Chapter 1

Introduction

1.1 Intelligent transportation systems

It’s the application of sensing, analysis, control and communications technologies to ground transportation in order to improve safety, mobility and efficiency. Intelligent transportation system (ITS) includes a wide range of applications that process and share information to ease congestion, improve traffic management, minimize environmental impact and increase the benefits of transportation to commercial users and the public in general. ITS is part of the Internet of Things (IoT), includes vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology and incorporates both wireless and wire line communications-based information and electronics technologies. Wireless technology is used to connect vehicle information and location to other vehicles, other transportation modes (such as pedestrians or bicyclists), local infrastructure and remote infrastructure in the cloud. The goal of ITS is to streamline the operation of vehicles that manages vehicle traffic, assists drivers with safety and other information, along with provisioning of convenience applications for passengers and road safety. [1, 2]

ITS can be applied in every transport mode (road, rail, air, water) and services can be used by both passenger and freight transport. Examples of ITS includes but are not limited to the following:

- Traffic and Transit Management.
- Traffic Signal Systems.
- Advanced Driver Assistance Systems.
- Global Positioning Systems.
- Weather Information System.
- Commercial Vehicle Electronic Clearance.
- Real Time Traveler Information.

1.2 Advanced Driver Assistance Systems

Each new generation of cars is equipped with more automated features and crash avoidance technology. Indeed, many of today's high-end cars and some mid-priced ones already have options, such as blind-spot monitoring, forward-collision warnings and lane-departure warnings. These will be the components of tomorrow's fully self-driving vehicles as shown in figure 1.1.

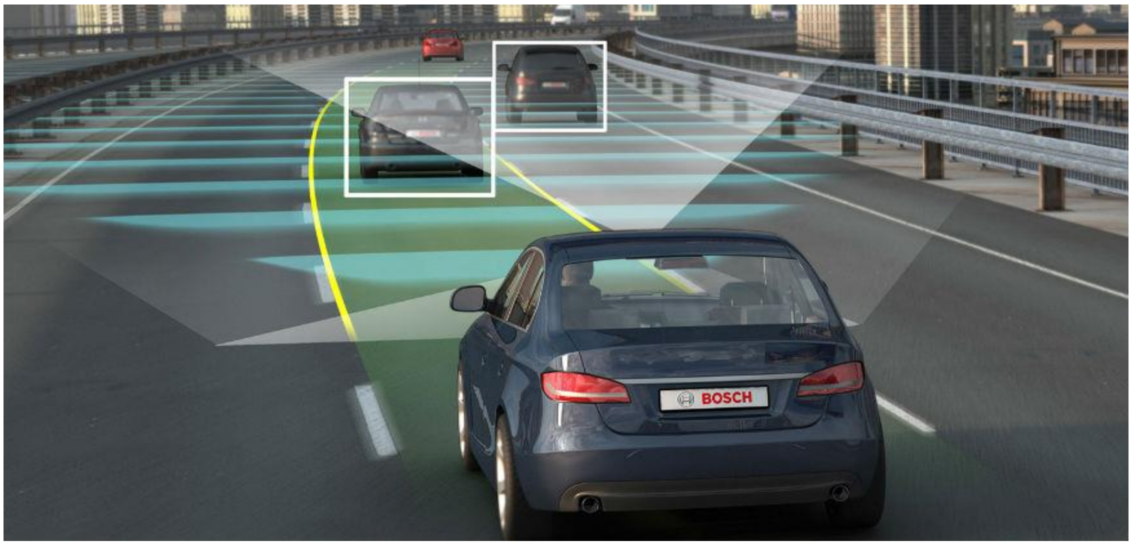

Fig.1.1: IDRS Self-Driving Car

Since most car crashes are caused by human error, in theory, taking control of the moving vehicle away from the driver is expected to drastically reduce highway fatalities.

1.2.1 The Progress Towards Full Automation

The Society of Automotive Engineers International has developed a classification system for defining driving automation for motor vehicles. This system has been adopted by the U.S. Department of Transportation and the United Nations. Experts vary as to when the changeover to self-driving cars will occur. A transport scholar at the University of Minnesota believes that by 2030 every car on the road will be driverless. According to the Insurance Institute for Highway Safety, it is anticipated that there will be 3.5 million self-driving vehicles on U.S. roads by 2025, and 4.5 million by 2030. However, the institute cautioned that these vehicles would not be fully autonomous, but would operate autonomously under certain conditions.

