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Internet of Things in Logistics

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Abstract:

The Internet of things (IoT) refers to the billions of physical devices around the world that are now connected to the Internet, all collecting and sharing data. It is a paradigm where physical objects, devices, and machines are embedded with sensors, software, and network connectivity to collect, exchange, and act upon data. The logistics sector is one of the domains where IoT has emerged as a formidable force, propelling innovation, efficiency, and transformation. IoT in logistics represents the integration of physical devices within the logistics and transportation industry network that communicate and exchange data without human intervention. IoT enables devices like sensors, vehicles, and equipment to connect over the Internet, creating a more dynamic, responsive, and interconnected logistics environment. In this paper, we will dig deep into the applications, benefits, and future trends of IoT in the logistics sector.

Keywords: Internet of things, IoT, industrial Internet of things, IIoT, logistics, transportation, supply chain.

INTRODUCTION

Technology has become the backbone of supply chain management, propelling logistics companies into a new era of efficiency and connectivity. Logistics is the art and science of managing the flow of goods and services from their point of origin to their point of consumption. It encompasses a complex web of activities, including transportation, warehousing, inventory management, order fulfillment, and more. For packages to successfully travel from fulfillment to the end consumer, it requires harmony between technology, processes, systems, and people. As shown in Figure 1, logistics is part of the supply chain management [1]. Today, the fast-pacing global market of goods requires businesses of all industries to be prompt and flexible in their production, delivery, and other operations. The best solution that modern IT companies can suggest is utilizing the Internet of things.

Internet of things (IoT) is a transformative force reshaping the fabric of logistics and transportation. It has evolved beyond a mere concept to become a powerful force that is reshaping industries, including logistics, in profound ways. IoT is essentially about enabling "things" to talk to each other, collect data, and make intelligent decisions without human intervention.

OVERVIEW OF 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. These devices contain hardware such as sensors and electronics which give them the ability to interact with other objects and to be monitored and controlled from afar. The idea is that the physical devices with sensors or the ability to capture data, shares that data with websites. The information is then used or analyzed in real time or at a later time, to create efficiencies. 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 2 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 3 [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.

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 4 [7].

IOT IN LOGISTICS

The transportation and logistics sector is at the core of economies around the world. It acts as a medium that facilitates the movement of people, goods, and products from one location to another. Logistics is the backbone of global trade and commerce, ensuring that products reach their intended destinations efficiently and cost-effectively. Logistics is a highly complex sector, which can profit

with the help of Internet of things technology. IoT technology can help businesses in transportation and logistics tackle their biggest challenges around visibility, agility, and sustainability. IoT in logistics encompasses diverse technologies that enable comprehensive monitoring, communication, and automation across supply chain operations. IoT logistics technologies form the foundation for next-generation supply chain management systems that deliver measurable business value. Figure 5 is a representation of IoT in logistics [1].

Implementing IoT technology in logistics requires careful planning and execution. IoT in logistics involves the use of IoT devices, such as sensors, GPS trackers, and RFID tags, to collect and transmit data in real-time. This data can be used to track shipments, monitor inventory levels, optimize routes, etc. IoT devices can help reduce waste, schedule maintenance proactively, and maintain optimal fleet utilization, leading to cost savings. IoT-enabled GPS tracking transforms the way shipping containers and maritime fleet tracking are managed and monitored globally. IoT solutions are not limited to tracking vehicles and containers, they also extend to equipment, parts, and accessories within logistics management. IoT technology can be used to optimize inventory management and warehousing operations [8].

