CHAPTER 13

IoT Applications in Transportation

This is the last chapter to explore applications of IoT in various industries. So far, we have seen that IoT has transformed almost every industry, and the transportation industry is no exception. The transportation industry is the second-largest segment investing in IIoT.

In this chapter I present the application of IoT in various types of transportation; that is, industrial transportation and public transportation, including air and water transportation. Huge monetary investments are taking place in this industry and I will give information on the positive changes IoT is making to make transportation safe, secure, and eco-friendly.

In this evolving world, with the adoption of the latest emerging technologies, every process is being automated so that the physical tasks that were previously required of people can be minimized. It is mainly due to the fact that humans are busy with so many other essential activities that they don’t have much time to focus on repetitive, physical regular or basic tasks. The main topic of discussion in this chapter is the role of IoT in the transportation industry.

This chapter focuses on various use cases to dive deep into the significance of IoT in the transportation sector and highlight multiple applications where IoT architecture can be deployed; for example, the impact of IoT on vehicles that change the way one interacts with a vehicle and utilization in traffic management, such as traffic lights and cameras embedded with IoT.

Due to its various benefits, we have adopted and widely applied the idea of smart transportation. At the same time, smart transportation problems are emerging, and IoT is providing a new direction for its development. Later in this chapter I discuss some benefits and challenges of IoT in this industry.
Transportation

When the car was invented, I am sure that our elders thought that it would never take hold in our society. The car was revolutionary, though, as were the truck, train, ship, and airplane. Transportation allows us to access public transit, helps us in shipping, allows us to share rides, and provides an immeasurable amount of convenience.

I have covered lot of industries thus far and have given examples of small Things like starting a coffee machine or heater while you are driving to your home on a cold evening, having your refrigerator place an order when you are low on eggs, and monitoring your heart rate, blood pressure, and the calories you are burning. Don’t be surprised, though, that I have not dedicated a separate chapter to the smart city. I believe the smart city is a combination of making every other service smarter; that is, smart agriculture, smart retail, smart medical, smart homes, and definitely smart transportation in the city. Looking beyond the minor home improvements from the previous chapters, transportation is arguably the sector where we would like to see the greatest transformation. The reduction in prices of sensors and improved coverage of faster Internet makes the adoption of IoT in the transport sector predictable.

In the world, the transportation industry is considered to be one of the nonnegotiable requirements, as it is essential in transporting various type of goods as well as people around the world. It was critical during the lockdowns during the COVID-19 pandemic that this industry kept working to move food and medicine and evacuate citizens from red zones. Consider another example of a company that is manufacturing something essential like seafood, but the company is located in a country where air transport is closed. Thus, the role of water transportation comes into play, by which these essential products can easily be transported to any location around the globe. In this mode of transportation, though, many variables changed. One of the most important factors is time, as it increased multifold as compared with air transport. How to keep this seafood fresh for such a long journey, though? There are various other aspects that have to be considered for accomplishing a proper transportation process, such as having controlled refrigeration, the position at which it must be kept, quality considerations of the items during and after the shipment, and so on. All these aspects are essential in the accomplishment of successful transportation of seafood to the desired destination. To manage all these new variables, we need a new, improved technology, planning, and methods, that can efficiently manage all of these factors. As consumers we expect even more convenience, safety, and commitment from business.
Wearing a business hat, we should understand the importance of these technologies early and capitalize on them as early adopters.

IoT was not alone; it had lot of friends, including sensors and an improved Internet network, pushing it to its boundaries. Finally, IoT found a dream partner, 5G. 5G has improved speed of by a factor of ten as compared with current 4G (LTE) and its latency improved by a factor of 100. This marriage gave birth to other opportunitys like connectivity between vehicles and roads, an essential element for autonomous driving. GPS was developed and launched in 2004 using a code-division multiple access (CDMA) system. The friendship of GPS with IoT enhanced tracking services can be used for a variety of applications including fleet management to answer when, locating a personal car to answer where, elderly patient monitoring to answer how, and pet recovery. Autonomous driving is another big leap in this industry.

