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Internet of Things the Transportation Industry

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ABSTRACT

The Internet of Things (IoT) refers to the network of interrelated computing objects, devices, and sensors that interact and exchange data sets over the Internet. IoT has had an impact on all aspects of life and business, and interestingly it is also changing the way we travel. It has already made its mark in the world of transportation and the change towards its transformation has begun. IoT in transportation incorporates a wide network of embedded sensors, actuators, smart objects, and other intelligent devices. Its use cases is growing rapidly, delivering gains in operational efficiencies, cost savings, safety, security, and mobility. This paper discusses IoT's common applications in the current transport sector.

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

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INTRODUCTION

The transportation industry has always been heavily influenced by technology. Technological progress has continuously enhanced operational efficiency and spurred innovation within the transportation sector. From changing the way businesses function to altering our personal lives, IoT is one technology that has made its mark everywhere. The transportation industry is the second largest industry investing in the Internet of things. Technology advances are driving the application of IoT in transportation that make cities smarter and the city's systems easier to manage.

By adding transparency to transportation processes, accelerating goods delivery, and enhancing operational processes, IoT has taken transportation to a higher level. Internet of things technology improves efficiency and transparency over the transportation cycle, keeping operations running smoothly and seamlessly.

Our lives run on transportation. It gets us to work in the mornings, delivers fresh food to our grocery stores, and encourages us to travel to far corners of the world. Transportation today allows us to access public transit, shipping, ride-sharing, and an unquantifiable amount of convenience. By nature, transportation industry is about delivering goods from one point to another. Its services can be split into two major groups: "supply" and "demand," with IoT technology finding its use in both [1]. Although the movement of goods from one point to another was the only goal of transportation companies before, increased competition and rising customer expectations have compelled the industry to focus on smart fleet management, real-time inventory tracking, faster deliveries, and flawless customer service.

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 some 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. Figure 3 shows a typical representation of IoT [6].

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 [7].

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 5 [8].

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 [9]. 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 [10].

IOT IN TRANSPORTATION

The rise in urbanization has led to the rise in megacities which means the doubling up of the global population every year. This has led to the development of the transportation industry with a higher demand for better and faster modes of transportation, newer roads and enhanced connected transportation networks. The transportation sector is always evolving to offer safer, faster, cleaner, and more comfortable commutes. The next significant industry shift is at hand, and IoT is leading the charge.

The transportation 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. An effective transportation system will not just boost the productivity of a business but can also increase its profitability. Due to technological progress and current challenges, the transportation industry has experienced a rapid transformation. To meet the new challenges and stay afloat, the transportation industry strives to embrace IoT. IoT, with its ability to connect devices, is the right key for effectively transforming transportation. IoT is a suitable choice for transportation-based businesses to achieve various goals as smart devices offer accuracy and precision through real-time data collection.

The utilization of IoT in the transportation industry has gained momentum in recent times. The Internet of things (IoT) surrounding the transport industry is gradually growing in size and also getting more sophisticated with time. IoT in transportation incorporates a wide network of embedded sensors, actuators, smart objects, and other intelligent devices. Transportation companies and agencies around the world are adopting IoT solutions to improve safety, performance, and cost effectiveness, as well as

comfort and convenience for passengers and motorists. Figure 5 depicts IoT in transportation [11].

APPLICATIONS OF IOT IN TRANSPORTATION

While there are multiple ways in which IoT is changing the way transportation takes place, we explore some of the top aspects of conveyance that have drastically changed since the integration of this technology. IoT devices are heavily deployed for a wide range of applications within the transportation industry. Smart parking, automatic traffic light system, and smart accident assistance are just a few applications of IoT. The aim of these applications is to offer efficient and secure transportation. Five popular applications of IoT in transportation are shown in Figure 6 [12]. Common application areas of IoT in transportation include the following [12]:

- *Asset Tracking*: IoT-driven inventory/assets management is the most widespread application of the Internet of things in transportation. This application allows to track inventory assets remotely, monitor their status, and learn about all the changes timely. IoT technology can track a vehicle or transport equipment, showing its movement in an IoT mobile application. The IoT-based vehicle tracking and management system can efficiently track routes, manage drivers and vehicles, and control fuel consumption. Radio frequency identification tags (RFID) and sensors allow fleet owners and managers to keep constant track of the stock levels and inventory items.
- *Delivery Tracking:* Tracking a product right from when it arrives at the warehouse until it reaches the customer's doorstep is a big challenge for logistics managers. By coupling IoT technology with GPS sensors and RFID tags, you can track any product with complete transparency, reduce the onus on your staff, and enhance customer satisfaction with instant updates on every movement till the product is delivered without any hassles.
- *Self-Driving Cars:* Self-driving cars or autonomous vehicles are the most impressive thing that happens to the transportation industry. The majority of advanced vehicles nowadays have IoT connectivity. Most of the companies in the automotive sector have started envisioning a future for motors in which IoT era makes vehicles "smart." IoT has made it possible to boost the innovative idea of self-driving cars. These cars can move safely by sensing the environment without human interference. Self-driving cars utilize sensors that can collect data about the surroundings.
- *Electric Vehicles:* Owners of e-vehicles (EV) can use connected apps to remotely control cars' functions like monitoring charge status, setting charging schedules, or even pre-conditioning the cabin before the ride. EV charging stations will require IoT connectivity for a range of functions. IoT can integrate EV charging with smart parking solutions, allowing drivers to book charging spots and receive navigation assistance to the nearest available charger. IoT sensors monitor the health and performance of charging stations, enabling operators to detect and fix issues remotely before they escalate. This minimizes downtime and ensures reliable service. As the world's auto industry shifts over to electric vehicles in the coming decades, a dense infrastructure of EV charging stations will grow along with the fleet of new electric cars, buses. and trucks. A charging station is shown in Figure 7 [13].
- *Traffic Management:* This is a core area of the transportation industry that needs the support of IoT. Traffic management is the biggest segment within the transportation industry where the adoption of IoT technologies is observed to be the most prominent. Traffic sensors and cameras are placed at intersections, roads, and other strategic locations to collect data on vehicle count, speed, and traffic density. The data helps in the real-time monitoring of traffic conditions. IoT can help manage traffic, reduce congestion, and improve safety. A magnanimous amount of traffic and vehicle-related data are gathered through CCTV cameras. A few applications such as smart parking, automatic traffic light system, and smart accident assistance are a great help to traffic and patrolling officers for the efficient management of traffic and reducing the risk of accidents. Figure 8 shows traffic congestion [14].
- *Predictive Analysis:* Capable of gaining various real-time metrics, IoT logistics systems can analyze obtained data and make predictions. With predictive analysis in public transport, a safer ride can be expected. Predictive analysis helps maintenance engineer predict when a part might need a replacement, thus, reducing the risk of accidents or downtime, henceforth, ensuring a safer ride to passengers that could otherwise be dangerous. IoT can also act as a bridge between authorities and citizens in case of an emergency to organize an evacuation, change traffic routes, etc.
- *Intelligent Transportation Systems:* ITS have video surveillance that they use to protect a customers' physical well-being and observe a driver's performance. It also has informed

navigation that enables drivers to avoid routes with risky conditions (e.g., chemical spill, fire, etc.). Essentially, the sensors combined with video surveillance can track all abnormalities and minimize any future crash or accidents. Figure 9 shows a typical intelligent transportation [15].

- *Automated Toll:* Traditional toll systems are becoming outdated and also proving to be ineffective for assisting the current flow of vehicles on the road. They are prone to manual errors and have become inefficient at tackling the recent increase in vehicles on busy highways. Automated tools are equipped with RFID tags and IoT connectivity to detect vehicles from a distance and lift the barriers. As the number of vehicles is increasing on the road every day, there is no surprise that toll booths have become busy and crowded. In addition, drivers have to wait for a long time on highways for their turn. IoT comes to the rescue in such scenarios as it offers automated tolls. RFID tags and smart sensors can efficiently manage tolls and ticketing which makes the job easier for officers.
- *Railways:* The IoT technology has been heavily used in railway applications, including railway operations, management, maintenance, video surveillance systems, and train control systems. IoT solutions support both light rail and heavy commercial rail systems. Trains are equipped with GPS and other sensors to track their exact location and movement in real-time. Data from all trains is sent to a central control center where operators can oversee the entire network. IoT can also monitor the railway infrastructure: tracks, bridges, tunnels, and more. IoT sensors monitor the condition of train parts, such as wheels, brakes, engines, and electrical systems. The data collected from these sensors is analyzed to predict when maintenance is needed. This helps manage train traffic, avoid collisions, and ensure optimal use of tracks. It also allows performing maintenance before a failure occurs, reducing downtime and extending the life of equipment. Sensors can detect issues like track misalignment, cracks, or temperature changes, allowing for timely repairs to prevent accidents. A typical railway is shown in Figure 10 [13].
- *Maglev Trains:* These have received increasing popularity due to their comfort, advantages of no friction, and low noise. The IoT-based applications are actively used in maglev trains. The appropriate personnel can review the data and evaluate the working state of a given maglev train. When necessary, a specific suspension control strategy can be deployed by the personnel to enhance the overall performance of the magnetic suspension system of the maglev train. The IoT-based technologies may assist with proper maintenance of the trains throughout the entire life cycle.
- *Public Transportation:* In public transportation, the Internet of things (IoT) refers to a network of connected sensors and devices installed on vehicles and infrastructure, allowing for real-time data collection and analysis to improve operational efficiency. The integration of IoT technology in public transportation is revolutionizing the way passengers experience transit systems. By increasing reliability, reducing wait times, and improving comfort for passengers, IoT is addressing many of the frustrations traditionally associated with public transport. These advancements are making public transit a more appealing option for commuters.
- *Commercial Transportation:* Commercial transportation companies rely heavily in satisfying the needs of their customers. By adopting new technologies, companies can change profit margins by a large percent. Cargo monitoring systems help track the package from shipment to delivery. They provide real time location of packages and notify the company in case of an emergency. IoT offers a constant flow of information in commercial transportation.