APPLICATIONS OF IOT IN LOGISTICS

The adoption of IoT in logistics has opened up a realm of possibilities. Applications of IoT in the logistics industry are now emerging at an unprecedented rate. From warehouse automation to cold chain monitoring, IoT in logistics applications address critical operational challenges while improving service quality and cost efficiency. Figure 6 shows some applications of IoT in logistics [9]. Key applications include the following [10-12]:

- *Fleet Management:* One of the most prominent applications of IoT in logistics is in fleet management. IoT is an essential part of modern-day fleet operations and when harnessed effectively provides safety, operational efficiency, and cost reduction. Companies can now equip their vehicles with a range of IoT devices, including GPS trackers, telematics units, and sensors, to monitor their location, performance, and condition in real time. This real-time data is a game-changer, enabling logistics managers to optimize routes, reduce fuel consumption, enhance driver safety, and improve maintenance scheduling. In the context of fleet management, telematics systems can track driver behavior, encouraging safe driving practices. Fleet management software has the task of gathering, storing, processing, and presenting data captured from sources such as vehicles, cameras, sensors, and mobile apps. Most fleet management software is powerful on its own, but by integrating your fleet IoT data with other platforms can go a long way to turn IoT data into decisions. Figure 7 shows a typical inventory [1].
- *Inventory Management:* IoT devices are revolutionizing inventory management in logistics by providing real-time tracking and monitoring of inventory levels. IoT sensors can track the location, movement, and levels of inventory, enabling logistics companies to optimize their inventory management and reduce waste. The real-time visibility into inventory ensures that logistics companies can maintain optimal stock levels, preventing overstocking or stockouts.
- *Smart Warehouses:* In the world of logistics, efficient warehousing is crucial. Smart warehousing is a warehousing and fulfillment company that operates as a direct extension of its clients' teams. IoT is expected to be increasingly used in developing smart warehouses that utilize data from IoT sensors to automate and optimize operations, from inventory placement to energy management. IoT-enabled smart warehouses utilize sensors, cameras, and RFID technology to automate and streamline operations. Goods are tracked as they move through the warehouse, and automated systems can optimize storage, improve inventory accuracy, and expedite the picking and packing process. Figure 8 shows a typical warehouse [13].

- *Cold Chain Monitoring:* The transportation of perishable goods, such as pharmaceuticals, food, and vaccines, demands precise temperature control and monitoring. IoT logistics solutions ensure temperature-sensitive products maintain quality through continuous environmental monitoring and automated alerts. IoT sensors embedded in refrigerated containers and vehicles continuously track and report temperature, humidity, and other environmental conditions. Any deviations trigger alerts, allowing timely intervention to prevent spoilage and ensure product safety.
- *Autonomous Vehicles:* Logistics managers are responsible to ensure the safety of truckers and the cargo being shipped. This can be accomplished by the implementation of self-driving vehicles. Autonomous trucks and drones are set to revolutionize last-mile delivery. These vehicles will be equipped with IoT sensors and technologies that allow them to navigate and make decisions independently.
- *Real-time Tracking:* Tracking products upon arrival at the warehouse is the first leg of the equation. GPS devices are used to track the specific location of vehicles at a given moment in time. The tracking tools help logistics industries calculate the estimated delivery time and monitor the tracks on the way to the warehouse, port, or ultimate destination. The Internet of Things will have a huge impact on the tracking and tracing of goods while they are in transportation from the manufacturer to the end consumer. Delivery services leverage IoT technology to optimize delivery routes and provide real-time tracking updates to customers. This integration ensures that businesses can deliver packages faster and more efficiently, reducing the risk of delays and improving overall customer satisfaction. Real-time tracking also improves customer experience by providing them with accurate and timely updates on their shipments. The transparency provided by IoT-based tracking systems fosters greater trust between businesses and their customers. Figure 9 shows the use of IoT for real-time tracking [1].
- *Demand Forecast:* Balancing supply and demand is a crucial part of effective supply chain management. By employing IoT in logistics, businesses can lean on technology to forecast demand and satisfy consumer needs. The application of IoT in logistics can also help keep up with demand, which facilitates effective supply chain management. Smart technologies can predict demand based on a comprehensive analysis of multiple factors such as user behavior, current market trends, customer intention, and preferences. Predictive modeling is performed by analyzing multiple factors to forecast future habits and demand.