1.2.2 Public Attitudes

An Insurance Information Institute Pulse survey conducted in May 2016 found that 55 percent of consumers say that they would not ride in a fully autonomous vehicle. Earlier polls found that 50 percent said that a driverless car's manufacturer should bear responsibility in case of an accident, and only 25 percent say that they would be willing to pay more for a driverless car to cover the manufacturer's liability in case of an accident.

1.2.3 Autonomous Vehicle Testing

Among the major automakers testing self-driving cars are Audi, Ford, Mercedes, Nissan, Tesla, Toyota and Volvo. Technology companies including Apple, Waymo, Lyft and Uber are also considerably invested in testing autonomous vehicles.

1.2.4 Automated safety features available now

A 2015 study by the Insurance Institute for Highway Safety (IIHS) has found that improvements in design and safety technology have led to a lower fatality rate in accidents involving late model cars. The likelihood of a driver dying in a crash of a late model vehicle fell by more than a third over three years, and nine car models had zero fatalities per million registered vehicles. Part of the reason for the lower fatality rate might also have resulted from the weak economy, which led to reduced driving, the IIHS said. The IIHS attributed the lower death rate to the adoption of electronic stability control, which has reduced the risk of rollovers, and to side airbags and structural changes that improve occupant safety. However, the IIHS said, there was a wide gap between the safest and the least safe models, with the riskiest cars mostly small lower cost models.

1.2.5 Risks of self-driving cars

A 2014 automotive study by IHS, a global information company, entitled "Emerging Technologies: Autonomous Cars—Not If But When" notes two major technology risks, software reliability and cyber-security. The risk of an accident is unlikely to be completely removed since events are not totally predictable and automated systems can fail. [4]

1.3 The IoT Three Layers Model

It consists of three layers: the edge, the fog, and the cloud layers as shown in figure 1.2.

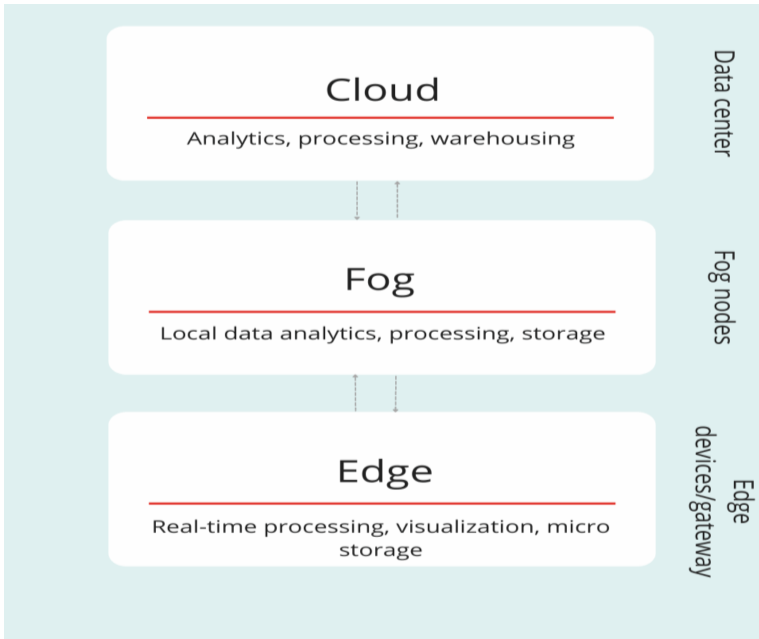

Fig.1.2: IoT data Layers model

As shown in figure 1.2 the here layers work together collects, processes, manipulate and store data from IoT different components.

1. **Cloud layer** is the uppermost layer and consists of cloud servers or data centers. It provides additional computational resources, storage capacity, and advanced analytics capabilities. The cloud layer receives processed data from the fog layer, performs further analysis, and stores large datasets for long-term storage or historical analysis. It also facilitates centralized management and scalability.
2. **Fog layer** sits between the edge layer and the cloud layer, and it performs more advanced data processing, analytics, and storage. It handles larger volumes of data and performs complex computations closer to the source. The fog layer includes fog nodes, fog servers, edge computing platforms, and communication infrastructure.
3. **Edge layer** is the closest layer to the edge devices and performs initial data filtering, preprocessing, and local analytics. It collects data from sensors and devices in transportation infrastructure and vehicles, making quick decisions based on real-time conditions.[7]

1.3.1 Difference Between cloud, fog and edge computing

The main difference between cloud, fog and edge computing is where, when and how data from endpoint devices are processed and stored.