5G will change maritime transportation as well. Currently, oceans are not covered by mobile networks, so geostationary satellites provide the vast majority of bandwidth to ships sailing in deep oceans, with limited Internet speed of a few hundred kb/s. With a growing number sensors, though, it could be anywhere between 10,000 and 20,000 sensors per ship. Low Earth orbit (LEO) satellites are being deployed that can provide speeds of up to 1 Gb/s, but this will take time. Another technology to cover maritime transport is 5G at sea, which could be provided by balloons or drones that need not leave Earth’s stratosphere, but stay just 20 km above ground. Therefore, 5G would be comparatively cheap and easy to expand. Another advantage of 5G is that it will be able to provide the on-board coverage needed to serve the dense needs of completely connected cargo with up to 20,000 containers.

Applications

IoT in transportation basically allows data to be collected from each entity. The availability of a wider collection of real-time data and the ability to analyze it will enhance strategic decision-making capabilities for logistics and supply chain companies. Thus, in the following sections, my discussion will be based on some associated use cases. First, let’s look at the vast and ever-growing network of connected entities in transportation.
Industrial Transportation

Issues with poor fleet management could be eliminated with scheduling, routing, monitoring, and maintenance of vehicles through technology. Fleet management technology is slowly and progressively being adopted with the associated improvements in operational efficiency, maintenance costs, fuel consumption, regulatory compliance, and faster accident response time. GPS tracking, geofencing, customized dashboards, and real-time business decisions are some of the key features any fleet management solution offers. Companies with fleets of vehicles spend millions of dollars in unnecessary costs when their vehicles suddenly break down while in route. Companies can also optimize other factors beyond vehicle health, such as idle time. This not only helps cut costs for the business, but also relieves drivers of monotonous and often error-prone tasks like manual reporting. Multiple IoT technologies can be employed to track shipments, optimize delivery and shipping routes, reduce costs associated with inefficiencies in logistics, and improve bottom lines. Incorporating data from weather advisories and road closure memos can help operations run smoother. It could also inform stakeholders of the status of operations in real time.

Transporters can attach internal and external sensors to gather and store real-time data on everything from temperature and humidity to carbon dioxide levels. It also facilitates real-time GPS tracking of containers, provides automatic notifications that keep cargo owners aware of any deviations in temperature, enables them to take immediate action, and thus improves product quality and security.

Earlier I used the word geofencing. When GPS captures the location coordinates of an asset or device, geofencing helps in generating alerts when an asset deviates from the prescribed path, as in the case of cargo destined for Europe offloading at a port in Japan. As it can prevent delays in delivery time and reduce accidental loss, geofencing is very important.

Rail Transport

IoT applications in the field of rail transport include monitoring train speed and automatically shifting routes. Integrating sensors to predict the failure of rail machinery and railway tracks helps maintenance departments to take preventive action. This also results in fewer maintenance breakdown delays, better safety, and higher reliability. Sensors and the connection between the server and the rail improve passenger and
rail safety. The subway in Times Square, New York City, has a frequency of two to ten minutes during rush hours. Currently almost all mass transit systems lack integration of passenger data with transit data. The opportunity here is to use passenger data to predict the number of passengers in each train, thus avoiding over- or undercrowding in stations. This is much needed mass transit systems everywhere.

**Road Transport**

Available parking spots in the cities across the world are hard to find, especially in the central city during peak hours, as well as during special events. Sensors make parking management easier with their ability to determine if a spot is available. This can be done using cameras and ground sensors to determine whether or not a car is parked in a spot, along with the spot’s exact location. Going a step further, IoT can help drivers get smartphone alerts about the availability of parking spots, including information about the fees required. Real-time spot availability displays not only save time, but save fuel, reduce traffic, and cut down on roadway congestion.

IoT devices can not only be installed on public transport vehicles like buses and trains, but also can be incorporated into the city infrastructure. Sensors on roads, streetlights, railway platforms, bus stops, and other parts of travel routes can enable transport regulators to conduct traffic flow analysis of the public transportation system. This traffic flow analysis can be used in automatic control of traffic signals. Smart cities are equipped with a complex network of road sensors that can communicate congestion and hazard data to other vehicles and to traffic lights, rerouting and load-balancing traffic throughout the city in real time. These are called connected cars.

Toll systems employing technology can adjust pricing based on congestion and facilitate real-time payment. I-405 in Seattle is a good example of this. The toll price ranges from 75 cents up to $12 during peak hours.

