MULTI-ACCESS EDGE COMPUTING ARCHITECTURE AND SMART AGRICULTURE APPLICATION IN UBIQUITOUS POWER INTERNET OF THINGS

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ABSTRACT

The Ubiquitous Power Internet of Things (UPIoT) is a deep integration of the interconnected power network and communication network, enabling full perception of the system status and business operations for power production, transmission, and consumption. To address the challenges of real-time perception, rapid response, and privacy protection, UPIoT can benefit from the use of edge computing technology. Edge computing is a new and innovative computing architecture that enables quick and efficient processing of data close to the source, bypassing network latency and bandwidth issues. By shifting computing power to the edge of the network, edge computing reduces the strain on cloud computing centers and decreases input response time for users. However, access latency can still be a bottleneck, which may overshadow the benefits of edge computing, particularly for data-intensive services. While edge computing offers promising solutions for the IoT network, there are still some issues to address, such as security, incomplete data, and investment and maintenance costs. In this paper, researcher conducts a comprehensive survey of edge computing and how edge device placement can improve performance in IoT networks. The paper includes a comparative use case of smart agriculture edge computing implementations and discusses the various challenges faced in implementing edge computing in the UPIoT context. The results also aim to inspire new edge-based IoT security designs by providing a complete review of IoT security solutions at the edge layer in UPIoT.

KEYWORDS

Edge Computing, Internet of Things, Computer Network, Edge Computing applications, Edge Server, IoT Gateway

1. INTRODUCTION

As technological progress continues, there has been a substantial proliferation in the quantity of internet-connected devices, consequently demanding expedited and effective data dissemination. The efficacy and cost-effectiveness of cloud computing have been well-established as a dependable means of establishing internet connectivity for various devices. However with the exponential growth of high-range wireless devices, virtual private servers may not stand a chance to adapt and respond quickly in real-time applications that require low-latency network. With the introduction of edge computing in UPIoT, it is possible to meet the requirements of rapid response, real-time perception, and privacy protection. Edge computing is a revolutionary computing architecture that processes data quickly and effectively close to the source, bypassing network bandwidth and latency issues. Edge computing technologies like cloudlets, fog

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computing, and mobile edge computing (MCC) can help solve cloud computing difficulties, providing efficient processing, low-latency network, high mobility, scalability, energy efficiency, and reliability. By moving computing capacity to the network's edge, edge computing reduces the processing and transmission strain on cloud computing centers while simultaneously reducing the time it takes for users to provide input. This enables UPIoT to efficiently and quickly process the massive edge data faced by traditional cloud-based centralized big data processing technology. However, challenges such as policy challenges, market challenges, and technical challenges may arise in edge computing implementation in UPIoT, including security, incomplete data, investment, and maintenance cost [1]. Despite the high level of security required for IoT applications, protecting IoT systems can be challenging due to a variety of factors. A combination of issues, such as limited resources and insufficient security architecture, contributes to security concerns in modern systems. While advanced security mechanisms, like Attribute-based Access Control, are already in place, implementing solutions such as group-signature-based authentication, homomorphic encryption, and public-key solutions require significant CPU power and memory space, which IoT devices for economical reasons are in need. Additionally the cloud normally provides virtually ample resources, is often located far from the signal devices, making it difficult to implement security measures [2]. Therefore, comprehensive surveys of edge computing and comparative studies of different edge computing implementations are essential in addressing the challenges and optimizing the benefits of edge computing in UPIoT.

In this article, the author begins with introducing the architecture and evolution of edge computing in UPIoT field, as well as the fundamental concepts that underpin it. The paper then examine the important factors to consider when deploying edge computing infrastructure and services. Furthermore, we explore several compelling use-cases and challenges of edge-centric services in various industry verticals, namely smart energy system, advanced metering infrastructure and smart agriculture. Finally, the article concludes by highlighting the open research challenges in this field and providing key insights.

2. UPIOT AND EDGE COMPUTING

This section of the thesis examines the fundamental concepts of edge computing and ubiquitous power in IoT (UPIoT) and explores their respective scales of implementation.

2.1. Ubiquitous Power Internet of Things and Edge Computing Definition

Ubiquitous linkage refers to the pervasive connection and interaction of information between people and things at the any time and anywhere. Specifically, it denotes the interconnection and interaction of various components, including power users, equipment, power grid enterprises, power generation enterprises, supplies, people and things, which comprise the concept “UPIoT”. This refers to the integration of multiple aspects of the power system, from power generation to consumption, and the communication and coordination between these components to optimize the performance and efficiency of each smart system.

UPIoT is a technology platform that is designed to enable devices to communicate with each other seamlessly, regardless of their operating system or communication protocols. It is a framework that allows devices to connect to the internet and share data with other devices in a standardized way. This standardization is essential because there are currently many different types of devices and communication protocols used in the IoT ecosystem, which can make it difficult for devices to communicate with each other.

UPIoT provides a set of standards that all devices can adhere to, allowing them to share data with each other in a uniform way. This data can be analyzed and managed in real-time, providing valuable insights into the performance of the devices and the systems they are part of. Additionally, UPIoT can be integrated with cloud-based services, providing a scalable and cost-effective way to manage and analyze IoT data.

