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SMART CITIES USING MACHINE LEARNING AND IOT TECHNOLOGY FOR BUSINESS INTELLIGENCE

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Abstract

Internet of Things (IoT) and its applications have grown to be smarter and connected various devices which give rise to its utilization in all aspect of a modern city. As the amount of the composed data increases, the Machine Learning (ML) method is usefully to the further development in the various intelligence and potential of the application. Smart transportation based application has concerned various researchers as well as it has been approach by means of both ML techniques and IoT methods. This article gives an importance to smart transportation which is measured to be an umbrella term which covers optimization of routes, the parking, accident detection / prevention, street lights, road anomalies, and the infrastructure based applications. The intention of this paper is to construct a self-contained evaluation of IoT based applications with Machine Learning techniques in Intelligent based Transportation Systems (ITS) and attain a clear examination of the tendency in the aforementioned fields, and to spot the possible coverage needs. From the reviews done, it becomes thoughtful that there is a probably lack of Machine Language coverage for the Smart Lighting based Systems and Smart Parking based applications. In addition, the route optimization, accident/detection and parking, be likely to be the majority popular Intelligent Transportation Systems (ITS) based applications among the researchers for better business intelligence (BI) and development.

Keywords: Internet of Things; machine learning; smart transportation; smart city; intelligent transportation systems; big data, Business intelligence.

1. INTRODUCTION

Over the few decades, the applications based on the sensors, mobile devices, and the actuators have turn into smarter, allowing the communication within the devices and be executed for more complex related tasks. In 2013, the quantity of connected devices exceeded the global population and the count keeps increasing huge until today. The smart phones, the embedded systems, wireless based sensors, and roughly the entire electronic device are been connected to a restricted network or the internet, leads to the age of the Internet of Things (IoT). As the number of devices gets increasing, the quantity of data composed by those devices is been increasing as well. The new applications appears in which different collected data's are analyzed to make significant correlations and the possible decisions, leading to introduction of Artificial Intelligence (AI) via Machine Learning (ML) algorithm. For better development in business intelligence and to improve the technical infrastructure that collects, stores, and analyzes the data produced by a company's activities this approach helps to achieve it.

2. Literature Review

Ensuring sustainable based development and the quality of human living in these modern complex social based ecosystems of the urban areas and cities are significant concerns. The cities are very highly increasingly conscious in aspects to "smart cities" and be very vigorously developing various approaches in the direction of the goal of fetching "smartness" and to manage the city resources in a more powerfully manner, whereas addressing the growth and the additional challenges. To comprehend the idea of the smart city, it is essential to commence with considerations the intangible relations between the models. Although inadequate in scope, it sets the speculative based framework to achieve the holistic perception of smart cities currently been understood through the urban based planning sphere. An origin of the thought lie in the Dutton's wired based city that promised toward the use of emerging the telecommunications techniques which provides the unprecedented kind of amounts of the data and the information to the households and other businesses through the idea of "information highways", which can generate a communications-centric society [3].

Another originator to idea of the smart city is digital based city, a technologically-defined city that uses widespread broadband infrastructure to support e-Governance and "a global environment for public transactions" [4]. The plan of smart city is recognized from the amalgamation of the acquaintance based society and the digital city. It is been defined as a "multi-layer based territorial scheme of innovation" which is made up of the digital networks, individual based intellectual capital, and the central social capital of the city, which jointly constitute combined intelligence [13]. The economic oriented competitiveness and the innovation attained by the knowledge-oriented economy that marks a city to be intelligent, allowing it to generate a "spatial competitive advantage" through industrial districts, regions, and learning clusters that produce sophisticated R&D and are supported by digital networks and artificial intelligence [10].

Based on the exploration of a wide and extensive array of literature from various disciplinary areas, the identified factors– Social, Management, Economy, Legal, Technology, Sustainability, (SMELTS) forms the basis of an integrative framework. This comprehensiveness is the distinguishing factor of the smart city, which integrates a number of physical, institutional, and digital components to create a holistic definition of what smart planning would look like.

3. Methodologies

Different methodology and modern techniques are discussed in this section for the improve the process of smart cities.