BENEFITS

The impact of IoT on the logistics industry is profound, offering numerous benefits such as improved operational efficiency, enhanced customer satisfaction, and increased revenue. The advantages of IoT, including enhanced efficiency, visibility, and data-driven decision-making, are clear and compelling. As organizations face increasing demands and cost pressures, IoT and logistics solutions deliver measurable outcomes through real-time monitoring, predictive maintenance, and automated operations. Other benefits include the following [10,14]:

- *Automation*: In modern industries, automation takes a significant place for all businesses in order to reduce the amount of manual work and labor costs and decrease the possibility of human mistakes. For manufacturers, the supply chain IoT enables the required automation of this segment of management and industrial procedures. You can use drones as means of IoT in warehouse management or create a whole infrastructure with a remote control to monitor logistics progress.
- *Transparency*: With the automation of functioning in the Internet of things supply chain and immediate data gathering, you can ensure the maximum level of transparency of practically all operations. All information about the activities with raw resources, assets, or finished products

is constantly tracked. You can check on the inventory and storage with the IoT in warehouse management at any time.

- *Enhanced Efficiency:* At the core of IoT's impact on logistics is its ability to make processes more efficient. IoT logistics solutions streamline operations through automation, real-time coordination, and process optimization that improve throughput while reducing delays. Real-time data and automation reduce delays, errors, and manual interventions. Innovative Internet of things solutions help to organize and control resource provision and distribution in the most productive ways.
- *Enhanced Safety:* IoT devices can play a significant role in enhancing safety. For example, sensors can monitor the condition of cargo, ensuring that hazardous materials are transported within the specified parameters.
- *Cost Savings*: Improved efficiency, better resource allocation, and reduced maintenance costs all contribute to significant cost savings over the long term. IoT in logistics reduces operational expenses through automated monitoring, predictive maintenance, and optimized resource allocation. IoT technology helps logistics companies reduce costs by optimizing routes, improving inventory management, and minimizing fuel consumption.
- *Decision-making:* The data collected by IoT devices is a goldmine of insights. It enables logistics managers to make informed decisions, optimize routes, allocate resources efficiently, and respond rapidly to changing conditions.
- *Predictive Analytics:* The data collected by IoT devices is vast. This data is transformed into actionable insights through predictive analytics systems and artificial intelligence, helping optimize routes and predict maintenance needs. Predictive analytics will enable logistics companies to anticipate issues, optimize routes, and make real-time decisions.
- *Predictive Maintenance:* Internet of things has helped industries to jump on predictive maintenance and condition-based maintenance instead of depending on scheduled inspection procedures. By collecting and analyzing data, predictive maintenance algorithms can predict when equipment is likely to fail, allowing for proactive repairs or replacements. This minimizes downtime, reduces maintenance costs, and keeps operations running smoothly. These preventive insights about their assets will help companies reduce risks and downtime that will further result in seamless process execution and timely delivery operations.
- *Environmental Impact*: Humanity has polluted the planet lately. The IoT can optimize the transportation system not only to bring material benefits but also to reduce the harm it causes. Applications of IoT in logistics can not only take care of people (your staff) but also the environment. IoT and logistics support sustainability goals through optimized routing, reduced fuel consumption, and efficient resource utilization. By optimizing routes and reducing fuel consumption, IoT can help reduce the carbon footprint of logistics operations. IoT helps to cut on wastage, offers route optimization, and reduces fuel consumption, therefore minimizing emissions and cutting costs.

CHALLENGES

IoT also presents challenges, including security risks, implementation costs, and privacy concerns. Implementing IoT in remote locations presents its own challenges, primarily related to connectivity issues. One of the key challenges in logistics is maintaining control over goods as they move through complex networks of warehouses, transportation hubs, and delivery routes. Other challenges include the following [10,14,15]:

- *High Costs:* IoT implementation comes with an initial cost, which can be a barrier for smaller logistics companies. The initial investment required to deploy IoT infrastructure, including

sensors, network connectivity, and data analytics platforms, can be substantial. Smaller businesses may find this cost prohibitive. Businesses may need to carefully assess the return on investment before committing to IoT adoption.