One of the key benefits of UPIoT is its ability to simplify the development process for IoT solutions. By providing a common platform for communication, developers can create solutions that work across different devices and operating systems without having to worry about compatibility issues. This makes it easier and more cost-effective to develop IoT solutions, which can be particularly beneficial for small and medium-sized businesses that may not have the resources to develop custom IoT solutions.

UPIoT has many potential applications in industries such as healthcare, transportation, and manufacturing. In healthcare, for example, UPIoT can be used to connect medical devices and provide real-time data on patients' health. In transportation, UPIoT can be used to monitor vehicles and optimize routes, while in manufacturing, it can be used to improve supply chain management and track inventory in real-time.

Edge computing is a distributed computing paradigm that brings computation and data storage closer to the location where it is needed, thereby reducing latency and increasing the efficiency of data processing. In thisparadigm, computation and data storage are moved from centralized cloud data centers to the edge of the network, which can be a mobile device, a gateway, or a local server.

The concept of edge computing emerged in response to the increasing demand for real-time data processing and the growing number of Internet of Things (IoT) devices. By processing data closer to the source, edge computing can reduce the amount of data that needs to be transmitted to the cloud, thereby decreasing network traffic and reducing latency. Edge computing also allows for more efficient use of bandwidth and resources, as data can be processed locally without requiring a round-trip to the cloud.The deployment of edge computing involves a range of technologies, including edge devices, edge gateways, edge servers, and edge data centers. These technologies enable data processing and storage at the network edge, while also providing connectivity to cloud services and other devices in the network.

2.2. Device to Device Communication Network

The model of gadget – to gadget communication illustrates two or more gadgets that directly link and share data between one and others, rather than through an intermedial application server [3]. It often interact through various kinds of networks, together with but not finite to IP (Internet protocol). Some communicating network examples to be included in :LoraWAN, Zigbee, Bluetooth 2.4GHz.

Table 1. Popular device-to-device communicating networkcomparison

Local Area Network Short Range Communication	Low Power Wide Area (LPWAN) Internet of Things	Cellular Network Traditional M2M
40%	45%	15%
Wellestablished standards in building	Lowpowerconsumption , low cost and positioning	Existing coverage High data rate
Battery Live, Provisioning, Network cost, dependencies	High rate data Emerging standards	Autonomy Total cost of ownership
Bluetooth, Wifi	Lora	3G, 4G, 5G

Table 1 shows analyzed data on three categories of network maily used in IoT. These type of communication model is used in various applications such as smart office systems and automatic monitoring in electrical systems, where small data packets are transmitted to one another. However, the lack of compatibility is a major issue in device-to-device interactions from an user's perspective. Different devices from different manufacturers use various protocols, such as BluetoothWave or ZigBee, to establish machine-to-machine communication. For instance, smart home devices using the ZWave protocol cannot interact with devices using the ZigBee protocol. These compatibility issues limit the perception and choice of users

2.3. Device-to-Cloud Communication

In the modern gadget-to-cloud communication, the gadget requests and receives packets of information from a service of the internet cloud like a provider of application services to exchange or swap the data and monitor the traffic of messages [4]. As included in figure 2, this approach continuously takes advantage of current procedure of communications like conventional ethernet or wifi connections, which open a direct link to the cloud. It is necessary to utilize the structure of the network to raise the execution of the model machine-to-cloud communication.

2.4. Machine-to-Gateway Communication

One approach to machine-to-gateway communication is the gadget-to-ALG (Application Layer Gateway) model, which can be implemented as either a middleware or proxy box. For instance, in smart home or smart farm systems, these kind of multi-functional devices called the Gateway or HomeController (HC). Figure 3 illustrates the machine to gateway communication framework. With these structure, security check methods such as software-based protocols or translation algorithms can be implemented on the gateway or other network devices, serving as a middleware bridge between the cloud's application services or IoT gadgets. This reduces power costs int IoT , improves network adaptability, and enhances security. A smart cellphone can function as the gateway, performing operations to interact with IoT gadgets and the cloud system.

2.5. Traditional Upiot Components and Edge Computing

There are several components in a network of UPIoT that can be mentioned afterwards:

- Devices/Sensors:

Sensors or gadgets in the IoT network, help in gathering even a minute data or info from the encircling environment. All the gathered data can have different degrees of complications ranging from a simple temperature controlling sensor. A device can have one or more than one sensor that can packed together to perform more than just sense things. In the IoT, all the end gadgets and sensors will be interlinked which allows them to swap their content with each other and give extra performances.

- Connectivity:
After collecting the data that gathered data is sent to a framework of cloud, and this process requires a means of transport. The sensors are linked to the cloud through different mediums of transports and communication like Bluetooth, Wi-Fi, cellular and satellite networks, WAN (wide-area networks), wide area network of low power and many more. So, in the IoT system, opting the right and best connectivity is important.

- Gateways of IoT:
The systems of the sensors and the core networks are connected by the gateways of IoT to the servers of cloud. For applications of IoT, when the end nodes produce resource needs, then they transmit the actions of storage or info processing to the servers of cloud. Before sending further the data to the servers of cloud, it is essential in the network to perform preprocessing of the data. Hence, the data from the gadgets or sensors are gathered and sent further to the servers of cloud by the gateways of IoT. Moreover, this component of IoT also carries out the preprocessing of data to avoid the data's redundancy in the network as well as sends further the output of the processing of info back to the end users from the servers of cloud.