3.1. Internet of Things for BI

In Internet of Things (IoT) terms, all connected device is measured a thing. Things typically include the physical based sensors, the actuators, and an embedded system with a microprocessor. Things need to communicate with each other, creating the need for Machine-to-Machine (M2M) communication. With the massive usage of IoT based devices in all forms of everyday modern life applications, it is very essential to maintain the cost of all IoT devices low. Also, the IoT based devices should be capable of handling the basic tasks like M2M, data collection, the communication, and even various pre-processing of the data depending on the application. IoT is also tightly attached to "big data", since IoT devices continuously collect and exchange a great amount of data. So, an IoT infrastructure usually implements methods to handle, store, and analyze big data. As a result, there is a need for an intermediate node, with sufficient resources, able to handle advanced processing tasks, physically located close to the end network elements, in order to minimize the overload caused by massive sending of all the data to some central cloud nodes. The solution came with the introduction of the "Fog nodes" [6]. Fog nodes help IoT devices with big data handling by providing storage, computing, and networking services. Finally, the data are stored in cloud servers, where they are available for advanced analysis using a variety of ML techniques and sharing among other devices, leading to the creation of modern added. Some of the examples of Business Intelligence software and systems include the comprehensive platforms, data visualization, embedded software applications, location intelligence software and self-service software built for non-tech users. Most important applications for better growth is discussed in the following categories.

3.1.1 Smart Homes: This category includes traditional home devices, such as fridges, washing machines, or light bulbs that have been developed and are able to communicate with each other or with authorized users via internet, offering a better monitoring and management of the devices as well as energy consumption optimization. Apart from the traditional devices, new technologies spread, providing smart home assistants, smart door locks, etc.

3.1.2 Health-care assistance: New devices have been developed in order to improve a patient's well-being. Plasters with wireless sensors can monitor a wound's state and report the data to the doctor without the need for their physical presence. Other sensors in the form of wearable devices or small implants can track and report a wide variety of measurements, such as heart rate, blood oxygen level, blood sugar level, or temperature.

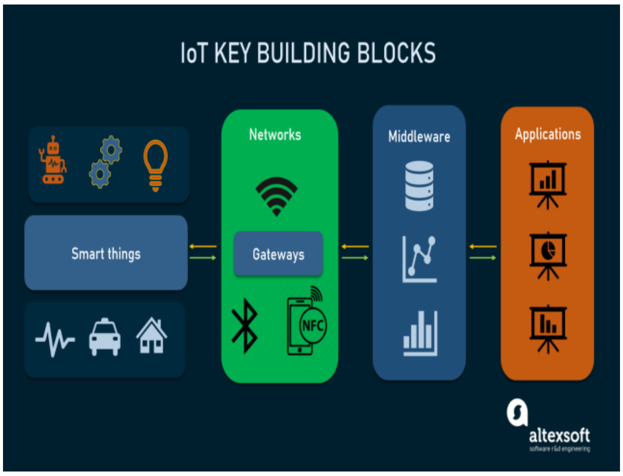

Fig 1: *Key elements of the Internet of Things (IoT) infrastructure (Benefits of BI)*

3.1.3 Smart Transportation: Using sensors embedded to the vehicles, or mobile devices and devices installed in the city, it is possible to offer optimized route suggestions, easy parking reservations, economic street lighting, for public means of transportation, accident prevention, and autonomous driving.

Fig 2: *Modern Analytics*

3.1.4 Environmental Conditions Monitoring: Wireless sensors distributed in the city make the perfect infrastructure for a wide variety of environmental conditions monitoring. Barometers, humidity sensors, or ultrasonic wind sensors can help to create advanced weather stations. Moreover, smart sensors can monitor the air quality and water pollution levels across the city.

Fig 3: *Environmental Monitoring*

3.2. Machine Learning for Smart Cities

Machine Learning (ML) is not a new concept. ML is closely related to Artificial Intelligence (AI). AI becomes feasible via ML. Through ML, computer systems learn to perform tasks such as classification, clustering, predictions, pattern recognition, etc. To archive the learning process, systems are trained using various algorithms and statistical models to analyze sample data. The sample data are usually characterized by measurable characteristics called features and an ML algorithm attempts to find a correlation between the features and some output values called labels. Then, the information obtained during the training phase is used to identify patterns or make decisions based on new data. ML is ideal for problems such as regression, classification, clustering, and association rules determination. Depending on the learning style, ML algorithms can be grouped into four categories:

