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Internet of Things in Pharmaceutical Industry

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ABSTRACT

The Internet of things (IoT) is the network of physical Internet-enabled devices that enables seamless cross-device communication. Future-facing companies across most sectors are racing to deploy IoT solutions and pharma is no exception. IoT has become popular because it is all about connection. It is transforming the pharmaceutical industry. It brings a whole new set of capabilities to the pharma industry, and is helping the pharma manufacturers reduce development costs, manage their supply chain better, control quality and compliance, maintain their equipment, and accelerate the process of drug development. Whether connected inhalers, smart pills, implanted devices or wearables, new technologies bursting into the pharma space are potentially transformational for both patient outcomes and the fortunes of traditional pharma companies. This paper explores how pharmaceuticals companies can employ the Internet of things to automate and revitalize manufacturing and supply chain management.

KEYWORDS: *Internet of things, IoT, industrial Internet of things, IIoT, pharmaceutical industry*

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INTRODUCTION

Digitization of processes and data across the value chain along with the emergence of Internet of things (IoT) has transformed the pharma industry, as a core part of healthcare sector. Some early adopters have already started exploring IoT to enable end-to-end digital integration across the value chain. The early signs of IoT adoption are quite palpable with some technology giants introducing patient centricity-based mobility products. Bayer, AstraZeneca, F. Hoffmann-La Roche, Johnson & Johnson, and Sanofi are among the top companies leading in IoT hiring within the pharmaceutical industry. The US leads in IoT adoption, with significant activity in patents, jobs, and deals, while other countries like the UK, Australia, China, and India also play key roles [1]. The Netherlands and Switzerland are not too far behind,

OVERVIEW ON INTERNET OF THINGS

The concept of the Internet of things (IoT) has been around since the late 1990s, but it gained momentum in the 2000s with the rise of Internet-connected devices. The Internet began with some military computers in the Pentagon called Arpanet in 1969. It expanded throughout the 1980s as a set of four parallel military networks, each at a different security level. The core technology which gives the Internet its particular characteristics is called Transmission Control Protocol/Internet Protocol (TCP/IP), which is essentially a set of rules for communication [2].

Internet of Things (IoT) is a worldwide network that connects devices to the Internet and to each other using wireless technology. IoT is expanding rapidly and it has been estimated that 50 billion devices will be connected to the Internet by 2020. These include smart phones, tablets, desktop computers, autonomous vehicles, refrigerators, toasters, thermostats, cameras, alarm systems, home appliances, insulin pumps, industrial machines, intelligent wheelchairs, wireless sensors, mobile robots, etc. Figure 1 illustrates the Internet of things [3].

There are four main technologies that enable IoT [4]: (1) Radio-frequency identification (RFID) and near-field communication, (2) Optical tags and quick response codes: This is used for low cost tagging, (3) Bluetooth low energy (BLE), (4) Wireless sensor network: They are usually connected as wireless

sensor networks to monitor physical properties in specific environments. Communications technologies in Internet of things are portrayed in Figure 2 [5].

IoT technology enables people and objects to interact with each other. It is employed in many areas such as smart transportation, smart cities, smart energy, emergency services, healthcare, data security, industrial control, logistics, retails, structural health, traffic congestion, manufacturing, and waste management. The Internet of things is extensively developed world-wide with a focus on civilian applications such as electric power distribution, intelligent transportation, healthcare, industrial control, precision agriculture, environmental monitoring, etc.

INDUSTRIAL INTERNET OF THINGS

The growth of the internet of things (IoT) is drastically making impact on home and industry. While the IoT affects among others transportation, healthcare, or smart homes, the Industrial Internet of Things (IIoT) refers in particular to industrial environments. IIoT is a new industrial ecosystem that combines intelligent and autonomous machines, advanced predictive analytics, and machine-human collaboration to improve productivity, efficiency and reliability. It is bringing about a world where smart, connected embedded systems and products operate as part of larger systems [6].