BENEFITS

The benefits of utilizing IoT for enabling smart transportation are limitless. A major benefit of the Internet of things in transportation is the enhancement of overall visibility of goods movement. The transportation sector can fundamentally transform operational efficiency including vehicle tracking, enhancing security, reducing cost, and increasing productivity. IoT connected ecosystems make it possible to track delivery vehicles and monitor the delivery process. Other benefits of IoT in transportation include the following [16-18]:

- *Enhanced Safety:* This is one of the most important factors in determining the efficiency of IoT. Safety is very important when it comes to transportation and that is the primary thing IoT is trying to address. Smart cars have smart sensors that allow you to alert other vehicles on the road of potential road hazards, reckless drivers, or likely traffic delays. US Department of Transportation is working with car manufacturers to incorporate IoT technology to reduce the occurrence of crashes. With predictive analysis in public transport, a safer ride can be expected.

- *Better Commuting Experience:* Focusing primarily on public transport and how unreliable it can be, IoT aims to make the commuting experience better. Public transport is usually prone to delays, and hence commuters are often left stranded and/or confused. With IoT-enabled tracking, buses and trains can give real-time information and their status to commuters. Passengers can use Wi-Fi on trains and buses, hence allowing them to work on their commute.
- *Vehicle Health:* A vehicle is an integral part of the IoT technology system and if there is any problem or defect in the vehicle, sensors will immediately notify and alert the owner about the condition of the vehicle. Even though the world is quickly moving towards driverless cars, it is of utmost importance to be able to track the health of a vehicle. With vehicles becoming a part of an IoT ecosystem and/or smart cities, they will be constantly inspected via sensors to ensure there is no problem with the vehicle. The sensors will also keep full track of the driver, emergency numbers, etc. along with investigating fuel, brake, speed, performance etc. multiple times in a day.
- *Smart Public Transport:* In urban areas, most people rely on public transport to commute on a daily basis. If a GPS sensor is used in public transport system, we can easily track the real-time location of trains, buses, cars or taxis. This will surely reduce the travel time of passengers. With this, a passenger can manage his travel easily.
- *Fleet Management:* Businesses use transport and logistics system to deliver products and services to their customers. Managing such a huge process, at times, becomes complex and difficult to handle. The use of IoT-based technology in fleet management will surely help the businesses track vehicles carrying their goods and quickly fix issues if there are any. IoT in fleet management will reduce problems and ensure proper operation of vehicles.
- *Cost Reduction:* Businesses can significantly cut expenses by leveraging IoT in the transportation industry for instant monitoring, predictive maintenance, and inventory optimization. Ride-sharing is becoming cost-competitive with the aggregate cost of car ownership (titling, insurance, maintenance, gas, and more). Telematics solutions offer performance insights that enable fleet operators to optimize fuel usage with efficient routing and improved driver behavior. It allows them to cut the associated costs with manual administrative tasks and extend vehicle lifespan with timely and effective maintenance scheduling.
- *Regulatory Compliance:* Fleet management systems with IoT capabilities can support managing regulatory compliance. The data captured from vehicle and driver tracking with parameters including hours of service, records of duty status, accurate fuel tax reporting, and driver vehicle inspection reports can be shared directly with the relevant authorities.
- *Curbing Traffic:* No one enjoys traffic. Besides its ability to cause irritation instantly, traffic wastes millions of gallons of gas and cuts deep into otherwise productive work hours. American commuters spend on average an extra 42 hours a year sitting in traffic on top of their commute. In highly congested urban areas, that number soars to over 80. IoT, including smart city IoT applications, is poised to address these pain points in transportation.
- *Automation:* The IoT applications are expected to facilitate automation of transportation services. The IoT technologies would allow achieving all the benefits from automation without affecting safety in a negative way. Advanced sensors, cloud computing, and predictive data analytics are some of the key IoT features that would promote further development of autonomous transportation systems.
- *Increased Efficiency:* IoT enables the automation of various processes within the supply chain, from inventory management in warehouses to paperwork reduction. This automation leads to increased efficiency and time savings. The wealth of data generated by IoT devices provides insights that drive smarter decision-making, leading to more efficient operations and reduced costs.
- *Sustainable Transportation:* As urban areas become more congested and the demand for sustainable transportation options grows, the role of IoT in public transport will continue to expand. By leveraging IoT technology, cities and transport authorities can offer smarter, more efficient, and more reliable public transportation services, ultimately making them an attractive alternative to private vehicles. Several studies were dedicated to the next generation communication technologies that could be potentially applied in the railway industry and facilitate sustainable railway management and operations.

