International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 9 Issue 1, Jan-Feb 2025 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Internet of Things in Architecture

Matthew N. O. Sadiku[1], Paul A. Adekunte[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]International Institute of Professional Security, Lagos, Nigeria
[3]Juliana King University, Houston, TX, USA

ABSTRACT

The Internet of things (IoT) is a term that describes a wide variety of devices that connect to computer networks such as the Internet. IoT consists of network-enabled devices embedded with sensors and connected to the Internet. It is about turning physical objects into smart objects. It connects sensor-based objects to a shared infrastructure. It is expanding rapidly. IoT devices and systems are everywhere, from the smartphones we carry with us, to the devices managing our home's temperature or lights. IoT devices and connectivity are impacting the architecture industry in several ways. This paper covers the IoT applications in the architecture industry.

KEYWORDS: *Internet of things, IoT, industrial Internet of things, IIoT, architecture*

How to cite this paper: Matthew N. O. Sadiku | Paul A. Adekunte | Janet O. Sadiku "Internet of Things in Architecture" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-9 | Issue-1, February 2025, pp.294-302, URL: www.ijtsrd.com/papers/ijtsrd73861.pdf

IJTSRD73861

INTRODUCTION

IoT connects sensor-based objects to a shared infrastructure. This infrastructure can be an extranet, the Internet, or a network that eliminates the need for a human-to-computer interaction to exchange data. The purpose of architecture is to serve the people and make day-to-day life more manageable. We can currently link almost every device to the Internet to provide new ways of easing our lives. IoT devices monitor everything from manufacturing equipment status to trends on social media. Your smartphone, your smartwatch, and your digital thermostat are all part of the Internet of things, meaning that they are all devices that connect to the Internet, and through the Internet, connect to each other and enable mutual communication. These devices connect to a larger computer network to transfer critical information.

The Internet of things has transformed how we interact with the world and how we use and retrieve information. For many people, the most relatable examples of IoT devices are items in the home like home voice controllers, doorbell cameras, and smart TVs. For example, the electric meters that allow professionals to read your meter remotely are IoT devices. In the construction and architecture fields, IoT devices in cameras and drones can monitor worksites, generate advanced digital renderings of building projects, and more [1].

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 various applications of 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]. Figure 4 shows a typical representation of IoT [10].

APPLICATIONS OF IOT IN ARCHITECTURE

Internet of things (IoT) is a reference to a network of connected devices and objects which have the capacity to gather information and share that data over the Internet. Like everything with the Internet of things, the use options are truly endless. Here are a few common ways the IoT in architecture and design is already making our lives easier [11,12]:

- *Smart Buildings:* Due to their ability to control their own environment, smart buildings depend on a variety of sensors to regulate everything from temperature to lighting and security. Buildings are moving from passive assets to active built environments by becoming "smart." Smart or intelligent buildings are the most promising field of application for IoT. They provide much control over the environment and functions. They lead to the creation of highly efficient, high-capacity collaborative workspaces, where a smart system centralizes data from separate devices into a single one. Intelligent buildings can interact, learn and adapt by connecting people with technology and the environment. They have lent support to energy conservation and environmental goals as well. As an exemplary smart building, Salesforce Tower in San Francisco, is shown in Figure 5 [11]. The building considers sustainability the main design feature and allows tenant employees to work wherever in the building. A smart building may use a IoT-powered rooftop solar panels that can support all of the building's power needs, as typically shown in Figure 6 [1].
- *Smart Contracts*: A smart contract for a smart building is a digital agreement that automatically executes based on predetermined operations in your facility. It guides all the stakeholders involved in your building functions. By partnering with contractors or vendors through smart contracts, you can invest in smart systems and devices for various building functions.
- *Smart Homes:* A home is considered smart when all of the home's technical components are merged into a unified, intelligent system. The smart home is a concept to manage and simplify the usage of all technical equipment to create comfort, safety, and pleasure in one's own home.

IoT in architecture enables smart homes to use a centralized system to control many devices. Smart homes contain a single automated system, linking all the devices such as a smartphone, tablet, laptop, door locks, cameras, lights, televisions, thermostats, house monitors, and even appliances like refrigerators as parts of the IoT technology. IoT plays a critical role in maximizing home security, remote controlling the home functions, and home management insights, making it a necessity rather than a facility. One of the main benefits of smart homes is that it facilitates the elderly living alone. A typical smart home is illustrated in Figure 7 [11].

