Internet of things applications using Raspberry-Pi: a survey

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ABSTRACT

The internet of things (IoT) is the communication of everything with anything else, with the primary goal of data transfer over a network. Raspberry Pi, a low-cost computer device with minimal energy consumption is employed in IoT applications designed to accomplish many of the same tasks as a normal desktop computer. Raspberry Pi is a quad-core computer with parallel processing capabilities that may be used to speed up computations and processes. The Raspberry Pi is an extremely useful and promising technology that offers portability, parallelism, low cost, and low power consumption, making it ideal for IoT applications. In this article, the authors provide an overview of IoT and Raspberry Pi and research on IoT applications using Raspberry Pi in various fields, including transportation, agriculture, and medicine. This article will outline the details of several research publications on Raspberry Pi-based IoT applications.

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1. INTRODUCTION

The internet of things is one of the fastest-growing industries for bringing social and economic advantages to emerging and developing economies. Internet of things (IoT) is a collection of interconnected computing devices, physical devices, embedded electronics, sensors, actuators, and network connectivity with unique identifiers and the ability to transport data across a network without human or computer intervention [1], [2]. IoT enables remote control of systems over the internet. IoT is gaining traction in many fields, such as medicine, transportation, and agriculture [3].

IoT is predicted to grow swiftly because of advancements in communication technology, device availability, and computational systems [4]. It allows users to automate and control actions that they need to do daily. Tasks can be accomplished via IoT without the assistance of a human, enhancing the quality of life by making it smarter and easier.

The IoT is realized using various technologies such as radio frequency identification (RFID), near field communication (NFC), machine-to-machine communication, and vehicle-to-vehicle communication. IoT security is critical as an emerging technology with many devices deployed and connected to the internet. Communication protocols and encryption methods should be established to mitigate these hazards to IoT systems.

There are a variety of IoT devices on the market, and the IoT device selection is based on the application and task to be completed. Arduino and Raspberry Pi, on the other hand, are the most widely utilized IoT devices because of their ease of use and operation. Furthermore, compared to other IoT devices, Arduino and Raspberry Pi are less expensive [5]–[8].

The Raspberry Pi is an open-source computer established by the Raspberry Pi foundation in the United Kingdom [9]. There are a variety of Raspberry Pi models available; Raspberry Pi model 4 is the latest version of Raspberry Pi. Raspberry Pi 4 with a 1.5 GHz processor supports different connectivity methods and has two micro-high-definition multimedia interface (micro-HDMI) ports for the display options. Depending on your application requirements, different random-access memory (RAM) capacities (1, 2, or 4 GB) are available for the Raspberry Pi model 4.

The IoT is currently used in transportation, agriculture, and medicine. The notion of smart cities is becoming increasingly popular nowadays. Smart cities have been outfitted with various IoT-based technological gadgets and have become more intelligent than previously, thanks to recent advancements in digital technology [10].

Smart transportation is a significant branch of a smart city. With the constant improvement of various countries' economic levels and urbanization in the transportation field, urban traffic crowding and accidents increase [11]. The advancement of the IoT makes the concept of a smart city increasingly feasible. IoT can tackle traffic congestion, road safety, accident detection, and automatic fare collecting [12]–[14]. Passengers benefit from this information since it allows them to drive more safely.

The IoT provides a cost-effective approach to monitoring patients in the healthcare area. The IoT boosts medical apparatus effectiveness by allowing real-time patient health monitoring, with sensors collecting patient data and reducing human error [15]. Integrating IoT capabilities into medical devices will increase the quality of care provided to patients, particularly the elderly, who require regular monitoring. Combining Raspberry Pi with IoT has created a new innovative technology in the healthcare sector. The Raspberry Pi acts as a miniature clinic after adding sensors such as temperature, respiration, and heartbeat [16]–[19]. Patient parameters are sent from the medical apparatus to the IoT via a gateway, where they are saved and analyzed.

As the rest of the world moves toward new technology, agriculture must follow suit. Thanks to intelligent agriculture, water and fertilizer waste are reduced, and crop yields are increased. IoT may also be used in agriculture. We must bring technology into agriculture, and it is essential to define the plants' condition. Identifying the right disease leads to the correct usage of chemicals to save money and time [20]–[24]. By improving quality and production management, agricultural development could solve many real-time challenges [25].

The authors give this survey a general overview of IoT and Raspberry Pi. Also, the details of a variety of research publications on Raspberry Pi-based IoT applications will be outlined in this article. The organization of the rest of this paper can be summarized as follows: section 2 gives an overview of IoT and Raspberry Pi. Section 3 shows prior research for IoT applications in diverse disciplines developed using Raspberry Pi. Finally, section 4 draws some conclusions.