Some of these benefits are depicted in Figure 11 [18].

CHALLENGES

The industry faces several significant challenges. Keeping up with rapid technological changes and integrating new solutions without disrupting existing operations is a significant hurdle. One of the primary challenges is integrating IoT solutions with existing legacy systems. Ensuring consistent and reliable connectivity for IoT devices, especially in remote areas or across international borders, can be challenging. Other challenges include the following [13,19]:

- *Data Security*: IoT systems, just like all other systems, are vulnerable to cyberattacks, hacking, and data breaches. The data generated by IoT devices is extremely sensitive as it includes real-time vehicle locations, route patterns, and driver behavior. To protect the system and its data, the storage and connection should be encrypted.
- *Integration Complexity:* The transportation industry often uses a mix of legacy systems and new solutions, devices from different manufacturers, and different communication protocols. The lack of standardization often results in compatibility issues, leading to complications in data sharing. As IoT in transportation and logistics often involves cross-border movement, complying with various international regulations and standards can be complex.
- *Scalability:* With the proliferation of IoT devices, scalability becomes a critical consideration in transportation. As the number of IoT devices grows, managing, monitoring, and updating them becomes increasingly complex. The massive amount of data generated by IoT devices can overwhelm existing IT infrastructure, and scaling up IoT solutions requires investment in cloud infrastructure, data storage, and network bandwidth.
- *Cost Implications:* IoT technology implementation can be expensive, especially for small and medium-sized enterprises. It includes the cost of IoT devices, infrastructure upgrades, and training employees. Implementing IoT solutions involves significant upfront costs, including purchasing sensors, devices, connectivity infrastructure, and cloud services. Maintaining the infrastructure is expensive, and managing the data will cost much. Managing operational costs while maintaining efficiency is a constant struggle. Fuel costs, vehicle maintenance, labor costs, and regulatory compliance all add to the financial burden.
- *Reliability:* Reliability is a key factor in the attractiveness of public transport. When public transport is dependable, people are more likely to use it. IoT systems rely on continuous connectivity to function effectively. In the transportation sector, connectivity can be inconsistent due to signal dead zones, especially in remote or urban underground areas. IoT devices deployed in transportation can be exposed to harsh environmental conditions, leading to potential hardware failures and data loss.
- *Interoperability:* Integrating IoT devices from various manufacturers and systems can pose interoperability challenges due to differences in communication protocols and data formats. Standardization and open-source platforms can facilitate seamless communication and integration between IoT devices and existing systems.
- *Supply Chain Visibility:* Ensuring visibility across the entire supply chain is crucial for timely deliveries and risk management. However, achieving complete transparency is challenging due to the involvement of multiple stakeholders and varying levels of technology adoption.
- *Customer Expectations*: In an age where same-day delivery is becoming the norm, there is increasing pressure on logistics companies to deliver faster, more reliably, and at a lower cost.
- *Environmental Concerns:* With growing awareness of environmental issues, the industry is pressured to reduce its carbon footprint and adopt more sustainable practices. Motor vehicle emissions can be reduced significantly by traffic management systems that enable cars and trucks to spend less time idling in traffic.
- *Regulatory Compliance:* Navigating the complex web of international regulations and compliance standards is a constant challenge. Adhering to data privacy rules and industry regulations is a paramount software requirement in IoT implementations. One must adhere to rules governing data protection, privacy, security, and industry-specific requirements for data handling and storage.
- *Standardization:* Standardization is one of the critical elements that substantially affects the development and deployment of IoT systems. Having a unique standard is essential, so all the relevant actors could easily access and use a given IoT system. Developed standards should be open to all the relevant representatives of a given enterprise. Furthermore, global standards are

expected to be more efficient compared to local standards.