- *Smart Cars:* These refer to cars that can programmatically regulate speed and steering and rely on the human driver to take over in abnormal situations, such as when bad weather interferes with the car's sensors. Smart car ambition is directly driven by IoT, which will enable cars to become integrated carriers of digital transformation as more sensors, processors, and software are added to them. Currently, designers are searching for smart environmentally-friendly cars with low running costs. An example of a smart car is shown in Figure 8 [11].
- *Construction:* Traditionally, construction sites were isolated from offices, companies, and logistics chains. As a result, much time is wasted on every project due to unexpected delays and miscommunication. IoT is a powerful technology for changing industries, automating processes, and increasing return on investment. IoT technology has a lot to offer to the construction industry as it is a ready-to-change industry due to its challenges. IoT automates tasks that waste human hours. It functions in diverse construction fields, mostly with project progress tracking, like tracking material deliveries to the construction site or using wearable technologies to track employee movements to ensure they work efficiently. Figure 9 shows a typical construction site [11].
- *Site Monitoring*: When it comes to the Internet of things on the building site, think about sensors. IoT devices that monitor construction site conditions, automate tasks, and track deliveries connect these work sites to vital information. The devices attached and monitored with the IoT software and techniques can monitor calculations of humidity, temperature, and pressure to alert management about any potential happening that could cause damage and that needs immediate attention. Not only can IoT devices monitor your structures, they can also help keep your personnel safe.
- *Remote Monitoring*: IoT enables remote monitoring and notification by leveraging security systems like CCTV, access controls, and remote monitoring technologies. Ultimately, it helps promote building security and occupant safety. For advanced surveillance, one needs to equip smart building with networked cameras and sensors through IoT.
- *Equipment Tracking:* Small sensors can be easily connected to apps via the Internet of things, meaning that you can track and monitor a wide array of things. Affixing an IoT sensor to your tools makes them traceable in case of loss or theft. For example, if you work with prefabricated building sections, you can easily use the IoT to know the precise location of every piece.
- *Building Information Modeling:* 3D building information modeling (or BIM) have become increasingly popular, as part of IoT in architecture and design, and are increasingly useful for engineers and builders. The integration of BIM and the Internet of things shows a great deal of promise.
- *Motion Detection:* Sensors that detect motion and vibration in large-scale structures can be used to help recognize dangerous situations and natural disasters before injury and loss of life occur. For example, specific disturbances that lead to catastrophic failures in bridges, dams, and buildings could be recognized before they occur.

BENEFITS

IoT is impacting architecture, construction, and engineering in a major way. IoT applications are making life simpler and more efficient. IoT a vital tool for the future for those working in the green building space. IoT ensures data centralization, regulatory compliance, and sustainability by consolidating information from various systems into a single platform. Other benefits include [13]:

- *Reliability and Resilience:* Consider the criticality of the IoT systems and data involved in the potential IoT solution. What level of downtime, if any, is an acceptable risk? What level of redundancy, failover, and disaster recovery capabilities are required? The answers to these questions will be unique to each organization.
- *Data Management:* Consider how the IoT solution handles data management, storage, processing, and analytics. Evaluate the scalability, performance, and flexibility of the data storage

and analytics components to derive actionable insights, make informed decisions, and optimize processes based on IoT data.

- *Automation:* Another major strength of the IoT is the ability to automate devices using data, like the data collected by sensors. IoT automates various systems in your building by integrating smart devices like sensors and meters. This automation can reduce manual work and accelerate plumbing, electrical, and HVAC system functions. IoT offers the benefits of automation for different processes and operations in industries.
- *Green Buildings:* The IoT has become a favorite tool of designers of green buildings. IoT in engineering can help buildings reach higher standards of functionality, safety, and environmental responsibility. IoT can also create advanced structures that are safer and more environmentally friendly. In today's business landscape, investing in green technology is best for saving money and improving operations. When it comes to this, the IoT can be a viable solution.
- *Efficiency:* IoT systems, including smart thermostats and meters, offer precise energy control and monitoring. They can enhance efficiency and sustainability in any property. By regulating energy consumption, these systems not only reduce utility bills but also improve ambiance, occupant comfort, and overall operations. Investing in energy-efficient devices and systems is crucial. Cutting-edge IoT technologies like intelligent lighting and dynamic glass enhance your building's aesthetics and functionality, ultimately increasing its overall value. Smart buildings are not only highly functional but are visually attractive, as typically shown in Figure 10 [1].