**Public Transport**

Public transit systems offer many benefits to passengers and to the environment. Tracking the real-time location of a bus and knowing when it will arrive at a stop was always a challenge. As real-time tracking of vehicles is possible with the help of IoT in transportation, location data are sent to a central system and it is then shared to Internet-enabled mobile devices and digital signboards at stops. IoT is eradicating challenges of
public transit systems and has enabled rerouting features to help people make alternate arrangements as real-time tracking of vehicles common. To encourage ride sharing, some governments are providing incentives, including free use of toll lanes and ride-sharing cars (including gas expenses).

**Water Transport**

A ship is no longer a ship; it is now a network of thousands of connected devices. Ship owners use sensors to submit verified emissions data to the European Maritime Safety Agency for each voyage they undertake within the European Union. Ship owners use technology for vessel tracking, emissions control, predictive maintenance, supply chain visibility, and safety. Sensors measuring vibration, sound, and temperature in the engine room provide real-time alerts and actionable insights for predictive maintenance.

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**Note**  When 80 percent of the world’s cargo is shipped by sea, then it should be efficient and safe.

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**Ride-Sharing**

Dedicating a section to ride-sharing is appropriate for this mode of transport. We are now transforming the meaning of vehicle ownership. One of the more interesting and recent applications of IoT in transportation is vehicle ownership. Due to the growing cost of a title, insurance, maintenance, gas, and parking, urban dwellers are selling or resisting purchasing their own cars. They’re choosing to ride with vehicle-sharing platforms like Uber and Lyft, in addition to relying on steadily improving public transportation services in the city. Ride-sharing is becoming cost-competitive with the total cost of car ownership. With a higher number of companies turning to IoT, these platforms will continue to expand, multiply, and get cheaper, driving down the demand for car ownership. This platform is using a business model that includes flexible pricing based on the time of day and vehicle tracking. Did you notice the notification “Your ride is five minutes away”? This is called vehicle-to-person communication.
I am an MBA graduate, so I must look for opportunities for vehicle insurers here. In Chapters 10 and 11 I covered advantages of IoT for insurance companies in the financial and medical sectors, respectively. Similarly, if vehicle insurers could get data about vehicle health and drivers’ operating habits, they could manage risk by analyzing those data. Through OBD devices, insurers have real-time insights into driver behavior, including factors like driving miles, speed, braking, tailgating, and frequency of night driving. OBD devices also help in improving fuel efficiency, predicting maintenance, and suggesting repairs. They can even help determine the meaning of a code from a check engine alert.

Applications

At a national level, governments around the world are starting to pilot IoT transportation initiatives. There are other applications of IoT in transport that are worth mentioning here, though. The following are the selected unique use cases associated with IoT applications in transportation.

Use Case: Transportation-as-a-Service

We used to know this using the simple word taxi or yellow cab. The definition of a taxi is enhanced under Transportation-as-a-Service (TaaS), though. This is another name for Mobility-as-a-Service (MaaS). It refers to the buying of miles, trips, or experiences, and none of these comes with the responsibility of car ownership. I agree that due to the TaaS model, car ownership is shrinking and creating an existential crisis within the transportation sector worldwide. Thinking about it differently, though, it is just a natural extension like in any other business. When a business process changes, we don’t call it disruption, we call it improvising. The automobile industry was working with the same model for decades and it was just waiting to be changed. From where I am looking, it is providing new business opportunities in this industry.

Thinking by numbers, an average U.S. family will save more than $5,600 per year in car ownership costs, equivalent to a wage increase of 10 percent. This cost of ownership includes parking and repairs. This money will go into other business and boost the economy overall.

Examples of TaaS are delivery services, ride-sharing services, rental transportation, car subscription services, bike shares, and private car rental (peer-to-peer rentals).
What is IoT doing in this use case? It starts with travelers; they can access schedules by smartphone to plan their trip based on real-time information from the transportation systems. Providers are next. With the use of IoT, vehicle pooling providers such as Uber will be able to keep track of rider and driver involvement during the course of travel. Rental companies can schedule vehicle maintenance based on actual utilization, which reduces disruptions from unexpected breakdowns. When accidents do occur, insurance telematics make for faster recovery, often at a reduced cost.

**Use Case: V2X Communication**

Vehicle-to-everything (V2X) occurs when a vehicle transmits messages to any potential entity that might affect that vehicle, like traffic lights, streetlights, and other vehicles. As shown in Figure 13-1, it consists of various type of communication. Vehicle-to-vehicle (V2V) technology is new.