- **Cloud** is the centralized storage situated further from the endpoints than any other type of storage. This explains the highest latency, bandwidth cost, and network requirements.
- **Fog** acts as a middle layer between cloud and edge and provides the benefits of both. Fog is placed closer to the edge. If necessary, it engages local computing and storage resources for real-time analytics and quick response to events.
- **Edge** is the closest you can get to end devices, hence the lowest latency and immediate response to data. This approach allows to perform computing and store limited volume of data directly on devices, applications and edge gateways.

Table 1.1 summaries differences between cloud, fog, and edge computing.

Table 1.1: Comparison between Cloud, Fog, Edge

	Cloud	Fog	Edge
Latency	Highest	Medium	Lowest
Scalability	High, easy to scale	Scalable within network	Hard to scale
Distance	Far from the edge	Network close to the edge	At the edge
Data analysis	Less time-sensitive data processing, permanent storage	Real-time, decides to process locally or send to cloud	Real-time, instant decision making
Computing power	High	Limited	Limited
Interoperability	High	High	Low

1.4 Fog computing in Intelligent Transportation System

It's a decentralized infrastructure that places storage and processing components at the edge of the cloud, where data sources such as application users and sensors exist as shown in figure 1.3.

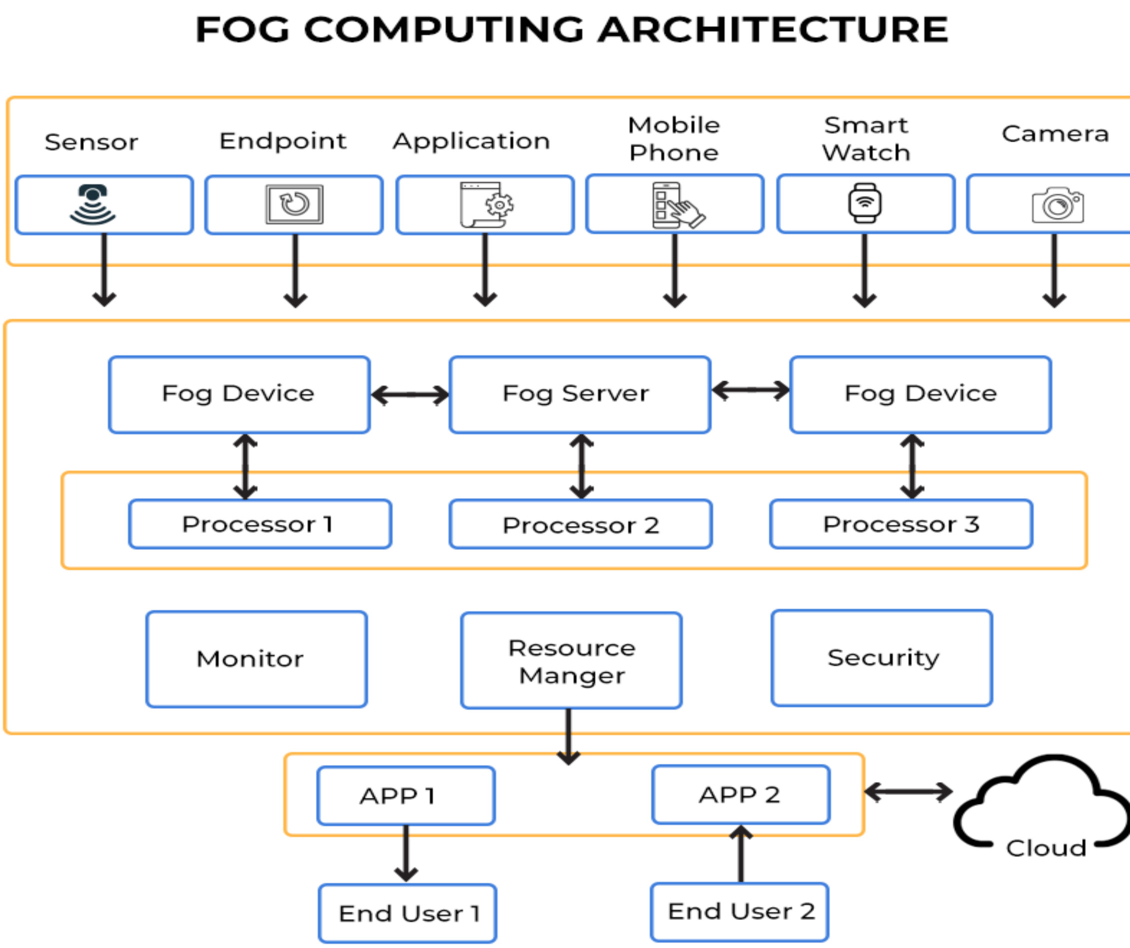

Fig.1.3: Fog Computing Architecture

There are multiple ways of implementing a fog computing system. The common components across these architectures are explained below;

- **Physical and virtual nodes:** serve as points of contact with the real world, including devices like application servers, edge routers, mobile phones, smartwatches, and sensors. These nodes generate data and can have different storage and processing capacities, as well as varying software and hardware configurations.