The industrial Internet of things (IIoT) refers to the application of the Internet of things (IoT) across several industries such as manufacturing, logistics, oil and gas, transportation, energy/utilities, chemical, aviation and other industrial sectors. A typical industrial Internet of things is shown in Figure 3 [7].

IIoT is often used in the context of Industry 4.0, the Industrial Internet and related initiatives across the globe. Industry 4.0 describes a new industrial revolution with a focus on automation, innovation, data, cyber-physical systems, processes, and people [8]. With Industry 4.0, the fourth industrial revolution is set on merging automation and information domains into the industrial Internet of things, services, and people. The communication infrastructure of Industry 4.0 allows devices to be accessible in barrier-free manner in the industrial Internet of things, without sacrificing the integrity of safety and security [9].

PHARMACEUTICALS

The pharma industry is facing the biggest transformation since the rise of the modern medicines in the nineteenth century. Healthcare payers and other customers of pharma companies are demanding more and better data on the medication efficacy and improved patient quality of life. These demands cannot be fulfilled by purely traditional means. The increasing price pressure caused by the tightening market price regulations and patent expirations is forcing pharma companies to challenge their current product and market strategies in order to survive.

The Internet of things describes devices that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices. IoT has made a massive effect on many industries worldwide. Essentially, it allows all of the devices within your organization to effectively "talk" to each other, using the data that they collect. Digital solutions are not new for the pharma industry, but embracing the power of IoT is something that is a focusable point. IoT can revolutionize the pharmaceutical sector by offering a bunch of benefits that bring digitalization and increase efficiency and help to achieve pharma 4.0. Figure 4 shows a typical representation of IoT [10].

The pharmaceutical industry has been rather conservative in adopting technological change. IoT has contributed to improving the entire supply chain process and logistics monitoring and boosting overall productivity cost-effectively. There are two broad areas where the IoT could have a significant impact on the pharma industry: production and administration of pharmaceuticals. Key factors driving the IoT in pharmaceuticals include active patient engagement and remote patient care, a much-needed solution especially during the pandemic when staying home and safe is the new mantra for healthy living. Figure 5 best illustrates different components of the pharmaceutical industry [11].

APPLICATIONS OF BIG DATA IN PHARMACEUTICALS

The Internet of Things (IoT) is a framework that comprises physical things that have sensors mounted on them. Pharma companies are leveraging new Internet of things (IoT) technologies through recent patents to innovate and improve their businesses. IoT offers substantial value across the entire pharmaceutical manufacturing value chain, from research and development, production, supply chain, predictive maintenance, to patient care. Some fast growing IoT applications across the pharma value chain include the following [12]:

- *Clinical Trials:* Clinical trials are prone to costly failures to recruit patients or meet desired timelines. Some trials are using Internet-equipped mobile devices to collect biometric data remotely. Remote data collection allows clinical trials to increasingly take place in "real world" settings,

letting participants go on with their daily lives with minimal disruption. An example of a company taking advantage of this IoT tech in clinical trials is Novartis, who partnered with Qualcomm to evaluate lung disease interventions. Clinical trials are prone to costly failures to recruit patients or meet desired timelines.