2. RESEARCH METHOD

2.1. IoT: general overview

In 1999, Kevin Ashton invented the phrase "internet of things," It has since been employed in various applications, including intelligent transportation, intelligent agriculture, and medicine. The well-known IoT notion describes a dynamic ecosystem of interconnected computer devices with diverse elements for data transfer and seamless connection [26]. IoT systems are effectively deployed by allowing internet communications interfaces in devices like sensors and actuators with storage and processing sections for successful machine interactions [27]. The IoT allows large items to "speak" and share data. The main concept is based on the range of objects that can connect with one other by having a unique address, such as RFID, sensors, NFC, actuators, and so on [28]. It is required in IoT applications to send data generated by devices or sources to the internet. For IoT applications, proving connection and coverage is a difficult challenge. IoT can be defined as a network of physical elements connected by: i) information-gathering sensors, ii) identifiers, iii) software, and iv) internet access for communication and notification.

All devices on the IoT are connected to the internet since they cannot work without it. Each object has its sensors that collect data from the outside world. Local processing analyzes data to remove extraneous data and save it locally. Data is transferred from local storage to cloud storage, where all objects send their acquired data. The objects can then be managed and controlled utilizing the information collected [29]. There are a variety of widely used IoT communication protocols as:

- MQ telemetry transport (MQTT) [30]: it is an IoT messaging protocol primarily geared for remote connections and consumes very little power.
- RFID: RFID works by allocating a distinct identifier to each object to record information.
- IEEE 802.11 Wi-Fi: a set of WLAN communication standards.
- LoRaWAN: is a Lora TM alliance-developed long-range communication protocol.

– Mobile Communications Standards (2G/3G/4G): devices that connect to the IoT utilize cellular networks to communicate.
– Bluetooth: a short range of personal area networks ideal for mobile communication.

The rapid growth of IoT technology is anticipated, especially to recent developments in digital technology. As demonstrated in Figure 1, a varied collection of intelligent IoT applications has been developed. Many of them are widely available, and there is still a lot of room for research in areas like smart agriculture, smart transportation, smart health care, smart homes, smart cities, and so on, all of which improve people's quality of life.

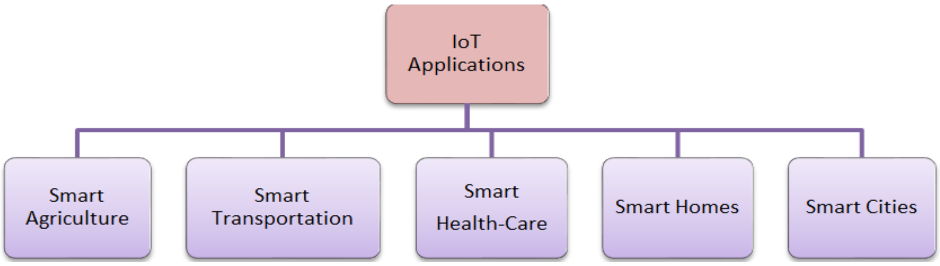

Figure 1. IoT applications

2.2. Raspberry Pi: general overview

The Raspberry Pi is a credit card-sized open-source computer created in the United Kingdom by the Raspberry Pi foundation. Several Raspberry Pi models are available; the Raspberry Pi model 4, as depicted in Figure 2, is the most recent version. The Raspberry Pi was initially introduced in February 2012, and the Raspberry Pi 2 was released in February 2015. Raspberry Pi Zero was introduced in November 2015, followed by Raspberry Pi 3 in February 2016, and finally came Raspberry Pi 4 in June 2019. Depending on your application requirements, the Raspberry Pi model 4 has several RAM sizes (1, 2, or 4 GB). The Raspberry Pi 4 has a 1.5 GHz CPU, several networking choices, and two micro-HDMI connectors. Raspberry Pi model 4B has the following specs, according to Raspberrypi.org:

– There are two USB 3.0 ports and two USB 2.0 ports.
– There are two micro-HDMI ports.
– GPIO header with 40 pins.
– Gigabit Ethernet.
– 2-lane MIPI DSI display port.
– 2-lane MIPI CSI camera port.
– LPDDR4-3200 SDRAM (2, 4, or 8 GB).
– Broadcom BCM2711.
– Quad-core Cortex-A72 (A.R.M. v8) 1.5 GHz processor.