![Figure 13-1. Types of V2X communication](image)

It means that a vehicle will transmit speed and position data to other surrounding vehicles on the road, thus preventing accidents using dedicated short-range radios. This is the core of automated cars (self-driving cars) and driverless public buses providing 360° situational awareness on the road. In vehicle-to-pedestrian (V2P) communications, a signal from the beacon will be released from the person and the car will detect it to avoid accidents.
Use Case: Location Tracking

As already discussed, transportation is a department that is functional around the clock, even during the time of a pandemic. Every day there is delivery of a vast number of items and movement of cargo as well as vehicles from any source to any destination around the world. In a condition in which there are a large number of items kept in a single place, then it is very difficult to find anything out. The packages can be integrated with a QR or barcode that can be scanned by cameras; further, accurate information can be delivered to the responsible authority. However, you cannot track its present location.

Now, in accordance with this provided case, IoT can help in maintaining a location record by using the sensors that are integrated in the warehouse, products, cargo, and vehicles. Thus, this integration of IoT in locating items is definitely considered a favorable use case.

In the lab that follows, we explore low-cost options to develop a location-aware application.

Lab: Logistics Monitoring

In 2016 at Seattle Code Camp, I presented a session on IoT. Most of my demo in that session was done using a smartphone, the cheapest IoT device anyone can have. This inexpensive IoT device comes with a touch screen display, full Android or iOS operating system, better memory, CPU power, battery, and all types of network connectivity, like Wi-Fi, Bluetooth, and NFC. In this lab I am once again using a smartphone to show how to track the location of a Thing. There are many different ways that you can track location data. Location data are important in every industry—we also learned of its importance in Chapters 9 and 10. In transportation, location data are now nonnegotiable data.

In this lab I am using Xamarin, the ultimate cross-platform mobile development platform for .NET developers. It creates a native application that is developed using the tools specified by the creator of the platform, such as an application developed for iOS with Objective-C, or an Android app developed with Java. Xamarin does produce a native app using a Windows app developed with .NET. It is a developer platform that is used for developing native applications for iOS (Xamarin.iOS), Android (Xamarin.Android), and macOS (Xamarin.Mac). One excellent feature of Xamarin is that it allows us to access both platform-specific APIs and platform-independent parts of .NET, including, for example, namespace systems. We can share a lot of code like business
logic and network calls between our target platforms by keeping code in a common project. Code sharing leads to shorter development times and higher quality.

As a manager you would like to cover the maximum number of users for your product, like a full range of Android and iOS devices. At the same time, you need to keep the cost of development and cost of maintenance down. You also want to reuse the current talent pool in the organization. That’s where Xamarin enters the picture. Because there are more .NET developers than Objective-C developers, it would be easier to find new developers. The in-house .NET developers can start building native mobile applications by just learning few APIs for the mobile platforms.

During installation of Visual Studio 2019, as shown in Figure 13-2, make sure to select the Mobile Development With .NET workload. If you already have Visual Studio 2019 installed, open Visual Studio Installer and click Modify to select Mobile Development With .NET.

![Figure 13-2. Mobile development with .NET](image)

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Let's see how to access location coordinates in your device in the Xamarin UWP application using Visual Studio 2019. For example, this project can be installed on the smartphone of a public bus or school bus driver, to track the location and time-of-arrival at a stop to avoid a long wait on cold winter or hot summer days.

Follow these steps to create a new Xamarin app.

1. Open Visual Studio 2019.
2. Select Create A New Project.
3. From the Project Type drop-down list, select Mobile.
4. Select the Mobile App (Xamarin.Forms) template and click Next.
5. Enter RouteMonitoringApp as the project name and click Create.
6. As shown in Figure 13-3 select the Shell template. Ensure that the Android and iOS check boxes are both selected. Ensure that the Include ASP.NET Core Web API Project check box is selected and click OK.

Figure 13-3. Creating a new Xamarin.Forms app
7. Wait until the nuget packages are restored (a “Restore completed” message will appear in the status bar). When asked, specific versions of the Android SDK are required to build projects. If your machine is missing the required SDK, you’ll see a prompt while the new project is loading. Click Accept to begin the automatic installation.

Your project is ready, as shown in Figure 13-4. You will see an Android project along with iOS and Web projects. The common code is shared between Android and iOS.