- Cloud/Core Network:
Servers of cloud receive the info as well as needs from the end users via backhaul networks. The servers of cloud have considerable efficiency for both storage as well as computation to endorse applications of IoT. Hence, the servers of cloud have the ability to indulge the needs of resources of various applications. After the completion of preprocessing, the servers of cloud send the outputs of data back to the end users.

The technology of Edge Computing is ultilized as a type of catch all for different technologies of networking including the edge of the cellular network, It also reduces the distance traveled by data in a network. Improving in the network security is also a primary advantage of the edge computing. In the age of data booming, researchers take their time in provoke architectures that can be safe and widely used at the same time.

- Architecture of the Edge computing : as mentioned in the figure 4 of the thesis, the edge computing's basic layers can be separated into three which are eleborated:

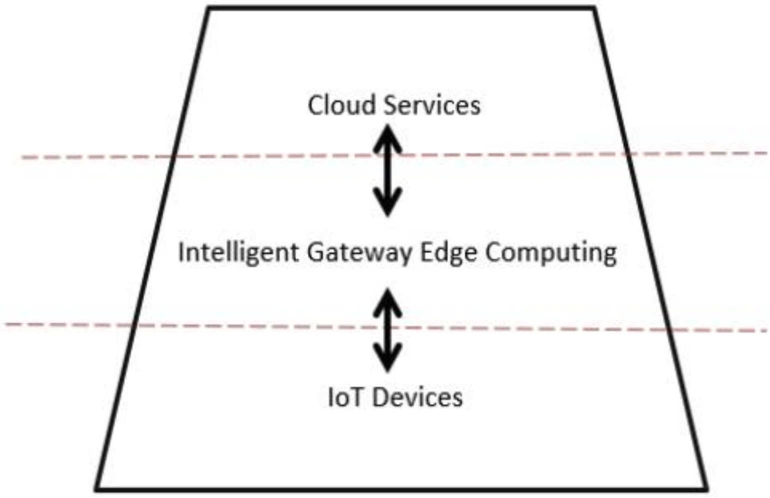


Figure 1. The three layers of edge computing

+ Far End: The aspect of servers and cloud SAAS or PAAS , supply ample storage space as well as the core IoT of computing. Any modern IoT system need a cloud service to compute, store data and visualize it to the end-user. Popular cloud service can be named as Amazon AWS, Google Cloud, Microsoft Azure.

+ Near End: In the atmosphere of near-end, the traffic flows in the network is supported by the distributed gateways. Most of the storage and computation migrate to this section. With a minor increment in the delay status, the end users obtain a better performance on storage and data responses speed. Few of instances can be named as Router, PC, Base Station , Edge Gateway , etc.

+ Front End: The front end atmosphere supplies direct communication and much better receptivity from the side of the end users. The front end concept refers to the IoT Smart System applied in multi fields like Smart City, Smart Home and Smart Transportation and components in those applications.

As a facet of UPIoT , edge computing can produce the capabilities in a large amount for services of IoT because networks of IoT are sensors and actuators gadgets-based in edge area and data of IoT proceated from sensors and collected through a gateway. Advantages of IoT based on edge computing , as we noticed that the majority of the technology iss to decentralize the data handling . This provides many advantages over the conventional cloud.

Table 2. Features of cloud computing, edge computing and internet of things

	Components	Computation	Deployment	Big Data	Response Time	Storage
Cloud Computing	Virtual Resources	Unlimited	Centralized	Process	Slow	Unlimited
Edge Computing	Edge Nodes	Limited	Disseminated	Process	Fast	Limited
Internet of Things	Physical Devices	Limited	Disseminated	Source	N/A	Small

+ Increases Security of Data: IoT solutions show a perfect hacker-proof and edge computing provides network security . Some smart model stay localized in each establishing location and owners need to have access to the internet through their static IP

+ Reduces operational costs: When most of the data is located and processed at the edge boundary, there is less necessary burden on the cost of establishing a powerful VPS / cloud services. On the other hand, filtration of no important data can also be reduced.

+ Better performance for app : as discussed in preceding views, the process of data transfer can be a benefit from transforming into edge computing architecture , the lag time and overall can be enhanced because the signal information becomes closer to its sources.

3. DEPLOY IOT SMART AGRICULTURE SYSTEM

In this section, the researcher will implement a scenario of deploying a smart system in a real case study focusing on smart agriculture using LoRa technology. The smart agriculture system will serve as a demonstration of the main concepts of UPIoT. smart agriculture plays a vital role in optimizing farming operations and requires the integration of various sensors and data streams with a connected digital platform. To explore the potential applications of this technology, it is essential to address the challenges of collecting data from diverse sensors and transmitting it to a centralized platform. Previous studies have primarily focused on smart LED street lighting systems in smart cities, integrating street lighting control with SmartGrid products in Portugal. These systems utilize RIIM-based wireless communication, adjustable correlated color temperature-based LED arrays, and a central web server. Some systems adjust the color temperature based on weather conditions, while others periodically transmit data to a fog computing server to enhance real-time response. However, these approaches have limitations in terms of reliability. Another architecture employs IoT devices and cloud computing, incorporating a dedicated wireless lighting controller, an IoT sensor gateway installed on LED lights, a smart collector, and a central management system. This architecture prioritizes scalability, security against cyberattacks, and a user-friendly web-based interface for controlling and monitoring smartagriculture components.