Figure 2. Raspberry Pi model 4

3. IoT APPLICATIONS USING Raspberry Pi

Researchers have proposed a wide range of intelligent IoT applications. This article provides an overview of the advantages of using Raspberry Pi in various IoT applications. This article also exhibits many related applications in various fields, including transportation, agriculture, and medicine.

3.1. Intelligent transportation

A key component of a smart city is smart transportation. The idea of a smart city is becoming more and more viable as IoT technology develops. Figure 3 demonstrates some IoT applications in the transportation field.

Kumar *et al.* [31] implement a surveillance system based on embedded tools and signal to process in autos to develop a comprehensive driver aid system. The implemented system comprises three interconnected modules: detection of driver tiredness, alcohol concentration, and vehicle collisions, as well as monitoring the driver's physiological condition, which can impact vehicle control. The Raspberry Pi was used as the prototype's brain, accessing user-programmed software algorithms on a storage disk card.

Jabbar *et al.* [32] developed a parking control system to assist staff and students in quickly locating accessible parking places via a smartphone app. The system contains a global policy and strategy (GPS) module to assist users in locating parking spots using the Blynk App, which searches the internet for available parking spaces. The Raspberry Pi gathers and processes the sensors' data.

Jaiswal *et al.* [33] construct a placing system using IoT and deep learning algorithms to identify the availability of parking slots. The suggested system develops an intelligent parking system using IoT, cloud platform, and machine learning techniques. The suggested system can intelligently resolve various issues, including analyzing available and busy slots in real-time and identifying multiple items in a parking slot, such as a bike in a card slot.

Herrera-Quintero *et al.* [34] implement a transportation system prototype that includes internet of Things techniques to aid transportation planning for bus rapid transit (BRT) systems. The model can identify Bluetooth signals from various gadgets passengers use while using the BRT system. Based on this information, the prototype can construct an origin/destiny matrix for many BRT routes. The administrative authorities may utilize this information to plan appropriate transportation for the BRT systems. The hardware comprises mostly two components: a sensor module implemented on a Raspberry Pi and a Bluetooth signal sniffer.

Prabu *et al.* [35] develop a system that leverages IoT technology to construct an effective Raspberry Pi-based parking management system and multidirectional cameras. This suggested solution will aid in the proper management of parking in congested metropolitan areas. Furthermore, OpenCV technology identifies vehicles and their position sectors. The Raspberry Pi device is powered and connected to an external camera to retrieve video data. Raspberry prepares the video outline information to see any available stopping space. Clients may then book a parking space on the site using the results.

Patil [36] suggested a system for monitoring car pollution and noise, with any vehicle exceeding its threshold value reported to the traffic department and national environmental agencies. The suggested system is low-cost and transportable. The sensors are so sensitive that they may detect gas generated by other vehicles while stalled in traffic, jeopardizing the system's integrity. This problem may be solved by reading the samples over time and then taking action depending on the average value.

Bansal *et al.* [37] proposed DeepBus, a pothole detection system that uses IoT to detect road surface flaws. End users and local governments could see the location of the discovered potholes on a centrally controlled map. The Raspberry Pi has a GPS module and IoT sensors like an accelerometer and a gyroscope. Accelerometer and Gyroscope sensors are used to identify potholes. Various machine learning models are tested using various performance factors to select the most effective pothole identification model and evaluate DeepBus' performance.

Godavari *et al.* [38] present a vehicle monitoring and tracking system for tracking the school bus from one location to another using Raspberry Pi. GPS is used to determine the vehicle's current location, GPRS transmits tracking data to the server, and global system for mobile communications (GSM) delivers alarm messages to the vehicle's owner's mobile phone. This system also uses gas leakage and temperature sensors to guarantee the passengers' safety.

Husni *et al.* [39] proposed an IoT system to track fuel use on an android application. The data from the car's engine is read by onboard diagnostics II (OBDII) and relayed through Bluetooth to the Raspberry Pi, which then sends it over a 3 G connection to the server and saves it. Users can access the data via MQTT via a mobile application, then process it on the server for analysis.

Alluhaidan *et al.* [40] developed a sensor model to monitor a moving vehicle. Data is created as the vehicle moves and encrypted with the Paillier homomorphic cryptography system (PHCS) algorithm before being sent to the cloud for vehicle tracking. The data collected by the various sensors is saved and tracked. If an abnormal condition occurs while driving, an alarm is sounded, alerting the motorist.