CHALLENGES

Although IoT adoption is transforming industries like agriculture and manufacturing, the increased connectivity also brings significant security risks. For IoT in architecture to work properly, the mass connectivity of several devices must be carefully managed so they work seamlessly together. When implementing IoT applications in architecture, major challenges include security concerns due to the vast network of connected devices, lack of standardization across different protocols and devices, managing large volumes of data, ensuring reliable connectivity, power constraints for battery-operated sensors, and addressing privacy issues related to collected data. Other challenges include the following [14]:

- *Security:* Data collection is one of the features of IoT technology, however, managing this data can lead to data security and privacy challenges. Security is a critical consideration for IoT solutions to protect data, devices, and networks from cyber threats, unauthorized access, and privacy breaches. Evaluate the security features and protocols implemented in the solution, including encryption, authentication, access control, secure bootstrapping, and firmware updates. Device-level security involves the integration of special safeguards in the firmware and hardware for IoT networks.
- *Privacy Concerns:* Privacy concerns refer to issues related to the collection, storage, use, and sharing of personal information. This can include concerns about who has access to personal information, how it is being used, and whether it is being protected from unauthorized access or misuse. In the digital age, privacy concerns have become increasingly important as personal information is being collected and stored on an unprecedented scale. To address privacy concerns, individuals and organizations need to implement appropriate security measures to protect personal information, be transparent about how it is being used, and respect individuals' rights to control their own information.
- *Zero Trust:* The need for zero trust IoT security is readily apparent when considering Industrial IoT (IIoT) use cases. Implementing zero trust IoT architecture is crucial for protecting networks by ensuring only secure, explicit connections between devices and resources. With only explicit connections from a user to a resource being allowed, IoT zero trust standards are critical for ensuring modern cellular and wide-area network (WAN) security. Zero trust architecture uses site-to-site encryption and can include IoT remote access functions to provide secure communication across sites, vehicles, devices, applications, users, and the cloud.
- *Lack of Standard:* There is lack of a single, unified standard for data communication and management. Without mandatory IoT standards, security continues to be an area for improvement for many organizations. Different manufacturers use diverse protocols and standards for their IoT devices, making integration difficult and complex.
- *Scalability*: Managing the increasing number of connected devices as an IoT system expands can

be challenging. Consider how a potential IoT solution will accommodate future growth, including not only actual data volume and usage, but also the number of IoT devices and types of devices used, as well as the complexity of the applications used and analysis being conducted.

- *Interoperability:* It is essential to choose interoperable IoT solutions based on open standards, not closed proprietary technologies. Interoperability facilitates the integration of new sensors and connected devices as needs evolve. It provides more flexibility to evolve installations over time.
- *Power Management:* This involves optimizing battery life for battery-powered sensors, especially in applications requiring long-term monitoring. It also involves balancing data collection frequency with power consumption.
- *Vulnerability:* Vulnerability to network attacks refers to the susceptibility of a network, system or device to being compromised or exploited by cyber criminals. This can happen due to weaknesses in the network infrastructure, unpatched software, poor password management, or a lack of appropriate security measures. Network attacks can result in data theft, loss of privacy, disruption of services, and financial loss. To reduce vulnerability to network attacks, it's important to implement strong security measures such as firewalls, encryption, and regular software updates.

CONCLUSION

The Internet of things is a set of rapidly evolving technologies. It shows exciting promise for revolutionizing the functions of architecture, construction, and engineering (ACE) in several ways. It is changing the architecture and design trades. The IoT technology has revolutionized how we design and build modern buildings. The IoT in architecture, design, and construction will shape processes and the outcomes as we move into the future. More information about Internet of things in the architecture industry can be found in the books in [15,16] and the following related journal: *IEEE Internet of Things Journal.*

REFERENCES

[1] "IoT applications for smart buildings: Use cases and top benefits," June 2024, https://www.digi.com/blog/post/iot-applications-for-smart-buildings-use-cases-and

[2] M. Townes, "The spread of TCP/IP: How the Internet became the Internet," *Millennium: Journal of International Studies*, vol. 41, no. 1, 2012, pp. 43 –64.

[3] "Internet of things (IoT)," https://www.geeksforgeeks.org/internet-things-iot-2/

[4] M. N. O. Sadiku, and S.M. Musa and S. R. Nelatury, "Internet of things: An introduction," *International Journal of Engineering Research and Advanced Technology*, vol. 2, no.3, March 2016, pp. 39-43.

[5] P. Sadeghi et al., "Towards a reliable modulation and encoding scheme for Internet of things communications," *13th IEEE International Conference on Application of Information and Communication Technologies (AICT),* October 2019, https://www.researchgate.net/figure/Communications-Technologies-in-Internet-of-Things_fig1_335104959

[6] M. N. O. Sadiku, Y. Wang, S. Cui, and S. M. Musa, "Industrial Internet of things," *International Journal of Advances in Scientific Research and Engineering*, vol. 3, no. 11, Dec. 2017, pp. 1-4.