3.1. Smart Agriculture Architecture and Installation

3.1.1. Setting Up Server / Cloud System

In the context of smart farming IoT system, backend deployment plays a crucial role in managing and processing the vast amount of data collected from various sensors and devices. The backend serves as the central infrastructure that handles data storage, processing, analysis and facilitates communication between different components of the systems.As mentioned above, IoT services are hosted with a monolithic based system and installed in a centralized Linux server.

Table 3. Backend services and server configuration

Server Services / Information	Port	Description
MongoDB	5004	Data Storage
Backend API	5000	Business logic controllers, definitions and messaging transmit
MQTT	1883	Gateway message communication
Redis	6789	Message caching and queuing
Web App	5002	Web UI for users
File service	5006	Over the Air services for gateway firmware upgrading
Socket service	5003	Real time data transmitting
Operation System		Ubuntu (20.04 LTS)
RAM		8GB
HDD		1TB

3.1.2. Setting Up Iot Gateway and Sensors / Edge Computing Module

IoT gateway signicantly features can be listed below:

- Collect environmental parameters from sensors: temperature, air humidity, soil moisture, light, CO_2,...
- Monitor environmental parameters, device status at the touch screen
- Control and monitor the control cabinet locally or on the Internet (Web, App)
- Support standard connection: LoRa, BLE Mesh, Wifi, 4G
- Control the actuator with 3 modes of manual, calendar and law
- Install and execute schedules, scripts, control rules
- Add, edit and delete devices and sensors to the system
- Connect and control BLE lights, Dimming 0-10V,modbusrelay

Sensor device features to be included in the real projects:

- Automatically measure and update the temperature and humidity values to the central control cabinet according to the set time cycle.
- Software to install and control on the Web or on Smartphone compatible with operating systems

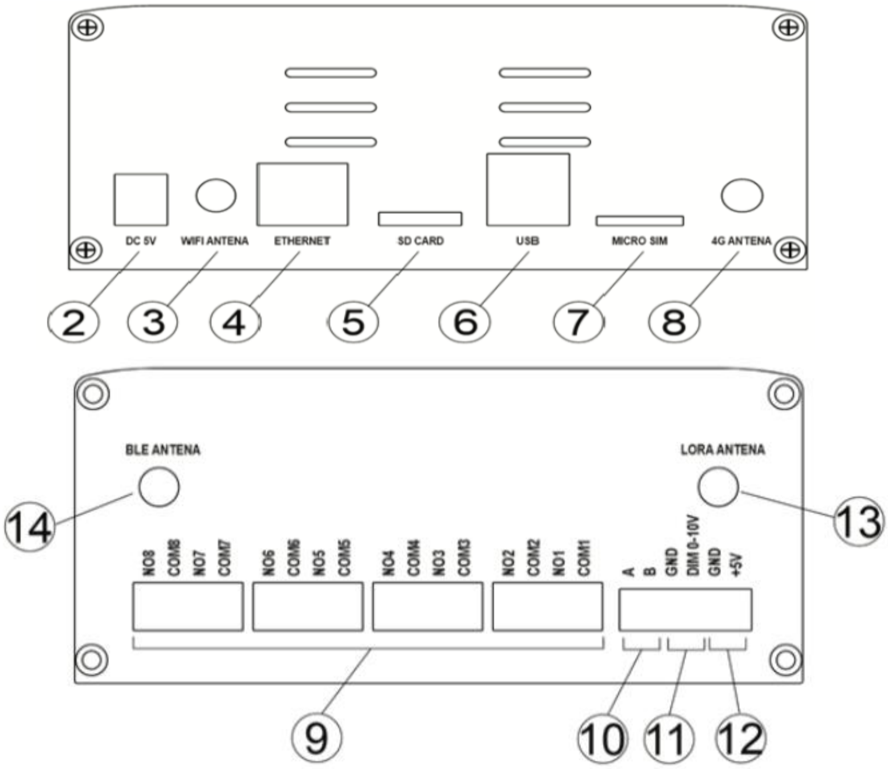


Figure 2. Gateway hardware structure and connection ports

Product Code	RD-NN.GW01
Input Power	220V
Gateway Size	150x170x60mm w 1.2mm
Automatic lightning protection	Yes
Output	8 or 16 relay channels/ BLE Mesh
Antenna	3G, BLE, Lora
Control mode	Manual , Auto (Smart Script)
Connectivity	Lora gateway, BLE Mesh, Wifi

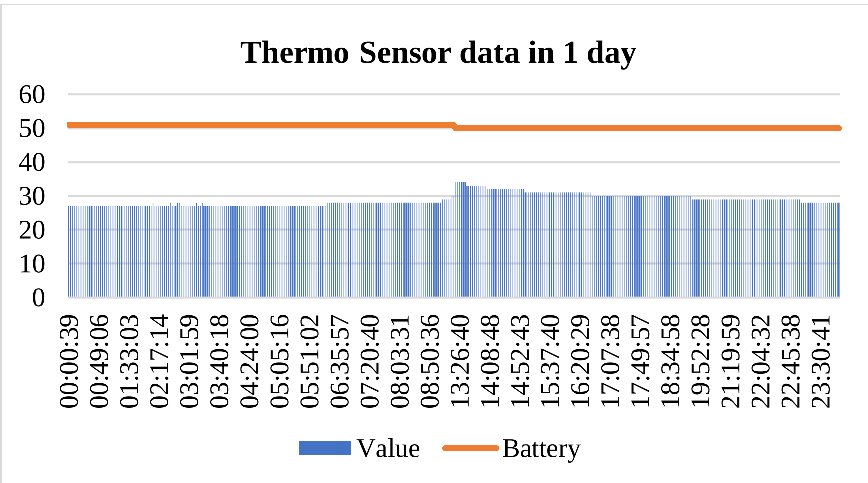
Figure 3. Gateway technical configuration