- *Security Risks*: The security issue is an overall concern that appears in most cases of implementation of new information technologies in business. As IoT devices proliferate within the logistics industry, so too do the risks associated with data security. As with any digital technology, IoT devices are susceptible to cyberattacks. Ensuring the security of data and devices is paramount, but it requires substantial investments and expertise. The connectivity of IoT devices can make them vulnerable to hacking, potentially exposing sensitive data or allowing malicious actors to gain control of devices.
- *Complexity*: Managing a large network of IoT devices is no small feat. It requires expertise in device management, data analysis, and cybersecurity. The complexity can be a barrier for organizations with limited resources or expertise.
- *Privacy Concerns:* IoT devices collect vast amounts of data, much of which is personal or sensitive. Ensuring that this data is handled and stored securely and ethically is a top priority. The constant monitoring and data collection enabled by IoT can raise privacy concerns. Customers and employees may be uncomfortable with the idea of being continuously tracked.
- *Skill Gap:* Managing a network of IoT devices and making sense of the data they generate requires specialized skills. There is a shortage of professionals with the necessary expertise to implement and manage IoT systems effectively.
- *Employee Training:* As IoT implementation leads to various modifications in the system, employees may not find it easy to adapt to those complex changes. Even though most processes of the supply chain get automated with IoT devices and software, you still need workers to operate these gadgets in warehouses and vehicles. To solve this challenge, managers or IoT service providers have to grant adequate training to the employees.
- *Integration:* One of the main challenges in adopting IoT technology in logistics is integrating it with existing systems and processes. Many logistics companies operate on legacy systems that need to be more readily compatible with the new wave of IoT technologies. Adopting IoT technology in logistics can seem daunting, but the right approach can significantly enhance efficiency and streamline operations.
- *Interoperability:* Interoperability challenges arise when diverse IoT logistics devices, protocols, and systems fail to communicate effectively, creating data silos and operational inefficiencies. Legacy systems may not support modern communication protocols, while devices from different manufacturers often use incompatible data formats. This fragmentation reduces visibility and limits the ability to coordinate operations across integrated supply chains.
- *Scalability:* Scalability challenges emerge as Internet of things and logistics deployments grow from pilot projects to enterprise-wide implementations spanning thousands of devices and multiple locations. Managing device provisioning, configuration updates, and performance monitoring becomes increasingly complex at scale. A scalable and flexible infrastructure that can handle surging data volume and adapt to changing system needs might help resolve this issue.
- *Regulatory Compliance:* The logistics sector is carefully regulated, IoT helps to meet industry standards by providing the user with better control of their operations. This might be through video surveillance, authenticity verification, or product tracking.

FUTURE OF IOT IN LOGISTICS

The Internet of things in logistics landscape is experiencing unprecedented growth and transformation. This explosive growth reflects the industry's recognition of IoT and logistics integration as essential for competitive advantage. The future of IoT in logistics is incredibly promising, with numerous exciting developments on the horizon and with more businesses adopting this technology to gain real-time visibility and control over their supply chains. As IoT continues to evolve, it brings transformative changes to the logistics industry. IoT will continue to contribute to sustainability efforts in logistics.

As IoT devices become more advanced and integrated with artificial intelligence and machine learning, businesses will be able to harness even more powerful insights to optimize their logistics operations further. Moreover, with the rise of autonomous vehicles and drones, IoT will continue to play a key role in driving the next generation of logistics innovations [1]. As the industry evolves, new issues emerge, caused by external factors such as the latest international market trends, higher customer requirements, and skyrocketing demand. As we look towards the future of the logistics industry, there is plenty for business leaders to consider.

CONCLUSION

The Internet of things refers to the network of interconnected devices that can communicate with each other and transmit data. Having right things at the right place and at right time is important and Internet of things plays a big role in ensuring the whole process runs smoothly. The Internet of things can be used anywhere, and it probably will be used everywhere very soon. It is not just connecting physical objects to the World Wide Web, but has the ability to get valuable data from a wide variety of devices.

