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Internet of Things (IoT) Technologies, Applications, Challenges and Future Directions: A Survey

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***Abstract*– The main aim of this paper is to discuss the IoT in a wider sense and prominence on protocols, technologies and application along related issues. The main factor IoT concept is the integration of different technologies. Recent developments in Internet and smart phone and machine-to-machine M2M technologies can be considered first phase of the IoT. In the coming years IOT is expected to be one of the main hubs between various technologies by connecting smart physical objects together and allowing different applications in support of smart decision making. It becomes a main part of our life critical infrastructure bringing interconnection of heterogeneous devices in different aspects. Personal computing, sensing, surveillance, smart homes, entertainment, transportation and video streaming are examples, to name a few. In this paper, we provide an overview study of the IoT paradigm, its concepts, principles and potential benefits. Specifically, we focus on the IoT major technologies, emerging protocols, and widespread applications.**

***Index Terms*– Internet of Things (IoT), Service Oriented Architecture (SoA), Information Communication Technology (ICT), Machine to Machine (M2M), Smart Objects and Heterogeneous Devices**

I. INTRODUCTION

HOW would the world be without the Internet? It is difficult to imagine such a scenario we have never seen. Today, the Internet is becoming more and more important for everybody in both personal life and professional life. Different devices such as smart phones, sensors, mobile computers, and more other smart objects are examples of things we are dealing with every day. The connectivity is enhanced from "any-time, any-place" for "any-one" into "any time, any-place" for "any-thing". In the ICT innovations and economic developments, a significant focus has shifted to the Internet of Things related technologies where it is widely considered as one of the most important infrastructures of their promotion and one of the future promise strategies. The main aim is to enable interaction and integration of the physical world and cyber space. The development of Internet of Things involves many issues such as infrastructure, communications, interfaces, protocols, and standards. The objective of this paper is to give general concepts of the Internet of Things, the architecture and layers in Internet of Things, some basic terms associated with it and the services provided. A micro grid system represents a good example of a cyber- physical system: it links all distributed energy resources (DER) together to provide a comprehensive energy solution for a local geographical region. However, a micro grid Internet of Things system still relies on traditional Supervisory Control and Data Acquisition (SCADA). An Internet of Things ecosystem involves web-enabled smart devices that use incorporated systems, such as processors, sensors, and communication hardware, to assemble, send, and act on the data they obtain Now and Then these devices communicate with other connected devices and act on the information they obtain from each other. The paper will address the topic of Internet of Things, the state of the art of Internet of Things, and how Internet of Things is used for fog, in 6G, and cloud computing. It surveys Internet of Things architecture and sensors used in development and security together with their potential applications, such as system tuning and diagnosis.

II. BACKGROUND

The Internet of Things architecture is based on a 3-tier/layer system which consists of a perception/hardware layer, a network/communication layer, and a layer of interfaces/services. Hardware, such as the sensors and actuators, comprises the most important elements in the Internet of Things. The typical microprocessor which is used at the hardware layer is usually based on the advanced Risk Machine (ARM), Microprocessor without interlocked pipeline stages (MIPS) or X86 architectures. Ideally, developers should also incorporate security hardware, which may include a cryptographic code processor or security chip. For the hardware operating system, Internet of Things devices typically use a Real Time Operating System (RTOS), which includes a microkernel, hardware abstraction layer, communication drivers, and capabilities such as process isolation, secure boots, and application sand- box. The concerns regarding the Internet of Things hardware are authentication capabilities, end-to-end traffic encryption, secure boot-loading processes, the enforcement of digital signatures during firmware up- dates, and transparent transactions.

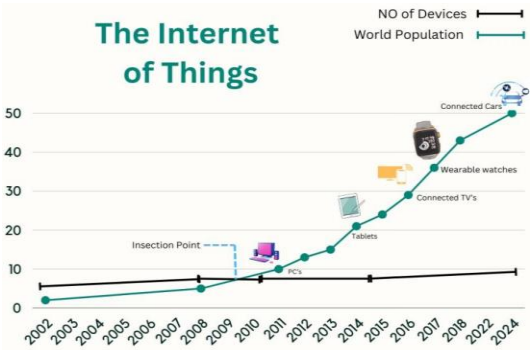

Fig. 1: No. of devices with world population

The next important component of an IOT system includes the communication and messaging protocols. A network of smart objects can communicate directly to the Cloud via a gateway, through cloud services such as Amazon Kinesis. However, the important concept of IOT is implementing a Wireless Sensor Network (WSN) as the main communication technology in IoT. Among the IEEE protocols, 802.15.4 is for Low Rate WPANs, which suits the requirements for an Internet of Things system.