- *Unexpected Events:* Unforeseen circumstances like breakdowns, road closures, or inclement weather can disrupt public transportation. IoT enables transport authorities to reroute vehicles and notify passengers promptly, helping them make alternate arrangements. Transit agencies can send alerts to passengers' phones ahead of time to keep them informed.

Some of these challenges are portrayed in Figure 12 [20].

CONCLUSION

Technology has always been pivotal in shaping the transportation industry. Technological advancements have consistently driven efficiency and innovation in the sector. The integration of the Internet of things (IoT) in transportation has brought about a multitude of benefits that are revolutionizing the industry. It offers immense potential for optimizing efficiency.

IoT in transportation is a game changer and most enterprises have already started to benefit from this emerging technology. IoT in the transportation industry has revolutionized the sector by making real-time data available. Transportation is beginning to rely more heavily on IoT. IoT in transportation empowers fleet companies to monitor activity in real-time. It is making the transportation industry more efficient. When used effectively to drive decisions, businesses are witnessing productivity increase, improvements in resource management, cost reductions, and safety improvements.

More information about Internet of things in the transportation industry can be found in the books in [21-24] and the following related journals:

- *IEEE Internet of Things Journal*
- *Transportation Research Procedia*

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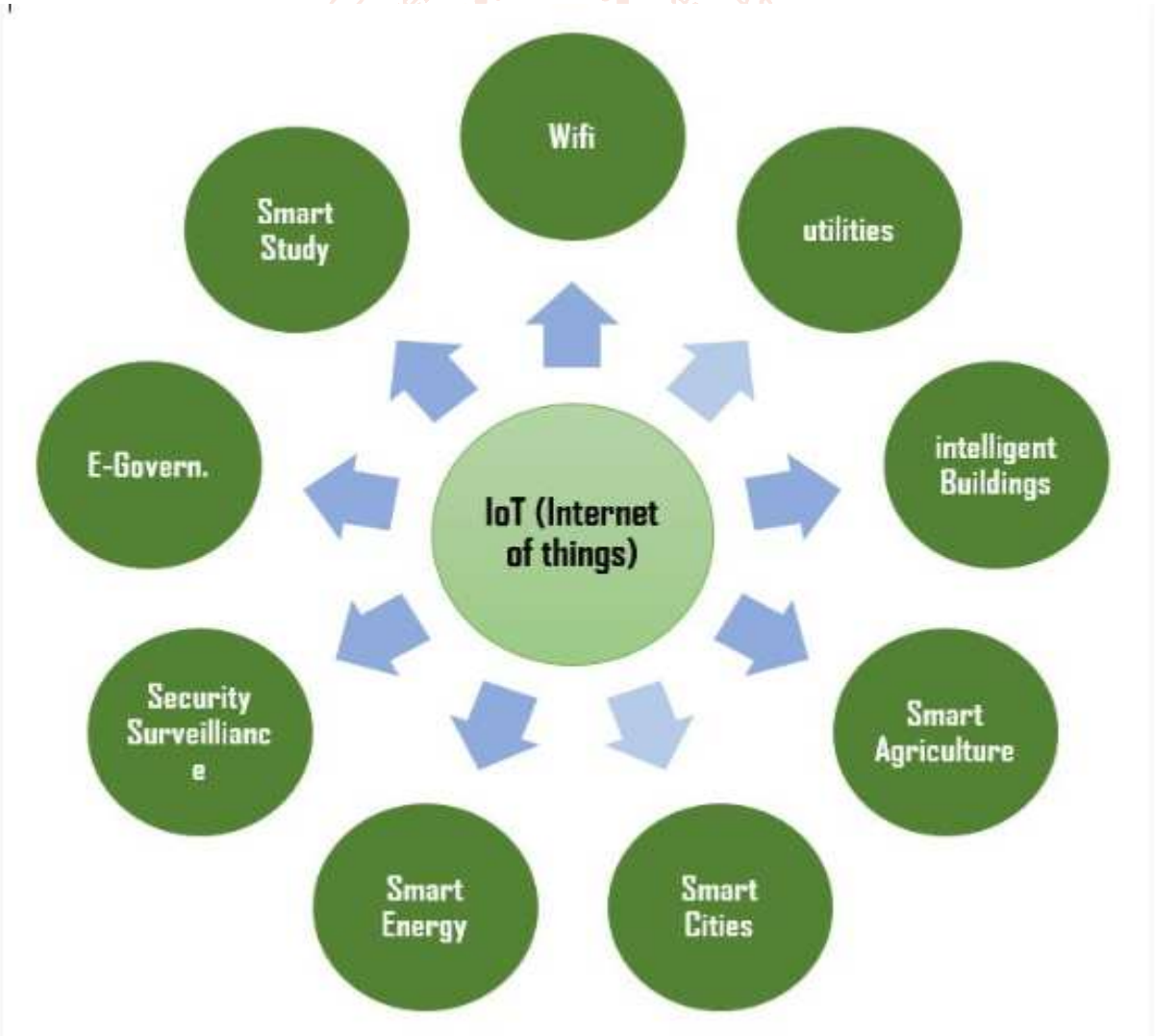