[7] A. R. Sadeghi1, C. Wachsmann, and M. Waidner, "Security and privacy challenges in industrial Internet of things," *Proceedings of the 52nd Annual Design Automation Conference*, June 2015.

[8] "The industrial Internet of things (IIoT): The business guide to Industrial IoT," https://www.i-scoop.eu/internet-of-things-guide/industrial-internet-things-iiot-saving-costs-innovation/

[9] D. Schulz, "FDI and the industrial Internet of things," *Proceedings of IEEE 20th Conference on Emerging Technologies & Factory Automation*, 2015, pp. 1-8

[10] J. Rahm, "Internet of things in the manufacturing industry," April 2017, https://blog.flexlink.com/internet-of-things-in-the-manufacturing-industry/

[11] S. Shakeri, "Top 7 IoT applications in architecture and design," January 2022, https://parametric-architecture.com/top-7-iot-applications-in-architecture-and-design/?srsltid=AfmBOoqjg-zqmBLzpm0gI_lqAPP8IBvG-B_oNZ_wguMHJjnCGyrgKpDG#google_vignette

[12] "How the Internet of things (IoT) is shaping architecture, design, and construction," https://largeformat.hp.com/au/blog/how-the-internet-of-things-iot-is-shaping-architecture-design-and-construction

[13] "IoT architecture explained," https://www.mongodb.com/resources/basics/cloud-explained/iot-architecture

[14] "Challenges in Internet of things (IoT)," February 2023, https://www.geeksforgeeks.org/challenges-in-internet-of-things-iot/

[15] M. N. O. Sadiku, *Internet of Things and Its Applications.* Moldova, Europe: Lambert Academic Publishing, 2024.

[16] P. Lea, *Internet of Things for Architects: Architecting IoT Solutions by Implementing Sensors, Communication Infrastructure, Edge Computing, Analytics, and Security*. Packt Publishing, 2018.

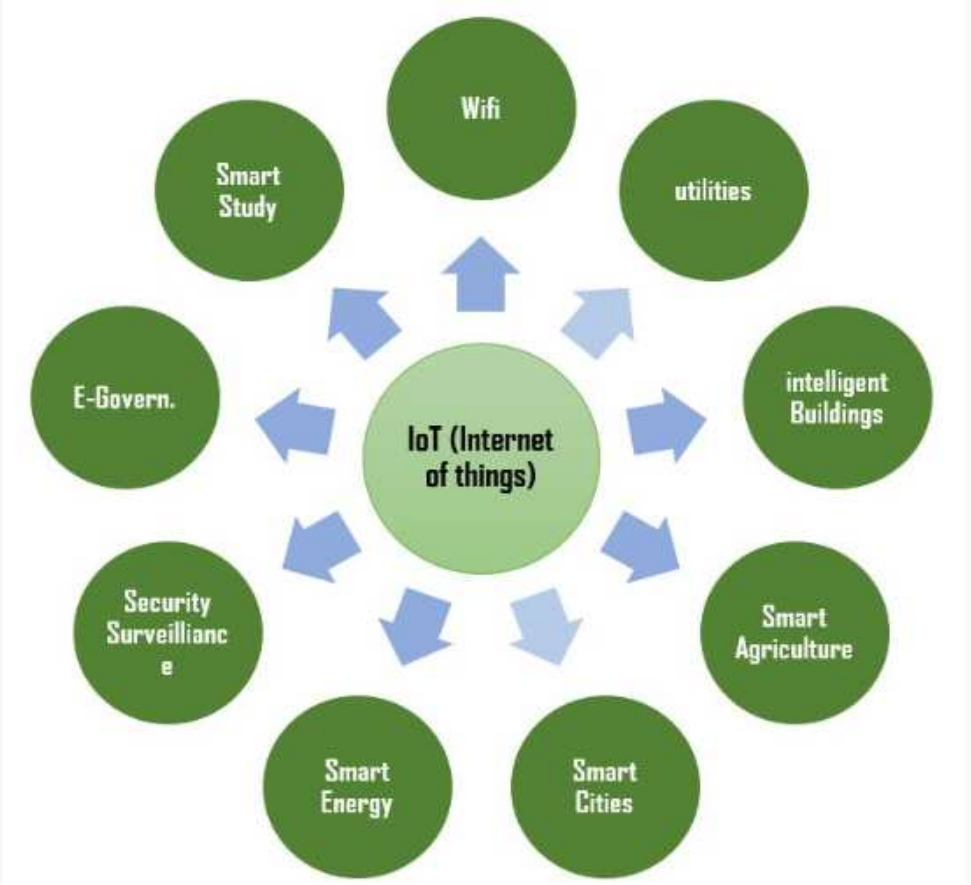

Figure 1 Applications of the Internet of things [4].