Table I: Related Work

Ref	YOP	Name of Paper	Domain	Explainable Methods
[1]	2024	"A Review of Internet of Things (IoT) Applications in Healthcare" by Umair A. Khan, Amir H. Abdullah, and Kamran Ahsan.	Health Issues	Review
[2]	2024	"Internet of Things: Architectures, Protocols, and Applications" by Dominique Guinard and Vlad Trifa.	Applications	Survey
[3]	2024	"The Internet of Things: A survey" by Luigi Atzori, Antonio Iera, and Giacomo Morabito.	IoT	Survey
[4]	2024	"Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications" by Mohammed Aazam, Elisabeth Uhlemann, and Hannu Tenhunen.	Enabling Technologies	Survey
[5]	2023	Internet of Things: A Survey on Enabling Technologies, Applications" by Mohammed Aazam	Finance Improvements	Survey
[6]	2023	"Energy Harvesting for the Internet of Things: A Review" by Jorge Torres, Javier Matamoros, and Carlos Medrano.	Agriculture , Energy Harvesting	Techniques
[7]	2023	"Blockchain Technology for the Internet of Things: A Systematic Literature Review" by Daniele Miorandi, Vincenzo Nitti, and Mario M. R. Dominguez.	Block chain Technology	Literature Review
[8]	2023	"A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications" by Jayavardhana Gubbi, Rajkumar Buyya, Slaven Marusic, and Marimuthu Palaniswami.	Architecture, Enabling Technologies, Security and Privacy, and Applications	A survey
[9]	2022	"Security in the Internet of Things: A Review" by Luis Munoz-Gonzalez, P. Manzoni, and F. Martin-Vega	Security in the Internet of Things	A Review
[10]	2022	A Review on the Internet of Things (IoT), Cyber-Physical Systems (CPS), and Big Data: Technologies, Challenges, and Solutions" by Mehdi Mohammadi, Alireza Almasi, and Mohammad Gharib.	IoT Challenges, and Solutions	A Review
[11]	2021	"A Survey on the Internet of Things (IoT) in Healthcare" by Hemamalini R., R. Pavithra, and R. Aarthy.	Healthcare	Survey
[12]	2021	"The Internet of Things (IoT) for Environmental Monitoring Applications: A Review" by Muhammad Shoaib Farooq, Amir H. Abdullah, and Abdul Hanan Abdullah.	Environmental Monitoring	A Review

According to Cisco Internet Business Solutions Group (IBSG) study, in 2021, there were 500 million devices connected to the Internet and approximately 6.3 billion people were living. Explosive growth of smart phones and tablet PCs brought the number of devices connected to the Internet to 12.5 billion in 2022, while the world‘s human population increased to 6.8 billion. It also predicts there will be 25 billion devices connected to the Internet by 2022 and 50 billion by 2023.

III. ARCHITECTURE OF IOT

Architecture of IOT is broadly classified into 4 layers. Sensor Layer This is the lowest layer of IOT Architecture, which consists of sensor networks, embedded systems, RFID tags and readers or other soft sensors which are different forms of sensors deployed in the field. Each of these sensors has identification and information storage (e.g., RFID tags),

information collection (e.g. sensor networks), etc. This Layer should have high performance and robust network. It should also support multiple organizations to communicate independently. Management Service Layer Security and privacy of the data should be ensured.