Figure 4. Environmental sensor device collection

3.2. Smart Agriculture Real Time Data Collection

3.2.1. Dataanalysis In Charts and Applications

Smart farm environmental statistic monitors integrate various sensors and data collection mechanisms to capture critical environmental parameters such as temperature, humidity, soil moisture, light intensity, and air quality. These monitors are deployed strategically throughout the farm to gather data from different locations, enabling farmers to gain a holistic view of their farming environment. The collected data is then processed and analyzed to provide meaningful statistics and actionable insights for informed decision-making. To support the monitor idea of the paper, data from a thermo sensor and a temperature sensor visualized as charts to support farmers in creating an ideal environment for plants.



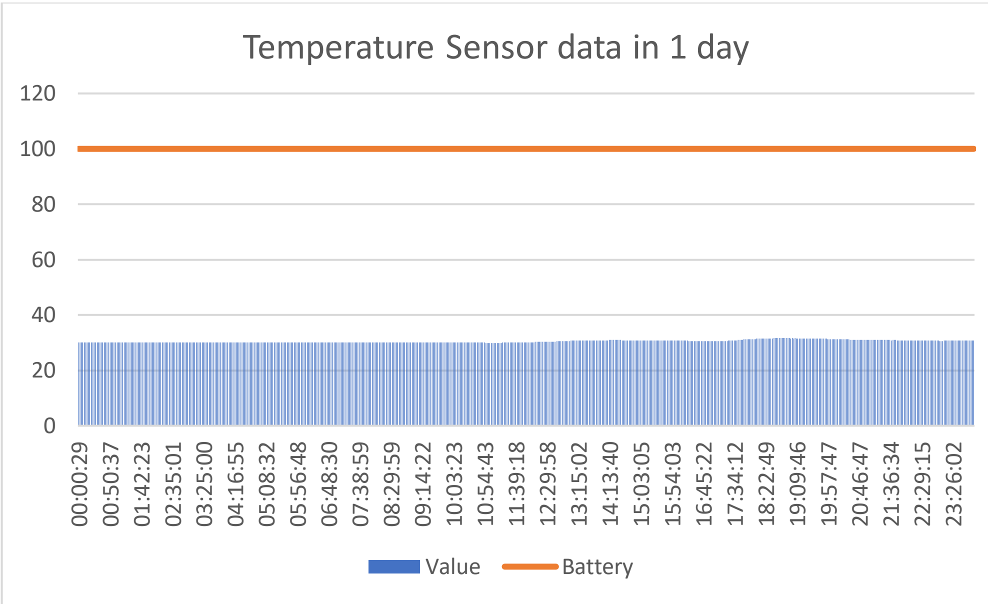
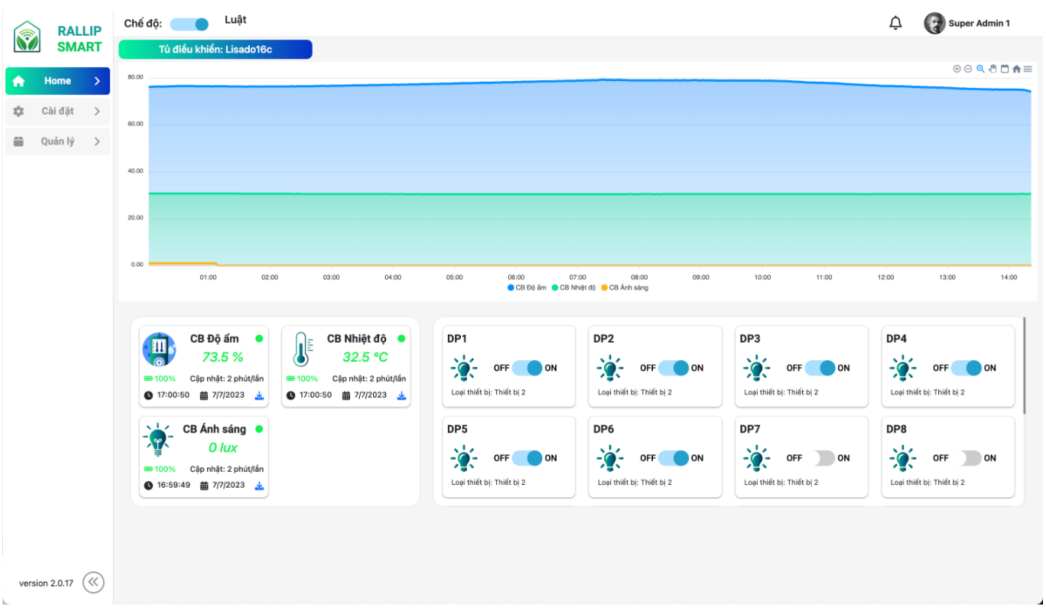


Figure 5. Thermo sensor and Temperature sensor data in 24 hour – day time

Data visualization through apps (like web application and mobile applications) in smart farms is heavily important in providing farmers with meaningful insights and facilitating informed decision-making. Rallip Smart – like other smart apps utilize the data collected from various sensors deployed in the farm to create visually appealing and interactive representations of the farm's environmental conditions, crop growth, and other relevant parameters. Through intuitive graphs, charts, and maps, farmers can easily monitor and analyze real-time data on factors such as temperature, humidity, soil moisture, light levels, and crop health. Additionally, these apps often offer customizable alerts and notifications, enabling farmers to proactively address any issues or anomalies. Overall, data visualization apps empower farmers to optimize their farming practices, improve resource management, and maximize crop productivity in a smart and efficient manner.