3.2.1 Supervised Learning:

Supervised learning deals with problems involving regression such as weather forecasting, estimating life experience, and population growth prediction, by using algorithms like Linear Regression or Random Forest. Additionally, supervised learning addresses classification problems such as digit recognition, speech recognition, diagnostics, and identity fraud detection, by using algorithms such as Support Vector Machines, Nearest Neighbor, Random Forest, and others. There are two phases in supervised learning. The training phase and testing phase. The data sets used for the training phase need to have known labels. The algorithms learn the relationship between the input values and labels and try to predict the output values of the testing data

3.2.2 Unsupervised Learning: Unsupervised learning deals with problems involving dimensionality reduction used for big data visualization, feature elicitation, or the discovery of hidden structures. Moreover, supervised learning is used for clustering problems such as recommendation systems, customer segmentation, and targeted marketing. Contrary to supervised learning, in this type, no labels are available. Algorithms in this category try to identify patterns on testing data and cluster the data or predict future values.

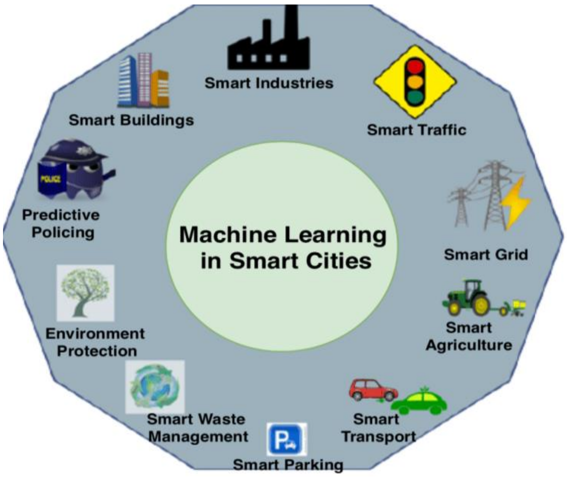

Fig 4: *Machine Learning in Smart Cities*

3.2.3 Semi-supervised Learning:

This is a combination of the previous two categories. Both labeled data and unlabeled data are used. It works mostly like the unsupervised learning with the improvements that a portion of labeled data can bring

3.2.4 Reinforcement Learning:

In this learning style, the algorithms try to predict the output for a problem based on a set of tuning parameters. Then, the calculated output becomes an input parameter and new output is calculated until the optimal output is found. Artificial Neural Networks (ANN) and Deep Learning, which will be presented later, use this learning style. Reinforcement learning is mainly used for applications like

3.3. Machine Learning in IoT

With IoT, devices are connected with each other, communicate with each other and collect an enormous amount of data every day. In many applications, IoT devices may also be programmed to trigger some actions based either on some predefined conditions or on some feedback from the Future Internet 2019, 11, 94 5 of 23 collected data. However, in order to analyze the collected data and extract meaningful information and create smart applications, human intervention is required. IoT devices need not only to collect data, and communicate with other devices, but also to be autonomous. They need to be able to take context based decisions and learn from their collected data. This need led to the creation of the term "Cognitive IoT" (CIoT) [10]. Also, there is a necessity for Intelligent IoT devices, able to create automated smart applications with automated resource allocation, communication, and network operation. Deploying ML algorithms in an IoT infrastructure can introduce significant improvements in the applications or the infrastructure itself. ML can be applied for network optimization, congestion avoidance, and resource allocation optimization, but also for real-time or offline data analyzing and decision making.