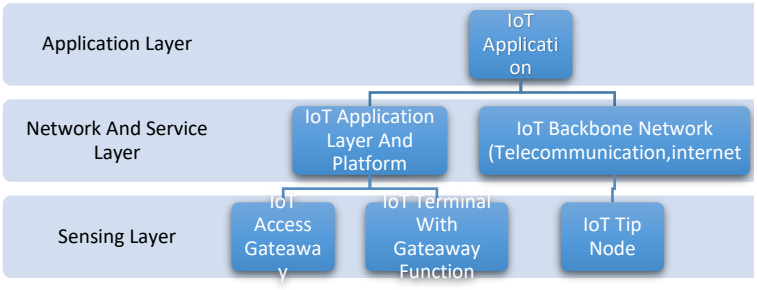

Fig. 2: Architecture Layers of IoT

A) IoT Application Domains

This technology has a lot of applications in various fields. The following are some possible areas where we can leverage the power of the Internet of Things (IoT) to solve day-to-day problems. However, it can be put to many more uses. Internet of Things applications try to make major shifts in our lifestyles. With the help, Internet of Things tech giant's companies are trying and already are making our lives connected. As per Gartner's research, by 2024 connected devices including all the technologies will reach 20.6 billion, which is tremendous.

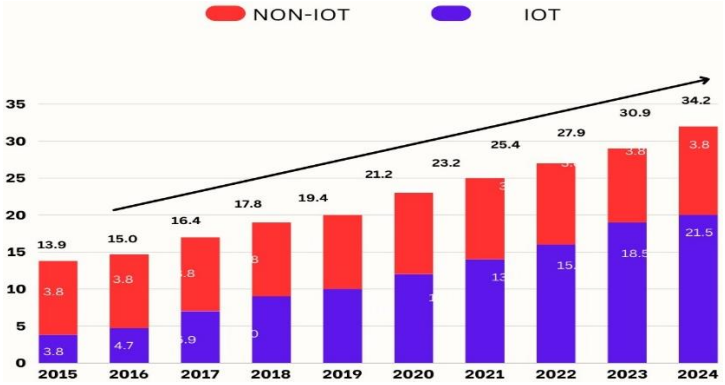

Fig. 3: Connected devices of companies with IoT domain

1: Smart Society	
Smart Home	Nowadays homes and offices use Internet of Things technologies. Various electronic gadgets and HVAC systems such as lights, fans microwave ovens, refrigerators, heaters and air conditioners are embedded with sensors and actuators to utilize the energy sufficiently, monitor and control the amount of heating.
Smart City	On a broader scale, Internet of Things technologies can be employed to make cities more efficient. The goal of smart cities is to leverage the IoT to improve the lives of citizens by improving traffic control, monitoring the availability of parking spaces, evaluating air quality and even providing notification when trash containers are full.
Smart Traffic	Currently traffic management is a bigger issue in the metropolitan cities. Managing them manually has become almost impossible. This problem can be overcome by implementing IoT for traffic management.
Smart Parking	Sensors will be placed in parking slots to know whether parking slots are available or not. The drivers park their vehicle looking into the application which provides the details of nearest parking slots available, parking cost based on the data collected and analyzed by the smart sensors which helps them to save time.
Smart Waste Management	A trash bin embedded with sensors which are capable to analyze and alerting the authorities when it is full and need to be emptied.
Smart Street Light Sensors	which can analyze the context such as time, season, and weather conditions will be embedded within streetlights which automatically turns light on or off and sets the dimming levels of individual or group of lights based on the context.
Smart Water Supply	Wireless Sensor helps to monitor their water piping systems more accurately and discovers water leakage and alerts them about the water loss which in turn saves money and natural resources too.
Smart Environment	A very important application of Internet of Things is detecting pollution and natural calamities. We can keep the water level of rivers and dams under surveillance to be alert in case of floods. The detection of forest fire is also possible with this technology.
Air-Quality Monitoring	By embedding sensors which collects context information such as amount of carbon monoxide (CO), nitrogen dioxide (NO2) in the air, sound levels, temperature, humidity levels in the environment.
Smart Water Quality Monitoring	Sensors which can detect context such as water quality, water flow, speed, temperature, water pollution, content of water placed or flowed in the water. This helps with the real- time analysis and management of the water resources available for use.
Smart Water Management	Embedded sensors in sewage tanks help to control the overflow of the wastewater flowing into; by continuously providing information about the level of wastewater stored. By these data, the maintenance people can schedule the water treatment process to avoid the overflow of sewage.
Natural Disaster Monitoring	Natural disasters such as earthquakes, landslides, forest fire, volcanoes, flood, etc. can be predicted by using wireless detection sensors. These detections are intimate with the respective authorities to take precautions before the disaster occurs.