IoT-powered solutions are integral to modern logistics and it is difficult to overestimate the benefits of IoT technologies for the logistics sector. The introduction of the IoT technology in the field of logistics allows you to optimize the entire system, including warehouse operations, transportation, and delivery. The penetration of IoT technologies allows increasing the productivity of delivery and ensures the integrity of cargo and their storage [16]. In the logistics industry, IoT devices such as GPS trackers, sensors, and RFID tags are used to gather real-time data, enabling businesses to gain visibility into every aspect of their supply chain. More information about Internet of things in logistics can be found in the books in [17-20] and the following related journal: *IEEE Internet of Things Journal.*

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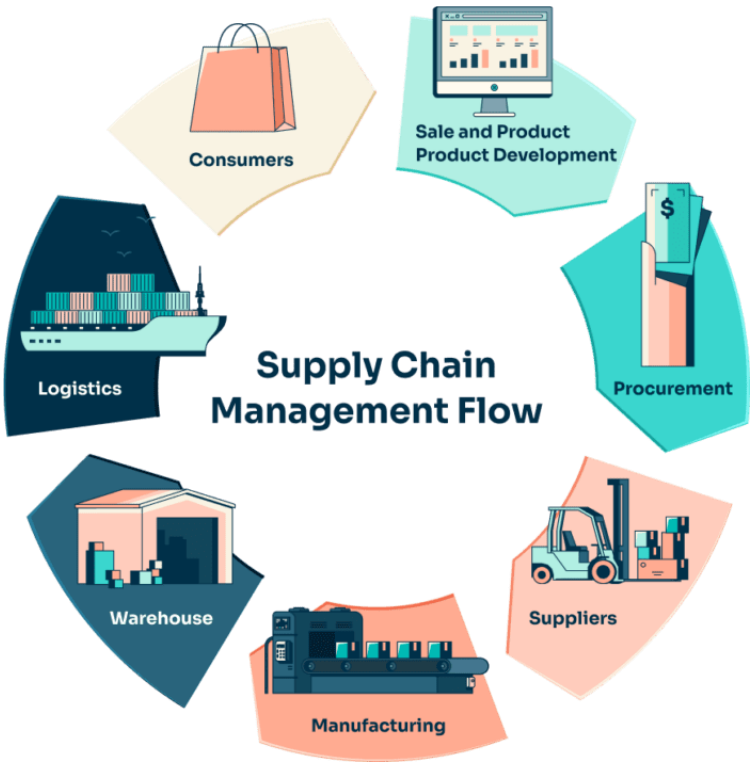

Figure 1. Logistics is part of the supply chain management [1].