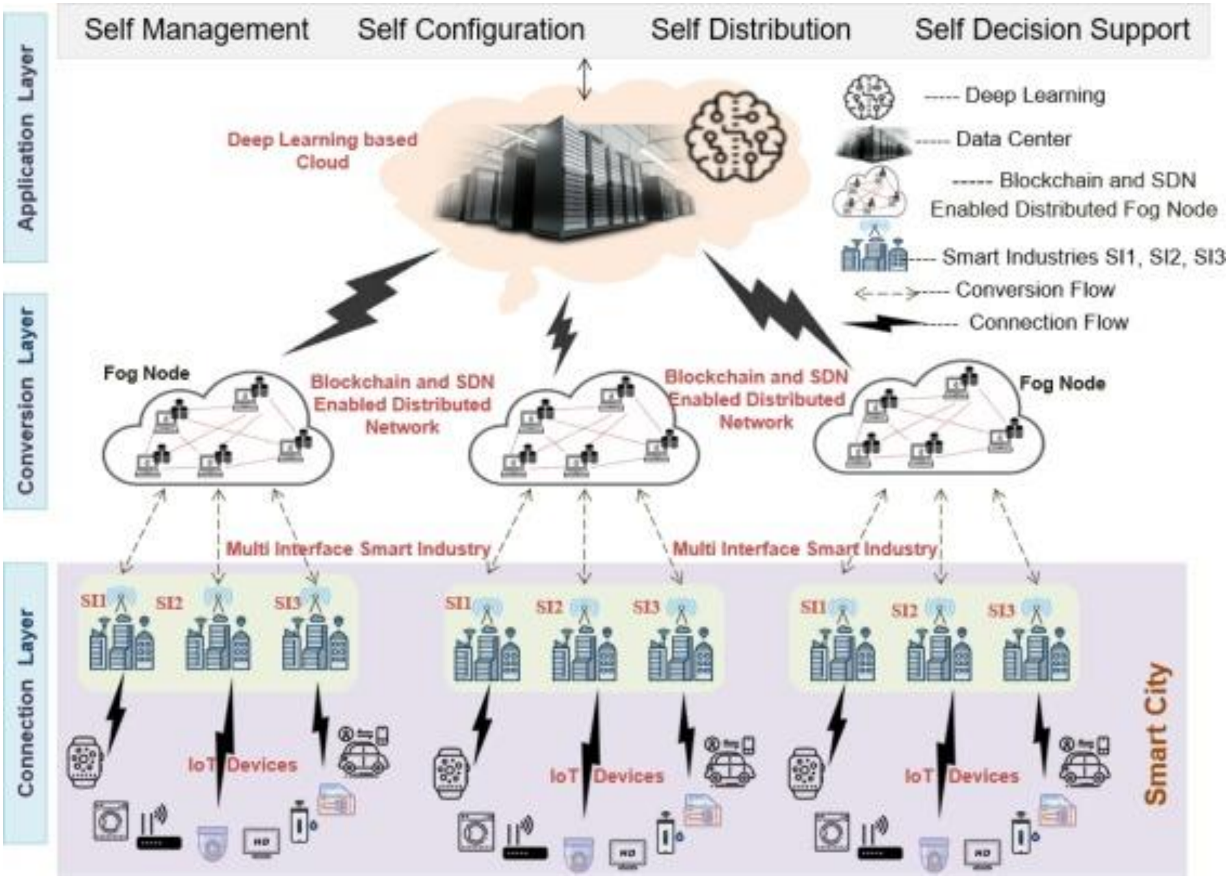

Fig 5: *Machine Learning and IoT in Smart Cities*

3.4. Smart Transportation

As the IoT technology expands, new applications are created in order to make people's lives better. Cities are getting "smarter" and smart city applications are developed to take advance of the latest technological improvements. With the introduction of IoT in the field of transportation, transportation systems begin to "feel" and "think", leading to the development of Intelligent Transportation Systems (ITS). Smart transportation has attracted the attention of many researchers since there are plenty of opportunities for further enhancements. One of the most significant areas of interest in smart transportation is navigation or route optimization. Using data from the users' mobile devices, or with side units placed in specified locations on the road [13], applications try to estimate traffic congestion and propose optimal route options to minimize traveling times, and therefore reduce car emissions and energy consumption.

Furthermore, to support the energy consumption reduction, street lights are proposed that can detect traffic conditions and operate accordingly, instead of being constantly on with a time schedule. IoT devices have been widely used to create smart parking systems, too. Using cameras, or other wireless sensors like magnetic field or IR sensors, researchers have proposed new parking reservation systems that allow maximizing a parking lot's availability and capacity and minimizing the searching time.

Moreover, systems that help detect road surface anomalies based on input data from sensors attached to cars or the driver's phone have been proposed. By detecting bad road conditions, accidents could possibly be avoided. There have also been efforts to detect or prevent road accidents using IoT devices. Finally, the IoT M2M communication option has given the opportunity to develop vehicle to vehicle communication and vehicle social networks, where vehicles can exchange useful information with each other and give many more possibilities for new applications. The rest of the article is organized as follows. In Section 3.5, there is a presentation and a detailed analysis of the ML algorithms used in the reviewed researches to support smart transportation applications. Additionally, in Section 3.3, there is a review of the IoT and ML applications about smart transportation, organized in categories, based on the application type. In Section 3.5, a discussion on the schemes presented is performed, and concluding remarks are drawn.