- **Fog computing:** are independent devices that collect generated information. They are classified as fog devices, fog servers, and gateways. Fog devices store data, fog servers compute data and make decisions, and fog gateways manage information transfer.
- **Monitoring services:** play a crucial role in overseeing system performance and resource availability. These services often utilize application programming interfaces (APIs) to track the status of end devices and fog nodes, ensuring uninterrupted communication.
- **Data processors:** are software programs that operate on fog nodes. They are responsible for filtering, trimming, and sometimes repairing faulty data received from end devices.
- **Resource manager:** is responsible for managing the allocation and deallocation of resources among various nodes. It handles the scheduling of data transfers between nodes and the cloud, optimizing resource utilization and network efficiency.
- **Security:** must be built into the system even at the ground level. Encryption is a must since all communication tends to happen over wireless networks.
- **Applications:** play a key role in delivering services to end-users by leveraging data from the fog computing system.

To ensure seamless communication and interoperability, an abstraction layer is implemented, which provides a common interface and protocols for efficient communication between components. [5]

1.4.1 Applications of FOG architecture

IoT an FOG computing is the most recent paradigm that has a wide range of applications, this includes;

- **Smart Utility Service:** saves cost and time through conservation of energy. Fog computing is beneficial in enabling analysis of data from the application at every minute for continuous update and addressing complication in transmission of other data heavy traffic created by IoT applications.
- **Smart Cities:** The most significant examples of the application of fog computing for smart cities is traffic regulation. The traffic signals and road barriers are installed with sensors to collect data on the movement of vehicles on the road. Fog computing allows real-time data analysis that enable the traffic signal to rapidly change according to the traffic situation.[6]

1.5 Problem Statement

Most of the car accidents are caused by human error, throughout the researches the general consensus among experts is that human error contributes to at least 90% of the auto accidents. The main cause to these errors is that, the driver may fall into a fainting state for any medical reason such as pressure problems, heart attacks, diabetes, etc. Also, the driver may fall asleep due to lack of sleep. Accordingly, these accidents cause traffic congestion for a long time and sometimes people pay their lives for it. The proposed solution was built on the basis of using artificial intelligence techniques and satellite technology to find a radical and effective solution to this problem and prevent its occurrence.

1.6 Project Aim

Sustainable development is one of the most significant societal challenges that will greatly affect the world's future. One of the most important goal of Egypt 2030 sustainable development is to make cities and human settlements inclusive, safe, resilient, and sustainable. IoT and AI technologies can provide this goal through smart models with advanced control systems. The project main goal is to provide intelligent and safer transportation systems that will prevent or greatly minimize the possibility of car crashes due to human errors. There is already the Egyptian emergency control system which is called NAC (Network Access Control 82), and our system is made to complete this system, because there are features in our system that isn’t in the NAC system.

Moreover, this model can be extended to be used in the next generation of future military battles by replacing the transportation civilian vehicles with military combat vehicles. This will reduce the number of human lives lost in battles.

1.7 Project motivation

We consider this project to provide intelligent, safer and reliable system in both civilian and military applications.

1.8 Proposed problem Solution

Our project will introduce a novel solution to this problem, specifically a hybrid model for vehicle driving based on IoT and Fog computing technology. Figure 1.4 shows the system context diagram. Moreover, this project uses the AI algorithms for analyzing Bioinformation of the driver. This solution will be implemented based on the decision taken according to the data collected and analyzed from the following two procedures;

- The first procedure will be implemented by measuring the driver’s vital signs such as pulse, pressure, sugar and others using IOT tools. This phase is established to determine the driver’s health status on which we measure his ability to drive.
- The second procedure will be implemented by analyzing the driver’s facial features such as his eye movement and facial expressions using AI tools. This phase is established to determine if the driver lost consciousness or fell asleep.