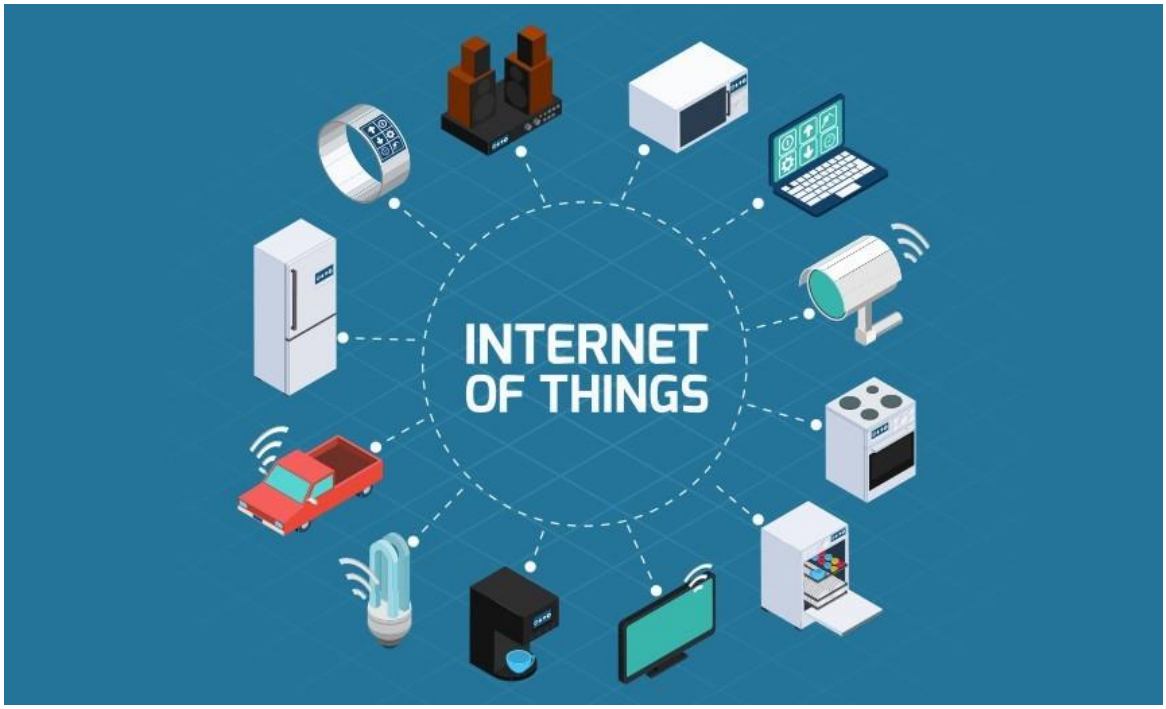

Figure 2. The Internet of things [3].

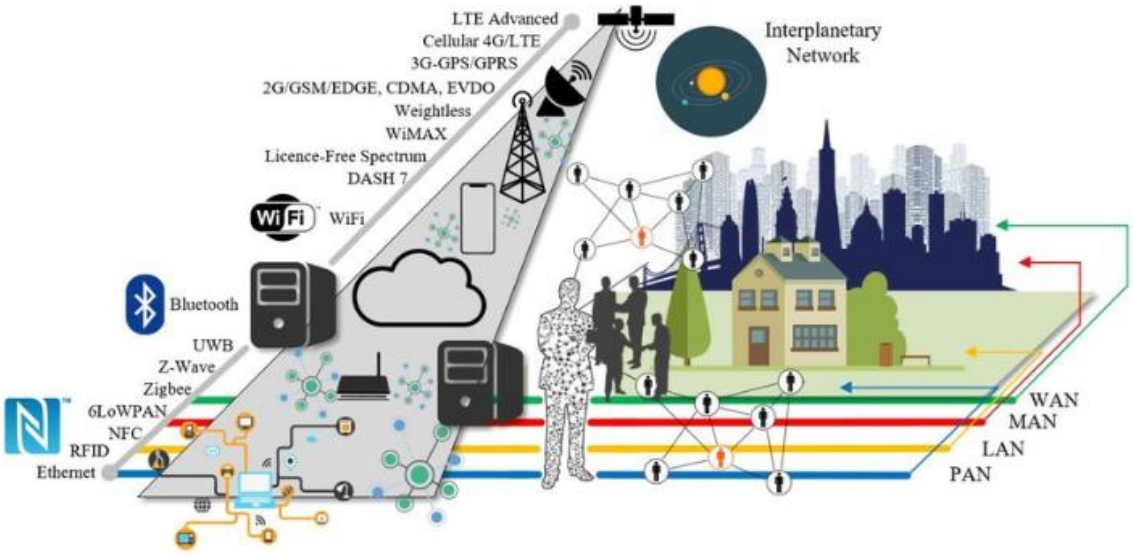

Figure 3. Communications technologies in Internet of things [5].