Fig 6: *Smart Transportation*

3.5 Machine Learning and IoT in Smart Transportation in cities

Smart Transportation is a very popular area of research, since it encounters many everyday problems, with a huge footprint in a modern smart city. Additionally, the nature of the problems it deals with favors the use of both IoT and ML technologies. This review aims to both identify the current trend in the use of ML and IoT in smart transportation, and examine the research coverage in Future Internet 2019, 11, 94 6 of 23 each one of the smart transportation categories. For this reason, the review focuses on the most recent research works, which address the smart transportation categories (route optimization, parking, lights, accident detection/prevention, road anomalies, and infrastructure), using IoT and/or ML techniques.

3.5.1. Machine Learning Algorithms

This section will focus on references that use ML algorithms to support Smart Transportation. The algorithms and their use will be thoroughly analyzed in the following subsections. The below diagram explains the smart transportation in IoT and Machine Learning.

No	Algorithm	Algorithm Type	Learning Type
1	AdaBoost	Ensemble	Supervised
2	Bayesian Network Seasonal Autoregressive Integrated Moving Average–(BN-SARIMA)	Bayesian	Supervised
3	Convolutional Neural Network-(CNN) and Deep CNN-(DCNN)	Deep Learning	Reinforcement
4	Coupled Hidden Markov Model–(CHMM)	Markov Model	Reinforcement
5	Decision Tree	Decision Trees	Supervised
6	Deep Belief Networks–(DBN)	Deep Learning	Reinforcement
7	Deep Recurrent Attention Model - (DRAM)	Recursive Neural Networks-Deep Learning	Reinforcement
8	Fuzzy C-Means–(FCM)	Clustering	Unsupervised
9	Feed Forward Neural Networks–(FF-NN)	Artificial Neural Networks	Supervised
10	Fully Connected Networks-(FCN)	Deep Learning	Reinforcement
11	Stacked Auto Encoder-(SAE) with Greedy Layer-wise training	Deep Learning	Reinforcement, Unsupervised
12	Inception Neural Networks	Deep Learning	Reinforcement
13	K-Means	Clustering	Unsupervised
14	*k*-Nearest Neighbor–(*k*-NN)	Instance Based	Supervised
15	Logistic Regression	Regression	Supervised
16	Markov Decision Process–(MDP)	Discrete Time Stochastic Control	Reinforcement
17	Markov Random Field-(MRF)	Markov Model	Unsupervised
18	Nonlinear AutoRegressive eXogenous model - (NARX)	Recursive Neural Networks-Deep Learning	Reinforcement
19	Q-Learning	Stochastic Control-Markov Model	Reinforcement
20	Random Forest–(RF)	Ensemble	Supervised
21	Regression Tree	Decision Trees	Supervised
22	Support-Vector Machine-(SVM)	non-probabilistic	Supervised

Fig 7: *Different Algorithms and its Types*

3.5.2. Ensemble

Ensemble algorithms address a problem, by training multiple classifiers and combining their results. The main advantage of ensemble methods is their ability to boost the so called weak classifiers to strong classifiers. In this way, the systems can use the weak classifiers which are easily constructed and also gain the quality of a strong classifier. In previous study, the authors aim to prevent road accidents by creating a framework to detect the driver's consciousness. The input data are collected by a camera fixed in front of the driver, in order to track eye movement and head nodding. Then, Human HAAR features are selected from an extracted integral image, which become input for the Adaptive Boosting (AdaBoost) algorithm. AdaBoost is an ensemble algorithm which is used together with other weak classifiers to form a strong classifier. In the research, a large number of features need to be processed in real time and AdaBoost shows a great advantage in that aspect.

3.5.3 Bayesian

A Bayesian network is represented by a Directed Acyclic Graph (DAG), which implements a probability distribution for a given set of random variables. Given a training set as variables, the model can be estimated, which can be used later to assign labels to new data. A Bayesian network is a model that describes all the variables and their relationship. Thus, the observation of some variables in a Bayesian network can give information about the state of another set of variables in the network.

3.5.4 Markov Models

Markov Models are stochastic sequence models based on probability distribution. The simplest Markov model is a Markov chain. In a Markov chain, a distribution of a variable that changes its value randomly over time depends only on the distribution of the previous state. A Hidden Markov Model is similar to a Markov chain, but it uses hidden states for fine tuning. Each state is represented by a probabilistic function of a state.