3.2. Intelligent agriculture

Technology must be used in agriculture because it is crucial for determining the health of the plants. The right plant disease must be identified to use the appropriate chemical. Figure 4 demonstrates some IoT applications in the agriculture field.

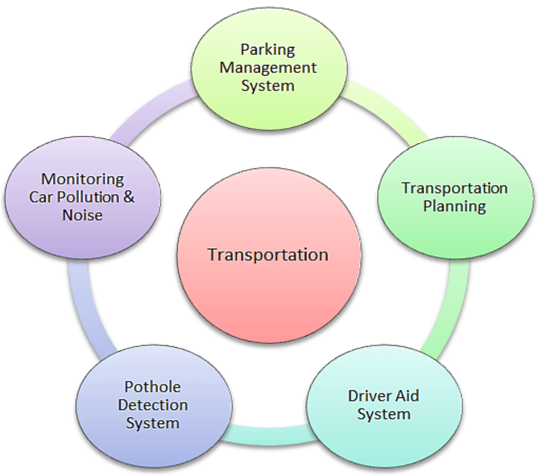

Figure 3. IoT applications in transportation

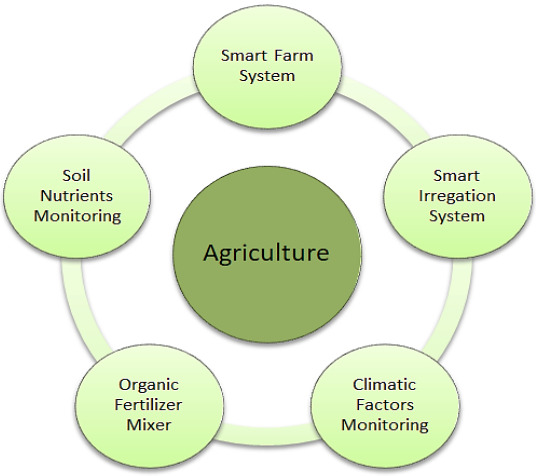

Figure 4. IoT applications in agriculture

Ishak *et al.* [41] proposed an enhanced organic fertilizer mixer remotely monitoring fertilizer output and providing employees with updates and alarms. Compared to today's automated systems, this designed prototype delivers operating cost reductions almost five times. The device is made up of a load sensor mounted to the static drum's bottom and measures the weight of the mixture before sending the data to a microcontroller. The Raspberry Pi was chosen as the microcontroller. The microcontroller receives the sensor's weight data, analyses it, and sends it to the cloud server through a wireless connection.

Arshad [42] produced a prototype that includes a sensor network, IoT analytics, and a Raspberry Pi to monitor climatic factors in a greenhouse setting and transmit parametric climate data to a gateway. The Raspberry Pi is the brain's central processing unit for monitoring real-time climatic parameter values in a greenhouse setting. In turn, depending on these readings, it compares current threshold values to received values and decides whether or not to modify certain climatic parameters if an imbalance is detected.

Benyezza *et al.* [43] developed a novel approach to monitor irrigation and maintain the appropriate soil wetness to help plants grow. The suggested system was built on a wireless sensors network in several greenhouse zones. This network uses radio-frequency communication to deliver data from the plant environment to a Raspberry Pi.

Using the nitrogen-phosphorus-potassium (NPK) sensor, Lavanya *et al.* [44] proposed a system that alerts farmers about lacking important soil nutrients such as nitrogen, phosphorous, and potassium. The Raspberry Pi microcontroller is used. The data collected by the built NPK sensor is transferred to a Google Cloud database for quick retrieval. Fuzzy logic is then used to diagnose nutritional deficiencies from sensed data.

Abioye *et al.* [45] proposed better monitoring of dynamic factors influencing mustard leaf plant irrigation. In this experimental framework, the IoT platform was employed to monitor using numerous sensors and a weather station based on the internet of Things, which revealed better precision irrigation. The acquired data, including plant photos, was sent for online storage to the Raspberry Pi and displayed on the IoT dashboard. MATLAB's system identification toolkit created a mathematical prediction model defining the link between water flow, water loss, and soil moisture.

Goap *et al.* [46] present an internet of things irrigation system and a hybrid machine learning-based technique for predicting soil moisture. The suggested method incorporates sensor data from the recent past and weather projected data to predict the soil moisture in the following days. Closed-loop control of the water supply is included in the system, allowing for a fully autonomous irrigation plan. The system prototype is inexpensive because it is built on open standard technology.