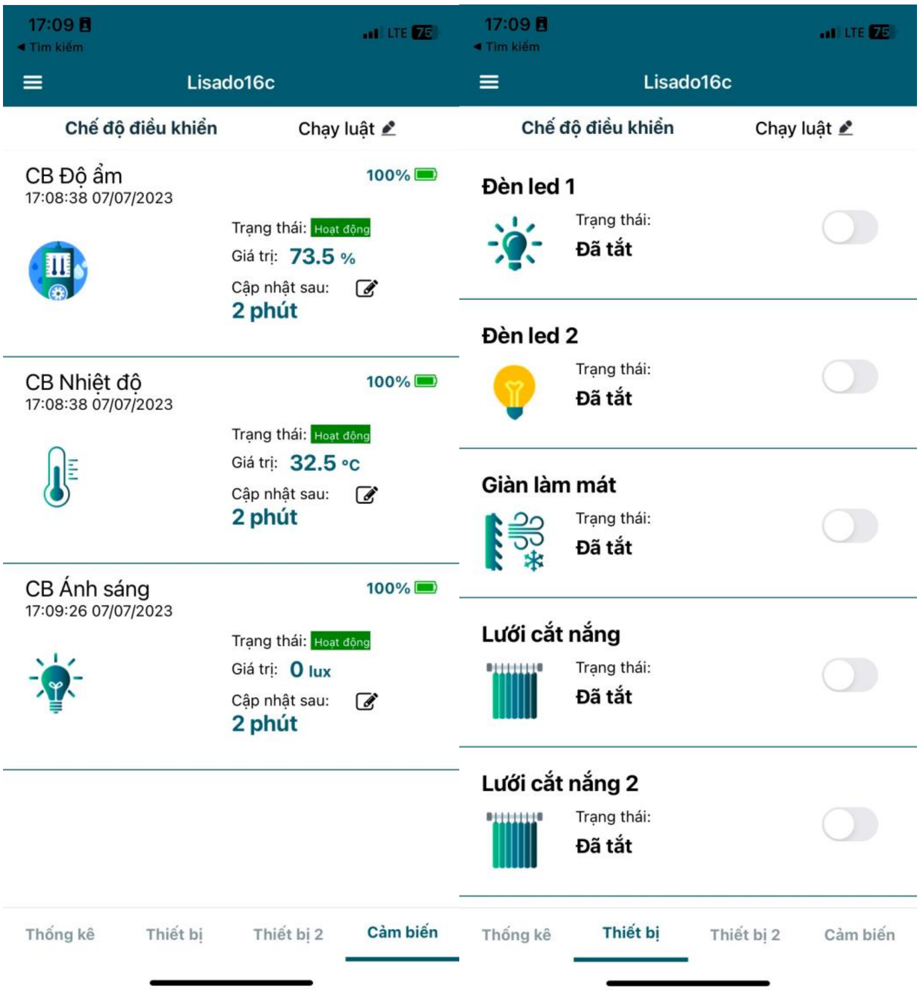


Figure 6. Smart Agriculture devices real-time visualization through apps

3.2.2. Data Transmitting Throught MQTT Protocol And Messaging Structures

In the context of smart farming, efficient and reliable data transmission is crucial for collecting and exchanging information between various components of the farm ecosystem. MQTT (Message Queuing Telemetry Transport) protocol has emerged as a popular choice for data transmission in smart farm applications due to its lightweight, low bandwidth, and publish-subscribe architecture. This section explores the utilization of MQTT protocol for data transmitting in smart farm environments.

MQTT is a lightweight messaging protocol designed for constrained devices and low-bandwidth, unreliable networks. It follows a publish-subscribe model where data publishers, known as MQTT publishers, send data to a central broker, and data subscribers, known as MQTT subscribers, receive the data from the broker. This asynchronous communication approach ensures decoupling between the data sources and data consumers, enabling scalable and efficient data transmission.

The implementation of MQTT in smart farm data transmission typically involves the following steps:

- MQTT Broker Setup: A central MQTT broker is deployed in the farm network to facilitate communication between MQTT publishers and subscribers.
- MQTT Publisher Configuration: Data sources, such as sensors or devices, are configured as MQTT publishers to send data to the broker. Publishers publish data to specific topics identified by unique names.
- MQTT Subscriber Configuration: Applications or services that require access to the published data are configured as MQTT subscribers. Subscribers subscribe to specific topics to receive data updates from the broker.
- Topic Structure and Granularity: An effective topic structure is defined to organize the published data. Topics can be hierarchical, allowing subscribers to selectively subscribe to relevant data streams based on their specific requirements.
- Quality of Service (QoS): MQTT offers different levels of QoS, such as QoS 0 (At most once), QoS 1 (At least once), and QoS 2 (Exactly once). The appropriate QoS level is selected based on the desired reliability and latency requirements of the data transmission.