3.5.5 Decision Trees

Decision trees are structures that deal with classification tasks and they represent a decision process with several possible outcomes. A decision tree is built top down and consists of several nodes, where every node can be either a class, or a condition that will drive a testing item to a class. It is a simplistic approach to classification problems. A new classification sub-process takes place at every level of a decision tree, breaking the main task to smaller sub-tasks .

3.5.6 Clustering

Clustering is an unsupervised method to classify elements into discrete groups based on their similarities or discovered patterns. Contrary to the classification methods, in clustering there are no known labels to train a model. Existing studies suggests a Fuzzy C-Means clustering method in order to make short-term traffic predictions. While in a regular clustering method, an instance has to belong to one of the examined classes, in Fuzzy C-Means

3.5.7 Artificial Neural Networks

Artificial Neural Networks are mostly characterized by the structure of the neural network and the learning method. A neural network is formed by creating weighted connections among neurons. In a neural network there is an input layer where the input variables are inserted to the network, and each neuron represents a variable, and there is the output layer where the labels are assigned and each neuron represents a label. Between those layers there are one or more hidden layers.

4. Results and Model

With the intervention of IoT along with the machine Learning Techniques, smart cities are formed with the use of algorithms and different technology as discussed. Some of the sample implementation/models are shown below

Fig 8: *Example of smart transportation in IoT and Machine Learning*

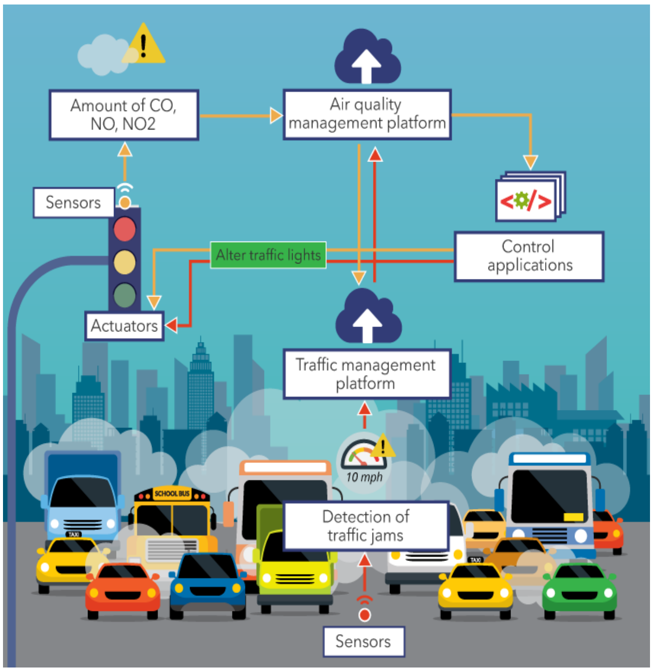

Fig 9: *IoT and ML for Smart Cities: Use Cases and Implementation Strategies*

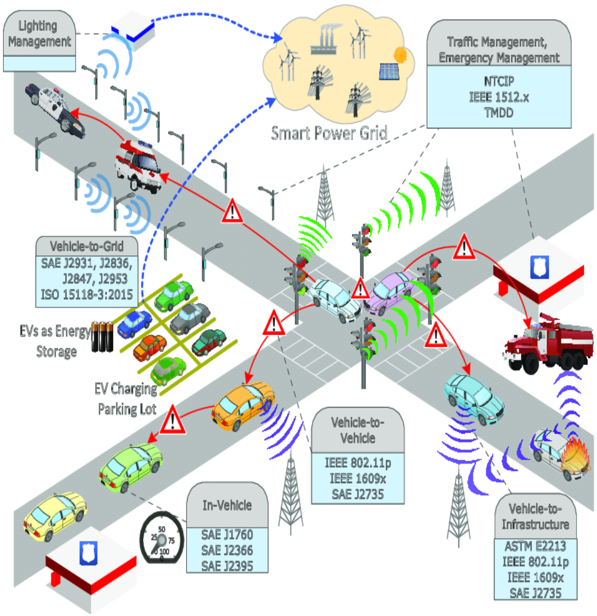

Fig 10: *Intelligent Transportation System and Smart City are closely coupled*

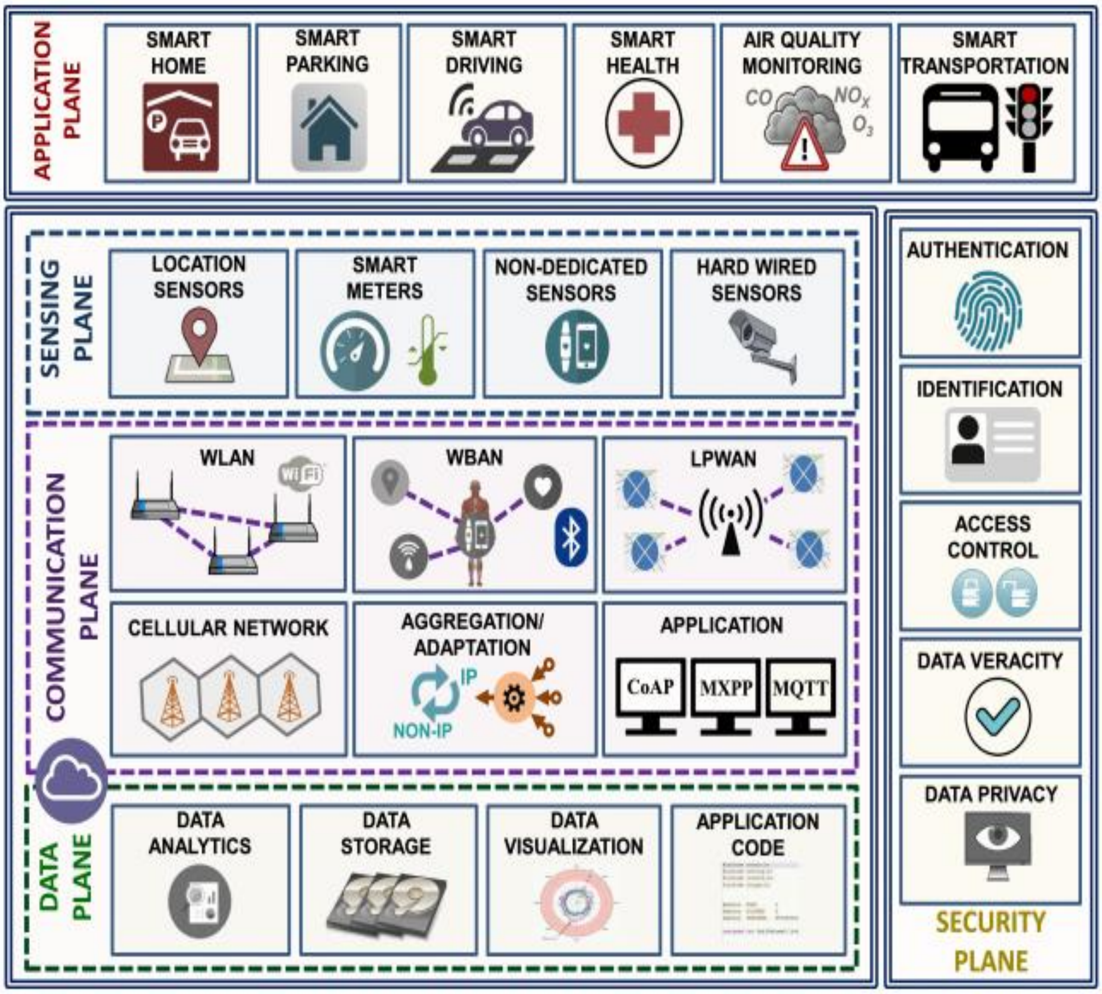

Fig 11: *Smart City System Model and Design*

5. Conclusion

The arrival of AI and IoT has drastically changed the entire business landscape. The amalgamation of IoT and ML can help management make informed decisions with zero error. While IoT accumulates large amounts of data through device connectivity via the internet, so creating and maintaining the modern smart cities with all AI and ML infrastructures helps in assimilating and evaluating this data. Machine learning (a subset of AI) in IoT devices helps to identify patterns and detect any faults in data collection through extremely advanced sensors. Intrinsic things such as stimulation to air, temperature, humidity, pollution, sound, vibrations, lights, etc., are derived with this technology over a period of time. Unlike traditional technology, IoT and machine learning make operational forecasts 20x faster with heightened accuracy.

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