Figure 1 Applications of Internet of things [3].

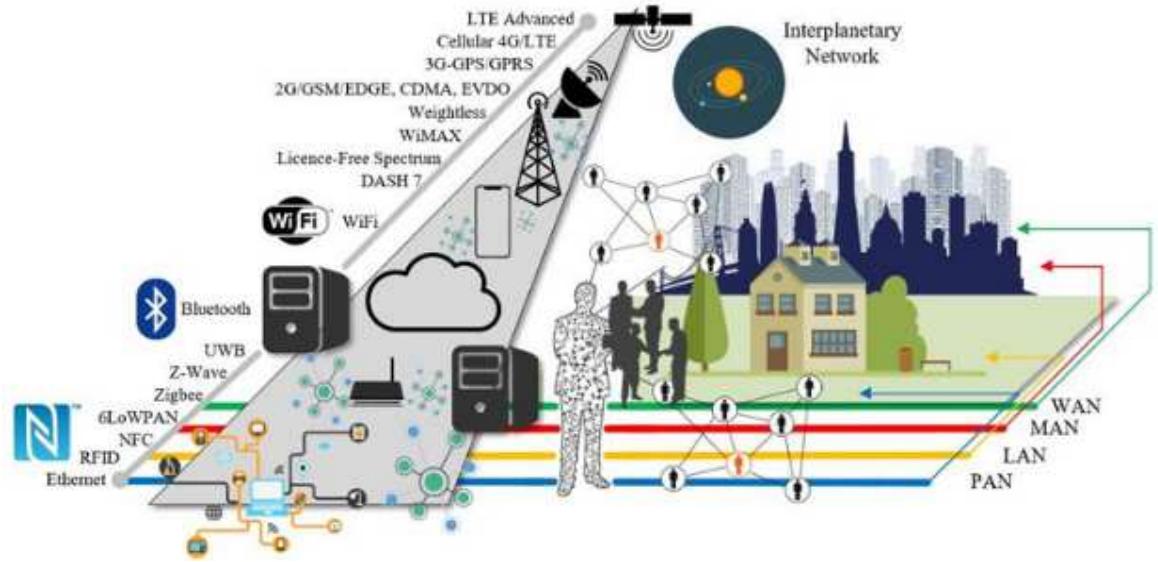

Figure 2 Communications technologies in Internet of things [5].

Figure 3 A typical representation of IoT [6].