Based on the data which has been collected about the driver's health status, his geographical location and the vehicle’s information, an analysis routine will be performed. As a result, in the case of emergency the proposed IDRS system immediately takes the control and kick up a rescue process. This process starts by sending a rescue acknowledge to an Emergency Control Unit at the Main Traffic Office of the current region (using Mobile application and web application). In conjunction with this step, the IDRS initializes a self-driving process to the vehicle, this process aimed to drive the vehicle under remote control until reaching the nearest safe place for parking using AI and IoT.

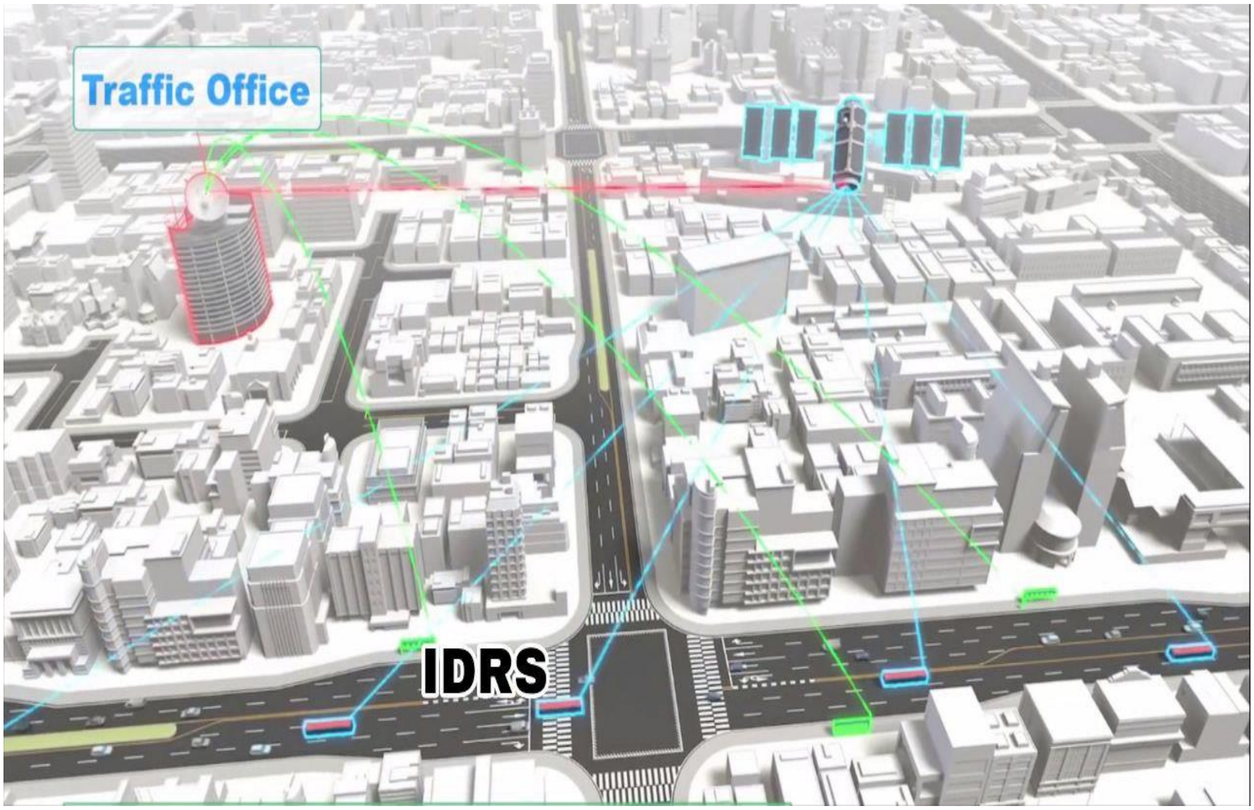

Fig.1.4: System Context diagram

The IDRS will initiate a warning operation to the surrounding environment through a Sound-light warning alarm and sending an acknowledge to the surrounding vehicles through the V2V protocol.

Summary

In this chapter, we covered the following topics; the definition of ITS and its various components, such as sensors, communication systems, data processing units, and control centers. We explored the specific applications of ITS, including real-time traffic monitoring and management, intelligent collision avoidance systems, onboard vehicle diagnostics and advanced driver assistance Systems. These applications aim to improve transportation efficiency, safety, and user experience. An overview of autonomous vehicles, including the risks and challenges they may face, the societal perception of them, their current status, and what the future holds for this project. Then we moved on to discussing fog computing, its definition, components, and the applications it is used for. Exploring the different types of layers associated with it, whether it's the 3-layer or 7-layer model. Discussing the differences between fog computing, cloud computing, and edge computing. Examining a specific problem and its solution. Following that, we delved into the project's objectives and what we aim to achieve.