- *Pharmaceutical Manufacturing:* Manufacturing, in general, finds IoT as a useful addition to its setup. It is already a major area for pharma IoT implementation. The pharmaceutical manufacturing industry is enormous. It comprises complicated supply chains and over-particular chemical processes and products that must always meet stringent quality controls. The industry is adopting IoT technologies in their manufacturing plants to improve the efficiency of their machines and processes and improve efficiency. IoT has made the lives of manufacturers a whole lot easier with its unprecedented power, unparalleled benefits, and limitless potential. Pharma companies use IoT technologies in manufacturing plants to aid in the process of continuous manufacturing. Many pharma manufacturers around the globe have gradually started utilizing its potential to revolutionize all aspects of their manufacturing processes. Almost a third of the top 20 pharma companies in the US have started introducing IoT tech in their manufacturing processes. For example, Microsoft's IoT Azure hub provides a centralized overview of manufacturing performance. These sensors can instantaneously feed all relevant facility data into a single dashboard. Manufacturing machinery embedded with sensors provides data from the equipment failure to the manufacturer on which they can decide if the equipment requires proactive maintenance. Figure 6 shows a typical pharmaceutical manufacturing [13], while Figure 7 depicts IoT in pharmaceutical manufacturing [14].
- *Drug Development:* One of the biggest IoT applications in pharmaceutical industry is the acceleration in R&D and drug discovery. The adoption of IoT in pharmaceutical industry is seen as a massive breakthrough for fastening and streamlining drug trials and preventing major concerns across the medical industry, such as drug counterfeiting. Accelerating drug development is necessary but pharmaceutical companies cannot help but produce drugs in batches. Figure 8 shows some drugs [15], while Figure 9 displays IoT in pharma supply chain [16].
- *Smart Pills:* Leading pharmaceutical companies are using smart devices to administer medications and monitor their effect on patients. This includes the delivery of medications or medical monitors in "smart pills." Smart pills or implanted devices are IoT-enabled pills that can help diagnose ailments without requiring invasive procedures. These little but powerful electrical devices are administered to patients through an ingestible medicinal capsule that works in multiple ways. These smart pills include bio or chemical sensors and can collect information throughout the body. After giving crucial diagnostic imaging and data, these pills are flushed out of the body through the digestive system. Cell-in-a-Chip and Organ-in-a-Chip, for example, are tiny laboratory trays developed from tissue engineering research that not only allow for experiments but also transmit the data results of what happened in the chip after the pharmaceutical compound was deposited. Organ-in-a-chip (OOAC) is an IoT-enabled micro-scale biomimetic system that replicates the structural and functional properties of human tissue.
- *Supply Chain:* Supply chains keep our economies pumping. Every time a cargo use airways, waterways, or roadways to transport goods from one point on the map to another, it is a collaborative effort of many people, and a lot can go wrong. Even a minor delay in the pharma can be highly disruptive. Any deviation from the product-specific requirements can compromise the quality and effectiveness of sensitive products. IoT-based technologies help to avoid potential disasters in such situations too. Supply chain management is a highly complex process that overlooks the entire lifecycle of a product, from raw materials to its final state. Application of IIoT provides much-needed transparency, control, and automation. Therefore, IIoT is used increasingly for complex business processes.

BENEFITS

IoT offers added quality, agility, and value to the business. Not only is IoT rapidly changing the patient experience, but also is making a dramatic difference in other areas of the industry such as R&D, clinical development, and supply chain. Integrating the medical Internet of things (IoT) into your existing technical foundation helps improve overall efficacy and keep your entire organization connected. By connecting the devices your organization already uses to an IoT network, you can quickly generate useful information specific to the markets, providers, and patients you serve. Other benefits of IoT in the pharmaceutical industry include the following [17]:

- *Cost Savings:* This will be attained throughout the value chain. Cost reduction will be achieved through savings attained in clinical trial phase as a result of continual feedback on subject diagnostics and monitoring using sensors, faster subject screening and analysis. Savings will also come from improved inventory planning reducing obsolescence cost and risk. The improved logistics planning will help in reducing redundant costs that was incurred due to wastages and incorrect supply. This will help bring down overall drug costs as well.
- *Improved Quality:* With smart systems, there will be a better control on precision and quality of drug produced and error rate would be reduced drastically. The smart systems in patient access phase will help improve quality of care
- *Better Compliance Adherence:* Smart devices will enable real-time data reporting to central systems. This will make the monitoring live and exceptions can be responded to
- *Lesser time to Market:* The real-time data reported across value chain components can be used for generating business value insights for leadership teams, thus resulting in near real-time decision making. The required feedback and changes related to drug research, efficacy, adoption, patient outcomes, etc. can also be easily percolated back to the systems. The efficiency improvement will optimize the time to market.
- *Patient-centered Care:* IoT technology can bring care to patients, creating more comfortable and positive patient experiences. The IoT is already being productively tapped to enhance patient care in numerous ways. Data reported by patients or gathered automatically from IoT-equipped devices help healthcare professionals understand their conditions holistically. Remote data collection helps providers quickly respond to negative side effects, rather than waiting until a catastrophic event. Increased connectivity brought by the IoT also allows patients and providers to communicate more directly.
- *Wearable Devices:* For pharma companies, wearable devices are a powerful tool to gather data, track medication adherence, and identify potential adverse medication side effects. IoT-enabled devices include popular consumer electronics as well as tiny devices such as sensors that attach to a tooth to monitor diet and food consumption. Some of the most popular devices have already been proven to help predict heart disease complications and other conditions, including diabetes, nutritional deficits, and more. They are also increasingly useful in clinical trial data gathering.
- *Predictive Maintenance:* Application of IoT in pharma facilitates predictive maintenance. By having connected devices at the plant floor, manufacturers can get real-time status information about the equipment with the help of monitoring sensors. This data can proactively alert the plant managers for any abnormal condition or necessary maintenance requirements.
- *Internet of Medical Things* (IoMT): This is a collection of medical devices and applications that connect to healthcare information technology systems by creating a network of devices, wearables, and healthcare systems connected to collect and exchange medical data, with the aim of remote monitoring and diagnosis. While IoT devices are typically more consumer-oriented, IoMT devices and applications are designed with healthcare in mind specifically. Integrating the medical Internet of things (IoT) into your existing technical foundation helps improve overall efficacy and keep your entire organization connected.
- *Automation:* While up to 40% of workers spend a large portion of their time on repetitive and routine tasks, automation can remove this burden. Industrial IoT applications include automation to reduce overhead costs, increase productivity, and improve employee satisfaction. Businesses can automate and increase the operational efficiency of their manufacturing processes. Paper-based methods of data gathering are bound to lead to human mistakes and inconsistencies. Data collection automation relieves employees from performing manual activities associated with capturing and storing information. For pharma businesses, devices that automate functions, save money, increase efficiencies, and make life easier will be the simplest business cases to establish and implement.
- *Warehousing:* This is a crucial area for the pharmaceuticals industry. Most companies manage a large number of storage facilities across countries to ensure a continuous and timely supply of essential medicines in a cost-efficient manner. Keeping warehouse operations in-house is a strategic decision for most pharma companies. Smart warehouses can increase visibility and efficiency by relaying metrics and real-time data to warehouse managers and technicians.

CHALLENGES

Implementing an IoT ecosystem is not hassle free. Adopting IoT systems as a pharmaceutical company can provide many opportunities but achieving success can be difficult. Developing smart technology can be very costly. As such, pharma companies should always be open to the possibility that a device might not be the best approach. Other challenges of IoT in the pharma industry include the following [18]:

- *Privacy and Security:* With the increasing use of data analytics, artificial intelligence, IoT, and other advanced technologies, the pharma industry is generating vast amounts of data. Ensuring data privacy and security is a major challenge, as the data is often sensitive and subject to regulatory scrutiny.
- *Cost:* Implementing IoT technologies requires a significant investment in infrastructure, software, and talent. Cost is a significant challenge for smaller pharma companies or those with limited resources.
- *Legacy Systems:* Many pharma companies still rely on outdated systems that cannot easily integrate with new digital technologies. Integrating legacy systems with modern digital technologies is a significant challenge that requires careful planning and execution.
- *Talent Acquisition and Retention*: Implementing IoT in pharma industry requires a new set of skills. Attracting and retaining top talent with these skills is a significant challenge for pharma companies.
- *Intellectual Property Protection*: With the increasing use of digital technologies in pharma, there is a growing concern over the protection of intellectual property. Ensuring that intellectual property is adequately protected is a significant challenge that requires ongoing attention. Patents can be applied for when it comes to the algorithms of AI systems or the hardware components that enable them to function.
- *Regulation:* The pharmaceutical industry has undergone several changes which are often introduced and enforced by regulatory bodies. Pharmaceutical companies deal with tight regulations and have a responsibility to protect patient health. This can make implementing new technology challenging. Pharma monitoring along the entire supply chain is an essential element of maintaining FDA and regulatory compliance. Pharmaceutical production processes have to be well-documented to establish and maintain consistent regulatory compliance.
- *Collaborative Culture:* Two of the largest roadblocks in successful deployment of IoT are legacy tech and a company's sheer size. Pharma companies tend to be used to working in isolation from one another, with a somewhat siloed workplace culture. However, the complexity of IoT tech and the interconnected nature of big data means companies are much more likely to succeed if they are willing to work with other organizations. In practical terms, CEOs and senior decision-makers are going to have to place a lot more trust in their tech teams and support a collaborative culture.