8. New Visual Studio 2019 installations won’t have an Android emulator configured. On the Debug button, click the drop-down arrow and choose Create Android Emulator, as shown in Figure 13-5, to launch the emulator creation screen shown in Figure 13-6.
Permissions can be set either from the Android Manifest tab in the properties of the RouteMonitoringApp.Android project or via the AndroidManifest.xml file in the Properties folder. When changes are made on the Android Manifest tab, the changes will be written to the Manifest file as well, so it doesn’t matter which method you prefer.
9. Open AndroidManifest.xml under RouteMonitoringApp.Android and give permission for Location and Coarse Location services.

```xml
<uses-permission android:name="android.permission.ACCESS_FINE_LOCATION" />
<uses-permission android:name="android.permission.ACCESS_COARSE_LOCATION" />
```

10. Depending on the use of Wi-Fi and a network to send these data to a server, you also need to give permission for Wi-Fi and network services.

```xml
<uses-permission android:name="android.permission.ACCESS_NETWORK_STATE" />
<uses-permission android:name="android.permission.ACCESS_WIFI_STATE " />
```

11. Right-click the project in Visual Studio and add the nuget package Xamarin.Essentials.

12. Open MainPage.xaml.cs. Under Common Project Name, add the following namespaces.

```csharp
using System.Net.Http;
using Xamarin.Essentials;
```

13. Paste the following code.

```csharp
HttpClient client = new HttpClient();
public static string AzureBackendUrl = DeviceInfo.Platform == DevicePlatform.Android ? "http://10.0.2.2:5000" : "http://localhost:5000";
Device.StartTimer(TimeSpan.FromSeconds(30), () =>
{
    Task.Run(async () =>
    {
        await SendLocationToServer();
    });
});
```
return true; // True = Repeat again, False = Stop the timer
});

public async Task SendLocationToServer()
{
    client.BaseAddress = new Uri($"{AzureBackendUrl}/");

    try
    {
        var request = new GeolocationRequest(GeolocationAccuracy.
Medium);
        var location = await Geolocation.GetLocationAsync(request);

        if (location != null)
        {
            var locationTuple = "$\{location.Latitude\}, \{location.
Longitude\}, \{location.Altitude\}\";
            var response = await client.PostAsync("api/location",
new StringContent(locationTuple, Encoding.UTF8,
"application/json");
        }
    }
    catch (Exception)
    {
        // Unable to get location
    }
}

14. To set the emulator device location, click ... next to the emulator and select a location. I am setting a location of Pike Market, Seattle, WA, as shown in Figure 13-7, which will send location Latitude, Longitude and Altitude “47.609655, -122.342151666667, 0” to the API.

Note For brevity in this chapter I am not showing you how to create a .NET Core Web POST API, which takes this location and save it in some storage for further processing.
That’s it. From the menu, select Debug ➤ Start Debugging or simply press F5 to see the result of your web API. Congratulations! You’ve built and run your first Xamarin app to track your location using an inexpensive IoT device, a smartphone.

To implement geofencing, Android supports multiple active geofences, with a limit of 100 per app, per device user. Geofencing is the combination of current location latitude and longitude with proximity to the location as a radius. The latitude, longitude, and radius define a geofence, creating a circular area, or fence, around the location of interest. Android provides entering and exiting events out of the box. Many open source and nuget packages available make it even simpler. I leave the implementation of a geofence in the preceding project for you to try.
Usually this kind of application should be able to run in the background. We can also enable background mode in our app with some more coding efforts. With Android, you need to create a JobService and schedule it. I am leaving the background scheduler for you to practice.

**Lab: Working with Sensors (Smart Parking)**

In this lab, I am using an ultrasonic ranging module (HC SR04) to measure the distance of a car from the sensor and print the result. Ultrasonic ranging modules use the principle that an ultrasonic signal will reflect when it encounters an obstacle.

We start counting the time when the signal is transmitted, and we finish counting after the signal is received back. The time difference is the total time of the ultrasonic signal from transmission to reception. Because the speed of sound in air is constant, and is about \( v = 340 \text{ m/s} \), we can calculate the distance between the model and the obstacle with the formula \( s = \frac{(v \cdot t)}{2} \).

We are using the same setup as in the lab in Chapter 6.

As shown in Figure 13-8, the ultrasonic sensor has four legs. HC-SR04 takes a 5V input and echo a 5V signal. From left to right, connect VCC to 5V. Connect the legs Trig and Echo to GPIO pins 23 and 24, respectively. Finally, connect GND to GND of GPIO.