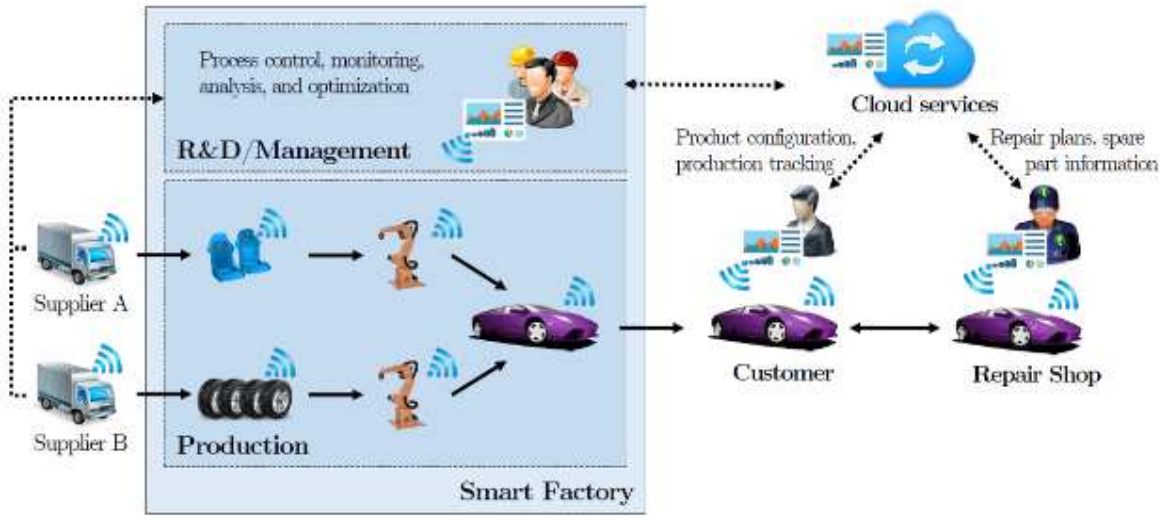

Figure 4 A typical industrial Internet of things [8].

Figure 5 IoT in transportation [11].

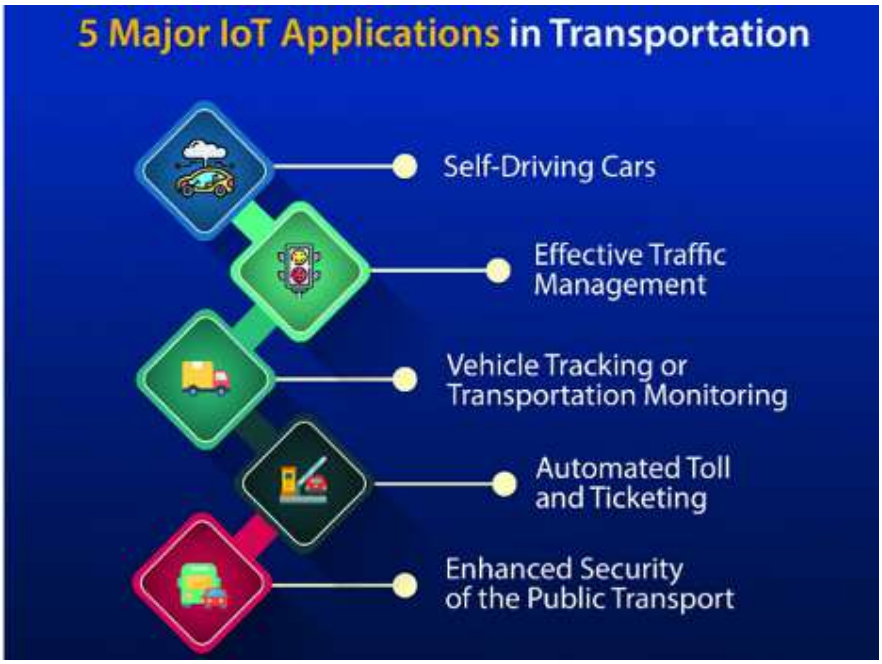

Figure 6 Five popular applications of IoT in transportation [12].

Figure 7 A charging station [13].

Figure 8 Traffic congestion [14].