Subscribed to topic 9c65f94c2a1egateway

```
{
 "Head": {
  "DateTime": 1688717516,
  "FormData": 0,
  "IDGateway": "9c65f94c2a1e",
  "IDMessage": "0c029e52-e034-4b28-bd17-d7ab3129d822",
  "TypeMessage": 0
 },
 "Sensor": [
  {
   "Battery": 100,
   "ID": "41d41e51-c8b3-4eac-8e51-fbcc79d72d70",
   "IsConfig": true,
   "TypeSensor": 0,
   "Value": 31.29
  },
  {
   "Battery": 100,
   "ID": "41d41e51-c8b3-4eac-8e51-fbcc79d72d70",
   "IsConfig": true,
   "TypeSensor": 1,
   "Value": 72
  }
 ]
}
```


Figure 7. MQTT message structure for Sensorsdata

Subscribed to topic 9c65f9468f7fhost

```
{
 "Head": {
  "IDMessage": "88a600ea-d999-4a07-aaef-0f102138b641",
  "TypeMessage": 0,
  "FormData": 3,
  "IDGateway": "9c65f9468f7f",
```

```
  "DateTime": 1688721840.626
 },
 "Rule": [
  {
   "ID": "1161790",
   "Name": "Rule for Lighting sensor",
   "Active": 1,
   "Type": 1,
   "Input": {
    "Schedule": [
     {
      "TimeStart": 62580,
      "TimeStop": 69780
     }
    ],
    "Loop": {
     "Monday": true,
     "Tuesday": true,
     "Wednesday": false,
     "Thursday": false,
     "Friday": false,
     "Saturday": false,
     "Sunday": false
    },
    "Condition": {
     "Logic": 0,
     "Compare": [
      {
       "ID": "44ca3eca-b1d8-4759-b374-ec70dadeb913",
       "TypeSensor": 3,
       "minValue": 0,
       "maxValue": 100000
      }
     ]
    }
   },
   "Execute": [
    {
     "Priority1": [
      {
       "ID": "1977687",
       "Type": 1,
       "Delay": 0,
       "Pull": 1,
       "During": 0
      },
      {
       "ID": "1437487",
       "Type": 1,
       "Delay": 0,
       "Pull": 1,
       "CCT": 0,
```

```
        "Dim": 0,
        "During": 0
       }
      ],
      "Priority2": [],
      "Priority3": []
     }
    ],
    "Action": 1
  }
 ]
}
```


Figure 8. MQTT message structure for Automatic Scripts setting up

4. OTHER USE CASES IN SMART UPIOT PLATFORMS AND CHALLENGES

4.1. Advance Technologies Developed from the Edge Computating group

The present discussion pertains to three forms of distributed computing, namely Fog Computing, Mobile Edge Processing (MEC), and Cloudlet Computing. These distributed computing paradigms are designed to reduce latency and enhance context-awareness by bringing computing and storage capacity to the network edge.

Fog Computing is a decentralized computing infrastructure, consisting of Fog Computing Nodes (FCNs), that can be deployed anywhere within the architecture between end devices and the cloud. The heterogeneous nature of FCNs enables the construction of devices with a range of components, such as routers, switches, access points, IoT gateways, and set-top boxes. Various protocol layers are supported by FCNs, and non-IP-based access technologies are also utilized for interaction between the FCN and the end device. Despite the heterogeneity of the nodes, the end devices remain oblivious to the underlying infrastructure as a consistent Fog abstraction layer is provided. This layer comprises a set of functions for resource allocation and monitoring, security and device management, as well as storage and computing services. The Service Orchestration Layer distributes resources based on the requests' requirements and employs multiple strategies to accommodate end-users' requests.

Mobile Edge Processing (MEC) is another form of Edge Computing that reduces latency and enhances context-awareness by placing computing and storage capacity at the edge of the network within the Radio Access Network. MEC nodes and servers are typically co-located with the Radio Network Controller or a macro base station, and multiple MEC hosts can run on the servers, performing computation and storage via a virtualized interface. The Mobile Edge Orchestrator monitors MEC hosts and manages Mobile Edge apps, keeping track of the services offered by each server, the resources available, and the network topology. MEC servers supply real-time network information such as load and capacity, as well as information on the end devices linked to the servers, such as location and networking.

Cloudlet Computing refers to a secure network of computers that share resources with adjacent mobile devices and are well connected to the Internet. A Cloudlet is a "data center in a box" that runs a virtual machine capable of delivering resources in real-time across a WLAN network to end devices and users. The Cloudlet architecture consists of three layers, namely the component layer, the node layer, and the Cloudlet layer. The component layer provides interfaces to the upper levels, which are supervised by an Execution Environment, as well as a range of services.

A Node is composed of one or more Execution Environments that run on top of an OS and are managed by a Node Agent. A Cloudlet Agent is responsible for the Cloudlet layer's cluster of co-located nodes. In their work, Satyanaranan et al propose an architecture for cognitive aid apps that includes a primary virtual machine leveraging the cognitive skills of other virtual machines in the Cloudlet. The information from the cognitive virtual machines is integrated into a user guidance virtual machine, which then transmits it to the end-user.

