the establishment of integrated nationwide IoT and IIoT systems. In June 2016, the Dutch telecoms provider KPN announced that The Netherlands had become the 'first country in the world to implement a nationwide long range (LoRa) network for the so-called Internet of Things.'

The company has already inked deals to connect an estimated 1.5 million individual objects - a number that it expects to rise steadily now that the LoRa network is available across the country.

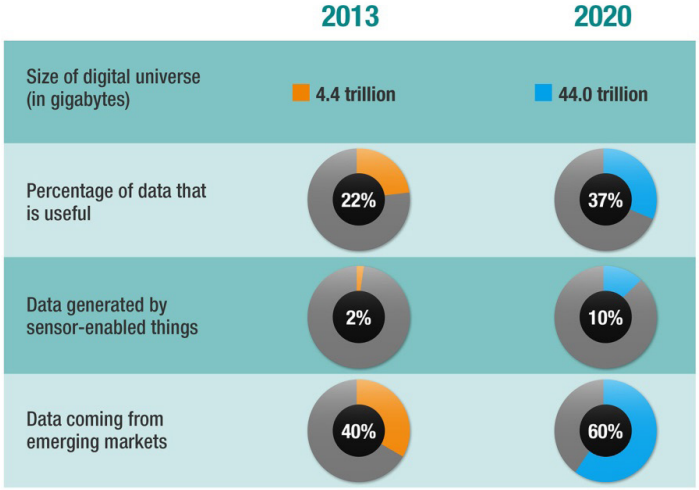
The new found levels of connectivity have already sparked a number of novel initiatives, including an experiment to use IIoT systems to handle baggage at Amsterdam's Schiphol airport - one of the continents' busiest air hubs.

Elsewhere, a scheme is already afoot to enable LoRa to monitor rail switches at Utrecht rail station and depth sounders at the port of Rotterdam have already been fitted with devices to connect them to the nationwide IoT network.

Conclusion

The IIoT: Yoking together a universe of things

Although undoubtedly still in its infancy, the analysis presented above - as well as the consensus formed in a welter of related industry reports - demonstrates that the IIoT looks set to enjoy a period of sustained growth.



Even so, those companies interested in establishing industrial internet systems will still be called upon to navigate a strange new landscape inhabited by a wide range of nascent technologies - and simultaneously come to terms with sometimes confusing terminology.

It is also difficult to deny that the IIoT holds the promise of great riches, not just in terms of financial gain -but also in relation to the potential benefits to productivity, output and industrial know how.

Despite a growing recognition of the likely benefits, it is also true to say that even the IIoT's most ardent supporters are still unaware of where, and how far, the industrial internet could eventually lead us.

Either way, the global manufacturing industry - as well as the robotics and automation sector - looks set to enter a new and exciting period, which will almost certainly shake up many existing sectors and perhaps inevitably result in a large number of winners and casualties.

In the long-run though - and with the proviso that enduring challenges relating to issues like interoperability, security, data handling and standardizations are tackled and eventually overcome - it is to be hoped that there will be rather more winners in the robotics sector than losers.

Many industry observers will also be hoping that the opportunities created by the new IIoT based industrial landscape will not be completely captured by the same old global players.

Although incumbents are sure to cash in as the burgeoning sector grows, it is perhaps likely that the biggest winners will be those companies and organizations that figure out new and innovative ways to capture value from IIoT enabled systems.

In particular, those software platform owners and partners that manage to harness the network effect inherent in the new digital business models created by the industrial internet will be perhaps well placed to generate all kinds of new value and revenue streams.

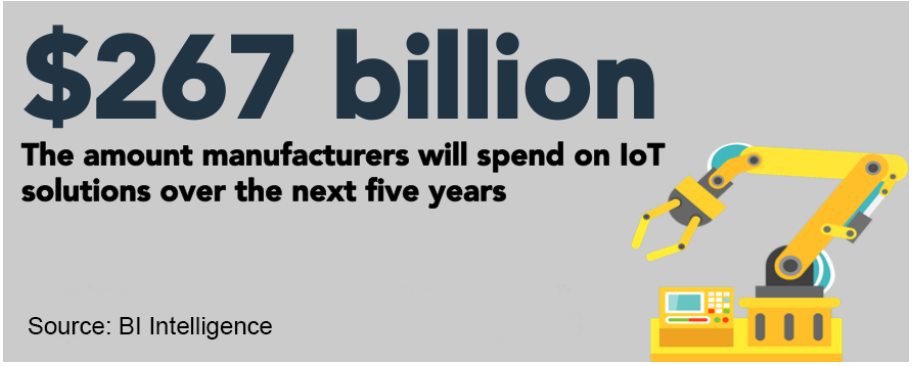
As already demonstrated in the case studies presented here, the IIoT has the capacity to reach far and wide - and in the long-run it is unlikely that any industrial sector will remain completely untouched.

As awareness of early success stories like those reported in the logistics, agriculture, health care, energy, packaging and manufacturing sectors grows, stakeholders throughout industrial supply chains - and perhaps even within and between whole sectors - will continue to make new connections and create and develop new and innovative applications.

In this way, the IIoT will continue to grow and evolve towards a future that even the most technologically literate can as yet see only dimly.

That said, despite the obvious uncertainty, the robotics sector is particularly well placed at the confluence of a variety of technological streams - including AI, cloud technologies, machine vision and big data - to enjoy a fair proportion of the likely rewards.

In this respect, there is now a need for strong leadership and vision within the global robotics sector to help in guiding the industry towards a central role in the constantly changing but ever growing IIoT.



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