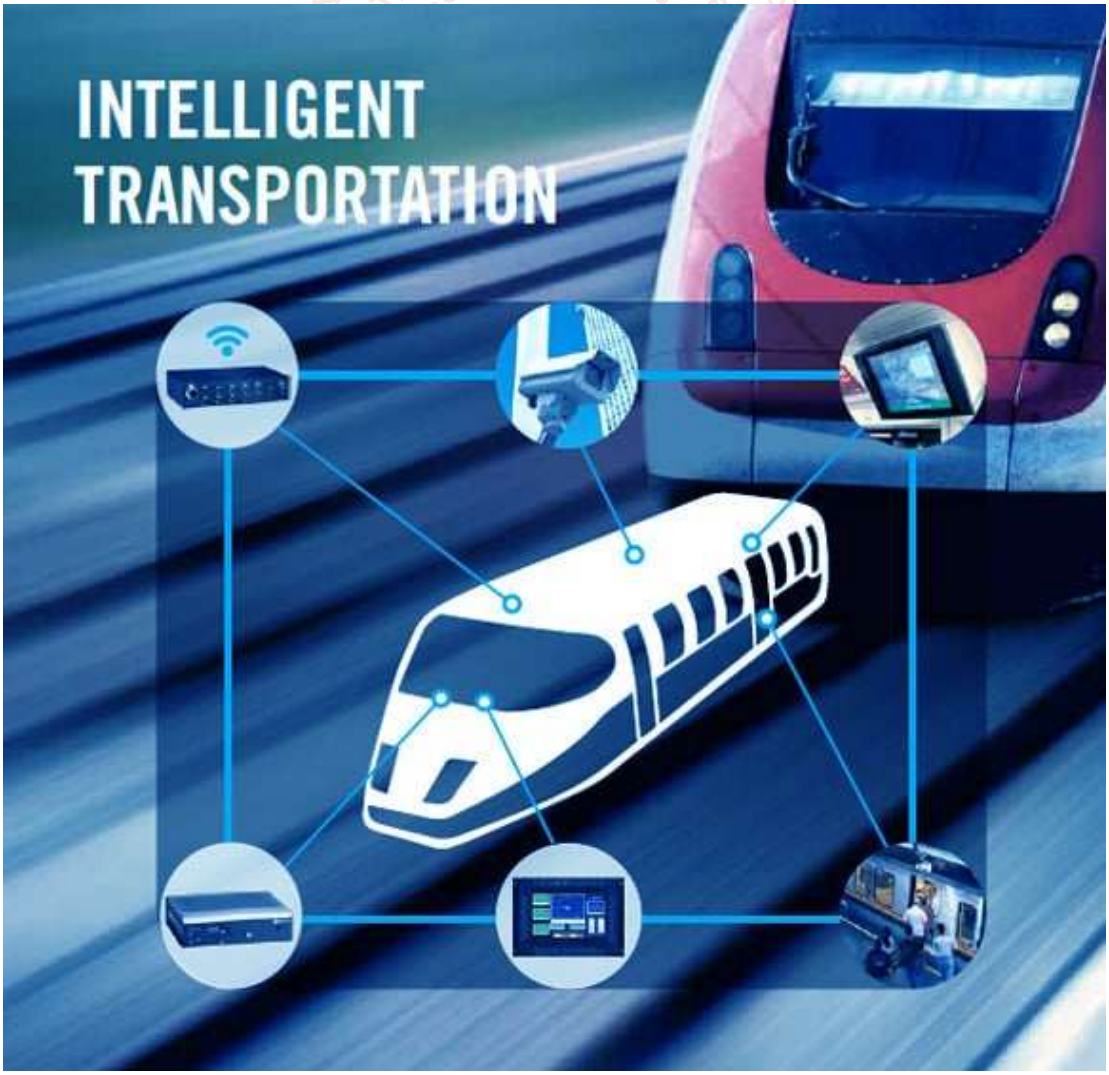

Figure 9 A typical intelligent transportation [15].

Figure 10 A typical railway [13].

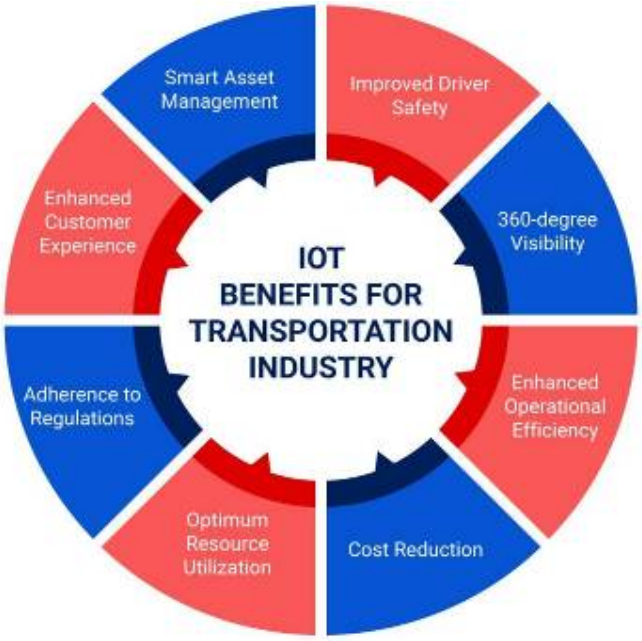

Figure 11 Some of the benefits of IoT in transportation [18].

Figure 12 Some of the challenges of IoT in transportation [20].