In summary, Fog Computing, Mobile Edge Processing, and Cloudlet Computing represent three prominent paradigms of distributed computing. These approaches offer the potential for reduced latency and enhanced context-awareness by bringing computing and storage capacity to the edge of the network. These paradigms enable a range of services, including resource allocation and monitoring, security and device management, and storage and computing services, all of which are critical for providing seamless and efficient communication between end-users and the network.

4.2. Challenges in Edge Computing Applications

4.2.1. Network Bandwidth

As a result, companies will need to rethink their bandwidth allocation strategy to accommodate the changing computing paradigm.

4.2.2. Distributed Computing

Edge computing requires the consideration of edge locations as a separate part of a company's computing use case. The component layer provides a range of services and interfaces to the upper layers, which are supervised by an Execution Environment. A Node, managed by a Node Agent and running on top of an OS, comprises one or more Execution Environments.

4.2.3. Latency

The proximity of computing resources to the data being collected reduces application and decision-making latency, resulting in faster responses and activity. Edge computing requires computing to be present both at the core and the edge, with application data traversing the network in both directions, sharing data and dealing with access rights.

4.2.4. Security and Accessibility

Centralizing computing and apps in a data center and establishing a virtual wall around the resources has traditionally allowed businesses to standardize both technological and physical security. Edge computing, however, requires the security footprint to be tailored to location and traffic patterns, necessitating the use of the same network and physical security models by remote servers. Edge computing may also require IT teams to explicitly map out user access across a larger number of devices, requiring access permissions for users across a larger number of devices.

4.2.5. Backup

The location of data generation is typically the driving force behind the concept of edge computing. Businesses require a robust data security policy capable of handling data from any location. Network bandwidth needs are just as important as concerns for storage media when considering how to preserve these assets, as network backup may not always be feasible.

4.2.6. Accumulating Data

Data is a valuable asset for businesses, and collecting it at the edge poses new challenges and risks if not handled appropriately. The network is critical for both data storage and access, which are essential components of the data lifecycle.

4.2.7. Management and Control

While the physical location of the edge can be flexible within a corporation, administration and management in a private or public cloud must follow the same procedures and rules regardless of location. Employing existing orchestration technologies to manage and control applications across multiple locations is advisable.

4.2.8. Scale

Edge computing adds more connected devices at the edge, which increases the scope of everything IT personnel handles. Edge computing requires the scaling up of all IT disciplines, including computation, network, storage, management, security, and licensing. Moving apps to the network edge requires businesses to consider that edge computing affects everything IT touches, not just more equipment in a remote location.

5. Conclusion and Future Work

In conclusion, the rapid development of high-range wireless devices has led to a need for efficient and fast data delivery. While cloud computing has proven to be a reliable and cost-effective way to connect devices to the internet, virtual private servers may not be able to keep up with real-time applications that require low-latency network. Edge computing, on the other hand, can meet the requirements of rapid response, real-time perception, and privacy protection by processing data close to the source, bypassing network bandwidth and latency issues. Edge computing technologies like cloudlets, fog computing, and mobile edge computing (MCC) can provide efficient processing, low-latency network, high mobility, scalability, energy efficiency, and reliability, and reduce the processing and transmission strain on cloud computing centers. However, challenges such as policy, market, and technical challenges may arise in implementing edge computing in UPIoT, including security, incomplete data, investment, and maintenance cost. Therefore, comprehensive surveys of edge computing and comparative studies of different edge computing implementations are essential in addressing these challenges and optimizing the benefits of edge computing in UPIoT. In this article, author has introduced the architecture and evolution of edge computing in the UPIoT field with a real-life smart system use case, examined important factors to consider when deploying edge computing infrastructure and services, explored compelling use-cases and challenges of edge-centric services in various industry verticals, and highlighted open research challenges in this field. There are several areas for future research and development in the field of edge computing for UPIoT.

Firstly, more work needs to be done to address the security challenges of edge computing in UPIoT. As mentioned, implementing advanced security mechanisms can be challenging due to limited resources and insufficient security architecture of IoT devices. Future research can focus on developing lightweight and efficient security solutions that can be implemented on resource-constrained edge devices.

Secondly, there is a need for standardization and interoperability in edge computing for UPIoT. Different edge computing implementations may have different requirements and specifications, making it difficult to integrate and exchange data between them. Future work can focus on developing standardized interfaces and protocols for interoperability and seamless integration between different edge computing solutions.

Thirdly, there is a need for further exploration of use cases and applications for edge computing in UPIoT. While this article highlights some compelling examples such as smart energy systems, advanced metering infrastructure, and smart agriculture, there may be other industry verticals that can benefit from edge computing. Future work can focus on identifying new use cases and applications for edge computing in UPIoT.

Lastly, there is a need for performance evaluation and optimization of edge computing solutions in UPIoT. While edge computing can provide significant benefits in terms of low-latency network, high mobility, scalability, energy efficiency, and reliability, it is important to evaluate and optimize the performance of edge computing solutions to ensure that they meet the requirements of specific use cases and applications.

Overall, future work in the field of edge computing for UPIoT can focus on addressing the challenges and optimizing the benefits of edge computing, through developing lightweight and efficient security solutions, standardizing interfaces and protocols for interoperability, exploring new use cases and applications, and evaluating and optimizing the performance of edge computing solutions.

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