![Circuit diagram of ultrasonic sensor connected with GPIO](image)

*Figure 13-8. Circuit diagram of ultrasonic sensor connected with GPIO*
1. Create a new project with File | New Project.
2. Select the template Blank App (Windows Universal).
3. Add a new class.

```
using System.Threading;
using Windows.Devices.Gpio;

class UcHCSR04Sensor
{
    GpioController gpio = GpioController.GetDefault();
    readonly GpioPin TriggerPin;
    readonly GpioPin EchoPin;

    public UcHCSR04Sensor(int triggerPin, int echoPin)
    {
        TriggerPin = gpio.OpenPin(triggerPin);
        EchoPin = gpio.OpenPin(echoPin);

        //Sets the drive mode of the general-purpose I/O (GPIO) pin
        //The drive mode specifies whether the pin is configured
        //as an input or an output
        TriggerPin.SetDriveMode(GpioPinDriveMode.Output);
        EchoPin.SetDriveMode(GpioPinDriveMode.Input);

        TriggerPin.Write(GpioPinValue.Low);
    }

    public double GetDistance()
    {
        ManualResetEvent mre = new ManualResetEvent(false);
        mre.WaitOne(500);

        Stopwatch pulseLength = new Stopwatch();

        //Send pulse
        TriggerPin.Write(GpioPinValue.High);
        mre.WaitOne(TimeSpan.FromMilliseconds(0.01));
        TriggerPin.Write(GpioPinValue.Low);
    }
}
```
//Receive pulse
while (this.EchoPin.Read() == GpioPinValue.Low) { }
pulseLength.Start();

//Read the signal from the sensor
while (this.EchoPin.Read() == GpioPinValue.High) { }
pulseLength.Stop();

//Speed 17,000 miles/hour or 27,350 kilometers/hour
//Calculating distance with sound speed 340m/s
double distance = pulseLength.Elapsed.TotalSeconds * 17000;
return distance;
}

Here the write and read drives the specified value onto the GPIO pin according to the current drive mode for the pin.

If the GPIO pin is configured as an output, the method drives the specified value onto the pin according to the current drive mode for the pin.

If the GPIO pin is configured as an input, the method updates the latched output value for the pin. The latched output value is driven onto the pin when the configuration for the pin changes to output.

4. Add the following code in MainPage.xaml.

<Grid Background="{ThemeResource ApplicationPageBackgroundThemeBrush}"
<TextBox x:Name="LocationBox" HorizontalAlignment="Left" Margin="431,405,0,0" Text="TextBox" VerticalAlignment="Top" Height="95" Width="406" FontSize="36"/>

Grid>
5. Add the following code in MainPage.xaml.cs.

```csharp
var uc = new UcHCSR04Sensor(23, 24);
var dist = uc.GetDistance();
LocationBox.Text = dist;
```

To compile and deploy the project you need to follow the steps given in Chapter 6. The final hardware setup is shown in Figure 13-9.

**Figure 13-9. Smart parking using an ultrasonic sensor connected with Raspberry Pi**

Congratulations! You just deployed your smart parking UWP application to a device running IoT Core and finished reading ultrasonic sensor data.

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**Note** You can connect multiple ultrasonic sensors with the Raspberry Pi.
Benefits of IoT Application in Transportation

After discussing the various use cases associated with this assignment, I present here a few ways in which IoT in transportation can benefit all the stakeholders involved. Based on the application, the benefit is classified into a different category, like traffic congestion, automotive telematics, reservations, tolls, ticketing, security, and surveillance.

Benefits to Commuters

Quite often public transportation commuters leave their homes or workplaces well ahead of time and are forced to wait at the train station or bus stop, wasting their valuable time. The primary reason for this is the highly unpredictable status of buses and trains. In the case of buses, although riders know the standard schedules, they don’t know if the buses are sticking to those schedules at any given time. Many cities are investing in IoT technology to solve this problem by relaying this information to passengers via mobile applications, digital signage at stops, or both. A few cities are also providing information on the number of passengers currently waiting and also recommending the best time to travel.

Mechanical breakdowns cause delays and frustrate passengers. Implementing modern maintenance techniques such as preventive and predictive maintenance help monitor the different health parameters of vehicles and infrastructure can help identify potential problems in advance. This leads to longevity of the vehicles, high uptime of services, minimal disruptions, and greater safety for passengers.