2: Agriculture	
Smart Farming	Context information such as current temperature, soil moisture conditions, leaf wetness, and solar radiation is collected and analyzed by the sensors, which in turn informs the owner regarding the requirements of water, pesticides, manure, fertilizer or treatment for the infected plants.
Proposed Idea for Agriculture	Traditionally in India farmer usually follows the following major phases for agriculture. They are Crop Selection, Land Preparation, Seed Selection, Seed Sowing, Irrigation, Crop Growth, Fertilizing and Harvesting.
Present Tools for Agriculture:	Crop ln technology has developed a mobile application which takes input related to farm and helps in efficient maintaining and ensuring the crop quality in short duration. Based on the survey, there are only few tools or applications are available for agriculture.

3: Healthcare	
Health Tracking	The Internet of Things is used in healthcare domain to improve the quality of human life by assisting basic tasks that humans must perform through application. Sensors can be placed on health monitoring equipment used by patients.
Digital Health	IoT in healthcare has grown in the last few years and will continue to be bigger in the upcoming years and decades. IoT in the healthcare department encourages people to by using connected devices and live a healthier life.
Pharmaceutical Products	The safety of pharmaceutical product is of utmost importance to prevent the health of patients. Attaching smart labels to drugs and monitoring their status with sensors has benefits like maintaining the storing conditions, expiry of drugs which will prevent the transporting the expired medicines to the patients.
Food Sustainability	Packed Food that we eat has to go through various stages of food cycle such as production, harvesting, transportation and distribution. Sensors are used to detect context like temperature, humidity, light, heat etc.

4: Supply-Chains	
Supply Chains	IoT monitors every stage of supply chain from purchasing raw materials from the suppliers by the manufactures, production, distribution, storage, product sales and after sales service. This will help to maintain the stock required for continuous sales, which in turn results in customer satisfaction and increased sales.
Connected Automobile	Connected Automobile is also coming up. In a few years, we would see IoT implementations in the budget sector cars too. Major brands in both the tech and auto mobile industry such as Google, Apple, BMW, Mercedes, and Tesla are trying to bring the next big revolution in the automobile sector.
Wearables	Wearables are a very in-demand tech product in recent years. Tech giants like Google, Apple, and Samsung have invested a heavy amount of money to build such devices. These devices serve the purpose of health, fitness, and entertainment.
Smart Retail	The Internet of Things can perform great in this field of Smart Retail With the help of Internet of Things, retailers can connect with their respective customers. The smartphone will be a device which will be mostly used for this purpose.

5: Capability for the IoT Application	
1:Location Sensing and Sharing of Location Info	The Internet of Things system can collect the location information of Internet of Things terminals and end nodes, and then provide services based on the collected location information. The location information includes geographical position information got from the GPS, Cell-ID, RFID, etc.
a)Mobile asset tracking	This application can track and monitor the status of commodities using the position-sensing device and communication function installed on the commodity.
b)-Fleet Management	The manager of the fleet can schedule the vehicles and drivers based on the business requirements and the real-time position information collected by the vehicles.
2:Environment Sensing	The Internet of Things system can collect and process all kinds of physical or chemical environmental\no break parameters via the locally or widely deployed terminals.
a) Environment Detection	Internet of Things systems offer environmental and ecological, such as forest and glacier, monitoring; disaster, such as volcanoes and seismic, monitoring; and factory monitoring. All are with automatic alarm systems using environmental parameters collected by large number of sensors.
b)-Remote Medical Monitoring	Internet of Things can analyze the recurring indicator data collected from the device placed on patients' body and provide the users with health trends and health advice.
3:-Remote Controlling:	Internet of Things systems can control Internet of Things terminals and execute functions based on application commands combined with information collected from things and service requirements.
a)-Appliance control	People can remotely control operating status of appliances through Internet of Things system.

b)-Disaster Recovery	Users can remotely start disasters treatment facilities to minimize losses caused by disasters according to the monitoring mentioned before.
4:-Ad-Hoc Networking	Internet of Things system shall have rapidly self-organized networking capability and can interoperate with the network/service layer to provide related services.

Secure Communication

IoT system can further establish secure data transmission channel between the application or service platform and IoT terminals based on service requirements. In practice, an Internet of Things application consists of different types of capabilities and even applications based on the service requirement. Table II shows examples of different Internet of Things applications.