CONCLUSION

The Internet of things has taken the world by storm. Today, everything from your phone in your pocket to the car you drive has turned into smart, connected products. Internet of Things is a reality in today's era of digitization and, therefore, it deems fit that pharma companies adopt it at the earliest. IoT plays a significant role in the pharmaceutical supply chain. From improved drug discovery to smart inventories, IoT can help companies optimize their operations, reduce downtime, and ensure regulatory compliance.

The pharma industry had been more reactive than proactive in technology adoption, primarily because of tight regulations and domain complexities. In the pharmaceutical industry, mistakes have serious consequences, so progress will always have to be slow and cautious. More information about Internet of things in the pharmaceutical industry can be found in the books in [20-22] and the following related journals:

- International Journal of Pharmaceutics
- IEEE Internet of Things Journal

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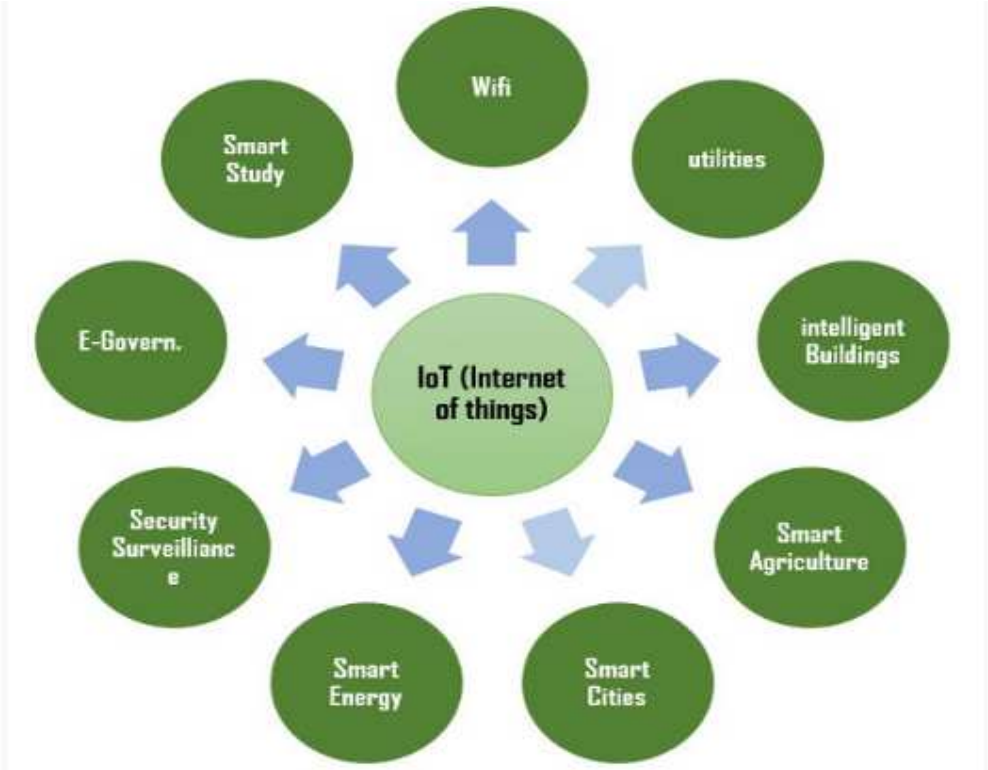

Figure 1 The Internet of things [4].