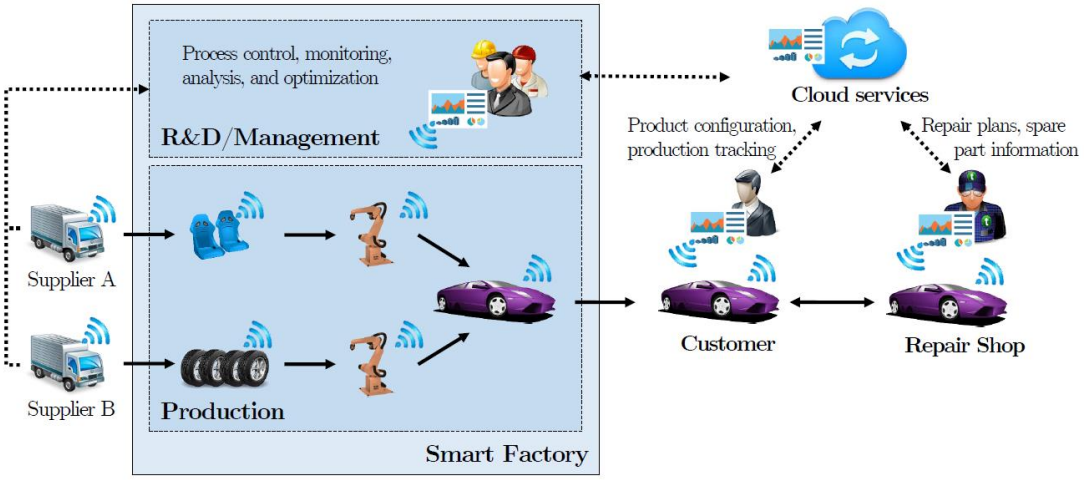

Figure 4. A typical industrial Internet of things [7].

Figure 5. A representation of IoT in logistics [1].

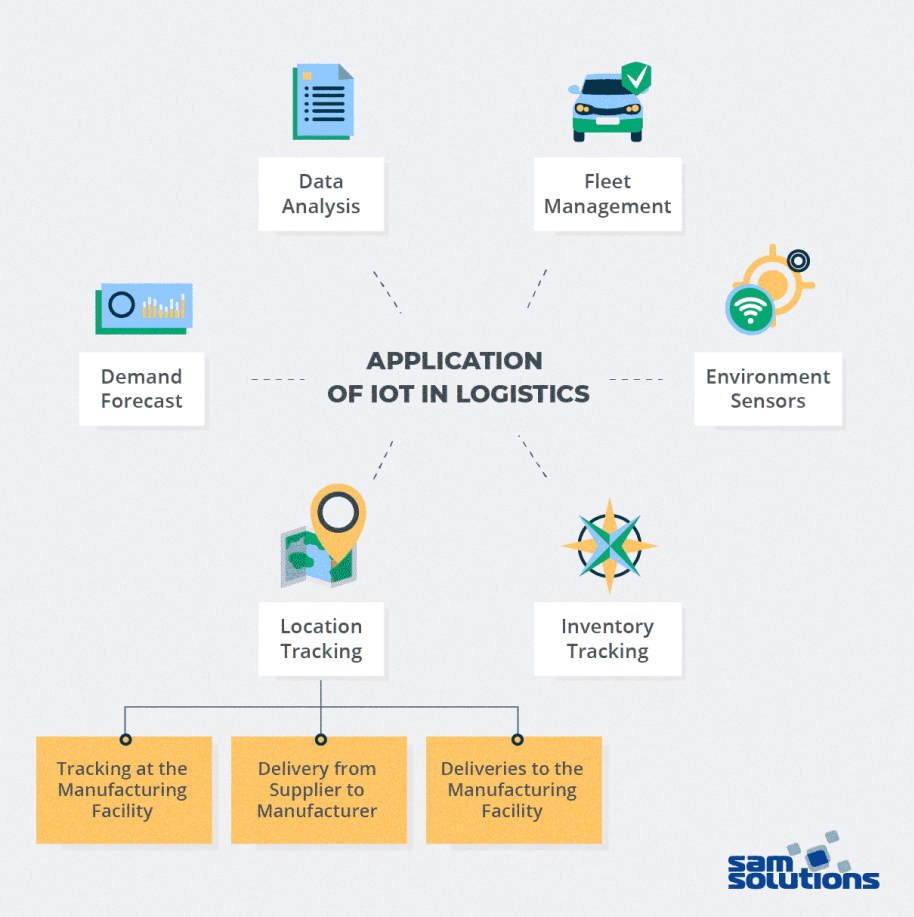

Figure 6. Some applications of IoT in logistics [9].

Figure 7. A typical inventory [1].

Figure 8. A typical warehouse [13].

Figure 9. Use of IoT for real-time tracking [1].