B) IoT Tools for Users

IoT can also function as a tool that saves people's money and time. Some of the tools used are:

- HAPIfork [14] is an electronic fork to monitor and track the eating habits of user. \
- HeatWatch [15] is a cattle monitoring solution that records the activities of animal which in turn helps farmer to breed more cows.
- Smart Traffic ParkSightis [16]: Is a parking management application to guide the driver regarding the availability of parking slots.
- SmartBelly [17] is a smart waste management solution to alert authorities when the trash bin is full
- Airqualityegg [18]: is an application which notifies the amount of air pollution.
- Aircasting [19] is a platform for sharing health (heart and breathing rate, pressure, etc.) environmental data (temperature, humidity, sound level, air contents).
- G.Dontflush [20]- is an application to intimate peoples to reduce the usage of water when the sewage tank is full.
- Insightrobotics [21]- is a forest fire detection system.

Some other tools are bumblebee, Floating Sensor Network and Intelligent river, MyVessylCup , Smart Tooth brush, Smart propane tank, Glucose monitoring, Smart Washing machines, Hydroponic System, Smart sprinkler Controller, Smart home security, Smart lightening, Smart a/c, Blood pressure monitor, Smart weather station, Smart slow cooker, Smart bike, Smart garbage cans, Smart gardening.

IV. THE ADVANTAGES AND DISADVANTAGES OF IOT

Advantages of IoT	
Communication	Since the Internet of Things has communication between devices, in which physical devices are able to stay connected and hence the total transparency is available with lesser inefficiencies and greater quality.
Automation and Control	Without human involvement, machines automating and controlling vast amounts of information, which leads to faster and timely output.
Monitoring saves money and time	Since IOT uses smart sensors to monitor various aspects in our daily life for various applications which save money and time.
Better Quality of Life	Internet of Things based applications increases comfort and better management in our daily life; thereby improving the quality of life.
New business opportunities	Creates new business for Internet of Things technology, hence increases economic growth and new jobs.
Better Environment	Saves natural resources and trees and helps in creating a smart greener and sustainable planet.

Disadvantages of IoT	
Compatibility	As devices from different manufacturers will be interconnected to the Internet of Things, presently, there is no international standard of compatibility for the tagging and monitoring equipment.
Complexity	The Internet of Things is a diverse and complex network. Any failure or bugs in the software or hardware will have serious consequences. Even power failure can cause a lot of inconvenience.
Privacy/ Security	Internet of Things has involvement of multiple devices and technologies, and multiple companies will be monitoring it. Since lot of data related to the context will be transmitted by smart sensors, there is a high risk of losing private data.
Lesser employment of menial staff	With the advent of technology, daily activities are getting automated by using the Internet of Things with less human intervention, which in turn causes fewer requirements of human resources. This causes unemployment in society.
Technology Takes Control of Life	Our lives will be increasingly controlled by technology and will be dependent on it. The younger generation is addicted to technology for every little thing.

A) IoT Security and Privacy

The most dangerous part of the Internet of Things is that consumers are giving up their privacy, bit by bit, without realizing it, because they do not know what data is collected and how it is used. As a result, consumer privacy can be compromised and have no real remedied. This helps to maintain the integrity of data and avoids hackers from examining it. All communication with your Internet of Things devices must be authentic, extending strong passwords or time-based authentication signs. Antivirus software can stipulate a critical layer of protection against outbreaks. Hardware, software, and connectivity must make sure secure for Internet of Things objects that work more effectively.

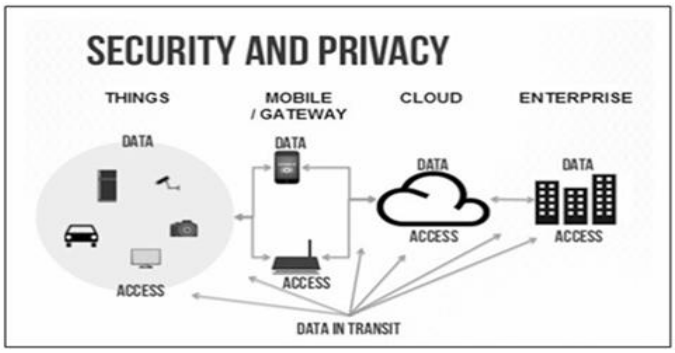

Fig. 4: Security and Privacy with data in Transit

B) Challenges and Issues

Scalability Spontaneously various new smart objects or devices are getting connected to the network. So IoT should be capable of solving issues such as addressing, information management and service management and also should support both small-scale and large-scale environments.