Benefits to the Environment

In reference to the preceding benefits, once we know the number of passengers on bus stops, a routing system could allocate the appropriate number of vehicles to different routes. When buses are filled, drivers can be alerted to skip stops and take shorter routes or take the fastest route based on traffic and signal information.

Similarly, railways take advantage of passenger data and decide how many seconds to wait at each spot. Trains can also increase or decrease their speed to efficiently utilize capacity.

City administrators use the same data to plan new routes and increase the number of buses and trains and the frequency of existing ones.
Citizens are also using public transportation to contribute to reducing pollution and helping to preserve the earth. On the other hand, cities have a similar responsibility and therefore provide reliable and predictable commuting options and attempt to reduce the number of private vehicles on roads. Cities use the same data to reduce their carbon footprint.

**Benefits to Businesses**

Through a rapidly increasing number of connected devices, embedded sensors, and analytics technologies, companies in the transportation sector can enjoy unprecedented visibility in almost every aspect of their business. The ability to control goods across the logistics can improve protection as well as product quality. Advanced telematics systems and GPS tracking sensors can be used to capture real-time data for monitoring and evaluating vehicle performance.

Different countries have different compliance requirements for businesses. Using sensors to record speed, distance, and driver activity ensure regulatory compliance and accurate recordkeeping for the entire fleet. These data are also shared with insurance companies to create customized insurance plans like user-based insurance (UBI) or models like pay as you drive (PAYD) and pay how you drive (PHYD).

Businesses reduce risk by identifying hazardous areas and damaged machinery so that it can be replaced in a way that causes little or no threat to employees like engineers and crew members. For example, drones can be used to identify leaks in an oil tanker and could also be used to patch the leak remotely.

**Challenges of IoT Application in Transportation**

Although IoT technology is exciting and futuristic, it comes with its own share of challenges. Referencing various advantages of IoT in transportation, there are various challenges as well. Let’s discuss challenges faced by companies while implementing IoT technology in their business activities.

- **Liability:** Semiautomatic or self-driving vehicles are designed to reduce accidents and eliminate loss of life, but accidents are inevitable. The responsibility of liability is a hotly debated topic. In the absence of a real driver behind the wheel, the other stakeholders
are the car manufacturer, the passenger as a standby driver, or the communication system. The lines are blurred, but for now we hold the passenger as standby driver responsible, and the reputation of the manufacturer could be damaged.

- **Network infrastructure cost**: Replacing existing towers with the new, sophisticated technology required for enabling 5G and laying fiberoptic cables throughout a city requires significant infrastructure upgrades and investment. Cameras and sensors are required for each parking spot to facilitate smart parking, an expensive proposition.

- **Employee training**: Although the use of IoT could be a lot of help, it will still require experience and knowledge of predictive maintenance charts and alerts, as the wrong interpretation of any condition could further damage the machinery and lead to costly repairs, which might be unacceptable to the company. Companies not hiring the right talent to deal with IoT work could see a delay in ROI. With more Edge computing coming into the picture, we need talent with knowledge of programming and cloud computing, or existing employees should be continuously adapting and learning. Companies might have to accept that they need a part-time consultant (or full-time employee in a larger organization) to work on AI, machine learning, and data analytics technologies to harness the true value of data.

- **Security**: Due to the involved sensors and devices connected to vehicles, the data are vulnerable to interruption and coordinated malware attacks. A malicious hacker could sell or exploit your location data. In case the of semi- or fully autonomous cars, hackers could even take over the operations of the car. Organizations need to implement processes to protect sensitive data and networks. Proper data governance and firewalls are essential to overcome this challenge.
Summary

Transportation is beginning to rely more heavily on IoT. The applications run far beyond those listed here. Any company working within the industry will soon learn, if they haven’t already incorporated IoT into their business, that this is the best way to beat the competition and future-proof their company.

When cities integrate wireless technology into traffic management and emergency response, the effect of IoT on transportation efficiency is projected to be immense. In this chapter, we have learned about the use of IoT in TaaS and how it is the backbone of V2X communication.

After practicing content from the lab section of this chapter, you should now have a good grasp of all the steps involved in creating a Xamarin.Forms application from scratch for Android and iOS devices. Using the knowledge gained from this chapter, you should be able to create any location-aware app you like.

To visualize what location data our app tracked, you will use the .NET Core API and a low-latency database.

This is the last chapter that discusses IoT in various industries. In the next chapter, you will take these concepts further and see the risks and challenges involved in implementing an end-to-end IoT project in an organization.