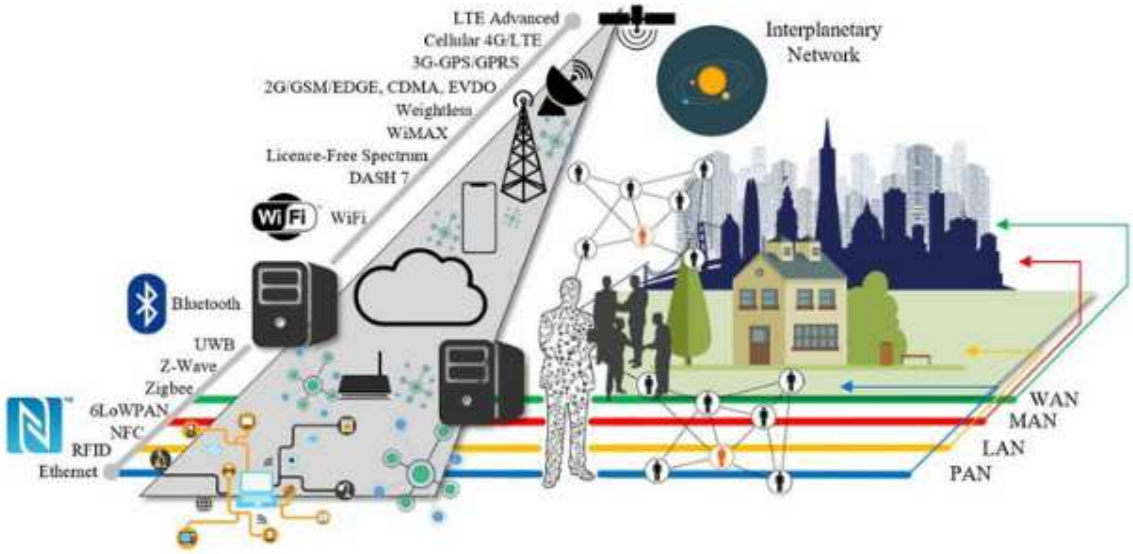

Figure 2 Communications technologies in Internet of things [5].

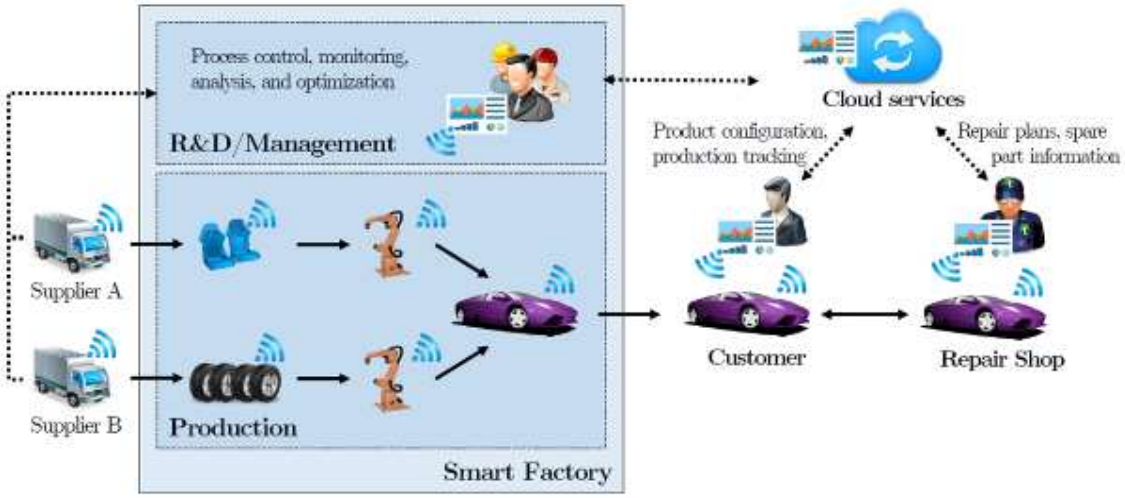

Figure 3 A typical industrial Internet of things [7].

Figure 4 A typical representation of IoT [10].

Figure 5 A typical smart building (Salesforce Tower in San Francisco) [11].

Figure 6 A smart building with IoT-powered rooftop solar panels [1].

Figure 7 A typical smart home [11].

Figure 8 An example of a smart car [11].

Figure 9 A typical construction site [11].

Figure 10 Visually attractive smart buildings [1].