Interoperability (Devices heterogeneity): In IoT many smart objects are connected, and each smart object has its own information collection capability, processing and communication capability. For communication and cooperation between smart objects of different types; they should have common communication standards.

Software complexity: Since software systems in smart objects work with minimal resources, there is a need for software infrastructure to support the network and requires a server in the background to manage and support smart objects of the network.

Storage Volume: Based on the scenario and context, smart objects collect either a small amount of data or a huge volume of data. So based on the amount of data, storage has to be allocated.

Data interpretation: It‘s very important to interpret the context, that sensor has to sense. Context has an important role in generating useful information and drawing a conclusion from the data sent by the sensors.

Security and personal privacy: In IoT, network formed by smart objects via internet, so providing security and privacy is a big challenge. In IoT, sometimes the user prevents other users from accessing some particular information at certain time or preventing some communication or some transaction to protect secrete information from competitors. So, handling all this situation is a big challenge.

Fault tolerance: In Internet of Things, smart objects or devices are dynamic and rapidly context may change. But still the network has to function properly automatically, to adapt to the changed conditions. So the Internet of Things has to be structured for fault tolerance and robustness.

Ubiquitous data exchange through wireless technologies: Issues such as availability, network delays, and congestion etc. of wireless technologies, which are used for communication of smart devices are big challenges**.**

Energy-optimized solutions: Network consists of many interconnected devices, which require high energy to keep the network active. So, energy optimization is the major aspect in Internet of Things.

C) Open Research Issues

The main purpose of this paper is to provide a review of Internet of Things areas and research challenges. In this section, we discuss challenges and directions for future research work according to areas as we discussed earlier in this paper.

Internet of Things Architecture Still, there is no standardized architecture provided by any researcher or organization. The different researchers give their ideas for architecture by using different types of sensors and technology according to their requirements.

Technologies for Internet of Things: In this research area still, a problem, what technology will be converted to Internet of Things because it is feasible to convert agriculture, home, health, and supply chain management.

Cloud IoT: Internet of Things devices generate big data, which will be sent to the cloud for the process this will cause delays for results and action due to communication delay from the cloud to the Internet of Things device.

Fog IoT: Internet of Things sensors continuously generate sensitive data of monitoring to send cloud for analysis and acting on contorted situations, but the cloud is far away from the Internet of Things system.

IoT applications: Internet of Things applications were developed by many researchers and organizations but, the quality of experience of users was not considered yet to improve their quality of service (QoS).

V. CONCLUSION

In this survey paper, we analyzed Internet of Things domain by considering its architecture and applications and advantages and disadvantages. We observed that still Internet of Things is not much used in the field of agriculture. So we find its very much necessary to improve the applications of Internet of Things in this field and educate the same to the agriculturist, this will in turn reduces the dependency on man power and also will improve the yield which leads increase in the economy. In this paper, we studied Internet of Things and supporting technologies such as cloud, fog, 6G, and applications. Further, we provide architecture, security, and privacy of Internet of

Things. Security and privacy of Internet of Things applications are important for data securing and avoid loss. Advantages and disadvantages and open research issues are also discussed for future research directions. We found that sensors are important components of the Internet of Things system; if sensors fail during the monitoring of the environment or controlling a vehicle or in health applications, it will cause serious damage. The Internet of Things will change everything drastically if implemented successfully. But still there are various issues which need thorough research to improve the quality of life. In this paper, we have discussed various technologies with their specifications that can result in making the Internet of Things a reality. In the next section, we presented some handsome applications of Internet of Things and its comfort in life. Finally, some important issues that needed to be resolved have been discussed before wide acceptance of this technology. Thus, the development of the Internet of Things as an intelligent system can proceed with interoperability, energy sustainability, privacy, and security. The Internet of Things has become an inevitable trend of development of the information industry, which is bound to bring new changes to our lives.

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