Ramli *et al.* [47] present a dependable, smart farm system with an adaptable mechanism. The network protocols used in the proposed system are LoRaWAN and IEEE 802.11ac. The sensor data is sent via the LoRaWAN protocol, which has a tiny data size and uses very little energy. Video data is sent via the IEEE 802.11ac protocol, which offers a faster data rate than LoRaWAN.

3.3. Medicine and healthcare

The Raspberry Pi and IoT combo has produced a brand-new, cutting-edge solution in the healthcare industry. The level of patient care will rise due to the inclusion of IoT features in medical equipment. Figure 5 demonstrates some IoT applications in the medical field.

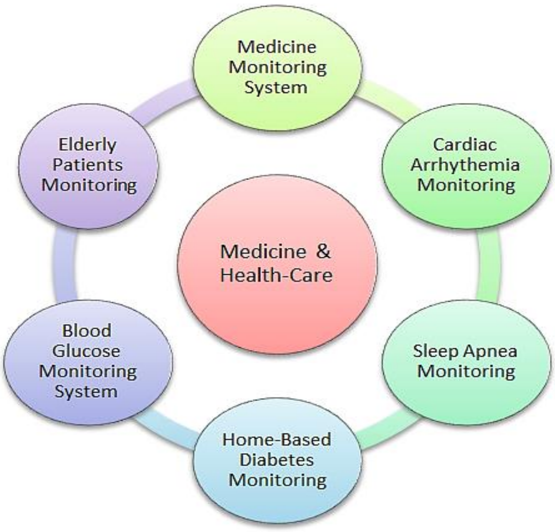

Figure 5. IoT applications in medicine & healthcare

Jesudoss *et al.* [48] present a monitoring, security, and maintenance system for medicine in an IoT context. The suggested platform includes an intelligent medication security box that updates the medicine room. The security camera records the picture of the person who enters the room, and if anybody enters the room, an SMS alert is sent. The VNC viewer program is wirelessly connected to the medication box. It is an Android application that runs on a Raspberry Pi and provides timely medication updates through a sensor.

Alarcón-Paredes *et al.* [49] presented a non-invasive blood glucose monitoring system. The model comprises a Raspberry Pi Zero powered by a battery bank, a visible laser beam, and a Pi camera integrated into a glove. The Raspberry Pi Zero collects data for glucose monitoring by capturing a series of photographs of the user's fingertip and generating their histograms.

Moghadas *et al.* [50] present a system for monitoring the cardiac arrhythmia of patients. The k-nearest neighbor method categorizes and validates the kind of cardiac arrhythmia. Instead of transmitting patient information to the cloud, fog technology is used, which reduces data transmission delays. The Arduino Uno and the AD8232 sensor module were used in the proposed system to launch a web service from the Raspberry Pi, allowing real-time electrocardiogram (ECG) and patient heart rate.

Bhatia *et al.* [51] present an efficient home-based diabetes monitoring system based on urine. For effective prediction analysis based on the temporal features of urine-based diabetes parameters and quantified in terms of level of diabetic infection and diabetic infection measure, a recurrent neural network has been implemented. The suggested system's visualization efficacy has been improved using a self-organized mapping method. Raspberry Pi was utilized to do real-time health data calculations.

Yacchirema *et al.* [52] developed a novel method to monitor and advise sleep apnea therapy. An edge node in the fog enables IoT connectivity and interoperability and pre-processing IoT data to identify and respond to events in real-time that may jeopardize the health of the elderly. A generic enabler context broker on the cloud maintains, stores, and injects data into the big data analyzer for processing and analysis.

Lomotey *et al.* [53] presented a wearable IoT architecture for healthcare services, focusing on data traceability. The authors propose an upgraded Petri Nets service architecture to help transparent data-trace path development, tracking, and possibly detecting medical data breaches to overcome the complexity of mapping and matching device data to users. Extensive testing is carried out in real-world circumstances, and the findings reveal that Petri Net adaptability outperforms alternative distributed network models.

Mano *et al.* [54] present a home monitoring system for elderly patients. Capturing a patient's facial expressions over time might indicate how much pain they are in, allowing a nurse or family to evaluate whether or not assistance is needed. The authors also discussed using visuals and emotions in smart home environments to aid healthcare in an automated manner using an IoT infrastructure.

4. CONCLUSION

The internet of Things is now being applied in a variety of fields. There are a variety of IoT devices to choose from on the market, and the type of IoT device to use depends on the application. The Raspberry Pi is the most popular IoT device that is inexpensive. In this article, an overview of IoT and Raspberry Pi is given. The authors' research IoT applications using Raspberry Pi in various fields, including intelligent transportation, agriculture, and medicine.

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