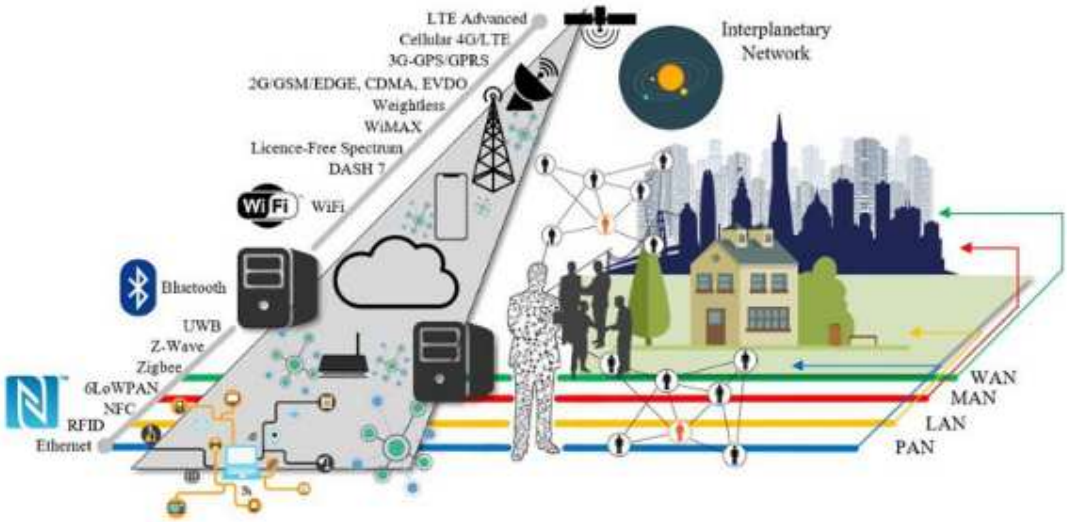

Figure 2 Communications technologies in Internet of things [5].

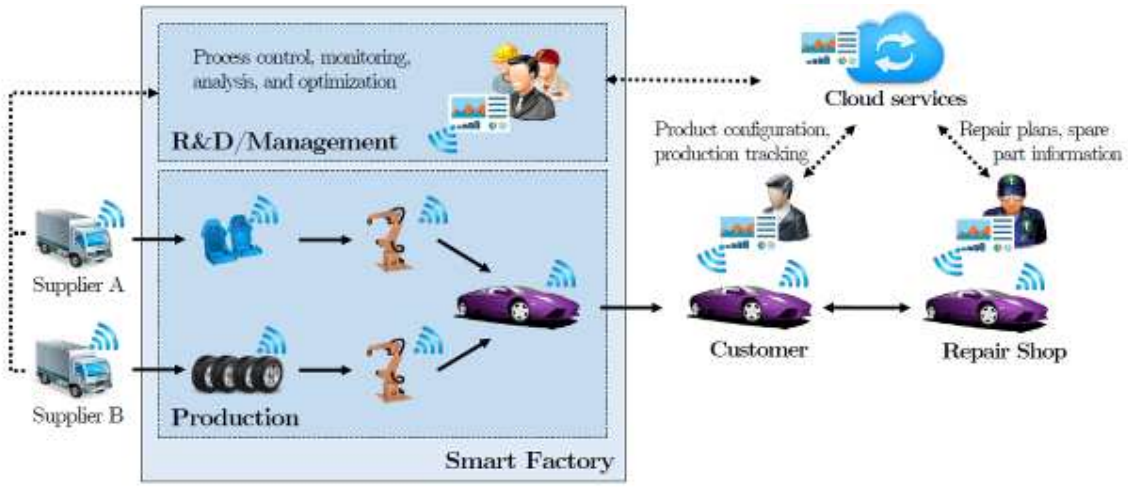

Figure 3 A typical industrial Internet of things [7].

Figure 4 A typical representation of IoT [10].

Figure 5 Different components of the pharmaceutical industry [11].

Figure 6 A typical pharmaceutical manufacturing [13].

Figure 7 IoT in pharmaceutical manufacturing [14].

Figure 8 Some drugs [15],

Figure 9 IoT in pharma supply chain [16].